Acq*Knowledge*® 5 Software Guide

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For Life Science Research Applications

Data Acquisition and Analysis with BIOPAC Hardware Systems

Reference Manual for

Acq*Knowledge*® 5.0.8.1 Software & MP160/MP150/MP36R, BioNomadix, BioNomadix Logger, BioNomadix Smart Center Hardware/Firmware, BioHarness (Windows), Stellar (Windows) on Windows® 10/11. Acq*Knowledge*® 5.0.8.1 supports Mac OS 10.13-12.

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Preface to Acq*Knowledge* Software Guide

Welcome

Welcome to the Acq*Knowledge* Software Guide. Acq*Knowledge* software is used in the BIOPAC MP160 (16-channel) or MP36R (4-channel) Research Systems, both of which perform acquisition and analysis of life science data.

In addition to the MP Systems, Acq*Knowledge* also supports BIOPAC's licensed BioHarness, B-Alert, and Stellar Systems. For more information on these wireless hardware solutions, see the Licensed Functionality Chapters at the end of the guide.

Acq*Knowledge* software not only makes data collection easier, but also performs analyses more quickly and easily than a chart recorder. Easily edit data, cut and paste sections of data, perform mathematical and statistical transformations, and copy data to other applications for reports and publication.

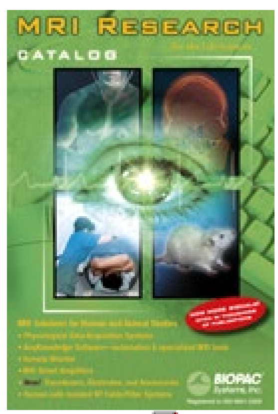
All BIOPAC data acquisition hardware with Acq*Knowledge* 5 is compatible with Windows® 11/10 or Mac OS 10.13-12

This manual covers use of Acq*Knowledge* software with MP160/150/MP36/Smart Center/BioHarness/Stellar hardware and details BIOPAC equipment available for a variety of applications. If a desired application is not addressed, visit the BIOPAC web site at www.biopac.com to download one of our many Application Notes, or call to talk to an Applications Specialist.

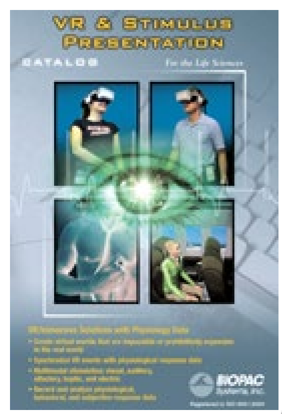
See also:

- BIOPAC Installation Guide—packed with the software installation disk.
- BIOPAC MP Hardware Guide—available under the Help menu and installed to the User Support folder. Provides details on Hardware System modules, transducers, electrodes, etc., and setup and calibration.
- BIOPAC Catalogs

MP Research Catalog



MRI catalog



VR & Stimulus Catalog

Supported Platforms

Acq*Knowledge* 5 is supported on the following:

Operating Systems	**Hardware**
Windows 11, 10	MP160 and MP150 UDP
Mac OS 10.13-12	MP36R
	BioHarness BT (Windows only)
	BioNomadix, BioNomadix Logger, BioNomadix Smart Center
	Stellar (Windows only)

What's new for Acq*Knowledge* 5.0.8.1

The following features have been added since Acq*Knowledge* 5.0.8 was released

- Bug fixes
- Support for Stellar Universal Receiver and Real-Time transmitters
- Licensing for NIPB100E now handled by Acq*Knowledge* through KEYLOK keys already used for Acq*Knowledge* authorization. No extra licensing files required.

The following features have been added since Acq*Knowledge* 5.0.7 was released

- Bug fixe
- Support for Workflow automated scripting (included with Scripting license)
- Support for MP36AR
- Trial period for software licensed features
- Check for software updates
- Derivative calculation channel
- Finite Difference calculation channel
- Finite Difference transform menu item
- Assembly for Stimulus Presentation
- Export event marks and data to MATLAB/Octave
- Import event marks
- Trigger for Stimulus Presentation
- Modified sample data/template files

The following features have been added since Acq*Knowledge* 5.0.6 was released

- Bug Fixes
- Support for the NIBP100E noninvasive blood pressure system and NIBP100E-HD noninvasive BP system with hemodynamic calculations (Licensed Feature)
- Integration of SDS200-SYS scent delivery system with Stimulus Presentation

The following features have been added since Acq*Knowledge* 5.0.5 was released

- Bug Fixes
- Stimulus Presentation Licensed Feature with EyeTech Eye Tracking and FaceReader support
- Argus Science Eye Tracking Glasses and ETVision software integration (Licensed Feature)
- Additional filtering options for EEG Specialized Analysis
- Event marks now have transparent backgrounds
- Support for B-Alert X24 EEG Headset (Licensed Feature)
- MP160/150 digital channels can no longer modulate stimulator output for STM100C
- BIOPAC Settings Assistant for exporting snapshot of registry entries used by BIOPAC products (Windows only)

The following features have been added since Acq*Knowledge* 5.0.4 was released

- Bug Fixes
- 3D Surface View for Find Cycle, AR-Time Frequency Analysis, Waterfall Plots
- Support for new EBI100D and NICO100D Smart Amplifiers
- Improved functionality for B-Alert Wireless EEG and new External Synchronization Unit (ESU)

The following features have been added since Acq*Knowledge* 5.0.3 was released

- Bug Fixes

- Support for new 100D Series Smart Amplifiers – compact amplifiers with automated setup that offer the same functionality as 100C Series Amplifiers in a lightweight, small-form design
- Support for new AMI100D interface for Smart Amplifiers
- macOS Mojave support (10.14)

IMPORTANT:

- Acq*Knowledge* 5 with MP160 hardware is not compatible with 32-bit operating systems. For 32-bit system support, use earlier-release Acq*Knowledge* 4.4.2 with MP150 hardware.
- Starting with Acq*Knowledge* 5.0.6, a current version of Acq*Knowledge* is required in order to add or upgrade licensed features.

Using this Manual

The Acq*Knowledge* Software Guide is divided into four parts:

Part A *Getting Started*

Please review *Getting Started* whether new to computer-based data acquisition systems or an old hand at physiological monitoring. Use this section to become acquainted with how the system works and the most frequently used features.

Part B *Acquisition Functions*

Explains data acquisition features and gives a detailed summary of different acquisition parameters. Provides an in-depth description of the commands used to determine acquisition rate, acquisition duration, and specialized functions such as triggering, averaging, and online calculation of different values.

Part C *Analysis Functions*

Details information on analysis features; covers the range of post-acquisition analysis functions and transformations available with the Hardware System. Describes how to edit data, take measurements and perform basic file management options (save, print, etc).

Part D *Appendices*

Answers frequently asked questions, offers hints for working with files, includes information on upgrading from previous versions, provides technical information about the Hardware Systems and other information about the Acq*Knowledge* software.

See also:

BIOPAC Installation Guide

This guide was included with the software package. It contains full instructions for hardware and software installation, and how to be up and running with the Hardware System in just a few minutes.

Hardware Guide

BIOPAC's MP Hardware Guide is available under the Help menu. It gives practical examples of how the data acquisition unit is used with different components for common types of data acquisition, and includes sample results and applications for widely used test procedures. This guide provides instructions for connecting external devices to the data acquisition hardware, electrodes, transducers, amplifiers, etc.

User Support System

User Support System files can be found in the following hard drive location; BIOPAC Systems, Inc/Acq*Knowledge* 5.x/User Support Systems in the Program Files or Applications folder.

- Acq*Knowledge* Software Guide is the software support document
- BIOPAC MP Hardware Guide is the hardware guide (with specifications)

The User Support files can also be opened directly from the installation media.

The files are in PDF format, and can be read by Adobe Acrobat Reader.

- Adobe Acrobat Reader can be downloaded for free at www.adobe.com.

The Samples folder in the BIOPAC program folder contains sample files and graph template ***Quick Start*** files for a variety of applications. ***Quick Start*** templates are pre-configured for the channel setups and acquisition parameters required for a variety of applications.

- In addition to the standard sample files, measurement sample data files are provided. These files are configured for specific measurement types and include spreadsheets providing external data necessary for measurement verification. Each spreadsheet contains procedures and examples for the associated measurement data file. These sample data files consist of Event Measurements.acq, Traditional.acq (standard mathematical measurements included in Acq*Knowledge*), Expression Sum_Calculate.acq and Correl Coef.acq (Correlation Coefficient).
- To open a graph template ***Quick Start*** file, choose File > Open then Browse to the BIOPAC Samples folder (be sure to select/enable the desired file type).

Graph (*.acq)
Graph Template (*.gtl)
Text (*.txt *.csv)
Journal (*.jcq)
Journal Template (*.jtl)
Windows AcqKnowledge 3 Graph (*.acq)
Macintosh AcqKnowledge 3 Graph (*) (*.*)
Advanced Averaging Experiment (*.aae *.avg)
PhysioNet - WFDB (*) (*.*)
MATLAB Mat-File (*.mat)
Raw (*) (*.*)
Batch Acquisition (*.bcq)
Igor Pro Experiment (*.pxp)
WAV (*.wav)
Biopac Student Lab 3 (*.acq *-L?? *.gtl)
EDF (*.edf *.eeg)
Actigraphy (*.act)
BIOPAC Basic Script (*.bbs)

Where do I find help?

The Introductory sections are intended to provide enough information to get up and running with the MP System, and become familiarized with some basic Acq*Knowledge* functions. For detailed in-depth information, the following resources are available.

- *Help menu*

  The online Help menu includes basic information about standard Acq*Knowledge* functions and links to the tutorial, software guide and hardware guide for online searchable Help while running Acq*Knowledge*, plus links to the BIOPAC web site.

  Please visit BIOPAC's Tutorial Video page for instructional screencasts of many analysis routines and software features.

- *Application Notes*

  The BIOPAC web site at http://www.biopac.com has more than 50 available Application Notes. Download the desired Application Note or call to request a hard copy.

- *Acquiring data*

  For more specific information on different types of acquisitions, see Part B—*Acquisition Functions*. It covers basic acquisition parameters in detail, and describes some acquisition features (such as *peak detection* techniques and *online Calculation channels*) not covered in the Getting Started section.

- Acq*Knowledge*

  Information about how to edit, display and transform data can be found in Part C—*Analysis Functions*. It explains how to import and export data, how to save files, and other file management commands. This section also explains how to use all of the post-acquisition features of the Acq*Knowledge* software.

- *Connecting input devices*

  To find out how specific modules connect to the data acquisition hardware, turn to the *BIOPAC Hardware Guide* PDF file. This section describes how to connect signal-conditioning modules to the data acquisition unit and how to connect electrodes and transducers to the modules.

- *Working with large files*

  Many users need to perform high speed (i.e., fast sampling rates) or long duration acquisitions. These types of acquisitions tend to generate large (several megabytes) data files that can be difficult to load, store, and view. The Hardware System can handle such acquisitions—see the Appendices for information on how to optimize setup for these types of acquisitions.

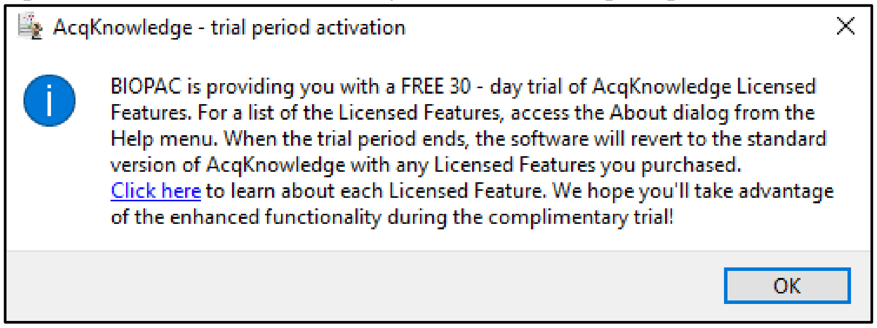
- *Troubleshooting*

  Includes a list of the most frequently asked questions regarding the Hardware System. Check this section (Appendix A) for commonly encountered problems and solutions.

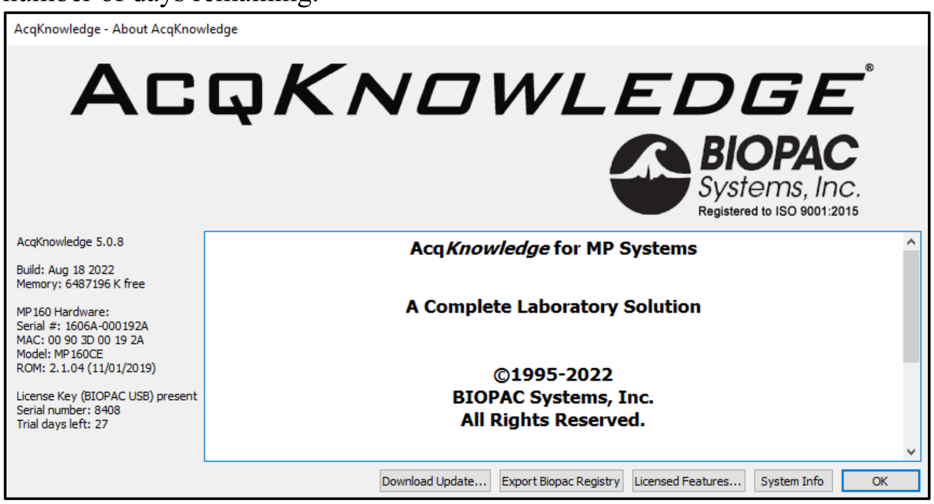
Trial Period

Beginning with Acq*Knowledge* 5.0.8, users have the option of trying Acq*Knowledge*'s licensed software functionalities for up to 30 days. The trial period begins with first usage following initial installation or update to Acq*Knowledge* 5.0.8.

1. Upon launch with a new USB key, the user will be prompted with the following message.



2. Clicking the "Click here" link opens the BIOPAC web page, which provides additional information on the Acq*Knowledge* License Trial.
3. To check how many days are left in the user's trial period, open the "About Acq*Knowledge*" window in Acq*Knowledge*. "Trial days left" will be displayed in the lower left side of the window along with the number of days remaining.

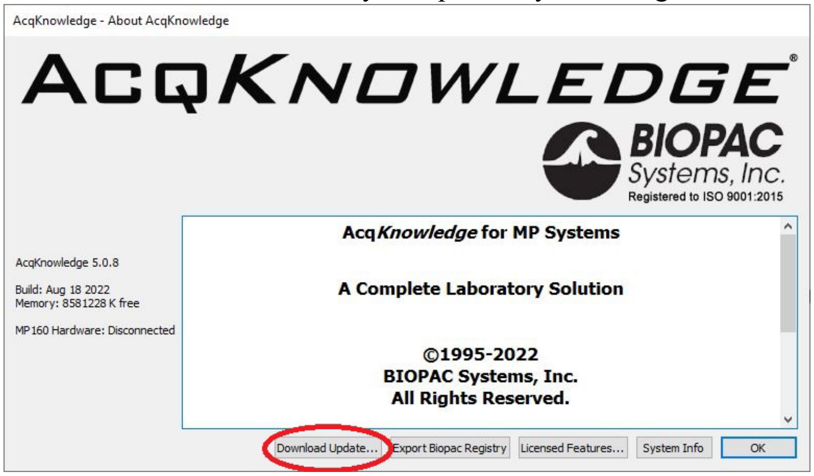


4. When the trial period ends, the Acq*Knowledge* software reverts to the standard version of Acq*Knowledge*, including any Licensed Features the user previously purchased.

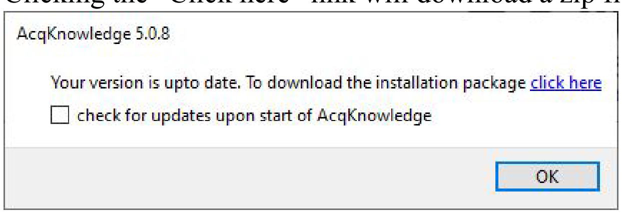
Check for Updates

Licensed editions of Acq*Knowledge* can now check for, download, and install software updates for existing customers. This simplifies the delivery and installation of update packages for the latest versions of Acq*Knowledge*.

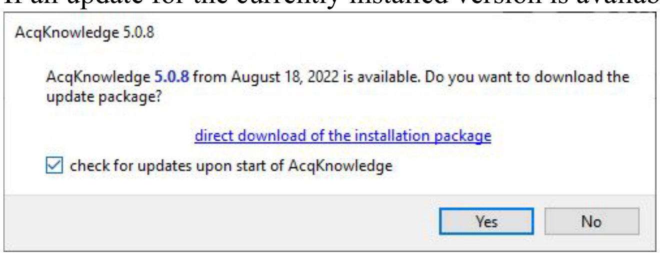
1. Users can check the availability of updates by accessing the "About Acq*Knowledge*" window.



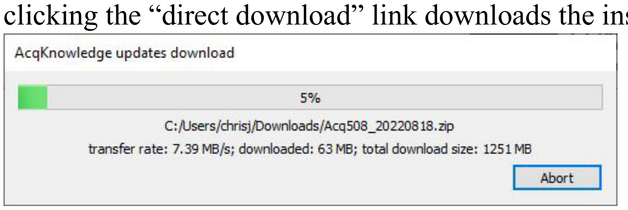
2. If the currently installed version of Acq*Knowledge* is up to date, a prompt like the following will appear. Clicking the "Click here" link will download a zip file of the installation package.



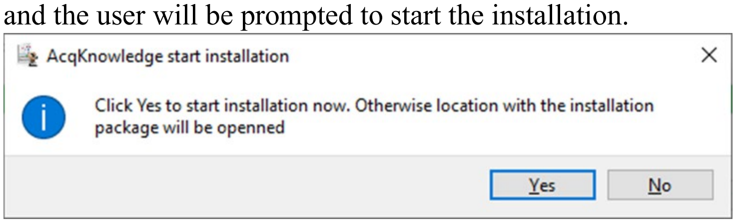
3. If an update for the currently installed version is available, the user will see a prompt like the following.



4. Click **Yes** to automatically begin the installation process. If the user wishes to automatically check for updates when Acq*Knowledge* is launched in the future, check the box at the bottom of the window. After clicking **Yes**, the user will be asked to select a destination folder for the downloaded files. Once the download folder is selected, the download process will begin by displaying a progress bar. Alternatively, clicking the "direct download" link downloads the installation package as a zip file for manual installation.



5. After the installation package has been downloaded, the archived installation files will automatically unzip, and the user will be prompted to start the installation.



IMPORTANT SAFETY NOTICE

BIOPAC Systems, Inc. instrumentation is designed for educational and research-oriented life science investigations. BIOPAC Systems, Inc. does not condone the use of its instruments for clinical medical applications. Instruments, components, and accessories provided by BIOPAC Systems, Inc. are not intended for the diagnosis, mitigation, treatment, cure, or prevention of disease.

The MP data acquisition unit is an electrically isolated data acquisition system, designed for biophysical measurements.

Exercise extreme caution when applying electrodes and taking bioelectric measurements while using the hardware with other external equipment that also uses electrodes or transducers that may make electrical contact with the Subject. Always assume that currents can flow between any electrodes or electrical contact points.

Extreme caution is also required when performing general stimulation (electrical or otherwise) on a subject. Stimulation currents should not be allowed to pass through the heart. Keep stimulation electrodes far from the heart and located close together on the same side of the subject's body.

It is very important (in case of equipment failure) that significant currents are not allowed to pass through the heart. If electrocautery or defibrillation equipment is used, it is recommended that all BIOPAC Systems, Inc. instrumentation be disconnected from the Subject.

Human Anatomy & Physiology Society Position Statement on Animal Use

(Adopted July 28, 1995, Modified January 2001, Approved April 29, 2012)

It is the position of the Human Anatomy and Physiology Society (HAPS) that dissection and the manipulation of animal tissues and organs are important elements in scientific investigation that introduce students to the excitement and challenge of their future careers. HAPS supports the use of biological specimens as part of a program of study, provided their use is in strict compliance with federal legislation and the guidelines of the National Institutes of Health and the United States Department of Agriculture, and that such use fulfills clearly defined educational objectives.

The mission of the Human Anatomy and Physiology Society (HAPS) is to promote excellence in the teaching of anatomy and physiology. A fundamental tenet of science is the ordered process of inquiry requiring careful and thoughtful observation by the investigator. As subdivisions of biology, both anatomy and physiology share a long history of careful and detailed examination, exploration and critical inquiry into the structure and function of the human and animal body.

Consistent with the origins and nature of scientific inquiry, HAPS endorses the use of animals as part of the laboratory experiences in both human anatomy and human physiology.

Historically, an important tool of investigation in human and animal anatomy has been dissection. A complete anatomy learning experience that includes dissection goes beyond naming structures and leads the student to conclusions and insights about the nature and relatedness of living organisms that are not otherwise possible. To succeed in their future careers, students must become thoroughly familiar with anatomical structures, their design features and their relationships to one another. Dissection is based on observational and kinesthetic learning that instills a recognition and appreciation for the three-dimensional structure of the animal body, the interconnections between organs and organ systems, and the uniqueness of biological material. Dissection conveys the inherent variability of living organisms not otherwise observable in simulations and models. Physiology experiments involving humans and live animals provide an excellent opportunity to learn the basic elements specific to scientific investigation and experimentation. It is here that students pose questions, propose hypotheses, develop technical skills, collect data, analyze results and develop and improve critical thinking and problem solving skills

Since effective teaching requires a diversity of strategies and approaches, HAPS endorses the use of computer atlases and simulations, modeling, and video programs to meet educational objectives and the needs of students. Science educators choosing not to use animals or biological specimens should choose alternatives that are able to convey equivalent anatomical and physiological intricacies to meet their educational objectives.

Science educators have in common a respect and reverence for the natural world and therefore have a responsibility to share this with their students. They must communicate the importance of a serious approach to the study of anatomy and physiology. HAPS also encourages educators to be responsive to student concerns regarding use of animals and to provide students who object to animal use with alternative learning materials.

HAPS contends that science educators should retain responsibility for making decisions regarding the educational uses of animals and other strategies and techniques for the betterment of their student's learning. Furthermore, it opposes any legislation or administrative policy that would erode the educator's role in decision making or restrict dissection and animal experimentation in biology.

Part A — Getting Started

Chapter 1 MP Systems Overview

Part A - *Getting Started* covers the basics of data acquisition and analysis with the MP System (MP160, MP150 or MP36R), since these are the most commonly-used BIOPAC hardware systems. All material in this section is covered in greater detail in subsequent sections (see *Using this Manual, page 14*).

BioHarness™ users should also see the **BioHarness User Guide** *available under the Help menu and installed to the User Support folder in the program folder. Other BIOPAC hardware types, such as B-Alert, and Stellar are covered in the Licensed Functionality chapters at the end of the guide.*

Overview

Data acquisition involves acquiring incoming signals (usually analog) and sending them to the computer, where they are (a) displayed on the screen and (b) stored in the computer's memory (or on hard disk). These signals can then be saved for later analysis. Graphical and numerical representations of the data can also be produced for use with other programs.

Function	MP160 (64-bit) and MP150 (32-bit)
Aggregate Sample Rate	
Internal MP160/150 Buffer:	400 kHz
To Cpt. Memory or Disk:	300 kHz
Internal Buffer Size:	6 Mbytes
A/D Converter Signal/Noise Ratio:	86 dB typical
D/A Resolution:	16 bits
D/A Output rate:	Independent of A/D rate
Communication to Computer:	Ethernet (10 base T, UDP and DLC Type II)

Acq*Knowledge* software included with the MP system allows full control over editing data, how it is displayed onscreen, and performs four general functions:

(a) Control the data acquisition process;
(b) Perform real-time calculations (such as digital filtering and rate detection);
(c) Perform post-acquisition transformations and analyses;
(d) Handle file management commands (saving, printing, etc.).

Acq*Knowledge* software shares the same interface on computers running Windows® or Mac® OS. However, most optionally licensed features are available in the Windows version only.

The heart of the MP System is the MP data acquisition unit, which converts incoming physiological data into digital signals to be processed and displayed in Acq*Knowledge* software. The MP160/150 data acquisition unit connects via Ethernet, the MP36R connects via a USB connection.

The MP160 System also includes a High Level Transducer Module (AMI100D or HLT100C) for connecting external devices to the MP160 unit. (The older-model MP150 System was supplied with a UIM100C Universal Interface Module.) These Modules connect to the side of the MP160/150 unit.

Newer MP160 units for Acq*Knowledge* 5.0.4 and higher use the upgraded AMI100D Interface Module with support for both 100D Series Smart Amps and earlier 100C Series Amplifier Modules.

A wall transformer is included with the MP System (MP160, MP150 or MP36R) to convert AC mains power into DC power suitable for system operation and safety.

MP36R support

The MP36R is a four-channel data acquisition unit designed to work with Acq*Knowledge* 4.1 and above. Acq*Knowledge* support for the MP36R unit includes:

- Standard data acquisition and data acquisition features (triggering, multiple channels, variable sampling rate, input values)
- Output control functionality for controlling stimulators, digital channel, and channel redirection to output.
- Standard analog presets for all SS series transducers
- Electrode Check support
- Multiple-MP device support. Similar to multiple MP160/150 support, each graph may acquire from a maximum of one unique MP device.
- Control channel support for changing digital output lines based on calculation channel analysis

MP36R Notes The computer sleep mode should be disabled—if the computer goes to sleep while Acq*Knowledge* 4 is running, communication with the MP36R may be lost and the application may freeze. To prevent this from occurring, modify the computer settings to prevent the computer from going to sleep.

- If sleep mode is enabled and causes the application to freeze, force quit the application and 'power cycle' the MP unit to re-establish communication.
- During an unresponsive period, the 'Connect Hardware' dialog may display odd characters in place of the MP serial number or the computer, upon waking up, may generate a "Driver irql not less or equal" error dialog.

Acq*Knowledge* software does not support MP36 units from the Biopac Student Lab product line (without the "R" designation).

Mac OS users: Connect the MP36R directly to the computer, do not connect MP36R via hub or keyboard.

MP System Requirements

Suggested minimum system requirements are detailed below. Recommendations are included to optimize system performance; more memory and a faster system will enhance MP System performance. If planning to acquire data for more than a few hours and/or are sampling at more than 2,000 samples per second, see the Disk Space note on the following page.

	For Acq*Knowledge* 5
OS	Requires Windows 10/8/7 or Mac OS 10.10-10.15
Port	MP160/150 Requires Ethernet (UDP), MP36R requires USB. **Note** To use an MP160/150 with UDP communication on a network with a non-Windows DHCP server, it is necessary to use firmware rev. 1.1.12 or greater in order for the MP160/150 unit to properly be assigned an IP address. This is also true for any DHCP system with non-Windows operating systems, such as Unix, Linux, Mac OS, and other DHCP-aware devices. UDP ports for MP160 are 16004 and 16005, for MP150, 15000 and 15001
Hard Disk	Requires 5 GB to store the software and online manuals; additional 5 GB recommended for data storage
RAM	4 GB minimum, 8 GB recommended
Processor	Windows: Intel Core 2 Duo minimum, Intel i5 dual-core or higher recommended Mac: Intel Core 2 Duo minimum, Intel i5 dual-core or higher recommended

Disk Space

With any program, adequate disk space is necessary for storage of data files. To acquire data for long periods (more than a few hours) while sampling at relatively fast rates (more than 2,000 samples per second), as much disk space as possible should be available. (A removable drive may also be used). See the Appendices for hints on working with large files.

Automator Integration and Scripting Support

Mac OS X includes a visual scripting environment called “Automator.” Automator allows for drag and drop creation of “Workflows.” Each workflow is a series of steps that is performed in another application. Each individual step is called an action. An action encapsulates a simple operation within another application, such as opening a text file in TextEdit or applying a filter within Photoshop.

Over 40 actions have been written to allow Acq*Knowledge* to be controlled from Automator workflows. Using these actions, workflows can be constructed to perform sequences of transformations, automating post-acquisition analysis, performing experimental protocols, and other repetitive operations.

Workflows can be constructed using Automator. It is also possible to create, edit, and execute workflows directly from within the Acq*Knowledge* environment using the new “Workflow” menu. The Workflow menu allows the creation of workflows specific to an individual user account or to one shared by all Acq*Knowledge* users. These workflows can then be edited in the Automator environment. Each workflow created using Workflow > New Workflow will appear at the bottom of the Workflow menu each time Acq*Knowledge* is launched. By simply selecting the name of the workflow from the Workflow menu, Acq*Knowledge* will execute the workflow.

Workflows executed from the Workflow menu should begin with either an “Open Graphs” or a “Get Active Graphs” action. Workflows intended for use outside of the Acq*Knowledge* environment (e.g. used as Folder Actions) should begin with a “Launch Application” action to start Acq*Knowledge* followed by an “Open Graphs” or a “Get Active Graphs” action.

For more information about Automator and help constructing workflows, see the Apple website at:

https://support.apple.com/guide/automator/welcome/mac

MP System with Acq*Knowledge* Features

The MP System (MP160, MP150 or MP36R) with Acq*Knowledge* software is a complete system for acquiring almost any form of continuous physiological data, whether digital or analog. The MP System can perform a range of recording tasks, from high-speed to long duration acquisitions. For physiological applications, the MP System is limited only by the computer speed and available memory or disk space. Features of the MP System include:

Easy to use	The MP System with Acq*Knowledge* offers power and convenience. In terms of hardware setup the MP System (MP160, MP150 or MP36R) uses simple plug-in connectors and standard interface cables.
Flexible	Acq*Knowledge* can be configured for a wide variety of applications, from single channel applications to multiple-device measurements (up to 16 analog and 16 digital, or multiple MP160s or MP150s). Control the length of acquisition, the rate at which data is collected, how data is stored, and more.
Menu flexibility	Customize menu displays to show only necessary functions, thereby reducing the risk of error or confusion in the lab. This is useful for teaching applications, giving instructors the option to hide unnecessary menu items. *See* Appendix D—Customizing Menu Functionality.
High Speed Sampling	Sample rates up to 400 KHz aggregate.
Variable Sample Rates	Apply different sample rates between channels or operate the STM100C stimulator at a different rate than the acquisition sample rate.
Template files	Acq*Knowledge* "*Quick Start*" templates are available for over 40 applications. Just open the template file and start the acquisition—appropriate settings are established for the selected application.
Online Calculation	Although Acq*Knowledge* includes an extensive array of measurements and transformations applicable to collected data, computations often need to be performed *while* data is being recorded. The online Calculation functions and presets allow users to calculate new channels based on incoming signals. For example, this feature supports real time extraction of BPM and many other signals based on raw ECG data.
Online measurements	Acq*Knowledge* can instantly extract over 40 measurements and computations for any given data point(s). These options are available from pull-down menus and include mean, peak-to-peak, value, standard deviation, frequency, and BPM.
Measurement Validation	Validate measurements with the ValidateMeasurements.acq sample file that was included with the software. The measurement definitions (page 98) include measurement formulas and "*Sample data file*" explanations.
Preview data	Acq*Knowledge* supports easy modification of the vertical scale and the horizontal scale. Change the amplitude scale or the time scale to any desired value, or have Acq*Knowledge* automatically scale them.
Simplified editing	Delete or edit sections data with a keystroke. Paste together sections from different waves, or simply edit out noise spikes from individual waves.
Append mode	For certain applications, it may be necessary to only record data during selected portions of an experiment. Acq*Knowledge* includes an "Append" recording mode, allowing unlimited pausing and resuming of an acquisition. Appending data conserves storage space and processing time for transformations.
Digital filtering	All data contains measurement error and noise. Reduce or eliminate errors in the data file by using the included digital filters and smoothing transformations. Smooth data across any number of samples, or filter out noise from any frequency or bandwidth. It's also possible to filter data as it is being recorded, rather waiting until post-acquisition. A wide range of online filters can be applied to incoming data and results viewed in real time.
Digital Output	Control external devices when an input or calculation channel meets self-defined trigger conditions. Use the Control channels to output a pulse when the analog channel signal falls above or below a given threshold.

X/Y plotting	View and acquire data in the form of an X/Y plot, with one channel displayed on the horizontal axis and another on the vertical axis. This allows exploration of relationships between different channels and opens up a whole range of applications, from chaos plots, to respiration analysis, to vectorcardiograms.
Histogram function	Easily examine the variability and central tendency measures of any waveform data with the histogram function. Set user-defined plotting options or let the software determine the “best fit” for graphing data.
Math functions	In many cases, simply collecting raw data is not enough. Acq*Knowledge* includes an array of built-in mathematical functions ranging from simple absolute value to computation of integrals, derivatives, and operations involving multiple waveforms (such as subtracting one wave from another). Daisy chain multiple functions together to form complex equations or expressions.
Annotation	Acq*Knowledge* includes a Journal window useful for adding comments relevant to the data, and can be used while online or post-acquisition. This is especially useful for noting the characteristics of an acquisition (what was involved, what manipulations took place, etc.) for future reference. *See also*: Text annotation, page 63.
Triggering	If an experiment requires measuring response times or starting an acquisition after a particular event has occurred, Acq*Knowledge* supports triggering acquisition via a variety of methods. Trigger on the level of a signal, or with an external synchronizing trigger.
Event markers	It’s often useful to make a note of when specific events have occurred so these events can be recorded and specific changes noted. The event function allows for the insertion of event markers into the recording and supports the addition of text for each event. Events can be added while data is being collected or post-acquisition. Event functionality can be automated for sequential application or customized to insert events using Function keys.
File compatibility	In Acq*Knowledge*, data can be saved and viewed in a number of different formats. For word processing programs such as Microsoft Word®, use Copy to Clipboard and then paste into the document. Use Save as Excel for Microsoft Excel®. Data can be outputted in text or graphical form, and supports import of raw data from a text file. Open (and Import) or Save As (and Export) supports many different file formats, such as MATLAB, Physionet, Igor Pro, SMI Begaze, Dataquest and more.
Pattern recognition	Using advanced pattern search/recognition algorithms, Acq*Knowledge* can automatically find a specific pattern within waveforms. This is useful for finding abnormal waveforms (such as irregular ECG waves) within a data file.
Cycle/Peak detection	Acq*Knowledge* has a built-in algorithm to find cycle data, such as positive or negative peaks, from any size data file. Search for all cycles/peaks with one command and automatically log statistics such as time and area to the Journal or spreadsheet.
Printing	Acq*Knowledge* provides a range of customizable graph printing options. No special printer drivers are required.
Report generation	Acq*Knowledge* includes many features to simplify report generation. Use the Journal for notes and quickly copy and paste graph data or measurements to the journal or to another program. Cascade event markers to prevent print overlap and select the range of data to print and which options to display (measurements, event markers, etc.). Use the Playback mode to simulate acquisition for presentations.
User Support	Questions about compatibility with existing equipment or need to develop a specialized measurement device? BIOPAC’s Applications Specialists are ready to help. (www.biopac.com/support)

Application Notes

BIOPAC has prepared a wide variety of application notes as a useful source of information concerning certain operations and procedures. These PDFs provide detailed technical information about either a product or application. View or print application notes directly from the *Support* section of the BIOPAC website https://www.biopac.com/application-note/.

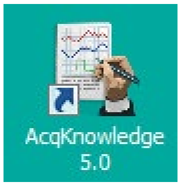
Application Features

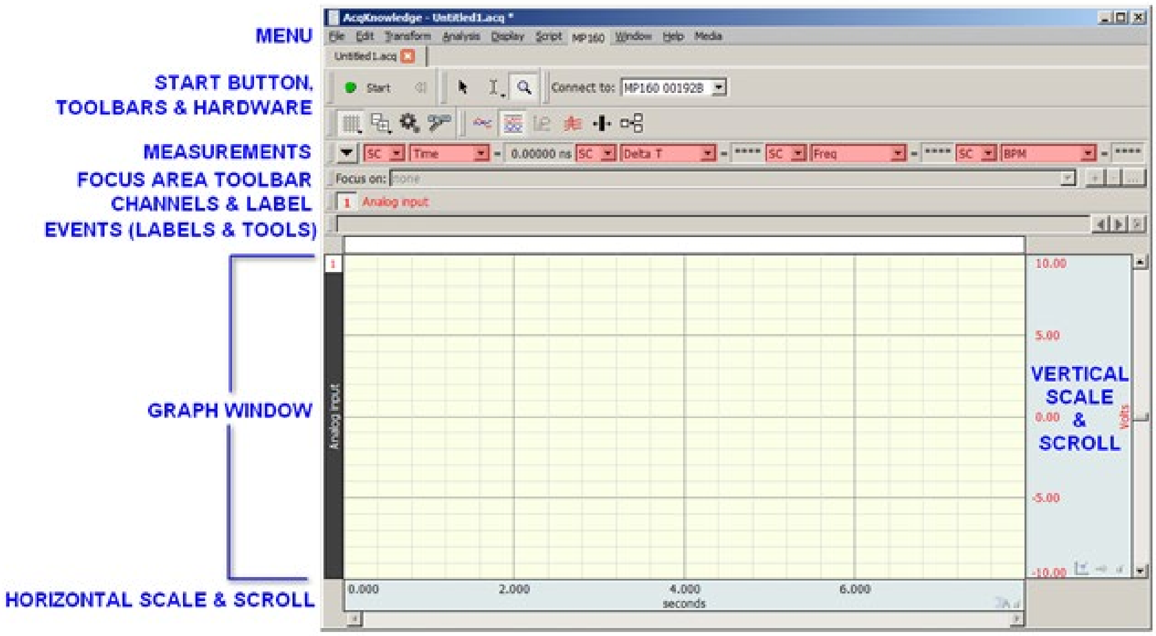
Use the MP System with Acq*Knowledge* software for a wide array of applications, such as:

Active Electrodes
Allergies
Amplitude Histogram
Anaerobic Threshold
Animal studies
Auditory Evoked Response (AER)
Automate Acquisition Protocols
Automated Data Analysis
Automatic Data Reduction
Autonomic Nervous System Studies
Biomechanics Measurements
Blood Flow / Blood Pressure /Blood Volume
Body Composition Analysis
Breath-By-Breath Respiratory Gas Analysis
Cardiac Output
Cardiology Research
Cell Transport
Cerebral Blood Flow
Chaos Plots
Common Interface Connections
Connect to MP System (MP160, MP150 or MP36R)s
Control Pumps and Valves
Cross- and Auto-correlation
Current Clamping
Defibrillation & Electrocautery
Dividing EEG into Specific Epochs
ECG Analysis
ECG Recordings, 12-Lead
ECG Recordings, 6-Lead
EEG Spectral Analysis
Einthoven's Triangle
EMG and Force
EMG Power Spectrum Analysis
End-tidal CO2
Episode Counting
Ergonomics Evaluation
Event-related Potentials
Evoked Response
Exercise Physiology
External equipment, controlling
Extra-cellular Spike Recording
Facial EMG
FFT & Histograms
FFT for Frequency Analysis
Field Potential Measurements
Fine Wire EMG
Forced Expiratory Flow & Volume
Gait Analysis
Gastric Myoelectric Activity
Gastric Slow Wave Propagation
Gastrointestinal Motility Analysis
Hardware Flexibility
Heart Rate Variability
Heart Sounds
Histogram Analysis
Imaging Equipment, Interfacing
Indirect Blood Pressure Recordings
Integrated (RMS) EMG
Interface with Existing Equipment
Interface with Third-party transducer
Invasive Electrode Measurements
Ion-selective Micro-electrode Interfacing
Iontophoresis
Irritants & Inflammation
Isolated Inputs & Outputs
Isolated Lung Studies
Isometric Contraction
Isotonic Contraction
Jewett Sequence
Langendorff Heart Preparations
Laser Doppler Flowmetry
Left Cardiac Work
Long-term Monitoring
Lung Volume Measurement
LVP
Median & Mean Frequency Analysis
Micro-electrode signal amplification
Migrating Myoelectric Complex
Motor Unit Action Potential
Movement Analysis
MRI Applications
Multi-Channel Sleep Recording
Nerve Conduction Studies
Neurology Research
Noninvasive Cardiac Output
Noninvasive Electrode Measurements
Nystagmus Investigation
Oculomotor Research
Off-line ECG Averaging
Online Analysis
Online ECG Analysis
Orthostatic Testing
Peripheral Blood Flow
Peristaltic (Slow Wave) Propagation
Planted Tissue
Pressure Volume Loops
Psychophysiology
Pulsatile Tissue Studies
Pulse Rate Measurement
Pulse Transit Time
Range of Motion
Real-time EEG Filtering
Real-time EEG Filtering
Recurrent Patterns
Regional Blood Flow
Relative BP Measurement
Remote Monitoring
Respiration Monitoring
Respiratory Exchange Ratio
Rheumatology
Saccadic Eye Movements
Sexual Arousal Studies
Signal Averaging
Simultaneous Monitoring
Single Channel Analysis
Single-fiber EMG
Software-controlled Stimulator
Somatosensory Evoked Response
Spectral Analysis
Spike Counting
SpO2 Analysis
Stand Alone Amplifiers
Standard Operating Procedures
Startle Eye Blink Tests
Startle Response
Stimulator, software-controlled
Systemic Vascular Resistance
Template Analysis
Tissue Bath Monitoring
Tissue Conductance Measurement
Tissue Magnitude & Phase Modeling
Tissue Resistance & Reactance
Ussing Chamber Measurements
Ventricular Late Potentials
Vestibular Function
Visual Attention
Visual Evoked Response
VO2 Consumption
Volume/Flow Loop Relationships
Working Heart Preparations

Chapter 2 Acq*Knowledge* Overview

Overview





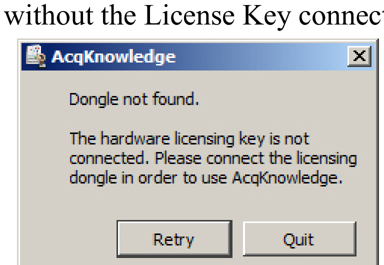
Acq*Knowledge* software performs two basic functions: acquisition and analysis. The acquisition settings determine the basic nature of the data to be collected, such as the amount of time data will be collected for and at what rate data will be collected. All acquisition parameters can be found under the hardware (or MP) menu. Other menu commands pertain to analysis functions such as viewing, editing, and transforming data.

Note: Minor differences exist between the Windows and Mac OS screen displays and keystroke/mouse functionality. These differences are noted throughout this section.

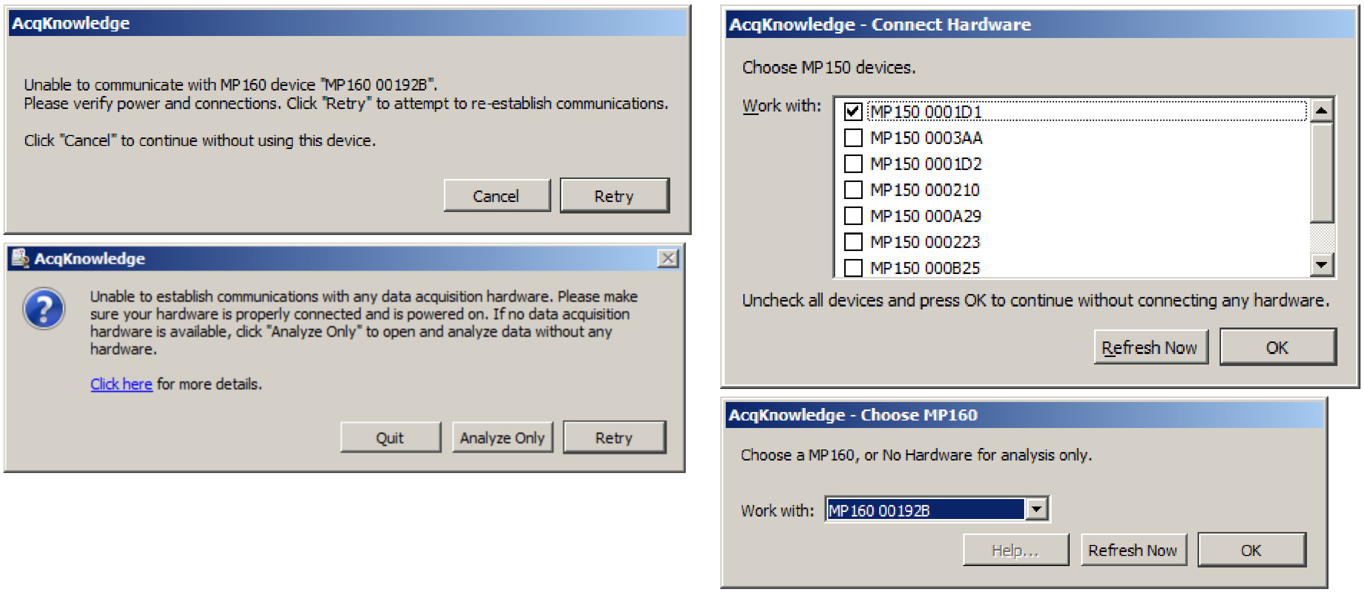
Menu	Functionality	See Page
File	New, Open, Open Recent, Open Sample Data File, Open for Playback, SMI BeGaze Import, Close, Dataquest Import, Dataquest Export, Save, Save As, Save Selection As, Save Journal Text As, Send Email as Attachment, Copy to Dropbox, Open from Dropbox, Page Setup, Print, Quit	286
Edit	Undo, Cut, Copy, Paste, Clear/Clear All, Remove Last Appended Segment, Insert Waveform, Duplicate Waveform, Select All, Remove Waveform, Create Data Snapshot, Merge Graphs, Clipboard (Copy Measurement, Copy Wave Data, Copy Graph, Copy Acquisition Settings, Copy Data Modification History for All Channels, Copy Data Modification History for Graph, Copy Focus Area Summary, Copy Event Summary), Journal (Paste Measurements, Paste Wave Data, Paste Acquisition Settings, Paste Modification History for All Channels, Paste Modification History for Selected Channel, Paste Focus Area Summary, Paste Event Summary, Manage PDFs, Show Journal)	317
Transform	*operations that primarily modify the data in the graph* Recently Used, Digital Filters, Fourier Linear Combiners, Math Functions, Template Functions, Integral, Derivative, Integrate, Smoothing, Difference, Resample Waveform, Resample Graph, Expression, Delay, Rescale, Waveform Math, Slew Rate Limiter	328
Analysis	*operations that derive data & measurements from the graph* Recently Used, Histogram, Autoregressive Modeling, Nonlinear Modeling, Power Spectral Density, Autoregressive Time-Frequency Analysis, FFT/IFFT, DWT Discrete Wavelets, Principal Component Analysis/Inverse PCA, Independent Component Analysis/Inverse, Find Cycle, Find Rate—plus a courtesy copy of the Specialized Analysis package with classifiers and automation routines	361
Display	Tile Waveforms, Autoscale Single Waveform, Autoscale Waveforms, Optimize Ranges, Overlap Waveforms, Compare Waveforms, Autoscale Horizontal, Show All Data, Show Default Scales, Zoom, Reset Chart Display, Reset Grid, Adjust Grid Spacing, Set Wave Positions, Set Channel Visibility, Wave Color, Horizontal Axis, Show, Customize Toolbars, Channel Info, Preferences, Size Window, Cursor Style, Split View, Create Data View, Create Focus Area, Organize Data Snapshots, Show All Data Snapshots, Load All Data Into Memory	486
MP160/MP150 MP36R B-Alert* BioHarness* Smart Center*	Set Up Data Acquisition, (Channels, Length/Rate, Event Marking, Segment Labels, Stimulator, Trigger, Sound Feedback), Set Up Advanced Averaging, Show Input Values, Show Manual Control, Show Gauge, MP160/150 info, Update Firmware, Search for BioNomadix Loggers, Quick Import BioNomadix Log, Import BioNomadix Logs, Disconnect BioNomadix Logger, Configure BioNomadix User Alarms, AutoPlotting, Scrolling, Sweep, Warn on Overwrite, Organize Channel Presets, Set Up Linked Acquisitions, Exit Playback Mode, Manage Hardware Connections *Not all MP hardware menu items listed above will be available with MP36R, B-Alert, BioHarness, Smart Center, or other hardware.	113
Playback	Replaces the hardware menu when Playback mode is active (use File > Open for Playback and Playback > Quit playback to toggle playback and acquisition modes)	41
Window	Controls the position of windows on the monitor	518
Help	Provides online support files (PDF format and web links).	518
Media	Capture or Playback media files (.avi, .wmv, or mpg) and synchronize with .acq data	521

Launching the Acq*Knowledge* software

After installation, connect the black or blue BIOPAC Acq*Knowledge* License Key to an available USB port. The License Key must be connected in order for Acq*Knowledge* to run. If Acq*Knowledge* is launched without the License Key connected, a prompt will appear:

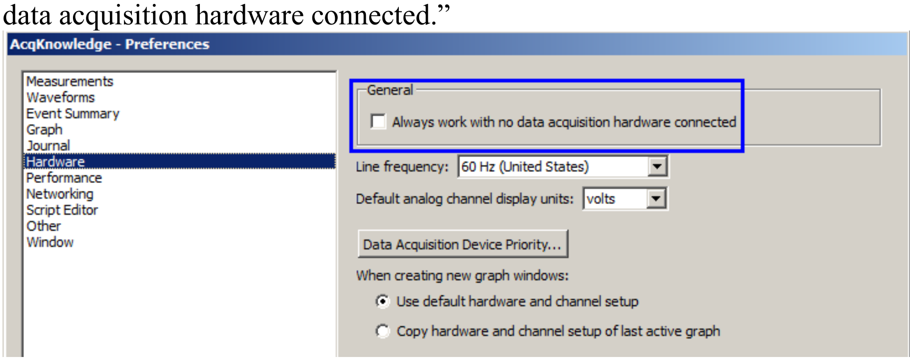


After connecting the License Key, launch the software by double-clicking on the Acq*Knowledge* icon. If hardware is not properly connected, the following messages may appear. (Examples shown are from commonly-used MP160 or MP150 hardware.)

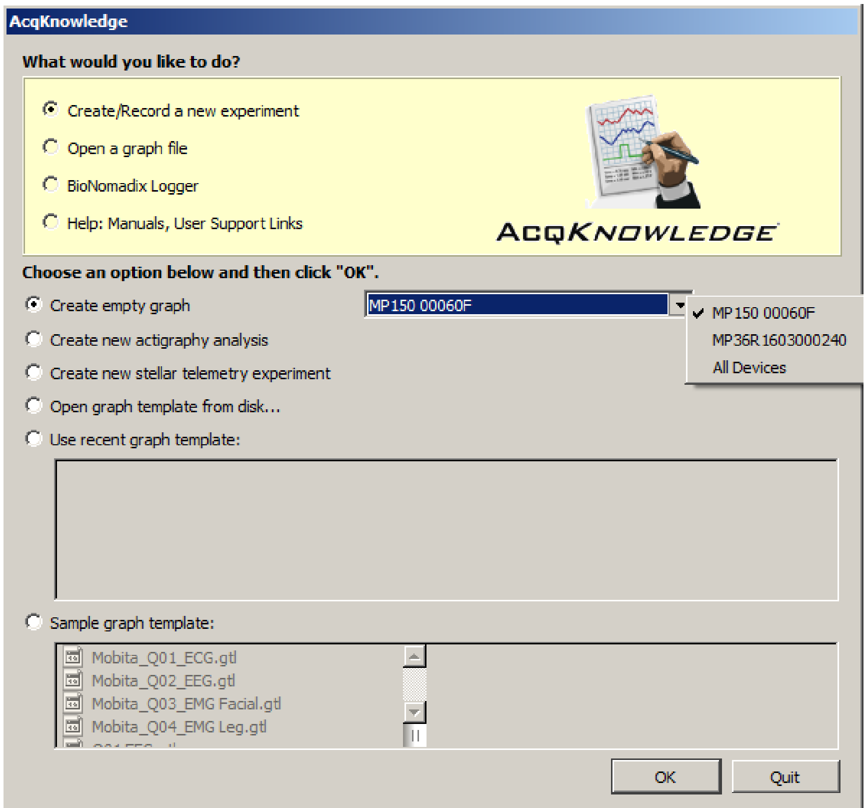


If a hardware prompt appears after launching Acq*Knowledge,* there are two primary causes: The hardware is not properly connected and/or the power is turned off.

- To use Acq*Knowledge* without a data acquisition unit (depending on the dialog), choose Cancel, Analyze Only, No Hardware, or set Preferences > Hardware > General to "Always work with no data acquisition hardware connected."



Assuming the hardware is properly connected, Acq*Knowledge* will launch the Startup Wizard. Use this wizard to choose whether to create a new experiment, open a saved graph for analysis or to access the Help and support options.



Standard Startup Wizard under 'Create and/or Record a new experiment'	Functionality
Create empty graph	Opens new graph window for acquiring data with hardware. Combo box to the right selects hardware, if more than one type is available.
Open graph template from disk	Brings up 'Open' window for browsing to location of saved graph templates.
Use recent graph template	Activates list of recently-opened graph templates for easy selection.
Sample graph template	Activates list of sample graph templates stored in Acq*Knowledge* program folder for easy selection.
Quit/OK	Quits application or confirms selected operation.
Hardware type menu (center right of screen)	If different hardware types have been previously added, they may be selected here upon subsequent application launches. (If not, this menu will not be displayed.)

NOTE: The Startup Wizard for BioNomadix Smart Center is different in appearance. See page 56.

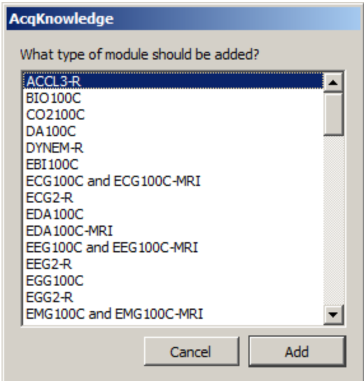
- **Open a graph file** Presents similar options for analyzing existing graphs, including a checkbox option to launch graphs in Playback mode. Playback mode will "replay" previously recorded graph data in real time.
- **BioNomadix Logger** Presents options for importing BioNomadix Logger data from the Logger device or from disk. Not applicable unless the wireless BioNomadix Data Logger is being used. For further information about the Logger, click here.
- **Help** Launch various help and support options, including Web screencast tutorials.

NOTE: The Startup Wizard may be disabled and bypassed if desired, after which Acq*Knowledge* will launch directly to a graph window. Choose "Display > Preferences > Other > When application is launched," change the default from "Show Startup Wizard" to "Create new empty graph window" and click OK.

It's good practice to create a new graph window for each acquisition. To create a new graph window after the original launch, choose "File > New."

Setting up channels using Module Setup (MP160 and MP150 Hardware)

By default, Acq*Knowledge* presents the Module Setup dialog when a new graph window is launched via "Create/Record a new experiment." This view enables stepwise configuration of Acq*Knowledge* modules and transducers simply by choosing from the list of supported hardware options, which can greatly simplify setup.



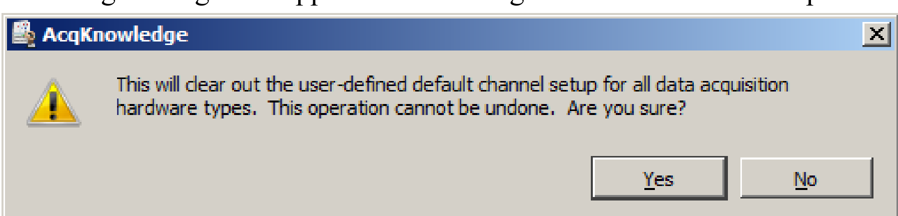
For further details on Module Setup, see page 116.

Setting up channels manually

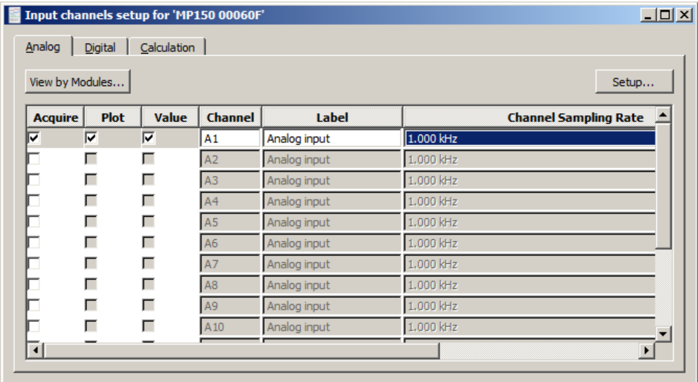
If manual setup of channels independent of hardware is preferred, click "Cancel" in the Module Setup dialog and choose the "View by Channels" option at the bottom of the channel setup screen. This will display the manually-configured Input Channels Setup dialog.

NOTE: If desired, disable the default factory channel setup by going to "Display > Preferences > Hardware" and changing the "**When creating new graph windows use:**" option from "Minimal channel setup" to "User-defined default channel setup." (For full details on this preference, see page 512.)

Also note that, when changing from "Minimal channel setup" to "User-defined default channel setup" the following message will appear after clicking the "Clear Default Setup" button:



Basic Analog Channel Information



If using Acq*Knowledge* with **BioHarness™**, Analog channels can be turned on/off but not changed.

By default, all channels are deselected on new graph windows. It's recommended that all three boxes (Acquire, Plot, and Value) be selected for each channel.

Acquire When the Acquire box is checked for a given channel, data will be collected on that channel.

Plot Determines if data will be plotted in real-time during the acquisition. If the plot box is unchecked, data will be recorded, but the associated channel will remain hidden.

Value Enables a separate Show Input Values window to display the values for each channel in real time, numerically and/or graphically.

Channel This is a dynamic alpha-numeric heading based on the type of channel selected: Analog (or continuous), Calculation, or Digital. In the sample above, "A1" indicates Analog channel one.

Label To the right of each channel number is an editable label for entering channel information.

Channel Sampling Rate The channel sample rate is a function of the acquisition sample rate: all channel sample rate options are equal to or less than the acquisition sample rate (as established via "Hardware > Set Up Acquisition"). The options are a specific power of 2 less than the acquisition sample rate. Use the pull-down menu to set the channel sample rate. See page 120 for details.

Basic Digital Channel Information

In contrast to analog data, Digital channels collect binary data that represent when a measuring instrument is "on" or "off." (For example, records whether a switch is open or closed, as in reaction time studies or control applications.) Digital channels are acquired, plotted, and have values listed the same fashion as analog channels. For more details about Digital channels, see page 148.

Basic Calculation Channel Information

Calculation channels are used for online computations and transformations of other channels. These channels are configured similarly to analog and digital channels, but also have additional dialogues to specify the types of transformations and computations to be performed.

Calculation channels include Presets as a quick way to get started—choose a preset and the software automatically sets the gain, offset, etc. appropriate for the selected application.

When a new Calculation channel is enabled, a simple setup dialog corresponding to the selected preset is presented, which helps facilitate proper setup. Choose from the list of available presets or create a custom preset; see page 119 for details.

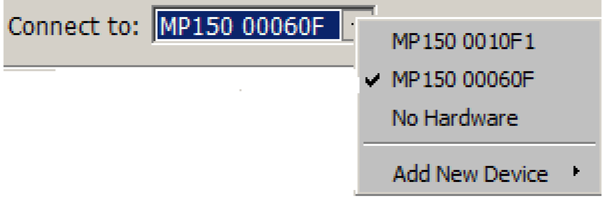
For a detailed summary of Calculation channel options, see the Calculation Channel section beginning on page 148.

For a detailed look at launching and setup of Acq*Knowledge* software, watch the [Tutorial video].

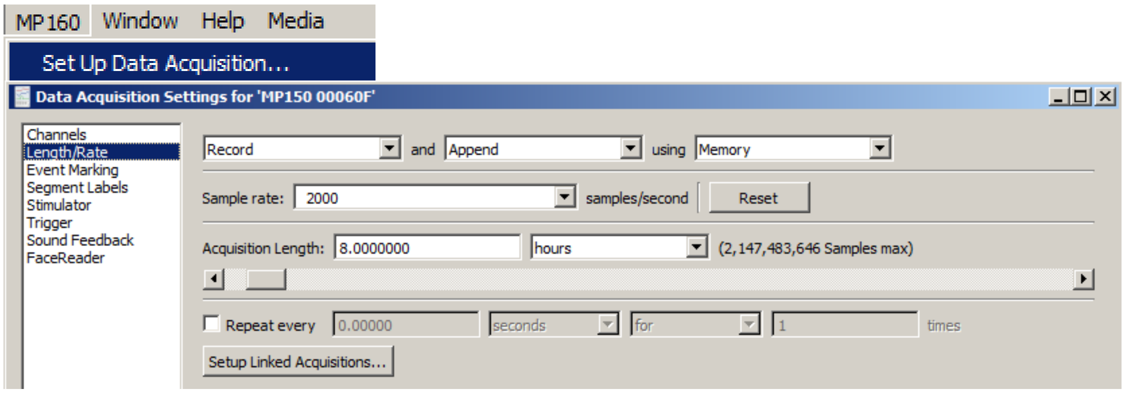
Selecting Hardware

When Acq*Knowledge* is first launched, an available data acquisition device can be selected from the "Connect to:" dialog. The dialog lists all devices that are powered ON and sitting on the same local area network. When using more than one MP160/150 device or working across a network, it will be necessary to lock/unlock an MP160/150 to acquire data (see Appendix E on page 696 for details). The selected MP160/150 unit will be listed in the upper left of the graph display as "Connect to:" if the Hardware toolbar display is enabled.

(To display the Hardware toolbar click the “add toolbar” icon and check the “Hardware” option.



Setting Up Acquisitions



Once the channel parameters have been defined, the next step is to specify the acquisition settings. Choose Hardware menu > Set Up Data Acquisition > Length/Rate from the Data Acquisition Settings dialog to specify the type of acquisition to be performed. The basic parameters involve:

a) How data should be collected and stored
b) The data collection rate
c) The acquisition duration (total length)

Storage

Record and Append using Memory is the default acquisition option. Under this option, the MP System automatically records data into a single continuous graph, and stores the data in computer memory during the acquisition.

The third popup menu at the top of the dialog (which defaults to Memory) specifies where data should be stored during the acquisition. Data can also be stored to disk or to the MP160/150 hardware. Up to 4 mb of data can be stored directly to the MP160/150. Data cannot be stored directly to the MP36R or other BIOPAC hardware types.

- The advantage of storing to the MP data acquisition unit is that much faster sampling rates may be obtained.
- The disadvantage of saving data to the MP data acquisition unit is limited storage space and that data is not displayed onscreen while being collected. When the acquisition has stopped, however, the data will automatically redraw on the screen.

The other option under storage is Averaging, which allows repeated trials of the same data. For more information on this feature, see the averaging section on page 191.

Rate

Acquisition Sample Rate refers to how many samples the MP System acquires each second. The higher the sample rate, the more accurate the signal processing. However, as the sampling rate increases, so does the demand for system resources (memory, disk space, etc.). There is a “point of diminishing return” in terms of sampling rate for almost all types of analog signals, where sampling above a given threshold adds relatively little information.

The MP160/150 sampling rate has a lower bound of 0.1 samples per second, and an upper bound of 400 kHz aggregate. The MP160/150 must use a pre-defined rate; it does not accept custom rates.

Choose the best acquisition sample rate from the pop-up list.

Note: Channel sample rates are variable based on the acquisition sample rate. All channel sample rate options are equal to or a specific power of 2 less than the acquisition sample rate.

Duration

The final acquisition parameter is Acquisition Length (Total Length), which controls how long an acquisition will last. This can be scaled in seconds, minutes, hours, milliseconds or number of samples. Set this value either by entering a number in the acquisition length box, or by moving the scroll box left or right.

Starting an Acquisition

Once the channels and channel characteristics have been specified, the next step is to start the acquisition. If a file window is not already open, choose File > New > Graph window.

Status light

To the left of the Start button is a circular status light. The status light indicates the communication link between the computer and the data acquisition hardware unit.

- If the data acquisition hardware unit is properly connected to the computer and is turned on, the circle will be solid and green.
- If the data acquisition unit is not properly connected or not communicating with the computer, the circle will be gray.
- Start

To start an acquisition, position the cursor over the 

button and click the mouse, or select **Ctrl+ Spacebar**. If electrodes or transducers are connected to the data acquisition unit, a small value of random signal "noise" with a mean of about 0.0 Volts will be collected.

- For information on how to connect measurement devices to Hardware Systems, see the *BIOPAC MP Hardware Guide.pdf*.
- To start an acquisition using a variety of "triggers," see page 202.
- Graphs that open without a Start Button
    - Compressed Graphs
    - Igor Pro Experiment
    - PhysioNet
    - DWT, IDWT
    - PCA, IPCA,
    - ICA, IICA,
    - AR Model separate graph output
    - Nonlinear Modeling separate graph output
    - HRV tachogram output
    - Chaos > Plot Attractor
    - Chaos > Detrended Fluctuation Analysis
    - MATLAB Graphs
    - Merge Graphs
    - Original Data Snapshot
    - Raw Data Files
    - Text Files
    - Transform menu operations: Off-Line Averaging; Filter Response
    - Analysis menu operations: Histogram; FFT (Magnitude and Phase); IFFT; Rate (put result in new graph option)

Once an acquisition has started, the Start button in the acquisition window will toggle to a Stop button, and two opposing arrows will blink, indicating that data is being collected (see below). The "BUSY" indicator light on the front of the data acquisition unit will also illuminate, showing that data is being collected.

Stopping an Acquisition

To stop an acquisition at any time, click the 

button or select **Ctrl+ Spacebar**.

An acquisition will stop automatically when it has recorded an amount of data equal to that indicated in the Total Length box. To save this data file, choose File > Save.

The double-arrow icon to the right of the Start/Stop button is the rewind segment button. Use this button to remove any unwanted recording segments from the graph. For more details, see page 198.

Display Modes

The display modes are Chart, Scope, X/Y, Stacked Plot, and Playback. The data display as it appears on the screen can be changed at any time, even during an acquisition. To change the display mode, click the corresponding icon in the toolbar.

Chart mode

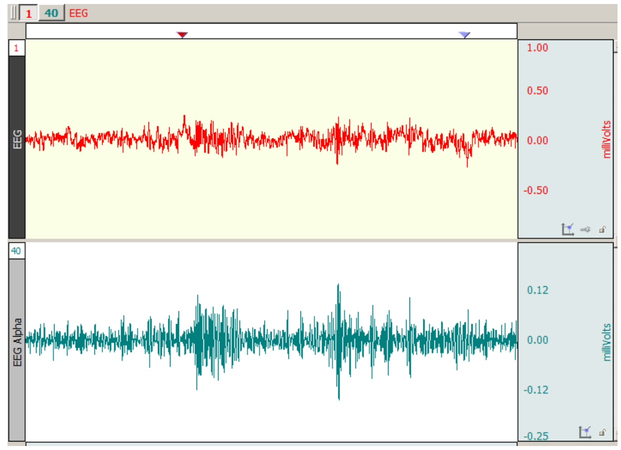
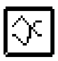


Chart mode is the default display mode.

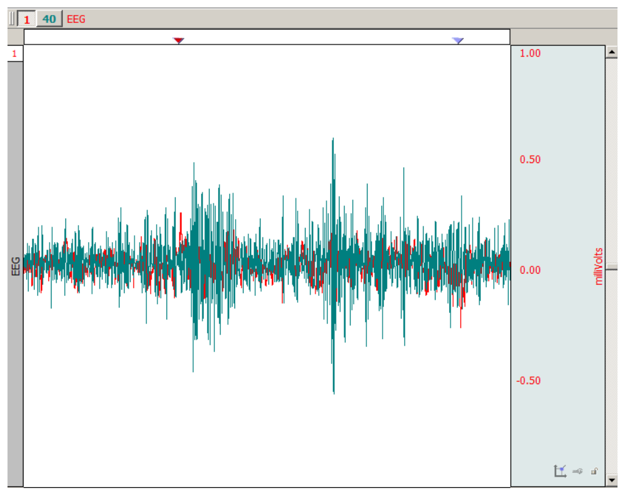
Chart mode plots data much as it might appear on a chart recorder, with time on the horizontal axis.

Each channel of data is in its own "track" across the screen, with borders between channels. The waveforms will not cross boundaries into the tracks of adjacent channels.

If a waveform is plotted off the scale of the channel track, choose autoscale waveforms and Acq*Knowledge* will select the "best fit" for waveforms to their tracks.



Scope mode



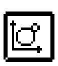
Scope mode plots data much as it might appear on an oscilloscope, with time on the horizontal axis.

Scope mode is similar to Chart mode, except there are no borders between different channels.

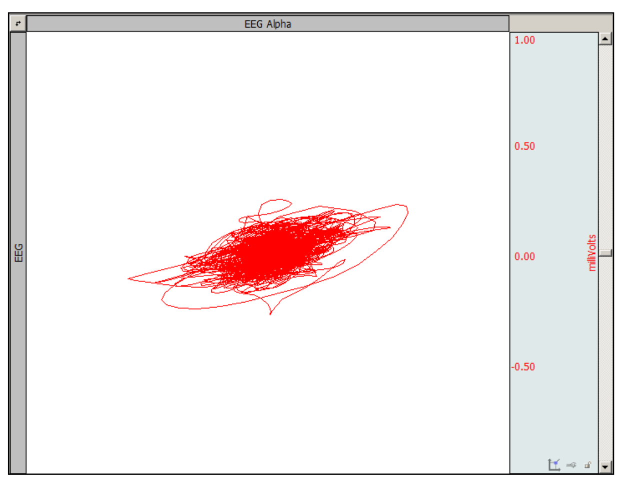
- To help emphasize the selected wave in Scope mode, select the "Gray non-selected waves" Preference (via Display > Preferences).

Waveforms can overlap. The autoscale waveforms command will automatically separate the waveforms in the graph window.

Note: When only one waveform is present, the scope and chart modes are identical.



X/Y mode

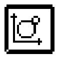


X/Y mode plots data from two channels against each other, with the values from one channel on the horizontal axis and the values from another channel on the vertical axis. Plotting a channel against itself displays a straight line.

X/Y mode can be useful for chaos investigations and respiration studies.

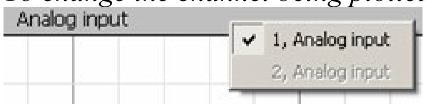
Note: When viewing data in X/Y mode as it is being acquired, plotting only the most recently acquired data point can be a useful option. To do this, select Display > Show > Dot Plot and then Display > Show > Last Dot only.

Switching to X/Y mode during acquisition can be slow. For best performance, switch to X/Y mode either before starting the acquisition or after stopping the acquisition.


X/Y mode continued

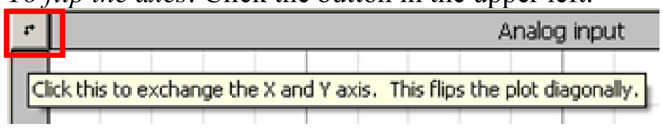
Plotted channels

- *To change the channel being plotted*: Click the Channel label once and hold.

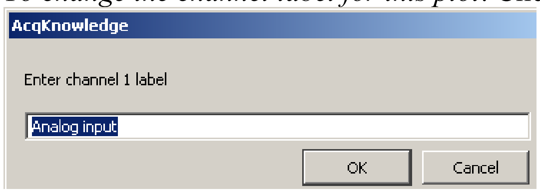


X-axis, click *above* the waveform; Y-axis, click *left* of the waveform.

- *To flip the axes*: Click the button in the upper left.



- *To change the channel label for this plot*: Click the Channel label.

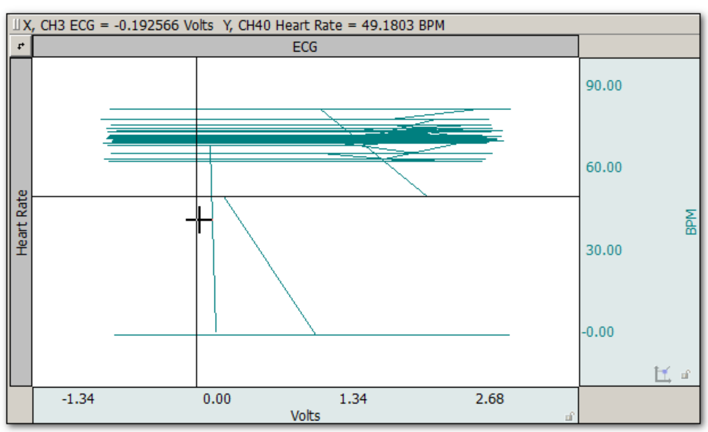


Toolbar icons

The center cluster of toolbar items is specific to X/Y mode. The left two buttons in this group are shortcuts for the Autoscale vertical and Autoscale horizontal functions. Adjacent to these buttons are two buttons that perform the center vertical and center horizontal functions.

Tools

Cursor: In X/Y mode, the I-beam tool in the lower right hand corner of the graph window changes into a crosshair. When the crosshair is moved into the graph window, the coordinates of the crosshair are displayed in the upper left corner of the graph window. The X value refers to the crosshair coordinate in terms of the horizontal axis, and the Y value describes the location of the cursor in terms of the vertical scale. By holding down the mouse, a crosshair is drawn over the closest data point and the measurement toolbar "snaps" to that position to show the amplitudes of the actual pair of data samples plotted on the screen.



X/Y plot with ECG on X-axis and BPM on Y-axis

Autoscale: In X/Y mode, the Autoscale waveform function changes to read Autoscale vertical, which plots the vertical channel so that it takes up two-thirds of the vertical channel space. This function controls the "height" of the data being plotted in the graph window.

Similarly, the Autoscale horizontal function plots the waveform so that the waveform is plotted in the center two-thirds of the window. This function controls the "width" of the data being plotted in the graph window.

Autoscaling adjusts the center point and the range of data displayed. To manually change the scale, click in either the horizontal or vertical scale area. In this case, the scale at the bottom edge of the graph windows (which usually reflects time) is the scale for the X variable, and the vertical scale controls the scale for the channel plotted on the Y-axis.

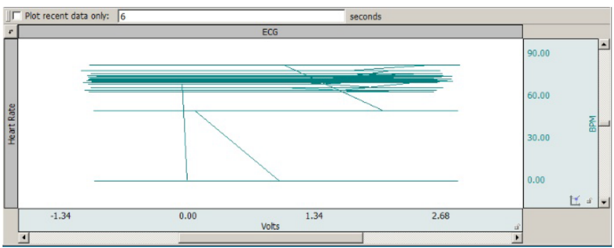
Center: In X/Y mode, since only two channels can be displayed at a time, tile waveforms and compare waveform are replaced with Center horizontal and Center vertical. These two Center commands change the midpoint of the horizontal and vertical scales (respectively) so that the midpoint of the scale is equal to the mean value (average) for that channel. These features are useful for centering the display so that it is easier to interpret.

Ch. # Box: In X/Y mode, the channel numbering boxes are disabled.

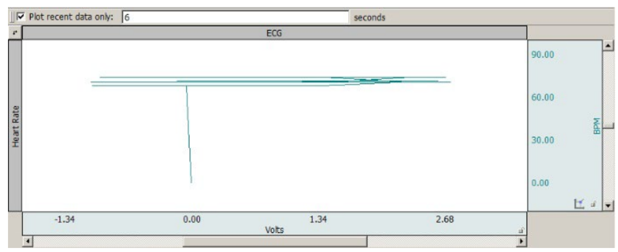
Meas. Menu: In X/Y mode, the measurement popup menus are disabled.

Plot Recent Data Only

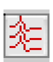
Use this option in X/Y mode to plot a user-defined amount of recent data. Checking the "Plot recent data only" and entering a value will hide plotting for all data not included in the entered time value.



Plot recent data option not applied



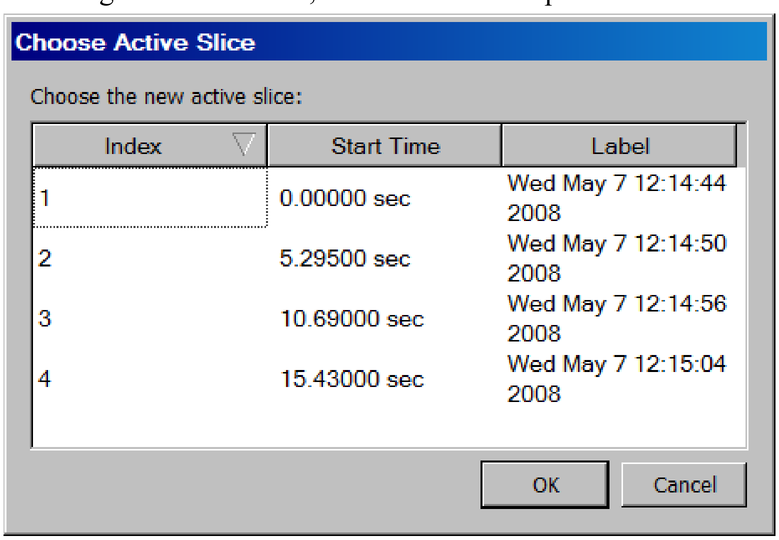
Plot recent data option applied with 6 sec. value

 Stacked Plot mode

Stacked Plot displays multiple time ranges on top of each other and is enabled for acquisitions set to Append (except when in X/Y mode). In this mode, all appended segments are stacked in the display, but only one segment "slice" is active ("selected"). To view an individual segment, click the Chart mode icon.

- Click the Stacked Plot mode icon to display the Stacked Plot controls beneath the toolbar:

To change the active slice, click the  Jump Tool or the … icon.



The selected segment is used for all enabled software functions. This means that autoscaling can easily create what looks like a mess if the selected segment is not appropriate for scaling the largest segment. In compound action potential graphs in Stacked Plot, the last segment slice will most often be the largest, so selecting the last segment before autoscaling will likely yield the expected result. The Transform menu is disabled in Stacked Plot mode.

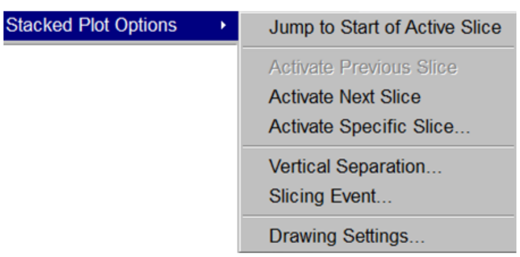
A commonly used data visualization technique for examining the evolution of waveform morphology is the 2D waterfall plot or "stacked plot." A stacked plot draws multiple traces for a single waveform on top of each other, or "slices." Each individual slice is a time-shifted plot of the original waveform. The slices toward the bottom of the plot occur earlier in time then the slices toward the top.

Data can be acquired in stacked plot mode, but it is processor intensive. If acquisition setup includes high sampling rates or control channels with low latency, acquire in chart or scope mode and switch to stacked plot mode after acquisition.

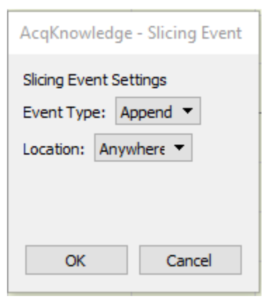
The slices can be aligned at any type of events in the graph. This allows for alignment at appended segments but also at locations found through other means. For example, an ECG waveform can be aligned at the start of the T-wave to examine how the T wave evolves in time.

Active slice	In stacked plot mode, there is a single slice called the "active slice." By default it is drawn in black. To change the color, select Stacked Plot Options > Drawing Settings. The values on the axes in the graph, grid, displayed events and text annotations, selections, and any transformations all apply to the active slice. The active slice can be changed using the navigation buttons in the graph toolbar.
Vertical Separation	The vertical separation between consecutive slices is expressed as a percentage of the entire visible area. This percentage is kept constant through zooming and scrolling operations.

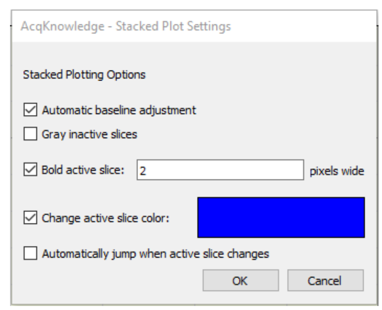
Stacked Plot Options



Display > Show > Stacked Plot Options



Slicing Event…



Drawing Settings…

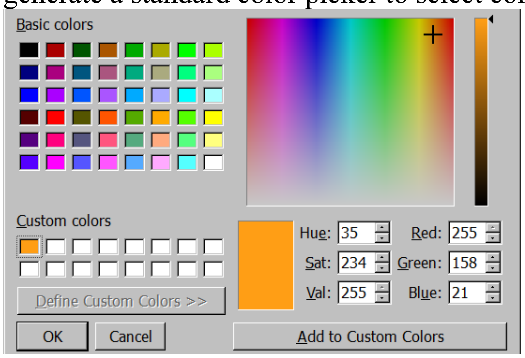
Use Stacked Plot Options to activate slices or visually distinguish the active slice from other slices being drawn in Stacked Plot mode.

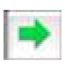
Automatic baseline — Adjusts the baseline of each inactive slice to overlap the baseline of the active slice prior to the application of any vertical separation. This helps compensate for baseline drift in a signal. If it is disabled, no baseline compensation is applied and the stacked plot may exhibit visual vertical segment ordering problems resulting from baseline drift (but in this mode can be used as a tool to examine baseline drift).

Gray inactive slices — Draws the active slice with a solid pen and draws inactive slices with a dashed gray pattern pen. The gray pattern alternates pixels between the chosen waveform color and the white background and has the effect of lightening the inactive slices, so it may be necessary to zoom in to see the effect.

Bold active slice — Draws the active slice with a thicker pen. In step and line plot modes, plotting normally occurs with a one pixel wide pen. Inactive slices will remain one pixel wide while the active slice will have the thicker pen as indicated in the edit field. When the waveform is in dot plot mode, the pixel width will be added to the waveform's default dot size to increase the dot size for the active slice.

Change active slice… — Draws the active slice in a different color than the chosen waveform color. When enabled, the same color is used for the active slice of each waveform in the graph. The color can be changed by clicking on the colorwell to the right of the checkbox to generate a standard color picker to select color.



Automatically jump…  Use the Jump tool (green arrow) to change the active slice. Each time the active slice is changed the left edge of the plot area will be changed to match the start of the newly activated slice. When disabled, each time the active slice is changed the display will be adjusted in such a way that the time interval between slice starting positions and the display origin is kept constant.

Functionality in Stacked Plot mode

Autoscaling

When a graph is displayed in stacked plot mode, all autoscaling and related display operations (tile, compare, overlap) will examine visible data of the active slice only. It's not possible to perform autoscaling operations using data of any inactive slice.

Autoscale Horizontal

In stacked plot mode, autoscale horizontal will make the active slice occupy the entire visible area. The slicing event corresponding to the beginning of the slice will be placed at the left edge of the screen and the next slicing event (or last sample point of the waveform if the active slice is the last slice) will be placed at the right edge of the screen. The vertical offset will remain unaffected.

Data Views

Different data views may have independent Stacked Plot settings. All settings are independent including drawing preferences, slicing events, vertical separation, and active slice settings. Stacked plot settings are stored individually for each data view in the graph file and will be restored when the graph file is opened from disk.

Any graph-wide operation that may affect the active slice will update all data views that are configured to use stacked plot mode. This includes operations that affect the data (e.g. transformations) or events (e.g. waveform editing).

Graphs Containing No Slices

It is possible that graphs may not contain any slices whatsoever if no events match the slicing event criteria. If a graph in Stacked Plot mode contains no active slices, it will be drawn as if the graph was in regular chart mode with the following differences:

All data is drawn using any active slice settings given in the stacked plot drawing options.

The “Active slice” index will read “N/A.”

The previous/next/choose slice graph toolbar buttons and “Display > Show > Stacked Plot Options” menu items will be disabled.

It will be possible to view all data using the horizontal scrollbar.

All autoscaling operations will function as if chart mode was active. Autoscale horizontal will make all of the data of the selected waveform visible on screen.

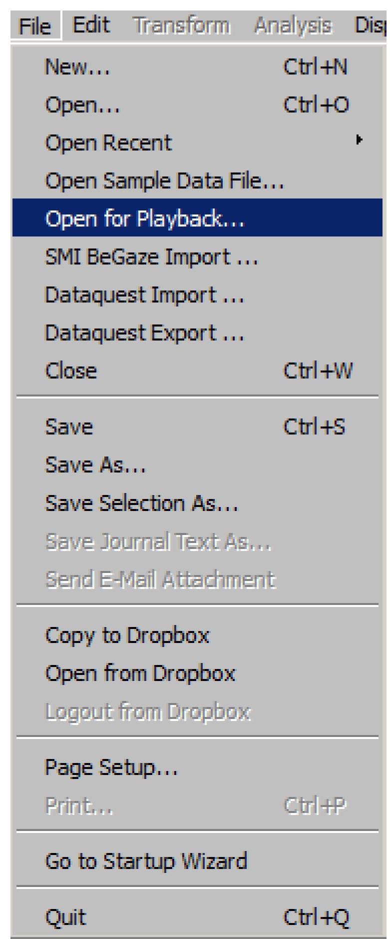
If the table of available slices was being displayed prior to the removal/editing of the last matching slicing event, the table will be emptied and the “OK” button dimmed. The cancel button will remain active for the table window to be dismissed.

The slicing event, vertical separation, and drawing menu items and toolbar controls will remain active.

Playback Mode (Replay)

Playback mode will replay a graph file stored on disk in real time to simulate acquisition. Analog, digital and calculation channels are replayed as stored in the graph file. Acq*Knowledge* allows calculation channels to be reconfigured, including adding channels without an offline equivalent. Calculation channels from the original graph can be modified, added, or removed without affecting the data stored on disk in the original graph file.

1. Select File > Open for Playback.
2. Locate a graph file and then click Open.
3. A new graph window will be generated.
   - The “Connected to…: hardware menu will indicate that the graph will be “acquiring” data from the specified file and the Start button will change to a “Replay.”
4. Press Replay to begin playback.
   - The replay can be stopped, but not paused. If the acquisition mode is changed to Append, no additional segments will be displayed.
5. Select Playback > Exit Playback Mode to return to acquisition status.



Use *Open for Playback* to experiment with different calculation channels settings on the same data or to recreate an experiment for demonstration purposes.

Playback mode has millisecond timing accuracy and allows for reconfiguration of most acquisition parameters. Exceptions include:

- Length is limited to the amount of data in the file
- Acquisition Sample Rate is fixed (use Channel Sample Rate to downsample)
- Number of analog and digital channels is fixed
- Save last, MP, and Averaging modes are disabled
- “Append” will replay the same data.

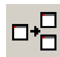
Do not record data while playing back a data file. If one data file is open in "Playback" mode and is 'replaying' and a second data file is open in hardware mode and is acquiring data, clicking back and forth between graph windows causes the hardware device menu to flip to the Playback menu (even though 'Connected to' shows communication with an MP160/150 unit).

Watch the Acq*Knowledge* Playback Mode video tutorial for a detailed demonstration of this feature.

Data Views

A "Data View" window is used to provide an alternate view of the same data. It allows the presentation of data in two or more modes for comparison, such as X/Y plots and chart plots. To compare responses in real time, turn off Autoplot in one Data View (e.g., Dose 1) and continue Autoplotting in another (e.g., Dose 2).

To create a new Data View for the active (selected) graph, choose:

- File > New and select type Data View
- Display > Create Data View
- Click the Data View toolbar icon 

This will generate a new window displaying the active graph's data, and will name the new window "Data View of 'Filename' 

.

TIP Use the Jump-to tool (see page 63) to correlate data views.

Data Views share fundamental data characteristics such as channel labels, events, and sampling rates, but can be customized for the following:

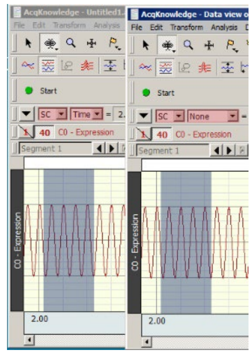
- horizontal scale, precision, and offset
- vertical scale, precision, and offset
- measurements, including number of rows, precision, visibility, and use of interpolation
- grid settings, including spacing, visibility, and locking state
- selected area
- autoplotting
- hidden channels
- autoscrolling
- channel button display state
- wave color
- event display state
- channel order
- plot mode
- channel drawing mode (step, line, or dot, including dot plot size and type)
- hardware "connected to" display

The Data View window can be used like any other graph window. The menus and controls can be used to change how the data is presented. An acquisition can be started or stopped in any of the Data Views for a graph, and any transformations performed on the data in the Data View will be reflected in the graph and all of the other Data Views. Printing a graph from a Data View will use the display settings of that Data View for outputting the graph.

When a file is saved to disk, the display configurations of any open Data Views are saved into the graph file. When the graph file is reopened, all of the Data Views and their display settings will be restored.

- Data Views are saved with the data file only if they are open at the time the original graph is closed and saved.
- Closing a Data View causes this view to be lost; it is not saved with original file.
- Closing a Data View that was previously saved with a data file will not be saved if the data file is saved after closing the Data View.
- Closing a Data View will not invoke a warning that the Data View will not be saved.
- Original Data Snapshot is not merged into the newly created data file.

In Acq*Knowledge* 4.3 and higher, a selected area can be shared across multiple Data Views by clicking and holding the left mouse button over the I-beam toolbar cursor and choosing the "Link Selections Between Data Views" option. (See example figure below.)


AcqKnowledge - Untitled1
AcqKnowledge - Data view
File Edit Transform Analysis
Start
SC
Time
None
40
C0 - Expression
Segment 1
2.00

Analysis

For purposes of illustration, a file containing data should be used. Sample files were installed with the software. Select File > Open and choose a file from the list in the dialog. Sample data files can also be selected from the Startup screen by choosing the "Open a graph file" and "Sample data file" options.

After opening the file called demo data.acq, the screen should resemble the following sample file display.

Sample File Display

The sample graph displays six different types of data, and there is a border between the waveforms.

To the left of each waveform is a vertical strip containing a text string that can be used to help identify each waveform.

The time scale along the bottom denotes when the data was recorded relative to the beginning of the acquisition.

- Only the last eight seconds of the total data record are visible, although the file contains the complete record.
- The data displayed on the left edge of the graph represent events that occurred about 22 seconds into the record, and the data displayed at the right edge of the screen represent events that occurred about 30 seconds after the acquisition was started.

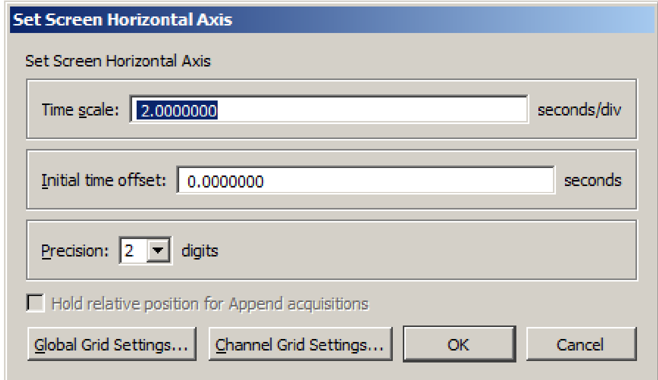
The maximum vertical scale range is from +10 to -10 Volts.

- This reflects the maximum input voltage the hardware unit can accept and is a greater range than normally encountered.
- The display scale can be adjusted to virtually any value range, as demonstrated in the graph window above.

As indicated by the horizontal scale, only a few seconds of data are displayed on the screen. Use Display > Statistics to determine the total length of the record.

To view data that was collected earlier in the record, use the horizontal scroll bar to move to different points in the record.

Alternatively, position the cursor in the horizontal scale area (where the numerical values are listed) and click the mouse button. This will generate the following dialog (see page 78 for details).



The Time scale box allows the amount of data that appears on the screen to be changed at any given time. In the sample dialog, this is set to 2 seconds per division. The divisions on the screen are indicated by the four vertical lines, thus displaying eight seconds at a time (two seconds per division times four divisions). By entering a larger value in this box, more of the record will be displayed on the screen at any given time. Conversely, entering a smaller value in this box will cause a shorter segment of data to be displayed on the screen.

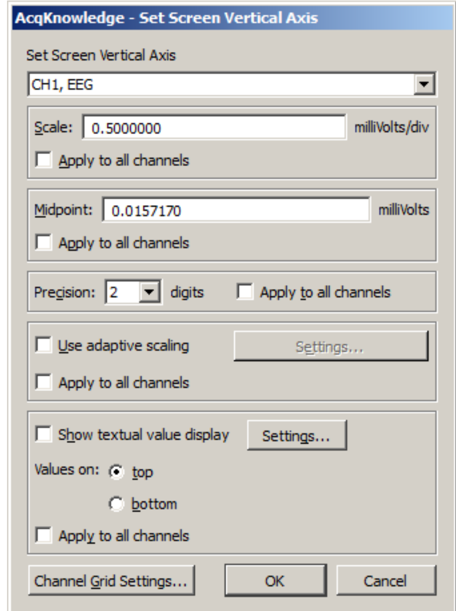
- ➢ To display the entire waveform (in terms of duration), a shortcut is to choose Autoscale horizontal from the Display menu. The Autoscale horizontal command fits the entire data file into the window, regardless of the total length of the acquisition.

The Initial time offset box allows "jumping" to a different point in the time display. Changing the value in this box allows for the display of data beginning at a certain point in the record. For example, to see the data at the beginning of this record, input an initial offset of 0 seconds.

As indicated in the time scale, the first data displayed (at the left edge of the screen) was collected at the beginning of the acquisition. Also, the scroll box has moved to the left, indicating that the data on the screen represents data collected earlier in the record.

After clicking in the horizontal scale area again, the same dialog will appear, and this time the value in the start box should have changed to reflect the new section of data being displayed on the screen.

Acq*Knowledge* also allows customization of the vertical scaling, or amplitude, of each waveform. Clicking the vertical scale area produces a dialog (see page 80 for details).



Use the vertical scale dialog to change the range of amplitude values displayed (scale) and set the value that appears in the center of the vertical scale (midpoint).

Vary the midpoint and apparent magnitude of each waveform by changing the values in each box. By changing the value in the scale box, a smaller value has the effect of increasing the apparent amplitude. Entering a number about half the current value will cause the amplitude of the wave to appear to double.

- Scale—In the sample dialog, the units are set to 2 Volts per division. As with the horizontal scale, there are four divisions on the vertical axis, so this setting should show 8 Volts range of data.
- Midpoint—The box below this controls the midpoint of this range. In this case, the midpoint is set to 2 Volts, which means that this channel will display the range from - 4 Volts to + 8 Volts.

As with the time scale, Acq*Knowledge* can automatically display the best fit in terms of midpoint and units per division. To do this, select the Autoscale waveform command from the Display menu, and the amplitude and offset of each wave will be adjusted to fit their sections.

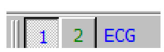
Any modification in terms of rescaling (either horizontal or vertical) will only affect the way data is displayed, and will not change the basic characteristics of the data file.

Selecting a waveform

Although all four waves are displayed at once, it's optimal to operate on only one channel at a time. To do this, select the desired channel by clicking it. Selecting a channel will allow for highlighting all or part of that particular waveform, and enables discrete transformations on a given channel.

In the upper left corner of the graph window, there is a series of boxes that represent each channel of data. The numbers in the boxes correspond to the channel used to acquire the data (the specifics of setting up channels are discussed on page 31). In the previously-shown sample waveforms, ECG channels are represented by Channels 1 and 2, with respiration on Channel 4 and blood pressure on Channel 5.

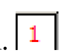
To select one of these channels:

- Position the  cursor over the channel box 

 that corresponds to the channel to be selected and click the mouse, or
- Position the  cursor on the waveform of interest and click the mouse.

Show/Hide Channel

To "hide" a waveform, press ALT for Windows or OPTION for Mac and click the channel box.

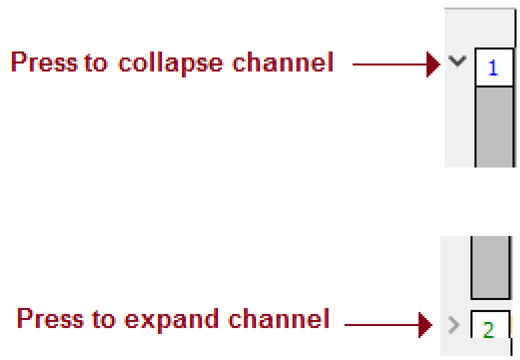
Or, Alt+click on the channel number at the top of the channel label region. 

To view a hidden waveform, repeat the appropriate key-click combination.

Alternatively, show/hide a channel via Display > Channel Visibility and checking/unchecking the channel boxes in the Channel Visibility dialog. (See this Display menu option on page 492.)

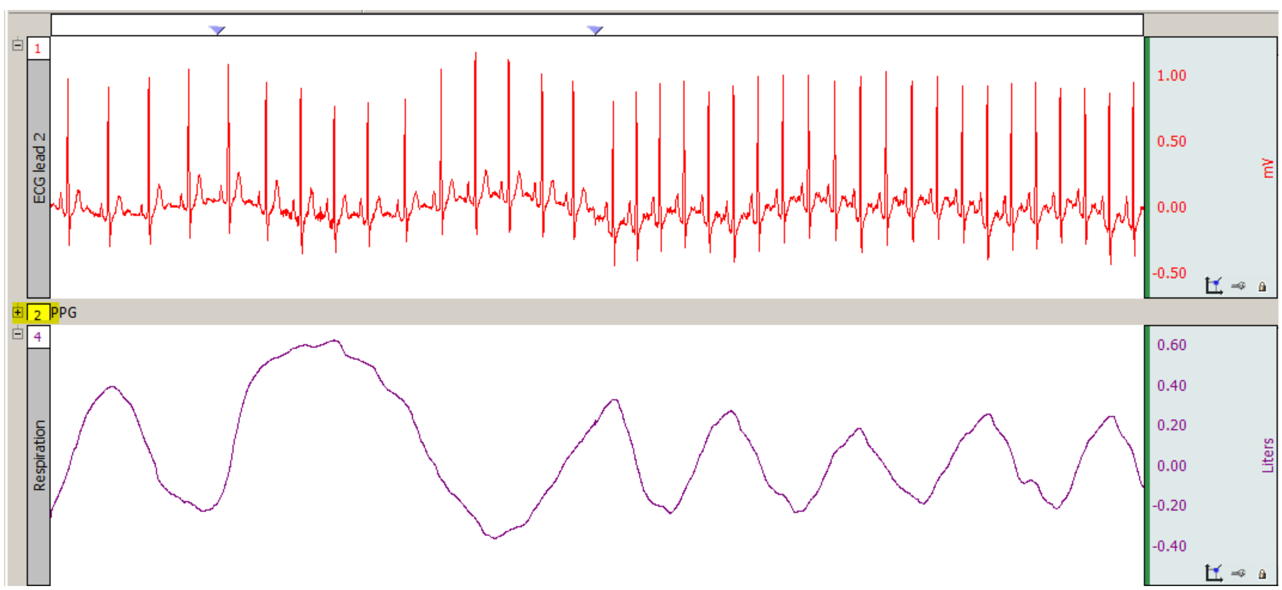
Collapsing Channels

In Acq*Knowledge* versions 4.4.1 and higher, individual or multiple channels may be quickly "collapsed" by simply clicking the button appearing in the upper left region of each channel. When a channel is collapsed, all data is retained but hidden from view, and the button status changes to while collapsed. Collapsing a channel allocates more vertical space to remaining channels, enhancing the view of visible data.



Channel "Collapse" button

NOTE: In certain operating systems, the or buttons may instead appear as and characters. See below example showing Channel 2 collapsed. Note that when a channel is collapsed, the channel label appears in a gray horizontal bar indicating the channels' location.



Channel 2 collapsed

To expand (unhide) the collapsed channel simply click the or button, or double click the collapsed channel's label.

NOTES:

- Collapsing or expanding channels is supported in Chart or Stacked Plot mode only.
- Pressing the Alt/Option key while clicking any button will collapse or expand all visible channels with the exception of one. (A minimum of one channel must remain uncollapsed. It is not possible to use the collapse or expand button on graphs with single channels.)
- Collapsed channels are retained when a graph is saved and reopened.

Zoom

Another way to examine data is to use the “zoom” tool. The zoom tool allows a selection of any portion of any wave to be magnified. To use the zoom tool, click the icon in the lower right portion of the screen. When moving the mouse into the graph area, notice it changes from an arrow to a crosshair (+). Start by positioning the cursor in one corner of the box, holding down the left mouse button, and dragging the crosshair horizontally, vertically, or diagonally to form a “box” which encompasses the area to zoom in on. After releasing the mouse button, Acq*Knowledge* will automatically adjust the horizontal and vertical scales. To “unzoom,” choose Zoom back from the Display menu.

Select an area

Once a channel has been selected, is possible to “edit” parts of that channel by selecting a section of the waveform. The options available include cutting, copying, and pasting sections of waveforms. It’s also possible to transform and analyze entire waveforms or specific sections of waveforms.

To use any of these functions, first select (or highlight) the area to be operated on. To select a section of a waveform, position the cursor over the icon in the lower right hand corner of the screen and click the mouse button. Now move the cursor to the first point in the area to be selected When moving the cursor into the graph area, notice that it changes from an arrow cursor to a standard I-beam editing tool.

To highlight a section of a waveform, position the cursor at the left edge of the area to be selected and hold down the mouse button. Now move the mouse to the right until the desired area has been selected.

To select more than one screen of data, position the cursor at the left edge of the section to be highlighted, then click and hold the mouse button. Use the scroll bars to move to a different point in the record, and when reaching the desired endpoint (right edge) of the selected area, hold down the Shift key while positioning the cursor and click the mouse. Selecting an area this way will also fine tune the selected area to include only a specific range of data.

Once a channel has been selected and a section of data highlighted, it’s possible to operate on and edit that section of the waveform. The editing commands behave much the same way as text editing functions. Cut, copy, delete or paste sections of data as defined by the selected area. In most cases (depending on available memory), undo an edit by choosing Undo from the Edit menu, or by using the shortcuts **CTRL + Z** for Windows or ⌘+Z for Mac.

Selecting a portion of a waveform also allows for applying transformations to a particular area rather than the entire area or all waveforms. Selecting an area also display snap measurements to be taken for parameters such as Delta T, Mean, Standard Deviation, Frequency, etc. Measurement options are discussed in the next section.

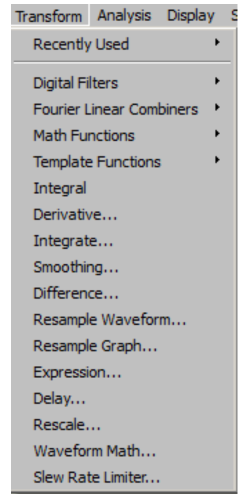
The Selection Palette (**Display > Show > Selection Palette**) can also be used to select an area.

Keyboard data selection

Keystroke combinations can similarly used to select or deselect graph data on a sample-by-sample basis. This helps add an enhanced level of precision to the selection operation. See data selection keyboard shortcuts on the following page.

Keyboard Shortcut	Description
Windows: Shift + Ctrl + Left Arrow **Mac:** Shift + Command + Left Arrow	Subtracts one sample interval from the right edge of the selection. If the selection is empty, no action is performed.
Windows: Shift + Ctrl + Right Arrow **Mac:** Shift + Command + Right Arrow	Subtracts one sample interval from the left edge of the selection. If the selection is empty, no action is performed.
Shift + Left Arrow	Adds one sample interval to the left edge of the selection.
Shift + Right Arrow	Add one sample interval to the right edge of the selection.
Left Arrow	Moves the selection one sample to the left, constructs a zero width selection.
Right Arrow	Moves the selection one sample to the right, constructs a zero width selection.

Transform data



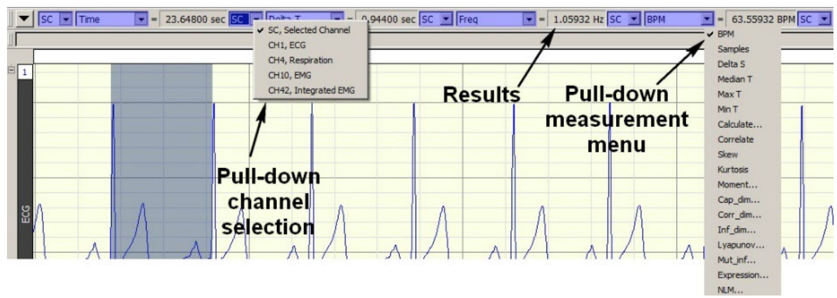
Acq*Knowledge* includes a library of functions to transform data or perform mathematical calculations on waveform data. All of these options are located under the Transform and Analysis menus, and are discussed in detail in the Analysis section beginning on page 361.

When performing transformations

- If a section of a waveform is highlighted, the transformation will apply to that section.
- If no area is selected, Acq*Knowledge* will always select a single data point.
- If the transformation can only be performed on a selected area (digital filtering, for instance) and a single point is selected, the entire waveform will be used (and the transform entire wave option will be disabled; close out of the dialog and select an area if desired).

Measurements

Measurements appear in the row of boxes across the top of the graph window. The number of visible measurement boxes and the display precision can be specified in the "Preferences" dialog of the Display menu. Each measurement consists of three parts: (a) the channel selection, (b) the measurement function, and (c) the result or actual measurement value.



For example, the results for "SC, Selected Channel" is:

Time	23.64800 sec
Delta T	9.44000 sec
Freq	1.05932 Hz
BPM	63.55932 BPM

The pop-up channel selection calculates a measurement either for the selected channel (SC) or from a numbered channel in the graph. To switch between the channel options, click in the channel window. The pop-up menu shows the channel numbers and labels for all channels in the file. By default, each measurement will reflect the contents of the selected channel.

The pop-up measurement menu allows selection between different types of measurements. To choose a measurement, click the measurement pop-up menu and select a measurement from the list.

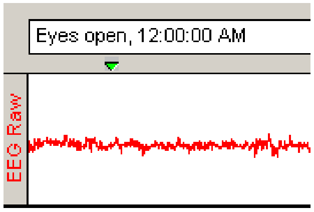
- Some measurements (such as Time or Value) look at only a single data point whereas other measurements (such as mean and delta T) examine a range of data on the selected channel.
- Some of the measurements that depend on a selected area (such as delta T) look at differences in the horizontal axis measurement whereas other range measurements (such as peak-peak) use the vertical scale information in calculating measurements.

For a complete description of each of the measurement functions, turn to page 98.

The final component of a measurement window is the measurement result.

- When an area is selected (or if the selected area is changed) the measurement result automatically updates to reflect the change.

Events (Markers)



In many instances it is useful to have the software mark an occurrence or event during an acquisition so it can be referenced later. For instance, a user may want to note when a treatment began or when an external event occurred to be examined later. The software uses "Events", which are marked in the data to record events.

Event markers can be pre-established and automated. Event icons and labels appear at the top of the graph window, and can be edited, displayed, or hidden from view.

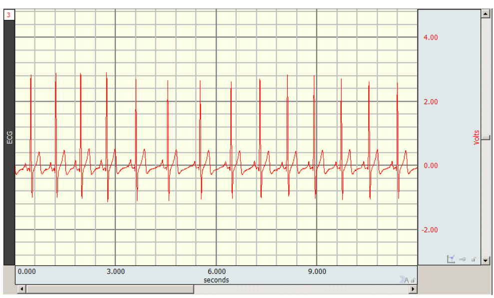
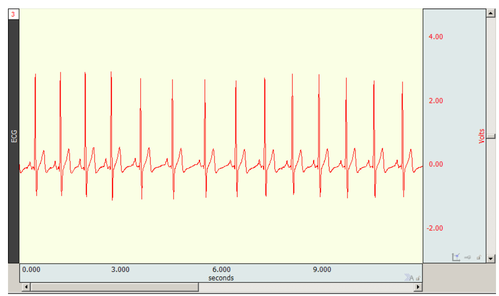
Automatically insert event markers during an acquisition by pressing the Esc key. This will insert a event at the exact time the key is pressed and will activate the text line entry, which allows immediate entry of a comment associated with the event.

For a detailed description of events and event functions, including options to pre-establish event labels and set function keys for different labels, see Set Up Event Hotkeys (page 247).

Watch the Acq*Knowledge* Events video tutorial for a detailed demonstration of this feature.

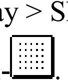
See also: Text Annotation, page 63.

Grids

Grid superimposes a set of horizontal and vertical lines on the graph window. The grid is designed to allow for easy measurements, since the grid lines correspond to horizontal and vertical scale divisions. The grid can be locked (analysis, printing) or unlocked (visual aid).

To activate the grid display, choose Display > Show > Grid or click the  toolbar icon.

- To display minor grid lines, use Ctrl-.
- To customize grid line and color and optimize the display and print features, choose Display > Show > Grid Options.

For more information about using and printing grids, see page 84

Note: The Scale dialogs change when grid lines are locked. See page 78 for details on Horizontal Scale and page 80 for details on Vertical Scale.

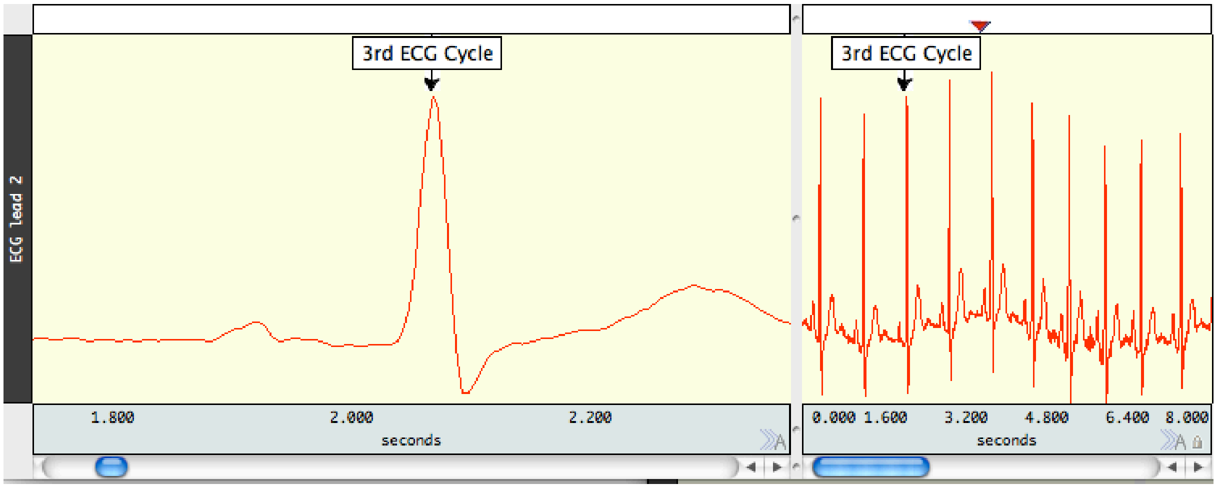
Horizontal Split View

Horizontal Split View is a tool for "splitting" the data in a single graph into two simultaneously viewable areas and displaying them side-by-side for convenient viewing. Split View is available for data plotted in scope, chart or stacked plot modes. Both views can contain independent time scales, initial offset and autoscroll settings. This can be useful for making side-by-side comparisons of data at different time ranges, or for reviewing the same section of data in two separate time scales for more detailed examination. Split View configurations and scalings can be saved and restored in the graph.

Split View can be activated via the following methods:

- Choosing Display > Split View
- Clicking the Split View toolbar button 

Either method divides the graph into two equal regions with independent time scales, and the bar in the center can be dragged to the desired location.



In the above example, the view in the left pane was rescaled independently of the view of the same data on the right pane. This will enable a closer view of an area of interest while maintaining the original data display. If a Split View encompasses any events, annotations or focus areas, these will be visible in both panes.

- Note that events, annotations, selected areas and focus areas appearing in the Split View are duplicate displays of the same items. If any of these items are added, modified or deleted in one view, this change will also be applied to the other view.
- Split View is not supported in XY mode.
- Printing of Split Views is not currently supported within the BSL application. If printing is desired, save the graph in *.jpg format or use standard operating system screen capture utilities.

To exit Split View, uncheck the Display > Split View option or drag the Split View bar back to its home position at the left of the horizontal scale.

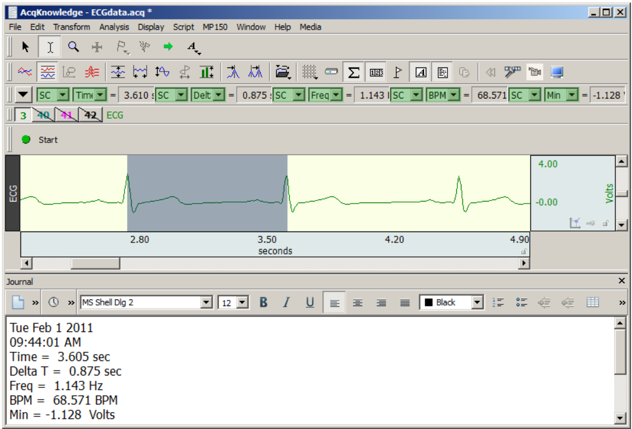
Autoscroll Horizontal Axis Controls

During data acquisition, three plotting modes are offered. These are normally accessed via the Hardware menu, but can be more easily dialed in by using the »M button in the lower right of the horizontal axis region. This button toggles between the following modes, and the button display changes to reflect the plotting type selected.

Status	Icon	Description
Manual	»M	Horizontal axis is not modified by application during data acquisition. Only manual adjustments affect the data plot. Equivalent to unchecking both Hardware Menu > Autoplotting and Hardware > Scrolling.
Sweep	»S	Data is plotted until it reaches the right edge of the graph. At this point the data is scrolled, clearing data display and showing the newly acquired data starting at the left edge. This mimics the “sweep” of an oscilloscope. Equivalent to checking Hardware Menu > Autoplotting unchecking Hardware Menu > Scrolling, and checking Hardware menu > Sweep.
Autoscroll	»A	New data is plotted at the right edge of the graph. When new data is acquired, existing data is scrolled to the left, creating space to plot new data. Equivalent to checking both Hardware Menu > Autoplotting and Hardware Menu > Scrolling.

Journals

The Journal is a general-purpose text editor built into Acq*Knowledge* that acts as a notepad for recording notes and data and saving text and/or numeric values for later review. The Journal can be used at the same time data is being acquired. Every graph file has a graph-specific Journal file permanently linked to it. There is also an option to generate independent Journals for data view, use with multiple graphs or protocols.



Graph-specific journal—Journal is saved with graph; preferable for retaining notes and analysis within a graph file. Display settings are independent. To save a graph-specific Journal independent of its graph, use File > Save Journal Text As option.

Independent Journal—Journal is saved into its own file, separately from graphs; preferable when performing analysis on multiple graphs at the same time. Independent journals allow multiple journal windows to be open at the same time (each graph view can have its own journal associated with it), but only one Independent Journal can be used at a time.

For more information on using Journals, see Journal Details on page 89.

Saving data

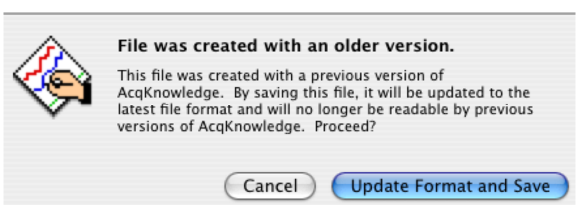
Once data has been collected, it can be saved as a file and opened later. The data file can be moved, copied, duplicated and deleted just like any other computer file. By default, files are saved as Acq*Knowledge* (.acq) files, which are a proprietary format designed to store information in a format as compact as possible. Although these files can only be opened from within Acq*Knowledge*, the data in these files can be exported either as a text file or as a graphic image.

Exporting data to a text file allows for examination of the data using other programs, such as a spreadsheet or statistical analysis package. Saving data as a graphic (.jpg) allows working with the data in graphic format.

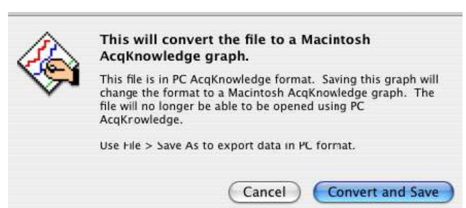
One of the most useful applications of this is the ability to edit and place Acq*Knowledge* data as it appears on the screen. Use this feature to paste graphs into word processors, drawing programs, and page layout programs. To learn more about these options, turn to the Save As section beginning on page 305.

Format change warnings

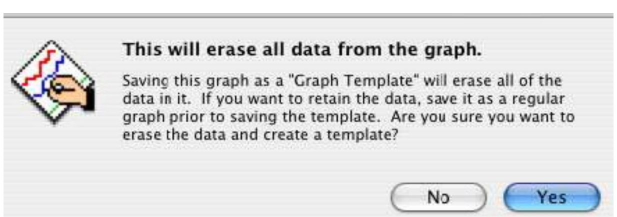
When a File > Save function requires a format change for compatibility or alters file content, a prompt is generated to require the user to confirm the option to update format or convert and save.



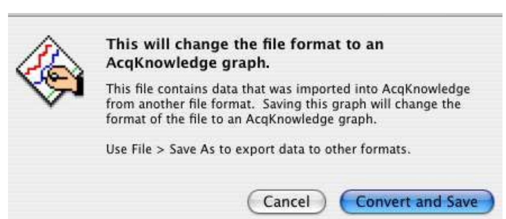
Created with a previous version of Acq*Knowledge*



Windows PC Acq*Knowledge* format



Saving as a “Graph Template” will erase all data



Imported from another file format

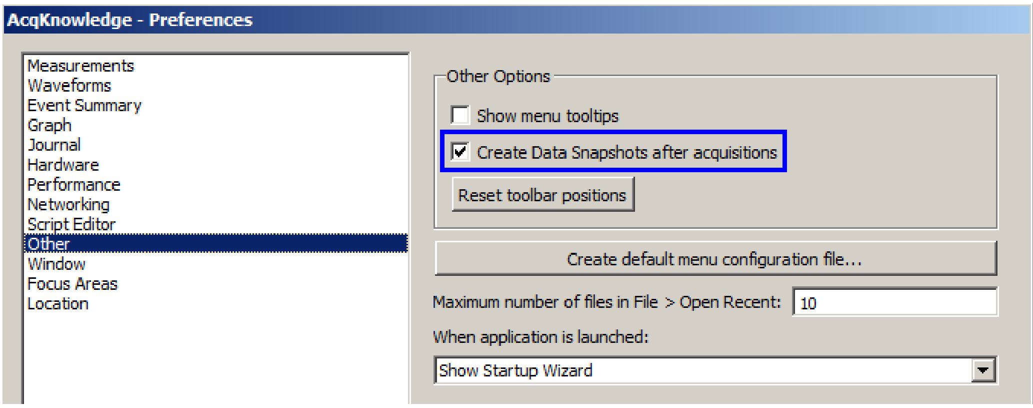
"Data Snapshot" — Embedded Archive

"Data Snapshots" are essentially embedded archives of the original acquired data stored with the graph file which can be viewed together at a later time to compare results to original waveforms or intermediate stages of analysis.

IMPORTANT Archive functions do not create a new file—they are not backup functions.
Original data is copied and pasted to the end of the original file.
This feature cannot be used to recover lost or damaged original data.

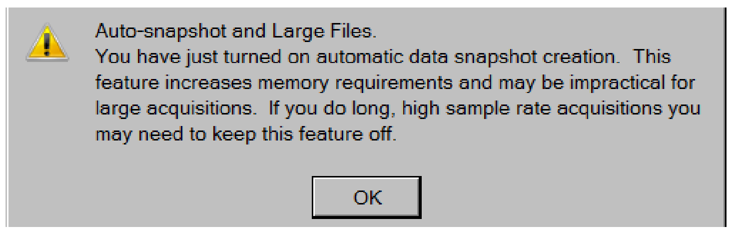
There are two ways to create a snapshot:

1. **Automatic after acquisition**: Display > Preferences > Other > Create Data Snapshots after acquisitions

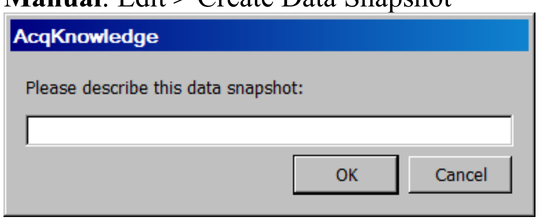


When this is enabled, a date-stamped archive of the data in the graph when acquisition stopped is created. In Append mode, the entire graph is archived with each Append, old data as well as the newly acquired data.

This is a memory intensive function; each archive that is added to a graph file will increase its size on disk by approximately 40%. When prompted, click OK to proceed.



2. **Manual**: Edit > Create Data Snapshot



A snapshot is then taken of the data at that point in time and stored with the graph. Manual archives allow preservation of intermediate stages in a complex analysis for future reference. A comment prompt will appear for describing the archive. This description will be used in the header the archive is displayed.

To view the embedded archive(s) associated with a graph file, choose Display > Show All Data Snapshots.

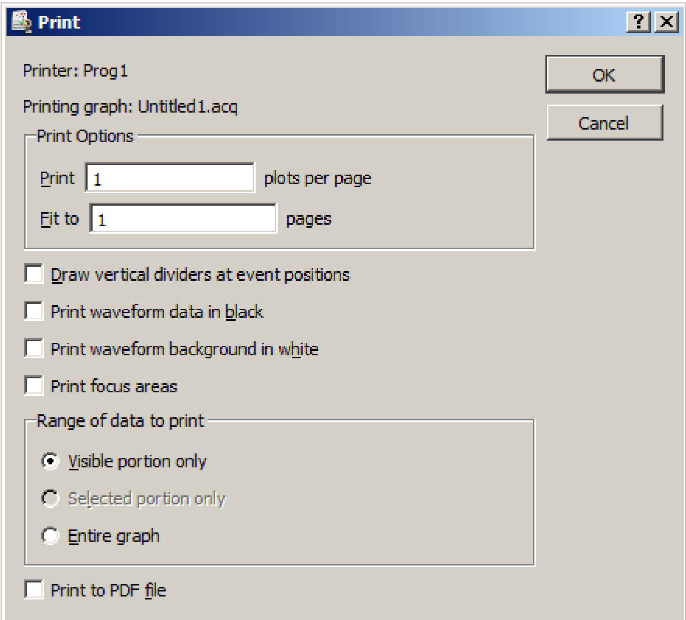
This will open a new graph window for each archive associated with the graph. The time portion of the Filename for each graph is from the computer clock (saved with semi-colons because using colons in a filename is not supported). The "Data Snapshot from…" graph will open with no Start button.

Manual Archive: description and time
Original file
Automatic Archive: time only

Snapshots will also retain the following in addition to the data:

- Events - Text annotations
- Graph-specific journals

Print



Acq*Knowledge* allows high-resolution printing of hard-copy graph plots much as they appear on-screen.

- To print a file, choose Print from the File menu. This will print the contents of the screen on the selected printer.
- To print the entire file, choose Autoscale Horizontal from the Display menu first.
- Printing a journal is a separate command from printing a graph file.

Instruct Acq*Knowledge* to print the contents of a file across several pages by entering a value in the Fit to box. Entering "4" in this box, for instance, will place the length of the page evenly across four pages when printing.

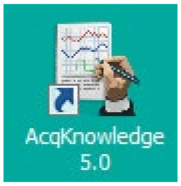
Print options are available after clicking OK in the initial File > Print dialog; see page 315.

Acq*Knowledge* with BioNomadix Smart Center

BioNomadix Smart Center, is a small-form wireless data acquisition system that joined the BIOPAC product line late in 2017. Smart Center works with BioNomadix Transmitters and combines ease-of-use and compactness with the full functionality of Acq*Knowledge* software. Guided prompts are used to pair and set up the transmitters.

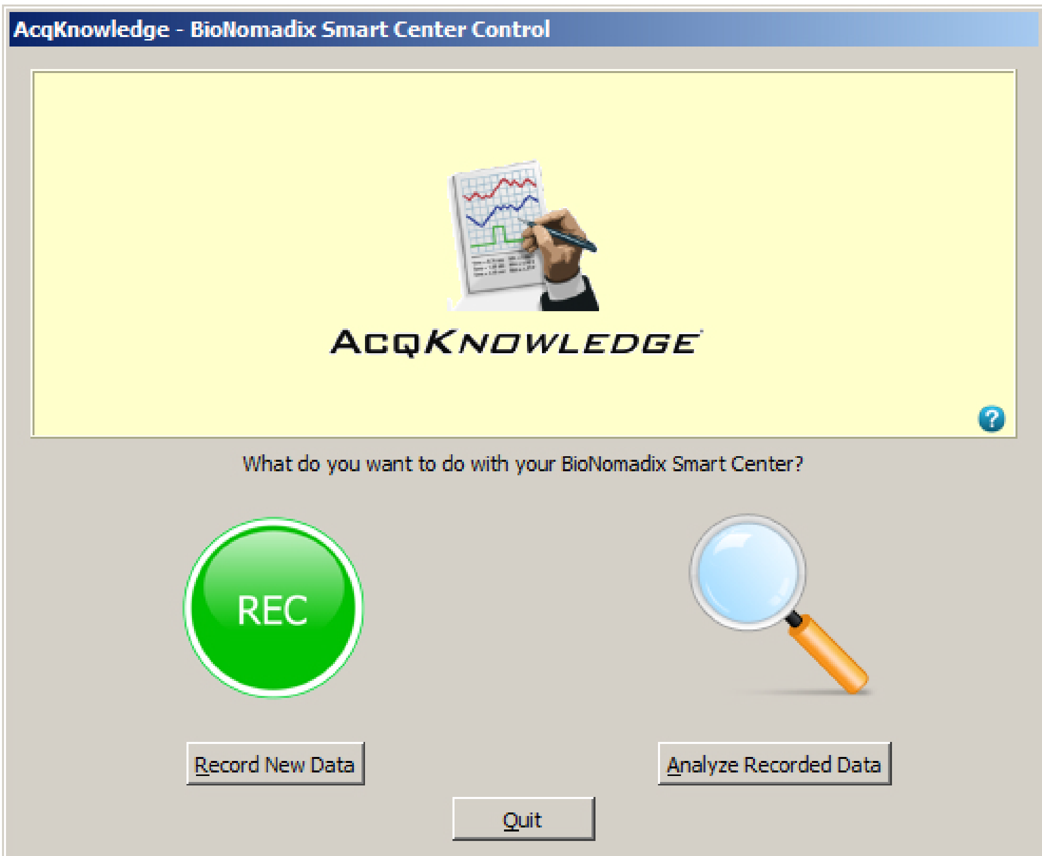
The Startup Wizard interface for Acq*Knowledge* with BioNomadix Smart Center varies from that of standard Acq*Knowledge* implementation. Additional minor UI differences are present in Acq*Knowledge* software when Smart Center hardware is being used.

Launching Acq*Knowledge* with Smart Center



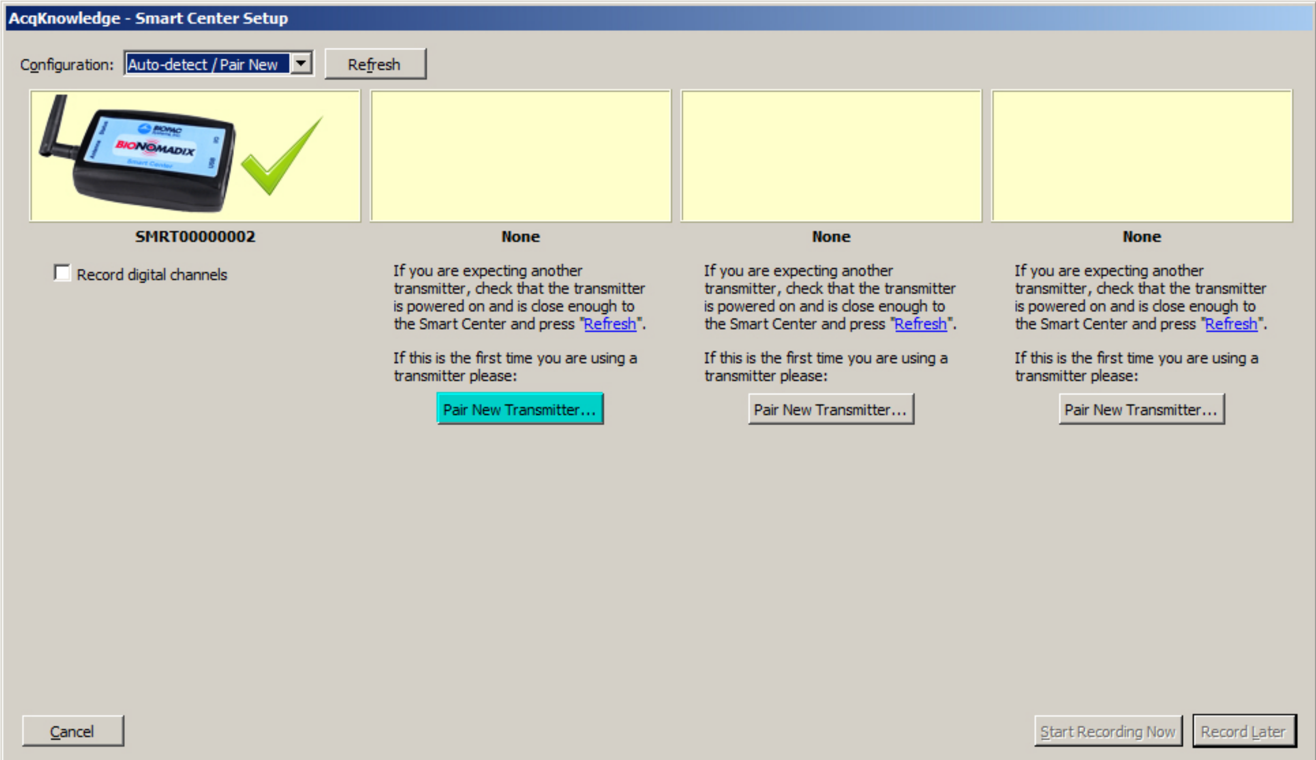
Acq*Knowledge* for Smart Center is launched in the same fashion as standard Acq*Knowledge*, by clicking the Desktop shortcut. The Smart Center License Key must be connected to a USB port in order to launch and run Acq*Knowledge* for Smart Center.

The Acq*Knowledge* with Smart Center Startup Wizard appears as follows:

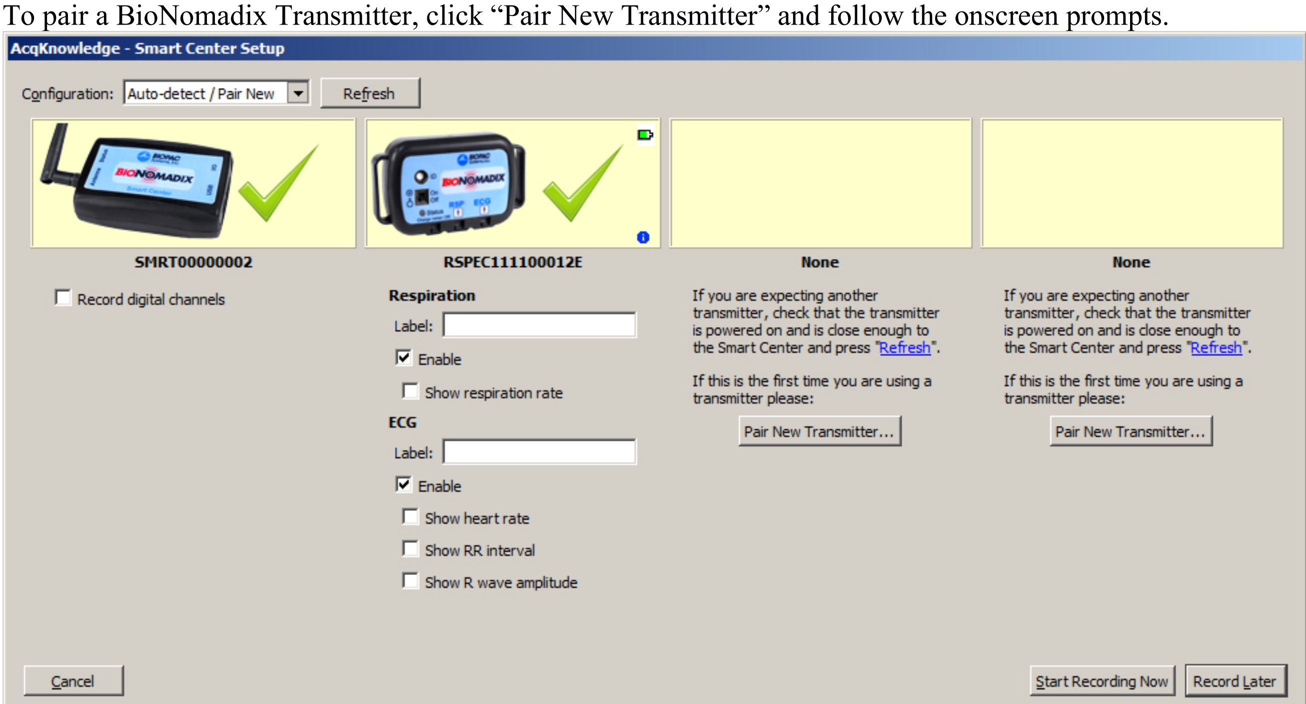


Record New Data	Launches the Startup Wizard for pairing transmitters and configuring other options.
Analyze Recorded Data	Launches a list of the 10 most recently-opened data files. The default number of 10 listed files can be modified by choosing "Display > Preferences > Other" in Acq*Knowledge*. • Highlighting any file in the list and clicking "Open" will open the selected file for analysis in the Acq*Knowledge* application. • Selecting "Search Disk" launches a window for navigating to files not appearing in the recent file list.
Quit	Exits application.
	Clicking the "question mark" icon opens a dialog with information about the software build and connected Smart Center unit.

Selecting the "Record New Data" Startup option launches the following window:



To pair a BioNomadix Transmitter, click "Pair New Transmitter" and follow the onscreen prompts.



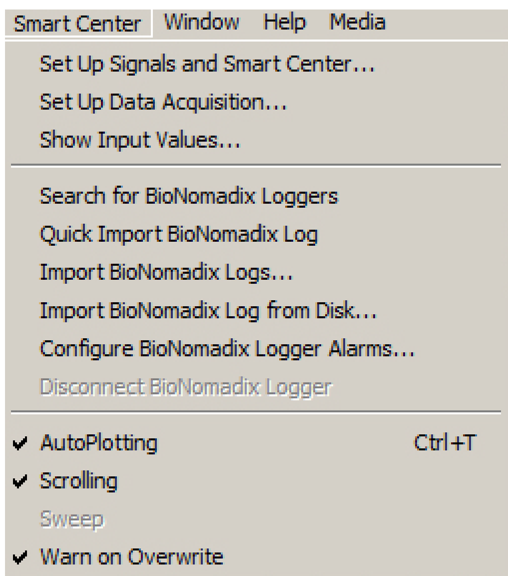
Once Transmitters are paired, there are two primary options, "Start Recording Now" and "Record Later." The "Start Recording Now" option launches the Acq*Knowledge* graph window and immediately begins recording data from the paired transmitter. The "Record Later" option launches the Acq*Knowledge* graph window but it's necessary to click the "Start" button in the graph to begin recording. Refer to the BioNomadix Smart Center Guide for further details about Smart Center operation.

TIP: Clicking the blue "exclamation point" to the right of the paired BioNomadix Transmitter icon will open a PDF detailing information and guidance about the paired transmitter.

Differences and Limitations – Acq*Knowledge* for Smart Center vs. Standard Acq*Knowledge*:

As noted earlier, there are some minor user interface and functionality differences between Acq*Knowledge* with Smart Center and Standard Acq*Knowledge*.

- Different startup screen (simplified wizard with record and analyze only, guided prompts for pairing transmitters)
- Hardware limited to Smart Center only – switching via "Manage Hardware Connections" not supported
- No manual channel setups, module setups, or calculation channels (number and type of channels dictated on front-end by transmitter hardware)
- Sample rate locked to paired transmitter type (2 kHz max compared to 400 kHz aggregate in MP160)
- Variable sample rates not supported
- No stimulation setup in software
- No triggering setup in software
- Averaging not supported in Length/Rate acquisition setup
- Linked acquisitions not supported

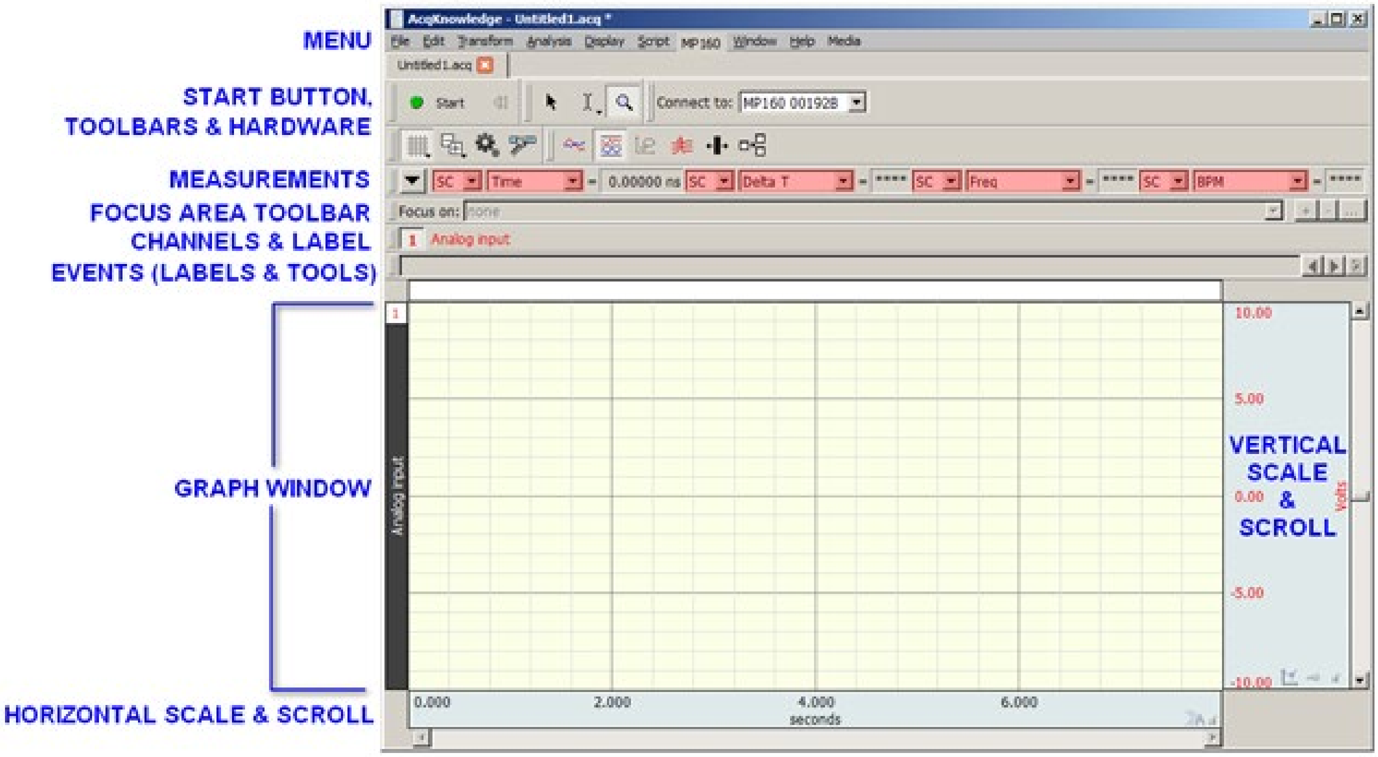


AcqKnowledge with Smart Center Menu

All remaining Acq*Knowledge* functionality is the same as in the standard MP160/MP36R application version.

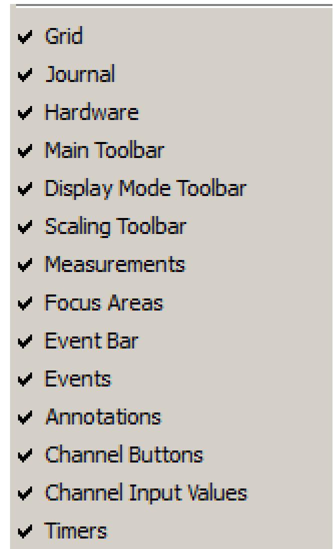
Refer to the BioNomadix Smart Center Guide in the Acq*Knowledge* Help menu for further details about Smart Center and BioNomadix Transmitter operation.

Chapter 3 User Interface & Context Menu Features



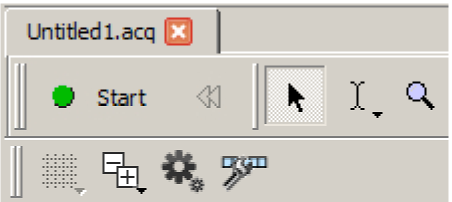
- Toolbars
- Keyboard Shortcuts
- Mouse Controls
- Custom toolbars for transformations and analysis
- Toolbar position retention and changes
- Event tool enhancements
- Typed event label drawing improvements
- Choose MP160/150 Help Button
- Button Transparency
- Customizable Chart Track Dividers
- Plotting Background Colors
- Vertical axis scaling buttons
- Long channel labels and units
- Graph window tooltip improvements
- Menu item tooltips
- Channel Info
- Transformation history
- Canceling Transformations
- Transformation Progress Bar
- Focus Areas

Toolbars



Many of the most commonly used features in Acq*Knowledge* can easily be executed with a mouse click. The toolbars contain shortcuts for some of the most frequently used Acq*Knowledge* commands. Click an icon to activate it; icons are grayed out when they are not applicable.

By default, a minimal toolbar configuration is presented when Acq*Knowledge* is first launched. The default toolbars will appear as follows:



The default toolbars consist of:

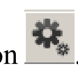
- Start/Stop button
- Cursor Toolbar (Arrow, I-beam and Zoom tools)
- Main Toolbar (Grid, Toolbar Display, Preferences and Customize Toolbar buttons)

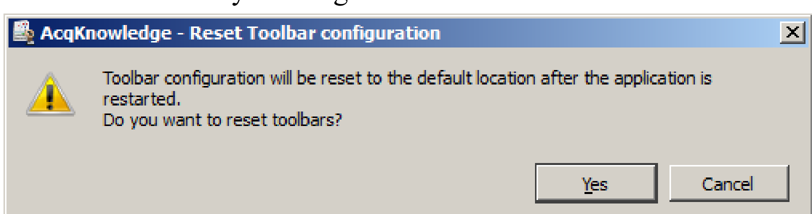
The full range of available toolbars can be displayed by enabling the checkbox options in the Toolbar Display shortcut button , or via Display > Show and enabling the desired options. Once the toolbar options have been selected, this will be the default toolbar display for all new graphs. All toolbars can be deselected and hidden with the exception of the Start/Stop button and the Cursor Toolbar (Arrow, I-beam and Zoom tools).

<u>Saved graphs created with different toolbar configurations will open with those toolbar options displayed</u>.

Toolbar position—Toolbars can be dragged and repositioned to any border of the graph window, or floated on top of a graph. Toolbars retain the last position they were left in after the application is closed and a new graph reopened.

Restoring the default toolbar position – The default toolbar positions can be restored by going to Display > Preferences > Other and selecting "Reset toolbar positions." The application must then be closed and relaunched for the reset to take effect.

TIP: Preferences can also be accessed by clicking the Preferences toolbar shortcut icon .

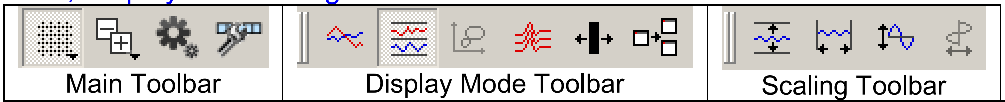


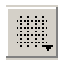
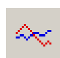
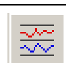
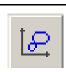
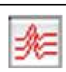
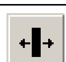
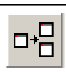
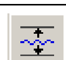
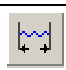
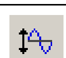
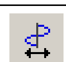
NOTE: The "Reset toolbar positions" option restores the default toolbar locations only; it does not hide toolbars or restore the default minimal toolbar configuration displayed upon first launch. To return toolbars to the default minimal configuration, it is best to deselect unwanted toolbars in the toolbar display menu.

(Use the Toolbar Display shortcut button  or Display > Show.)

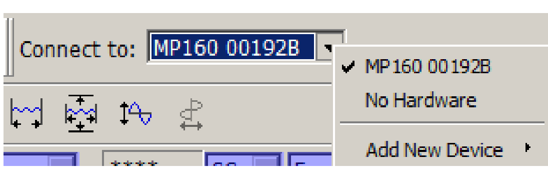
The toolbars can be reset to the default minimal configuration by holding down the Shift key while launching Acq*Knowledge*, but this is a "nuclear" option." Choosing this option will reset ALL program defaults to the factory configuration. Do not choose this option if the configuration contains custom settings that need to be saved.

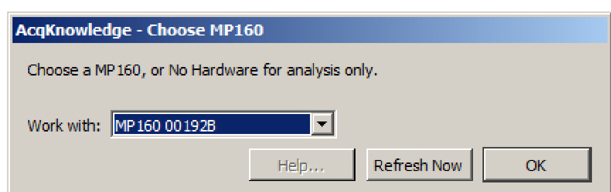
Main, Display and Scaling Toolbars



TOOLBAR ICONS	FUNCTION
	Show/Hide gridlines in the graph window. Click and hold the mouse to display various grid preset options.
	Opens popup menu for showing/hiding individual toolbar options.
	Opens the Preferences dialog.
	Opens the customize toolbar menu.
	Change display to scope mode.
	Change display to chart mode (default).
	Change display to X/Y mode.
	Toggle Stacked Plot (overlap segment) mode; see page 38.
	Horizontal Split View; see page 51.
	Create Data View; see page 43.
	Autoscale selected waveform only.
	Autoscale waveforms along the horizontal axis.
	Center waveforms vertically in the active window.
	Center waveforms horizontally in the active window (X/Y mode only).

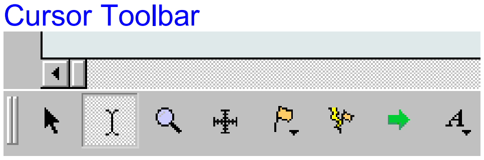
Hardware Toolbar





The hardware toolbar displays connected to information and includes quick access to add/change hardware.

Cursor Toolbar

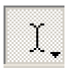
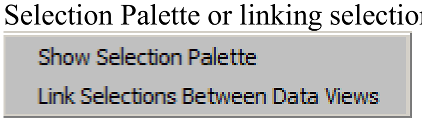
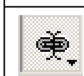
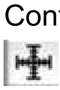


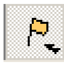
Cursor tools are used in many of the on-screen functions described below, including editing, measurements, and the amount of data displayed.

NOTE: The four rightmost icons on the Cursor toolbar (Event tool, Zap tool, Jump tool, and Annotation tool) do not become visible until data has been acquired, or a graph containing data has been opened. See below for full description of all toolbar button functionality.

Cursor Tools

The cursor tools are also accessible via the Display menu (Display > Cursor Style)

	This is a general-purpose" arrow" cursor tool, used for selecting waveforms, scrolling through data, and resizing the chart boundaries between waveforms when in chart mode. All other cursors default to this mode when the cursors are moved outside the graph area. Use Alt-click to step through the channels; each click makes a new channel "active." The arrow cursor can also be activated by the Ctrl+B keystroke. Holding down the left mouse button with the arrow tool positioned over a graph channel will activate a single data point, which displays as a solid black vertical line. This is known as "spot measurement" mode. Dragging the mouse will then update selected measurement values to the new horizontal locations of the arrow's position in the graph. The mouse button should be depressed for approximately 0.5 seconds in order for spot measurement mode to become active. Releasing the button restores the arrow cursor to its normal status.
	This is a standard "I-beam" editing tool. This tool is used for selecting an area of a waveform (or waveforms) to be edited or transformed. However, editing of the selected area is limited to the channel currently selected in the graph. Click to I-beam icon to activate it. Now move the cursor toward the waveform. Notice that the cursor changes from an arrow to an I-beam when it is placed over the graph area. When this cursor appears, select an area of data by holding down the mouse button and dragging the mouse to either the left or right. Extend the selected area to include data that is not on the screen by positioning the cursor at the left edge of the area to be selected and clicking the mouse button. Next, use the scroll bars to scroll through the data until the desired data appears on the screen. Hold down the shift key while positioning the cursor to select the right edge of the area to be selected. Click the mouse button to select the area. To extend the selection, hold the Shift key and move the cursor or the arrow keys. The I-beam cursor can also be activated by the Ctrl+I keystroke. Clicking and holding on the I-beam tool will generate a pop-up menu for displaying the Selection Palette or linking selections between Data Views. 
	When "Link Selections Between Data Views" is selected, the standard I-beam cursor icon will change to one with a link appearing across it. When enabled, any area selected in a Data View or source graph will also be applied to any other associated data view. For more details, see Data Views on page 43.
	This is a standard "zoom" tool. The zoom tool is used for selecting and magnifying any portion of any wave. Click the  icon to use the zoom tool. When moving the mouse into the graph area, it will change from an arrow  to a crosshair (+). Start by positioning the cursor in one corner of the box, then hold down the (left) mouse button and drag the crosshair horizontally, vertically, or diagonally to form a "box" that encompasses the area to be zoomed in. Release the mouse button, and Acq*Knowledge* will automatically adjust the horizontal and vertical scales. To "unzoom," choose Zoom back from the Display menu or use the Ctrl+minus keystroke. Hold the "Alt" key to change the zoom mode to zoom out ("– "in the magnifier). The zoom tool can also be activated by the Ctrl+G keystroke.
Grid Control 	Adjust the grid lines horizontal and vertical. Hold the option key for locked grids to drag to the end.

<table>
<tr><td>Event Definition
</td><td>
Inserts an event at the mouse click location. See page 254 for Event details.

On a plot, the horizontal location matches the ‘x’ coordinate of the click

In Chart mode, the event will be placed on the channel track where the click took place.
In Scope mode, the event will be defined on the active channel.

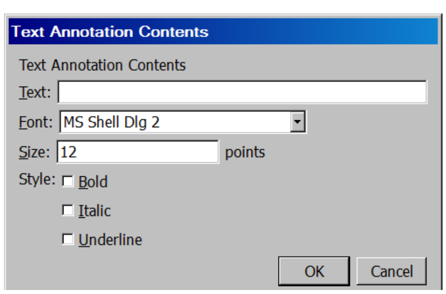
Within the events bar, clicks define global events.

When Event Definition is active, the cursor changes to a flag and the cursor includes a downward pointing arrow to indicate where the event will be defined.
The Event Definition tool is disabled in X/Y mode and if events are not visible.
</td></tr>
<tr><td>Event Removal “Zap”
</td><td>
Deletes event(s) from a graph with the mouse. It allows for quick editing to eliminate misclassified events found through visual inspection.

If the user clicks a single event, that event will be removed from the graph.
If the user clicks and drags to define a rectangular area (similar to the zoom tool), all events between the left and right edges of the area will be removed; the event icon does not need to lie vertically within the bounded area in order to be removed.

When Event Removal is active, the cursor changes to a lightning bolt.
</td></tr>
<tr><td>Jump-to
</td><td>
Data views and advanced analysis output display multiple representations of the same data at the same time. Sometimes this association may be abstract or difficult to visualize. The Jump-to tool is a green arrow, and is available in all display modes and during acquisitions.
Use the “Jump-to” tool to correlate data.

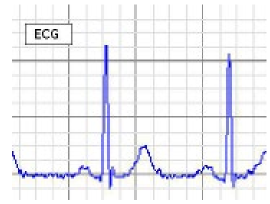
Click the Jump tool on a data point to “jump” all of the open data views for that graph to the same time.
Click the Jump tool on a point in an X/Y plot to jump data views in chart or scope mode to the point in time corresponding to the point in the X/Y plot. This can be useful for correlating PV loops back to other acquired signals.
Rate analysis output graphs will jump back to the corresponding point of source data at the start of that cycle.
Clustering scatterplots will select the appropriate segment of the source graph corresponding to the chosen data point.
Change the active segment in Stacked Plot mode; once a trace is selected the display will adjust to show the new active segment.

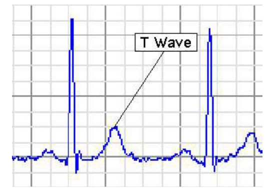
</td></tr>
<tr><td>Text Annotation
</td><td>
Use Text Annotation to add floating text notes on top of data in a graph; the text notes move and scale with the data. During report or figure preparation, it is nice to be able to add additional textual information on top of signals to help clarify signals for readers or draw their attention to particular areas of visual interest. AcqKnowledge provides a text annotation facility to assist in figure preparation.
Click the A icon and then click in the graph window to generate the Text Annotation Contents dialog. Drag the red “handles” from the annotated text to add connector lines to connect the text to the data.


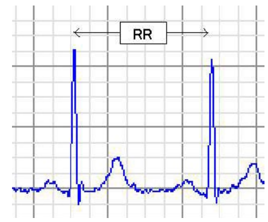
</td></tr>
</table>

Text Annotation

continued





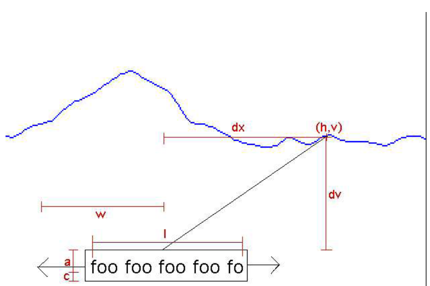


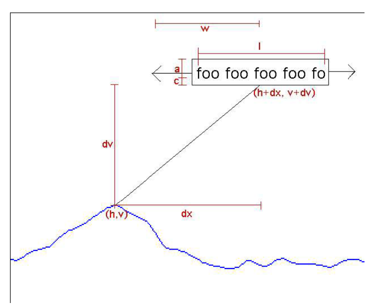
Connector handles

Resize a range

Add a range

Move a connector





Text annotations are short pieces of text that float above channel data and can be used to draw visual attention to particular areas of interest in a graph. These text annotations can be simple outlined text, can have a connector from the outline boundary to a specific sample point on the waveform, or have a range indicator of a specific width. Each text annotation is tied to a sample of data in a channel; when the data is moved by copying, pasting, or other waveform editing operations, text annotations remain fixed to their corresponding sample positions, similar to channel events.

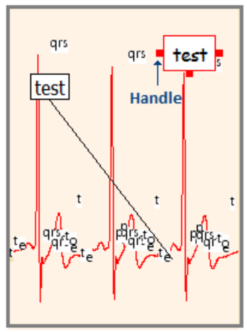
Although text annotations are tied to horizontal locations like event markers, they are displayed in a relative fashion. The relative pixel distance between the text annotation outline boundary and the sample of data remains the same under zoom and autoscaling operations.

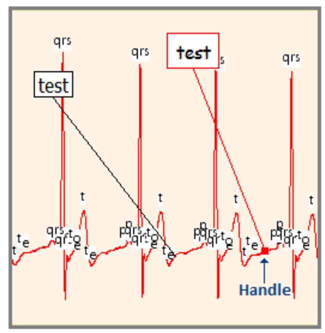
- For example, an annotation that is 20 pixels above a T-Wave peak position will continue to be drawn 20 pixels above regardless of zoom. This allows for flexible data viewing while maintaining text annotation visibility.

Text annotation controls

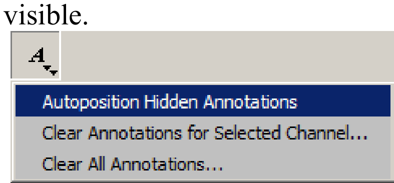
With the tool active, click in the graph to define a new annotation.

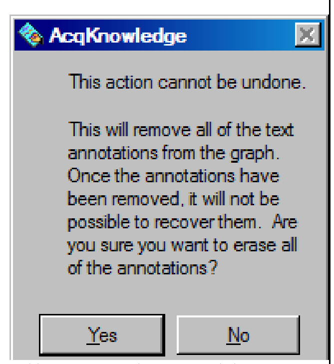
Select	Click an annotation once to select it.
Reposition	Drag a selected annotation to reposition it.
Add Connector	Connectors or range indicators can be added to selected annotations by using the editing handles on the edges of the selected annotation.
Edit Connector	If the selected annotation has a connector to a data point of the graph, an editing handle will appear on the end of the connector. The connector can be moved to a different data sample of the graph by dragging the editing handle on the end of the connector to the new position in the channel. To remove the connector, grab the editing handle on the end of the connector and drag the mouse inside the text annotation.





Range Indicator	If the selected annotation has a range indicator, editing handles will appear at both ends of the range indicator. To resize the range indicator, grab an editing handle and move the mouse. To remove the range indicator, grab an editing handle and move the mouse back inside the text annotation.
Autoposition	Resizing windows or adding channels may reposition text annotations outside of the visible area. Click and hold down the text annotation tool to activate the text annotation popup menu. The "Autoposition Hidden Annotations" option automatically repositions all annotations so they are visible.





Clear all	Click and hold down the text annotation tool to activate the text annotation popup menu. The "Clear annotations" option will clear annotations for a selected channel or for all annotations. This action cannot be undone, so a prompt will appear confirm the selection:

Selection Palette

Many tools within Acq*Knowledge* are based around the selection. The selected range of data in the graph is used as the source for measurements, waveform editing, transformations, and other operations. The Selection Palette is a floating dialog that can be used to precisely enter the selection. See page 496 for Selection Palette guidelines.

Start/Stop Toolbar

toggles to

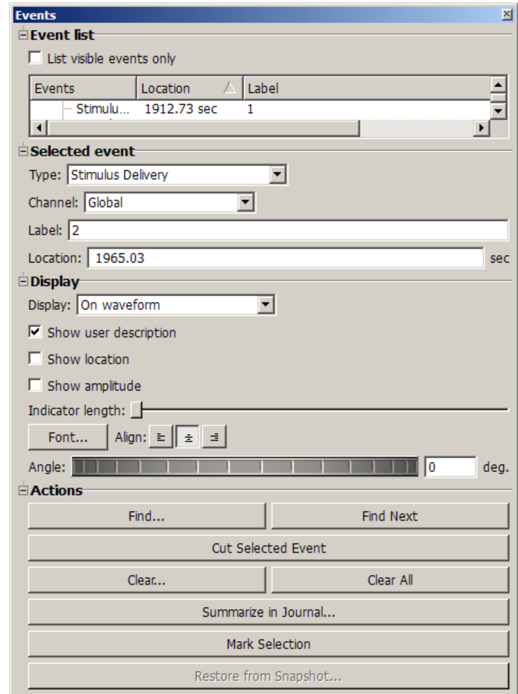

Channel Button Toolbar

Toggles the display of channel number and label region.

Event Toolbar

Select an event to enable the toolbar. (Events and Event bar must first be enabled via Display > Show Events and Event bar). Use the arrows to move forward or backward through all event marker types. (If events are placed in the waveform, the arrow navigation will locate events in the selected channel only.)

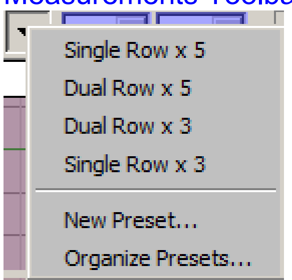
Click the event palette icon to generate the event palette.

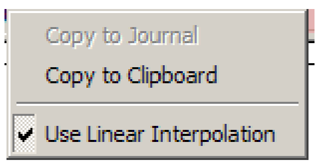


Focus Area Toolbar

Use the Focus Area feature to isolate portions of data that are of particular interest within a graph. Focus Areas can be defined, added, labeled and deleted within any portion of the graph. For more details on creating and using Focus Areas, see page 96.

Measurements Toolbar

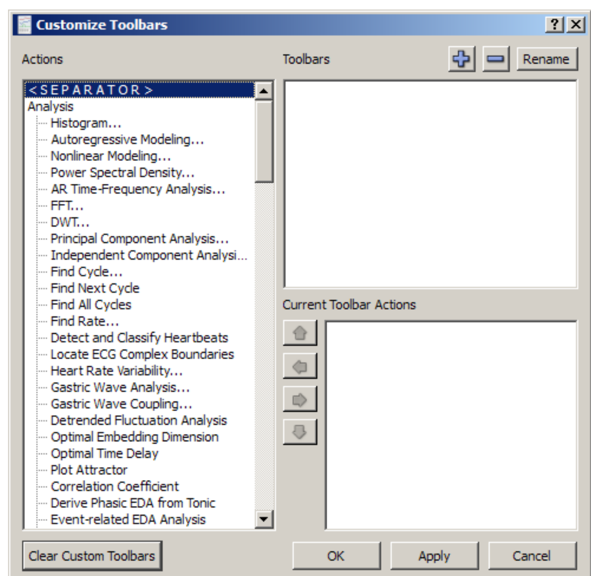




Click the down arrow for quick access to measurement preset functions, including pre-loaded options for organizing measurement rows and columns. Or create and save custom measurement display presets by choosing New Preset, entering a name for the preset and clicking OK.

Right-click in the measurement bar for quick access to options for copying measurement and using linear interpolation.

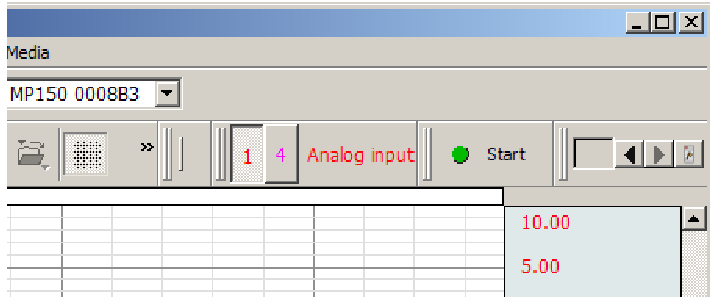
Custom Toolbars for Transformations and Analysis



Acq*Knowledge* 4.1 and above allows users to construct new toolbars for triggering transformations and analysis. An arbitrary number of toolbars may be created and populated with buttons that can trigger any menu item in the Transform and Analysis menus. The contents of the text-only buttons match the menu item title. These toolbars will persist for each user and their positions and visibility within the graph window will be retained.

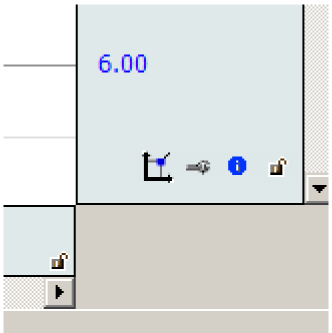
Transformation toolbars may be accessed via the "Customize Toolbars" button.

Toolbar Position Retention and Changes

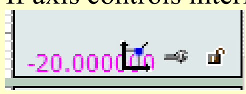


Toolbars can be rearranged within the graph window or detached and turned into floating tool windows. Any modifications made by the user to the position of most toolbars within the graph window will be stored as an application preference and used for new graph windows as they are created and graph files that are opened from disk. Default toolbar positions have changed to move the Start button and cursor tools to the top of the graph window; users preferring the ordering in previous versions may manually reposition the toolbars. **Toolbar Tooltips** may be deactivated when toolbars are detached from a graph.

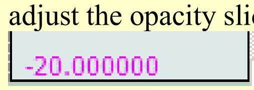
Axis Controls



If axis controls interfere with scale values,

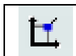
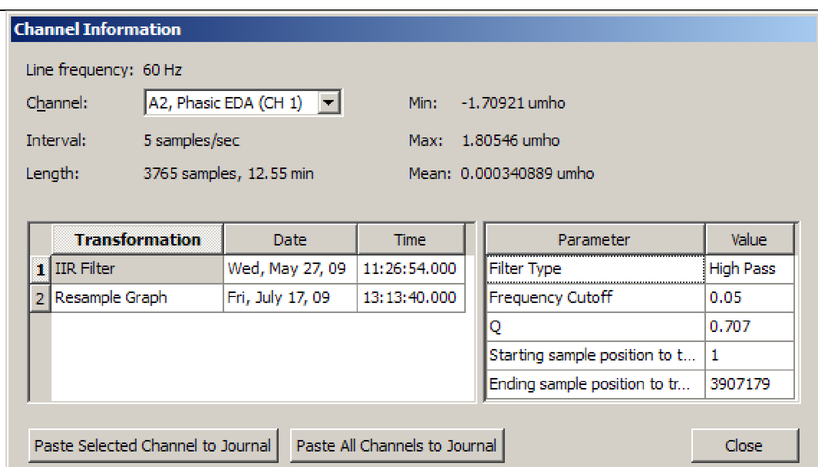


adjust the opacity slider in Preferences > Graph



to hide the icons until the cursor passes over them

.

<table>
<tr><td></td><td>A “scaling” button acts as a shortcut for opening the grid and visible range dialog, similar to double-clicking the axis. If a channel corresponds to an analog channel that has calibration steps, a calibration wrench button be displayed and will open the hardware calibration dialogs. This allows visual access to commonly used operations for channels.</td></tr>
<tr><td></td><td>Module dependent: Generate the scaling or calibration dialogs for the channel input or calculation. Analog inputs will open to the scaling dialog and channels that require calibration will initiate a repeat calibration routine.</td></tr>
<tr><td></td><td>

Use Display > Channel Info or use the channel’s contextual menu to display the Channel Information.</td></tr>
<tr><td></td><td>Toggle the lock icon at the right edge of the window to change the lock state of the grid for horizontal axis or the channel. Unlocked is open (latch to right); locked is closed.</td></tr>
</table>

Enable Cursor Tools During Acquisitions

Enables access to cursor tools while recordings are in progress. (Acq*Knowledge* 4.2 and higher only, Display > Preferences > Graph)

Button Transparency

Scaling, calibration, transformation history, and grid lock buttons may be made semi-transparent to allow units, axis values, and other information underneath the buttons to remain visible. The Preferences > Graph panel includes an "Axis controls" slider to change drawing from fully transparent to fully opaque.

When the mouse is positioned within the buttons, they will be drawn fully opaque regardless of transparency setting. The transparency is shared by the scaling, calibration, transformation history, and grid lock buttons and is the same for all open graphs as this is an application-level preference.

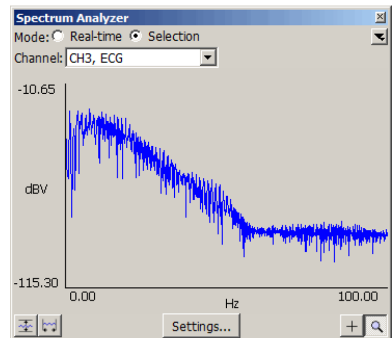
Customizable Chart Track Dividers

Users may change the color used to draw the dividers between channels tracks The Preferences > Graph panel contains "Chart Track Divider Appearance" options.

Plotting Background Colors

Customizable background colors for individual graph channels are available in Preferences > Graph > Plotting Background Colors.

Spectrum Analyzer Palette



The Spectrum Analyzer Palette provides a dynamic display of the frequency decomposition of data, in real time or post-acquisition.

See page 501 for details.

Keyboard Shortcuts

Menu Option	Windows OS	Mac OS
Program info	Help > About Acq*Knowledge*	Help > About Acq*Knowledge*
Quit	Ctrl + Q	⌘ Q
Hide Acq*Knowledge*	minimize (corner box)	minimize (corner box)
File menu		
New	Ctrl + N	⌘ N
Open	Ctrl + O	⌘ O
Open > Recent	Ctrl + 1 (for most recent)	⌘ + 1 (for most recent)
Open Sample Data File		
Open for Playback		
Import/Export		
Close	Ctrl + W	⌘ W
Save	Ctrl + S	⌘ S
Save As		
Save Selection As		
Save Journal Text As		
Send E-Mail Attachment		
Copy to Dropbox		
Open from Dropbox		

Menu Option	Windows OS	Mac OS
Logout from Dropbox		
Page Setup		
Print	Ctrl + P	⌘ P
Quit	Ctrl + Q	⌘ Q
Edit menu		
Undo (when applicable)	Ctrl + Z	⌘ Z
Cut	Ctrl + X	⌘ X
Copy	Ctrl + C	⌘ C
Paste	Ctrl + V	⌘ V
Clear (journal)	none	none
Clear All		
Remove Last Appended Segment	Use the Rewind toolbar icon	
Insert Waveform		
Duplicate Waveform	Ctrl + D	⌘ D
Select All	Ctrl + A	⌘ A
Remove Waveform		
Create Data Snapshot		
Merge Graphs		
Clipboard > Copy Measurements > Copy Wave Data > Copy Graph > Copy Acquisition Settings > Copy Data Modification History for All Channels > Copy Data Modification History for Selected Channels > Copy Focus Area Summary > Copy Event Summary	 Ctrl + K Ctrl + L Ctrl + U	 ⌘ K ⌘ L ⌘ U
Journal > Paste Measurements > Paste Wave Data > Paste Graph > Paste Acquisition Settings > Paste Modification History for All Channels > Paste Modification History for Selected Channels > Paste Focus Area Summary > Paste Event Summary > Manage PDFs > Show Journal	 Ctrl + M Ctrl + / Ctrl + J	 ⌘ M ⌘ + / ⌘ J
Transform Menu		

Menu Option	Windows OS	Mac OS
Recently Used		
Digital Filters		
Fourier Linear Combiners		
Math Functions		
Template Functions		
Integral		
Derivative		
Integrate		
Smoothing		
Difference		
Resample Waveform		
Resample Graph		
Expression		
Delay		
Rescale		
Waveform Math		
Slew Rate Limiter		
Analysis menu		
Find Cycle	Ctrl + F	⌘ F
Find Next Cycle	Ctrl + E	⌘ E
Find All Cycles	Ctrl + R	⌘ R
Display menu		
Tile Waveforms		
Autoscale Single Waveform	Ctrl + Shift + Y	⌘ Shift Y
Autoscale Waveforms	Ctrl + Y	⌘ Y
Overlap Waveforms		
Autoscale Horizontal	Ctrl + H	⌘ H
Show All Data	Ctrl + Shift + D	Shift ⌘ D
Show Default Scales		
Zoom Back	Ctrl + - (minus key)	⌘ -
Zoom Forward	Ctrl + = (equal key)	⌘ +
Reset Chart Display		
Reset Grid		
Adjust Grid Spacing		
Set Wave Positions		
Wave Color		
Horizontal Axis		
Show > Selection Palette > Location Palette	Ctrl + Shift + = Ctrl + Shift + L	⌘ + Shift + = ⌘ + Shift + L
Customize Toolbars		

Menu Option	Windows OS	Mac OS
Channel Info		
Preferences		
Size Window		
Cursor Style > Arrow > Selection > Zoom	Ctrl + B Ctrl + I Ctrl + G	⌘ B ⌘ I ⌘ G
Create Data View Create Focus Area		
Organize Data Snapshots		
Show All Data Snapshots		
Load All Data Into Memory		
Script Menu		
Script Step	Ctrl + Shift + T	⌘ + Shift + T
Hardware Device Menu		
Set Up Data Acquisition > • Channels • Length/Rate • Event Marking • Segment Labels • Stimulator • Trigger • Sound Feedback Set Up Advanced Averaging Show Input Values Show Manual Control Show Gauge MP160/150 Info		
Autoplotting	Ctrl + T	⌘ T
Scrolling		
Warn On Overwrite		
Organize Channel Presets		
Set Up Linked Acquisitions		
Exit All Playback Graphs	Ctrl + Exit Playback Mode	Option + Exit Playback Mode
Manage Hardware Connections		
Start/Stop Acquisition	Ctrl + spacebar	Ctrl + spacebar
Delete recorded data Deletes all recorded data segments	Ctrl + Rewind button	Option + Rewind button

Window menu Select Next Tab Select Previous Tab	 Ctrl + Tab Ctrl + Shift + Tab	 ⌘ Tab ⌘ Shift + Tab
Help Tutorial Screencasts from the Web Open Acq*Knowledge* Tutorial Application Notes from Web Open Acq*Knowledge* Manual Open Hardware Guide About Acq*Knowledge*		
Cursors I-beam Arrow (pointer) Zoom Grid Event Jump to Annotation	 Ctrl + I Ctrl + B Ctrl + G	 ⌘ I ⌘ B ⌘ G
Horizontal Scroll Location	In chart, scope, or stacked plot mode (i.e., all but X/Y) these keyboard shortcuts can be used to scroll to various parts of the graph.	
Home	Jumps to t = 0 (i.e., places first sample of data flush with left of graph window)	
End	Jumps to the end of the currently selected waveform (i.e., places last sample of data of the selected waveform flush with right of graph window)	
Page Up	Scrolls backward in time one full screen (i.e., places leftmost sample of previous visible area at the right of the new visible area).	
Page Down	Scrolls forward in time one full screen (i.e., places rightmost sample of previous visible area at the left of the new visible area).	

Tooltips

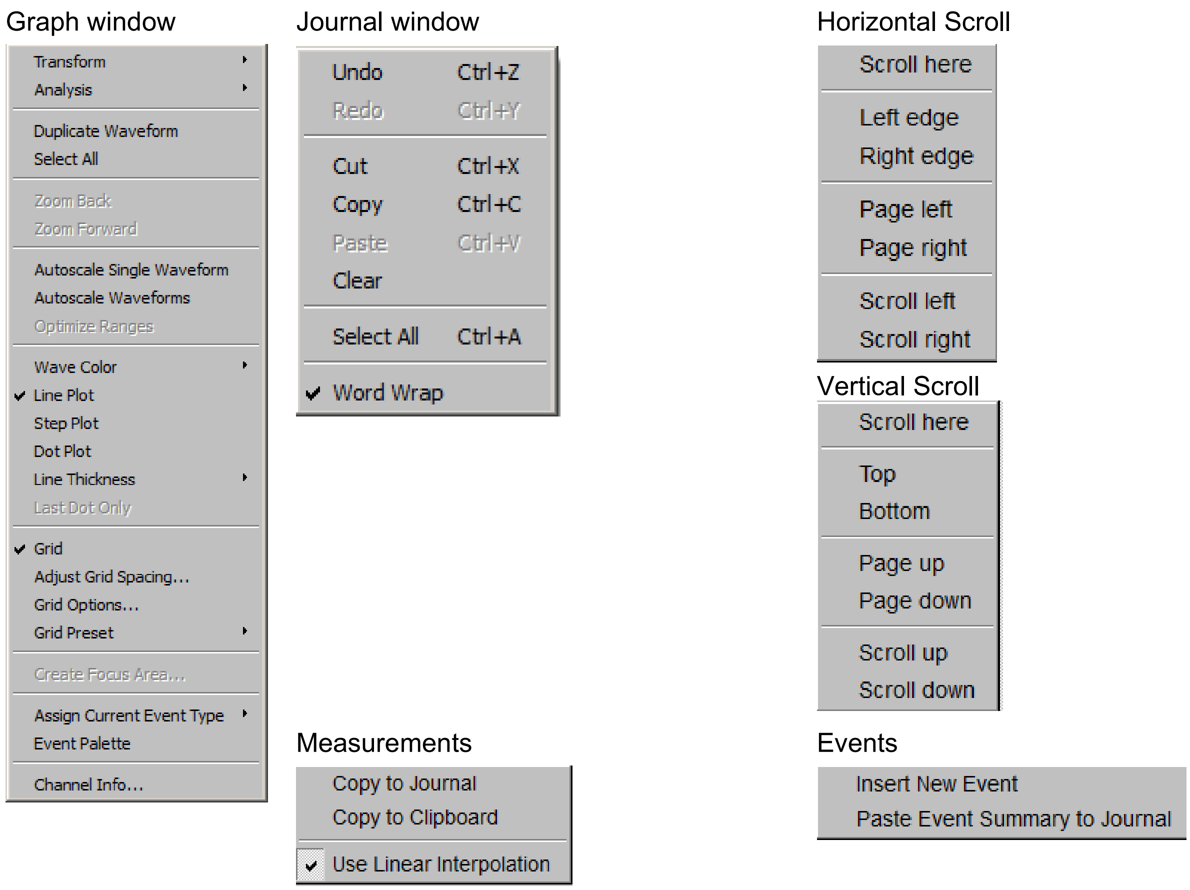
Tooltips is an assistance feature to help novice users learn how to use Acq*Knowledge*. Text is generated to describe the software functionality of the item under the mouse. Unavailable items/controls will indicate why they are unavailable. Tooltip visibility can be controlled by selecting or deselecting the “Show Menu Tooltips” checkbox in “Preferences > Other.”

Mouse Controls

Contextual menu items correspond to the Acq*Knowledge* main menu state.

The following options can be accessed with a right-click for Windows or Control-click for Mac.

- *Mac OS only*: If the mouse is over a portion of the graph that has a context menu available, the cursor will change to an arrow with a menu.



Mouse Scrollwheel Support

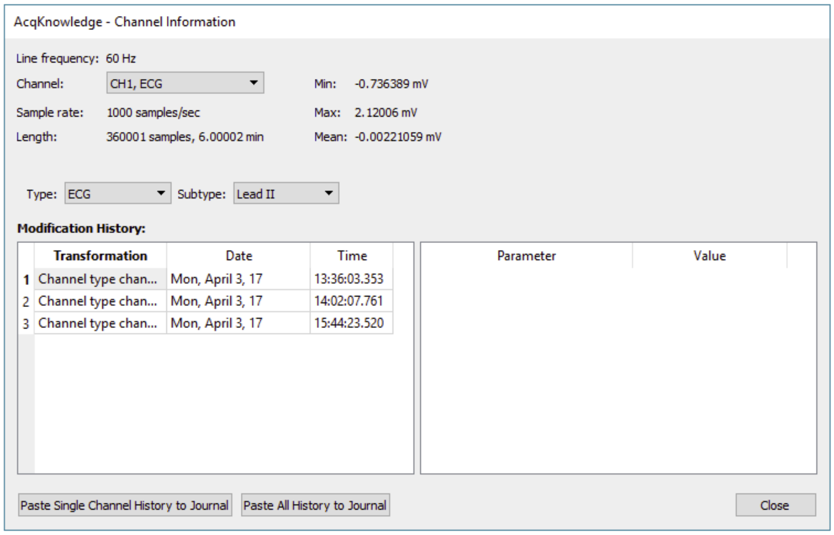
The scrollwheel operates on whatever window is underneath the mouse; this window does not need to be the topmost window. Many third-party mice include scrollwheels, scrolling balls, or trackpads to allow for quick access to navigating through a document. Mice may provide two separate controls, one for scrolling vertically and one for scrolling horizontally.

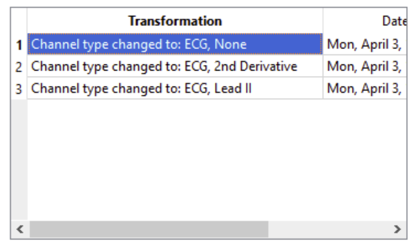
Acq*Knowledge* supports horizontal and vertical scrolling using the scrollwheels on the mouse. Scrolling is supported in graph windows, journal windows, the event list in the event palette, and a number of other dialogs and windows that contain scrollable lists. A dynamic zoom operation can easily be performed in an Acq*Knowledge* graph channel by holding down the Ctrl key (PC) or the Option key (Mac). Scroll 'up' to zoom in and 'down' to zoom out. (Zoom operation supported in Acq*Knowledge* 4.2 and higher)

- Mac OS: To increase the scroll speed, hold down the "Option" key while using the scrollwheel.

Modification History

Modification history provides the ability to track operations performed on channel data. This gives a visual indicator of whether operations have been applied to a channel and a record of the sequence of operations and parameters for the operation. The channel history is viewed in the "Channel Info..." dialog. This dialog is accessible via the “Channel Info” option in the graph channel’s contextual menu or the Display > Channel Info menu item.



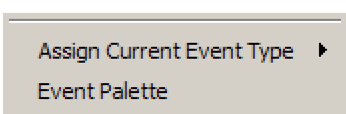


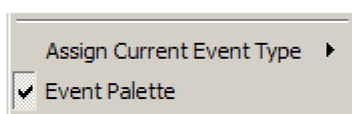
Cancelling Transformations and Transformation Progress Bar

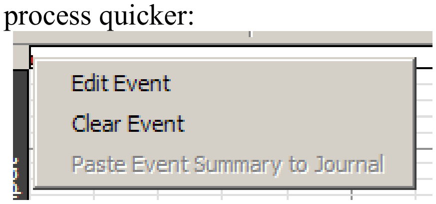
Transformation cancel support offers Cancel buttons for in-progress dialogs that indicate the completion status of threaded transformations. Progress dialogs have also been enhanced so the textual message includes a graphical progress bar with the percentage that is completed. If the progress message does not contain a percentage, an indeterminate progress bar will be displayed.

Acq*Knowledge* 4.1 and higher extends the analysis package to display dialogs while analysis routines are in progress. This progress dialog contains a cancel button which may be used to terminate the analysis before it is complete.

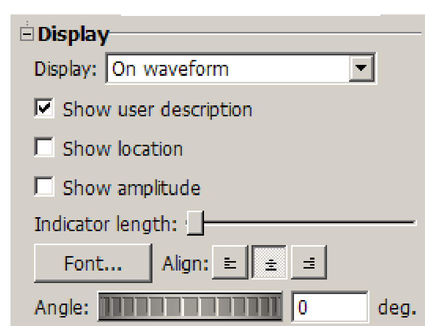
The event tool allows events to be inserted on a graph with the mouse. When performing event editing, three new context menu shortcuts have been added to help make the process quicker:







- Assign Current Event Type: Right-click an area with no data to set the type of event that will be inserted on the next left-click of the mouse.
- Event Palette: Toggles event palette displays.
- Edit event: Right-click a specific event to open the event palette to Selected Event controls for the event that was right-clicked.



Typed Event Label Drawing Improvements

The Event system has been enhanced to allow different drawing options for channel-specific events when they are drawn in the data plotting area. These drawing options are applied to event labels, event amplitude markings, and event time location text. The following drawing options may be customized:

- Font (including family, size, italic/bold, and other options)
- Rotation angle of text baseline
- Text alignment (left, center, right)

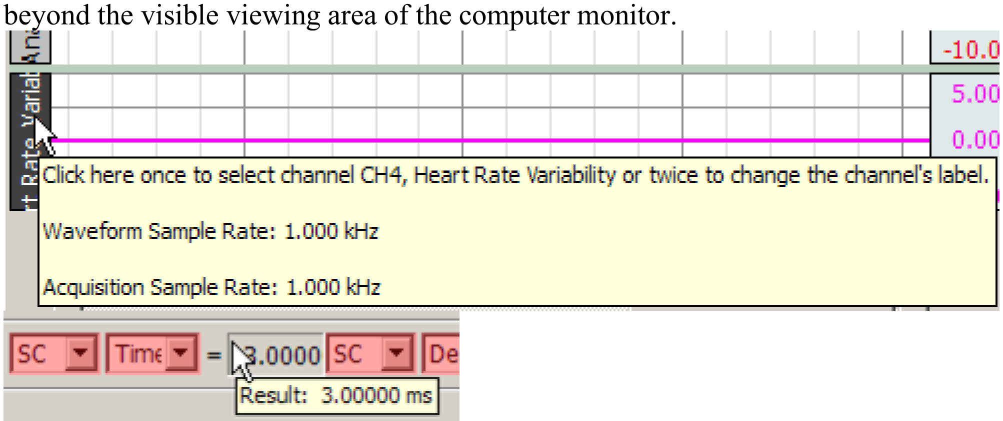
Choose MP160 and MP150 Help Button

A Help button is available in the "Choose MP160" or "Choose MP150"dialog that appears when the application is attempting to locate an MP device. The Help button opens a "Troubleshooting MP Communications.pdf" document from the application's User Support System. This troubleshooting guide provides common information from Technical Support for decoding the network blink states of the MP unit and other steps to take to troubleshoot why the MP unit and computer cannot communicate properly.

Tooltips

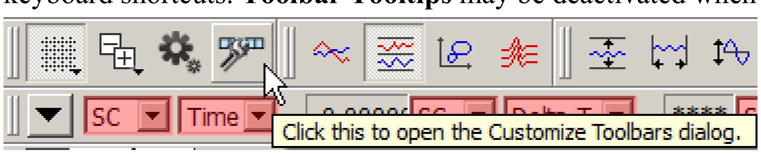
Channel Label, Units Length and Tooltips

Character length limitations for channel label and units have been expanded: labels may now be up to 1032 characters and units may be up to 511 characters. Tooltips have been added to display the full channel units when the vertical axis is moused over. Tool tips do not wrap, so long labels may extend beyond the visible viewing area of the computer monitor.



Graph Window Tooltip Improvements

Several of the toolbar buttons and the Start/Stop button in the graph window are associated with keyboard shortcuts that may be used instead of the buttons. Tooltips for these toolbar buttons display the corresponding keyboard shortcuts. **Toolbar Tooltips** may be deactivated when toolbars are detached from a graph.



Menu Item Tooltips

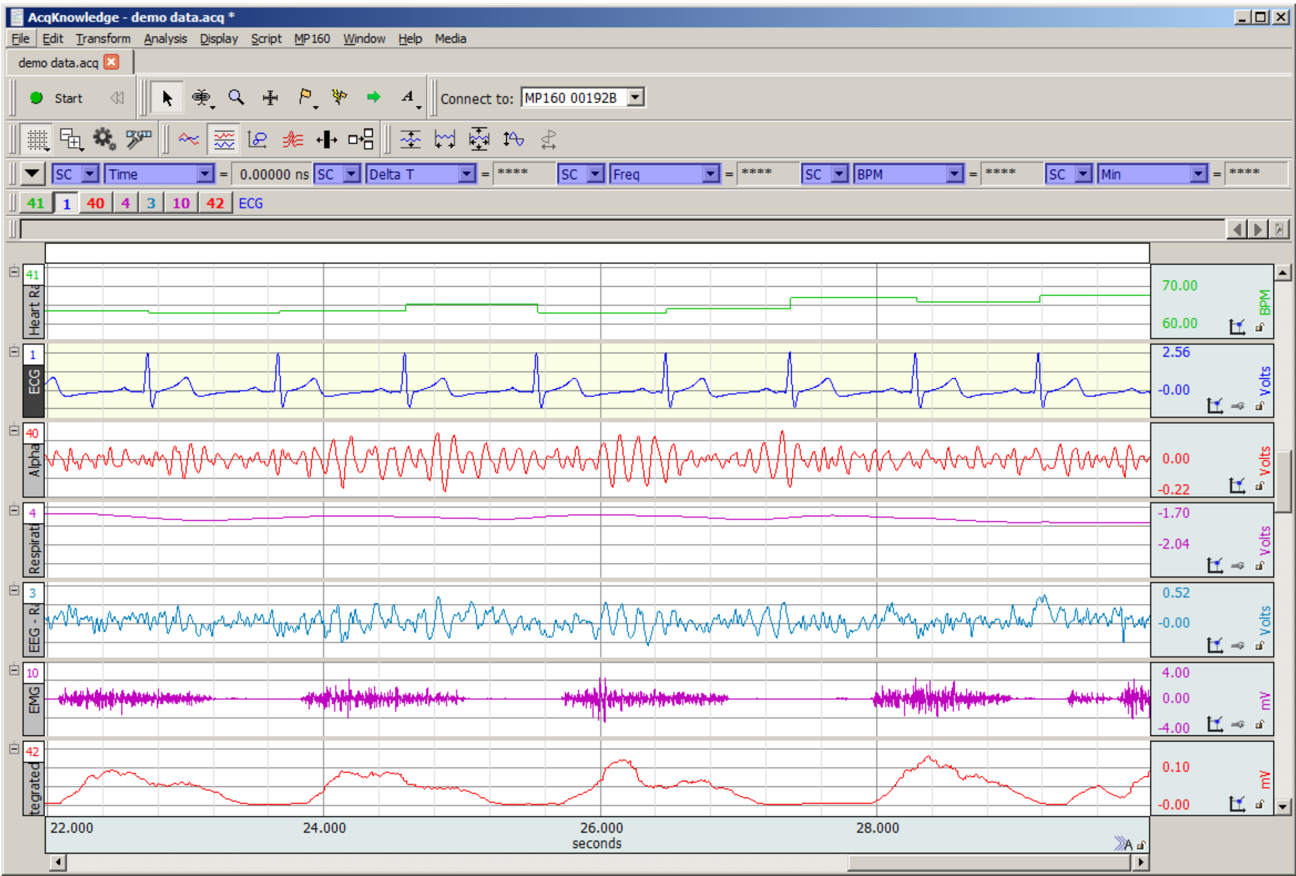
Menu item tooltips display informational text about how menu items may be used. (Similar text was displayed in earlier versions of Acq*Knowledge* for Windows in the status area and in earlier versions of Acq*Knowledge* for Mac as Balloon Help). Analysis menu tooltips have been expanded to provide more detail regarding the types of analysis that are performed by the selected item.

Chapter 4 Editing and Analysis Features

Overview

This section provides a brief overview of some of the most frequently used Acq*Knowledge* features and functions. For more detailed information about specific features, turn to Chapters 9 through 13.

With Acq*Knowledge* running, choose File > Open Sample Data File and select the file called "demo data.acq." The screen should look like this:



Edit menu functionality during acquisition

The following Edit menu functions may move or alter memory and cannot be performed during acquisition: Undo, Cut, Clear, Clear All, Paste, Insert Waveform, Duplicate waveform, and Remove Waveform.

Scroll bars

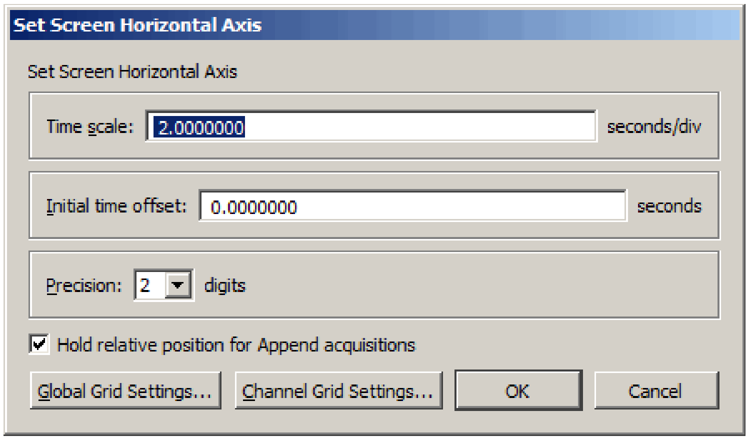
Note that there are four channels of data in this file (Heart Rate, ECG, EEG, Resp, EMG Raw, EMG, Integrated EMG). Although this record is 30 seconds long, only a few seconds are displayed on the screen at one time. Move to different locations in the record by moving the scroll box at the bottom of the screen. Dragging the box left moves to earlier points in time, and moving right displays events closer to the end of the record. Clicking on the arrows at either end of the horizontal scroll bar allows moving to different points in time at smaller increments.

A vertical scroll bar is on the right side of the screen, and. When clicking the scroll arrow at the top of the box, note that one waveform appears to move down within its "track" on the screen. Moving this scroll box changes the amplitude offset of a selected channel. As with the horizontal scroll bar, either move the box or click the arrows.

Scaling

Horizontal axis

Click the horizontal scale (above the scroll bar) to generate a dialog where values can be entered for units per division and horizontal scale offset.



Time Scale

The time interval (units per division) between the on-screen grid marks. There are four vertical divisions per screen, and the default is 2.00 seconds per division, so eight seconds of data will be displayed on the screen display. Entering a larger value will display more of the record, and entering a smaller value will display less.

Initial offset

The time corresponding with the first data point displayed. For example, to display the middle 1/3 of the data file (assuming the record is 30 seconds long), set the offset to 10 seconds and the seconds per division to 2.5 seconds.

Precision

Controls number of decimal places following whole units appearing in the horizontal axis.

Hold Relative Position for Append acquisitions

This option is active in **Append** acquisition mode only. When checked, the display for appended acquisitions will show the same relative position with respect to the start of acquisition. This is convenient when performing short-duration; high-speed acquisitions where a user needs to zoom in on a signal of interest and have the relative position (from the start of acquisition) stay the same.

When zooming in on a section of data within a recording segment, the next appended segment will "hold" its relative horizontal position (start and end times with respect to the start of each segment).

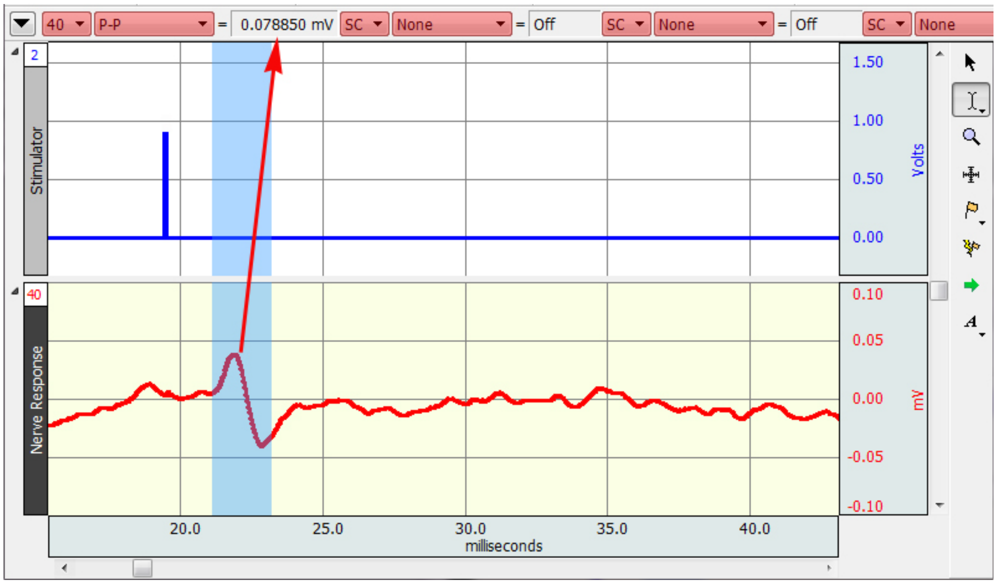
When using the I-beam tool to select a sub-section of the data, this sub-section will hold its relative position and update the measurement values on each subsequent appended segment.

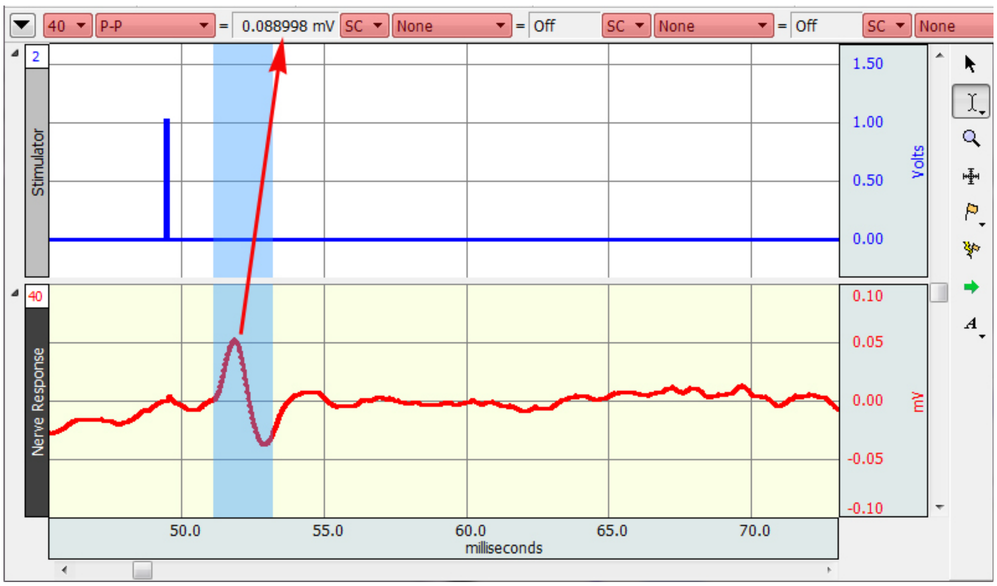
If the selected data area falls within two or more appended segments, this feature is not implemented.

Example of Hold Relative Position feature:

Action Potential setup: 100,000 samples/sec, 50 millisecond recording length, Append mode and stimulator set to output 19 milliseconds after the start of the recording.

After the first recording segment, the zoom tool is used to expand the area of interest (top figure below). The I-beam cursor is used to select a measurement area around the nerve response. The "P-P" measurement shows the nerve response amplitude. After clicking **Start** and recording the next segment, the relative position of both the horizontal time scale and the measurement selected area, with respect to the start of recording is maintained (bottom figure below). This makes it very easy to measure the changes in the amplitude of the nerve response with changes in stimulus level.





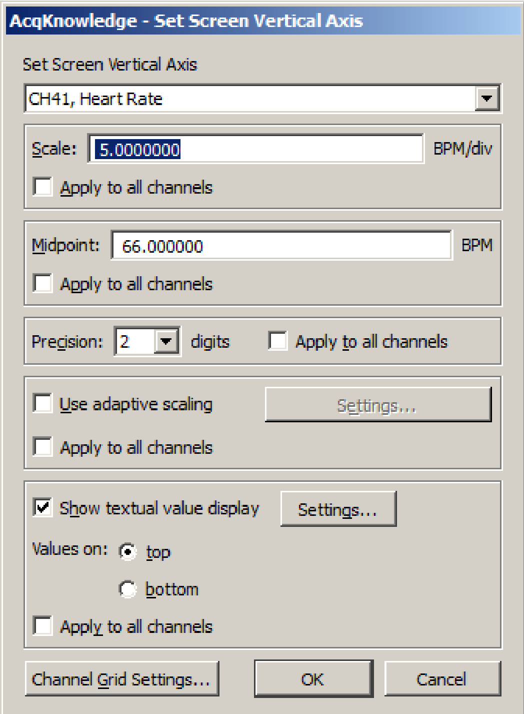
Global Grid Settings

Opens dialog for applying master grid settings for all channels. For more details, see Grids on page 84.

Channel Grid Settings

Opens dialog for selectively applying grid settings to one or more channels. For more details, see Grids on page 84.

Vertical (Amplitude) axis



Clicking in the vertical scale area (where the amplitude of each channel is displayed) generates the Set Screen Vertical Axis dialog, where values can be entered for units per division and vertical scale offset.

Scale

Determines the limits of the viewable vertical axis scale (usually Volts). Acq*Knowledge* divides each channel into four vertical divisions. When data is displayed in chart mode, each “track” is divided into four divisions. When data is displayed in scope mode (or if there is only one channel of data) the entire screen is divided into four intervals. To increase the apparent amplitude for a given channel, set this value to a smaller number; entering a larger number will cause the waveform to appear to have less variability.

Midpoint

Refers to median displayed value for a particular channel. A checkbox to the left of each of these options allows these scaling options to be applied to all channels. By default, the selected scaling options will only apply to the channel indicated in the dialog. To apply these to all channels, enable all checkboxes.

Precision

Controls number of decimal places following whole units appearing in the vertical axis. Can be applied to selected or all channels.

Apply to all channels

Applies settings selected in the various dialog options to all channels.

Range Guide (MP36R Hardware only)

The Range Guide is a green bar that runs along the vertical scale in the graph window for analog channels (see right).

It displays the maximum signal range for the Gain established for that channel. The Range Guide can be used as a visual aid to establish the proper Gain.

The MP36R hardware measures the actual input voltage and compensates for the Gain. As Gain increases, the peak-to-peak of a waveform stays constant but the resolution increases.

Proper Gain will have a smoothing effect on the signal. For the best resolution, establish Gain such that, allowing for baseline drift (if applicable) and the maximum peak-to-peak of the signal, the maximum signal display is close to the maximum range. If the signal is clipped (Fig. 1), lower the Gain. If the signal is too small compared to the range (Fig. 2), increase the Gain to improve signal resolution. Gain settings create a trade-off between range and resolution.

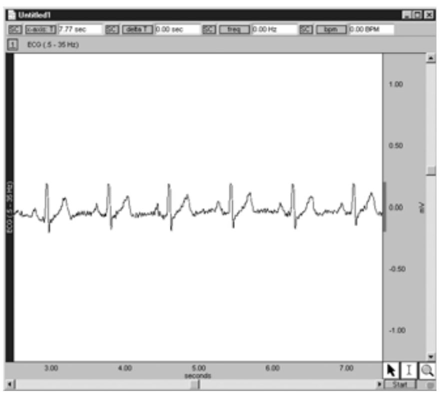


Fig.1: "Clipped" signal

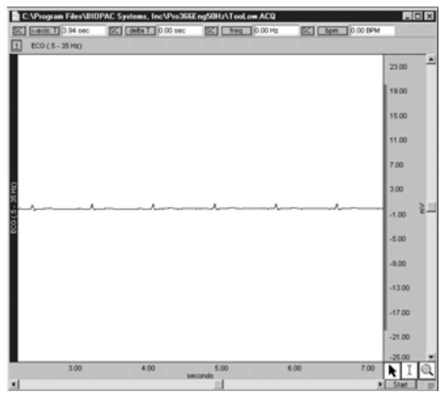


Fig 2: Signal too small compared to range

Different gain settings applied to the same signal source show that

Higher Gain = better resolution + lower range (Figure 3, top)

Lower Gain = worse resolution + higher range (Figure 3, bottom)

To display the full range (Fig. 2 vs. Fig. 3, for example), adjust the Vertical Scale.

The Range Guide will always reflect changes made to the channel Scaling.

To quickly see the total range of each input channel, select **Optimize Ranges** from the Display menu. This will automatically adjust the upper and lower viewable limits of the Vertical Scales for all channels. For more information on Optimize Ranges, see page 489.

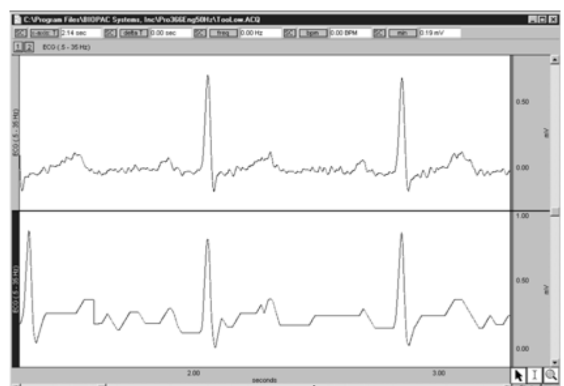


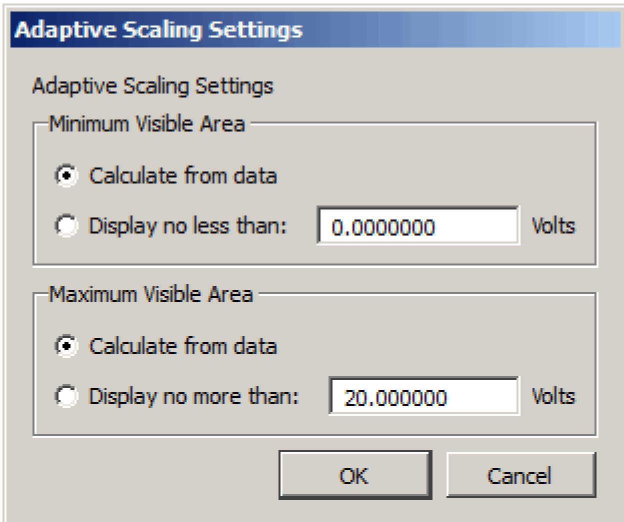
Fig. 3

NOTE: Range Guide and Optimize Ranges are not available when using MP160 or MP150 hardware.

Adaptive Scaling

Adaptive scaling uses the data to automatically determine the appropriate visible range for the data. As the data changes or the baseline shifts, the visible area shifts along with the data to ensure that data will always be plotted on the screen. Rather than limiting data visibility to a fixed voltage range, the range adjusts for factors such as background noise, electrode movement, EMG interference, disconnection, etc.

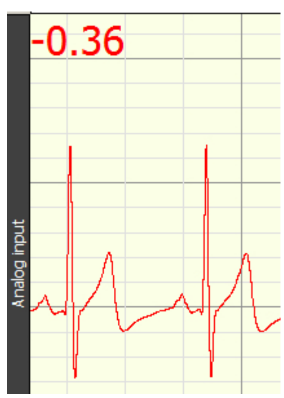
Adaptive scaling can be applied to channels individually and can be unique for each Data View. A "settings" button is activated when to "Use adaptive scaling" is enabled.



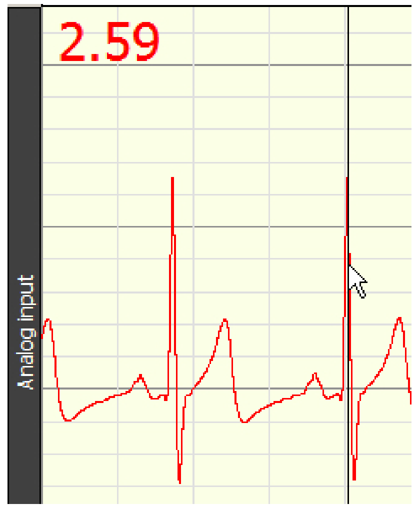
Scaling changes will be applied whenever the domain of the plot area is changed. This includes manual changes to the horizontal scale, horizontal scrollbar use, horizontal auto-scrolling when dragging out a selected area, auto-scrolling or auto-plotting during acquisition, initial enabling of adaptive scaling and auto-scrolling when executing Find Cycle/Peak functions.

Show Textual Value Display

This option enables a real-time display of the most recently acquired values on a channel-by-channel basis, providing amplitude information akin to clinical monitoring displays. This can be useful for obtaining a quick visual numerical summary of incoming data while a recording in progress.



In post-processing, the value display can be seen by performing a "spot measurement" (clicking the arrow cursor on a single data point).



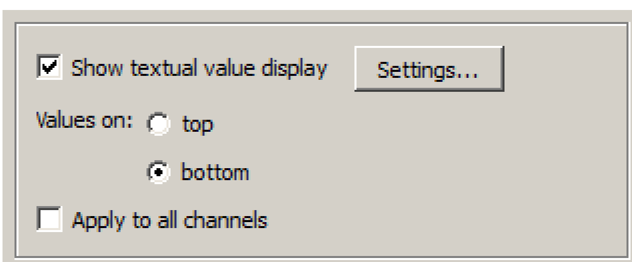
Textual value display in spot measurement mode

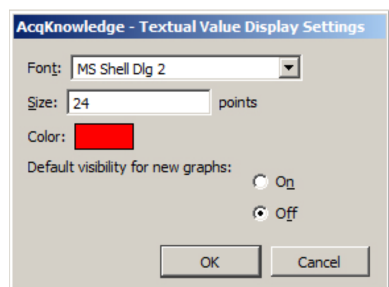
Textual value display can be customized for font, color and style, and positioned at the top or bottom of any selected channel. These options can be configured independently per channel or applied to all channels.

- In chart and stacked chart modes, the value display will appear for all enabled channels.
- In scope mode, the value display will appear only if the selected channel has the value display option enabled.
- Textual value display is not supported in XY mode.

To enable textual value display:

Click on the vertical axis area to open the setup dialog and enable the "Show textual values display" checkbox. Use the Settings button to set the font style, size and color.



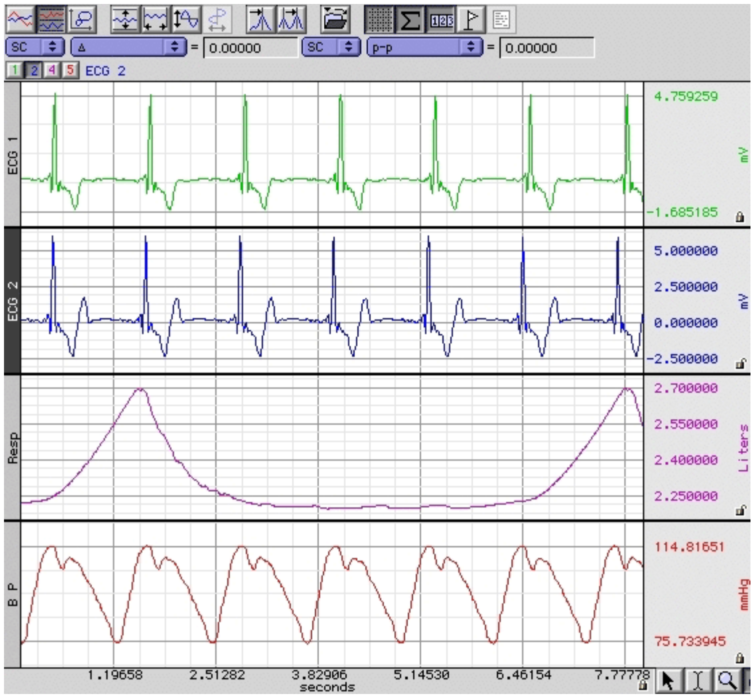


Channel Grid Settings

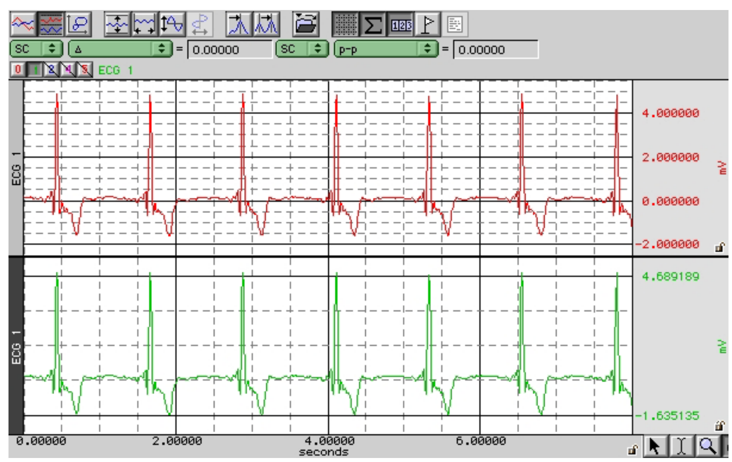
Opens dialog for selectively applying grid settings to one or more channels. For more information, see Grid Details on page 84.

Grid Details

Customize the grid behind the waveforms displayed in graph windows in a number of ways.



Grid Lock/Unlock



Each scale has a small padlock in the lower right hand corner that displays the current state of the grid lock for that axis and channel. Click the padlock to change the lock state.

-  Unlocked grid—the number of grid lines and their pixel spacing on screen is kept constant through zoom and scaling operations
-  Locked grid—the grid lines themselves are maintained at constant values through zoom operations, e.g. a grid line which is located at .753 volts when the grid is locked will continue to be located at .753 volts regardless of changes in scale.

Grids can be locked and unlocked on individual channels.

- The lock for the horizontal axis is shared by all channels.
- The vertical scale can be locked and unlocked independently.

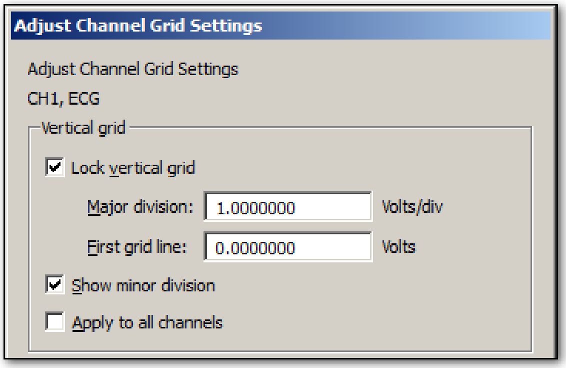
The lock state of the grid can also be changed through the axis dialogs displayed when the mouse is clicked on the axis scale values in the graph window.

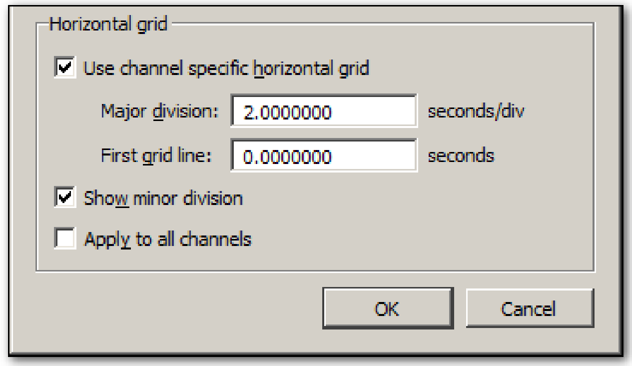
- Click the “Lock units/div” checkboxes.

Grid Scaling

When the grid is locked, the scaling factors controlling how much data is visible on the screen (the distance between consecutive major lines of the grid and a fixed location for one of the lines of the grid) are specified differently. When the grid is unlocked, these scaling factors do not affect the grid.

The Grid Spacing option specifies the scaling factors and whether or not to "Show minor divisions" on the grid display. Changing these values only affects the grid display, not how the waveform is scaled.





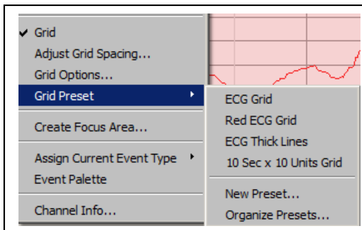
- Vertical grid: the total range of vertical units displayed per track is specified (Major division) along with the first value that should be displayed (First grid line).
- Horizontal grid: the scaling factors are specified in how many seconds of data should be visible on the screen (Major division) and the time offset of the left hand side of the display (First grid line).
- Settings can be applied to a selected channel or all channels. (Controlled by checking or unchecking 'Apply to all channels").

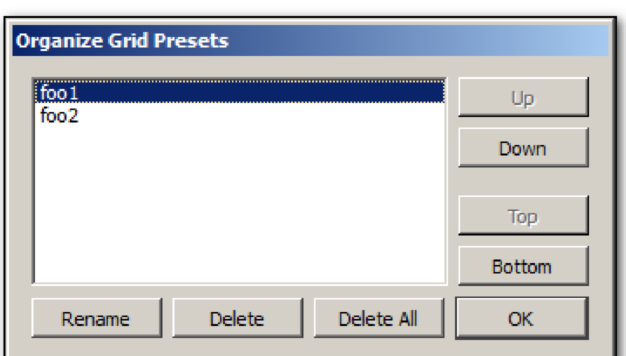
Adjust Grid Spacing

To modify the horizontal and/or vertical grid spacing, choose "Display > Adjust grid spacing." This will generate the aforementioned dialog for modifying the locked axes of the selected waveform. ("Lock vertical grid" and "Use channel specific horizontal grid" must be enabled in order for the gridline fields to become active). Enter the desired values and click OK.

- Settings can be applied to a selected channel or all channels. (Controlled by checking or unchecking 'Apply to all channels").

The following Grid items can also be selected by right clicking with a graph channel and using the contextual menu.



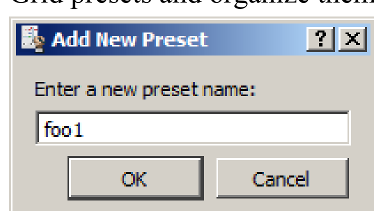


Grid: Toggles Grid display on and off.

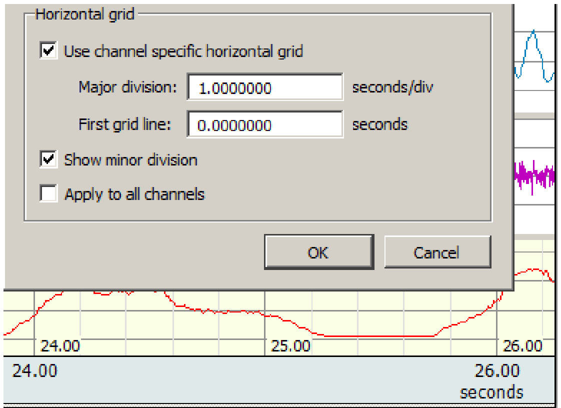
Adjust grid spacing: Use to change Grid spacing for one or all channels (divisions between gridlines and position).

Grid Options: Use to change Grid display for one or all channels (Color, width, style, dash length, dash spacing, and scale adjustment position).

Grid Preset: Use to select/create /save custom Grid presets and organize them in a list. (left)

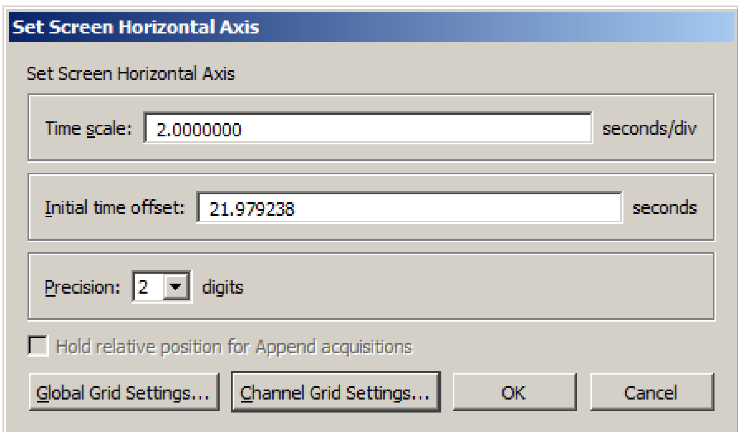


Example of channel specific horizontal grid



Note in figure on left, the horizontal time scale division is one second per division in the graph channel, but two seconds per division in the horizontal axis. (Green bar area)

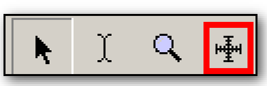
Horizontal Axis Grid Controls



- **Global Grid Settings**: Brings up dialog specifying grid settings used in the shared Horizontal Axis of the graph.
- **Channel Grid Settings**: Brings up the 'Adjust grid spacing dialog' referred to on previous page.

Individual channel-specific grid settings take priority over the Global Grid Settings. If no channel-specific grid setting exists, the Global settings are applied.

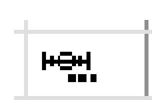
Grid Tool



The Grid Tool allows divisions of the grid to be specified with the mouse. This tool has four states:

Ø	Inactive	The cursor changes to a circle with a line running through it. The grid cannot be adjusted since both the horizontal and vertical axes are unlocked.
	Horizontal axis locked	The cursor changes to a horizontal line. A mouse click and drag will change the location of the horizontal lines of the grid.
	Vertical axis locked	The cursor changes to a vertical line. The tool can be used to adjust the vertical spacing of the grid.
	Both axes locked	The cursor changes to a crosshair. The rectangle of a full grid division can be drawn over the data. Adjust the spacing of locked grid lines underneath the waveform.

If the "Alt" (PC) or "Option" key (Mac) is held down for the Grid Tool in any of the active modes, an ellipsis will appear under the cursor. After a mouse click or drag, a Grid Settings dialog will be generated. This dialog is functionally similar to the grid dialogs accessible via the axis settings dialogs.



- Based on lock status, the dialog will allow the adjustment of Horizontal, Vertical or combined settings.
- The values displayed in the dialog correspond to the grid ranges that were just drawn out on the screen with the grid tool if a mouse drag occurred.
- If the mouse was simply clicked, the current grid settings are displayed.
- This dialog allows the grid drawn out with the grid tool to be made more precise.

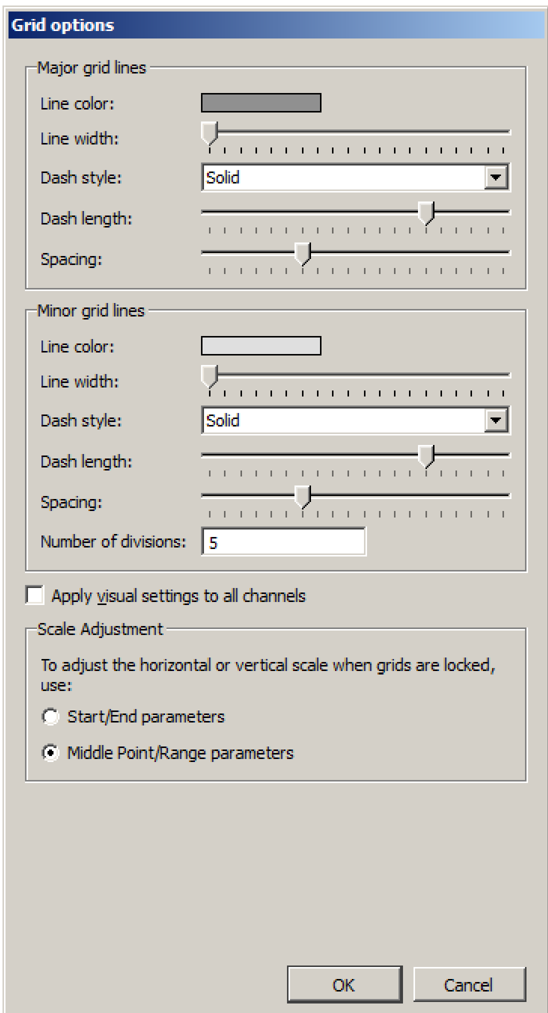
Grid Reset

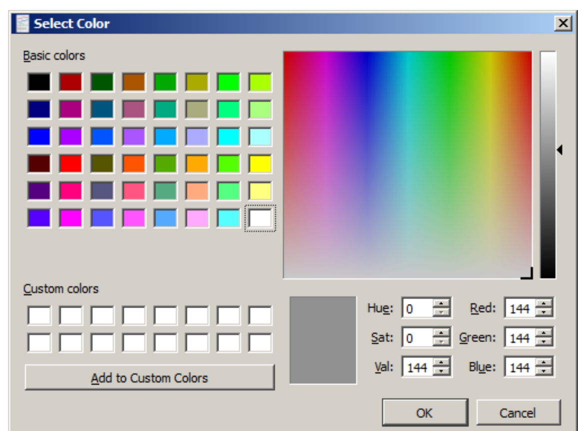
To return to the original grid, choose “Display > Reset grid.”

This will reconstruct the default, unlocked grid of four divisions per screen with solid light gray grid lines.

Grid Options

The major and minor grid lines can be further customized with spacing, number of divisions, and different colors and dashing styles. These are modified under the dialog generated via Display > Show > Grid options.





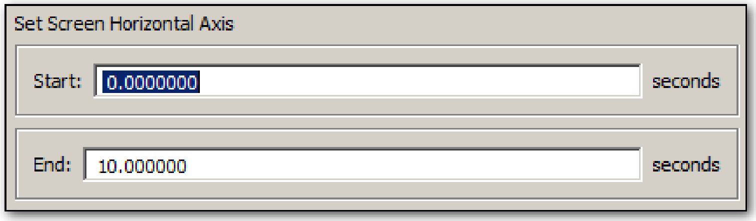
Line color	Click the color well to generate a color chooser.
Line width	Adjust the corresponding slider.
Dash style	Select a style (solid or broken) from the pop-up menu.
Dash length	Adjust the corresponding slider (for any dash mode that is not a solid line).
Spacing	Adjust the corresponding slider (for any dash mode that is not a solid line).
# of Divisions	Enter a value in the text field to set the maximum number of minor grid lines to be displayed in a single major grid division.

Apply visual settings to all channels

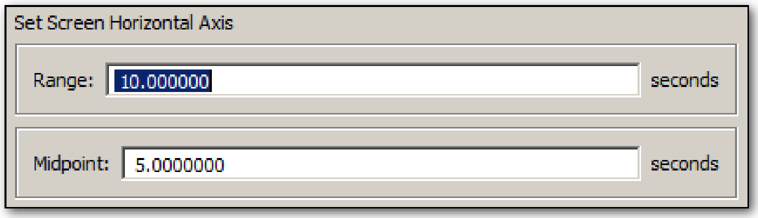
When checked, the visual settings for major and minor grid lines are applied to all channels. When unchecked, the settings will be applied to the selected channel only.

Scale Adjustment

Select whether to use Start/End or Range/Midpoint parameters to determine horizontal and vertical scale adjustments. Applied only when grids are locked.



10 sec. Horizontal Scale adjustment set to 'Start/End' parameters



10 sec. Horizontal Scale set to 'Middle Point/Range' parameters

To undo the selections and return to the original grid, choose "Display > Reset grid." This will reconstruct the default, unlocked grid of four divisions per screen with solid light gray grid lines.

Friendly Grid Scaling

Too much precision can create numbers that are difficult to quickly interpret, so "friendly" grid scaling adjusts the range to the nearest possible whole numbers. For example, it's easier to comprehend 4.1000000 than 4.1427385. Unlocked grids always restrict precision to the minimum needed for a given magnitude. This produces a "friendly" scale that makes it easier to determine the range between the gridlines when data is formatted for display or printing.

With unlocked horizontal grids, the horizontal scale values printed on a graph may not match the horizontal scale values displayed on the application screen. For example, horizontal scale values

Displayed in the application:	0.00000	7.50000	15.00000	22.50000
Printed:	0.00000	7.50125	15.00250	22.50375

The precision will only match when using the "Visible area" print option. With selected area or entire graph options, the precision will not match when grids are unlocked because friendly grid scaling is applied on screen, but is not used during printing where the range is fixed to fill the entire page.

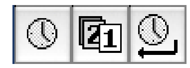
Note that the Zoom tool and vertical autoscale may produce different results. To accommodate the grid precision, the Zoom result may be slightly more than specified in the zoom box. For precise correlation from selected area to result, lock the grids (horizontal and vertical). Precision is not restricted for locked grids or display ranges manually entered in the axis setting dialogs.

Watch the Acq*Knowledge* Grids video tutorial for a detailed demonstration of this feature.

Journal Details

To create a journal, choose **File > New > Graph-Specific Journal** or **Independent Journal** or choose **Display > Show >Journal** or **Edit > Journal > Show Journal**.

Once a Journal is open, text and data can be entered. To enter text, just begin typing when the journal is open. Acq*Knowledge* will automatically "wrap" the text to fit the screen width.



In addition to formatting tools, Time Stamp, Date Stamp and Auto Time functions are available in the journal window.

- Time and Date stamps refer to the computer's clock to record the time and date, respectively, directly into the Journal.
- Auto Time function records the time at the instant the carriage return is pressed, which is useful for tagging commands as data is collected.

Measurements and data may also be pasted into an open Journal. To paste measurements into an open Journal, select an area and choose "**Paste measurements**" from the **Edit > Journal** menu. Paste to Journal functions only work if a Journal is open and vary for each journal type:

- Graph-specific journals can only receive measurements and wave data from their associated graph view
- Independent Journals can receive measurements and wave data from any open graph. Results will be put into both the graph-specific journal and the independent journal. Use Journal Preferences to auto-paste to an independent journal if desired.

Set the Journal Preferences (page 512) to simultaneously record measurement name and units or control Event (marker) paste functionality and detail.

To paste waveform data into a Journal, select an area and choose "**Paste Wave Data**" from the **Edit > Journal** menu. Allow several seconds for the text file to be written. The result is a text file of the wave data pasted into the active journal.

> TIP: When pasting a graph into a Journal: Pressing the Ctrl key (PC) or the Alt key (Mac) will launch a dialog allowing the image to be resized prior to pasting.

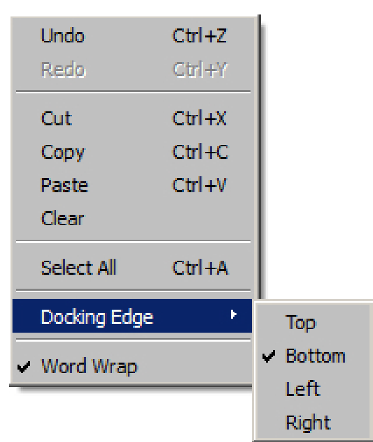
A useful feature of the Journal is that it works in connection with the Cycle/Peak Detector and other measurement functions to paste in values from waveform data for further analysis.

In the example above, the *peak-to-peak* and *delta t* measurements were pasted from the open graph window to the Journal. See the Journal paste section on page 325 for more information on how to paste information to Journal files.

Use **Save as/Open Journal Template** to retain SOP text, or standardize lab/computer details for record keeping.

Journal Contextual Menu

The Journal contextual menu allows quick access to common text editing functions, as well as a tool for easily re-docking the Journal window to any edge of the graph. To activate this menu, right-click anywhere within the Journal window.



Rich Journals

The Acq*Knowledge* Journal includes powerful rich text editing tools, offering advanced word processing functionality. The following toolbar options are available within the Journal window:

- Font family
- Font style: bold, italic, underline
- Paragraph alignment: left, right, center, justify
- Font color

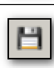
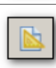
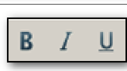
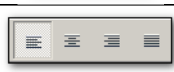
The following items can be pasted or embedded into the Journal text:

- Images
- Numbered lists
- Bulleted lists
- Tables
- Numerical statistics or expressions

Images must reside within a document in order to be pasted into the Journal. Pasting image files directly from a location such as the Desktop is not currently supported.

Journal Toolbar Buttons

The Journal toolbar controls all formatting functions within the Journal window. Although the settings customized in this toolbar are retained within a saved Journal, global default settings for subsequent Journals are not overridden. To change the global defaults, the overall Journal Preference settings must be modified. (Edit > Journal > Preferences). For more information, see Journal Preferences on page 512.

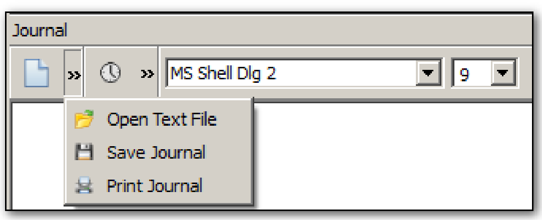
Journal Toolbar Icon	Function	Explanation
	Clear	Clears text from Journal window
	Replace	Replaces Journal text with contents of external text file
	Save	Saves selected or full Journal text to an external text file
	Page Setup	Opens dialog for modifying Journal text print configuration
	Print	Prints the Journal text to the default printer
	Time stamp	Inserts current time into Journal
	Date stamp	Inserts current date into Journal
	Time AND Date	Inserts current time and date into Journal when Enter/Return key is pressed
	Font	Use to select font type and size for Journal session
	Text style	Use to bold, italicize or underline text
	Text alignment	Aligns paragraph text to left, center, right or justified position
	Font color	Selects color of Journal text
	Numbering	Toggles text numbering on and off

	Bulleting	Toggles text bulleting on and off
	Increase indent	Increases indent in a bulleted or numbered list*
	Decrease indent	Decreases indent in a bulleted or numbered list
	Insert link	Adds hyperlink to Journal
	Table	Inserts a table into the Journal
	Table row	Adds a row to the table **
	Table column	Adds a column to the table
	Delete table row	Removes selected row from the table
	Delete table column	Removes selected column from the table
	Merge cells	Merges selected cells within the table
	Split cells	Splits selected cells within the table

*Active only when cursor is positioned within a bulleted or numbered list.

**Additional table tools are active only when a table is present.

NOTE: If the Acq*Knowledge* graph or Journal windows are decreased in size, the Journal toolbar will become truncated and some buttons may no longer be in view. Buttons no longer visible on the toolbar can be found in drop-down menus indicated by arrows. (*See below*)

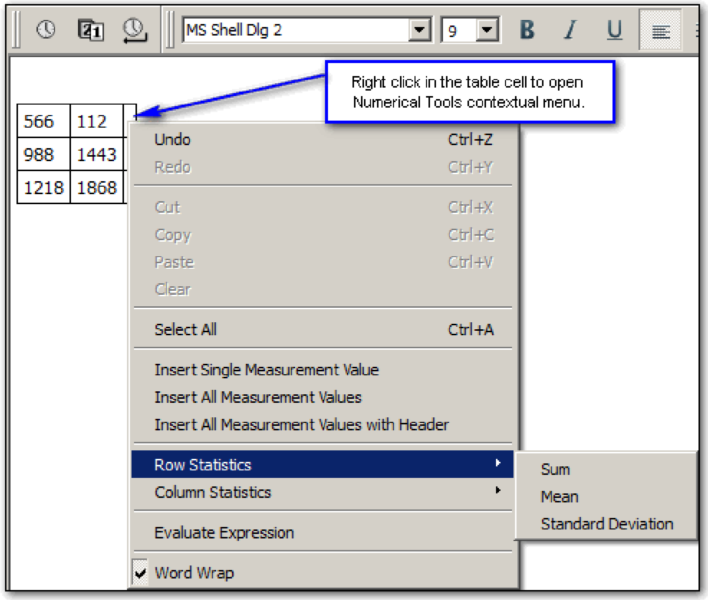


Journal Numerical Table Tools

The Numerical Table Tools function allows easy insertion of measurements and numerical data into a Journal table, which can then be computed and evaluated via basic mathematical operations and expressions. This eliminates the need to export data to a spreadsheet application in order to validate statistics gathered during the course of an experiment.

Numerical Tools operations permitted within a Journal table:

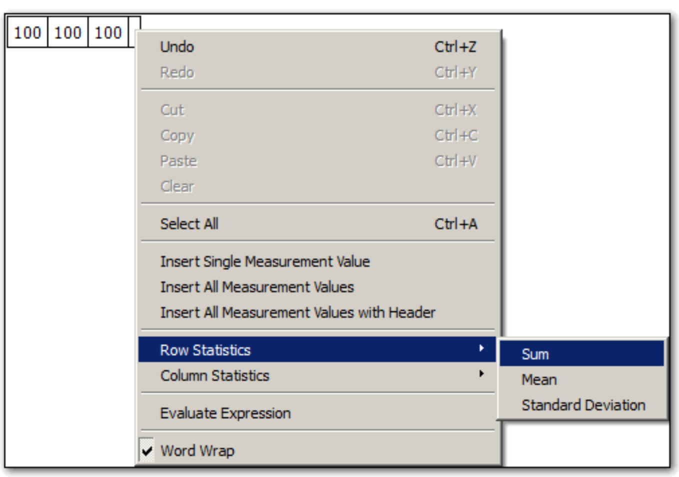
- Insert a single measurement value
- Insert all measurement values
- Insert all measurement values with header row
- Sum, Mean and Standard Deviation statistics for table rows and columns
- Expression evaluation

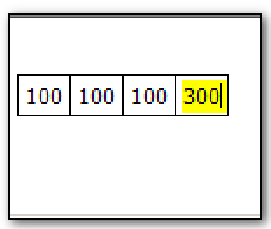


Menu Item	Function
Undo	Removes previous operation
Select All	Selects all cell contents
Insert Single Measurement Value	Pastes single selected measurement value into cell
Insert All Measurement Values	Pastes all measurement values into cells
Row Statistics	Performs Sum, Mean or Standard Deviation operations on row data
Column Statistics	Performs Sum, Mean or Standard Deviation operations on column data
Evaluate Expression	Performs mathematical operations and functions on cell contents
Word Wrap	Wraps text within visible Journal area. (Does not apply to table cells)

Example of Sum, Mean or Standard

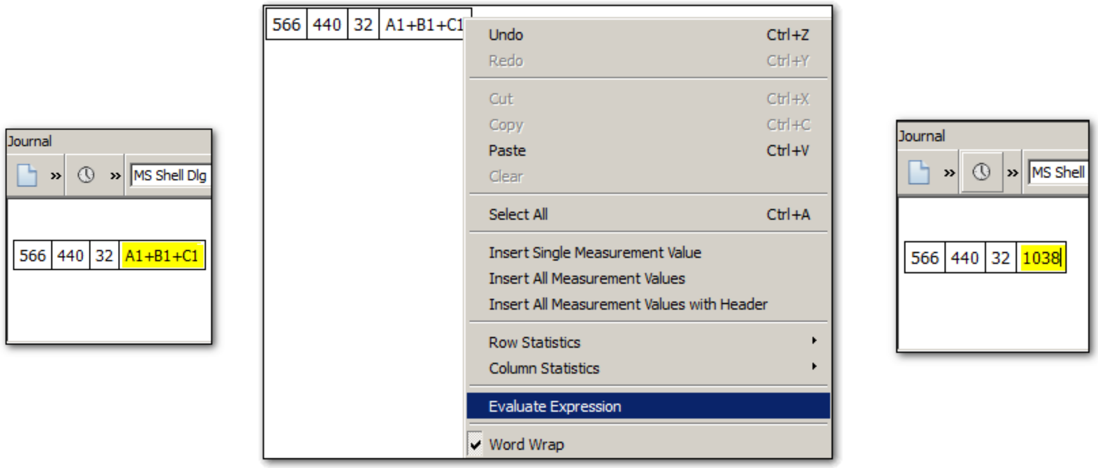
Sum, Mean or Standard Deviation operations can be easily performed on table data. Right clicking within a cell opens a contextual menu containing available operations under ‘Row’ or ‘Column’ statistics. Choose an operation, and the result will appear in the selected cell. *(See sum example below*)



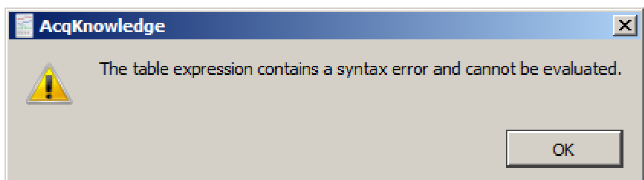


Example of Evaluate Expression

This feature works very much like Excel®. Simply enter the cell identifiers into an empty cell, then right-click and choose 'Evaluate Expression." The formula occupying the cell will be computed and be replaced by the result. The mathematical operations and functions available for standard Biopac Expression syntaxes may be used. (Transform > Expression). Expressions can be created beforehand then copied and pasted into a Numerical Tools Table cell.



If the expression syntax used is incorrect or invalid, a warning dialog will appear.



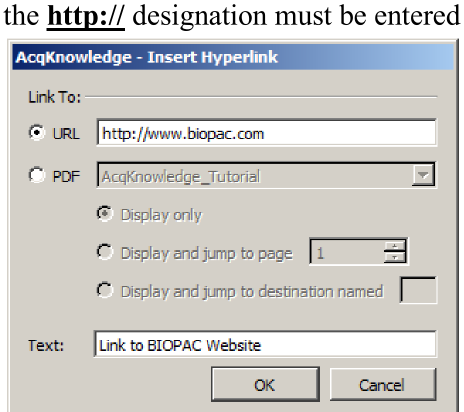
> TIP: To correct a mistake, use the Ctrl+Z (PC) or Command+Z (Mac) keystroke to restore the previous cell data. Multiple levels of undo are supported.

Adding a hyperlink to the Journal

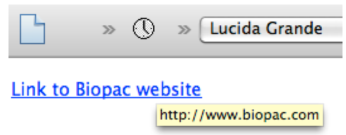
Use the Journal hyperlink  toolbar button to insert a link to a web address into the Journal. This operation is very similar to adding regular text.

1. Click into the Journal at the desired position for the link to appear.
2. Click on the "Insert link" toolbar button
3. Add the web address and some text identifying the link into the URL and Text fields.

NOTE: For the link to be active, the **http://** designation must be entered before the web address.



4. Click OK, and the live link will appear in the Journal.



- To format the link text, select the link and use the Journal formatting tools.
- To edit the link text, position the cursor at the end of the link and use the arrow keys to navigate to the desired portion. Backspace to remove unwanted text and type in new text.
- To delete a link, select the text and use the Delete key.
- Once a link has been created, the URL portion cannot be edited from within the Journal, nor can the original "Insert hyperlink" dialog be recalled. If the URL itself needs to be edited, a new link must be created using the "Insert Link" button.

NOTE: Once a hyperlink is inserted into the Journal, entered additional text is also treated as a hyperlink. To nest hyperlinks among existing text:

1. Insert hyperlink(s) at the end of Journal text.
2. Select the hyperlink text, right-click and choose "Cut" (or Ctrl+X).
3. Paste the hyperlink into the text at the desired location. (Ctrl+V) Pasting the link into existing text does not affect formatting of subsequent text.

Embedding PDFs in Journals

Multiple PDF files can be pasted into a Journal as convenient tabbed windows with all formatting and graphics intact. To do this, simply choose Edit > Journal > Manage PDFs, browse to the location of the desired PDF files and choose "Embed new."

TIP: It's possible to also embed PDFs while in the Journal by right-clicking in the Journal window and choosing "Manage PDFs" from the contextual menu.

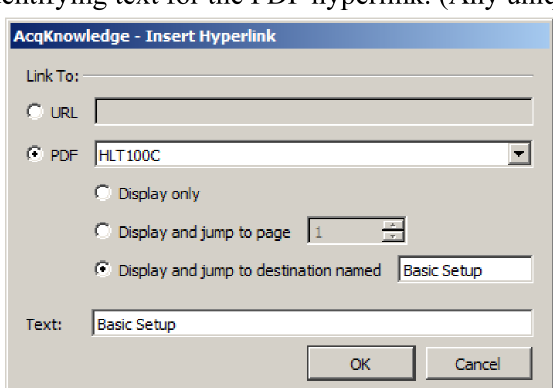
The hyperlink tool described above can also be used to insert links to an embedded PDF. Simply choose "PDF" and select the desired PDF display option:

Display only – Toggles to the embedded PDF's tab and displays it in the Journal window.

Display and jump to page number – Toggles to the embedded PDF's tab and jumps to the entered page number.

Display and jump to destination named – Toggles to the embedded PDF's tab and jumps to a named destination in the PDF. (Enter the exact name of the destination present in the PDF and enter the desired text to appear in the Journal link.)

Text – Use this field to enter identifying text for the PDF hyperlink. (Any unique identifier can be used.)

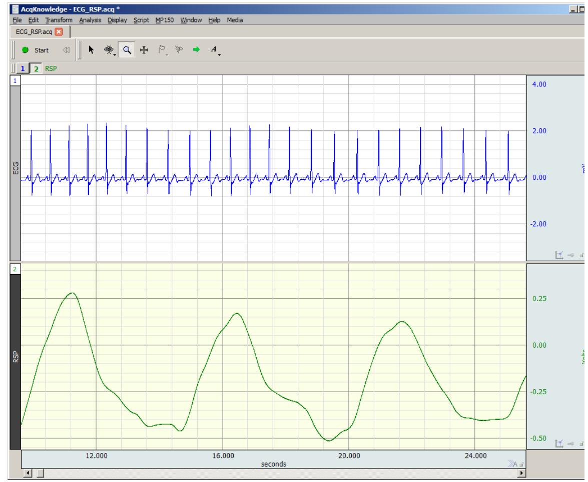


Note that a defined destination must be present in the embedded PDF in order for the "Display and jump to destination" feature to function.

For more details on managing embedded PDFs, see page 327.

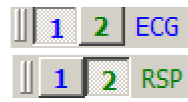
Watch the [Acq*Knowledge* Journal video tutorial] for a detailed demonstration of this feature.

Select a waveform / channel



Although multiple waveforms can be displayed, only one waveform at a time is considered “active.” Most software functions only apply to the active waveform, which is also referred to as the “selected” channel. Selecting a channel allows for highlighting all or part of that waveform, and enables transformations to be performed on a given channel.

In the upper left corner of the graph window there are a series of numbered buttons that represent each channel of data. The numbers in the buttons correspond to the channel used to acquire the data (the specifics of setting up channels are discussed on page 32). In the sample file, ECG channels are represented by Channel 1, with respiration on Channel 2.

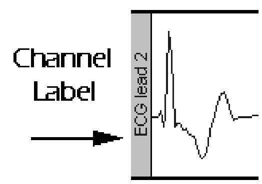


To select a channel, position the cursor over the channel button that corresponds to the desired channel and click the mouse button or position the cursor on the waveform of interest and click the mouse button.

Note that the selected channel box appears depressed and the channel label to the right of the channel boxes changes to correspond to the selected channel.

Additionally, the channel label in the display (on the left edge of the track) will be highlighted for the active channel.

Channel Labels



Each channel has a label on the left and right edge of the graph window.

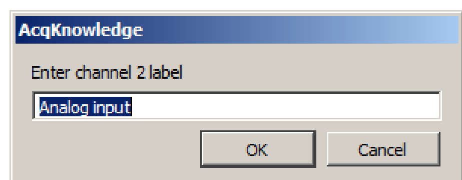
The left label is used to identify the contents of each channel (ECG, Respiration, etc.).

The right label is used to denote the units for each channel’s amplitude scale (usually scaled in terms of Volts).

When a channel is active, its label is highlighted and also appears by the channel buttons.

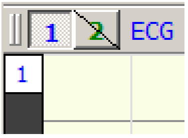
To change the label for a given channel

- <u>during or before acquisition</u>
  (including Append mode)
  revise the Hardware menu > Set Up Channels label text
- <u>post-acquisition / analysis only</u>
  click the left label enter the desired text in the dialog



Acq*Knowledge* 4 Channel label

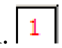
Show/Hide Channel



It possible to "hide" a waveform display without changing the data file. To hide a channel:

Windows: Alt+click in channel box.

Mac OS: Option+click in channel box.

Or, Alt+click on the channel number at the top of the channel label region. 

To view a hidden waveform, repeat the appropriate key-click combination.

Alternatively, a channel can be shown/hidden via Display > Channel Visibility and checking/unchecking the channel boxes in the Channel Visibility dialog. (See this Display menu option on page 492.)

When a channel is hidden, the channel button will have a slash through it. View a hidden channel by holding down the Alt or Option key and clicking in the channel box again.

Focus Areas

Focus areas are comprised of selected time ranges within the graph. The purpose of the "Focus on" tool is to easily isolate selected areas within the graph window for discrete analysis. This can be useful for identifying areas of interest within a larger data set by highlighting, naming and storing them permanently in the graph. When a focus area is assigned, that portion of the graph will appear shaded with borders appearing at the edges. The assigned focus area label will be displayed vertically in the shaded area. (See following page for example.) Focus areas may be defined via the "Focus on" toolbar above the graph, in the Output tab of the Find Cycle Analysis feature, and once defined, can be selected within the setups for most Specialized Analysis tools.

- Focus areas are graph level data, similar to events. Defining a focus area in one data view defines it for all data views, etc.
- Focus areas are drawn only for graph windows in chart, stacked plot, or scope mode. They are overlaid on top of data and events but underneath text annotations and selections.
- Focus areas may overlap.
- Each focus area is required to have a unique name.

Creating Focus Areas

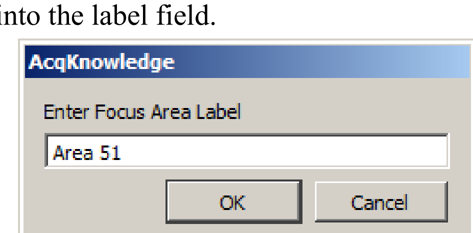
To create a focus area:

1. Select an area of interest in the graph data using the I-beam tool or selection palette.

2. Create the focus area using one of the following methods:

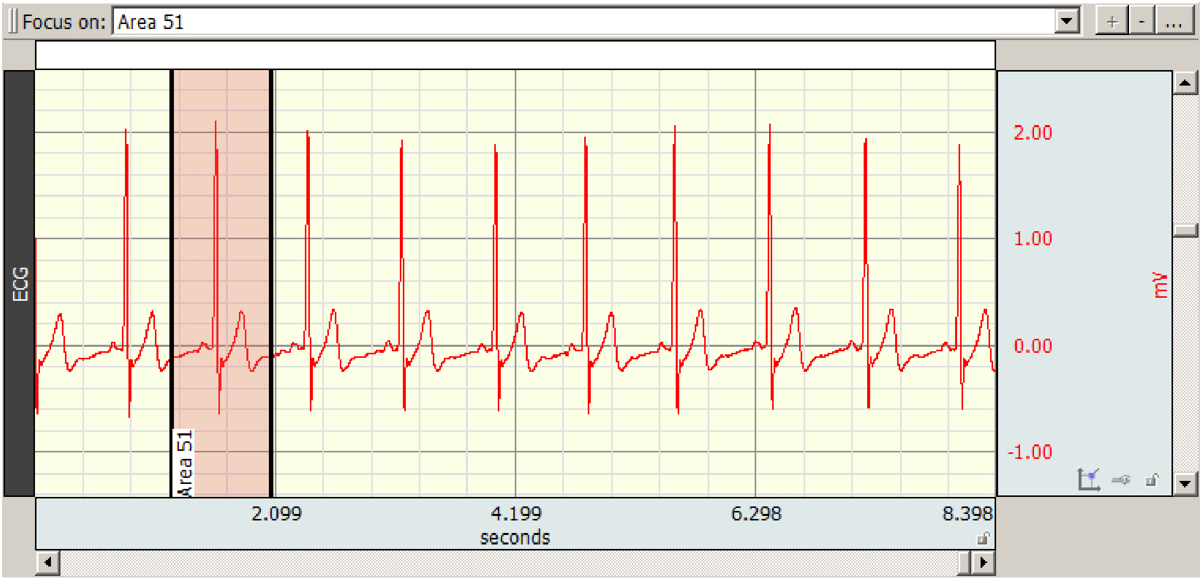
- Click on the "add" button to the right of the "Focus on" toolbar.
- Choose "Display > Create Focus Area."
- Right-clicking in the graph and choosing "Create Focus Area" from the contextual menu.

3. Name the focus area by typing into the label field.



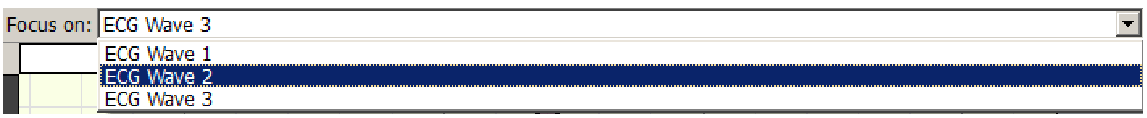
The new focus area label will appear in the "Focus on" toolbar field.

The new focus area and label will appear in the graph.



Multiple and overlapping focus areas can be created by selecting additional data and using the "add" button.

Navigate quickly to a focus area time selection in the horizontal axis by selecting its label from the "Focus on" toolbar field.



To remove a focus area, use the "minus" "Focus on" toolbar button. 

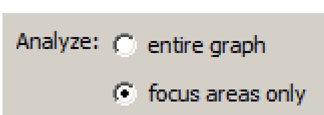
TIP: To remove multiple focus areas at once, hold down the Ctrl key (PC) or Option key (Mac) and click the "minus" focus area toolbar button.  (A confirmation dialog will appear before focus areas are removed.)

To rename a focus area, use the "ellipses" toolbar button.

To highlight the current focus area, click the "highlight" button. 

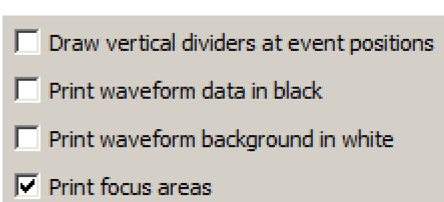
Focus Areas in Specialized Analysis

Most Specialized Analysis tools can be limited to running analysis on a focus area by choosing the "focus areas only" option in the setup dialog.



Printing Focus Areas

Focus areas can be included or excluded from a printed graph by selecting or deselecting the "Print focus areas" option in Print Setup.

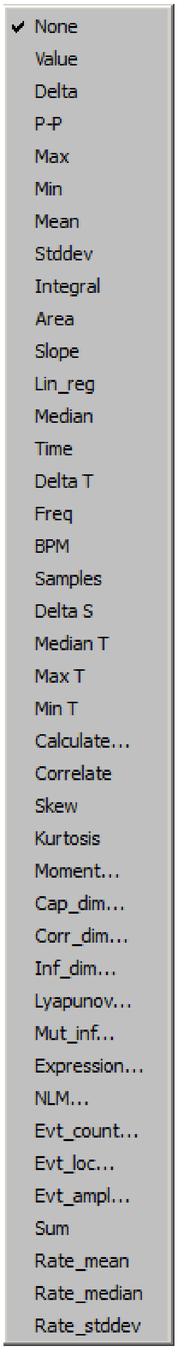


Focus area preferences can be modified by using Display > Preferences > Focus Areas. For further details see pages 509 and 514.

For Find Cycle focus area options, see the Find Cycle section on page 374.

To create focus areas in analysis mode based on events or appended segments, see the Specialized Analysis > Focus Areas section on page 433.

Watch the [Acq*Knowledge* Focus Area video tutorial] for a detailed demonstration of this feature.



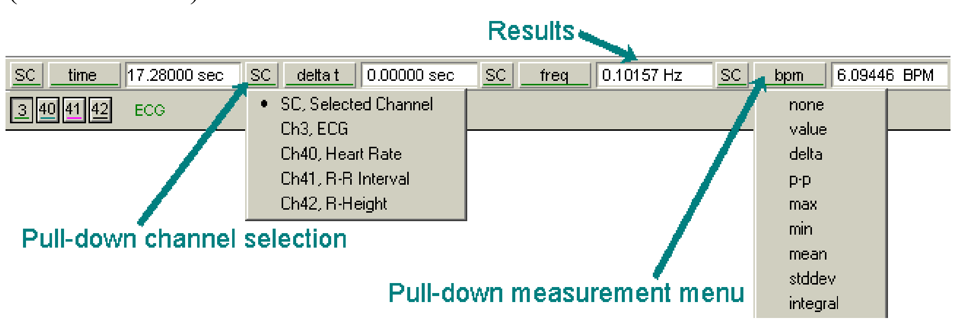
Measurements

A convenient feature in Acq*Knowledge* is the popup measurement windows. A variety of different measurements can be taken, and different measurements can be displayed from the same channel and/or similar measurements from different waveforms. Acq*Knowledge* can display measurements for the selected channel or for any other channel. By default, Acq*Knowledge* displays measurements from the selected channel (as denoted by the “SC” in the measurement boxes).

To select a channel for measurement, position the cursor over the part of the measurement window that reads “SC.” Click the mouse button and choose a channel number from the pull-down menu. The channel numbers in the pull-down menu correspond to the numbers in the channel boxes in the upper left corner of the graph window.

To select a measurement, position the cursor on a measurement box and click the mouse button. Choose a measurement from the pull-down menu; see page 102 for measurement functions and the minimum samples for each (some of the values are single point measurements while others require at least two points to be selected).

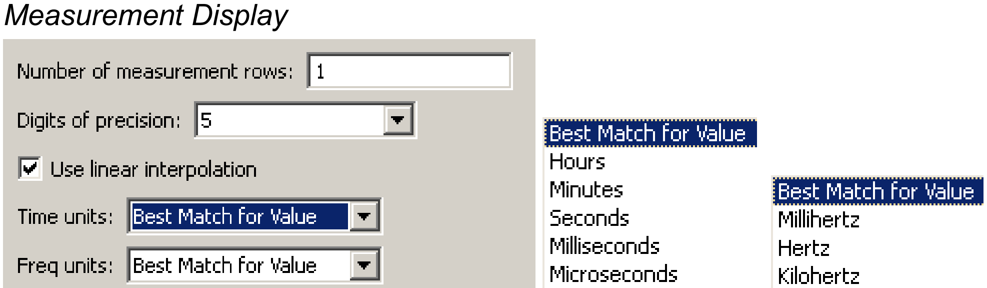
The measurements in the upper half of the menu reflect amplitude measurements, or measurements which contain information about the vertical (amplitude) scale. Other measurements use information taken from the horizontal axis (usually) and are found on the section of the pull-down menu below the dividing line. Some of the measurement options change (or are disabled) if units are selected for the horizontal scale.



In some cases, the computations involved in the measurement can produce nonsensical results (such as dividing by zero, or calculating a BPM from a single point). In those cases, a measurement value like INF or **** may be displayed. This means that the result was undefined at this point.

Measurement menus are tinted to match the color of the corresponding waveform.

Measurement Display



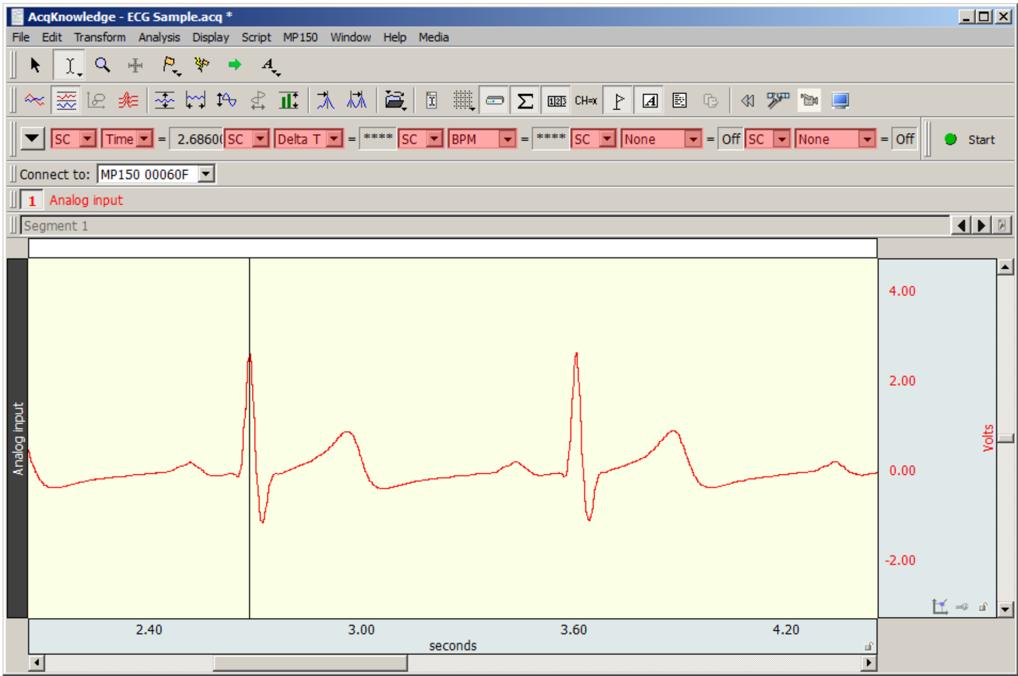
The number of measurement rows is set in Preferences > Measurements, as well as precision of units.

Measurement Area

It is important to remember that Acq*Knowledge* is always selecting either a single point or an area spanning multiple sample points. If an area is defined and a single point measurement (such as *Time*) is selected, the measurement will reflect the last selected point.

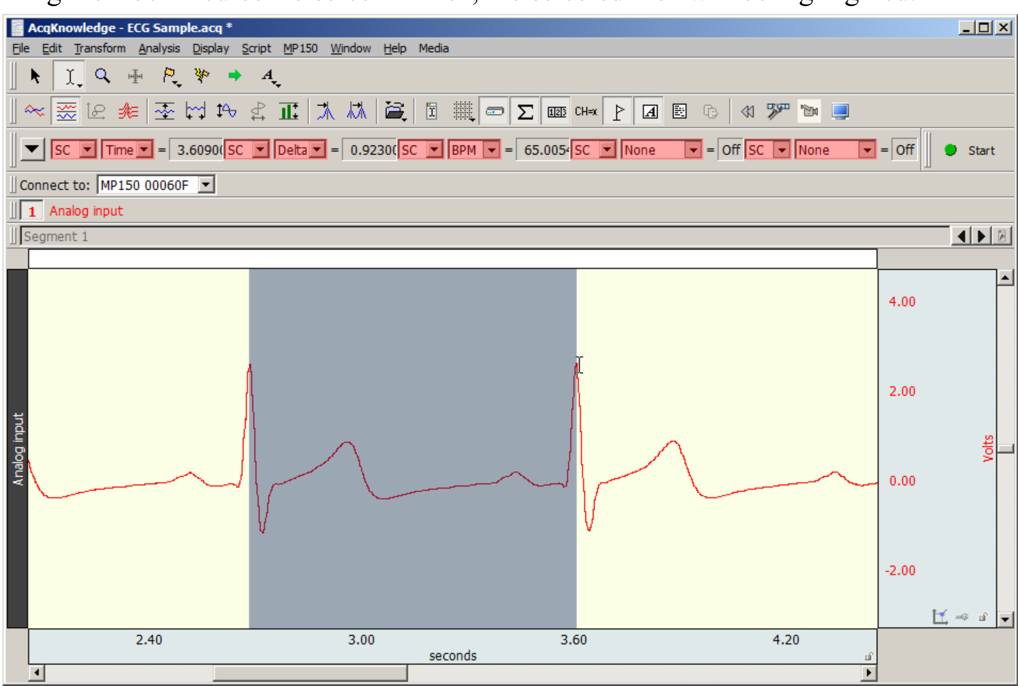
- Single-point measurements

  When a single point is selected, the cursor will "blink." The following graph shows how the I-beam is used to select a single point for measurements.



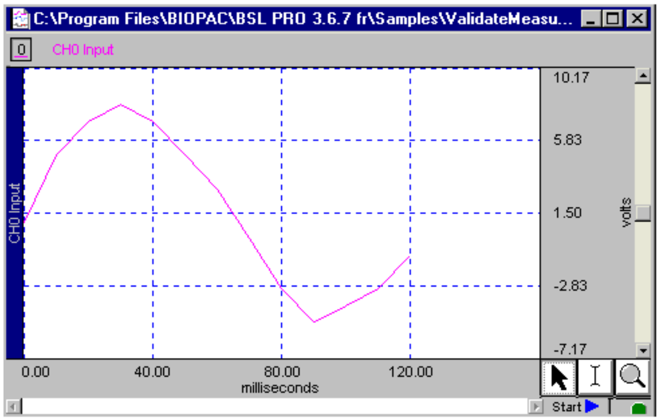
- Selected range measurements

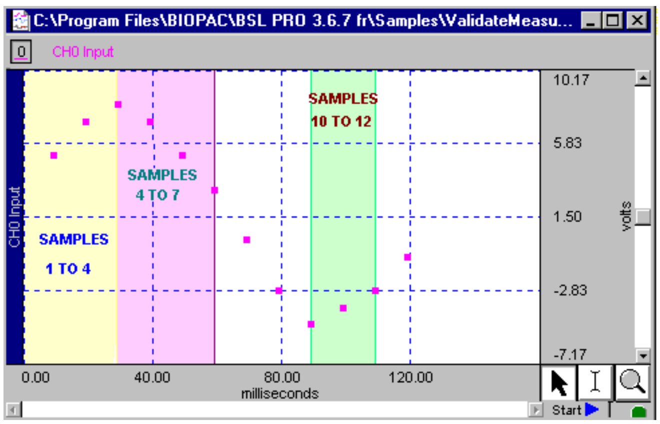
  Drag the I-beam cursor to select an area; the selected area will be highlighted.

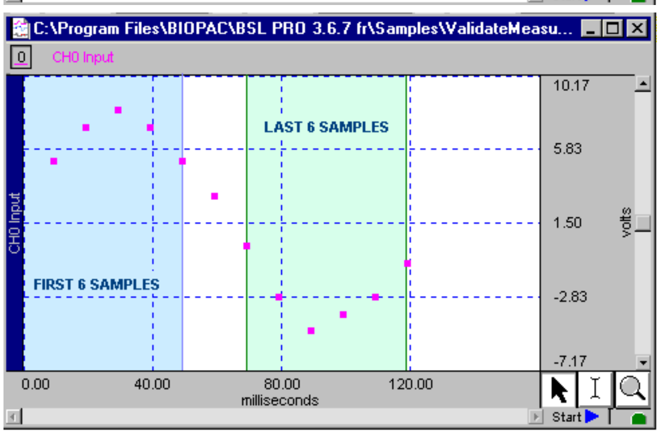


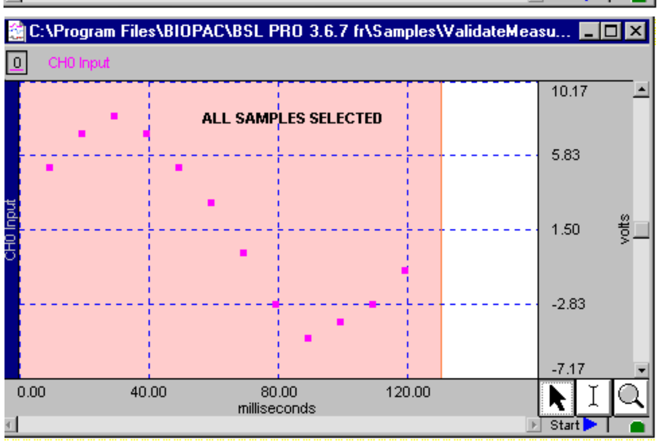
IMPORTANT!

The first data point is "plotted" at zero (on the left edge of the graph); the first visible data point is sample point 2. The selected areas below demonstrate this concept.









Measurements and Measurement Presets

Measurements are commonly used in conjunction with the cycle detector and other analysis protocols to perform data reduction. In complex data analysis using the cycle detector, often multiple different sets of measurements may be used to perform multiple extraction passes on the data. The measurement presets feature allows users to create multiple predefined measurement configurations and apply them to the graph to change between different configurations. All aspects of the measurement configuration are stored, including measurement functions, any parameters for the measurement, source channel, and number of measurement rows. For more details on this function, see Measurements Toolbar section on page 67.

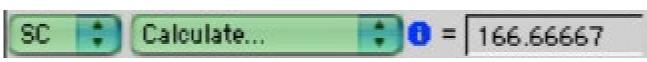
IMPORTANT: Calculations performed within expressions or measurement channels **DO NOT** incorporate units such as milli, micro, centi, deci, etc. All calculations are performed with numbers as they are exhibited within the text field. Time/frequency axis measurements may have their units fixed by using Preferences > Measurements > Time Units/Freq Units. Selecting "Best Match for Value" will change the units based upon the magnitude of the value.

Measurement Validation

Measurements can be validated with the ValidateMeasurements.acq sample file included with the software. Pay attention to the "*Sample data file*" section of the measurement definitions that begin on page 102, and where included, note which sample points to use for validation (i.e., the first four sample points are used to validate the Correlate measurement using the ValidateMeasurements.acq file).

Other sample files configured for specific measurement types include spreadsheets to provide external data necessary for measurement verification. Each spreadsheet contains procedures and examples for the associated measurement data file. These sample data files consist of Event Measurements.acq, Traditional.acq (standard mathematical measurements included in Acq*Knowledge*), Expression Sum_Calculate.acq and Correl Coef.acq (Correlation Coefficient).

Measurement Info / Parameters



Measurements containing parameters have an "i" for info button next to the measurement type in the measurement bar. Click the button to generate a dialog to edit the parameters. To paste parameters, enable the Journal Preference via Display > Preferences > Journal > Measurement paste settings > Include measurement parameters.

Measurement Interpolation

On a down-sampled channel, the cursor can fall on a point between physical samples. In such cases, in the Line Plot mode only, some measurements will display interpolated values; the value is obtained by linear interpolation with respect to the two adjoining samples.

- To disable measurement interpolation, uncheck the "Use linear interpolation" option in the Display > Preferences dialog.
- If interpolation is disabled for Line Plot, or any time Step Plot or Dot Plot is selected, measurements take on the value of the first physical sample immediately to the left of the cursor or edge of the selection.
- When measurements are pasted to the Journal, there is no indication of interpolated measurements.
- A Calculation measurement can be an interpolated value. When a measurement uses an interpolated value, the result box background changes from gray to light purple.
- The "Delta S" and "Samples" measurements are never interpolated.
- Measurements will not be interpolated if all measurements are set to "SC" (selected channel); the cursor will snap to the left for the measurements.
- Measurement tooltips will reflect measurement interpolation.

Exporting measurements

One of the most important reasons to take measurements is to save them; Acq*Knowledge* allows storage and export of these measurements in different formats.

- Copying measurements to the journal:

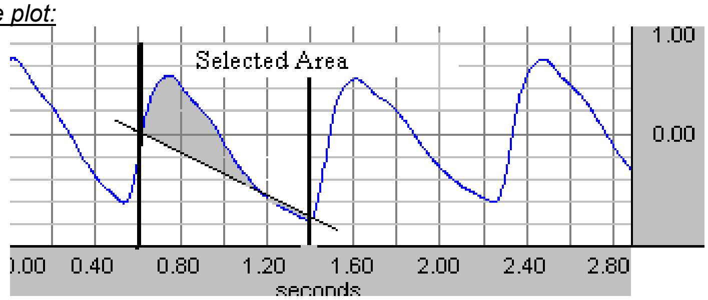
To copy measurements (exactly as they appear in the measurement windows) and paste them to the Journal, select Edit > Journal > Paste measurement. Under the default settings, only the values themselves are copied to the journal; the settings can be changed to include the measurement name and other options under Display > Preferences > Journal

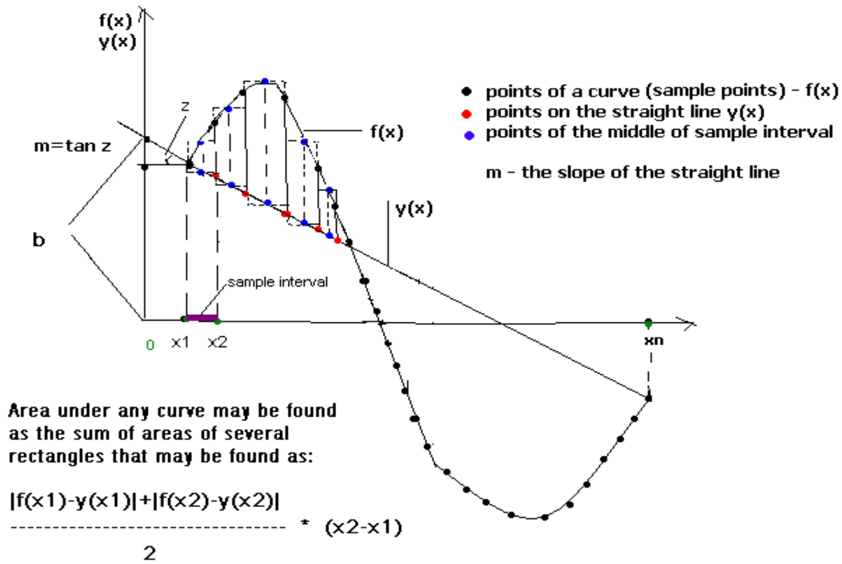
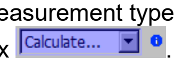
- Copying measurements to the clipboard:

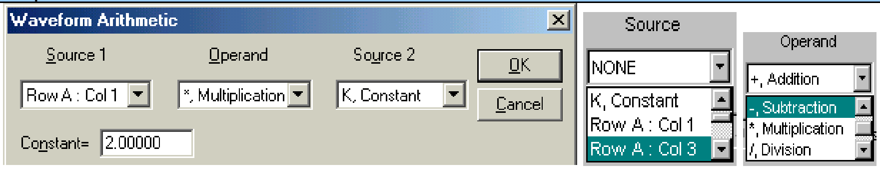
  To copy measurements (exactly as they appear in the measurement windows) to the clipboard and paste them into a word processor or other application, select Edit > Clipboard > Copy measurements. Under the default settings, only the values themselves are copied to the clipboard. These settings can be changed to include the measurement name and other options via Display > Preferences > Journal.

Measurement Definitions

The table below explains the measurement options available and the range required for each. The default option is for time to be displayed on the horizontal axis, although it can be set to display frequency or arbitrary units (see page 493 for details on how to change the horizontal scaling options). Unless otherwise noted, all of the measurements described here relate to those displayed when the horizontal scale reflects time.

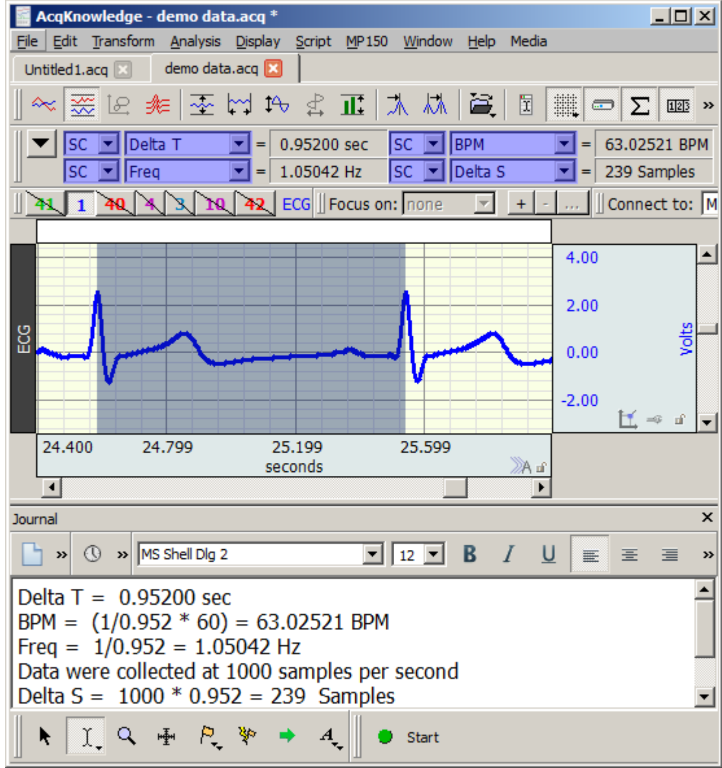
Measurement	Area	Explanation
Area	<u>Minimum area</u>: 3 samples <u>Uses</u>: All points of selected area	Area computes the total area among the waveform and the straight line that is drawn between the endpoints. Area is expressed in terms of (amplitude units multiplied by horizontal units) and calculated using the formula: $Area = \sum_{i=1}^{n-1}\left(\left\|f(x_i)-y(x_i)\right\|+\left\|f(x_{i+1})-y(x_{i+1})\right\|\right)*\frac{\Delta x_i}{2}$ *<u>Where:</u>* *n—number of samples;* *i—index (i = 1.n-1);* x_i, x_{i+1} *- values of two neighboring points at horizontal axis (* x_1 *– the first point,* x_n *– the last point);* $f(x_i), f(x_{i+1})$ *- values of two neighboring points of a curve (vertical axis);* $y(x_i), y(x_{i+1})$ *- values of two neighboring points of a straight line (vertical axis).* *At the endpoints y(* x_1 *)= f(* x_1 *) and y(* x_n *)= f(* x_n *).* $\Delta x_i = \frac{\Delta X}{n-1}$ *- horizontal sample interval;* *The value of a straight line can be found by formula:* $y(x_i) = m * x_i + b$ $b = f(x_1) - m * x_1$ *- intercept;* $m = \frac{\Delta Y}{\Delta X}$ *- slope of the straight line;* $\Delta Y = f(x_n) - f(x_1)$ *- vertical distance of increase at vertical axis;* $\Delta X = x_n - x_1$ *- horizontal distance of increase at horizontal axis.* *<u>Sample plot:</u>*  The area of the shaded portion is the result.

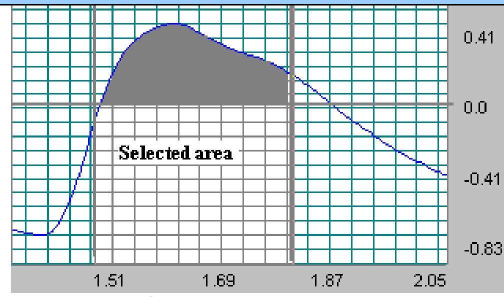
Measurement	Area	Explanation
		Note: The Area measurement is similar to the *Integral* measurement except that a straight line is used (instead of zero) as the baseline for integration.  *Results:* This calculation will always return a positive result. *Units: Volts - sec.* *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: 0.4533 Volts - sec.*
BPM (Time domain only)	Minimum area: 2 samples Uses: Endpoints of selected area	BPM (beats per minute) computes the time difference between the first and last points and extrapolates BPM by computing the reciprocal of this difference, getting the absolute value of it and multiplying by 60 (60 sec). The formula for calculation of BPM is: $$BPM = \left(\frac{1}{\lvert x_n - x_1 \rvert} \right) * 60$$ *Where:* x_1, x_n *- values of the horizontal axis at the endpoints of selected area.* *Note:* As mentioned, this measurement provides essentially the same information as the *Delta T* and *Freq* measurement. *Results:* Only a positive value. *Units: BPM.*
Calculate	Minimum area: 2 sources Uses: Results of measurements used in calculation	Calculate can be used to perform a calculation using the other measurement results. For example, the mean pressure can be divided by the mean flow. When Calculate is selected, the channel selection box disappears.  The result box will read "Off" until a calculation is performed, and then it will display the result of the calculation. When the selected area is changed, the calculation will update automatically. To perform a calculation, generate the "Waveform Arithmetic" dialog via Ctrl-Click or right mouse click the Calculate measurement type box or click the "info" button next to the measurement type box .

Measurement	Area	Explanation
		 Use the pull-down menus to select Sources and Operand. Measurements are listed by their position in the measurement display grid (i.e., the top left measurement is Row A: Col 1). Only active, available channels appear in the Source menu. Calculation measurement Source operands are updated before a Calculation is performed, which means that Calculations can be based on measurements that are located after them in the measurement row/column ordering. Calculation measurements can include other Calculation measurements as their operands. • If a cyclic dependency is introduced, the result reads “Error.” • When interpolation is being used, a Calculation measurement can also be an interpolated value. • If either of the operands of a Calculation is interpolated, the result will be displayed as an interpolated value (with a light purple background). The Operand pull-down menu includes: Addition, Subtraction, Multiplication, Division, Exponential. The Constant entry box is activated when selecting “Source: K, constant” and it allows definition of the constant value to be used in the calculation. To add units to the calculation result, select the Units entry box and define the unit’s abbreviation. Click OK to see the calculation result in the calculation measurement box.
Cap_Dim		Capacity Dimension; fractal dimension estimate. (Fractals measure the amount of self-similarity in a data set. Acq*Knowledge* offers three alternate estimates for fractal dimension: Cap_Dim, Corr_Dim, and Inf_Dim. The estimates will not agree, based on the heuristic and the parameters.)
Corr_Dim		Correlation Dimension; fractal dimension estimate. Always greater than capacity if parameters are the same. (See fractals note at Cap_Dim.)
Correlate	<u>Minimum area</u>: 2 samples <u>Uses</u>: All points of selected area	Correlate provides the *Pearson* product moment correlation coefficient, r, over the selected area and reflects the extent of a linear relationship between two data sets: x_i - values of horizontal axis and $f(x_i)$ - values of a curve (vertical axis). Use Correlate to determine whether two ranges of data move together. *<u>Association</u>* — *<u>Correlation</u>* Large values with large values — Positive correlation Small values with large values — Negative correlation Unrelated — Correlation near zero The formula for the correlation coefficient is: Correlate = $\dfrac{n*\sum_{i=1}^{n}(x_i*f(x_i))-\left(\sum_{i=1}^{n}x_i\right)*\left(\sum_{i=1}^{n}f(x_i)\right)}{\sqrt{\left[n*\sum_{i=1}^{n}(x_i)^2-\left(\sum_{i=1}^{n}x_i\right)^2\right]*\left[n*\sum_{i=1}^{n}(f(x_i))^2-\left(\sum_{i=1}^{n}f(x_i)\right)^2\right]}}$ *<u>Where:</u>* *n—number of samples;* *i—index (i = 1..n);* x_i *— values of points at horizontal axis (* x_1 *– the first point,* x_n *– the last point);* $f(x_i)$*- values of points of a curve (vertical axis).* *<u>Results:</u>* Returns a dimensionless index that ranges from -1.0 to 1.0 inclusive. *<u>Units:</u> None*

Measurement	Area	Explanation
		<u>*Sample data file:*</u> *"ValidateMeasurements.ACQ"* *Result: -0.74825(for whole wave) and 0.95917 (for first four sample points).*
Delta	<u>Minimum area</u>: 2 samples <u>Uses</u>: Endpoints of selected area	Delta returns the difference between the amplitude values at the endpoints of the selected area. $$\text{Delta} = f(x_n) - f(x_1)$$ <u>*Where:*</u> $f(x_1), f(x_n)$—*values of a curve at the endpoints of selected area.* <u>*Results*</u>*:* If the data value at the starting location is greater than the data value at the ending location of the cursor, then a negative delta will result. Otherwise, a positive delta will result. <u>*Units*</u>*: Volts* <u>*Sample data file:*</u> *"ValidateMeasurements.ACQ"* *Result: -2 Volts (for whole wave). This result shows the absolute value of change of amplitude (2) and the minus sign means a decrease of amplitude.*
Delta S	<u>Minimum area</u>: 1 sample <u>Uses</u>: Endpoints of selected area	Delta S returns the difference in sample points between the end and beginning of the selected area. <u>*Results*</u>*:* This calculation will always return a positive result. <u>*Units*</u>*: Samples*
Delta T(time) Delta F (frequency) Delta X (arbitrary unit)	<u>Minimum area</u>: 2 samples <u>Uses</u>: Endpoints of selected area	The Delta T/F/X measurement shows the relative distance in horizontal units between the endpoints of the selected area. *Only one of these three units* will be displayed in the pop-up menu at a given time, as determined by the horizontal scale settings. <u>*Measurement*</u> — <u>*Horizontal Axis*</u> Delta T — Time Delta F — Frequency (FFT) Delta X — Arbitrary units (Histogram Bins) The formula for Delta T/F/X is: $$\text{Delta T} = x_n - x_1$$ <u>*Where*</u>*:* x_1, x_n - *values of horizontal axis at the endpoints of selected area.* <u>*Results*</u>*:* If the data value at the starting location is greater than the data value at the ending location of the cursor, then a negative delta will result. Otherwise, a positive delta will result. For Delta T measurements with the horizontal axis format set to HH:MM:SS. ✓ Values less than 60 seconds will result in a value in decimal seconds. ✓ Values greater than 60 seconds will result in an HH:MM:SS format value (See page 78 for details on how to change the horizontal scaling). <u>*Units*</u>*:* Delta T: *Seconds (sec.)* Delta X: *"arbitrary unit"* Delta F: *Hz* <u>*Sample data file:*</u> *"ValidateMeasurements.ACQ"* *Result: 0.12 sec. (for whole wave).*
Evt_amp		Extracts the value of the measurement channel at the times where events are defined. The measurement result is unitless. Specify Type, Location, and Extract; see page 260 for details. ▪ The amplitude is always taken from the measurement channel, which may be different from the channel on which events are defined.

Measurement	Area	Explanation
		Evt_amp can be useful for extracting information such as the average T wave height within the selected interval.
Evt_count		Evaluates the number of events within the selected area. The measurement result is unitless. Specify Type and Location; see page 261 for details.
Evt_loc		Extracts information about the times of events. The measurement result uses the units of the horizontal axis. Specify Type, Location, and Extract; see page 261 for details.
Expression		Generates the Expression transformation dialog (page 167) and offers Source "MC" Measurement Channel instead of "SC" Selected Channel to build recursive formulas, i.e. result of the expression as it was evaluated x samples ago. Data within the selected area is not changed. Evaluation rules: When a new selection is made, the first step in evaluation searches through the measurement expression for any MMT() invocations. Any measurement whose value is needed by MMT () is computed at this time prior to the expression evaluation. This behavior is similar to calculation channels and successfully allows measurements to the right and bottom of the expression measurement to be used in the expression. The expression is subsequently evaluated from the leftmost sample in the selection to the right most sample. It is evaluated at the waveform sampling rate of its source channel. Interpolation is not used at the boundaries to maintain a consistent sample interval for the expression. After each expression evaluation, the result is cached in memory for potential negative MC result references. The rightmost value of the final expression becomes the value of the measurement.
Freq (time domain only) It is important to note… This does not compute the frequency spectra of the data. To perform a spectral analysis, use the FFT function (see page 367).	Minimum area: 2 samples Uses: Endpoints of selected area	Freq computes the frequency in Hz between the endpoints of the selected area by computing the reciprocal of the absolute value of time difference in that area. The formula for Freq is: $\text{Freq} = \left(\frac{1}{\lvert x_n - x_1 \rvert} \right)$ *Where:* x_1, x_n - *values of horizontal axis at the endpoints of selected area.* The information provided by this measurement is directly related to the *Delta T* and *BPM* measurements, and is related to a lesser extent to *Delta S* measurement. That is, if the *Delta T* interval between two adjacent peaks is calculated, the *BPM and Freq* measurement can be extrapolated. If the sampling rate is known, the *Delta S* can also be derived. In the following example, observe the *Delta T, Freq* and *BPM* measurements for the particular area. The *Delta S* can also be derived.

Measurement	Area	Explanation
		 *Selected area with measurements that describe the same interval in different terms.* <u>Note</u>: It is important to note that this does not compute the frequency spectra of the data. To perform a spectra analysis, use the FFT function (described on page 367). *Freq (or frequency) is only available in time domain windows.* <u>Results</u>: This calculation will always return a positive result. <u>Units</u>: Hz <u>Sample data file:</u> *"ValidateMeasurements.ACQ"* *Result: 8.33 Hz (for whole wave).*
Inf_Dim		Information Dimension; fractal dimension estimate. (See fractals note at Cap_Dim.)
Integral	<u>Minimum area</u>: 2 samples <u>Uses</u>: All points of selected area	Integral computes the integral value of the data samples between the endpoints of the selected area. This is essentially a running summation of the data. Integral is expressed in terms of (amplitude units multiplied by horizontal units) and calculated using the following formula. Integral = $\sum_{i=1}^{n-1}\left[f(x_i)+f(x_{i+1})\right]*\frac{\Delta x_i}{2}$ <u>*Where:*</u> *n—number of samples;* *i—index (i = 1.n-1);* x_i, x_{i+1} - *values of two neighboring points at horizontal axis (* x_1 *– the first point,* x_n *– the last point);* $f(x_i), f(x_{i+1})$ - *values of two neighboring points of a curve (vertical axis);* $\Delta x_i = \frac{\Delta X}{n-1}$ - *horizontal sample interval;* $\Delta X = x_n - x_1$ - *horizontal distance of increase at horizontal axis.* The following plot graphically represents the Integral calculation.

Measurement	Area	Explanation
		 The area of the shaded portion is the result. *Results:* The Integral calculation can return a negative value if the selected area of the waveform extends below zero. *Units: Volts—sec.* *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: 0.300 Volts -sec.(for first 6 sample points) and –0.155 Volts -sec.(for last 6 sample points—the wave below zero).*
Kurtosis		Kurtosis indicates the degree of peakedness in a distribution, e.g. the size of the "tails" of the distribution. Distributions that have sharp peaks in their center have positive kurtosis; flatter distributions have negative kurtosis. A normal distribution has a kurtosis of 0. The following formula is used to extract kurtosis $$kurtosis = \frac{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^4}{n}}{\left(\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n}\right)^2}$$ *Where* from a signal (x) containing n points:
Lin_reg	Minimum area: 2 samples Uses: All points of selected area	Linear regression is a better method to calculate the slope when noisy, erratic data is present. ▪ For advanced modeling options, see Nonlinear modeling on page 363. Lin_reg computes the non-standard regression coefficient, which describes the unit change in *f (x)* (vertical axis values) per unit change in *x* (horizontal axis). *For the selected area*, Lin_reg computes the linear regression of the line drawn as a best fit for all selected data points using the following formula: $$\text{Lin\_reg} = \frac{n * \sum_{i=1}^{n}(x_i * f(x_i)) - \left(\sum_{i=1}^{n} x_i\right) * \left(\sum_{i=1}^{n} f(x_i)\right)}{n * \sum_{i=1}^{n}(x_i)^2 - \left(\sum_{i=1}^{n} x_i\right)^2}$$ *Where:* *n—number of samples;* *i—index (i = 1.n);* x_i *— values of points at horizontal axis (* x_1 *– the first point,* x_n *– the last point);* $f(x_i)$*- values of points of a curve (vertical axis).* *Note: For a single point*, Lin_reg computes the linear regression of the line drawn between the two samples on either side of the cursor. *Results:* If the data value at the starting location is greater than the data value at the ending location of the cursor, then a negative delta will result. Otherwise, a positive delta will result. *Units: Volts/sec.* This value is normally expressed in unit change per second (time rather then samples points) since high sampling rates can artificially deflate the value of the

Measurement	Area	Explanation
		slope. If the horizontal axis is set to display *Frequency* or *Arbitrary units*, the slope will be expressed as unit change in corresponding vertical axis values (frequency or arbitrary units, respectively). *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: 230.00 Volts/sec. (for 1-4 samples) and –170.00 Volts/sec. (for samples 4-7).*
Lyapunov		Lyapunov exponent describes the exponential rate of divergence of a system when perturbed from its initial conditions. For example, if the system is started from two slightly different locations, this indicates how different their results will be with time. Stable experiments have exponents equal to zero. Specify an embedding dimension and a time delay; produces a single-valued measure. This measure is quite dependent on the amount of data used.
Max	Minimum area: 2 samples Uses: All points of selected area	Max (maximum) shows the maximum amplitude value of the data samples between the endpoints of the selected area. To compare peak heights, select each peak to see the maximum peak values or paste the results to the journal. Also, since it's possible to simultaneously obtain measurements for different channels, maximum values for different channels can be easily compared. *Note:* For a single point, Max shows the amplitude value in this point. *Units: Volts*
Max T	Minimum area: 1 sample Uses: All points of selected area	Max T shows the time of the data point that represents the maximum value of the data samples between the endpoints of the selected area. *Note:* For a single point, Max T shows the time value in this point. *Units: Seconds*
Mean	Minimum area: 2 samples Uses: All points of selected area	Mean computes the mean amplitude value of the data samples between the endpoints of the selected area, according to the formula: Mean = $\frac{1}{n} * \sum_{i=1}^{n} f(x_i)$ *Where:* *n—number of samples;* *i—index (i = 1.n);* x_i *— values of points at horizontal axis; (* x_1 *– the first point,* x_n *– the last point);* $f(x_i)$*- values of points of a curve (vertical axis).* *Units: Volts* *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: 1.538462 Volts (for whole wave).*
Median	Minimum area: 2 samples Uses: All points of selected area	Median shows the median value from the selected area. *Note:* The median and calculation is processor-intensive and can take a long time, so it's recommended that this measurement option only be selected when actually ready to calculate. Until then, set the measurement to "none." *Units: Volts*
Median T	Minimum area: 2 samples Uses: All points of selected area	Median T shows the time of the data point that represents the median value of the selected area. *Note:* The median and calculation is processor-intensive and can take a long time, so it's recommended that this measurement option only be selected when actually ready to calculate. Until then, set the measurement to "none." *Units: Seconds.*
Min	Minimum area: 2 samples Uses: All points of selected area	Min (minimum) shows the minimum amplitude value of the data samples between the endpoints of the selected area. *Note:* For a single point, Min shows the amplitude value in this point. *Units: Volts.*
Min T	Minimum area: 1 sample	Min T shows the time of the data point that represent the minimum value of the data samples between the endpoints of the selected area. *Note:* For a single point, Min T shows the time value in this point.

Measurement	Area	Explanation
	Uses: All points of selected area	*Units: Seconds.*
Moment	Uses: All points of selected area	Central Moment is a general-purpose statistical computation that can be used to compute central variance and other higher-order moments of the data within the selected area. Specify the order as an integer (generally). The central moment is computed using the following formula: $$\mu_m = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^m}{n}$$ *Where:* *x—signal;* *n—points;* m—order.
Mut_inf		Mutual Information determines how much could probabilistically be known about an unknown signal given a known variable. Specify a time delay. Produces a single valued result.
NLM		Nonlinear modeling (also called “arbitrary curve fitting“) determines the “best fit” model for the selected data of the selected channel. The measurement result corresponds to the value of one of the parameters of the best fit. NLM can be used to extract Tau (time delay LVP constant) for assessing cardiac condition. See page 363 for nonlinear modeling details. ▪ If a Model Expression uses MMT() syntax to reference a measurement and that referenced measurement is linearly interpolated, the results of the NLM measurement will also be displayed as being linearly interpolated. ▪ When combined with the Cycle/Peak Detector (on page 374), the NLM measurement can be useful for extracting cycle-by-cycle best fit models for an entire waveform.
None	n/a	None does not produce a measurement value. It’s useful when copying a measurement to the clipboard or journal with a window size such that several measurements are shown but don’t all need to be copied.
P-P	Minimum area: 2 samples Uses: All points of selected area	P-P (peak-to-peak) shows the difference between the maximum amplitude value and the minimum amplitude in the selected area. *Results:* The result is always a positive value or zero. *Units: Volts* *Sample data file:* *“ValidateMeasurements.ACQ”* *Result*: 13 Volts (for whole wave).
Rate_mean	Uses: All points of selected area	Extracts the mean value of the rate outputs within the selected area. Unless this measurement is used on a rate analysis or calculation channel, this measurement is not defined (****). The units of this measurement will match the amplitude units of the measurement channel.
Rate_median	Uses: All points of selected area	Extracts the median value of the rate outputs within the selected area. Unless this measurement is used on a rate analysis or calculation channel, this measurement is not defined (****). The units of this measurement will match the amplitude units of the measurement channel.
Rate_stddv	Uses: All points of selected area	Extracts the standard deviation value of the rate outputs within the selected area. Unless this measurement is used on a rate analysis or calculation channel, this measurement is not defined (****). The units of this measurement will match the amplitude units of the measurement channel.
Samples	Minimum area: 1 sample Uses: All points of selected area	Samples shows the exact sample number of the selected waveform at the cursor position—the first data point is not displayed, but is plotted at zero. See page 100 for examples of selected area Samples. *Note:* When an area is selected, the measurement will indicate the sample number at the last position of the cursor. Units: Samples.
Skew		Skew is a statistical measure of the degree of asymmetry in a distribution (away from normal Gaussian distribution), e.g. if the distribution is weighted evenly or trends toward an edge. • A normal distribution has a skew of 0. • A distribution with a prominent left tail has a negative skew. • A distribution with a prominent right tail has a positive skew The following formula is used to extract skew:

Measurement	Area	Explanation
		Where a signal (x) contains n points:
Slope	Minimum area: 2 samples Uses: All points of selected area	Slope computes the non-standard regression coefficient, which describes the unit change in *f (x)* (vertical axis values) per unit change in *x* (horizontal axis). *For the selected area*, Slope computes the slope of the straight line that intersects the endpoints of the selected area, using the formula: Slope = $\frac{f(x_n) - f(x_1)}{x_n - x_1}$ *Where:* $f(x_1), f(x_n)$ —*values of a curve at the endpoints of selected area.* x_1, x_n *- values of horizontal axis at the endpoints of selected area.* This value is normally expressed in unit change per second (time rather then samples points) since high sampling rates can artificially deflate the value of the slope. *Note:* Lin_reg (linear regression) is a better method to calculate the slope when noisy, erratic data is present. *For a single point,* Slope computes the slope of the line drawn between the two samples: the selected sample point and the sample point to its left. *Results:* If the data value at the starting location is greater than the data value at the ending location of the cursor, a negative delta will result. Otherwise, a positive delta will result. *Units: Volts/sec.* (or corresponding to Freq or Arbitrary setting) *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: 233.33333 Volts/sec. (for samples 1-4)* *-166.66667 Volts/sec. (for samples 4-7) and* *-16. 66667 Volts/sec. (for whole wave).*
Stddev	Minimum area: 2 samples Uses: All points of selected area	Stddev computes the standard deviation value of the data samples between the endpoints of the selected area. Variance estimates can be calculated by squaring the standard deviation value. The formula used to compute standard deviation is: Stddev = $\sqrt{\frac{1}{n-1} * \sum_{i=1}^{n} \left(f(x_i) - \bar{f} \right)^2}$ *Where:* *n—number of samples;* *i—index (i = 1.n);* x_i *— values of points at horizontal axis (* x_1 *– the first point,* x_n *– the last point);* $f(x_i)$ *- values of points of a curve (vertical axis);* $\bar{f} = \frac{1}{n} * \sum_{i=1}^{n} f(x_i)$ *- the mean amplitude value of the data samples between the endpoints of the selected area.* *Results:* The result is always a positive value or zero. *Units: Volts* *Sample data file:* *"ValidateMeasurements.ACQ"* *Result: 3.09570 Volts (for samples 1-4),* *1.000 Volts (for samples 10-12).*

Measurement	Area	Explanation
Sum	Minimum area: 2 samples Uses: All points of selected area	Sum extracts a mathematical sum of the amplitudes of all of the samples within the selected area. This straight sum can be used as a building block for more complicated formulas. Examples of its utility include HRV measurements, various statistical measurements, and simple criteria for clustering. Sum is available from within the measurement popup menus and from analysis scripts that allow for extraction of measurements.
Time	Minimum area: 1 samples Uses: All points of selected area	See the X-axis: T measurement for explanation.
Value	Minimum area: 1 sample Uses: All points of selected area	Value shows the exact amplitude value of the waveform at the cursor position. *For the selected area,* Value indicates the value at the last position of the cursor, corresponding to the direction the cursor was moved (the value will be the left-most sample point if the cursor was moved from right to left). *Units: Volts*
X-axis:T/F/X (horizontal units)	Minimum area: 1 sample Uses: All points of selected area	The X-axis measurement is the exact value of the selected waveform at the cursor position, based on the Horizontal Axis setting: Measurement Horizontal Axis Setting Units X-axis: T Time Sec. X-axis: F Frequency Hz. X-axis: X Arbitrary units Arb. units For X-axis: T measurements, the time value is relative to the absolute time offset, which is the time of the first sample point. The X-axis: F measurement applies to frequency domain windows only (such as FFT of frequency response plots). The Freq function for time domain windows is described on page 106. *Note:* If a range of values is selected; the measurement will indicate the horizontal value at the last position of the cursor. *Results:* This calculation will always return a positive result.

Part B—Acquisition Functions: The Hardware Menu

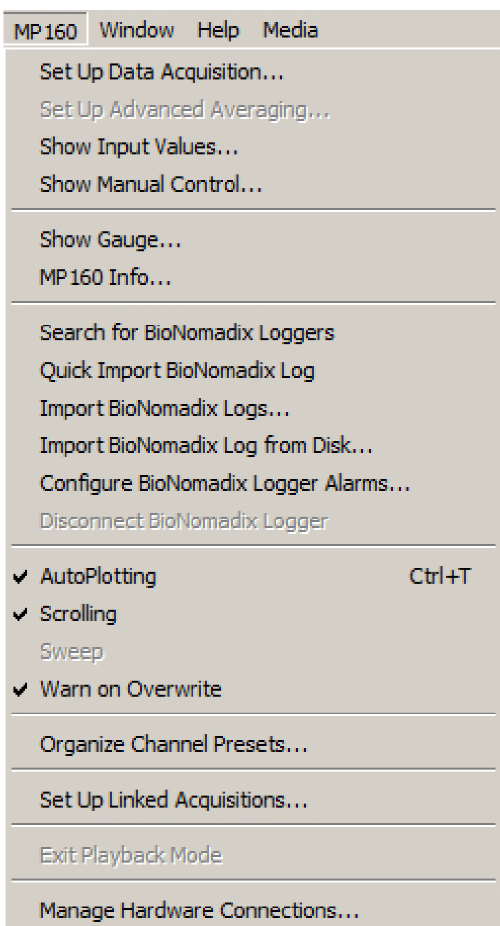
Overview

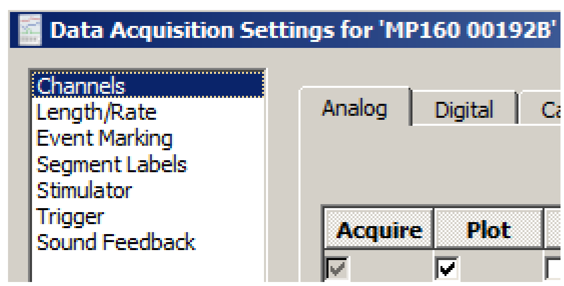
Acq*Knowledge* software adds acquisition and control capability to the complete MP160/MP150/MP36R Systems and other BIOPAC data acquisition hardware, such as wireless BioHarness or BioNomadix. The MP (or Hardware) menu items will vary in appearance depending on the type of data acquisition hardware in communication with the software, and the Hardware menu title will reflect the currently connected hardware type. (It is also important to note that certain features in the MP160/150 and MP36R hardware menus are not supported in all hardware types.) For the purposes of this guide, all supported data acquisition systems will be referred to generically as being under the umbrella of the “Hardware” menu, unless otherwise noted.

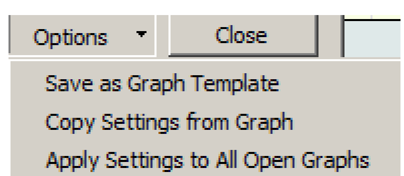
This section describes the commands and procedures used to establish the various acquisition parameters for the hardware, including how to:

- Set Up channels for data acquisitions
- Control acquisition parameters such as sampling rate and duration
- Perform online calculations and digital filters
- Set acquisitions to begin on command from a mouse click or external trigger
- Display values numerically and graphically during an acquisition
- Output waveforms and digital signals during an acquisition
- Control the on-screen waveform display characteristics

Some of the basic functions involved in setting up an acquisition were covered in *Part A—Getting Started*, but this section will cover them in more detail, as well as describe some additional features. All commands referenced here can be found under the hardware device menu.







The **Options** button (Acq*Knowledge* 5.0.3 and higher) is at the lower right of the Data Acquisition Settings screen.

The supported Options are:

- Saving all modified Data Acquisition Settings as a Graph Template for convenient use later
- Copying settings from one open graph to another
- Applying the settings of the active graph to all other open graphs.

Set Up Data Acquisition > Data Acquisition Settings

In Acq*Knowledge*, many key setups are accessed by selecting Hardware menu > Set Up Data Acquisition. This option displays the Data Acquisition Settings window, comprised of the following items:

- Channels – all channel and hardware module setups – see page 116
- Length/Rate – all acquisition setup parameters for the hardware – see page 187
- Event Marking – for setting up hotkeys to insert custom events during acquisition – see page 250
- Segment Labels – for creating custom append segment labels – see page 274
- Stimulator – for configuring all stimulator options – see page 205
- Trigger – for configuring all triggering setups see page 202
- Sound Feedback – for setting up audio output of channel data – see page 274

Clicking a listed item populates the Data Acquisition Settings window with the selected item's setup dialog. At the bottom right of the Data Acquisition Settings window is a "Save Graph Template" button. This enables unique settings from any selected feature to be saved into a graph template for future use.

It's also possible to save user-defined default settings for new graphs by selecting Display > Preferences > Hardware and choosing "User-defined default channel setup." Following this, each selected parameter change must be accepted by clicking "Yes" to the resulting "save default settings" dialog. Once the settings are accepted, this dialog does not reappear unless the settings are subsequently modified.

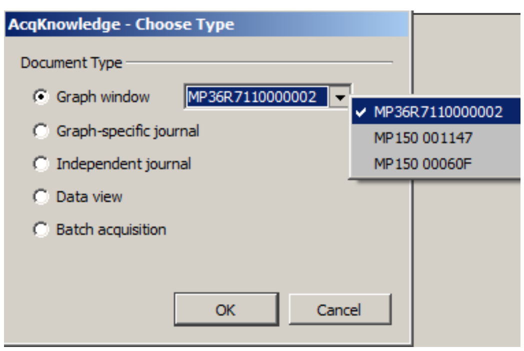
Acquisitions

Acquisition is defined as data collection from an external source (such as electrodes connected to an amplifier).

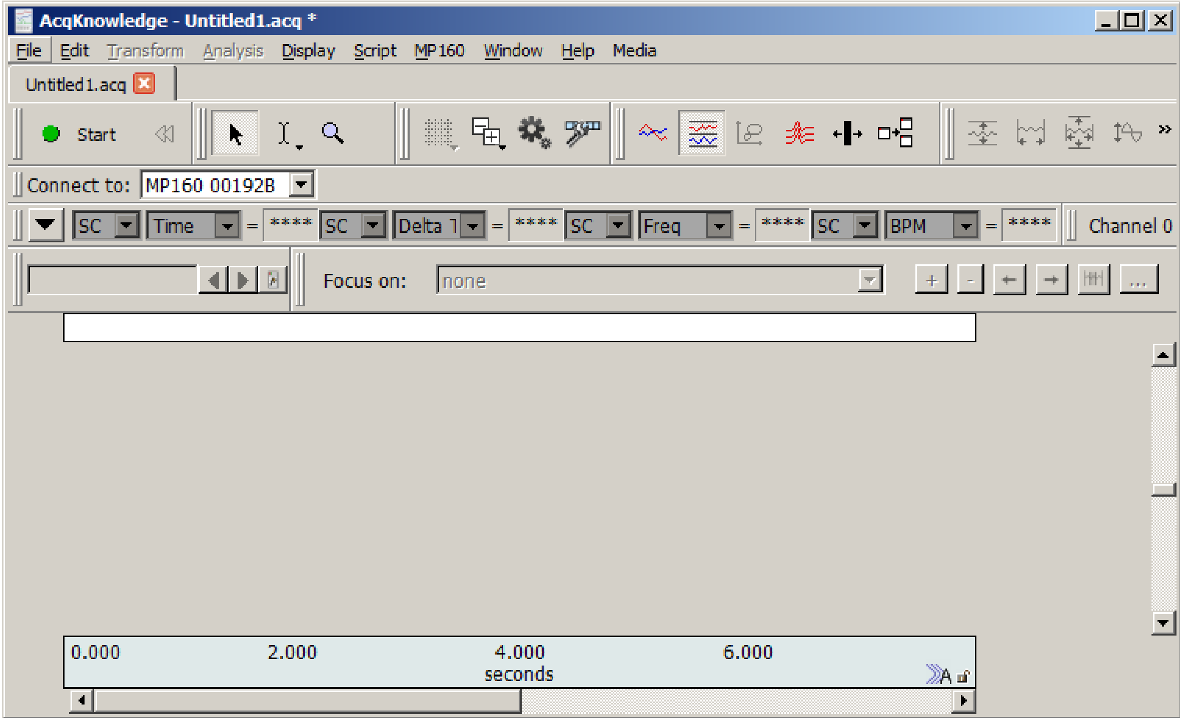
➢ Before starting an acquisition, make sure the data acquisition hardware is turned on and connected to the computer. Please refer to the BIOPAC MP Hardware Guide for more information on connections for the particular hardware type being used.

To begin collecting data and display data as it is being collected:

1. Launch the Acq*Knowledge* application (double click the Acq*Knowledge* icon).
2. Choose File > New and select document type "Graph Window."



NOTE: If more than one hardware type has been previously added via the "Connect to" menu, these will also appear in the "Choose Type" dialog (left).For details on connecting additional hardware types, see page 191.



3. Set up the specific channels to acquire before starting the acquisition.
   - See the Set Up Channels chapter (page 116) for details.
4. Set up the acquisition parameters (such as sampling rate, acquisition length, and data storage options.
   - See the Set Up Data Acquisition chapter (page 187) for details.

Edit menu functionality during acquisition

The following Edit menu functions may move or alter memory and cannot be performed during acquisition: Undo, Cut, Clear, Clear All, Paste, Insert Waveform, Duplicate waveform, and Remove Waveform.

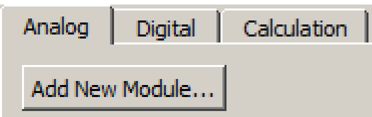
Chapter 5 Set Up Channels

Set Up Channels—The Basics

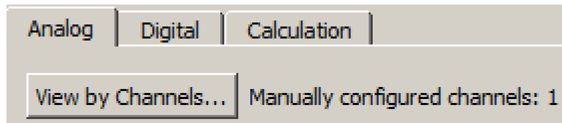
Before collecting data, it is necessary to specify how many channels data will be collected on, and at what rate that data is to be collected. Both functions are accomplished through menu items and dialogues. To enable collection on a given channel, select **Set Up Data Acquisition > Channels** from the hardware menu.

Acq*Knowledge* for MP160 and MP150 with 100C*amplifiers offer two methods of analog channel setup:

Module-based setup



View by Channels *see page 119 for details*



If using Acq*Knowledge* with **BioHarness™** or **B-Alert™**, Analog channels can be turned on/off but not changed.

***For setup and information about 100D Series Smart Amps, see page 128.**

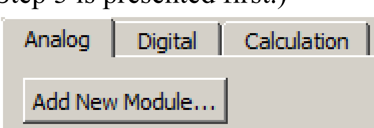
Module-based analog channel setup

For MP160 and MP150 units, Acq*Knowledge* offers a module-oriented analog channel setup option. In module mode, setup prompts the user to add modules/transducers and establish parameters, plus it detects potential channel conflicts between software assignment and the module channel switch setting and scales the signal to the correct value and units. Module setup is supported in MP160 and MP150 hardware only.

The module setup is recommended for easier setup and automatic scaling. In module mode, setup prompts the user to add individual modules based upon the module number. For modules with transducers, the unique transducers are added. The user is then prompted to input the settings of all of the switches on the modules and then perform any calibration steps, if required. Using this information, the module setup automatically sets the scaling and initial visual range to match the physical input units from the module or transducer. Additionally, module-based setup detects potential channel conflicts between software channel assignment and module channel assignment (red switch position).

1. From MP160/150 > Setup Data Acquisition > Channels, select the analog tab and click Add New Module...

   NOTE: Module setup mode is automatically activated by default when the "Create/Record a new experiment" launch option is selected in the Startup Wizard window. (The add module dialog shown in Step 3 is presented first.)

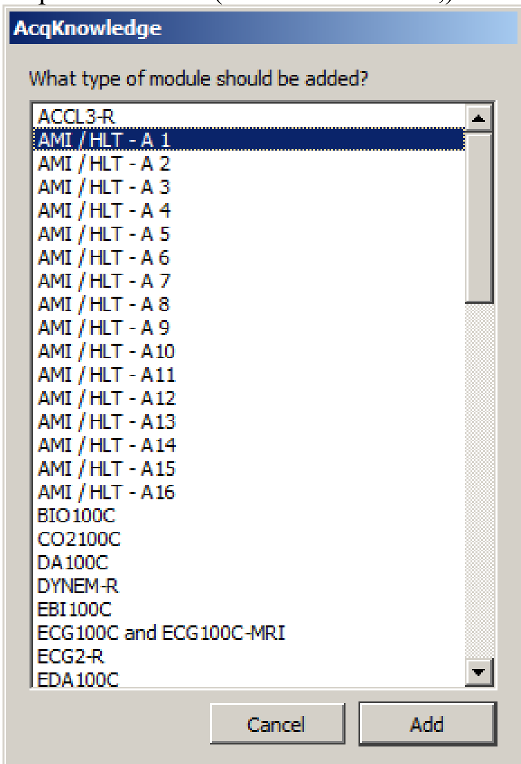
   

2. Click Add New Module from the bottom of the dialog.

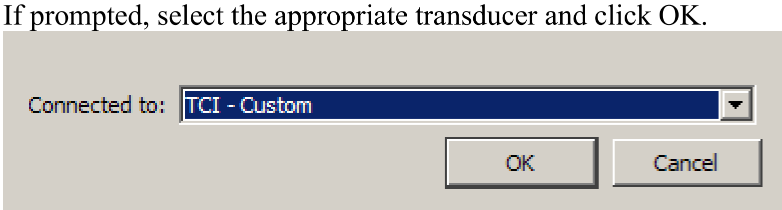
   

3. Select a module and click Add.

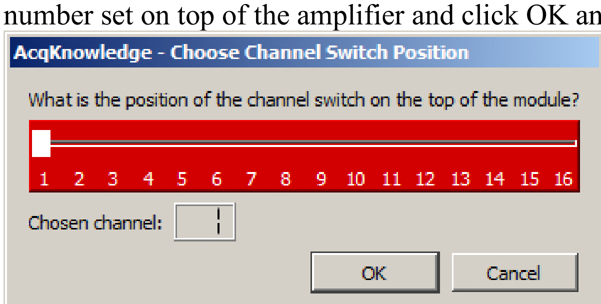
NOTE: If adding an AMI/HLT option, a "select transducer" prompt will appear (Step 4). If selecting an amplifier module (such as ECG100C,) a "Choose Channel Switch Position" prompt will appear (Step 5).

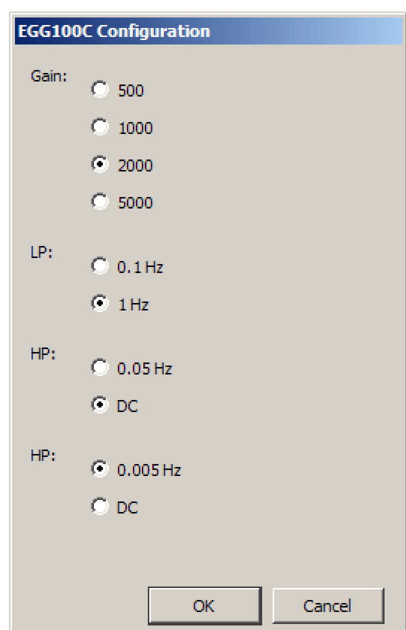


4. If prompted, select the appropriate transducer and click OK.



5. If selecting a100C amplifier from the module list, set the "Choose Channel Switch Position" to the channel number set on top of the amplifier and click OK and see Step 6.





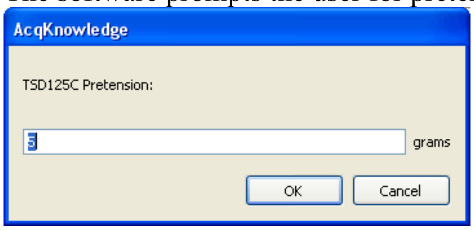
- Setup detects any potential channel conflicts between software assignment and the module's channel switch position.

6. Establish the configuration parameters (gain and filters, see right example) and click OK. It is important to set the Gain and Filter settings to correspond to the switch settings on the amplifier. The software uses this information to scale the signal to the correct units. If the Gain is not set to match, the signal will be scaled incorrectly.

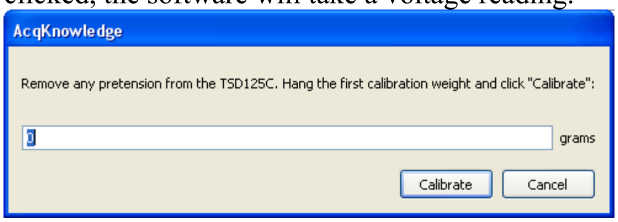
7. Perform calibration steps, if required. The software will automatically scale certain signals, if they only require a zero setting. However, some signals require a two-point calibration. In this case, the software will generate additional prompts for the scale values.

   The following examples show the dialogs for setting up a force transducer.

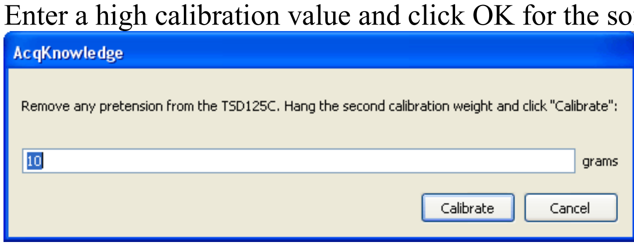
   a. The software prompts the user for pretension amount; enter "0" if pretension is not required.

   b. Enter a low calibration value or "0" if calibrating between zero and a second weight, when OK is clicked, the software will take a voltage reading.

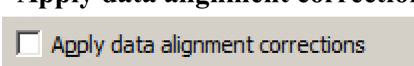
   c. Enter a high calibration value and click OK for the software will take a voltage reading.

   Note When recording is started, the data may show an offset. This offset is the amount that was entered in the pretension dialog. Adjust the tension applied to the transducer to center the signal on zero.

   Using this information, the module setup automatically sets the scaling and initial visual range to match the physical input units from the module or transducer.

"Apply data alignment corrections" option (Acq*Knowledge* 4.4.2 and higher)



This checkbox option is found at the bottom of the Channels > Add New Module screen and is recommended when using the following hardware modules:

- NIBP100D (via DA100C general purpose amplifier) : adds 50 msec delay.
- NIBP100D-HD (via AMI100D or HLT100C high level transducer module): adds 50 msec delay
- When combining BioNomadix wireless signals with wired signals: adds 15.6 msec delay (+/- 0.5 ms RMS)

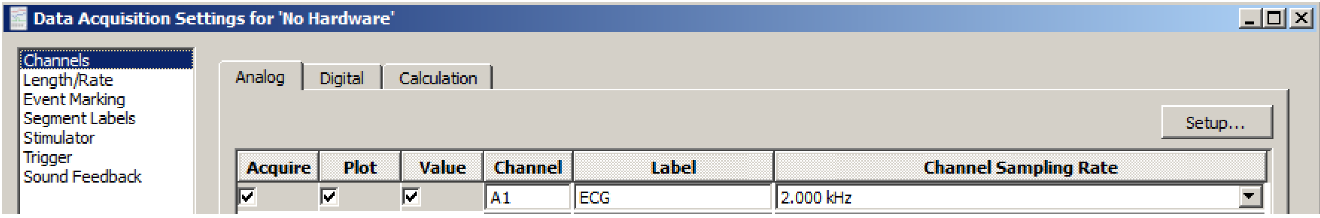
Checking this box automatically adds appropriate delays, ensuring all data will be properly aligned when the above combination of hardware is used. This avoids the need to use calculation channels to manually align data when combining hardware types that apply varying amounts of fixed delay.

NOTE: If NIBP100D is not being used, or if BioNomadix is being used only with other BioNomadix receivers, then checking this option is not necessary. (It is unchecked by default.)

View by Channels

Channel Type

To specify the channel type—Analog, Digital, or Calculation—click its tab at the top of the dialog.



For each channel, there are three options for channel setup: Acquire, Plot, and Value. These options appear as boxes on the left side of the Input Channels dialog.

Acquire

This option dictates whether data will be collected on that channel. The default setup is not set to acquire any channels. To collect data, position the cursor over the Acquire box (on the far left) and click the left mouse button.

To leave hardware connected to the data acquisition unit, but have the software essentially "ignore" the channel, leave the Acquire box unchecked. For example, if an input device (such as an ECG100C amplifier) is set to Channel 7, data from that channel will not be collected unless the Acquire box is checked.

Plot

The second option is for plotting data. The Plot option determines whether or not data will be plotted on the screen for each channel. Checking this option instructs the software to plot data on the computer screen.

When this box is left unchecked, data will still be collected (assuming the Acquire box is checked) but will not be displayed during the acquisition.

In most cases, checking this option is recommended. However, in large-scale acquisitions (i.e., many channels and/or high sampling rates) unchecking this option for some channels allows for faster display rates or to increase the display area for important channels (see Appendix B—Hints for working with large files). Alternatively, use a separate data view and enable channels for as desired for optimum viewing.

The Plot state is applied only on initial acquisition into a graph or template. If data has been previously acquired, use the channel buttons in the graph window to change channel visibility, OR use the Display > Set Channel Visibility option to select/deselect the channels to be shown in the graph.

Values

The third option enables incoming data values to be displayed either numerically and/or in a "bar chart" format in a separate window during an acquisition. Checking this option enables a bar graph (by selecting Show Input Values... under the Hardware menu) that displays the numeric value for channels with this option checked. This is especially useful for tracking slowly changing values such as heart rate, respiration rate, or concentrations of chemicals in a substance. For more information on how input values are displayed, please turn to page 264.

Channel

Click in the channel number box (i.e. A1) to make that channel active ("selected") so its settings can be established or edited.

Label

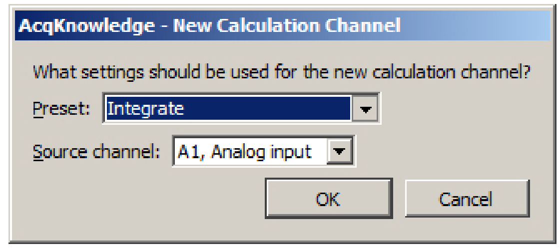
Editable labels can be attached to each channel. To change the label for any channel, position the cursor in the area to the right of the channel numbers (A1 through A16) under the label heading and enter a text label. Up to 38 characters are supported and these labels will appear next to the channel label boxes in the graph window. To edit the label after setup, use the Set Up Channel dialog at any time, or right-click the active channel label in the graph window to generate the Assign Channel Label dialog.

Calculation Channel Presets

When a new Calculation channel is enabled for the first time, a setup dialog is presented to assist in setting the correct preset type, source channel and preset parameters.

To set an initial calculation channel preset:

1. Click the Calculation tab.
2. Enable the desired Calculation channel by checking the "Acquire, Plot and Value" checkboxes.
3. The following setup dialog will appear. Select the desired Calculation preset and analog source channel, and click OK.



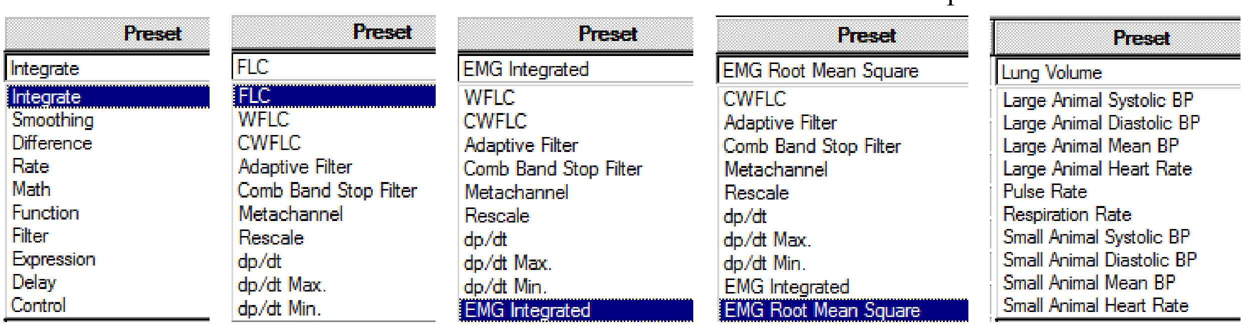
4. After clicking OK, the setup dialog for the selected preset will appear. Set the desired parameters and click OK. (For detailed information about setting Calculation channel parameters, see Chapter 6 on page 152.)

Calculation Presets are like "templates" for calculation channels. Each Preset stores:
   a) Calculation channel type
   b) Parameters for that calculation
   c) Channel name.

Calculation Presets establish settings to target application-specific analysis. Presets exist for a broad range of analysis functions, including Fourier Linear Combiners and Adaptive Filtering. Start with existing presets for a specific species or protocol—for example, human vs. small animal, or stationary vs. exercising measurements.

The Channel Setup dialog contains a "Preset" pop-up menu by each channel that lists the current Preset or, if no Preset has been selected for that channel, the Calculation type (Integrate, Difference, etc.). When a Preset is selected for a particular channel, the channel is configured with the settings associated with that Preset.

The Setup dialog has a "Presets" pop-up menu that contains all of the Presets for the Calculation type being configured. For instance, if a Difference Calculation channel is being configured, all Presets for the Difference Calculation will be listed. Just click the Presets head and scroll to select the desired preset.



Calculation Presets

When a Preset is selected, the Setup dialog is updated with the corresponding information.

- The Setup dialog reads "none" if the channel configuration doesn't match any Preset. The menu will flip to "none" when the settings for a channel are changed such that they no longer match a Preset.
- Create a new Preset from existing Calculation channels. Click "Setup" to display the Calculation Setup dialog and click the "New Preset" button. The settings will be applied to the current channel, and a prompt will appear to enter a name for the new Preset. Preset names cannot be duplicated, nor can the default name of a Calculation channel type be used (Integrate, Difference, etc.). The new Preset will be included in the pop-up menus and saved with the file.
- To reorder channel Presets (by type, use, etc.), choose Hardware > Organize Channel Presets and then use the up/down buttons as appropriate (see page 281).
- Presets are not applicable to and therefore not selectable on Analog or Digital channels.

Channel Sampling Rate

The Variable Sampling Rate feature allows different channels of data to be down-sampled from the acquisition sampling rate; calculation channel must use sampling rate less than or equal to the source channel. Choosing lower sampling rates for signals where meaningful data falls below the Nyquist frequency of the acquisition sampling rate allows more data to be stored in memory or on disk.

- Offline operations that involve multiple channels must use the same sampling rate for all Source and Destination channels. These operations include waveform editing, Waveform math, Expression calculations and Template functions; notable exceptions are “Off-line Averaging” under Find Cycle/Peak and “Reset via a Control Channel” under Integrate.
- When wave data is copied to the clipboard or journal, data values will be inserted at the highest sampling rate.
- There is no restriction on the acquisition length when using Variable Sampling Rates.
- When Variable Sampling Rates are used in conjunction with the Append mode, and the mode is started and stopped manually, it is statistically possible that, prior to the next pass of the Append, extra data points may be inserted in various data channels to “line up” the data (see sample on page 120). These extra data points simply replicate the last sample in any affected channel.

  To minimize the impact of the extra data points:

  a) Make sure the lowest sampling rate is on the order of 10 Hz or higher, or

  b) Don’t use Variable Sampling Rates.

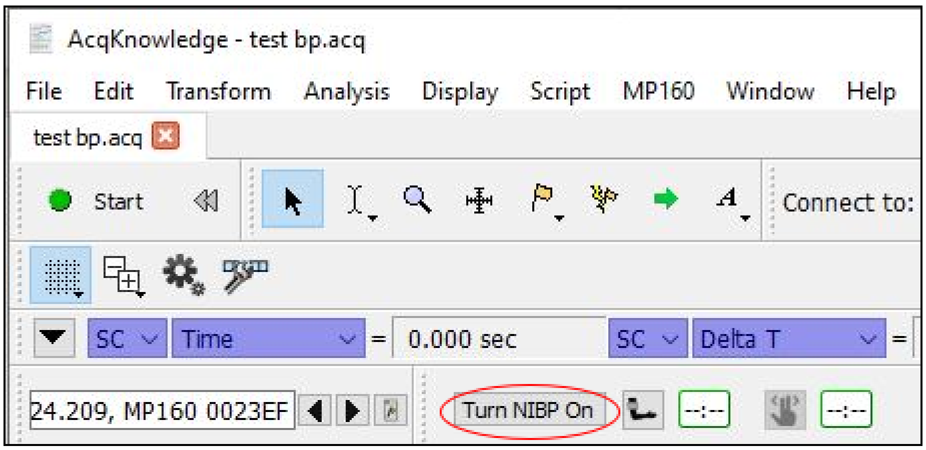
Setting up NIBP100E/NIBP100E-HD

The NIBP100E/NIBP100E-HD is a noninvasive blood pressure system that provides a continuous, beat-to-beat blood pressure signal recording from the fingers of a subject. The system outputs a continuous blood pressure waveform that is similar to a direct arterial pressure waveform.

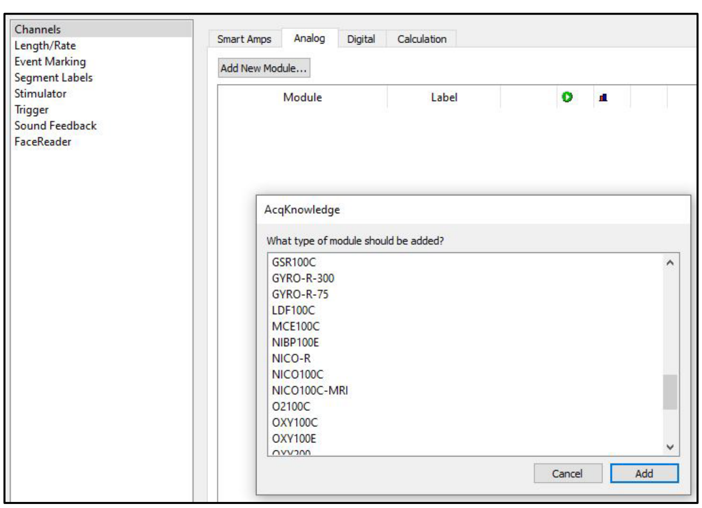
Initial Channel Setup:

1. Ensure that the NIBP100E module is properly connected to the MP160 device, that the arm and finger cuffs are properly connected, the device is powered on, and the USB cable is connected to a Windows computer equipped with Acq*Knowledge* version 5.0.7 or later. See product specification sheets for the NIBP100E and NIBP100E-HD for detailed instructions on setting up these modules.
2. **Setting up equipment for the first time or creating a new experiment:** Open Acq*Knowledge* and select "Create/Record a new experiment" and "Create Empty Graph," then click **OK**.

   Using an existing NIBP100E graph file: Make sure the finger cuffs are properly fitted and position on the subject or an error may occur. Select "Open a graph file" and select the graph or template to open and click **OK**. Because configuration data is stored in graph files, the user will skip the configuration process. Make sure the finger cuffs are properly fitted and positioned on the participant. After creating a new graph or opening an existing one, click **Turn NIBP On**. This will open the Calibration window (Skip to Calibration and Recording below).

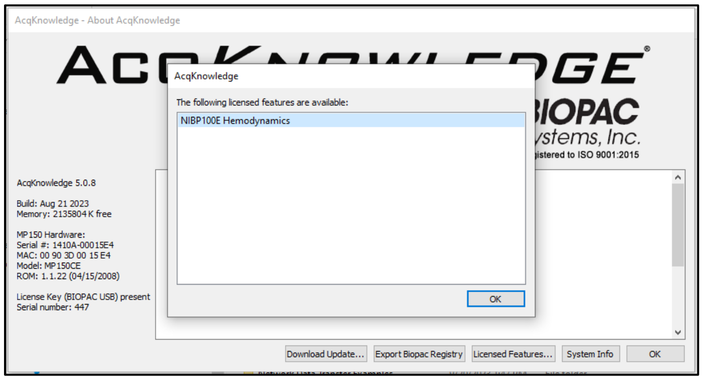


3. Depending on the selected Preferences, opening a new graph may automatically open the Data Acquisition Setup window. If the window does not open, open it manually by selecting "MP160>Set Up Data Acquisition" (Note: Select "MP150" if this is the model of data acquisition device used). Next, select "Channels" and click the **Analog** tab. Click on the **Add New Module** button, and when prompted by the pop-up menu "What type of modules should be added," select "NIBP100E" from the module list. Typing "N" will jump the selection directly to "NIBP100E" in the module list.



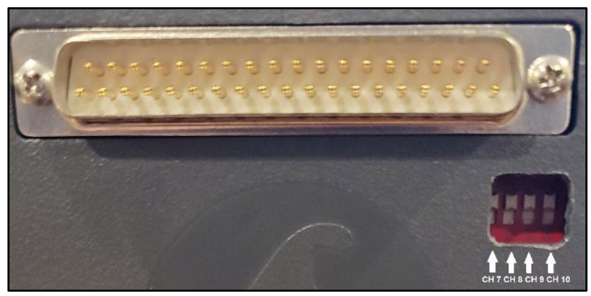
NIBP100E-HD Licensing

1. To check if the NIBP100E-HD license has been installed, click the **Help** tab, select **"About Acq*Knowledge*,"** and click the **Licensed features…** button. "NIBP100E Hemodynamics" will appear in the window listing all available licensed features if the license has been installed. If an HD license was purchased but "NIBP100E Hemodynamics" is NOT displayed in this window, please contact customer support.

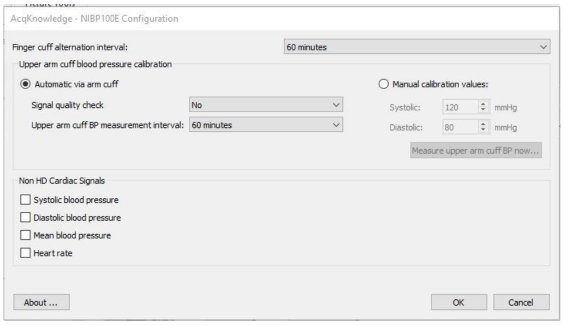


If the HD license is available, the window will display checkboxes for the four (4) non-HD cardiac channels or the four non-HD channels plus six (6) HD cardiac channels.

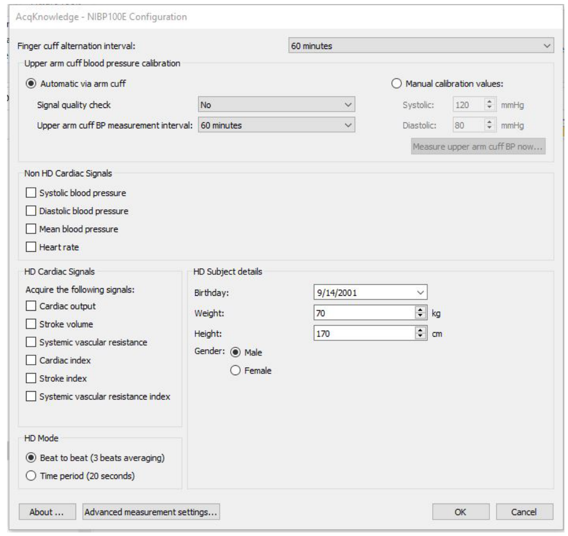
Note: Raw blood pressure data is recorded through Analog Channel 7 on the MP160/150. The HD cardiac signals use channels 8, 9, and 10. Only up to three (3) HD signal calculations can be recorded during a session. Each NIBP100E and NIBP100E-HD unit is equipped with four dip switches on the left side panel (see image at right; the NIBP100E module must be separated from the MP system to expose the left side panel). These switches are numbered 1-4 (left to right) and control channels 7, 8, 9 and 10, respectively (i.e., 1=7, 2=8, 3=9, and 4=10). All units (HD and non-HD) will by default have the dip switch for channel 7 set to the "on" or up position. HD units will also have switches for channels 8, 9 and 10 in the "on" or up position by default. The NIBP100E-HD user may choose to switch channels 8, 9, or 10 to the "off" or down position to free up those channels for other hardware.



NIBP100E-HD dip switch configuration



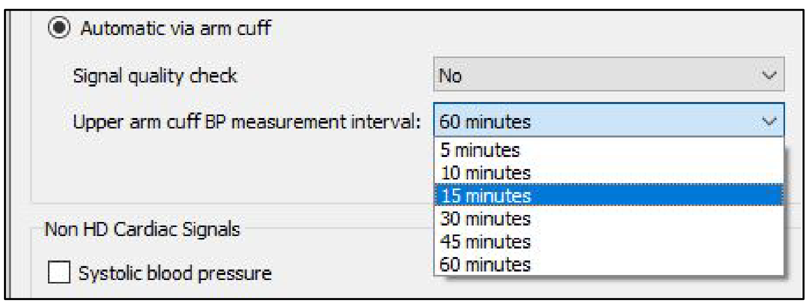
NIBP100E Configuration Window



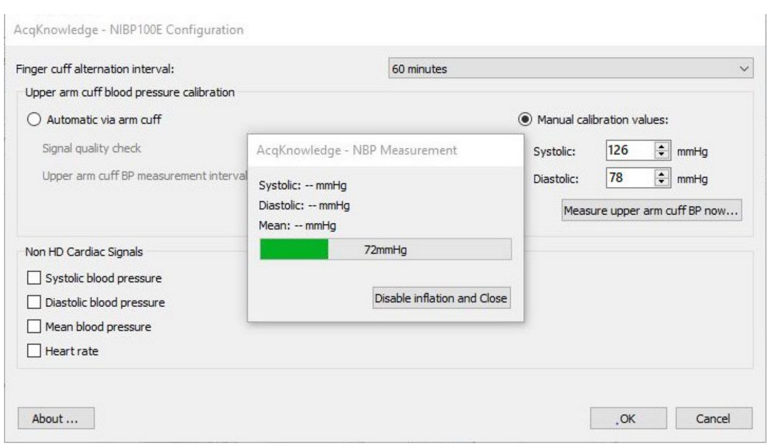
NIBP100E-HD Configuration Window

Cuff Configuration:

1. Select the “Finger cuff alternation interval” pulldown menu to set the finger cuff interval to the desired period (i.e., 15, 30, 45 or 60 minutes). The default setting is 60 minutes.
2. Set arm cuff calibration to either “Automatic” (recommended) or manual. When selecting “Automatic” calibration, use the pulldown menus to choose whether to apply a signal quality check and to set the upper arm cuff blood pressure interval.

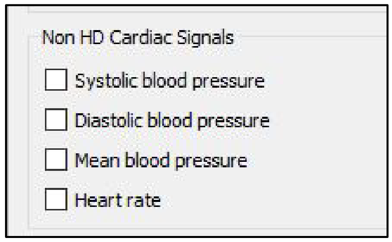


3. Selecting “Manual calibration setup” allows the participant's current blood pressure to be taken by clicking the **Measure upper arm BP now** button. This will activate the upper arm cuff (ensure it is properly fitted to the participant). When the measurement is complete, the software will apply the measured systolic and diastolic pressures to the manual calibration values.



Adding Non-HD Calculation Channels:

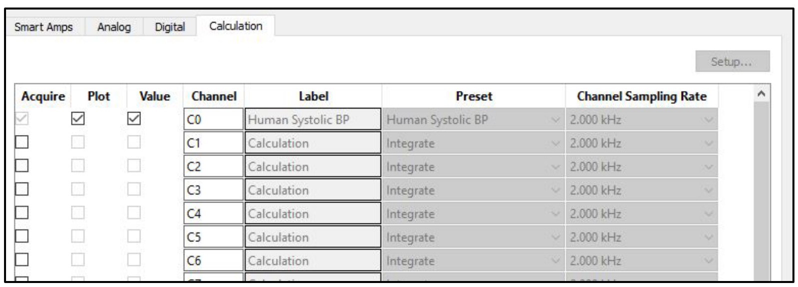
1. Up to four non-HD cardiac signals can be selected to calculate systolic BP, diastolic BP, mean BP, and heart rate. Checking the corresponding boxes in the NIBP100E Setup window selects default calculation channel presets. See the following section on Calculation Tab Setup for instructions on modifying these presets.



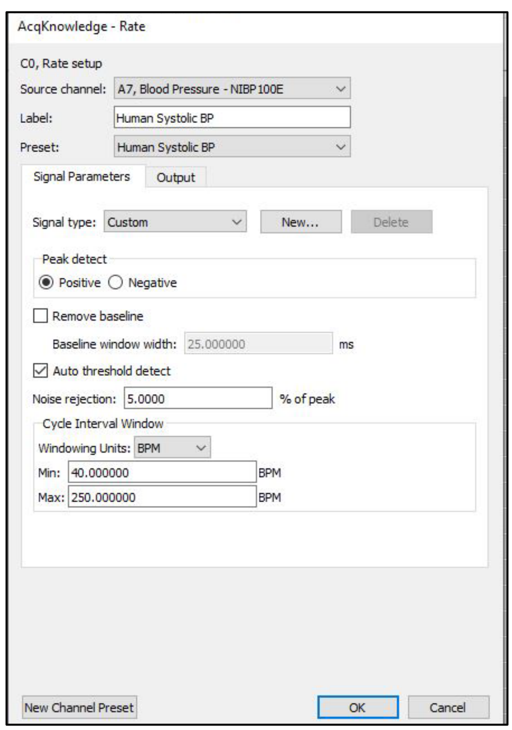
Note: These checkboxes enable calculation channels. Selecting any or all of them will not cause any interference with analog channels and thus will not change the number of other analog signals that may be recorded.

Calculation Tab Setup (Optional)

1. To modify the channel presets for the non-HD Cardiac Signals, select the Calculation tab in the Setup window to display channel labels, presets, and channel sampling rates.



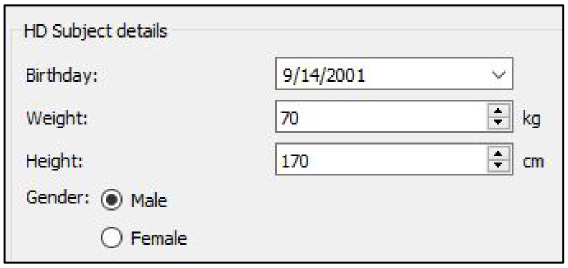
2. Select a channel and click the **Setup** button to open the Rate window, which allows the user to create labels and redefine preset values for signal parameters and output. Refer to Application Note 142 for additional information on rate detection.



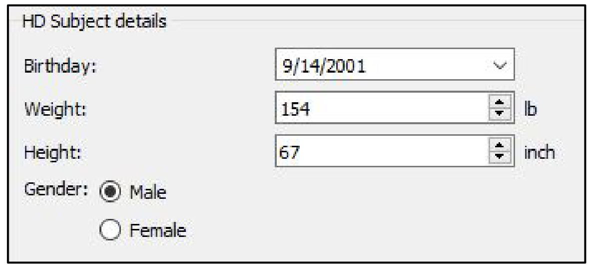
Configuring HD Cardiac Signals:

To configure for **HD Cardiac Signals**, use the corresponding pulldown menus to select HD Subject details: Birthday, Weight, Height, and Gender. This information allows the device's algorithm to estimate the participant's heart size as this is needed to estimate stroke volume using only blood pressure as a signal.

> **Note:** Measurement units are metric by default but can be changed to imperial by clicking the **Advanced Measurement Settings** button at the bottom of the Configuration window (see below for additional **Advanced Measurement Settings**).



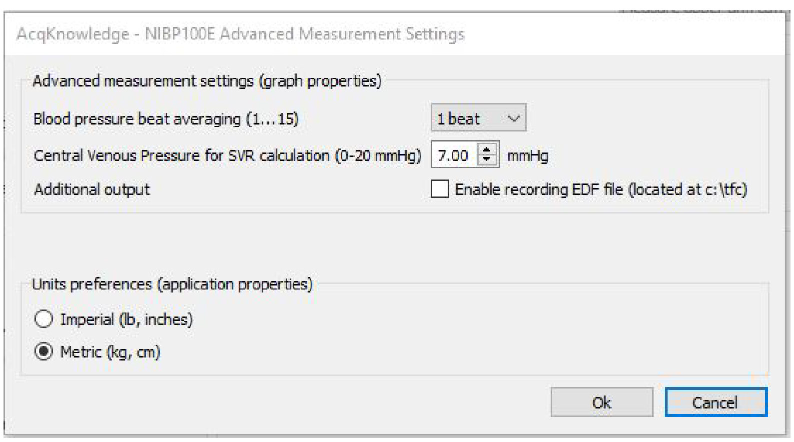
Subject Details (metric units)



Subject Details (imperial units)

Using NIBP100E-HD Advanced Measurement Settings:

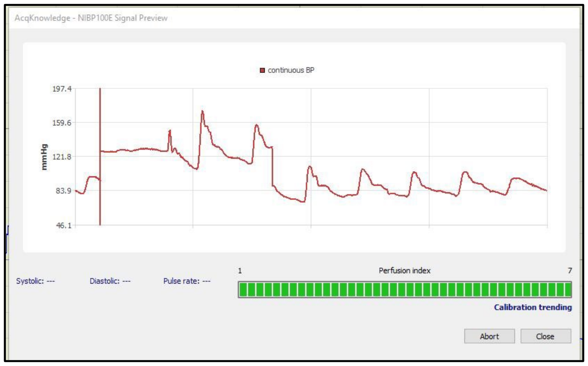
On modules purchased with the NIBP100E-HD license, a button for **Advanced Measurement Settings** will be available at the bottom of the Configuration window. Clicking this button opens the Advanced Measurement Settings Window, which allows advanced graph properties to be set up, including blood pressure beat averaging (1–15), central venous pressure for SVR calculation, and additional output (recording of EDF file). Users can also choose between metric and imperial units



Calibration and Recording

1. Make sure the arm and finger cuffs are properly fitted and positioned on the participant. Click **OK** to close the Configuration window.
2. If Automatic calibration has been selected, the software will begin the calibration process and open the signal preview window. The dual-finger cuff and the upper arm cuff will inflate and begin to configure the signal.
3. The Signal Preview window will display a Continuous Blood Pressure graph and a bar displaying Perfusion Index readings on a scale of 1 to 7. The BP graph will be displayed in **red** while calibrating and shift to **green** when calibration is complete.
4. The Perfusion Index bar will show signal strength and clarity. The bar will be displayed **red** until a suitably strong signal is achieved; at which time it will change to **green**. Ideally, the user will receive an index reading of as close to 7 as possible.

Note: A poor signal may be the result of improperly fitted finger cuffs. To improve signal quality, adjust or reposition both cuffs and begin the calibration process again. Users may achieve the best results by placing the finger and upper arm cuffs on different arms of the research participant.

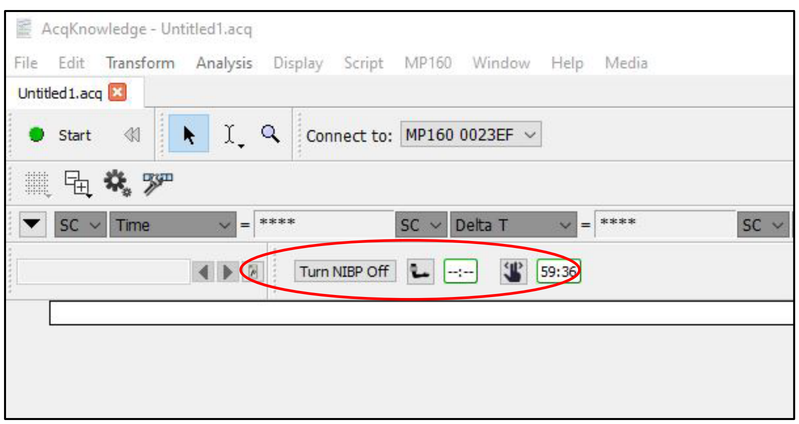


Blood pressure graph appears red during calibration.

BP graph turns green after calibration is complete. Close button begins countdown to auto close window.

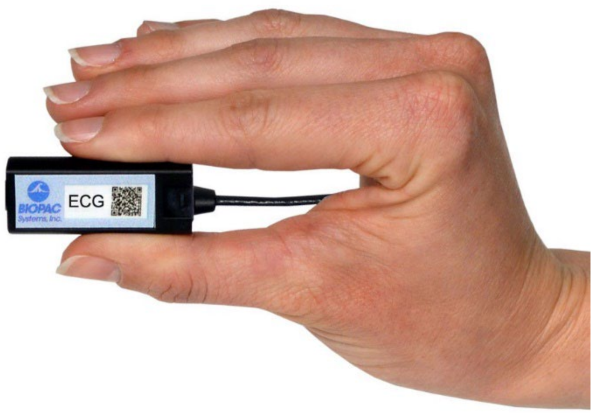
5. When the configuration is complete the **close** button will display a 15-second countdown. The user can click the **close** button or wait for the countdown to complete, at which time the Signal Preview window will close automatically and the NIBP100E graph window will open.

6. After the preview window closes, the graph window displays a set of controls for the module (see image below). Click **Start** to begin acquiring data from all configured channels. If **Turn NIBP Off** is clicked during recording, the NIBP module shuts down, but other signals will continue recording. The button changes to **Turn NIBP On** when it is off, so NIBP data may be acquired again without re-starting the MP160's acquisition. If the NIBP unit is off, Channel 7 (and any configured HD channels) will only produce noise. The  button begins a new arm cuff calibration measurement while the  button switches fingers from which a measurement is taken, which will also trigger an arm cuff calibration measurement.



When the NIBP100E has been added, a new set of controls appears in the graph window.

Setting Up Data Acquisition and Channels for 100D Series Smart Amplifiers



Acq*Knowledge* 5.0.4 and higher supports BIOPAC's line of 100D Smart Amplifiers, offering full functionality of the 100C Series Amplifier Modules in a small form factor. These lightweight modules are small enough to attach to a subject's clothing and use standard BioNomadix leads or transducers to connect with the MP160 unit via the AMI100D interface module. (This upgraded unit resembles the HLT100C module known to MP160 users but is designed to support 100D Smart Amps, as well as earlier-model 100C Amplifier Modules).

In addition, Smart Amplifiers are self-configurable in Acq*Knowledge* software, and additional filters and calculation channels are selectable via onscreen checkboxes.

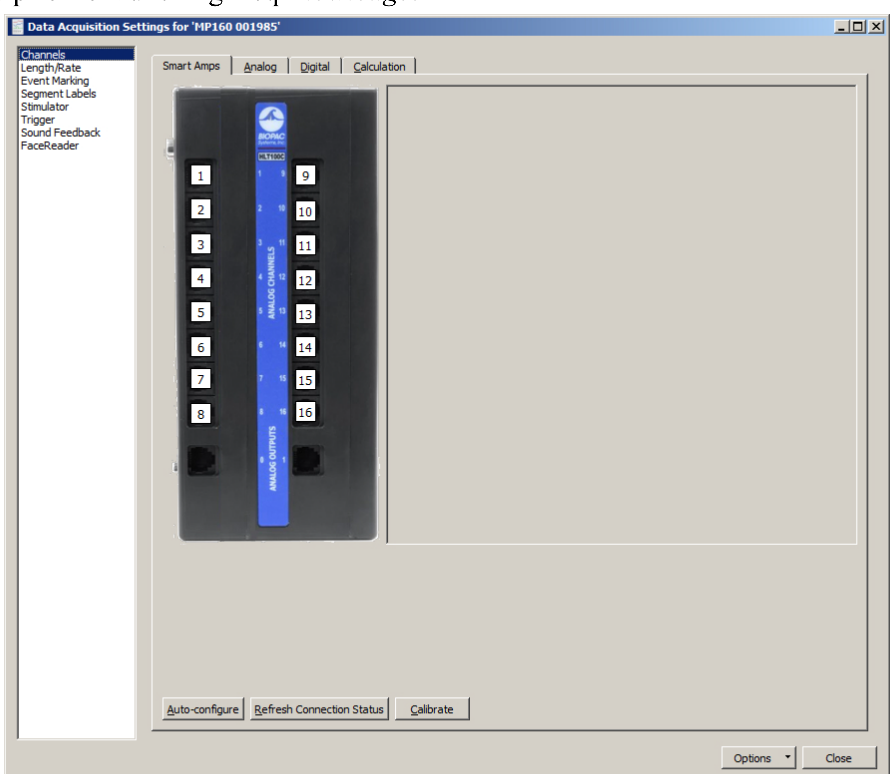
Signals supported; ECG, EMG, fEMG, EDA, EOG, EEG, EGG, RSP, SKT, PPG, ERS, and NICO.

System Requirements for Smart Amps

- Acq*Knowledge* 5.0.4 or higher (Smart Amps are not supported in earlier software versions.)
- MP160 unit with firware version 2.1 or higher. (Contact BIOPAC for firmware upgrades.)
- AMI100D Interface Module (Smart Amps are not supported with earlier-model HLT100C or UIM100C modules).
- Smart Amps are not supported in MP150 or MP36R hardware systems.

Smart Amps connect to the AMI100D interface module's channel inputs via the included RJ11 cable.

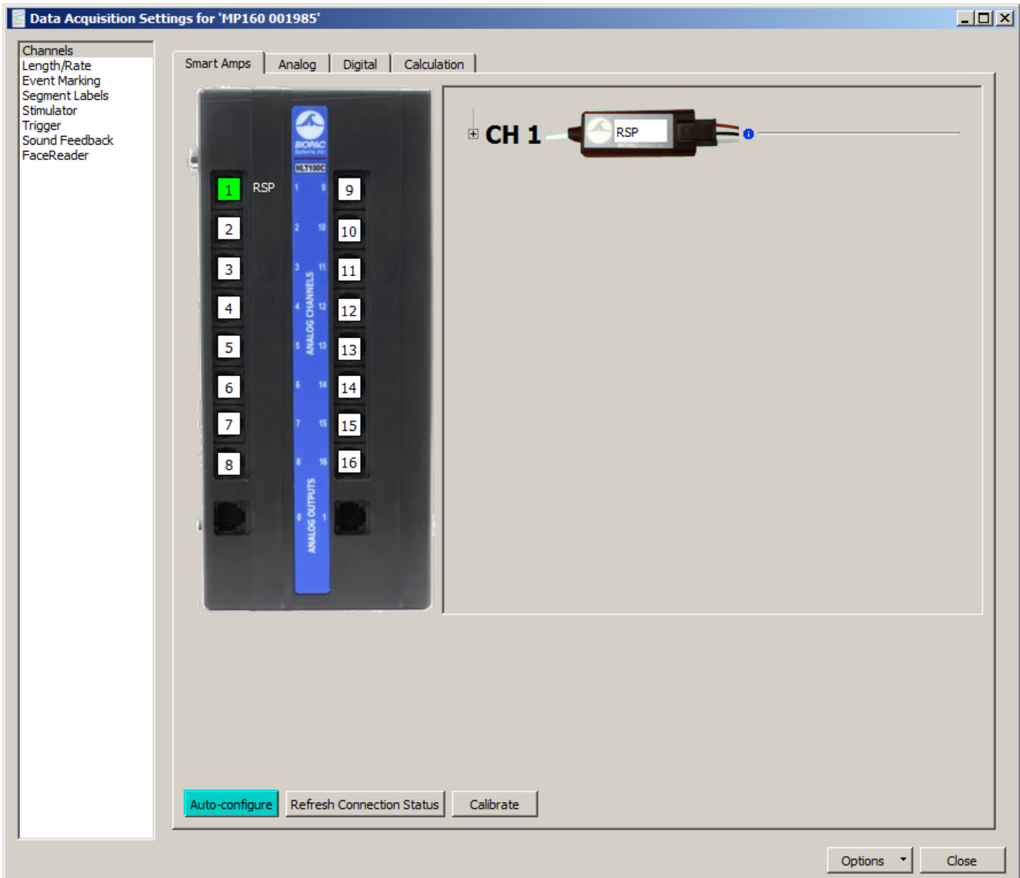
Acq*Knowledge* 5.0.4 with current MP160 hardware features an additional "Smart Amps" tab in the Channel Setup screen. When no amps are connected (as shown below) the right pane of the window is blank. Connected amps become visible in this pane after clicking "Auto-configure" or immediately, if amps are connected to the AMI100D module prior to launching Acq*Knowledge*.



To Connect Smart Amps:

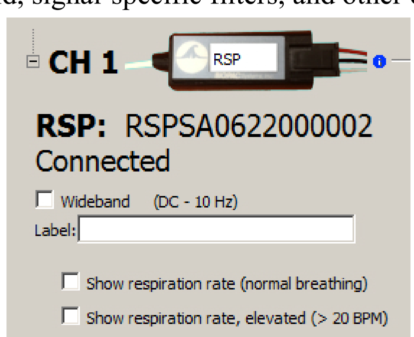
1. Make sure that operational MP160 hardware is connected to the computer, and that an AMI100D module is connected to the right side of the MP160 (see MP Hardware Guide for details).
2. Connect the Smart Amp RJ11 cable to a channel input on the AMI100D front panel.
3. Launch Acq*Knowledge*. Connected Smart Amp will be visible under the Smart Amps tab and will be ready for use. The corresponding channels the amps(s) are connected to will be illuminated in green in the software.

   NOTE: If Acq*Knowledge* is running before Smart Amps are connected to the AMI100D, it will be necessary to click the "Auto-configure" button in order for them to appear in the Channels screen.



Repeat above steps to connect additional Smart Amps at any time. Up to 16 Smart Amps may be connected, simultaneously or individually. Smart Amps do not require calibration, with the exception of the EDA100D (electrodermal activity). Connected amplifiers will also appear under the Analog channel tab.

Expand additional amplifier options/info by clicking the  button to the left of the amplifier icon. These options consist of an editable label field, signal-specific filters, and other derived calculation channels.

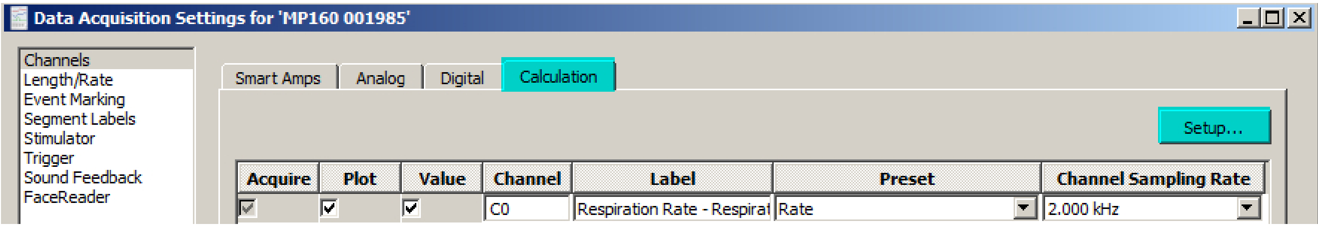


Toggling the "-" button collapses the listed options.

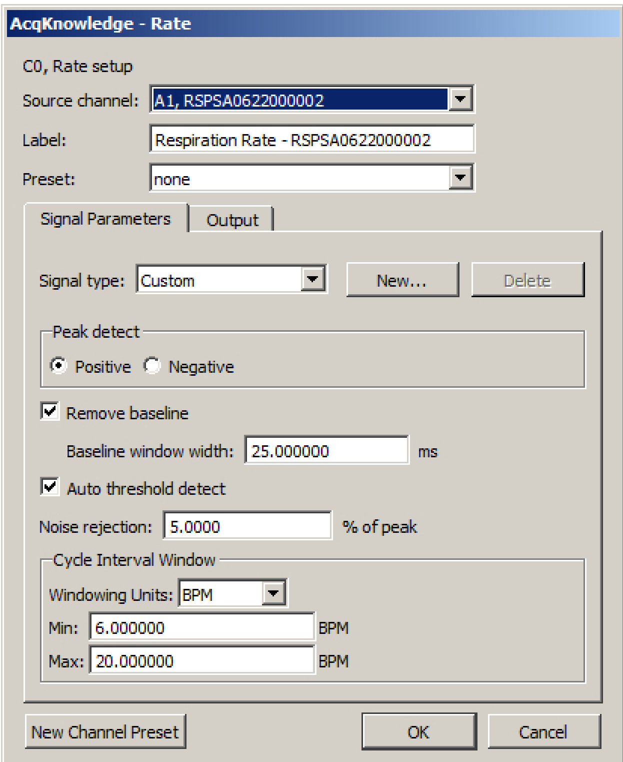
Available amplifier checkbox options vary depending on the amp type connected. For a complete overview of all amp configuration options, see page 134.

Selected derived signals (such as "Show respiration rate" in the above figure) will appear as separate calculation channels the Acq*Knowledge* graph, and will also show up as enabled channels under the Calculation tab.

To view or modify the calculation channel default settings, select the Calculation tab and click "Setup."



As an example, the default setup for the RSP100D Respiration Rate Calculation Channel is shown below.



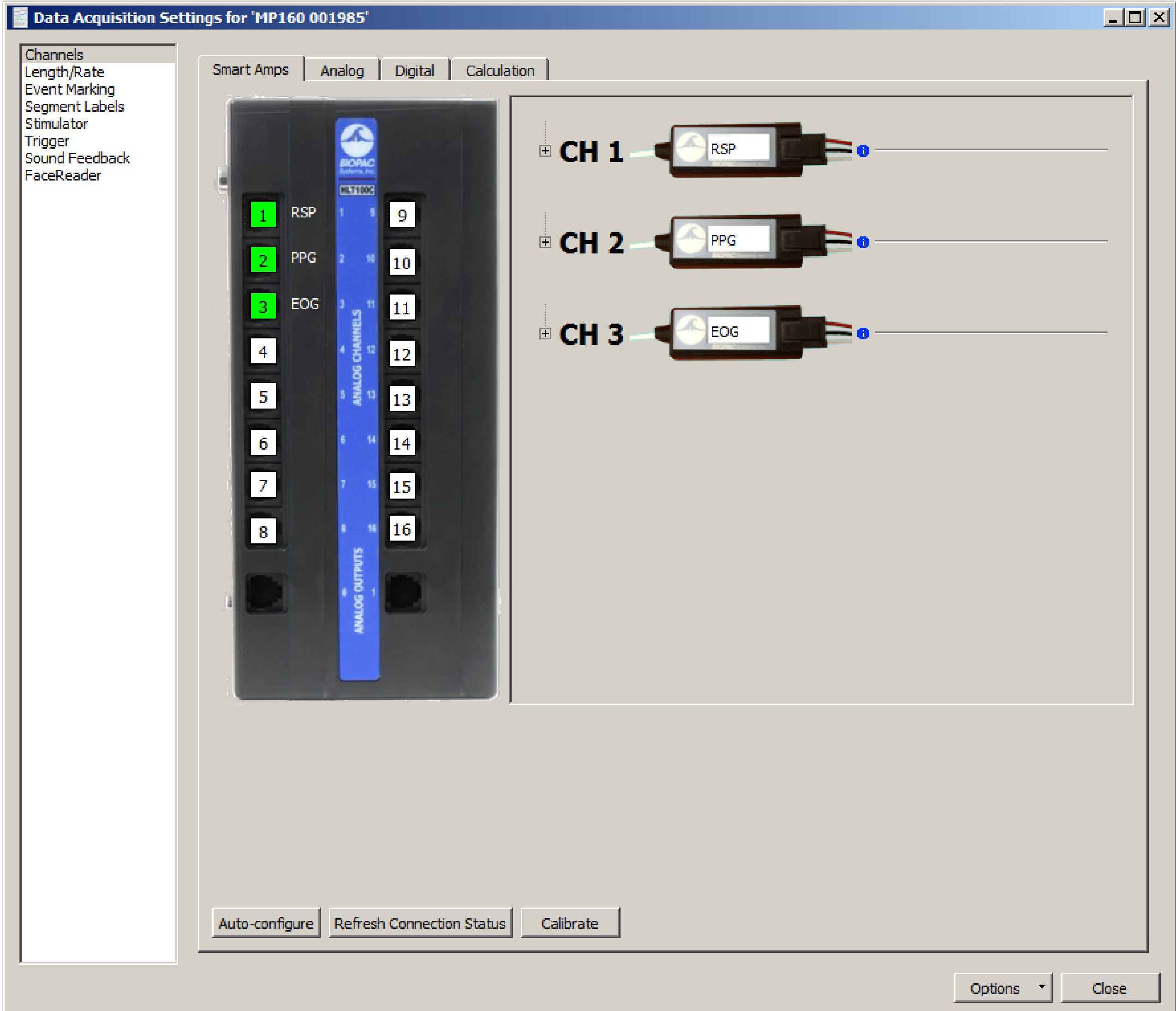
As detailed in this manual's Calculation channel section, modified "Custom" settings can be saved as new presets under the "Signal type:" menu. It may be necessary to reselect the custom setting if the Smart Amp is disconnected and plugged back in.

Under normal circumstances, the default Smart Amp derived signal settings should be adequate for most applicatons.

Connecting Additional Amps

Up to 16 Smart Amplifiers may be connected at any time but must then be enabled by clicking "Auto-configure" if Acq*Knowledge* is running prior to connecting the amp. Channels occupied by previously configured amplifiers are not affected by the addition of new amplifiers in remaining available channels. For example, if eight amplifiers are connected and a ninth one is added later, choosing "Auto-configure" will add the new amp without affecting the status of the others. If eight amplifiers are connected for the first time, clicking "Auto-configure" will simultaneously enable all eight amps in their respective channels.

See the following page for details about options available in the Smart Amp window.



Auto-configure	Configures connected Smart Amps for use in Acq*Knowledge* software. Channels that amps are physically connected to on the AMI100D module will illuminate in green in the software. “Auto-configure” does not need to be repeated unless a different amp is connected to a previously-occupied channel.
Refresh Connection Status	Checks each smart amplifier channel to determine if an amplifier is connected. To retain an earlier connection, the amplifier must be of the correct type and match the expected serial number. If a different amplifier is connected, a dialog will be displayed. To connect the different amplifier, choose “Auto-configure.”
Calibrate	Checks calibration for the connected amp.

Channel Status

The Smart Amp channel connection status is indicated by the following color codes.

Green: Smart Amp connected.

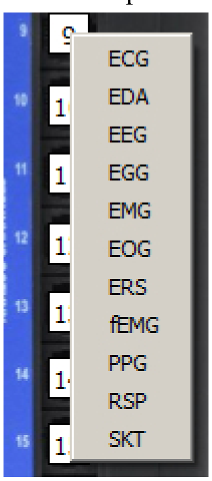
Red: Disconnected from previous Smart Amp in memory. To connect, make sure an amp is plugged into an AMI100D channel and click "Auto-configure" button at bottom left of Smart Amps window.

White: Empty channel (available).

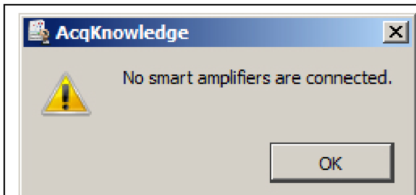
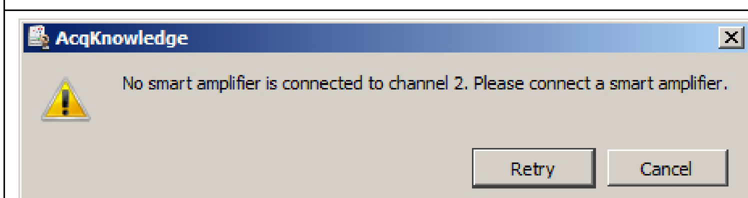
Criss-cross pattern: Channel occupied by other signal or hardware type.

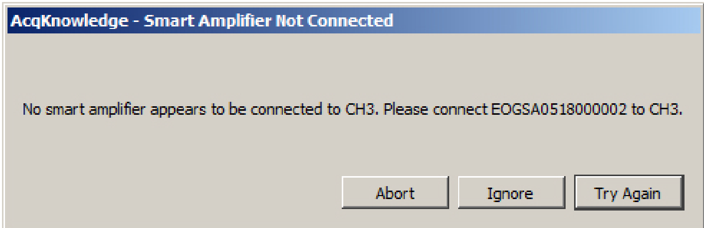
Contextual Menus

Smart Amps can be connected or disconnected from a channel by right-clicking a channel button.



Connection/Disconnection dialogs

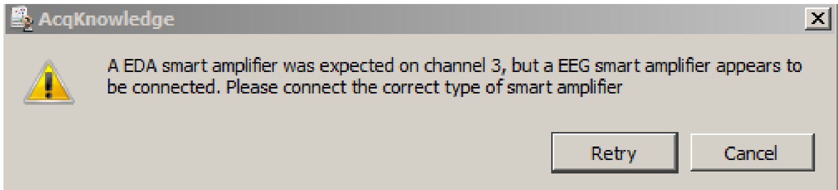
	**Cause:** No amp detected in any channel. **Solution:** Connect an amp (or amps) to AMI100D hardware channel(s) and click the "Auto-configure" button in the Smart Amps screen.
	**Cause:** No amp detected in an individual channel. **Solution:** Connect an amp to the indicated channel and click "Auto-configure."

<table>
<tr>
<td>


</td>
<td>

Cause: A specific amp type and serial number was previously configured in a particular channel, but is no longer detected or has been disconnected.

Solution: Re-connect the specific amp to the channel and click “Refresh Connection Status.”

</td>
</tr>
<tr>
<td>


</td>
<td>

Cause: A specific amp type was configured in a particular channel, but another amp type is now detected.

Solution: Re-connect the previously-detected amp to the channel and click “Refresh Connection Status,” or, to connect the new amp, click “Auto-configure.”

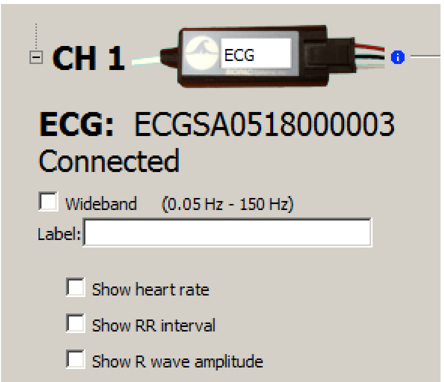
</td>
</tr>
</table>

Onscreen Configuration Options for Smart Amps

Amplifier information and other configuration options are available in Acq*Knowledge* software for all connected Smart Amps. These options include signal-specific filters and calculation channel presets.

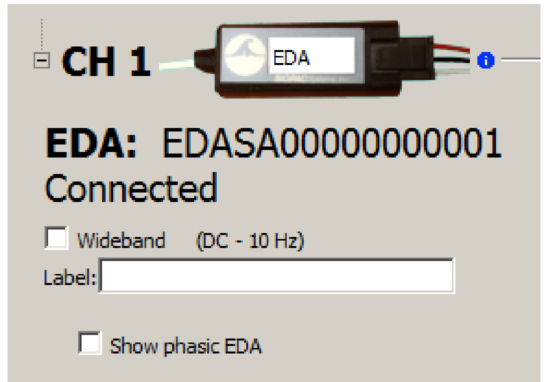
Click the ⊞ button to the left of an amplifier icon to expand these options, as shown below:

ECG100D



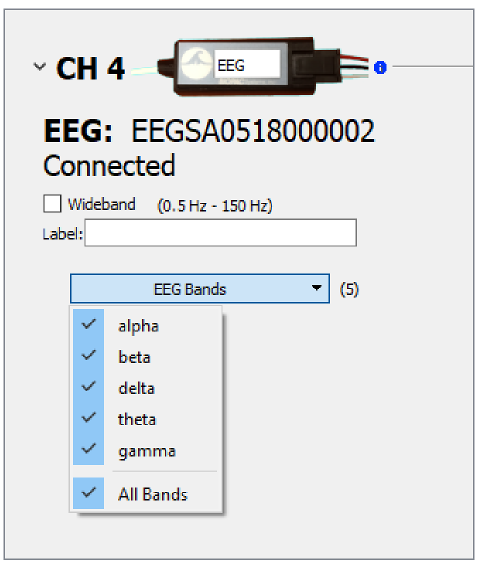
To create a custom channel label, type into the “Label:” field.

EDA100D



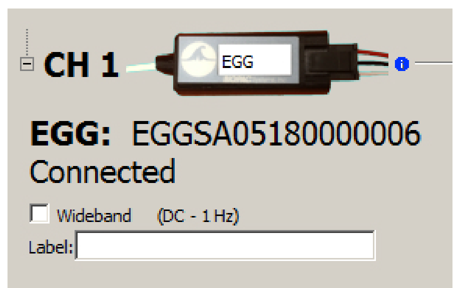
Click the ⓘ icon to display Smart Amp specs and other technical information.

EEG100D

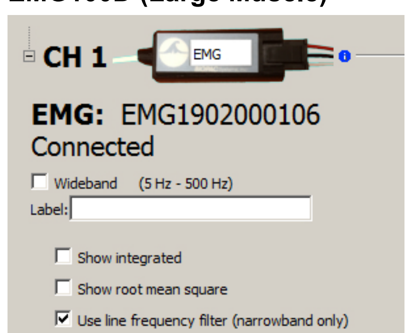


Click the “EEG” Bands button to expand a menu for selecting/deselecting the EEG bands to appear in the Acq*Knowledge* graph:

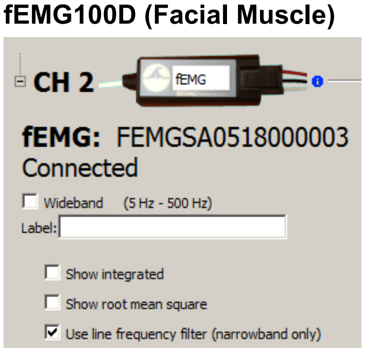
EGG100D



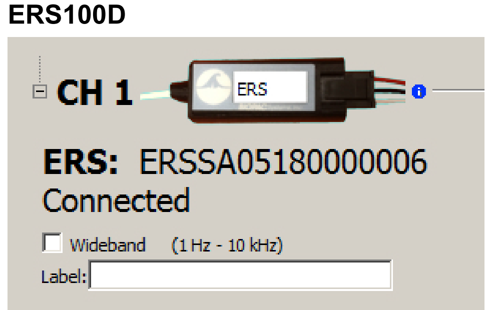
EMG100D (Large Muscle)



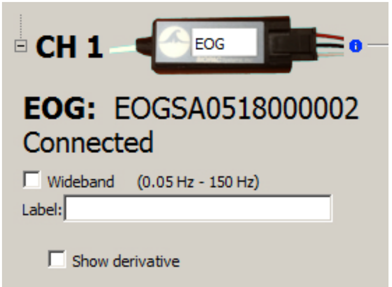
fEMG100D (Facial Muscle)



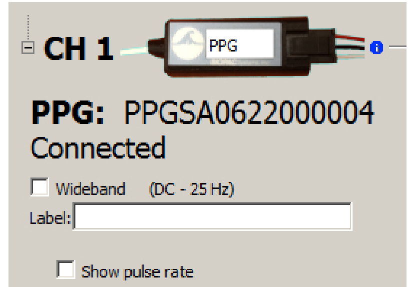
ERS100D



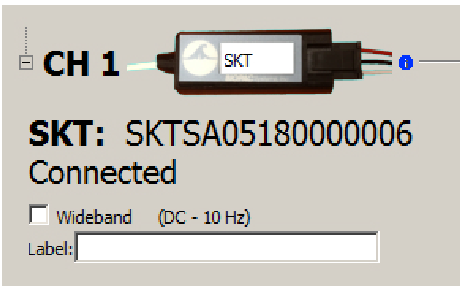
EOG100D



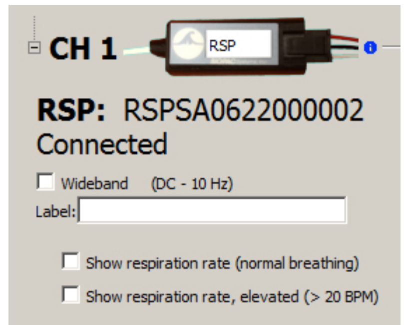
PPG100D



SKT100D

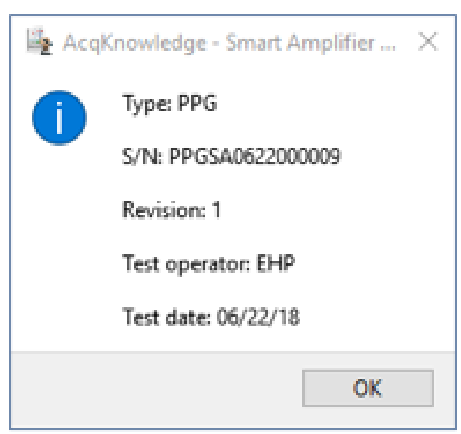


RSP100D



NICO100D

Right-click the amplifier icon to display a “Show Info…” menu. Selecting this option opens an information dialog for the selected amplifier.



Set Up Channels—Advanced

The previous section covered the basic options used in almost all acquisitions. In addition to the features described above, a number of other options are available in terms of setting up channels. These advanced features are also found under the Set Up Data Acquisition > Channels menu item.

Most acquisitions involve collecting analog signals and then displaying them on screen. It is frequently useful, however, to collect other types of data (digital data, for instance) or to perform transformations on analog data as it is being acquired. Channels containing digital signals and transformed analog signals can be collected in addition to the 16 analog channels.

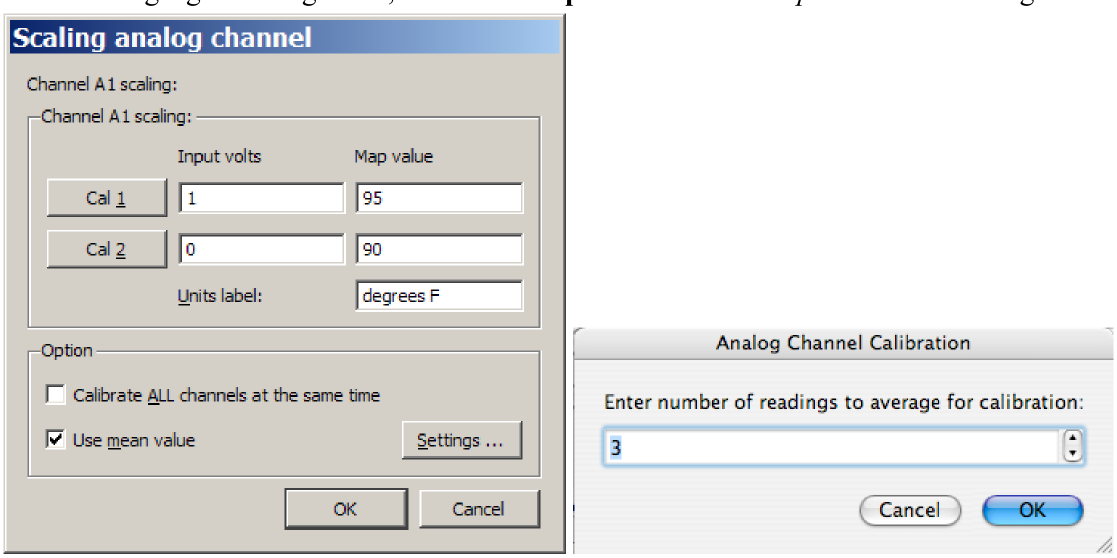
In the upper left corner of the Channels dialog, there are three tabs titled Analog, Digital, and Calculation. These refer to the three respective channel types available in Acq*Knowledge*. The general features (acquiring, plotting, and the like) are the same for each type of channel, although there are considerable differences between the type of data each channel is designed to handle. Up to 16 channels each of analog, digital, and Calculation channels are supported in MP160 and MP150 hardware, and 4 channels of analog, 8 channels of digital and 16 Calculation channels are supported in MP36R hardware. Analog and digital channels may be acquired in any combination, and the only requirement for Calculation channels is that at least one input channel (either analog or digital) is enabled.

Analog channels

Analog channels are the most common type of acquired channel and should be used to acquire any data with "continuous" values. Examples of this include nearly all physiological applications where input devices (transducers and electrodes) produce a continuous stream of varying data. The range of values for analog channels is ±10 Volts.

Acq*Knowledge* supports the rescaling of Analog channel signals to more meaningful numbers. As an example, imagine a temperature transducer is connected to an SKT100C amplifier with a gain setting of 5°/Volt, and output set to channel 1. Ordinarily, the values from the amplifier would be read in as Volts or millivolts. For this acquisition, the signal from the transducer would need to be expressed in terms of degrees Fahrenheit. To calibrate the transducer, bring it to two known temperatures. At the first temperature, take a voltage reading by selecting "Show Input Values" from the Hardware menu. (See page 264 for a description of the Show Input Values options). At 90° F, a reading of 0 Volts will be displayed. The transducer is then brought to a temperature of 95° F, resulting in a reading of +1 Volts.

To scale the incoming signal to degrees F, click the **Setup…** button in the *Input Channels* dialog.



Scaling dialog set to rescale Volts to degrees Fahrenheit and Use Mean Value Settings dialog

The Input Volts and Map (Scale) Value boxes reflect the value of the incoming signal and how it will be plotted on the screen, respectively. Thus, an incoming signal of +1 Volts would be plotted as 95° F, whereas a signal of 0 Volts would be plotted as 90° F. Acq*Knowledge* will perform linear extrapolation for signal levels falling outside this range (i.e., -2 Volts will be scaled to 80 ° F), as well as perform similar interpolation for values between this range. Enter these numbers in the scaling dialog, type in “degrees F” for Units, and click OK.

As a shortcut for scaling channels, use the Cal 1 and Cal 2 buttons. Click either of these buttons to read in the current voltage for the selected channel. In the above example, the transducer could simply be set to a known temperature, then Cal 1 could be clicked, and then the temperature could be entered in the Map (Scale) value box for Cal 1.

Next, the transducer could be brought to another known temperature that is considerably higher or lower than the first. Click Cal 2 and the new known temperature could then be entered in the Map (Scale) value box for Cal 2. Acq*Knowledge* calculates the slope and offset from the two points entered. Each data sample from channel 1 will now be scaled according to the slope and offset calculations previously made. When an acquisition is performed, the amplitude scale (vertical axis) will reflect the rescaled units.

> *It is important to note* that Cal 1 and Cal 2 cannot be used when data is being acquired. In other words, a channel must be calibrated before it can be acquired. To set the calibration for a given channel, connect the input device to the data acquisition unit, power up the Hardware, and then perform the calibration before starting data acquisition.

The Calibrate all channels at the same time option is used when identical types of transducers or signals are being simultaneously recorded on two or more channels.

If this option is selected, when Cal 1 or Cal 2 is pressed:

- Map (Scale) Value will be updated for all active channels
- Input Volts need to be updated for each channel individually.

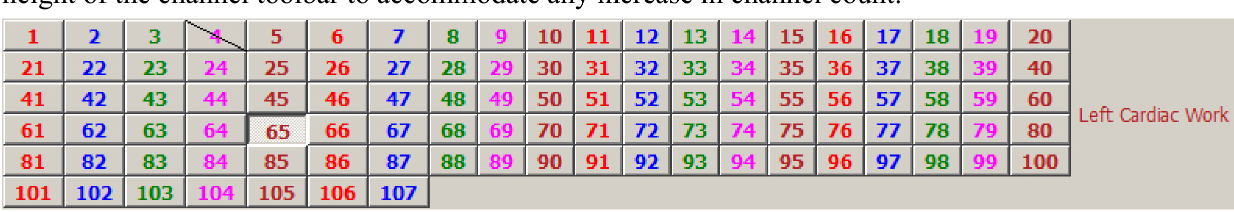
The **Use mean value** option is useful if the input voltage signal is noisy around a mean value. The “Input Volts” value returned will be the mean value over the specified number of readings. When this option is selected, a Settings… button is activated and generates an “Analog Channel Calibration” prompt for the number of readings.

The data is read the number of times indicated in the prompt and then the readings are averaged. The rate of obtaining these readings is indeterminate because the rate depends on the actual hardware unit as well as the communication type.

Increased Channel Count Support

Previous versions of Acq*Knowledge* software supported a total maximum of 60 analog, digital and calculation channels per graph. In Acq*Knowledge* 4.3, channel count capability was extended to a theoretical maximum of 15,000 channels. While it is not generally feasible or useful to work with this many channels, it is now possible to store and combine data derived from multiple hardware units, and perform complex specialized analysis with data output to channels in the existing graph. (For example, advanced ICG analysis can potentially add up to 20 additional channels to the existing total.)

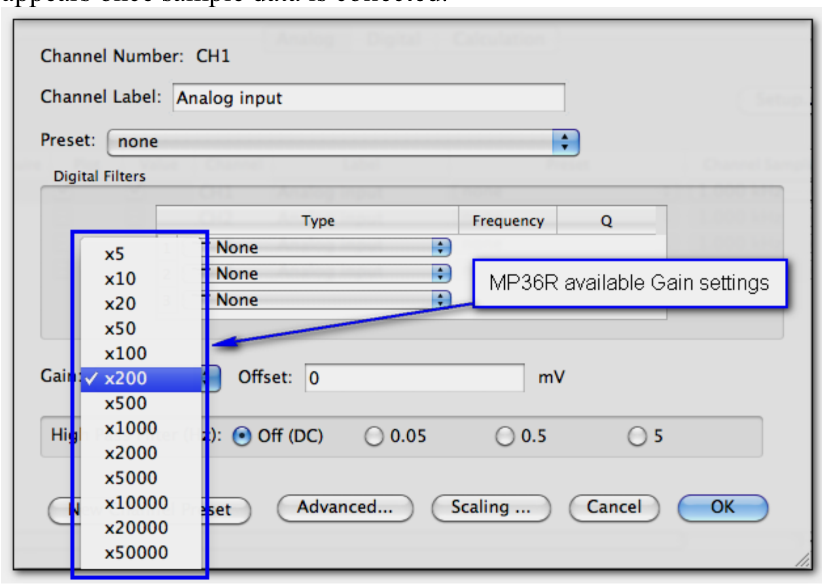
When a large number of channels are present, the channel buttons appear in rows of 20 and will extend the height of the channel toolbar to accommodate any increase in channel count.



Clicking into the right pane of the channel toolbar opens a contextual menu listing all channel numbers and channel labels.

Analog channels MP36R

The MP36R analog channels may also be configured for gain and other parameters, but additionally allows the channel gain to be configured directly with a variety of input ranges. Gain settings are accessible via a pop-up menu in the Channel setup dialog. (MP36R > Set Up Data Acquisition > Channels > Setup) The **Gain** setting specifies the extent to which an incoming signal is amplified. The Gain is automatically set when a data type is selected from the available **Presets**. The preset Gain settings are only educated guesses and should be used as initial starting values. It may be necessary to adjust the gain settings depending on how the amplified signal appears once sample data is collected.



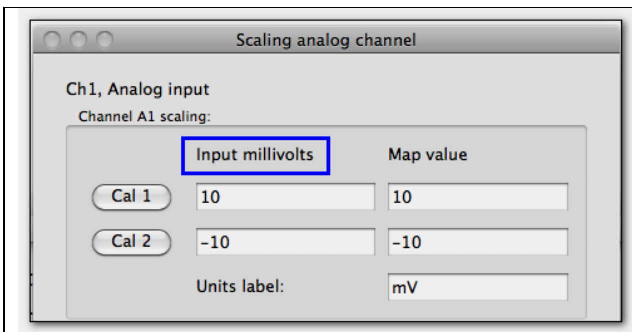
Offset

To correct the offset of an incoming analog signal, a constant can be added to or subtracted from the signal prior to amplification. Offset can occur if a transducer or electrode has inherent offset. By default, **Offset** is set to zero, and the allowable entry range will vary depending on the **Gain** and **Scaling** values.

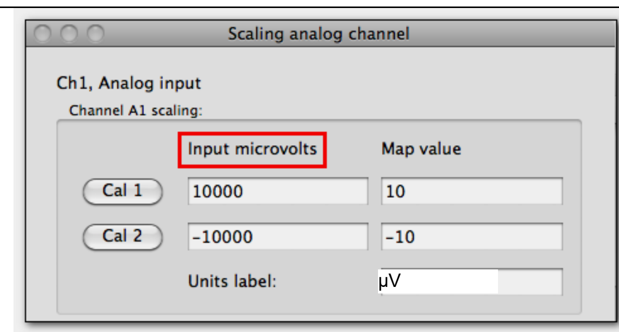
To make inputting voltages easier, the analog channel scaling dialog for the MP36R displays the input voltages in units that adapt to the gain setting. (x200 is the default)

The scaling units will adjust dependent upon the gain setting as follows:

- If the gain is set to < x1000, the Scaling input units will display as millivolts (mV).
- If the gain is set to > x1000, the Scaling input units will display as microvolts (µV).



Channel gain set to **< x1000** displays mV input units

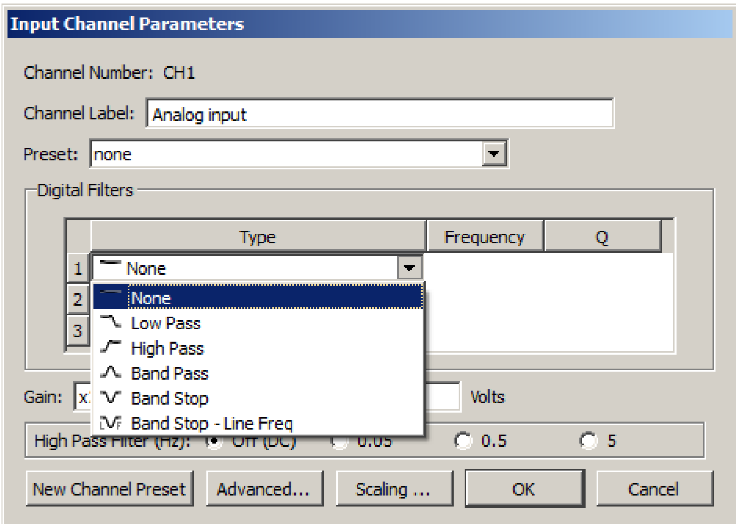


Channel gain set to **> x1000** displays µV input units

Adjustable, user defined, digital IIR filters for MP36R

The MP36R Unit allows up to three user-configurable, sequential, biquadratic (second order) Infinite Impulse Response (IIR) filters per MP unit channel. These filters are typically configured by choosing a **Preset** but can be changed manually via the Input Channel Parameters dialog (MP36R > Set Up Data Acquisition > Channels > Setup button). Each of these three filters can be uniquely set up as a low pass, band pass, high pass or notch (band reject) filter.

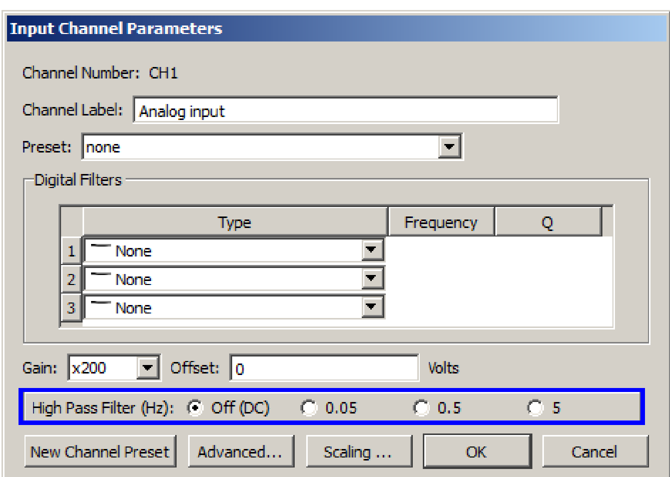
In the "Digital Filters" section, select Filter 1, 2, and/or 3 and then adjust the *Type*, *Freq*, and *Q*.



The default setting is no filters applied.

High Pass Filters MP36R

These filters are implemented using resistors and capacitors in the front end circuitry of the MP36R unit. They are set via the "**High Pass**" section of the Input Channel Parameters dialog (MP36R > Set Up Data Acquisition > Channels > Setup").



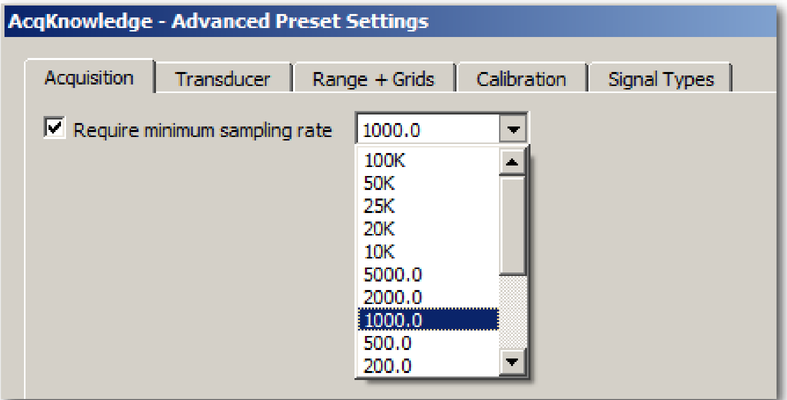
High Pass Filter	Appropriate use
0.05 Hz HP	ECG Respiration data
0.5 Hz HP	ECG when there is a lot of motion artifact causing a shifting baseline EEG Pulse plethysmograph Most other types of AC Coupled data
5 Hz HP	EMG Heart Sounds

Additional controls in MP36R Input Channel Parameters

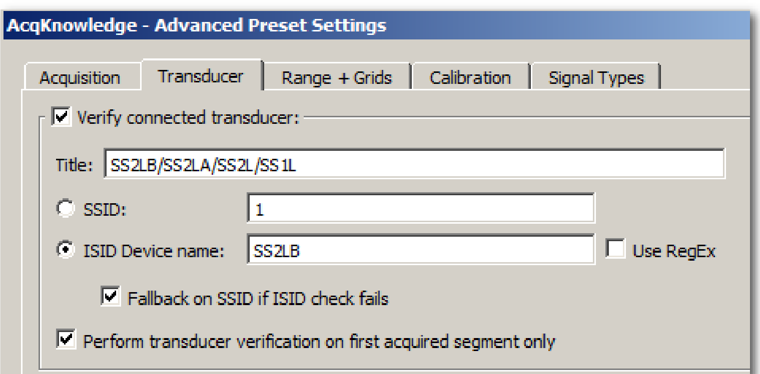
Button	Explanation
New Channel Preset	Allows a custom Preset to be saved under a unique name
Advanced	Opens Advanced dialog. The Advanced dialog may be used to specify additional settings, requirements, and dependencies for the preset. See below for complete explanation of all Advanced options.
Scaling	Use to configure the value of the incoming signal and how it will be plotted on the screen.

MP36R Advanced Preset Settings

Click the Advanced button to open a dialog containing the following optional preset configuration options.



Acquisition Tab	Explanation
Require minimum sampling rate	When enabled, specifies that a minimum sampling rate must be selected for acquisition to continue.



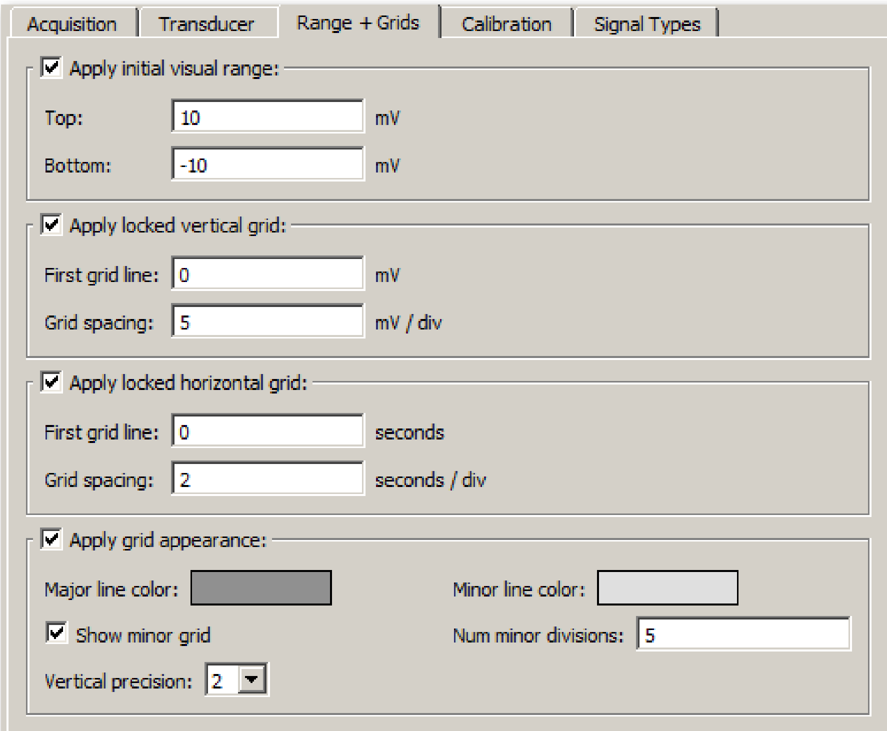
Transducer Tab	Explanation
Verify connected transducer	When enabled, the software will check for a specific transducer according to the settings in this group box prior to the start of each appended segment.
Title	Editable text field used to identify transducer name.
SSID	If checked, indicates which SmartSensor resistor ID should be validated for this channel prior to each acquisition. The ID must be an integer between 1 and 23. See SSID table on page 141.
ISID Device Name	If checked, indicates that the internal transducer description should be validated for this channel prior to each acquisition.
Use RegEx	Check this to treat the ISID device name as a regular expression to match against ISID device names.

Fallback on SSID if ISID check fails	If the ISID device name check is unsuccessful for a connected transducer, fall back and check the SmartSensor resistor ID. See SSID table on page 141
Perform transducer verification on first acquired segment only	When enabled, the software will check for a specific transducer according to the settings in this group box prior to the start of first segment only.

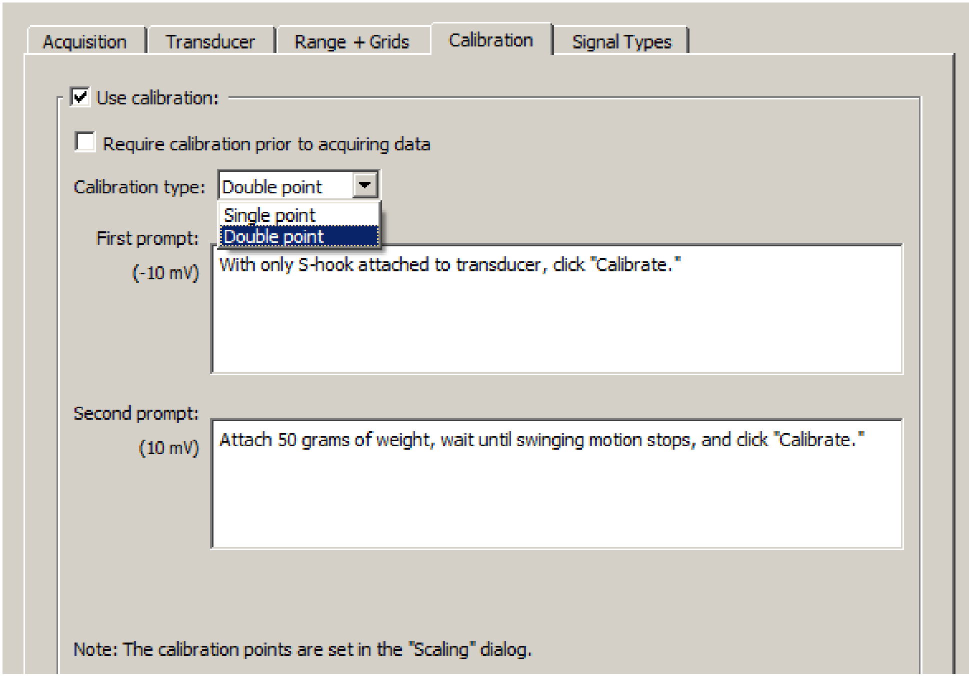
MP36R Transducer SSID Table

Device Part #	Description	SSID	ISID Name
BSLCBL3A, BSLCBL4B	Recording cable	1	
BSLCBL5	3.5mm phone plug adapter	6	
BSLCBL8, BSLCBL9	High-impedance recording cable	1	
BSLCBL14A	3.5mm phone plug adapter to MP35 Input.	6	
BSLSTMB/A	10 V setting	18	
BSLSTMB/A	100 V setting	19	
BSL-TCI13	Piezo interface cable	1	
BSL-TCI21	pH probe interface	12	
SS1L, SS2L, SS2LA	Electrode lead set	1	
SS2LB	Electrode lead set	N/A	SS2LB
SS3LA	EDA (GSR) finger electrodes	2	
SS4LA	Pulse Plethysmograph finger transducer	3	
SS5L, SS5LA, SS5LB	Respiration Belt (for Chest)	4	
SS6L, SS7L, SS8L	Temperature transducer	5	
SS9L, SS9LA	BNC Adapter	6	
SS10L	Pushbutton switch	7	
SS11LA	Airflow transducer	8	
SS11LB	Airflow Transducer	N/A	
SS12LA	Variable range force transducer	9	
SS13L	Blood Pressure (Arterial)	10	
SS14L	Displacement transducer	11	
SS17L	Piezo microphone	14	
SS19L	Blood Pressure cuff (with Gauge)	10	
SS19LA	Blood Pressure cuff	N/A	SS19LA
SS19LB	Blood Pressure Cuff	N/A	SS19LB
SS20L, SS21L, SS22L, SS23L, SS24L	Goniometer	16	
SS25L, SS25LA	Hand Dynamometer	9	
SS25LB	Hand Dynamometer	N/A	SS25LB
SS26L, SS26LB, SS27L	Accelerometer	17	
SS28L	Heel Toe Strike assembly	9	
SS29L	Multilead ECG cable	1	
SS30L	Stethoscope, electronic	14	
SS31L	Non-Invasive Cardiac Output Module	15	
SS32L	Dissolved Oxygen probe	20	
SS33L	GAS – O_2 (Used on GAS-System2)	21	
SS34L	GAS – CO_2 (Used on GAS-System2)	22	
SS35L	Flow transducer	18	
SS36L	Reflex Hammer	9	
SS39LA	MP3X Circuit Probe and Power Cable for Breadboard	6	
SS40L, SS41L, SS42L	Diff. Pressure transducer	10	
SS43L	Psychological response indicator	11	
SS56L	Clench Force (Bulb) transducer	N/A	SS56L
SS57L	EDA (GSR) with electrode pinch leads	2	
SS57LA	EDA (GSR)	N/A	SS57LA
SS59L	Superlab Interface cable for MP35	6	
SS61L	Finger Twitch transducer	16	
SS62L	Microphone	14	

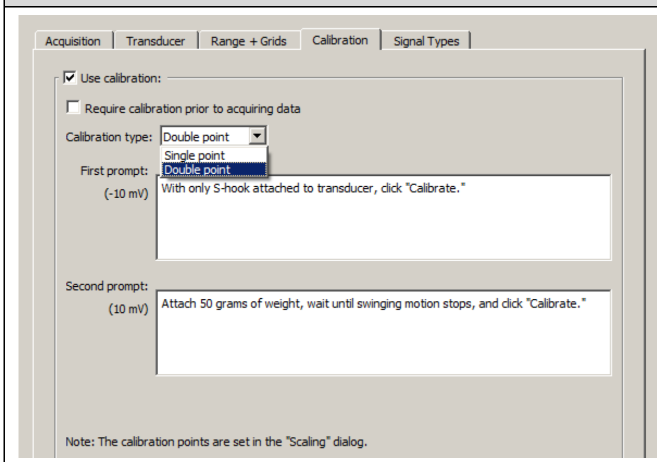
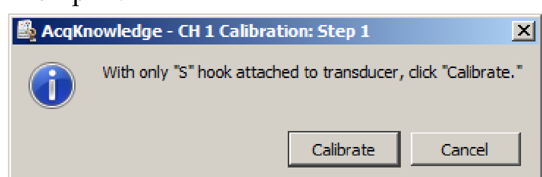
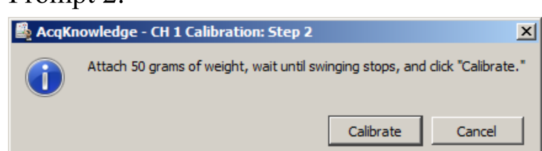
SS63L, SS64L, SS65L, SS66L	Fixed Range Force Transducer	9	
SS67L	Pneumogram transducer	10	
SS68L	Ph Probe	12	
SS70L	BNC Adapter (for MP35), Isolated version	6	



Range + Grids Tab	Explanation
Apply initial visual range	The initial vertical axis range of plotted data will be set as indicated at acquisition start of the first data segment.
Top	Indicates the maximum vertical visual range in destination channel units.
Bottom	Indicates the minimum vertical visual range in destination channel units.
Apply locked vertical grid	Locked vertical grid settings are applied for the channel. For more details on grid setups, see Grid Details on page 84.
First grid line	Provides the fixed location of the origin of the vertical grid.
Grid spacing	Sets the spacing interval between major vertical grid divisions.
Apply locked horizontal grid	A channel-specific independent horizontal grid will be applied when the channel is added to a graph.
First grid line	Sets the origin location of the horizontal grids.
Grid spacing	Sets spacing between major horizontal grid lines based on the time domain.
Apply grid appearance	Enables options for setting grid color/appearance of major and minor grid lines.
Major line color	Allows customization of major grid line color.
Minor line color	Allows customization of minor grid line color.
Show minor grid	Shows/hides minor gridlines
Vertical precision	Indicates number of digits displayed on vertical axis.
Num minor divisions	Sets the number of minor grid divisions for the channel.

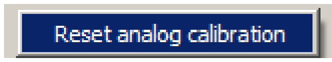


Calibration tab options are designed to assist in channel setup. They allow "custom" calibration prompts to be used to guide users through the setup/calibration process. These prompts will appear in the main graph window after clicking the graph's Calibration icon (or 'Start' button, if "Require calibration" is checked.) The 'Calibrate' button in the prompts are linked directly to the Cal 1 and Cal 2 input values found in the standard "Scaling" dialog and offers an alternate method of setting these values. If multiple channels use the calibration option, the calibration prompts will be presented in sequential channel order.

Calibration Tab Setup Example:	**Resulting User Prompts:**
	Prompt 1: 
	Prompt 2: 

See table for detailed explanation of calibration options.

Calibration Tab	Explanation
Use Calibration	Calibration procedure is applied after clicking the "Calibration' icon in the graph channel's vertical scale region. One (if single point) or two (if double point) custom prompts are presented in place of the usual 'Scaling analog channel" dialog. Each prompt has a 'Calibrate' and "Cancel' button, one of which must be responded to in order to continue.
Require calibration prior to acquiring data	The above procedure is applied, except calibration prompts are presented as follows when the 'Start' button is clicked. • Append mode: Calibration required at start of first segment recording only. • Save Once or Autosave mode: Calibration required at start of first recording only. (Subsequent passes do not require re-calibration.)

	NOTE: The "Require calibration prior to acquiring data" option has been modified in Acq*Knowledge* 5.0.2 to improve usability when using transducers that require calibration and the rewind mode. After initial calibration of the first data segment, that calibration will be retained even after rewinding the data to remove the segment. This allows users to perform a calibration and verification acquisition, and then remove that verification segment prior to the next data acquisition. **If recalibration is desired**: Press the Shift key when clicking the Rewind toolbar button, or right-click the rewind toolbar button and choose "Reset analog calibration" from the contextual menu. 
Calibration Type	Specifies calibration option to be performed. Two types are available: • Single point – Useful for quickly zeroing the baseline offset or establishing a preload offset value. Presents a single prompt to the user. Upon click of “Calibrate”, the input voltage is set as the new “Cal2 Input voltage” in the Scaling dialog (equivalent to clicking “Cal2”). It then calculates the difference between the old and new Cal2 Input values then adds this to the Cal1 Input value. In other words, it preserves the Scaling’s slope while shifting the offset. • Double point – records two independent voltages in a sequence of two prompts and records the first as the input voltage for Cal2 and the second for the input voltage in Cal1 For more details see examples below
Prompt	Use to input “custom” calibration prompt text. Up to 500 characters can be entered and carriage returns can be used. The resulting prompts will be dynamically sized according to the amount of text entered. Note: The Scaling dialogs “map values” are displayed for reference to the left of the Prompt field and can only be modified in the Scaling dialog. Any changes will be dynamically updated in the Calibration dialog.
Apply using hardware voltage offset	This option is available only for single point calibration. It is intended for single point zeroing where, instead of adjusting the scaling values, the voltage offset of the channel is changed to zero it in hardware. This is used for some transducers that have additional correction that requires a hardware zero voltage, namely the SS11LB and SS25LB.
Do not adjust “Cal 1” offset.	This option is available only for single point calibration. When this option is enabled, the Cal 1 voltage value will remain fixed

Examples of how to use the Calibration option

Example of “Double point” calibration for the SS12LA Force Transducer:

1. Connect the SS12LA to the MPs CH 1 input and choose MP > Set Up Data Acquisition > Channels.
2. Select “Force 0-50 grams” from the Preset pull-down menu then click “Setup”.
3. From the “Input Channel Parameters” dialog, click “Advanced” then click on the “Calibration” tab.
4. Check “Use calibration”, “Require calibration prior to acquiring data” and choose “Double point” as the Calibration type.
5. Enter the desired “First prompt” text. For example,

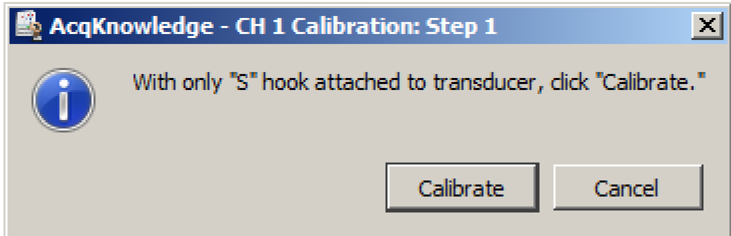
“With only “S” hook attached to transducer, click “Calibrate”.

6. Enter the desired “Second prompt” text. For example,

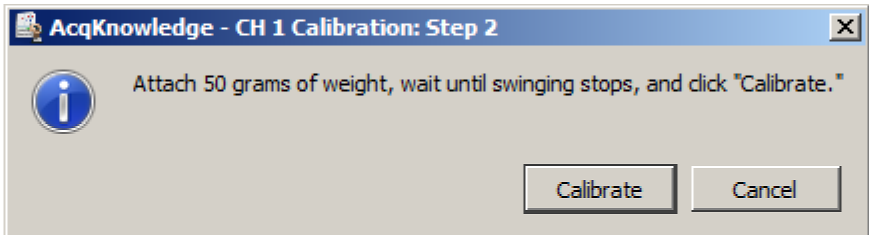
“Attach 50 grams of weight, wait until swinging motion stops, then click “Calibrate”.

7. Click OK and exit the “Input Channel Parameters” dialog.

8. Click the Start button. The first prompt will appear:

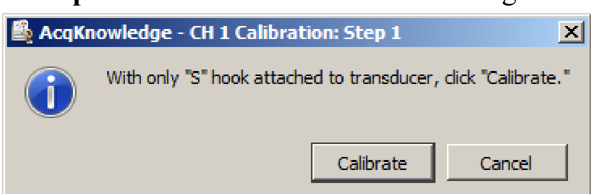
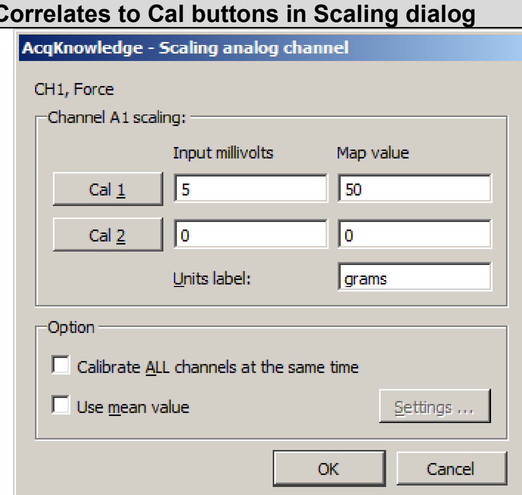
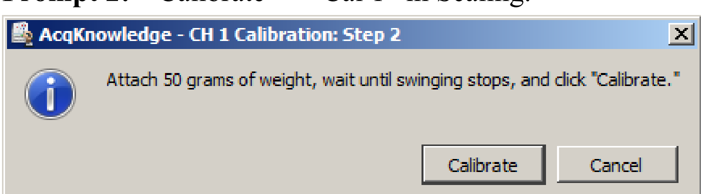


9. Follow the directions and click ‘Calibrate’. The second prompt will appear:



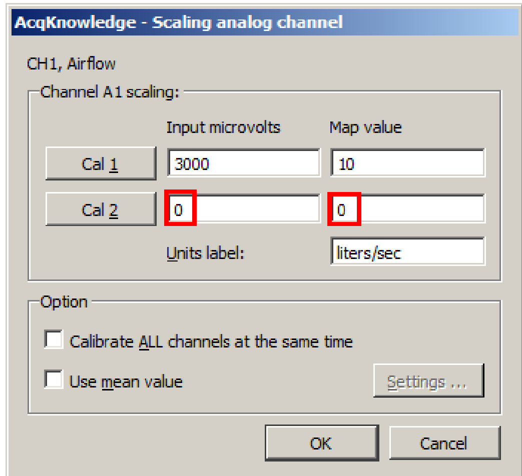
10. Follow the directions and click ‘Calibrate’. Calibration is complete and data recording will start.

Note: The Scaling dialogs Map values (i.e. 0 and 50 grams) are assigned to the calibration prompts as follows: Cal 2 Map value is assigned to Prompt 1 and Cal 1 Map value is assigned to Prompt 2.

<table>
<tr><th>“Calibrate” in Prompts</th><th>Correlates to Cal buttons in Scaling dialog</th></tr>
<tr><td>Prompt 1: “Calibrate” = “Cal 2” in Scaling.

</td><td rowspan="2">
</td></tr>
<tr><td>Prompt 2: “Calibrate” = “Cal 1” in Scaling.

</td></tr>
</table>

Example of "Single point" calibration for the SS11LA Airflow Transducer:

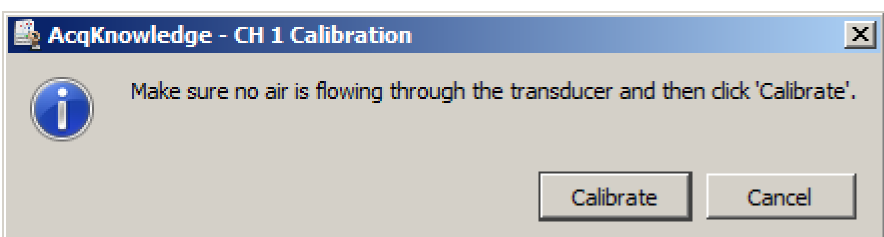
1. Connect the SS11LA to the MPs CH 1 input and choose MP > Set Up Data Acquisition > Channels.
2. Select "Airflow (SS11LA)" from the Preset menu then click "Setup".
3. Click "Scaling" and change both the "Cal 2" Input and Map values to "0", then click "Ok".



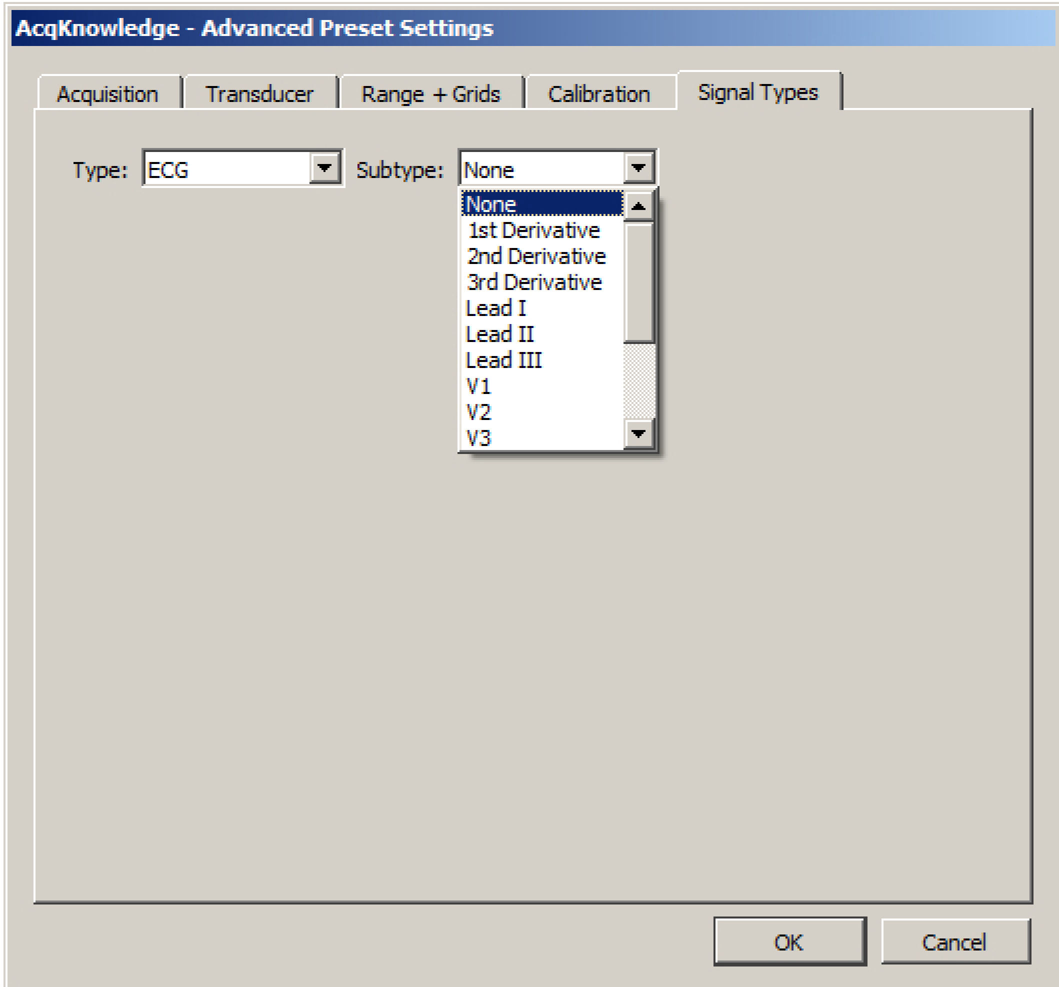
4. From the "Input Channel Parameters" dialog, click "Advanced" then click on the "Calibration" tab.
5. Check "Use calibration", "Require calibration prior to acquiring data" and choose "Single point" as the Calibration type.
6. Enter the desired "prompt" text. For example,

"Make sure no air is flowing through the transducer and click "Calibrate"."

7. Click OK and exit the "Input Channel Parameters" dialog.
8. With the SS11LA held upright, click the Start button. The single prompt will appear:



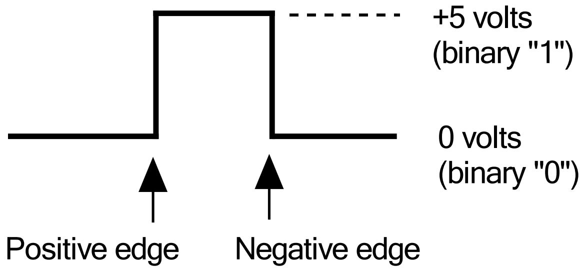
The recording should show 0 liters/second with no air flowing through the transducer.



The Signal Types tab offers advanced options or "subtypes" to add to the selected preset or signal type. The subtype options available are dependent upon the type of signal selected. For example, the ECG type contains a variety of ECG lead configurations and common ECG signals, whereas Respiration offers various airflow options. The subtypes are used for cases when users wish to retain specific information about lead configuration or other details about the signal. Also see the Analysis Shortcuts section on page 284.

Digital Channels

In contrast to analog channels, digital channels are designed to collect data from a signal source with only two values (0 and 1). This type of data can be useful in recording whether a switch is open or closed, and ascertaining if a device is on or off. Input values for digital channels have two values, +5 Volts and 0 Volts. The hardware interprets +5 Volts as a digital 1 and interprets 0 Volts as a digital 0. Since digital channels have a fixed value, the scaling option is disabled for these channels. The main function of digital channels is to track on/off devices such as push-button switches and/or to receive digital signals output by timing devices. Similarly, these channels are also used to log signals from devices that output auditory/visual stimulus for examination of stimulus response patterns.

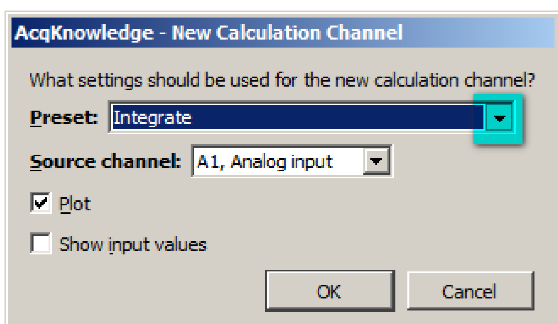


Calculation Channels

Compared to either analog or digital channels, Calculation channels do not collect external data, but transform incoming data in some way. These channels do not alter the original data, but create new channels (with channel numbers starting at CH40) that contain the modified data.

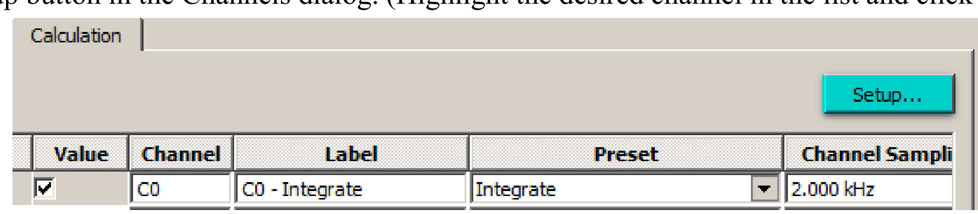
Calculation channels can be used to compute a host of new variables by using transformations (including BPM, integration calculations, and math functions). The channels are Set Up in much the same way (using Acquire/Plot/Values boxes) as analog or digital channels, with the exception of the pull-down menu next to the Calc button and the Setup dialog.

To enable a Calculation channel or channels, check the Acquire box for each channel to be added (the Plot and Value boxes are optional). When a new Calculation channel is enabled, a dialog will appear enabling the selection of the desired Preset type and Source channel. To change the Preset and Source channel types from the defaults of Integrate and A1, click the  button to the right of the Preset and Source channel fields and choose the desired option.



After clicking OK in the above dialog, an additional Setup dialog for the selected preset is presented. See Chapter 6 for a detailed explanation of the various Calculation channel setup options.

Once the Calculation channel parameters are set, the options referenced above can be subsequently modified by using the Setup button in the Channels dialog. (Highlight the desired channel in the list and click "Setup.")



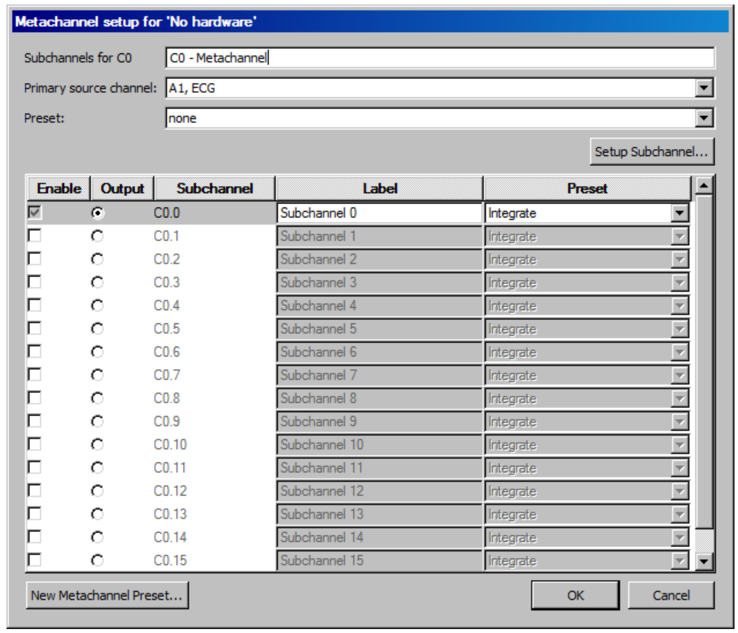
Up to 16 Calculation channels can be acquired, and the output of one Calculation channel can be used as the input for another channel, as long as the output channel has a higher channel number than the input channel. In other words, it's possible for Calculation channel 3 to include the result of Calculation channel 1, but not the other way around. This allows for complex Calculations to be performed that involve two or more Calculation channels such as filtering ECG data then computing BPM.

TIP: All of the operations (except Control and Metachannel) that can be performed online can also be performed after an acquisition has been completed. These options are available under the Transform and Analysis menus.

Metachannel

Calculation metachannels provide a method for expanding the 16 available calculation channels to allow for more complex online analysis. The metachannel calculation channel type combines multiple steps into a single calculation channel so that a chained computation can be performed using a single calculation metachannel.

- Acq*Knowledge* can display the results of up to 16 metachannels, allowing for a total of 256 intermediate subchannel steps.



One metachannel can contain up to 16 subchannels, each of which can be individually configured. Subchannels can perform any of the functions of top-level calculation channels.

Each metachannel has one user-defined output channel. The output subchannel is the only waveform data that will be recorded in the graph for that metachannel. All other subchannels associated with that metachannel are temporary; they do not display in the graph and require no extra space in the graph file to compute.

Metachannels alleviate the need to use top-level calculation channels for computing intermediate steps where only the final computation is desired. Metachannels also can be used as the basis of presets, allowing multi-step analyses to be applied with a single preset.

Computation takes place at the lowest waveform sampling rate of all of the referenced source channels, and all subchannels are computed at this rate.

Metachannels labels display in the graph as C#.#

To have Acq*Knowledge* perform a Metachannel calculation:

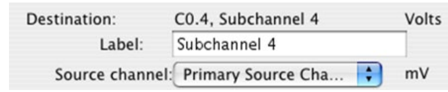
1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. If necessary, check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Metachannel.
5. Click the Setup button in the Input Channels dialog to generate the Metachannel dialog.

Primary Source

The primary source for a metachannel can be set to any analog or digital enabled channel, or an enabled calculation channel with a lower number.

Set Up Subchannel

Click this button to display the calculation setup dialog for the selected subchannel and then set the calculation parameters and the source channel.



Source channel: Each subchannel can be set to use the primary source channel as its data source or another channel (analog, digital, or lower-index calculation channel). When the primary source channel for the metachannel is changed, the source channel of each subchannel will implicitly be changed.

Limitations on Subchannels

Subchannels are allowed to take on any of the main calculation channel types. All calculation types are available, with some restrictions.

- Output of reset events is not supported for Integrate and Rate subchannels.
- For Expression subchannels, the expression language will be enhanced to allow for "PSC" to be typed into the expression to refer to the data of the primary source channel.
- Unlike regular calculation channels, the actual data for subchannels is not retained in memory. Subchannels are only used as temporary data and the results discarded after the value of the output subchannel has been computed.

AcqKnowledge *QUICK STARTS*

Quick Start templates (.gtl graph template files) are installed to the Sample Data folder. Use ***Quick Start*** files to establish the settings required for a particular application or as a good starting point for customized applications. *See* Open As Graph Template on page 290 for details.

Q##	Application(s)	Feature
1	EEG Sleep Studies	Real-time EEG Filtering Real-time EEG Filtering
2	EEG	Evoked Responses
3	EEG Evoked Response	Event-related Potentials Event-related Potentials
4	Nerve Conduction Velocity	Nerve Conduction Studies
5	Evoked Response	Auditory Evoked response & Jewett Sequence
6	Evoked Response	Visual Evoked Response
7	Evoked Response	Somatosensory Evoked Response
9	Neurophysiology	Extra-cellular Spike Recording
10	Psychophysiology	Autonomic Nervous System Studies
12A	Psychophysiology Plethsimography	Female Sexual Arousal Studies
12B	Psychophysiology Plethsimography	Male Sexual Arousal Studies
13	EBI Cardiovasc. Hemodynamics Exercise Physiology	Cardiac Output Noninvasive Cardiac Output Measurement Noninvasive Cardiac Output
15	EOG	Nystagmus Investigation
16	EOG	Saccadic Eye Movements
17	Plethsymography	Indirect Blood Pressure Recordings
18	Psychophysiology Hemodynamics	Pulse Transit Time
19	Sleep Studies	Multiple-channel Sleep Recording
20	Sleep Studies ECG Cardiovasc. Hemodynamics	Online ECG Analysis Online ECG Analysis ECG Analysis
21	Sleep Studies	SpO_2 Analysis
22	ECG	Einthoven's Triangle & 6-lead ECG
23	ECG	12-lead ECG Recordings
24	ECG	Heart Sounds
25	Cardiovasc. Hemodynamics	Online Analysis
26	Cardiovasc. Hemodynamics	Blood Pressure
27	Cardiovasc. Hemodynamics	Blood Flow
28	Cardiovasc. Hemodynamics	LVP
31	NIBP	Psychophysiology
32	*In vitro* Pharmacology	Tissue Bath Monitoring
33	*In vitro* Pharmacology	Pulsatile Tissue Studies
34	*In vitro* Pharmacology	Langendorff & Working Heart Preparations
35	*In vitro* Pharmacology Pulmonary Function	Isolated Lung Studies Animal Studies
38	Pulmonary Function	Lung Volume Measurement
39	Exercise Physiology	Respiratory Exchange Ratio
40	EMG	Integrated (RMS) EMG
41	EMG	EMG and Force
42	Biomechanics	Gait Analysis
43	Remote Monitoring	Biomechanics Measurements
44	Biomechanics	Range of Motion
45	Vibromyography	Muscle Activity
46	Pressure Volume Loop	Blood Pressure & Flow
47	Heart Rate Alarm	Monitor heart rate with audible alarm
48	Segment Timer Gauge	Record and display ECG with segment timer in the gauge window

Chapter 6 Calculation Channel Presets

Integrate	Blackman-Windowed Tone	Small Animal Mean BP
Smoothing	dp/dt @ 200 samples/sec.	Small Animal Heart Rate
Difference	dp/dt @ 500 samples/sec.	Square Wave
Rate	dp/dt @ 1000 samples/sec.	Ramp Plateau Ramp
Math	ECG R-R Interval	Vibromyography
Function	ECG R Wave Amplitude	Electrocardiogram (ECG), .5 - 35 Hz
Filter - IIR	EEG Alpha (8 - 13 Hz)	Electrocardiogram (ECG), .05 - 35 Hz
Expression	EEG Beta (13 - 30 Hz)	Electrocardiogram (ECG), .05 - 100 Hz, AHA
Delay	EEG Theta (4 - 8 Hz)	Electrocardiogram (ECG), 0.5 - 150 Hz
Control	EEG Delta (0.5 - 4 Hz)	Electroencephalogram (EEG), .5 - 35 Hz
FLC	EEG Gamma (30 - 90 Hz)	Electroencephalogram (EEG), .5 - 100 Hz w/notch
WFLC	EGG (.02 - .125 Hz)	Electrogastrogram (EGG)
CWFLC	Lung Volume	Electromyogram (EMG), 5 - 250 Hz w/notch
Adaptive Filter	Pulse Rate	Electromyogram (EMG), 5 - 500 Hz
Comb Band Stop Filter	Random Pulses	Electromyogram (EMG), 5 - 1000 Hz
Metachannel	Respiration Rate	Electromyogram (EMG), 30 - 250 Hz w/notch
Rescale	Respiration Rate, Elevated (> 20 BPM)	Electromyogram (EMG), 30 - 500 Hz
Run Macro	Segment Timer	Electromyogram (EMG), 30 - 1000 Hz
Slew Rate Limiter	Sine Wave	Electrooculogram (EOG), .05 - 35 Hz
Filter - FIR	Small Animal dp/dt Minimum	Evoked response (ERS), 1 - 500 Hz
Derivative	Small Animal dp/dt Maximum	Evoked response (ERS), 20 - 500 Hz
External function	Small Animal Systolic BP	
Finite Difference	Small Animal Diastolic BP	

Calculation Presets establish settings to target application-specific analysis. Presets exist for a broad range of analysis functions, including Fourier Linear Combiners and Adaptive Filtering. Start with existing presets for a specific species or protocol—for example, human vs. small animal, or stationary vs. exercising measurements.

The Channel Setup dialog contains a "Preset" pop-up menu by each channel that lists the current Preset or, if no Preset has been selected for that channel, the Calculation type (Integrate, Difference, etc.). When selecting a Preset for a particular channel, the channel is configured with the settings associated with that Preset.

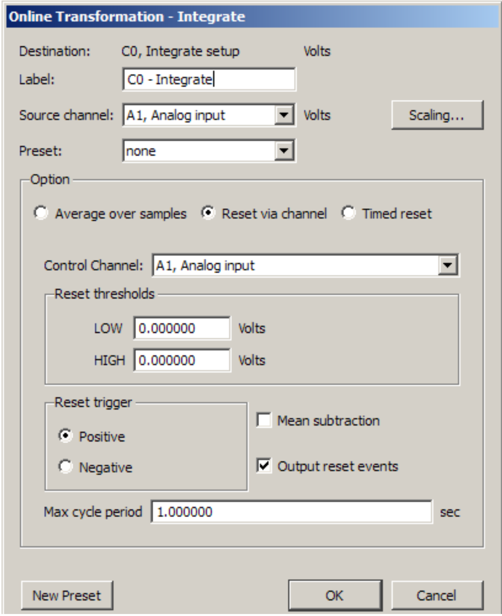
The Setup dialog has a "Presets" pop-up menu that contains all of the Presets for the Calculation type being configured. To enable the Preset pop-up menu, set at least one analog channel to "Acquire" (calculation channels require a source channel). For example, if a Difference Calculation channel is being configured; all Presets for the Difference Calculation will be listed. Just click the Presets head and scroll to select the desired preset.

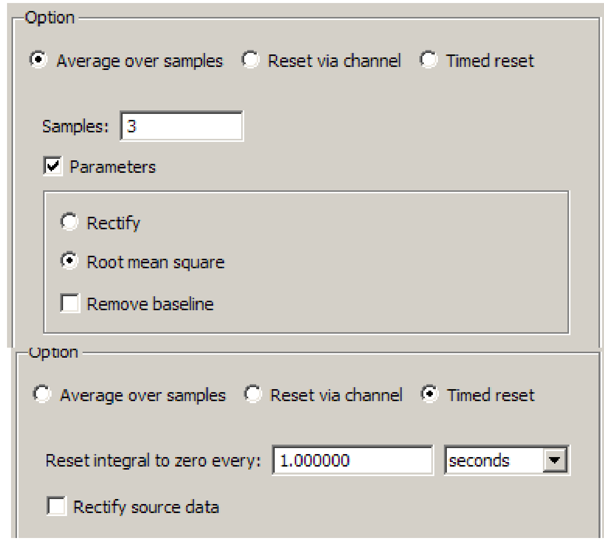
After selecting a Preset, the Setup dialog is updated with the corresponding information.

- The Setup dialog reads "none" if the channel configuration doesn't match any Preset. The menu will flip to "none" when the settings for a channel are changed such that they no longer match a Preset.
- To create a new Preset from existing Calculation channels: Click "Setup" to display the Calculation Setup dialog and click the "New Preset" button. The settings will be applied to the current channel, and a prompt will be generated to enter a name for the new Preset. Preset names cannot be duplicated, nor can the default name of a Calculation channel type (Integrate, Difference, etc.). Newly-created Presets will be included in the pop-up menus and saved with the file.
- To reorder channel Presets (by type, use, etc.), choose Hardware > Organize Channel Presets and then use the up/down buttons as appropriate (see page 281).
- **MP160/MP150 hardware**: Presets are not applicable to and therefore not selectable on Analog or Digital channels.
- **MP36R hardware:** Presets are available on Analog channels but not Digital channels.

Watch the Acq*Knowledge* Preset Option video tutorial for a detailed demonstration of this feature.

Integrate Calculation





The online Integrate Calculation offers three basic options:

Reset via channel. Perform a real-time integration of input data over a variable number of sample points. This option is extremely useful for converting flow signals into volumetric equivalents. The integral of flow is volume. For example, when recording airflow with a pneumotach, volume can be precisely calculated as the flow varies in a cyclic fashion:

a) Real-time conversion of flow signals into volume signals (i.e., Blood flow → Blood volume; Air flow → Air volume)

b) Any processing involving a need for a cyclic, continuous integral calculated in real time. For example: Acceleration → Velocity; Velocity → Distance; Frequency → Number of cycles; Power → Energy

Average over samples. Perform a moving average (mean) and associated processing (Rectify; Root mean square) over the specified number of sample points. This option is useful to process EMG signals to:

a) Smooth noisy data

b) Display the real-time “integration” (rectified, then sample averaged) of the raw EMG data

c) Display the real-time “root mean square” calculation of the raw EMG data

d) Return real-time windowed standard deviation

Timed reset. This option is available in the Integrate calculation channel and transformation. This mode computes a straight sum of the source data points and resets this sum after a fixed amount of time has elapsed. This periodic integral is used in several types of analysis, such as EMG analysis where it can generate an EMG signal or estimate the power in fixed time intervals. The time interval at which the integral resets to zero may be specified in seconds or in samples. The timed integrate reset functionality may also be used in calculation channel presets and by the Mac OS Integrate automator action.

To have Acq*Knowledge* perform an Integrate calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels (click “View by Channels).
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the modified data. If necessary, also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Integrate.
5. Click the Setup button in the Input Channels dialog to generate the Integrate dialog.

(Off-line Integrate is available under Transform > Integrate.)

Destination

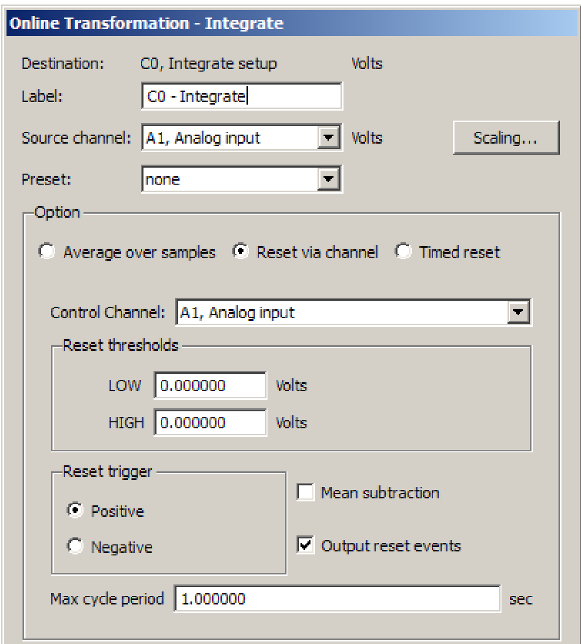
Determined by the calculation channel selected. (C0, C1, C2, etc.)

Acquire	Plot	Value	Channel	Label
☑	☑	☑	C0	C0 - Integrate
☑	☑	☑	C1	C1 - Smoothing

Source

Any Analog or Digital channel being acquired as well as any enabled Calculation channels with a lower number.

Reset via channel (Integrate option)



This feature is used to integrate data over a data-dependent interval. Either the source channel or a different channel can control the integration process.

Control channel

Allows user to select any active channel as the integration control channel. (Calculation channels must have a lower number.)

Reset Thresholds

The threshold is to be set at points surrounding the flow level. Typical values are:

LOW: a negative value close to 0.00

HIGH: a positive value close to 0.00

For airflow to volume conversion, the flow signal will vary positively and negatively around zero flow.

Reset trigger

The Reset trigger polarity determines on which slope (Positive ↑ or Negative ↓) the integration process will begin and end.

Mean Subtraction

This option will subtract the mean from the data evaluated during the integration period. If this option is selected, the integration will only proceed after all the data in the integration period has been collected. When collected, the mean value of all the data is subtracted from each data point in the integration period. In this fashion, the integral of the corrected data points will result in the integral returning to exactly zero at the end of the integration interval. Although this option will result in "well-behaved" integrations, the integrated data will be delayed by a fixed amount of time, as specified by the max cycle period.

Online — Enabling mean subtraction delays the signal by the mean cycle length. It waits for that period of time to pass so it can determine a mean value for the initial cycle, and it then tries to re-compute this mean for each cycle. If the resets are too short or too long, the window expires and the processing halts again until a new mean can be recomputed. Online processing may reset from threshold crossing in the control channel or window expiration when it loses mean tracking.

Offline — Transformation version of this operation. Since all the data is available, the mean is computed from the data in the channel and the signal is not delayed. Also, since it isn't doing windowed means, there are no window expiration events inserted. Offline processing may reset from threshold crossing in the control channel.

Max cycle period

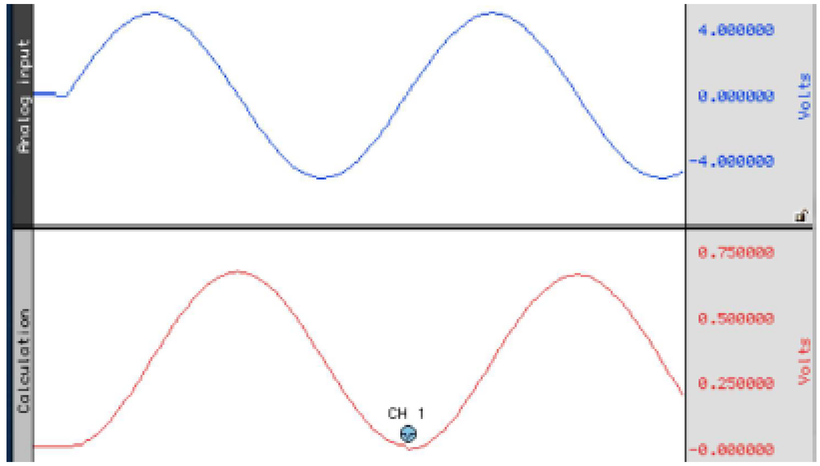
The Max cycle period should be longer than the maximum time expected from trigger event to trigger event in the Control Channel. Typically, the default scale settings for cyclic integrated data will be fine.

Output reset events—*not available for metachannels*

Add Events (markers) to show where Reset occurred and distinguish why the channel reached zero.

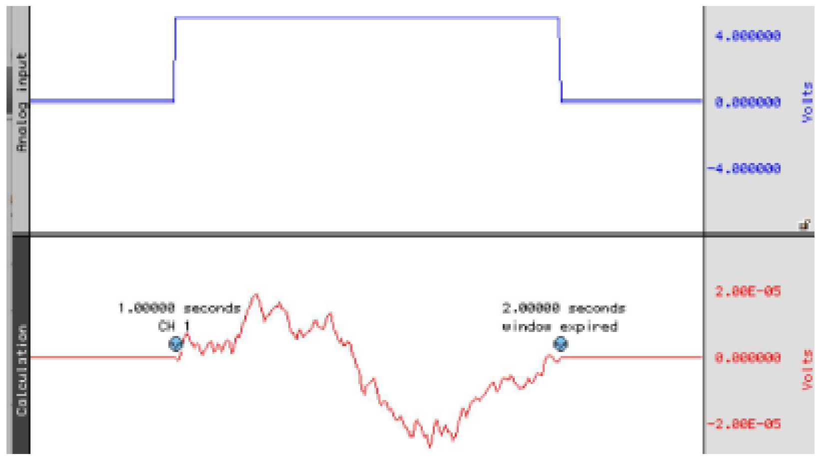
- Threshold crossing on the control channel

  For example: Calculation channel resetting on positive crossings of 0V on CH 1.



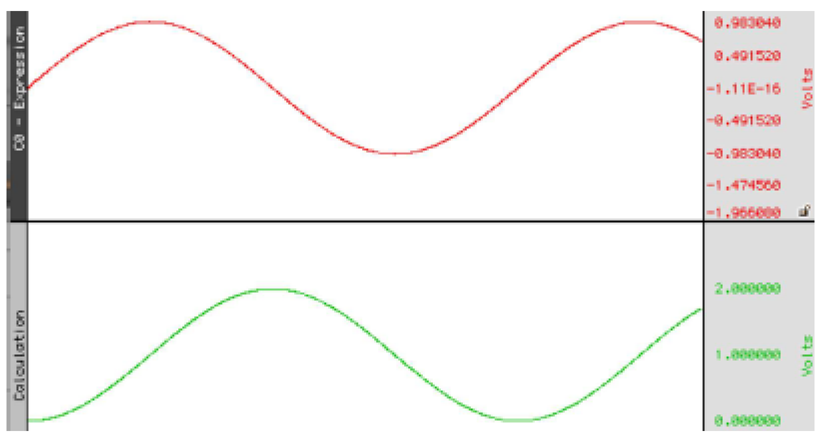
- Window expiry when mean removal is enabled

  For example: No threshold crossing within “mean cycle width” as specified in calc channel setup. Settings of calc channel: threshold crossings positive, 3V, Mean cycle subtraction, 1 second period width. First reset is due to threshold crossing; second reset is due to window expiry.



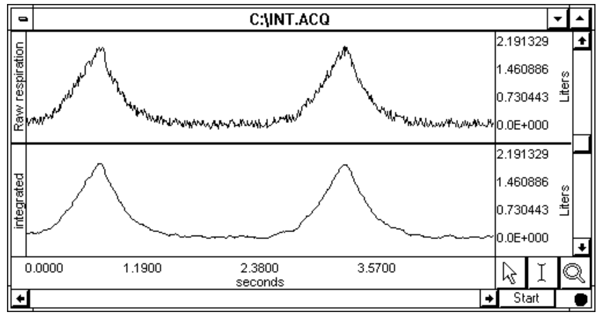
- Zero value due to “true” zero being achieved due to mathematical results

  For example: Mathematical Source is sine wave, integral is cosine. Input (10V) never crosses threshold levels. Signal reaches zero mathematically; no reset events appear on output.



Average over samples (Integrate operation)

Online sample averaging can be useful when there is a high degree of noise present in the data. At least some of this noise can be "averaged out" by pooling some number of adjacent data points together, taking the average of these points, and replacing the original values with the new averaged values. This process creates a "window" of moving averages that moves across the waveform smoothing the data.



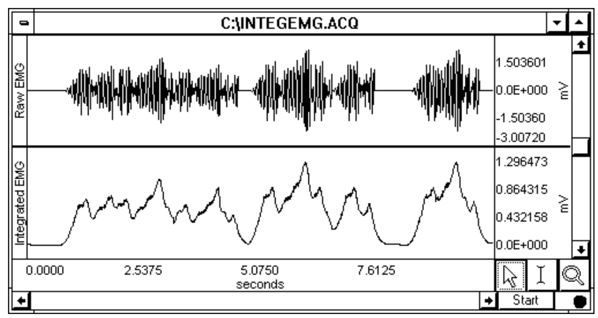
Integration used to smooth noisy data

<u>Samples</u>

To specify the number of data points to average across, enter a value in the Samples box. The number selected will depend in large part on the selected sampling rate and the type of noise present. All things being equal, for slower sampling rates it's recommended to perform mean average across a smaller number of samples. As the sampling rate is increased, integrate across more and more samples. As the number of samples specified in the samples box increases, the amount of high frequency information contained in the data will decrease.

<u>Parameters</u>

Rectify —The Average over samples calculation can also be used for producing an envelope of modulated data. For instance, EMG waveforms frequently contain high frequency information, which is often of little interest compared to the low frequency information also contained in the data. When the Rectify option is checked, Acq*Knowledge* will take the absolute value of the input data prior to summing and a plot of the waveform's mean envelope over a specified number of samples will be obtained.



Online "Average over samples" feature used as an envelope detector

Typically, this option is only used for processing raw EMG and similar types of applications. The signal for Rectify is normalized by a factor of (# samples averaged)/(Channel sampling rate).

Root mean square—provides the exact root mean square (RMS) of the input data (typically EMG) over the specified number of samples.

Remove baseline—provides the exact standard deviation of the input data (typically EMG) over the specified number of samples. When the mean of the input data equals 0-0, the standard deviation and the RMS will be equivalent.

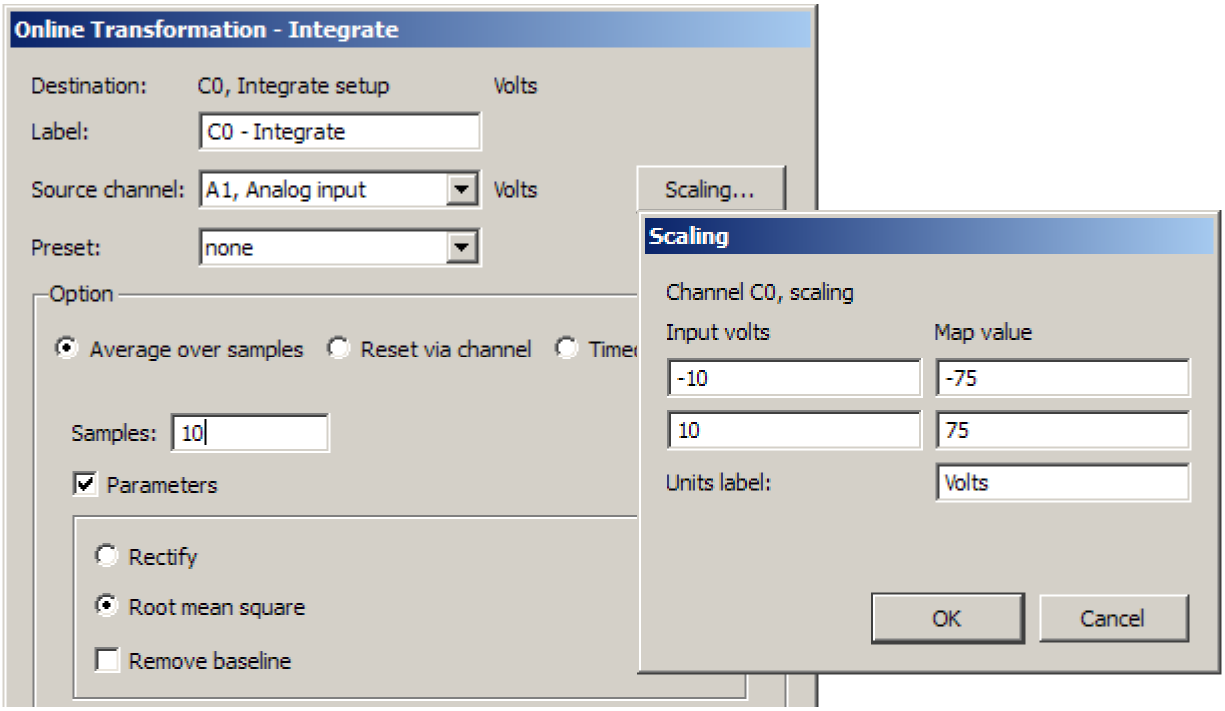
Scaling… button—Since the integration values are going to be on a different scale than the original units, it's necessary to change the scale of the integration channel to reflect the new units. Click the Scaling… button, to generate the Change Scaling Parameters dialog.

The rescaling involves multiplying the "Input units" values by a factor determined by the sampling rate and number of samples mean averaged across.

$$\text{Map or Scale value} = \text{Input units } x \; \frac{\text{Sampling rate}}{\text{Number of samples to be mean averaged}}$$

As an example, if data was being acquired at 75 samples per second, and the integration is to be completed across an interval of 10 samples, configure the Integrate Setup Scaling parameters so that +10 Volts corresponded to a Map (Scale) value of 75 and a Map (Scale) value entry of –75 reflected an Input value of –10 Volts.

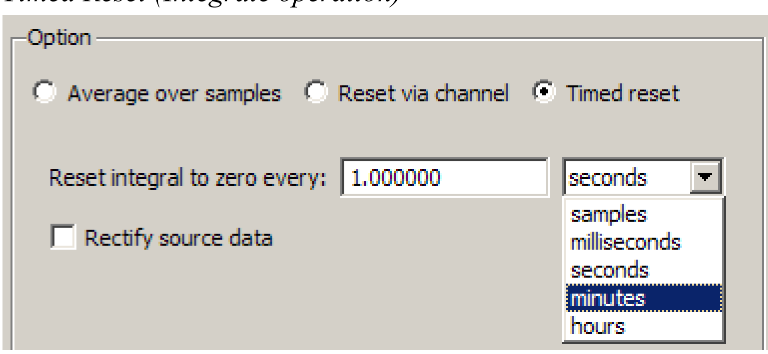
- ➢ It is important to note that this rescaling should be performed independent of any rescaling performed on analog channels themselves. Even if an analog channel is being rescaled to some other units, the input values in the integration scaling should be set to +10 Volts (next to Cal 1) and –10 Volts (next to Cal 2).



Integrate Calculation and Scaling dialogs for 10 point averaging

When data is averaged in this way, a portion of the data at the beginning of the record (equivalent to the number of samples being integrated) should be ignored, as they will reflect a number of zero values being averaged in with the first few samples of data.

Timed Reset (Integrate operation)



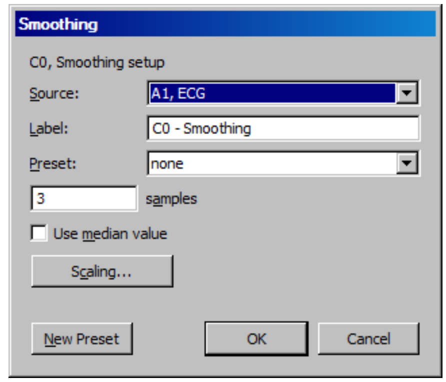
Timed Reset operation computes a straight sum of the source data points and resets this sum after a fixed amount of time has elapsed. This periodic integral is used in several types of analysis, such as EMG analysis where it can estimate the power in fixed time intervals.

The time interval at which the integral resets to zero may be specified in samples, milliseconds, seconds, minutes or hours.

Timed reset functionality may also be used in calculation channel presets and by the Mac OS Integrate automator action.

Smoothing Calculation

The Smoothing Calculation is useful for removing noise of varying types from a data set.



1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the modified data. Check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Smoothing.
5. Click the Setup button in the Input Channels dialog to generate the Smoothing dialog.

(Off-line Smoothing is available under Transform > Smoothing.)

Source	Source is a pull-down menu of the available channels.
Smoothing factor	enter the number of samples to use as a smoothing factor.
Smoothing method	This calculation channel provides real-time Mean (default) or Median smoothing.
Mean value	The default is mean value smoothing. Use Mean value smoothing when noise appears in a Gaussian distribution around the mean of the signal.
Use Median value	Click in the box to activate Median value smoothing if some data points appear completely aberrant and seem to be "wild flyers" in the data set.

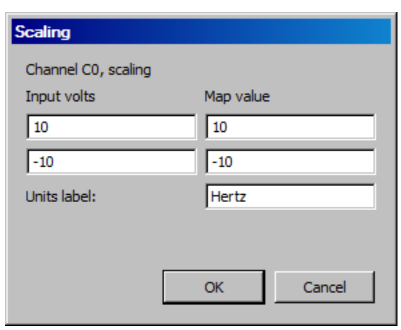
For a given sequence of wave data, $x = \{x_1, x_2, \ldots, x_n\}$, Median value smoothing will sort the sequence and extract the median equivalent to the recommended NIST (National Institute of Standards and Technology) formula:

- *n* is odd: median is the center element of the sorted list of *n* items.
- *n* is even: median is the mean of the center pair of elements of the sorted list of *n* items.

The smoothing calculation channel is the primary method of computing real-time median values using the definition of median as given above. The smoothing output at a sample position is the median of the window of source channel samples including the current sample and the previous samples in the window.

The size of the window is 1 at the start of acquisition and increases incrementally until the final window size is reached. The median extraction method shifts between even and odd definitions as the window size is incremented.

Scaling — Click the Scaling button to access options that allow modification of units or to linearly scale the output.



Watch the Acq*Knowledge* Smoothing video tutorial for a detailed demonstration of this feature.

Difference Calculation

The Difference calculation returns the difference between two data samples over a specified number of intervals and divides the Difference by the time interval spanned by the data values. The Difference Calculation is useful for calculating an approximation of the derivative of a data set in real time.

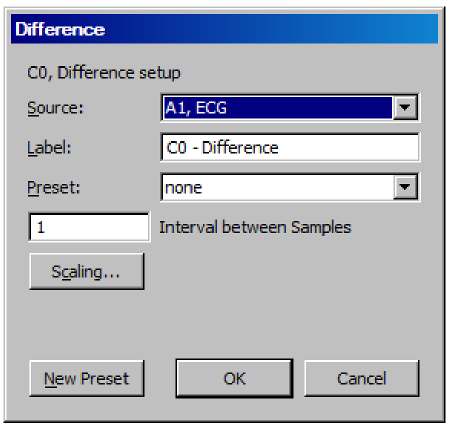
To have Acq*Knowledge* perform a Difference calculation in real time:

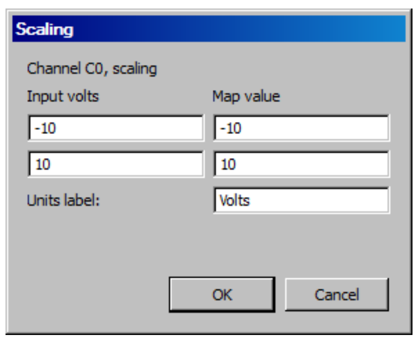
1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the modified data. If necessary, also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Difference.
5. Click the Setup button in the Input Channels dialog to generate the Difference dialog.

(Off-line Difference is available under Transform > Difference.)

Options in the Difference Calculation dialog specify the source channel and the number of intervals between samples over which the difference is to be taken, and includes the option of rescaling the channel to reflect different units.

Click the Setup button in the Input Channels dialog to generate the Difference dialog:





Source When the Source channel contains relatively high frequency data, the Difference Calculation may result in a very noisy response, so it's best to use Difference on relatively smooth data.

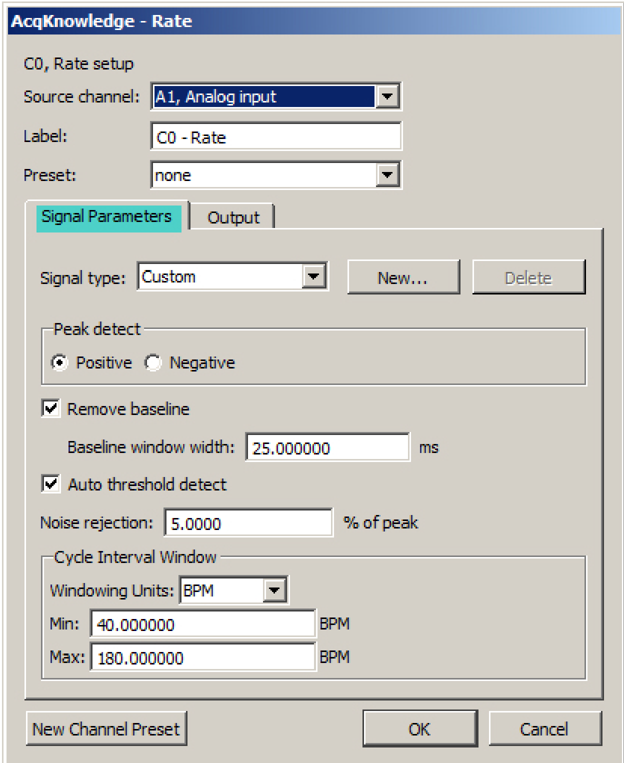
Intervals Difference is calculated with respect to the number of intervals between points (rather than the number of sample points). For instance, two sample intervals span three sample points:

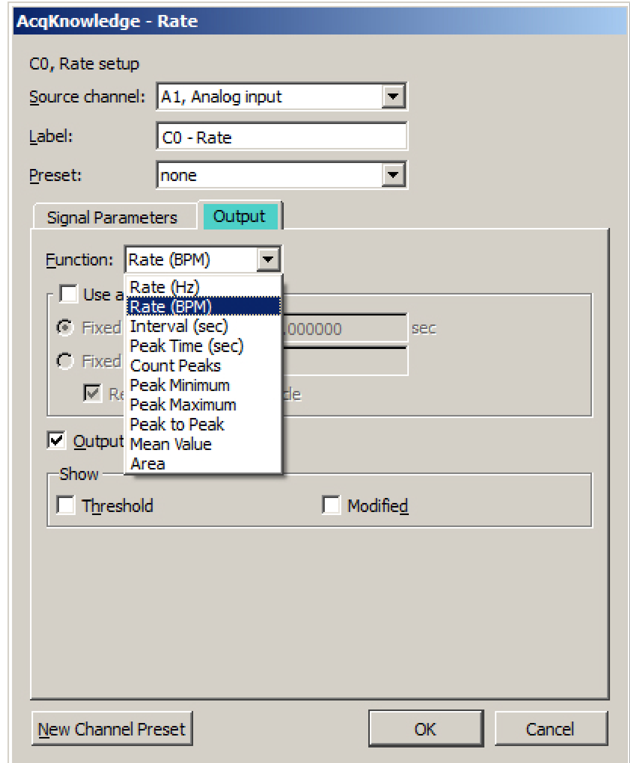
POINT<interval > POINT<interval > POINT

A 1-interval difference transformation applied to a blood pressure (or similar) waveform will result in the widely used "dP/dT" waveform.

✓ See page 355 for a complete description of the online Difference function.

Rate Calculation





The Rate Calculation is used to extract information about the interval between a series of peaks in a waveform. This interval can be scaled in terms of BPM (the default), frequency (Hz), or time interval between peaks.

- The BPM (or beats-per-minute) Rate function is used as a measure of peaks or events that occur in a sixty-second period.
- The frequency rate function is commonly used to describe the periodicity of data, or the amount of time it takes for data to complete a full cycle (from one peak to the next peak).
- The Interval Rate function returns the raw time interval between each adjacent pair of peaks, which is essentially the inter-beat interval (IBI), frequently used in cardiology research.

These three functions essentially provide the same information in different formats, since a frequency of 2Hz is equal to an inter-peak interval of 0.5 seconds, both of which are equivalent to a BPM of 120. Other options allow for the recording of maximum or minimum value of all peaks (the peak max/min option), or to count the aggregate number of peaks (the count peaks option).

In order to calculate Rate information, there is the option to specify the threshold manually or have Acq*Knowledge* automatically compute the default threshold value. This section describes the basic parameter settings for typical online Rate Calculations.

NOTE: Parallel functions can be performed after data has been acquired. A detailed description of the Rate Calculation options can be found in the Find Rate section on page 396.

To perform a Rate Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the modified data. If necessary, also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Rate.
5. Click the Setup button in the Input Channels dialog to generate the Rate dialog.

(Off-line Rate calculation is available under Analysis > Find Rate.)

Source—selected from the Source popup menu at the top of the dialog.

Label—Use to create a label for the Rate channel

Preset—Use to select from 17 pre-defined calculation channel presets. New presets affecting source channel, label and output settings can be created and saved by clicking "New Channel Preset."

Signal Parameters Tab

Signal Type—Contains parameters for specific human and animal waveform morphologies. Choose from six pre-defined heart rate and respiration signal types, or click "New" to create and save custom setups. Unlike channel presets, all pre-defined and custom signal types appear in both calculation channel Rate (online) and analysis Rate (offline) dialogs. Signal type modifications affect settings in the Signal Parameters tab only. For more details on Rate signal types, see page 399.

Peak Detect—Choose whether to look for positive or negative peaks in the signal.

Remove baseline—provides the exact standard deviation of the input data (typically EMG) over the specified number of samples. When the mean of the input data equals 0-0, the standard deviation and the RMS will be equivalent.

Baseline window width—Width of the window for the difference operation applied prior to peak detection. (E.g. the value of the source x ms previously is subtracted from the current value to generate the signal that is analyzed with the peak detection.)

Auto Threshold detect—The most convenient way to calculate a Rate channel online is to have Acq*Knowledge* automatically compute the threshold value (the "cutoff" value used to discern peaks from the baseline). This is done by checking the Auto Threshold detect box.

Noise rejection—Acq*Knowledge* constructs an interval around the threshold level when Noise rejection is checked. The size of the interval is equal to the value in the noise rejection text box, which by default is equal to 5% of the peak-to-peak range. Check this option to help prevent noise "spikes" from being counted as peaks.

Cycle Interval Window—When "automatic" Rate Calculations are set, specify a minimum rate and a maximum rate. These parameters define the range of expected values for the Rate Calculation. By default, these are set to 40 BPM on the low end and 180 BPM on the high end.

The Rate Calculation will use these values to find and track the signal of interest, assuming the input BPM range is reasonably well bracketed by these values. Depending on the shape of the input cycle waveform, the Rate window settings may be closer or further from the expected rates.

- For ECG-type data (where the waveform peak is narrow with respect to the waveform period), the Rate window values will closely bracket the expected values.
- For more sinusoidal data, with the waveform energy distributed over the waveform period (as with blood pressure or respiration), the Rate window will closely bracket the expected rate on the high-end, but can be up to twice the actual measured rate at the low-end.

One of the most frequent applications of the Rate Calculation is to compute BPM online for ECG, pulse, or respiration data. For more information on optimizing ECG amplifiers for online calculation of heart rate, see the ECG100C section of the *Hardware Guide*.

Windowing Units—Use to select the unit type to be used in the rate detection. The options are Hz, BPM and seconds.

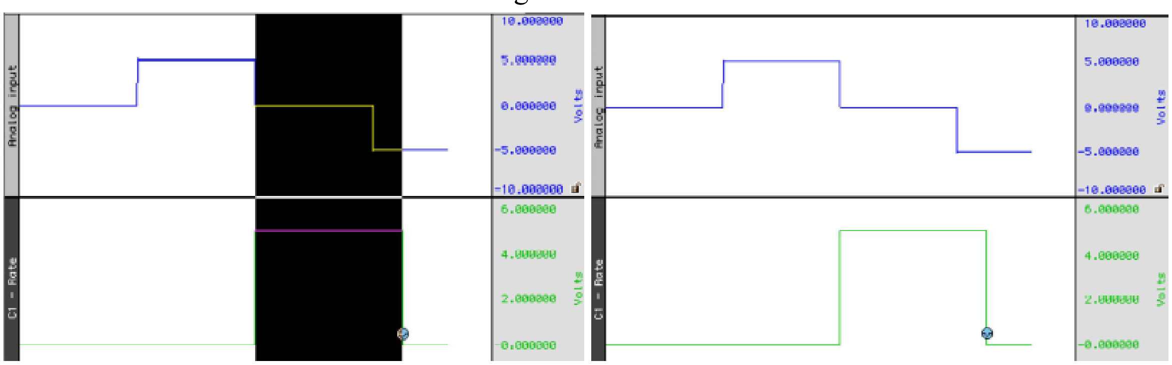
Output Tab

Function —The popup menu includes options to scale the rate in terms of Hz, BPM, Interval, Peak Time, Count Peaks, Peak Minimum/Maximum, Peak-to-Peak, Mean Value, Area or Sum.

- For more information on each of these functions, see the Calculation Channels section beginning on page 148.
- Calculate systolic using the peak maximum Function, diastolic using the peak minimum Function, and mean blood pressure using the mean value Function.
- NOTE: All of these Function options are available in the post-acquisition mode through the Analysis > Find Rate function.

Use Averaging mode—Use to average the output of the selected function. Averages can be based upon a fixed time window or a fixed number of cycles. The 'Recompute on every cycle' option will start the averaging output after *N* numbers of cycles are detected and then remain fixed until the next *N* cycles are detected.

Output reset events (not available for metachannels)—When auto threshold detection is being used, the minimum and maximum rates of the signal are specified in the Windowing controls. If the input signal falls out of this range, the value of the rate function and automatic threshold level will be reset. By enabling "Output reset events" a reset event will be placed on the output at the location of these window expirations. Rate detector is set to "Peak function, default window of 40 BPM to 180 BPM, auto threshold detect for positive peaks. The reset event occurs after the window expiration, approximately a full 40 BPM interval after the "peak" transition from 0 to 5 volts in the source signal.



Show Threshold—Plots the threshold used by the Rate calculation function.

Show Modified—Plots the modified data as processed by the Rate Detector. Typically, the modified data is a differential version of the original input data. The data will be modified if the "remove baseline" feature is checked.

Math Calculation

The Math Calculation performs standard arithmetic calculations using two waveforms or one waveform and a constant. Calculation channels with lower channel numbers may be also used as a waveform.

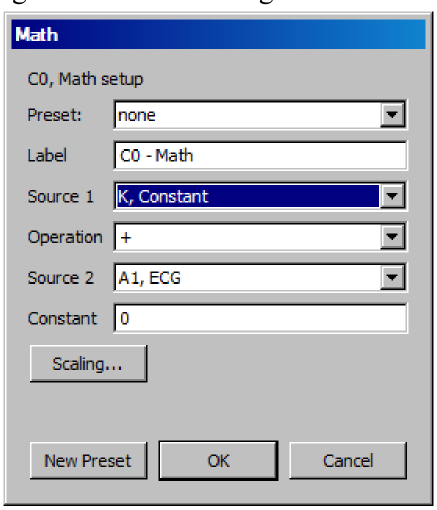
1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the modified data. If necessary, also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Math.
5. Click the Setup button in the Input Channels dialog to generate the Math dialog.

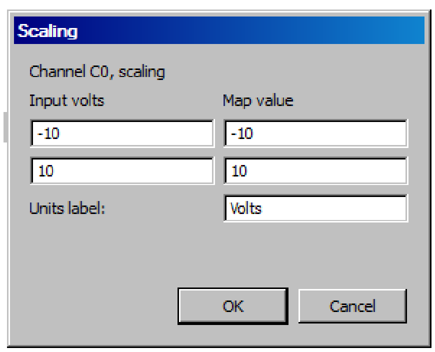
(Off-line Math calculation is available under Transform > Waveform Math.)

Use the pull-down Source menus to select the source channels (Source 1 and Source 2).

The Sample rate line provides the sample rate for the channel selected as Source; the channel sample rate may be different than the acquisition sample rate.

Use the pull-down Operation menu to select a function. In the example below, analog channel 1 (Source: A1) is added to analog channel 2 (Source: A2). To use this summed waveform as an input for another Math Calculation channel. One useful application would be to divide this waveform (C0) by K, where K=2, thus producing an arithmetic average of source channels A1 and A2.





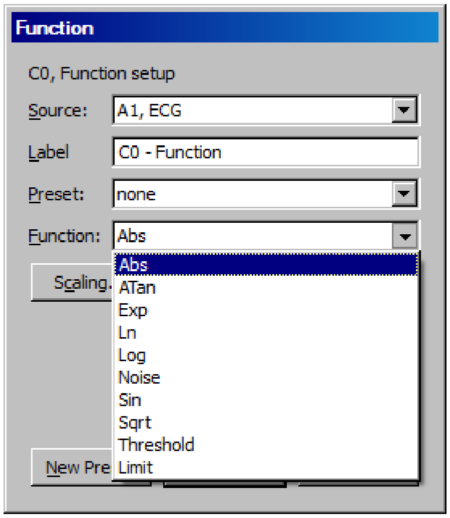
The “Constant” entry is activated when “K” is selected as a Source.

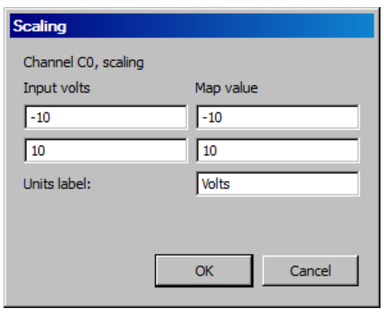
As an alternative to creating an additional Calculation channel for dividing the summed waveform, use the scaling function to perform the same task. To do this, click Scaling… button and then set the Map (Scale) value for the summed waveform equal to +5 and –5 (to correspond to Input Volts values of +10 and –10 respectively). This will effectively plot the sum of channels A1 and A2 as the arithmetic mean of the two waveforms.

For additional information, see the sections on Function Calculation channels (page 164) and online Expression, page 167).

For complex calculations (such as squaring a waveform then adding it to the average of two other waveforms,) Expression is a more efficient solution. These calculation channels allow more complex operations. Metachannels (page 149) allow the user to chain multiple calculation channels together.

Function Calculation





The Function calculation can be used to perform a variety of mathematical functions to a single waveform. Like math Calculation channels, function Calculations can be chained together to produce complex functions (such as taking the absolute value of a waveform on one channel and Calculating the square root of the transformed waveform on another channel). These same functions are also available under the transform menu in Acq*Knowledge* for *post-hoc* operations. Many of these functions can also found in the online Expression, see page 167 for details).

To have Acq*Knowledge* perform a Function Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the modified data. If necessary, also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Filter.
5. Click the Setup button in the Input Channels dialog to generate the Function dialog.

(Off-line Function calculation is available under Transform > Math Functions.)

Other mathematical Functions are available in the online Expression (see page 167). Function Calculations can be chained together to produce more complex Calculations, although it is more efficient to program complex functions using the Expression calculation.

The Sample rate line provides the sample rate for the selected channel (may be different than the acquisition sample rate).

Function

Abs	Returns the absolute value of each data point
Atan	Computes the arc tangent of each data point
Exp	Takes the e^X power of each data point
Limit	Limits or “clips” data values that fall outside specified boundaries
Ln	Computes the base e logarithm for each data point
Log	Returns the base 10 logarithm of each value
Noise	Creates a channel of random noise with a range of ± 1 Volt
Sin	Calculates the sine (in radians) of each data point
Sqrt	Takes the square root of each data point.
Threshold	Converts above an upper threshold to +1 while converting data below a lower threshold to 0.

Thresholding Algorithm Assume a domain variable

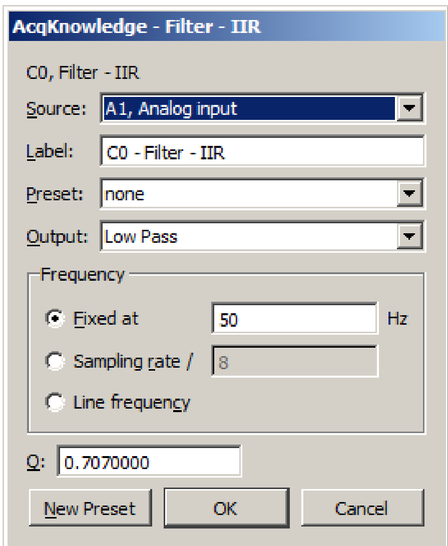
with t_{start} being an integer, a real-valued signal y(t) defined for all t, and two real valued levels y_{low} and y_{high} satisfying the relation .

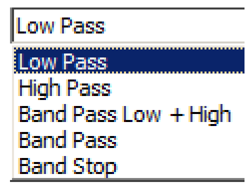
Define the Threshold function thresh(t) function such that:

Filter IIR Calculation

The Filter IIR Calculation channel performs real time digital filtering on analog, digital, or calculation channels. To have Acq*Knowledge* apply a digital Filter IIR Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. If necessary, also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Filter.
5. Click the Setup button in the Input Channels dialog to generate the Filter dialog.





Filter Setup & Output Options

In the dialog above, the signal on analog channel one (A1) is run through a low-pass filter that attenuates data above 50 Hz. The “Q” for this filter is 0.707, which is the default.

> One possible application of the online filtering option is in conjunction with the Show Input Values option (see page 264). Raw EEG data, for instance, can be filtered into distinct bandwidths (alpha, theta, and so forth) using one source channel and multiple filter Calculation channels. The filtered data can then be displayed in a bar chart format during the acquisition using the Show Input Values option.

Source	Set the source channel.
Sampling rate	Select this to compute the frequency at the start of acquisition as a fraction of the channel sample rate. (Unselected by default.)
Type (Output)	Lists the filter options: low pass, high pass, band pass, band pass (low + high), band stop, and comb band stop. See *About Filters* in this section for more details on filter types.
Frequency	Fixed value—Type a value in the entry box. Sampling rate—Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified. Line frequency—Uses the line frequency at which the data was recorded.
Q coefficient	The online IIR have a variable Q coefficient. The Q value entered in the filter setup box determines the frequency response patterns of the filter. This value ranges from zero to infinity, and the “optimal” (critically damped) value is 0.707 for the Low pass and High pass filters, and 5.000 for the Band pass and Band stop filters. If desired, the Q can be changed. A more detailed explanation of this parameter and digital filters in general, can be found in Appendix B.

About Filters

While the technical aspects of digital filtering can be quite complex, the principle behind these types of filters is relatively simple. Each of these filters allows a cutoff point to be set (for the low and high pass filters) or a range of frequencies (for the band pass and band stop filters).

- A Low Pass filter allows specifies a frequency cutoff that will “pass” or retain all frequencies below this point, while attenuating data with frequencies above the cutoff point.
- High Pass filters perform the opposite function, by retaining only data with frequencies above the cutoff, and removing data that has a frequency below the specified cutoff.
- Each type of Band Pass filter is optimized for a slightly different type of task.

  The Band Pass (low + high) filter is designed to allow a variable range of data to pass through the filter. For this filter, it’s necessary to specify a low frequency cutoff as well as a high frequency cutoff. This defines a range or “band” of data that will pass through the filter. Frequencies outside this range are attenuated. The Band pass (low + high) is actually a combination of a low pass and a high pass filter, which emulate the behavior of a band pass filter. This type of filter is best suited for applications where a fairly broad range of data is to be passed through the filter. For example, this filter can be applied to EEG data in order to retain only a particular band of data, such as alpha wave activity.

  The alternative Band Pass filter requires only a single frequency setting, which specifies the center frequency of the band to be passed through the filter. When this type of filter is selected, the “width” of the band is determined by the Q setting of the filter (discussed in detail below). Larger values for q result in narrower bandwidths, whereas smaller Q values are associated with a wider band of data that will be passed through the filter. This filter has a bandwidth equal to Fo/Q, so the bandwidth of this filter centered on 50 Hz (with the default Q=5) would be 10 Hz. This type of filter, although functionally equivalent to the band pass (low + high) filter, is most effective when passing a single frequency or narrow band of data, and to attenuate data around this center frequency.
- The Band Stop performs the opposite function of a band pass. A Band stop filter defines a range (or band) of data and attenuates data within that band. In this case, the Band stop filter is implemented in much the same way as the standard Band pass, whereby a center frequency is defined and the Q value determines the width of the band of frequencies that will be attenuated.
- The Comb Band Stop removes interfering harmonics; resonance, aliasing, and other effects may generate interference at multiples of a base frequency. It combines all the required filters instead of requiring a separate filter for each interfering overharmonic. For setup details, see page 335.

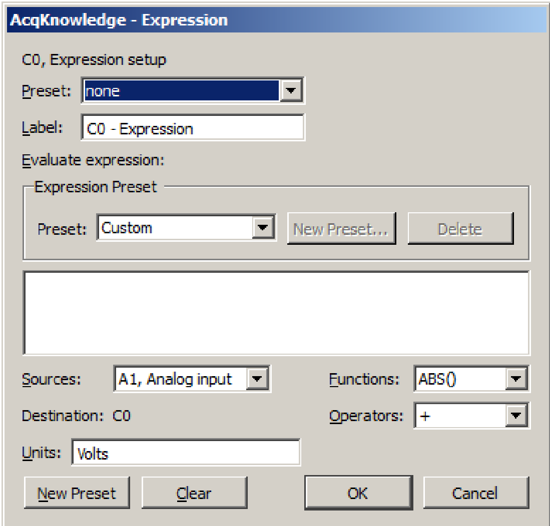
Off-line filtering

Apart from these online filter options, similar filters can be applied after an acquisition is terminated via the Transform > Digital Filters menu. Many of the biopotential amplifiers available from BIOPAC have selectable filters, which allows for filtering of certain frequencies (including 50 Hz or 60 Hz electrical noise) and possibly reduce the need for online filters.

Digital filtering can also be performed after an acquisition using the same types of filters. Choose from the different filter types by selecting Digital filters from the Transform menu. The filters available after the acquisition use a different algorithm but operate in essentially the same way.

For more information on digital filters and filters that can be applied after an acquisition, turn to the Digital Filtering section on page 329 or Appendix B.

Expression



The online Expression calculation channel is available for performing computations more complex than possible in the Math and Function calculations, and is additionally available as an offline transformation and a measurement. (Different attributes may apply to each available Expression type.) The Expression calculation will symbolically evaluate complex equations involving multiple channels and multiple operations. Acq*Knowledge* can perform conditional evaluation, data extraction, logical operations, expressions requiring a range of samples or the results of the previous expression, and evaluation of generic formulas that can be expressed in a closed, recursive form.

Unlike the Math and Function calculations—which can only operate on one or two channels at a time—the Expression calculation can combine data from multiple analog channels, and can also specify other Calculation channels as input channels for Equation channels. Also, computations performed by the Expression calculation eliminate the need for “chaining” multiple channels together to produce a single output channel.

While the Expression calculation is more powerful than other Calculation channels, each Expression calculation requires more system resources than other Calculations. This essentially means that acquisitions that utilize Equation calculations are limited to a lower maximum sampling rate than acquisitions without online Expression functions. When an expression is evaluated, it is actually evaluated multiple times. The expression is computed starting at the first sample acquired, and is then evaluated once for each successive acquired sample.

Acq*Knowledge* can accept the notations SC, MC, and CH*n* to reference the sample at the current evaluation position or SC(*x*), MC(*x*), and CH*n*(*x*) for values at locations prior to the present evaluation location using an offset expressed in sample intervals. For example, CH1(-1) will give the previous sample of Channel 1*.

The same features that are available in online Calculation channels are also available under the Transform menu for evaluation of complex equations after acquisition. Thus, simple Calculations such as summing two channels or finding the absolute value of a channel (and so forth) are best performed in either the Math calculation channels or the Function calculation channels.

On the other hand, for complex Calculation channels, such as squaring one channel, multiplying it by the sum of two other channels, and dividing the product by the absolute value of another waveform, a single Expression calculation channel is more efficient than chaining five Math and Function calculation channels.

***Exception:** Negative offsets are not defined when appending data to disk. Expressions making use of such notation are invalid after the first segment of data has been acquired in this acquisition mode.

<u>Save to Calculation Channel</u>

To evaluate an expression and save the result to a Calculation channel in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.

3. Check an Acquire box for the Calculation channel to contain the modified data. If necessary, also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Expression.
5. Click the Setup button in the Input Channels dialog. This will produce a dialog for entering the expression to be evaluated.

(Off-line Expression is available under Transform > Expression or Measurements > Expression.)

The different components of each expression can be entered either by double-clicking buttons from the button rows (sources, functions, and operators) in the setup expression dialog, or by typing commands directly into the Equation box. The Expression calculation uses standard mathematical notation.

For each expression, it's necessary specify at least one source, the function(s) to be performed, and any operators to be used. Sources are typically analog channels, although Time may also be selected from the source button row and Acq*Knowledge* will return the value of the horizontal axis (usually time) for each sample point. When the horizontal axis is set to frequency (in the Display > Horizontal axis dialog), the "time" item in the source button row will switch to "frequency."

When using the online Expression calculation channel, it is important to keep in mind that while different channels, functions, and operators can be referenced, the Calculation cannot reference future sample points. See the section on post-acquisition expression commands (beginning on page 356) for ways around this limitation.

Functions — The arguments to each function are represented in the Functions table in italics and may be replaced by any valid expression. Each argument is separated from its next argument by a comma. Expressions can only contain commas within balanced parenthesis pairs. An ellipsis (."..") at the end of a function description indicates that any number of arguments may be present provided they are in a comma separated list. When a function is added to an Expression, the cursor is placed between the parentheses.

Conditionals — Change output based upon a condition test. All of the conditionals treat the value zero as false and any non-zero value as true. Expressions can only contain commas within balanced parenthesis pairs.

Offset Notation — Offset notations take integer offsets in terms of the number of samples using the formation CH#(P) *where* CH# is the channel number and P is the number of points. For example, an offset of -1 will return the data point immediately to the left of the selected point and an offset of +1 will return the data point immediately to the right of the selected point.

To refer to previously acquired data, offsets must be negative. For notational convenience, offsets that result in an invalid negative sample position (e.g. no data is defined prior to the first sample in the graph) evaluate to zero. Any attempt to access a sample beyond the end of the data will result in an error. Any attempt to use a positive offset for an online Expression calculation channel will result in an error.

`CH`*n*(*x*) Returns the value of channel with index n *x* samples away from the current evaluation position.

`SC`(*x*) Returns the value of the selected channel *x* samples away from the current evaluation position. Only allowed for Transformations and Measurements; not allowed for Calculations.

`MC`(*x*) When *x* is zero or positive, returns the value of the measurement channel *x* samples away from the current evaluation position. When x is negative, returns the result of the expression evaluation that occurred *x* steps previous to the current evaluation position. Only allowed for Measurement Expressions (see below); not allowed for Calculations or Transformations.

Recursive notation

Since transformations and calculation channels replace the source data of the channel with the result of the expression evaluation in sequence, negative offsets are equivalent to returning the final result of the expression that was evaluated a certain number of steps in the past. The channel where the expression results are stored can be thought of as a storage record of the previous evaluation steps. Negative sample offsets, therefore, can be used to compute any formula that can be expressed in closed recursive form. For example, the recursive definition of the Fibonacci sequence is:

$$F_n = F_{n-1} + F_{n-2}$$

To evaluate this as an expression transformation, use the expression:

SC(-1)+SC(-2)

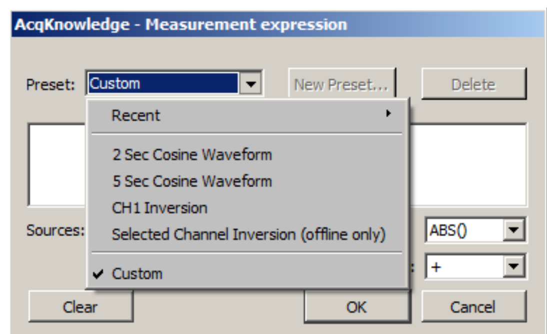
Note that to actually get the Fibonacci sequence; the selected channel would need to have a constant value of one prior to the transformation.

Expression Measurement

Measurements are powerful tools for quick manual analysis and also for advanced automated analysis when combined with the Cycle/Peak detector. Expression measurements extend measurements to evaluate simple formulas or complex data reduction. Each Expression measurement has an expression associated with it and the measurement result is derived from computing the Expression(s) on the selected data.

Measurement expression dialog is generated the first time a measurement is set to Expression or when the measurement preset button is clicked.

Preset menu allows access to pre-loaded commonly used expressions and displays user-defined custom presets, along with a list of recently-used expressions.



OK invokes a syntax check. If there is an error, the user will be prompted to correct the error and the error will be selected (highlighted) in the Expression edit field.

Cancel discards any changes to the Expression measurement and reverts back to the previous Expression.

Clear erases the current contents of the expression edit field.

Measurement Channel

Expression measurements can reference the "measurement channel" (MC), which refers to either the selected channel or a specific channel as set in the measurement channel selection box within the graph window.

Negative sample offsets to MC are interpreted as returning the result of the Expression from a prior step. Transformations and calculation channels achieve this as they replace the contents of their destination channels sequentially. Measurements, however, do not actually replace the data of their source channels. Expression measurements are actually executed on a temporary copy of the channel data in memory. This implies that negative indicies to the measurement channel are interpreted exactly the same for measurements as for transformations and calculation channels even though the "transformed" data of the measurement is not visible. Negative sample offsets to MC that refer to the sample position prior to the leftmost sample of the selected area will always return zero.

Evaluation Rules

When a new selection is made, the first step in evaluation searches through the Expression measurement for any MMT() invocations. Any measurement whose value is needed by MMT() is computed at this time prior to the Expression evaluation. This behavior is similar to calculation channels and successfully allows measurements to the right and bottom of the Expression measurement to be used in the expression.

The expression is subsequently evaluated from the leftmost sample in the selection to the rightmost sample. It is evaluated at the waveform sampling rate of its source channel, with one expression evaluation per sample contained within the selected area. Interpolation is not used at the boundaries to maintain a consistent sample interval for the expression. After each expression evaluation, the result is cached in memory for potential negative MC result references.

The value of the final expression, the rightmost sample, becomes the result of the measurement.

Circularity Detection

Expression measurements may reference other expression measurements or calculation measurements by using the MMT() function in the expression. This raises the possibility of circular dependencies being formed by the user if a measurement expression either directly or indirectly needs its own value to compute a MMT() invocation. Circular dependency checking will be in place at execution time and will result in an error.

To refer an Expression measurement to its own value, use the MC notation.

Error Reporting

The Expression measurement result will display the text "Error" if there are syntax errors in the Expression measurement, errors computing measurements referenced by MMT(), or a circularity.

Validation Tip

To function correctly, Acq*Knowledge* requires real-valued data. BIOPAC recommends ensuring that all expression results are real-valued. To test if a floating point number x is a real-valued number, use the expression:

NOT(OR(ISINF(x), ISNAN(x)))

Note for variable sample rate processing:

The Expression and Waveform Math functions will constrain operations between waves of different rates as follows:

If an equation is operating on two or more waves of different sample rates, the result of the operation will always be output at the lowest sampling rate from the waves (Flow). If the destination channel for the result has an assigned rate other than (Flow), the operation will not be permitted. If the destination channel is set to a new channel, the operation will always be permitted.

In Acq*Knowledge* 4 and higher, all sources for Expressions and Waveform Math operations must be sampled at the same waveform sampling rate.

VSR data padding—If the channels are of unequal length (as a result of variable sampling rate or waveform editing), they will be padded for Append acquisition. Digital and Analog channels are stored as short integers by default; a waveform paste into a digital or analog channel, however, will result in its underlying data being converted to floating point. This will generate the "Abort/Replace" warning for pastes to Digital or Analog channels since the data format has changed since the last acquisition.

Additionally, if an Analog or Digital channel is used as the source waveform for a Copy, it will also be converted to floating point and will result in the "Abort/Replace" warning being generated.

Since Calculation channels are already floating point, pasting into them or copying from them will not change their data format. The channels will be padded with their last value and the append will commence.

Waveform Cut operations do not change the underlying data format for Analog, Calculation, or Digital channels. If only Waveform Cut is used, no data format conversion will occur and channels will be padded with their last value and subsequent appends are allowed.

Source	Description
ACQLENGTH	*Calculation only* Acquisition length from Set Up Acquisition; keeps Appended segments the same whereas "Sample" would increase with each segment.
CH	Value of the designated channel (CH*n*) at the current evaluation step.
Primary Source Channel *metachannels only*	Appears as PSC in the dialog. Refers to the data of the primary source channel of a metachannel.
Time	Time (in sec) of current evaluation step
Sample	Sample index of evaluation step; the first sample in the graph will always be reported as a value of zero.
MC	*Measurements only* Value of the channel in the measurement menu—either the explicit channel or "SC"—at the current evaluation step.
Pi	Value of pi (3.141592654…) to double-precision accuracy.
SC	*Transformation and measurement only* Value of the selected channel at the current evaluation step; can still back-reference samples points.
True	Evaluates to the value 1 (non-zero values are interpreted as True)
False	Evaluates to the value 0
Segment Timer	Used as a source for the onscreen Stopwatch gauge view.
Random	Generates random white noise.
Gaussian Random*	Generates Gaussian white noise for startle responses. Returns a random value from a Gaussian distribution.

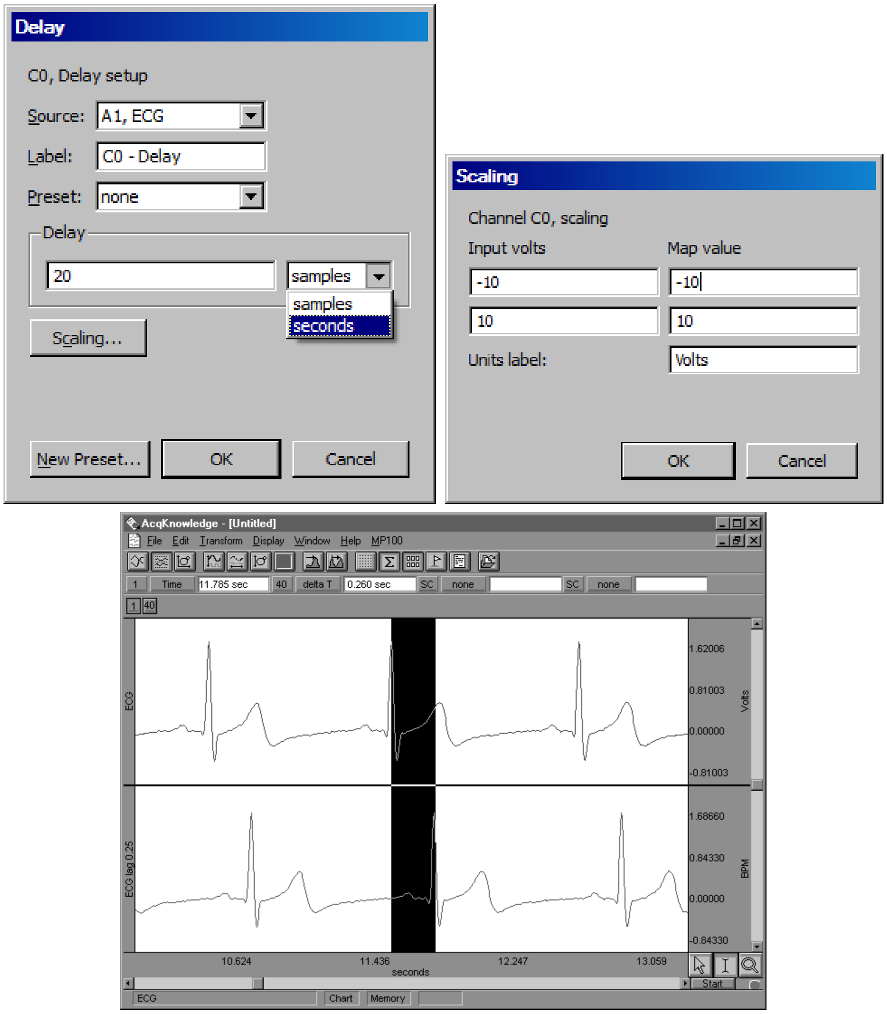
*Standard Gaussian model; useful for peak fitting.
param(0)*EXP(-((TIME-param(1))/param(2))^2

Operator	Operation
+	Addition
-	Subtraction
*	Multiplication
/	Division
^	Power
(	Open parentheses
)	Close parentheses

FUNCTION	RESULT
ABS	Returns the absolute value of each data point.
ACOS	Computes the arc cosine of each data point in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
AND(*x, y, …*)	Computes a logical "and" operation for its arguments. Accepts up to eight (8) arguments and evaluates to 1 if all of its arguments are non-zero values. 0 if one of its arguments is zero.
ASIN	Calculates the arc sine of each value in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
ATAN	Computes the arc tangent of each sample point in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
CEIL(*x*)	Computes the ceiling function (the closest integer larger than the value x).
COND(T, A, B, C)	Three-way conditional takes four arguments: COND(*test_expr*, *neg_test_value*, *zero_test_value*, *pos_test_value*) Evaluates test_expr and if < 0, returns neg_test_value = 0, returns zero_test_value > 0, returns pos_test_value
COS	Returns the cosine of each data point in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
COSH	Computes the hyperbolic cosine of each selected value
EQUAL(*x, y, …*)	Performs a Logical equal (numerical comparison) of its arguments. Accepts up to eight (8) arguments and evaluates to 1 if all of its arguments are equal. 0 if one of its arguments is not equal to the others.
EXP	Takes the e^x power of each data point..
FLOOR(*x*)	Computes the floor function (the closest integer less than the value x).
IF(T, A, B)	Two-way conditional takes three arguments: IF(*test_expr*, *true_value_expr*, *false_value_expr*) The conditional evaluates test_expr and if non-zero, returns true_value_expr 0, returns false_value_expr
ISINF(*x*)	Filters out infinities and unrepresentable numbers from data; important because such values can cause erratic behavior in autoscaling and other operations. Use to test whether any expressions have resulted in floating point overflow and have generated numbers too large to be represented in the computer. Evaluates to 1 if x is inf, the floating point representation of infinity. 0 if x is NaN or a real-valued floating point number.
ISNAN(*x*)	"Is not a number" can be used to test whether any expressions have resulted in floating point errors such as division by zero. Use to ensure that the output of transformations and equations does not produce numbers that Acq*Knowledge* cannot display. Evaluates to 1 if x is NaN, the invalid floating point number. 0 if x is inf or a real-valued floating point number.
LESS(*x, y*)	Performs a numerical comparison of its arguments and evaluates to 1 if x is less than y. 0 if x is greater than or equal to y.

FUNCTION	RESULT
LOG	Computes the natural logarithm of each value
LOG10	Returns the base 10 logarithm of each value
MAXIMUM	Returns the maximum value of all input arguments.
MINIMUM	Returns the minimum value of all input arguments.
MMT(*x, y*)	Indicates that “x” is the row and “y” is the column of the measurement being referenced. x and y are zero-based meaning that the measurement at the top left is "MMT(0, 0). MMT is available in Transform > Expression and in Measurement > Expression but is not supported in the online Expression Calculation Channel Functions.
MOD(x, y)	Computes the floating-point modulus; returns integer portion of modulus. Example: MOD(5,2) evaluates to “1”
NOT(*x*)	Computes a logical negation of its argument. Evaluates to 1 if x is zero. 0 if x is non-zero.
OR(*x, y, …*)	Evaluates multiple variables; true if any are true. Computes a logical “or” operation for its arguments. Accepts up to eight (8) arguments and evaluates to 1 if any one of its arguments is non-zero. 0 if all of its arguments are zero.
ROUND(*x*)	Returns an integer closest in value to the argument. For example: round (2.4) = 2 round(2.5) = 3 round(-1.5) = -1 round(-1.6) = -2
SIN	Calculates the sine (in radians) of each data point. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
SINH	Computes the hyperbolic sine for each sample point.
SGN	Performs the ‘sgn’ sign extraction function. Evaluates 1 if x > 0, -1 if x < 0, and 0 if x = 0.
SQR	Squares each data point.
SQRT	Takes the square root of each data point.
TAN	Computes the tangent of each sample point in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
TANH	Calculates the hyperbolic tangent of each sample point.
TRUNC(*x*)	Removes the fractional part of the number and returns an integer. For example: TRUNC(2.4)= 2 TRUNC(2.5)= 2 TRUNC(-1.5)= -1 TRUNC(-1.6)= -1 *Note* When used with scientific notation, TRUNC(x) applies only to the fractional portion after the exponential factor is taken into account: TRUNC(2.93E+4) = TRUNC(29300) = “29300.” Since 2.93e+4 (29,300) has no fractional portion, the number is returned unchanged. Similarly, TRUNC(2.931245E+4) = TRUNC(29312.45) = “29312.”
XOR(*x, y, …*)	Logical exclusive OR; true if an odd number is true. Computes a logical “exclusive or” for its arguments (e.g. “one or the other, but not both”). Accepts up to eight (8) arguments and evaluates to 1 if an odd number of its arguments are non-zero. 0 if an even number of its arguments are non-zero or if none of its arguments are non-zero.

Delay Calculation



Delay setup dialog and resulting graph showing a 20 sample delay

This option allows a Calculation channel to be used to plot another channel lagged (delayed) by an arbitrary interval. To have Acq*Knowledge* apply a Delay Calculation in real time:

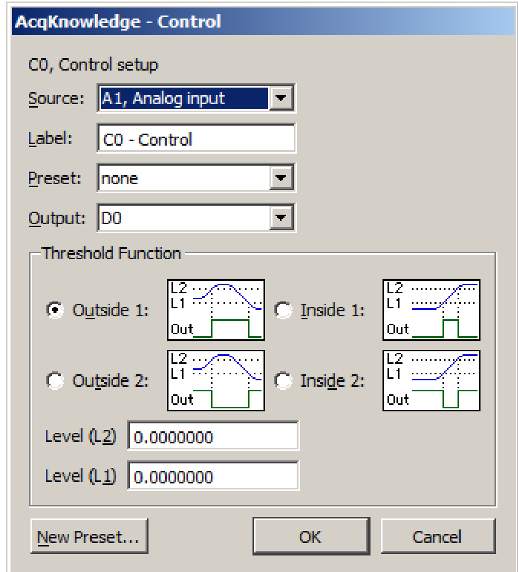
1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the modified data. If necessary, also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Delay.
5. Click the Setup button in the Input Channels dialog to generate the Delay dialog.

(Off-line Delay is available under Transform > Delay.)

The delay interval can be specified either in terms of samples or seconds. These types of plots are useful for producing non-linear (“chaos”) plots in Acq*Knowledge*’s X/Y display mode (see page 36 for a description).

When a delay channel is recorded, there is a segment at the beginning of the Calculation channel (equal to the value of the delay) that will read as 0 Volts. This is normal and occurs because the delay channel is waiting to “catch up” with the original signal. Acq*Knowledge* fills this buffer with zeros until the delay channel begins to plot actual data. In the example above, the delay channel contains a 0.25-second interval of zeros at the beginning of data file.

Control Calculation



The Control function is used to output a digital pulse when the value for a specified input channel exceeds a certain level, falls inside a given range, or falls outside a given range. This feature is unique in that the output is on a digital channel (which ranges from I/O 0 through I/O 15) rather than a Calculation channel. Also, unlike other Calculation channels, this Control Calculation can only be performed in real time (i.e., while data is being acquired) and cannot be performed in post acquisition mode.

In addition to outputting a signal on a digital channel, the Control Calculation will also plot an analog version of the digital signal on the selected Calculation channel. In the example below, Calculation channel C0 is used to perform a control function using analog channel 1 (A1) as an input and digital channel 0 (D0) as an output. In addition to outputting a pulse on D0, the setup below will also produce a plot on channel 40 (the first Calculation channel) that emulates the signal being output on digital channel 0. Since Calculations are analog channels, the Calculation channel does not contain a “true” digital signal, but is a reasonably good approximation. To retain the physical output generated by a Control channel, the output digital channel should be looped back to another digital input channel of the Hardware unit and acquired as well as being connected to any external devices. The calculation channel values are not guaranteed to precisely match the actual digital output.

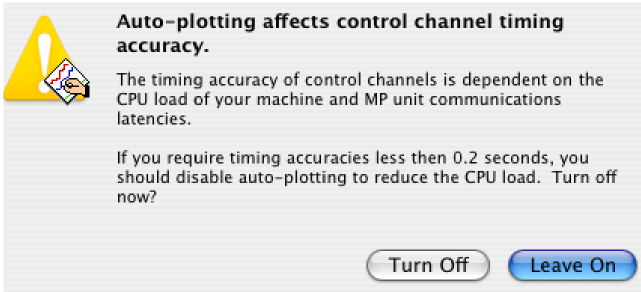
To configure Acq*Knowledge* to apply a Control Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the modified data. If necessary, also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Control.
5. Click the Setup button in the Input Channels dialog to generate the Control dialog.

There are four parameters that need to be specified for each Control channel:

a) Source channel
b) Output channel
c) Type of threshold function
d) Threshold level values

“Source” refers to the input channel to be used for the Control function. As with other Calculation channels, the Control function can use either an analog channel or another (lower) Calculation channel as an input. In the previous example, analog channel 1 (A1) is used as the input channel. It is not possible to use a digital channel as an input channel for a Control Calculation.



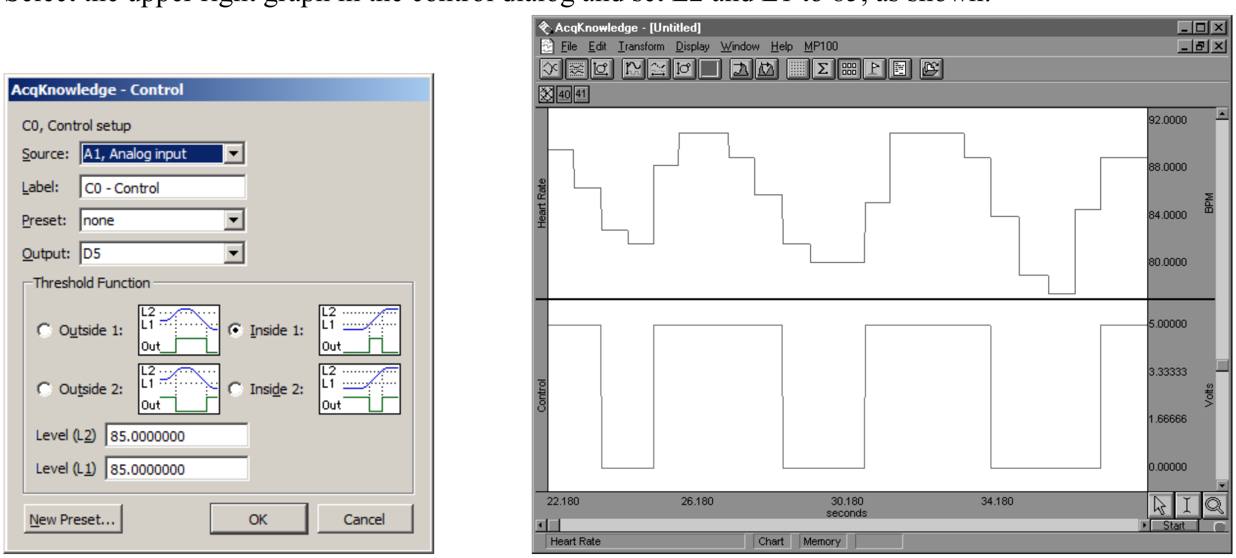
The channel selected in the Output Channel section determines which digital channel the pulse will be sent to. The digital channels range from 0 to 15 (D0 through D15) and external devices can be connected as described in the section on AMI100D/HLT100C/UIM100C connections in the *Hardware Guide*. In the sample dialog shown, the digital pulse is sent over I/O line D0.

Digital channels have two levels, 0 Volts and +5 Volts. When the signal transits from 0 Volts to 5 Volts, an "edge" is created and since the signal is going from low to high, this is referred to as a positive edge. Similarly, as the signal transits back from 5 Volts to 0, a negative edge is created. These transitions or edges can be used to trigger external devices when an analog signal level meets certain threshold criteria.

The Threshold Function option sets the criteria for the Control channel. Threshold conditions can be configured so that the digital I/O line goes to +5 Volts when the conditions are met, or it's possible to program the digital line to go to 0 Volts when the threshold conditions are met. Threshold conditions can be set so that either (a) the digital line is switched when the value of an analog channel exceeds a specified value or (b) the digital line is switched when an analog channel falls within a given range. Acq*Knowledge* also supports configuration of a single level threshold or a "wide" threshold.

Tip To use test conditions more complicated than simple thresholding, combine the conditional tests of Expression calculations with the Control channel to change digital output based on the Expression result.

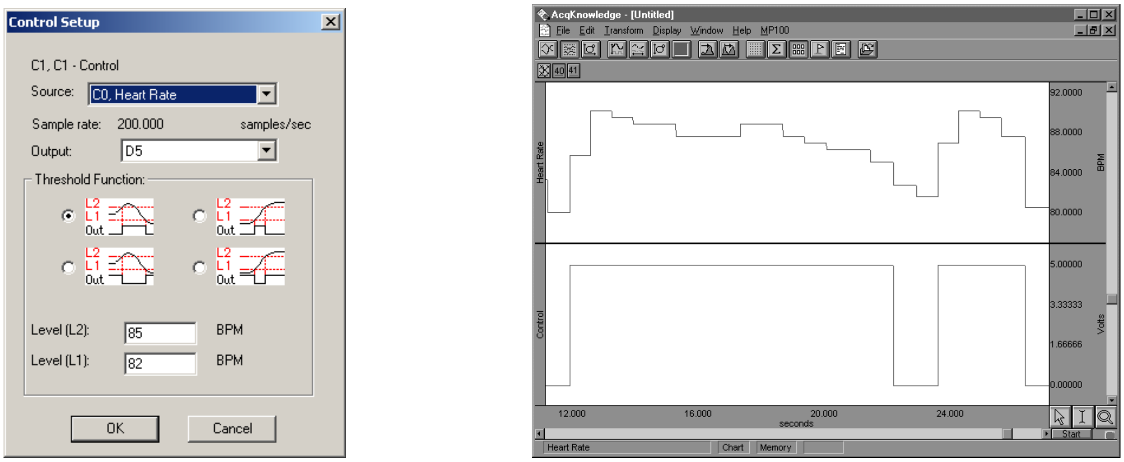
For example, suppose the user needs to set a Control channel to switch digital line 5 from low to high whenever the signal for Calculation channel one (C0) exceeds 85 BPM. Set the source channel to C0 and the output to D5. Select the upper right graph in the control dialog and set L2 and L1 to 85, as shown:



Control dialog and graph showing result of BPM control example

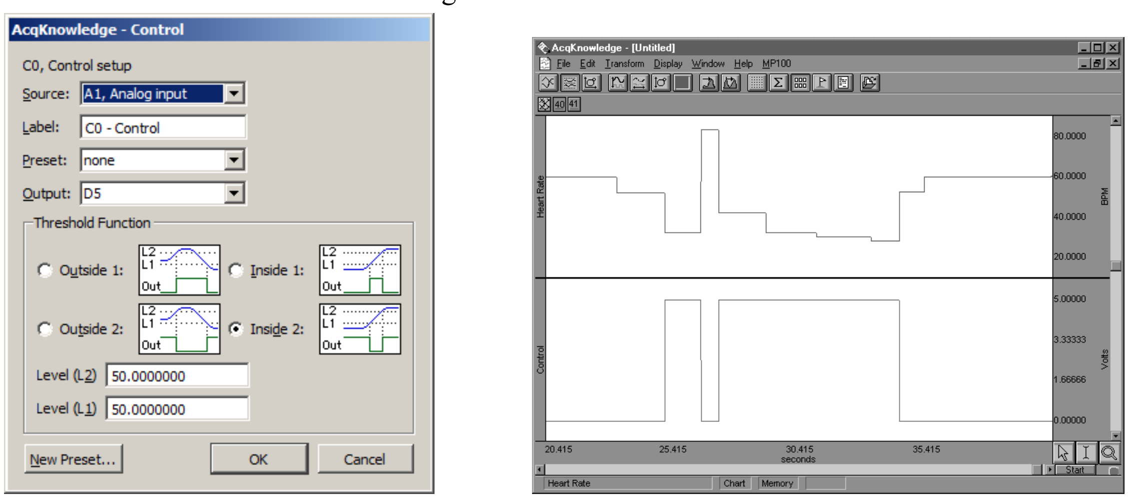
As observed in the preceding graph, there are a number of instances where C0 (heart rate) exceeds 85, usually for a short period of time. When it does drop below 85, it appears to return to a value greater than 85 within a second or two. In instances such as this, it might be useful to "widen" the threshold so that the digital line is triggered whenever the input value is greater than 85, but the signal must drop significantly below the threshold value before the threshold is reset.

As another example, the upper threshold value (L2) is set to 85 and the lower threshold (L1) is set to 83, which means that the threshold will not reset until the signal from the source channel drops below 83. In the following example, the digital line is switched from low to high (from zero to +5 Volts) when the heart rate channel exceeds 85, and stays at +5 Volts for several seconds even though the source channel drops below 85 (but above 83). The digital line does not switch back to zero until the heart rate channel drops below 83 (toward the end of the record). Once this occurs, the threshold is reset and the digital line will switch again the next time the source channel exceeds 85 BPM.



Control dialog and graph showing control channel with "wide" threshold

It is also possible to have the digital line switch when the source channel drops below a certain value. In the example below, a simple threshold is used to switch the digital line high each time the source channel drops below 50 BPM. Since L2 and L1 are set to the same value, this is not a "wide" threshold (as above) and the threshold resets each time the source channel goes above 50 BPM.

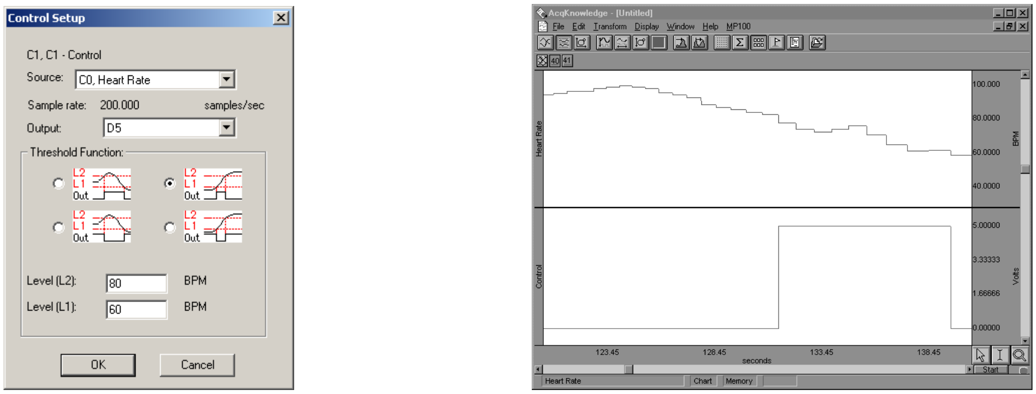


Control dialog and graph showing control channel detecting source channel levels less than 50 BPM

These examples are only a few of the possible applications of the control channel using the two threshold icons on the left-hand side of the Control Setup dialog. It's possible to construct variations of these (i.e., switching the digital line from low to high using a wide threshold whenever the source channel drops below a given channel) that are not discussed above. Moreover, each of the options can be construed somewhat differently than they have been presented here. For example, the previous example switches the digital line from low to high each time the signal on the source channel drops below 50 BPM. Conversely, it also switches from high to low each time the source channel value is greater than 50 BPM. This allows the default setting for the digital channels to be varied (whether the default is zero or +5 Volts) depending on what types of devices are connected.

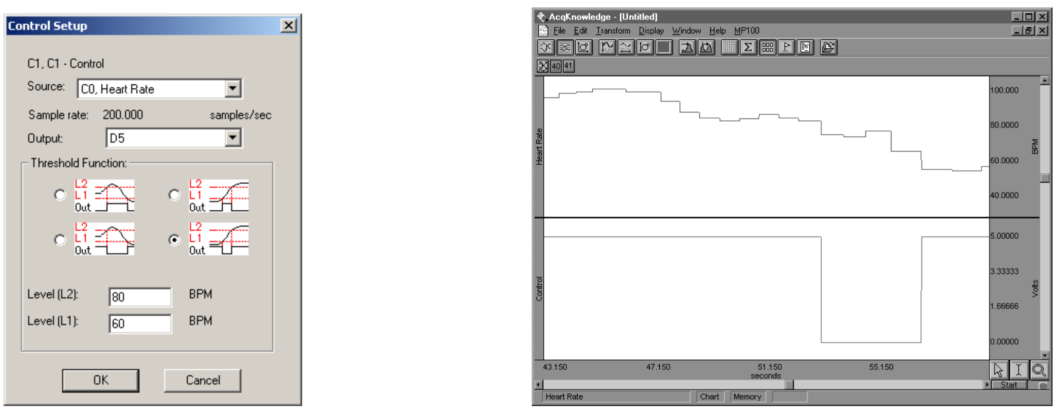
(For a description of how to connect various digital devices, see the section on AMI100D/HLT100C/UIM100C connections in the *MP Hardware Guide*.)

In addition to setting “above and below” type thresholds, it’s also possible to program the Control channel such that the digital line is switched whenever the source channel falls within a given range or outside a specified range. In the example that follows, digital line 15 is set to switch from zero to +5 Volts whenever the source channel signal falls between the values entered in the L1 and L2 boxes. In this case, I/O is switched to +5 Volts whenever the heart rate is greater than 60 BPM but less than 80 BPM.



Control dialog and graph showing control channel switching from low to high when source channel is between 60 BPM and 80 BPM

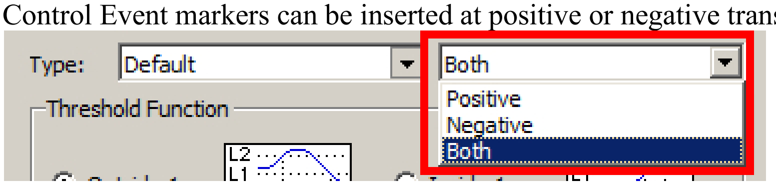
The digital line can be programmed to switch from high to low when the signal on the source channel falls *within* a given range. This is equivalent to setting the digital line to shift from low to high when the source channel values fall outside a given range (as shown below).



Control dialog and graph showing control channel switching from high to low when source channel is between 60 BPM and 80 BPM

Acq*Knowledge* 5.0.3 and higher: In addition to digital pulses, the Control function can also be used to output any supported Event marker type. To do this, select **Events** and **Event type** from the Output menu options.

Control Event markers can be inserted at positive or negative transitions or recorded for both directions.



For more information about Events, see the Chapter 11 “Set Up Event Marking” on page 247.

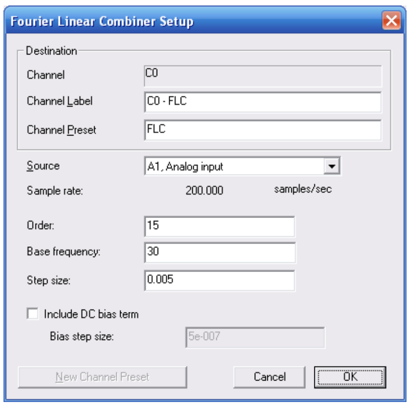
Fourier Linear Combiners: FLC, WFLC, CWFLC Calculations

Fourier Linear Combiners are linear combinations of adaptable sinusoidal functions that are particularly well suited to processing cyclic data. Sine and cosine are harmonics that are multiples of a *base frequency* that are summed together, and the *order* is the fixed number of harmonics used in the model. *Step size* provides mu, the gain factor used to adjust the weights of the harmonics at each processing step. Step sizes must be much less than 1 for the system to converge. As step sizes decrease, relaxation time lengthens. The FLC model is adjusted based on the source data using least means square (LMS) feedback and the *bias* compensates for DC offset.

To have Acq*Knowledge* apply an FLC Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. If necessary, also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select FLC, WFLC, or CWFLC.
5. Click the Setup button in the Input Channels dialog to generate the appropriate dialog.

➲ For offline calculation, see FLC Transform options, including *Scaled FLC*, on page 338.



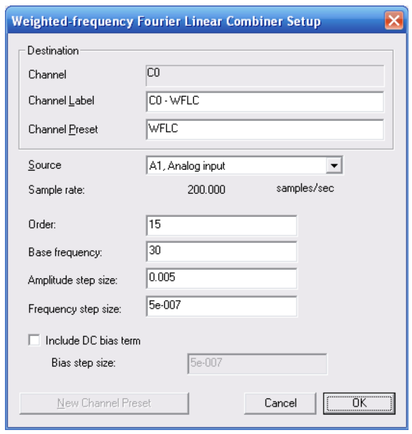
Basic FLC

Simple summation of fixed numbers of sines and cosines; uses harmonics of a fixed frequency and adjusts weighting coeffiicients of the mixture.

Operates on a single channel at a time.

Well suited for extracting data of a known frequency band from a signal with a stable frequency.

- Use as an adaptive noise filter to remove non-periodic and semi-periodic noise uncorrelated to the base harmonic frequency.



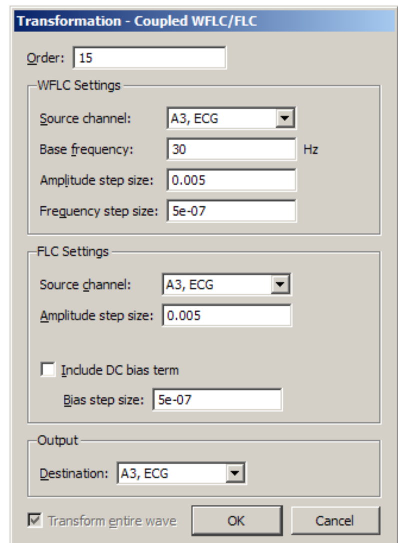
Weighted-Frequency FLC

Base frequency of the harmonics is variable; adapts the frequency in response to the input signal using LMS feedback; the frequencies are similarly adjusted to the amplitudes.

Operates on a single channel at a time.

Well suited for modeling periodic signals of an unknown and potentially varying frequency and/or amplitude.

- No cycle boundaries or frequencies need to be pre-determined.



Coupled WFLC/FLC

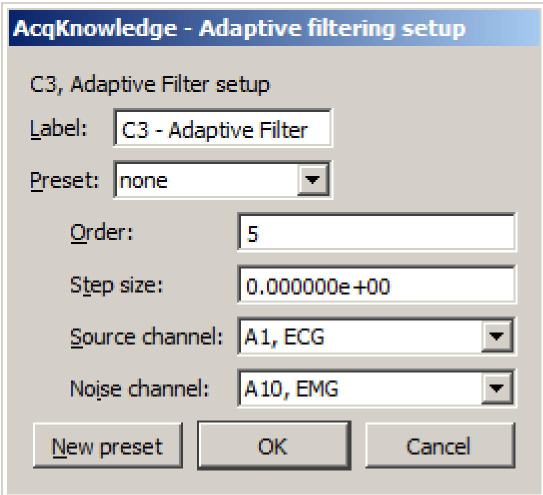
Runs a WFLC on the signal to determine the harmonic frequency and then runs the result through an FLC using the computed harmonic.

The second FLC can be run on the same or a different channel.

Well suited for real-time extraction of information from one signal based upon the frequencies contained in another signal.

- Use to remove movement noise from ECG.
- Unique configurations can be established with two input signals, one for frequency and one for amplitude.

Adaptive Filtering Calculation



Adaptive filtering is a signal processing technique that processes two different signals in relation to one another and can be used for noise estimation, noise reduction, general-purpose filtering, and signal separation. Adaptive filtering creates efficient high-quality filters with a minimal number of terms, which can be very useful in blocking mains interferences or other known periodic disturbances.

- Useful for noise filtering where it is possible to acquire a signal that is correlated to the noise (similar to the way noise-cancelling headphones detect and remove outside noise). Applications include removing EMG from ECG or EOG from EEG.

➲ See the Adaptive Filtering transform on page 335.

To have Acq*Knowledge* apply an Adaptive Filtering Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. If necessary, also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Adaptive Filtering.
5. Click the Setup button in the Input Channels dialog to generate the Adaptive Filtering dialog.

The weights within an adaptive filter are modified on a step-by-step basis. Acq*Knowledge* uses the N-tap FIR adaptive filter, with coefficients updated using least means squares (gradient) feedback.

Order	Specify a positive integer for the number of terms to be used in the internal FIR filter.
Step size	Provides *mu*, the rate of adaptation of the coefficients within the FIR filter.
Source channel	The source channel will be replaced by the adaptive filter results.
Noise channel	The noise channel is the signal that is correlated with the noise to be eliminated from the Source; it is not modified by adaptive filtering.

Source and Noise channels must have the same channel sampling rate (under Channel Set Up).

Comb Band Stop Filter Calculation

To have Acq*Knowledge* apply a Control Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. If necessary, also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Comb Band Stop.
5. Click the Setup button in the Input Channels dialog to generate the Comb Band Stop dialog.

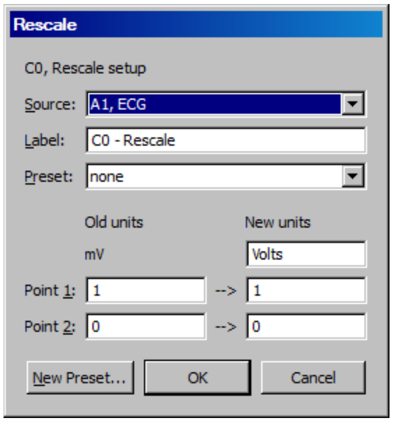
See page 165 for details.

(Off-line Comb Band Stop filter is available under Transform > Digital Filters > Comb Band Stop. See page 335.)

Metachannel

See Metchannel details on page 149.

Rescale Calculation



Rescale applies two-point linear mapping and allows users to change the measurement units (for example, to change temperature from Celsius to Fahrenheit). The text corresponding to the new units can be manually entered.

To have Acq*Knowledge* apply a Rescale Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. If necessary, also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Rescale.
5. Click the Setup button in the Input Channels dialog to generate the Rescale dialog.

(Off-line Rescale is available under Transform > Rescale.)

- Use the Rescale transformation (after acquisition) to adjust forgotten calibration of analog channels or reverse incorrect calibrations.
- A "Rescale" Automator action has been added to allow rescaling to be performed in workflows. The Automator function is accessed from the Workflow menu in the Mac version of Acq*Knowledge.* (Not applicable to Windows.)

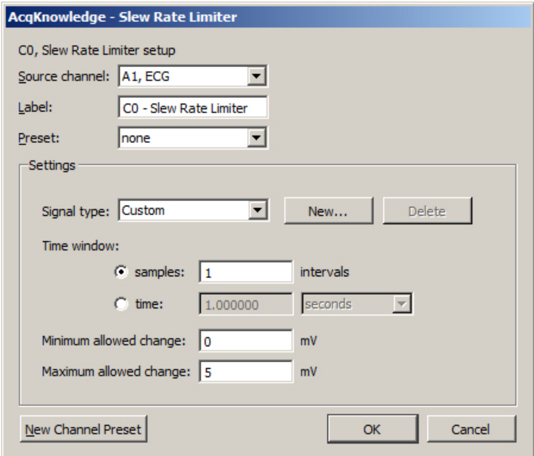
The rescale formula is:

$$v_{new} = \frac{y_{new} - y_{old}}{x_{new} - x_{old}} v_{old} + \left(y_{new} - \frac{y_{new} - y_{old}}{x_{new} - x_{old}} x_{new} \right)$$

Rescale Source	Displays the label and number of the selected channel.
Old Units	Displays the values of the current vertical units of the channel
New Units	Allows for manual entry of the new units to be used. The new units will be displayed in the vertical units of the channel

Note Transform > Rescale: The units cannot be modified when transforming from the selected area because it is not possible to display different vertical units for different time ranges in the same channel.

Slew Rate Limiter



Slew Rate Limiter is an effective tool for signal separating, denoising and removing motion artifact during and after recording. The algorithm restricts the rate of change of a signal to a specific time window or sample width window. The allowable amount of motion artifact over a given time/sample window can be precisely adjusted from a minimum allowable change to a maximum allowable change, thereby eliminating artifacts that exceed the selected amplitude range within a given time period.

The slew rate limiter algorithm restricts the rate of change of a signal to a specific window. If two different types of signals with significantly differing rates of change are mixed together, limiting the allowable rate of change of the mixed signal allows for signal separation by reducing the impact of a fast moving signal on a slow one (and vice versa). The slew rate limiter formula is:

Assume a mixed signal *y*. Define a time window width *w*. Define the minimum allowable change in amplitude over the time window *w* as and a maximum allowable change in amplitude as $K_{max} \geq 0$ where $K_{max} \square K_{min}$. The slew rate limiter function is then defined as:

$$slf(y,t)=\left\{\begin{array}{cc} t<w & y(t) \\ t\geq w \wedge |y(t)-slf(y,t-w)|<K_{min} \wedge y(t)=slf(y,t-w) & slf(y,t-w)+K_{min}\,sgn(random) \\ t\geq w \wedge |y(t)-slf(y,t-w)|<K_{min} \wedge y(t)\neq slf(y,t-w) & slf(y,t-w)+K_{min}\,sgn(y(t)-slf(y,t-w)) \\ t\geq w \wedge |y(t)-slf(y,t-w)|>K_{max} & slf(y,t-w)+K_{max}\,sgn(y(t)-slf(y,t-w)) \\ t\geq w \wedge K_{min}<|y(t)-slf(y,t-w)|<K_{max} & y(t) \end{array}\right\}$$

where sgn is the standard mathematical sign function and is used to preserve the relative direction of the change in the signal and random is a pseudorandom non-zero number used to avoid the singularity where sgn is zero, enforcing that the rate of change will not drop below K_{min} .

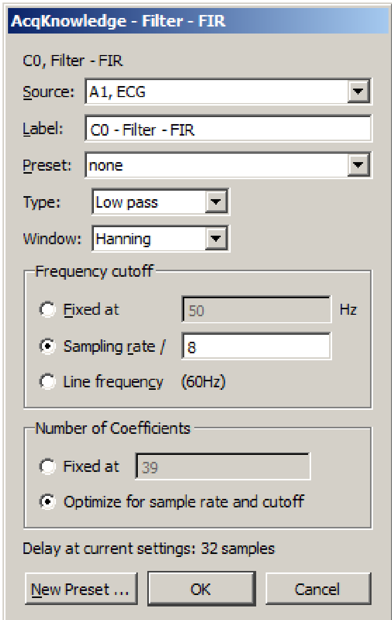
The slew rate limiter may be applied in real time as an online calculation channel, or in post-processing via the Transform menu (see page 359). As with all online and offline transformations, signal type settings can be saved as custom presets by clicking the "New…" button and naming the new preset.

To have Acq*Knowledge* apply the Slew Rate Limiter in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel to contain the filtered data. If necessary, also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull down menu and select Slew Rate Limiter.
5. Click the Setup button in the Input Channels dialog to generate the Slew Rate Limiter setup dialog.
6. Set the desired time window to apply the slew rate limiter algorithm based on seconds or samples.
7. Set the minimum and maximum allowed change to adjust the sensitivity to motion artifact.

8. Click OK and run the acquisition. Any artifact that falls outside the boundaries of the maximum/minimum allowed change setting will be eliminated from the recorded data.

Watch the Acq*Knowledge* Slew Rate Limiter video tutorial for a detailed demonstration of this feature.



Filter - FIR

In Acq*Knowledge* 5, FIR Filters are available as an online calculation channel. Until recently, real-time FIR filtering during acquisition wasn't feasible due to processing power limitations, but these constraints are no longer an issue for modern dual-core and quad-core processors.

Online FIR filters are similar to their offline transformation menu counterparts with the exception of the following convention.

Delay at current settings: For FIR filtering in general, a delay is imposed on the output signal, and this parameter shows the number of delay samples the current settings will introduce. If the number of coefficients is fixed, the delay value will equal the number in the "Fixed" editable field. If the number of coefficients is set to be optimized for sample rate and cutoff, the delay value will vary. The filter algorithm compensates for this delay in order to assure proper alignment of filter output with the acquired signal.

When modifying the fixed number of coefficients or the frequency, the delay value is updated accordingly. However, it should be noted that a close comparison between online and offline FIR filters will reveal that they are not perfectly in phase, but out of phase by half of the imposed FIR calculation channel delay.

As in other Acq*Knowledge* calculation channel presets, any modified Filter – FIR setup can be saved as a custom preset by selecting "New Preset."

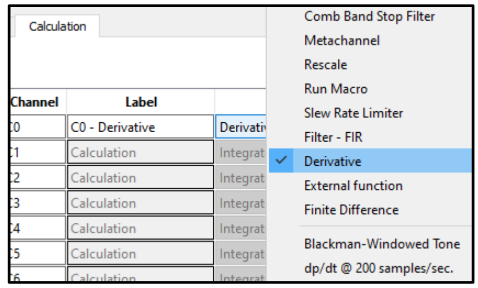
To have Acq*Knowledge* apply the Filter – FIR in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check the Acquire, Plot, and Values box for the Calculation channel to contain the filtered data.
4. Click the Preset pull down menu and select Filter – FIR.
5. Click the Setup button to generate the Filter – FIR settings dialog.
6. After starting acquisition, real time FIR filtering will appear in a dedicated calculation channel for the duration of the recording.

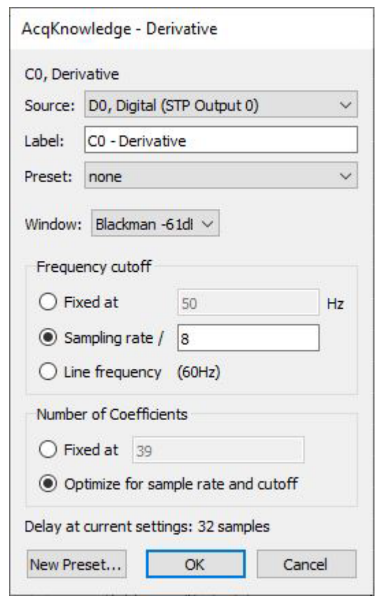
For specific details on the various FIR filter types, windowing, and recommended settings, see the offline Filter – FIR Transform option on page 332.

Derivative Calculation

The Derivative calculation channel preset allows FIR-based online derivative calculation. This calculation channel performs the same computations available in post-acquisition processing via ‘Transform > Derivative…’ (see Chapter 15). As with other FIR calculation channels, output of the derivative calculation channel is delayed by half of the window width. This preset channel is adaptable and can be used for online signal processing by utilizing the incorporated lowpass filter, which can be tuned for optimal operation at a variety of frequencies.



1. The Derivative calculation channel can be accessed in both the regular calculation channel setup menu and the metachannel setup.
2. When selected, a derivative calculation channel setup dialog box will appear.
3. The derivative calculation channel setup dialog allows users to select or define the following controls:



Control	Description
Source	This pulldown selects the channel for which the derivative will be calculated.
Label	Displays the title that is to be given to the graph channel holding the derivative output on the initial data acquisition.
Preset	Pulldown applies user-defined derivative calculation channel preset to this configuration dialog.
Window	Allows user to select type of windowing used to construct the filter, including Bartlett, Hanning, Hamming, Blackman, Blackman 61, Blackman 67, Blackman 74, Blackman 92, and KaiserBessel.
Frequency Cutoff	
Fixed at	When selected, the built-in lowpass filter will be applied at the user specified frequency.
Sampling rate	When selected, the lowpass filter will be set at a fixed, user-defined fraction of the waveform sampling rate for the calculation channel.
Line frequency	When selected, fixes the lowpass filter to either 50Hz or 60Hz, depending on user preferences.
Number of Coefficients	
Fixed at	When selected, this allows the overall number of coefficients to be manually specified. Windows will always be of an odd integer width. If an even number is specified internally, it will be extended by 1 automatically.
Optimize for sample rate and cutoff	When selected, the number of coefficients will be automatically set to four times the sample rate divided by the cutoff frequency.

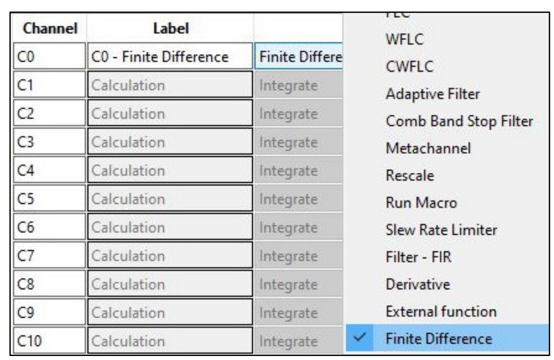
Delay at current settings	Automatically updates as the frequency and coefficient settings are adjusted. Displayed number indicates how many samples of the derivative channel will be delayed compared to the source channel. To make direct comparisons with time-aligned samples, add a separate Delay calculation channel with the same source as used for the derivative channel. This number provides the parameter to align the Derivative and Delay channels.
New Preset	Click to create a new derivative calculation channel preset with the current settings of the dialog. User will be prompted to create a unique preset name.
Cancel	Dismiss the dialog without modifying any settings.
OK	Apply the settings and close the dialog.

Saving Derivative Calculation Channel Settings

Derivative calculation channels and their settings will be saved in graphs and graph templates. Calculation channel presets may be saved for derivative channel types and for metachannels that contain derivative subchannels.

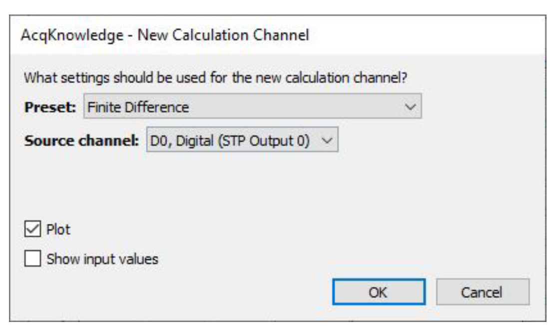
Finite Difference

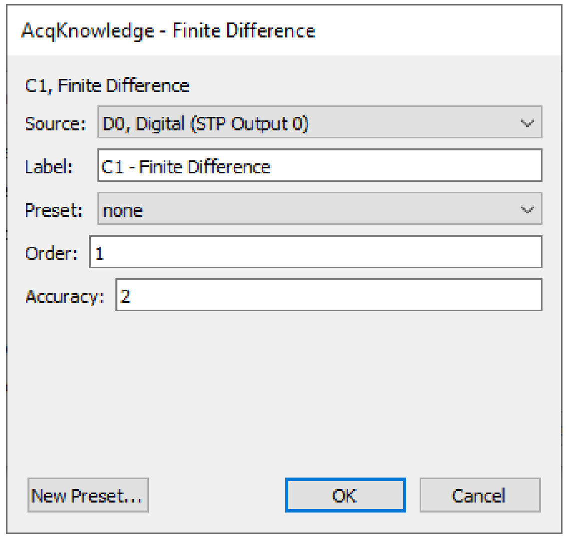
The Finite Difference calculation channel applies an algorithm that performs numerical approximation of higher order derivatives. The finite difference is used to approximate derivatives in numerical methods, such as solving differential equations and boundary value problems. It can be scaled to approximate derivatives over intervals with larger numbers of samples and to approximate partial derivatives for multivariate systems.



The Finite Difference calculation channel is included with Acq*Knowledge*'s built-in channels. It is available both as a primary calculation channel and as a metachannel subchannel.

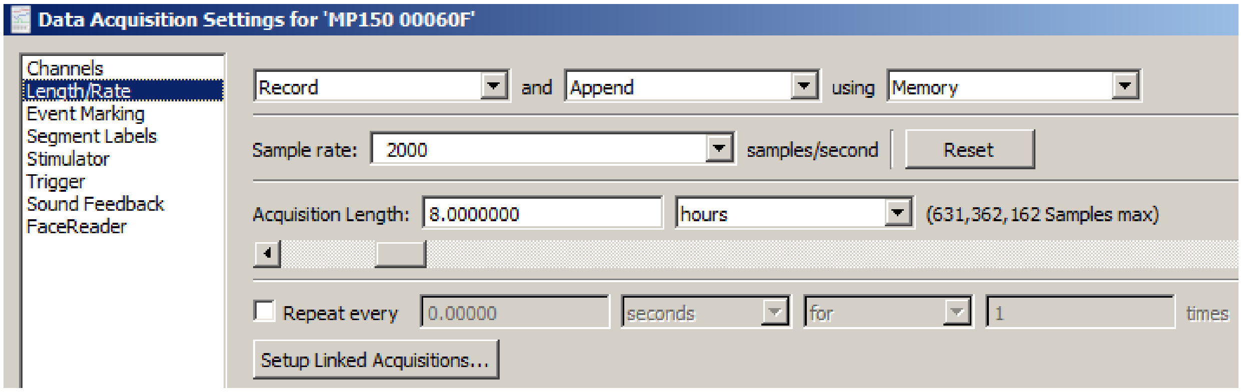
1. From the **Data Acquisition Settings** window, select the **Calculation** tab.
2. Check the “Acquire” box for the channel to be used for the calculation and select Finite Difference from the Preset column.
3. This will open the preset configuration window, which will display the name of the preset (in this case “Finite Difference”) and the source channel. Click **OK** to select the preset.
4. The Finite Difference dialog box allows users to define the following controls:





Control	Description
Source	This pulldown lists the present source channel for the finite difference calculation and contains all valid source channels for the Finite Difference channel or Metachannel subchannel.
Label	Displays the y axis label which will appear on the left side of the channel in the graph window when data are acquired.
Preset	If a user's finite difference preset is shown, indicates the preset name, otherwise "none." Individual user presets may be chosen from the popup menu and will be applied to the dialog settings. Users can create channel presets for Finite Difference calculation channels that will be stored persistently across application launches.
Order	Order of the derivative that should be estimated.
Accuracy	Number of extra samples to include in the finite difference. Must be at least 2. Accuracy numbers are rounded to even numbers, so any odd entry here will be automatically rounded.
New Preset…	Creates a new calculation channel preset from the displayed settings in the dialog. After clicking this button, provide a name for the preset. That name will then appear in the Preset dropdown menu (see above) when setting up any Finite Difference channel. The preset may also be selected directly from the channel preset popup menu for any channel in the channel setup dialog box or any subchannel from the Metachannel setup dialog box. The new preset will appear at the end of the list and can be moved, renamed, or deleted via "[Hardware] > Organize Channel Presets…"
Cancel	Exits the dialog without changing any channel parameters. Note: if this dialog box was reached by selecting a preset, clicking "Cancel" does not undo that selection. The channel will retain the default settings for that selected preset.
OK	Applies the settings to the calculation channel and closes the dialog.

Chapter 7 Data Acquisition



Data Acquisition—The Basics

Once the channels to be acquired have been selected (see **Chapter 5 Channel Setup** on page 116), the next step is to set up the acquisition parameters. These options control the data collection rate, where data will be stored during an acquisition, and the duration of each acquisition. Choose Hardware > Set Up Data Acquisition > Length/Rate to generate the following options.

Storage Mode

At the top of the dialog are three popup menus that controls a number of aspects for storing the data from each acquisition.

Record/Record last controls whether the software saves all the data or only the most recent segment of the data.

- **Record**—the hardware will store data for the amount of time specified in the acquisition length box. This is the default and is appropriate for almost all types of acquisitions.
- **Record last**—only available when acquisitions are set to "Save Once" using "Memory"—the hardware will acquire data continuously, but will only store the most recent segment of data equivalent to the duration in the acquisition length dialog. That is, if the value in the acquisition length box is 30 seconds and record last is selected, the hardware will acquire data ad infinitum, but will only store the most recent 30 seconds of the data.

Save once/Autosave file/Append sets how the data is saved to a file. **Append** mode is the default setting..

- **Save once**—Acq*Knowledge* will begin an acquisition after clicking the Start button, and will stop recording automatically when the acquisition length has been reached or when the Stop button is clicked.
- **Autosave file** — this mode performs several acquisitions one after another, and saves the data from each acquisition to a separate file. When Autosave is selected, a File button will appear to the left of the sample rate dialog. Click "File" to generate a standard Save dialog to enter the root file name for the data from each acquisition. After clicking "Save," another dialog is generated with options to append an incrementing number, time (system clock), or date (system clock) to the filename: Media functionality does not support the *Autosave file* acquisition mode.
- **Append** —similar to 'Save Once', except that Append allows acquisitions to be started and stopped at arbitrary intervals. Append mode is unique in that clicking on the Stop button only pauses the acquisition, which can then be restarted by clicking the Start button.

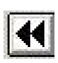
Each time an acquisition is restarted in Append mode, an append event is inserted into the recording. Append events can be configured to include user-defined labels and time/date stamps via the Segment Labels setup (see page 274). Although acquisitions can be paused for any period of time, the Hardware will only acquire data for the amount of time indicated in the Acquisition Length box. Data can be acquired in Append mode while being saved to memory, disk, or the MP hardware unit (but not in Averaging mode).

Sample data Acquired in "Append" mode.
Events indicate where Acquisition was paused.

Appended segments can be stored to disk, memory, or MP160/150. (MP36R, BioHarness, or B-Alert do not support data storage to the hardware unit.)

- **Append to Disk**: In this mode, it is usually best to record all channels at the same rate. If the user stops the acquisition, the length will be the same for all channels—so the next segment of appended data will neatly link onto the end of the existing record.
  - Any existing Acq*Knowledge* 5 file can be appended. Change the acquisition mode to Append; any of the storage options are applicable
- **Append to Memory**: In this mode, data is appended to the "uneven" waves in the same manner as described for Append to Disk. When channels are sampled at different rates, this mode will respond faster than Append to Disk because the data files are already in memory, so the software doesn't need to rewrite all the data files in the graph.

A **Reset** button is generated in the Set Up Acquisition dialog when Append is selected. Click the Reset button to erase the acquired data file and start a fresh acquisition file (this is essentially the same as clicking OK to an "Overwrite existing data?" prompt).



The **Rewind** button to the right of the Start/Stop button will delete the last recorded segment. Ctrl-Rewind (Windows) or Option-Rewind (Mac OS) will delete all recorded segments (similar to the Reset button).

Append plus **external trigger**

Appended segments can be started with an external or internal trigger. The experiment can be tailored to start at points of interest by applying a trigger. See Triggering details on page 202.

Append plus **Variable Sampling Rates**

If the mode is started and stopped manually, it is statistically possible that, prior to the next pass of the Append, extra data points may be inserted in various data channels to "line up" the data (see sample on page 120). These extra data points simply replicate the last sample in any affected channel. To minimize the impact of the extra data points, make sure the lowest sampling rate is on the order of 10 Hz or higher, or don't use VSR.

Disk/Memory/MP/Averaging determines where to store data during an acquisition. Once data has been acquired and is stored in a file, it is stored on a hard disk or other similar device. There are a number of options for storing data *during* an acquisition. The best choice as to where data should be stored during an acquisition depends in large part on the nature of the acquisition itself, and the type of computer being used.

- Memory stores data in computer memory during an acquisition. After the acquisition is completed, it will be necessary to select Save As... from the File menu to permanently save this to the computer's hard disk. This usually allows for faster acquisition rates, although most computers have less available RAM than disk space.
- Disk saves data directly to the computer's hard disk during an acquisition. Disk mode is fast enough (in terms of maximum sampling rate) for many applications, especially when only a few channels are being acquired. Saving data to Disk also allows for longer acquisitions. A final advantage of saving data directly to Disk is that if there is a system failure (including power outage), all the data collected up to that point is saved on disk and can normally be recovered, whereas the data is deleted if it is being saved to computer memory.

  IMPORTANT—When saving files to Disk, always be sure to save files under a different name BEFORE starting each acquisition. Otherwise, any previous data in that file will be overwritten. In Memory mode, simply save the file after the acquisition.
- MP160 and MP150 stores a small amount of data on the hardware itself. The MP160/150 is limited only by internal memory, with storage estimated at 4 MB and 400 kHz aggregate sampling rate.

  Obviously, data cannot be sampled this fast for a very long period of time if it is to be stored in the hardware. Also, as more and more channels are acquired, the duration of acquisition to the hardware unit will shorten. Data stored to the hardware is not plotted on the screen as it is being acquired, but will automatically be plotted on the screen as soon as the acquisition is terminated.
- Averaging is used exclusively for acquisitions involving repeated trials; see page 191.

Acquisition Sample Rate

The value in the box labeled "Sample rate" indicates how many samples the hardware should take per channel during each second of data acquisition. The sample rate can be changed by clicking on the pull-down menu. Individual channels can be down-sampled (variable sample rates), on the channel pane of the Data Acquisition Settings dialog. The down-sampled or channel sample rates are limited to specific power of 2 less than the acquisition sample rate; for example, If the acquisition sample rate is 100 samples/seconds, then the available channel samples rate are 100, 50, 25, 12.5, etc.

Depending on the nature of the data being acquired, the "best" choice in terms of sampling rate will vary. Technically speaking, the minimum sampling rate should be at least twice the highest frequency component of interest. This means that if the observed phenomenon has frequency components of 100 Hz, the sample rate should be at least 200 times per second. Fourier analysis (FFT) can be used to determine what frequency components are present in the data (see page 367 for a more detailed description of the FFT function).

> TIP: A good rule of thumb is to set the sampling rate to at least three to four times the highest frequency component of interest.

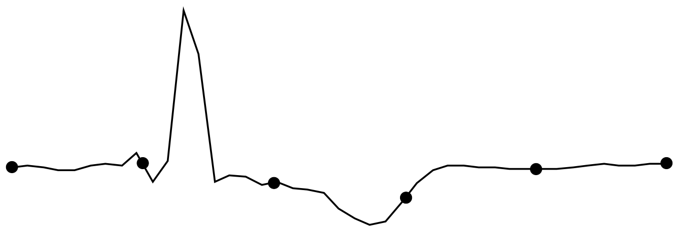
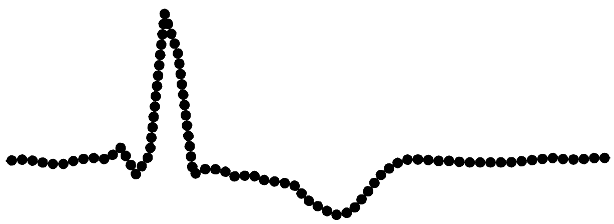
In less technical terms, lower sampling rates can be used for data with slowly changing values (e.g. respiration, EDA, GSR), whereas higher sampling rates should be set for data where values change markedly in magnitude or direction (e.g. ECG, EEG, evoked response).

The maximum allowable sampling rate will automatically adjust itself according to the storage mode, how many channels are being acquired in the channel setup window and the type of computer being used.

If data is being stored to disk or computer memory (RAM) during an acquisition set to a sample rate that is too high, the acquisition will begin normally, but Acq*Knowledge* will stop the acquisition and display a message indicating that the acquisition buffer has overflowed. The data up to this point has been saved, and acquisition or channel settings should be adjusted; lower sampling rate; shorter length or fewer channels

The sample ECG waveforms below illustrate the effect of different sampling rates on quality of data. Each black dot corresponds to a sample point.

- Top waveform: data is sampled relatively slowly; difficult to make out the shape of the waveform.
- Bottom waveform: sampled at a relatively high rate; increased resolution of the waveform. Waveform components that were obscured at slow sampling rates are now well defined, and measurements taken on this waveform would be able to better establish the maximum amplitude, time between different ECG complexes, etc.

	Representation of ECG waveform sampled with relatively few samples per second "True" ECG wave is superimposed over dots that indicate sample points.
	Representation of same ECG waveform sampled at a relatively higher sampling rate.

As shown, under-sampling completely misses the QRS complex of this waveform, although it might detect components of the QRS in subsequent beats. Although this is an extreme example of how under-sampling can affect digitally processed data, it is important to note that the rate at which data is sampled has important implications for the interpretation and analysis of data.

Acquisition length

To set the duration of an acquisition, enter a number in the acquisition length box. By default, 8 hours of data will be recorded for MP and Smart Center hardware. Select the length units from the popup menu to the right of the length box. The units are milliseconds, seconds, minutes, hours, or samples. Changing this option will not change the length of the acquisition, only the units used to describe it. Thus, the same acquisition can be described as lasting 30 seconds, or 0.5 minutes, or 30,000 milliseconds. Scaling the duration of an acquisition in terms of samples is essentially the same as the time scaling options, except the length of the acquisition will be expressed in the total number of samples to be collected on one channel.

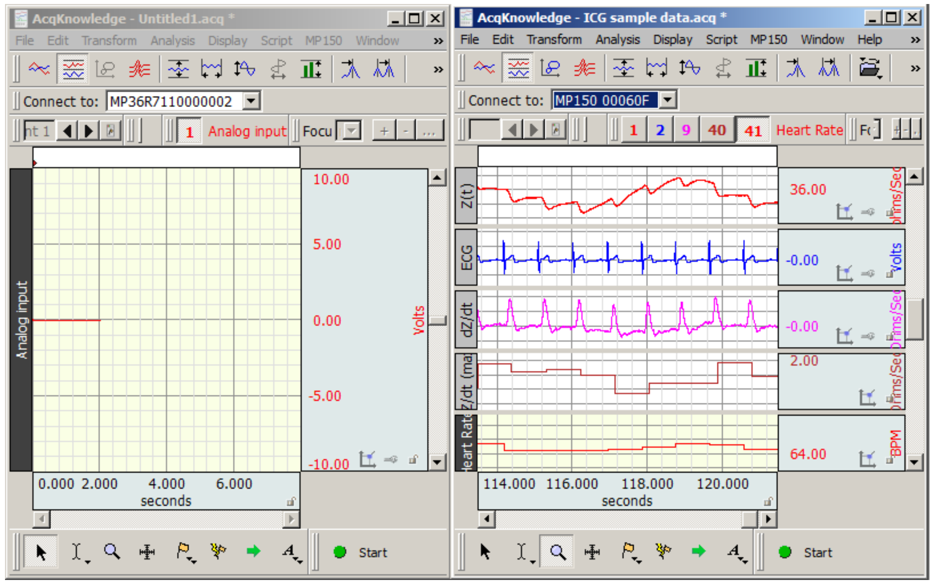
Regardless of units used to determine the length of acquisition, Acq*Knowledge* will end an acquisition when the value in the total length box is reached. The acquisition can be halted at any time by clicking the "Stop" button.

Multiple Hardware

Acq*Knowledge* can be used with multiple data acquisition units to:

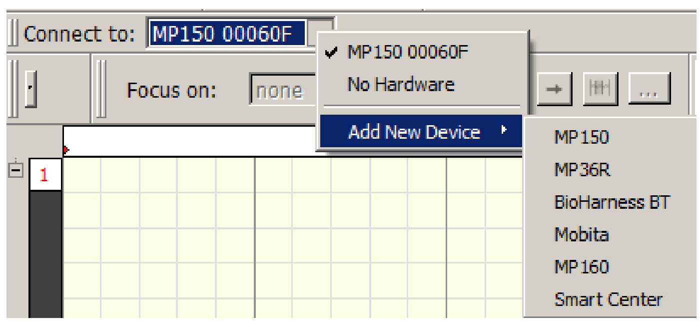
- Control multiple, independent experiments on one computer.
- Increase the total number of channels used for a single experiment (e.g., 32-channel EEG)
- To synchronize the Start of multiple units, use the External Trigger function.
- To combine nearly unlimited channels of data into one file, use the Merge Graphs feature (see page 322).

Each graph window can support a different Hardware unit. To open a graph for a separate hardware unit, select File > New > Graph.



To show/hide the “Connect to:” information, go to Display > Show > and toggle the “Hardware” option, or select this item from the “Show/Hide” popup menu .

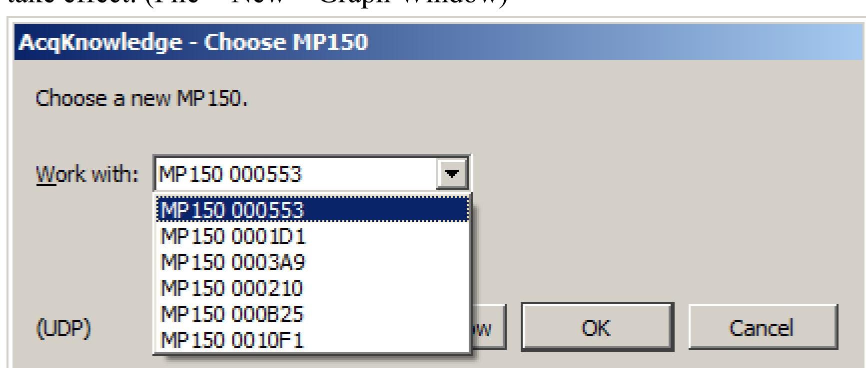
To switch the hardware unit associated with a graph window, click the “Connect to” box and select an available unit or choose Add New Device. Different hardware types may be added and consolidated in the list by selecting ‘Add New Device.’



NOTE: When switching to a BioHarness BT device from another hardware type, a new graph must be launched in order for the BioHarness settings to take effect. (File > New > Graph Window)

The “Choose MP160” or “Choose MP150” dialog shows the MP160/150 units residing on a local network. (Network functionality is limited to MP160/150 hardware only.)

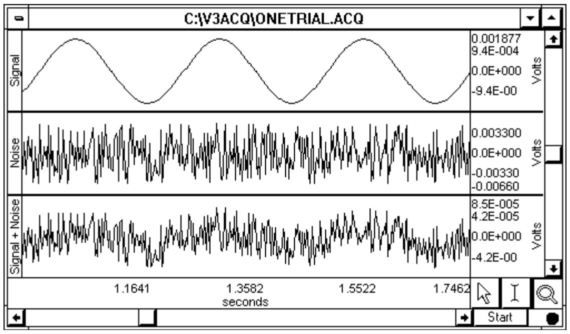
Click the **Help…** button to open a troubleshooting guide for communication problems.



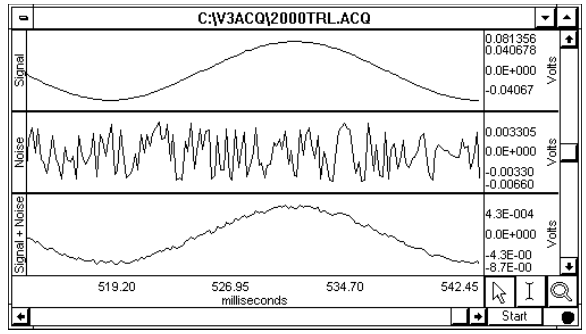
Averaging (MP160 and MP150 Hardware only)

Overview

In some instances, the signal of interest does not stand out against the background or ambient noise (the level of ambient noise exceeds the signal produced by the object of interest), and the only way to detect the signal of interest is to perform repeated trials as part of one acquisition, and average the trials together. Since the “noise” associated with the signal is assumed to be random, and the “signal” is assumed to be systematic, the noise should approach zero as the individual trials are averaged together.



Signal (top) measured in the presence of noise (middle), which results in the bottom waveform when measured in standard Acquisition mode



Same signal averaged in the presence of noise over 2,000 trials to produce the lower waveform.

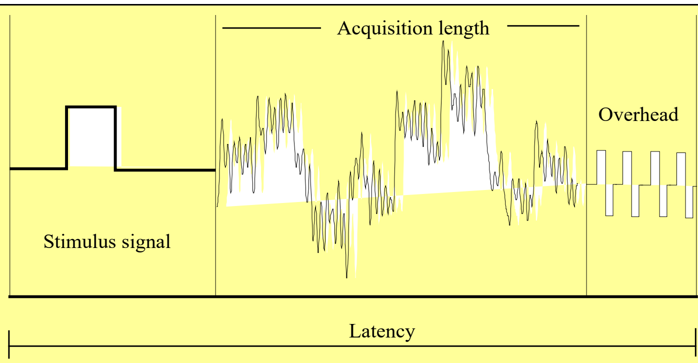
Typically, any averaging acquisition consists of three general components:

(a) the stimulus signal

(b) the duration of the acquired data, and

(c) a small amount of processing time (or overhead) that takes place between acquisitions.

The duration of the stimulus signal and the duration of data to be acquired can be set by the user. The amount of overhead required is a function of the acquisition length, the sampling rate, and the number of channels being averaged.



Stimulus signal	usually some sort of pure tone or pulse; occurs at the beginning or during each trial.
Acquisition length	refers to the amount of data to be acquired during each trial.
Overhead	refers to a period of time after data has been acquired that is needed to perform the mathematical averaging.
Latency	refers to the total time elapsed between the start of one trial and the start of the subsequent trial.

Important usage notes

- **The maximum length of a single averaging pass is restricted to 2 seconds**; if longer averaging passes are required, use regular data acquisition and use the Ensemble Average offline analysis option to generate averages in post-processing.
- **The preferred hardware setup for on-line averaging mode is direct connection to the MP160/MP150** via cross-over cable. To improve stability, avoid interruptions during acquisition:
  - Do not access top-level menus (File, Edit, Transform, etc.) or generate popup dialogs (Setup…).
  - Avoid running other programs—helps ensure that required system resources (processor time, memory, and network throughput) remain available.
  - If the MP160/150 is connected over a network, avoid running applications that consume network traffic (Internet Explorer, mail client, media player)—these may interrupt/delay communication to the MP160/150.

Averaging Setup

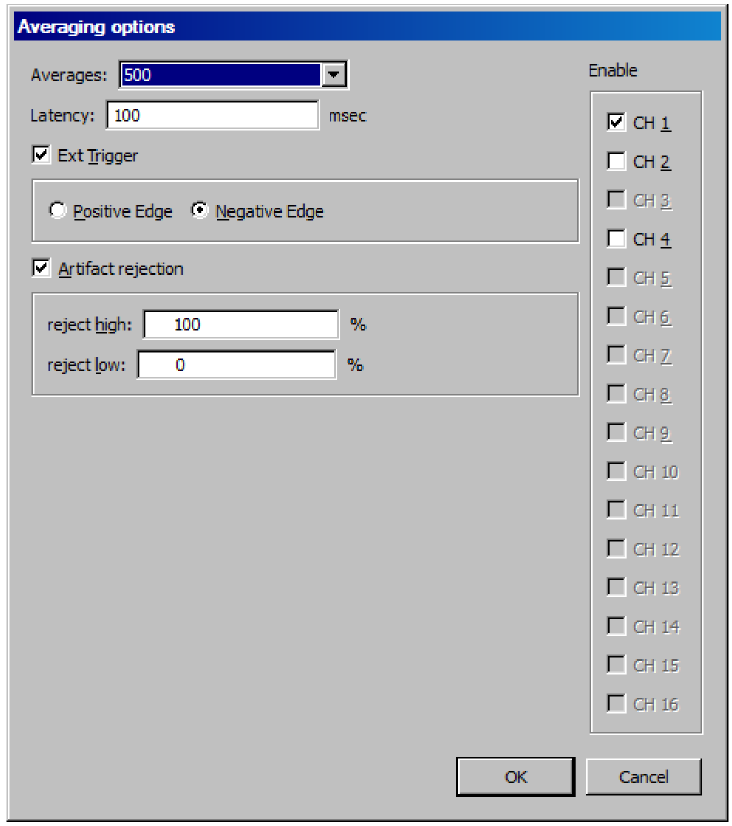
For Advanced Averaging, see page 194

To set up Averaging:

1. Choose MP160/150 > Set Up Data Acquisition > Length/Rate and select "using Averaging" option.
2. Click the Setup button to generate the Averaging options dialog.
3. Set the Averaging options as detailed below.
4. Click OK to close out of the dialog.
5. Set the Stimulus (see page 205).
6. Use the buttons in the graph window to Start or Stop the averaging acquisition.

Online averaging progress bar

An online status bar is added to graph windows when online averaging acquisitions are in progress. The status bar displays the number of averaging passes that have been completed and the number of passes that have been rejected by the MP160/150 firmware.



<u>Averaging Options</u>

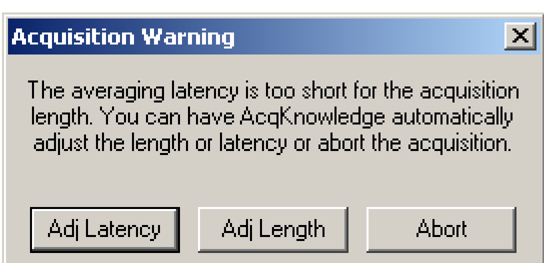
Averages

Select the number of trials to perform from the pull-down menu, to a maximum of 10,000.

Latency

Latency is the total time from the start of one trial/average to the next; it includes the time for stimulus signal, acquisition and overhead. As a rule, set latency to three times acquisition length plus any experimental delays, for example allowing the subject's signal to return to the baseline. The default setting for latency is 100 msec.

If the latency is set to a value too short to allow for averaging to take place, an Acquisition Warning will be generated:



- Adj Latency: automatically adjust the latency to the shortest possible value that still allows for data to be acquired and processed.
- Adj Length: reduce the amount of data acquired without changing the latency.
- Abort: return to the graph window without any data being collected.

External trigger

To initiate a trial from an External Trigger signal enable the Ext Trigger in the Averaging options dialog as well as the Positive or Negative Edge. The trigger can be set up in the Trigger pane of the Data Acquisition Setting dialog. See page 202.

Artifact rejection

Occasionally during an acquisition, extreme levels of unwanted signal artifact may be present. Checking artifact rejection allows the determination of which signal levels constitute artifact, and has the MP System reject these trials. When artifact rejection is enabled, the MP System will ignore any trials that contain signals exceeding the artifact rejection thresholds, keep track of how many trials have been rejected, and add that number of trials to the total number of trials to be acquired. This allows a user to "re-try" a trial that was rejected due to the presence of artifact.

To set these parameters, it's necessary to set a high threshold and a low threshold. Both thresholds refer to the scale limits (normally ±10 Volts). If the high and low artifact rejection thresholds are set to 80% and 30% (respectively), the MP System will reject any trial where the signal exceeds +8 Volts or –3 Volts.

When the channel scaling feature is used to change the range of Map (Scale) values to something other than ±10 Volts, the artifact rejection formula for symmetrical limits is: $y = ((2 \cdot PV)/100) \cdot x - PV$

where y = voltage threshold
PV = Peak Value
x = percent threshold (whole number)

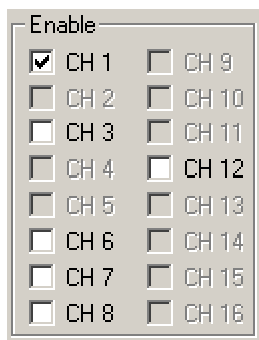
If non-symmetrical limits are used, the following equation is used: $y = ((V1-V2)/100) \cdot x + V2$

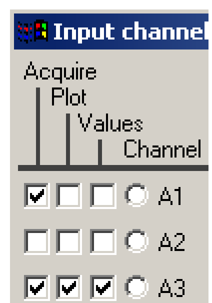
where y = voltage threshold
V1 = Higher Peak Value
V2 = Lower Peak Value
x = percent threshold (whole number)

Enable Channels

To add analog channels to the average, check additional channels in the Enable list.

- Channels must be set to "Acquire" under Hardware > Set Up Data Acquisition > Channels to be selectable here; otherwise the channel box will be grayed out.





Stimulus Signal

Although Acq*Knowledge* does not require a stimulus signal to be output for Averaging trials, most applications that use signal averaging make use of a stimulus signal. Digital stimuli (i.e., clicks) or analog stimuli (i.e., tones, pulses, and arbitrary waveforms) may be output.

In almost all cases, the most convenient way to output a stimulus signal is to output a predefined wave on analog output channel A0 and/or A1. It's possible to create pulse waveforms, tone waveforms, ramp waveforms, and arbitrarily shaped analog waveforms. Use MP160/150 menu > Set Up Data Acquisition > Stimulator to set all of the stimulus output functions (see page 205).

After Averaging is started, the Start button turns to Averaging status and the green dot turns to "A" to indicate that Averaging is in process.

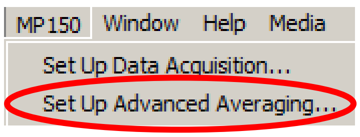
Advanced Averaging—P300

Advanced averaging can be used to set up P300 protocols. A sample P300 setup, P300.avg, is included in the Samples folder.

To set up Advanced Averaging:

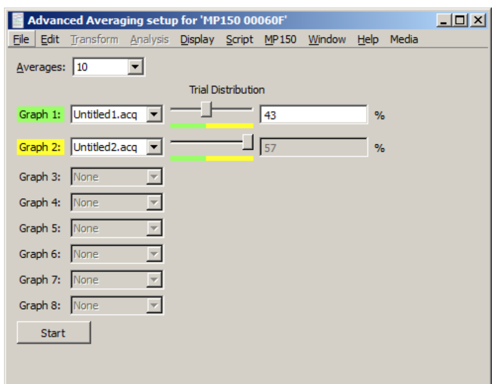
1. Open two or more graph files.

2. Use Set Up Data Acquisition > Length/Rate to set each graph file for Averaging (see page 191).
3. Click the Averaging Setup button and set Averaging Options as desired for each graph file.
   - Advanced Averaging uses the last entered settings for each Averaging graph. The number of Averages is controlled by the Advanced Averaging Settings, not the settings for a single Averaging graph.
4. Use Setup Stimulator to establish the desired stimulus output for each graph file (see page 205).
   - Set the Stimulator Output channel to the same channel (A1 or A0) for all graph files.
   - Set the Stimulator Output to During Averaging Pass (recommended).
5. Save each graph file with an appropriate name.
6. Choose MP160/150 > Set Up Advanced Averaging.



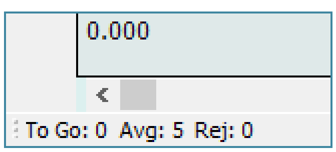
This menu option is only enabled if two or more open graphs are set to Averaging.

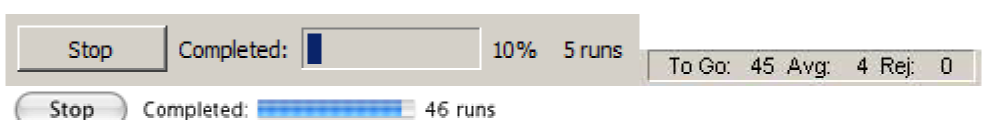
7. Set the Advanced Averaging options:



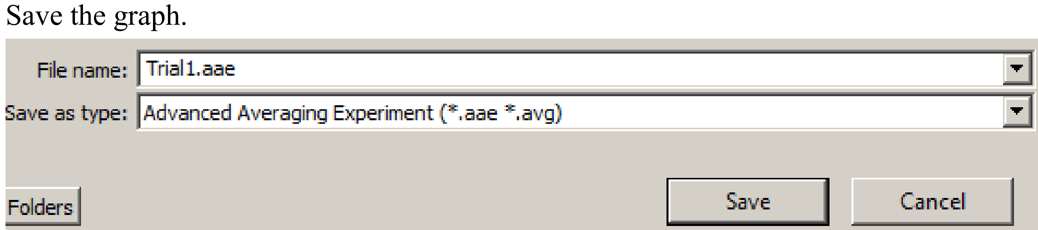
   a. Averages: Select the number of averages from the pull-down menu (max 10,000).
   b. Graph: Assign a Graph from the pull-down menu of open graph files. Up to eight graph files can be used in Advanced Averaging.
   c. Trial distribution: Use the slider or type a value into the text box.

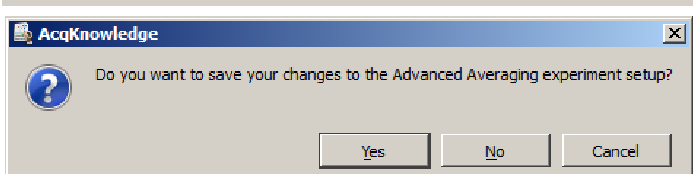
8. Click the Start button in the Advanced Averaging setup dialog to begin acquisition. Status information for each graph is displayed in the lower left corner of the graph.





9. Save the graph.





Repeating

Use the Repeat mode to acquire data from repeated trials using the same parameters for each trial. Checking the Repeat every box at the bottom of the acquisition setup dialog enables two additional popup menus at the bottom of the dialog. These allow for control of how many times an acquisition will repeat as well as the interval between trials. When this is unchecked, the acquisitions will repeat as soon as possible (usually instantaneously, but slightly longer if data must be saved to a file between trials).

Interval The entry to the right of the "Repeat every" checkbox tells Acq*Knowledge* how long to pause between the start of one acquisition and the beginning of the next acquisition. This can be scaled in terms of seconds, minutes, or hours using the first popup menu.

It is important to note that this value measures the interval between the start of two adjacent trials, rather than the interval between the end of one trial and the start of the subsequent trial. If the repeat interval is set for 15 minutes and the acquisition length is set to 60 seconds, then there will be a 14-minute pause between the end of the one trial and the beginning of the next.

Trials Set how many trials to acquire:

for perform a finite number of trials; enter the number of trials to acquire in the "times" field.

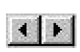
forever perform an infinite number of trials. Trials will be repeated at the specified interval until the acquisition is stopped either by clicking on the stop button in the graph window or if there is not enough free memory on the target storage device.

Regardless of which options are checked, data for each trial is acquired according to the acquisition parameters specified in the dialog. In the above example, each trial of data will be sampled at 50 Hz and will last 1 minute; the trials will be repeated every 15 minutes for a total of 8 trials.

Selecting the option to Record and Save Once to Disk/Memory will overwrite the previous collected data. However a warning will appear unless the "Warn on Overwrite" option is disabled. Another option is to select Autosave file from the Save once/Autosave file/Append option. When the repeating option is checked and Autosave is selected, Acq*Knowledge* will save the data from each trial using the file name and extension indicated by the autosave feature. See page 187 for a more detailed description of Autosave.

Setup Channel Options

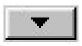
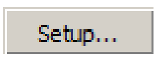
Channel The **Channel** column contains the alpha-numeric channel numbers. "**Analog**" (or continuous) input channels begin with "**CH**" and run from CH1-CH4 for MP36R and A1-A16 for MP160/150. "**Digital**" input channels begin with "**D**" and run from D1-D8. "**Calculation**" channels begin with "**C"** and run from C0-C15.

Use the scroll button  to set up additional Digital or Calculation channels.

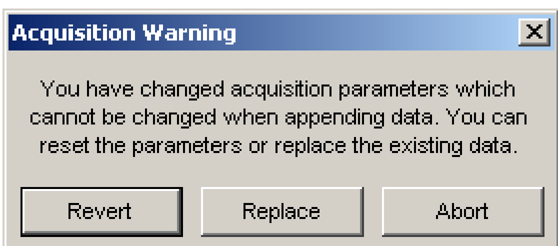
Acquire When the **Acquire Data** box is checked for a given channel, data will be collected on that channel.

Plot If **Plot on Screen** is also checked, data will be plotted on screen in real-time during the acquisition. If the plot box is unchecked, data will still be recorded for that channel, but the waveform display will be disabled. To display the waveform plot during or after acquisition, show the channel. (Alt+click the channel box above the graph.)

Value Checking the **Value** box allows for the display (numerically and/or graphically) of the values for each channel in real time. To display the values, **Show Input Values** must be selected via the Hardware menu. Input values are displayed in a separate bar graph window.

Setup Channel Options	
Default	For MP36R, the default is to collect one channel of data on analog channel 1 (CH1), and to plot and enable value display for this channel. For MP160/150, a channel must be enabled by choosing “acquire” prior to recording, if “View by Channels” mode is used.
TIP	Normally, all three boxes should be checked for each data channel.
Label	The **Label** entry for each channel supports up to 49 characters to identify the channel.
Presets 	Clicking on the **Presets** button will generate a menu of available presets for the channel. Presets for common applications configure the hardware gain, filters, etc. ➢ For a detailed summary of **Analog Input channel, Digital Input channel,** and **Calculation channel** options see the **Presets** section beginning on page 148.
Setup 	To **Change Parameters** for a Preset, click the **Setup…** button. Changing parameters presents the option of creating a **New Channel Preset** which makes the established parameters available to other channels.

If a preset is changed a recording started in Append mode, the following prompt will appear. Choose Abort, save the data, and then change the presets to acquire as a new data file.



Starting an acquisition

After setting up the channels and defining the acquisition parameters, the next step is to start the acquisition. If a file window is not already open, choose **File** > **New** to generate a graph window.

In the lower corner of the screen, next to the Start button, there should be a button with a circle to the left of it. The circle indicates the communication status between computer and hardware. If the unit is properly connected to the computer and is turned on, the circle should be solid and green. If the unit is not properly connected, a solid gray circle will appear.

Start the acquisition by clicking the Start button or by selecting "**Ctrl + Spacebar**." If there are no input devices (e.g., electrodes or transducers) connected to the hardware, the system will collect a small value of random signal "noise" with a mean of about 0.0 Volts.

- For information on how to connect measurement devices to the MP36R, see the *BSL Hardware Guide*.
- Acquisitions can also be started using a variety of "triggers," which are discussed on page 202.

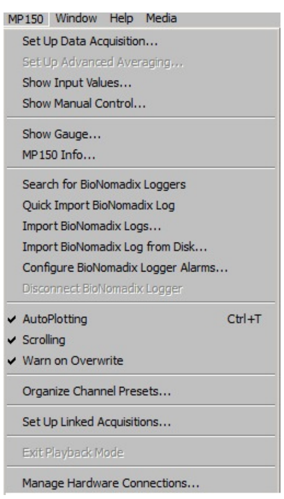
Once acquisition starts, the Start button in the acquisition window changes to Stop. The two opposing arrows to the right of the button indicate that data is being collected. The "Busy" status indicator light on the front of the MP160/MP150/MP36R will then illuminate, indicating data is being collected.

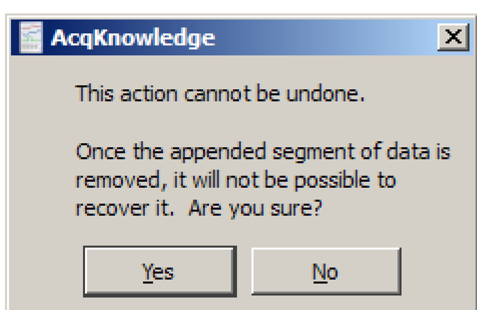
Stopping an Acquisition

To stop an acquisition at any time, click the Stop button in the lower right corner of the screen or select "**Ctrl + Spacebar**." An acquisition will stop automatically when it has recorded an amount of data equal to the **Acquisition Length** entry.

Rewind

The Rewind button to the right of the Start/Stop button allows the last recorded data segment to be erased and subsequent appended data to be added to the existing data file. This function will erase the last segment along with the Append Event for that segment; the application will keep track of Append Event labels, so that the label always matches the segment number.





If the "Warn on Overwrite" option is active, a warning dialog will be generated before the segment is deleted.

Saving acquisition data

To save a data file, pull-down the File menu and choose the Save command.

Timers (Stop watches and Elapsed timers)

The Timers function allows for easy visualization and measurement of elapsed time within the Acq*Knowledge* user interface, and consists of a simple toolbar display. Timers can be helpful when actions need to be performed at specific intervals prior to and during an experiment. The Timers function provides an easy-to-read digital display in the toolbar region, and supports the creation of multiple timers, which can be added or removed as needed.

Timer Types

There are two main types of timers, acquisition controlled (“elapsed” timers”) and independent timers (“stop watches”). Manual “stop watch” timers can be used at any point for tracking time independently of acquisition, while elapsed timers are tied to a recording in progress and unavailable unless an acquisition is running.

Independent Timers (Stop watches)

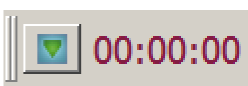
Independent timers are manually started and stopped, and have a countdown feature with an audible alarm and flasher. Multiple timers can be added to the toolbar region, and can be started and stopped independently. Pause mode is not supported. Although the timer can be stopped at any time, restarting it resets the timer back to 0:00:00.

Elapsed Timers (Acquisition controlled)

Elapsed timers start when the acquisition “Start” button is clicked and continue counting for the set duration of the recording, or until the acquisition “Stop” button is clicked. When acquiring in Append mode, the elapsed timer is reset at the beginning of each new segment. Any trigger or delay time applied between segments is not included in the elapsed time. Multiple elapsed timers can be added to the toolbar region. This mode does not support the countdown or alarm feature.

To set up a timer:

1. Display > Show > Timers or click the Show/Hide toolbar button  and choose “Timers,”
2. The timer toolbar will appear as shown below:

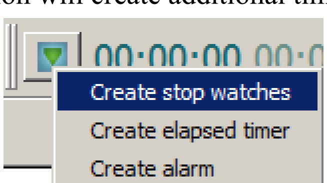


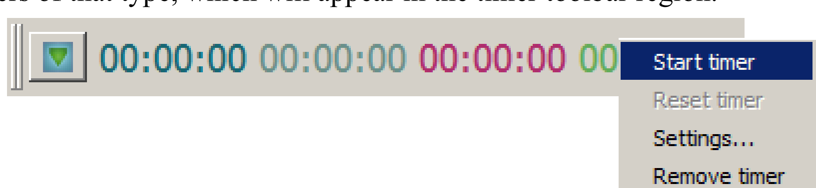
3. The **elapsed timer** option is enabled by default. If only a single elapsed timer (acquisition controlled) is desired, simply start the acquisition and the timer will start automatically.
4. If an **independent timer** (stop watch) is desired, right click on the numbers portion of the timer toolbar and choose “Settings.” In the Timer Settings, choose “Independent start” and click OK.

To start/stop independent timers: Click on the toolbar number display to toggle start/stop, or right click on the toolbar number display and choose “Start timer” or “Stop timer” (see figure below).

To set up multiple timers:

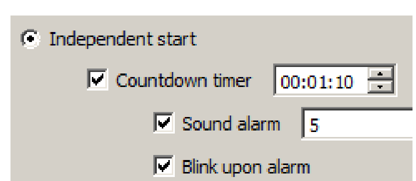
Click the Timers toolbar icon and choose the desired timer type. Repeated clicking on a timer option will create additional timers of that type, which will appear in the timer toolbar region.





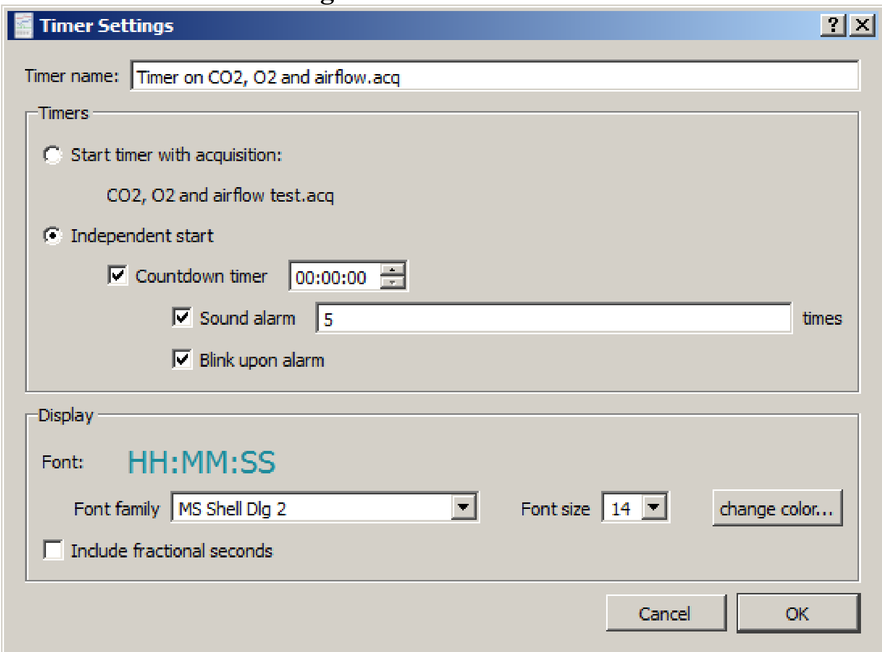
To set an alarm:

1. Click the Timers toolbar icon and choose “Create alarm.”
2. Right click on the numbers display portion of the new alarm and choose “Settings.”
3. Set the desired time in the “Countdown timer” field.
4. Check “Sound alarm” and “Blink upon alarm.”



NOTE: These settings will remain the default for subsequent alarms until the settings are changed.

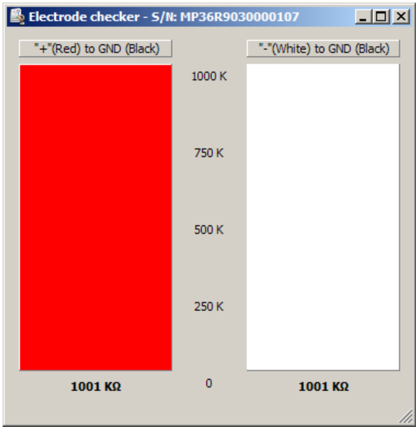
Overview of Timer Settings



CONTROL	DESCRIPTION
Timer name:	Field for assigning name to timer.
Start timer with acquisition:	Timer will start and stop with data recording only.
Independent start	Timer is started and stopped manually, independent of acquisition status.
Countdown timer	Sets the countdown time duration.
Sound alarm	Selects the audible alarm option and specifies the number of times the alarm will sound.
Blink upon alarm	Enables the timer numbers to flash on and off when the countdown is complete.
Display > Font family: > Font size > change color	Selects timer font style, size and color.
Include fractional seconds	Sets option to display 1/100ths of a second in timer display.

All parameters established in the Timer Settings are retained in saved graphs and graph templates.

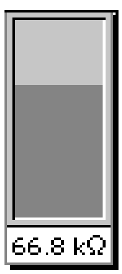
Electrode Checker



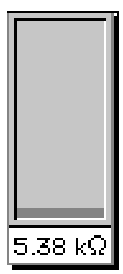
The **Electrode Checker**, in conjunction with the MP36R unit, measures how well electrodes are making contact with the surface of the skin. To use this feature:

1) Attach the electrodes to subject.
2) Connect the electrodes to an electrode lead set (such as the SS2LB).
3) Instead of connecting the electrodes to one of the four analog inputs, connect the Simple Sensor end of the electrode lead to the **Electrode Check** port on the front of the MP36R acquisition unit.
4) Click the **MP36** menu and scroll down to select **Electrode Checker**.

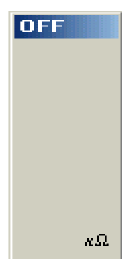
This will generate a small “thermometer-like” display. At the bottom of the display, a number with a kΩ (Kohms) symbol should be visible. This value describes the impedance of the electrode/skin contact, with lower numbers being associated with better conductivity. The better the conductivity, the “cleaner” the signal displayed on the screen. If the MP36R is off or no nothing is connected to the “Electrode Checker” on the MP36R unit, the Electrode Checker display will say “OFF.”



Poor contact



Good contact



Off

TIP While there are few absolutes as to what constitutes “good” contact, one rule of thumb is that this number should be below 10 kΩ, and the lower the better.

TIP To decrease the impedance of an electrode connection, it’s recommended to “abrade” the surface of the skin with an abrasive pad (such as ELPAD). This removes a thin layer of dead skin cells and should result in a signal that has relatively little noise. EXCEPTION: Do not abrade the skin if collecting EDA (Electrodermal Activity) data.

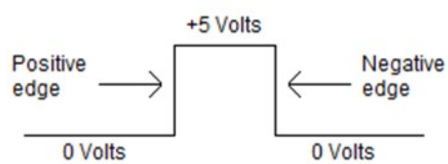
Chapter 8 Set Up Triggering

During a normal acquisition, the MP hardware will begin collecting data as soon as the Start button is clicked. It is also possible to begin an acquisition in a delayed fashion using a trigger. This feature enables an acquisition to start "on cue" from a variety of different trigger sources. All trigger options are configured in the Triggering dialog, which is accessed via **MP menu > Set Up Data Acquisition > Trigger**. By default, the trigger is Off. Other options can be selected from the popup menu in the Trigger Setup dialog. To begin an acquisition with a trigger, first choose the trigger options most appropriate for the experiment and click the Acq*Knowledge* graph Start button. After the Start button has been clicked, data will be acquired as soon as the trigger is activated. There are two general types of trigger sources: digital channels and analog channels.

Digital Triggers (MP160 and MP150)

Digital channels are channels that contain binary (either/or) data as typified by a switch being either open or closed. This type of data can be acquired from a push-button switch or other device that produces an on/off pulse. For example, it is sometimes useful to set up an acquisition to start when a subject presses a button or when a signal generator sends a pulse. These are typical digital signals and the external trigger devices that emit them must be connected to a BIOPAC STP100C Isolated Digital Interface (shown interfaced with the MP160 System on right*).

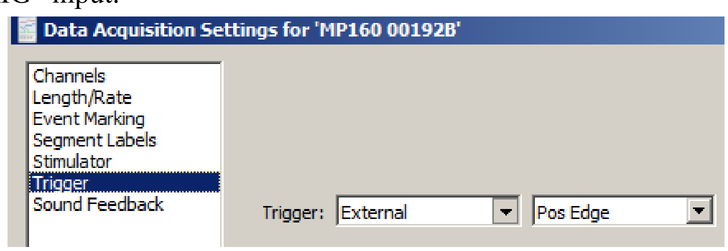
In a simple trigger design, the external switch is connected to the STP100C BNC "TRIG" input. Since the switch will be either open or closed, the resulting digital data will consist of two levels, +5 Volts and 0 Volts. A value of +5 Volts is interpreted as a binary 1, and a level of 0 Volts is interpreted as a binary 0.



When the switch is closed (i.e., the button is pressed), the signal changes from +5 Volts to 0 Volts, creating a transition or "edge."

External trigger example:

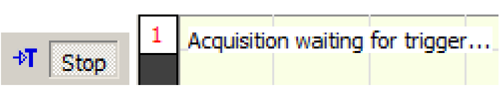
1. Connect the external BNC trigger to the STP100C "TRIG" input.



2. In Acq*Knowledge*, choose MP160 menu > Set Up Data Acquisition > Trigger.

3. Set the Trigger parameters to "External" and "Pos Edge." Close the dialog.

4. Click "Start" in the Acq*Knowledge* graph. Note that the acquisition does not start. The "Start" button will toggle to "Stop" with a trigger status icon indicating that a trigger is pending. A trigger notification will also appear in the graph window.



5. Push the button on the external trigger connected to the STP100C module. The acquisition will then start.

*The earlier-version MP150 System uses the "TRIG" and "GND D" inputs on the back of the UIM100C (Universal Interface Module) for external trigger connection.

For MP36R hardware: The external trigger is connected to the "Trigger" input on the back of the unit. The software setup is the same as that shown above.

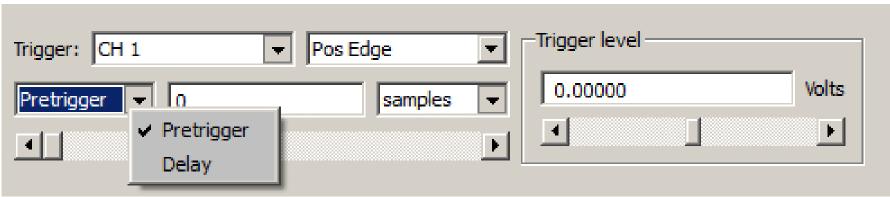
MP36R note: Due to processor limitations at sampling rates of 25 kHz and higher there may be an occasional delay of up to 40 milliseconds between detection of an External Trigger and the start of data acquisition.

Use either an analog or digital channel as a trigger when acquiring data at 25 kHz, 50 kHz or 100 kHz, if accurate timing of the start of acquisition is required.

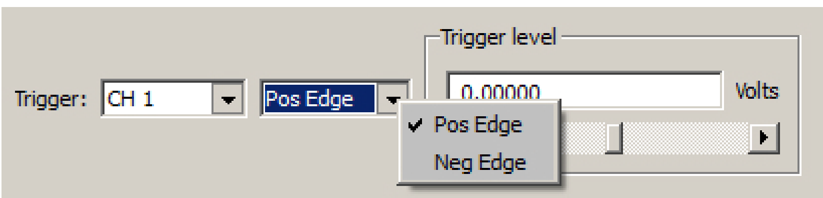
Analog Triggers

Initiate an acquisition when an analog channel reaches a certain voltage level. To enable the analog trigger feature, data must be acquired to either memory or disk, and a value must be entered in the Delay box (although the delay may be set to zero). The channel containing the data to be used as a trigger requires that the acquire/plot/values boxes be checked in the Set Up Data Acquisition > Analog Channels dialog. Leaving these boxes unchecked will allow the incoming data to trigger an acquisition but will not allow the trigger channel to be acquired or plotted.

Select Hardware > Set Up Data Acquisition > Trigger to generate the Trigger dialog:



MP160/150 Triggering options



MP36R Triggering options

External: Select for Digital Trigger.

CH #: Select for Analog Trigger; must be acquiring to Memory or Disk. Specify the analog channel that contains the trigger data and then specify a voltage Level to initiate the trigger. Acquisition will begin when the data on the specified channel reaches the specified Level.

- To trigger an acquisition when an ECG wave on analog channel 1 reaches a certain voltage or value, set "Source" to CH 1 and then set the Level when the entry box is enabled.
- Triggering from an analog channel requires oversampling by a factor of 4, which ensures that the trigger signal will not be missed. The sampling rate can be adjusted in the Set Up Data Acquisition > Length/Rate dialog.
  - For example, an initial sampling rate of 1,000 samples/second should be increased to 4,000.

Level The Level option is activated when a Source CH is selected. Set a level to initiate the trigger (e.g., if the ECG wave peaks at 2 mV, set the trigger level just under 2 mV).

Edge Triggers can have a positive or negative edge, defined as follows:

Edge	Digital	Analog
Pos	Signal changes from 0 to 1	Signal changes direction from downward to upward. Once the trigger level is crossed, the acquisition will start.
Neg	Signal changes from 1 to 0	Signal changes direction from upward to downward. Once the trigger level is crossed, the acquisition will start.

- For ECG data (and other types of data with peaks of relatively short duration) there will be only minor time differences between one edge and the next, although the positive and negative edges can be widely separated in time for data with slowly changing values (such as EDA or skin temperature data).

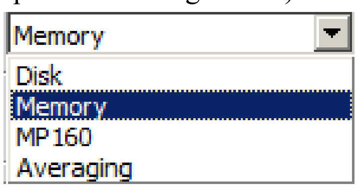
Mode Once the trigger channel and level have been specified, the final parameter is the delay. Delay can be measured in terms of samples, milliseconds, seconds, or minutes, and may be set to zero if desired. The delay option instructs the hardware to wait a specified period after the trigger level is reached before beginning the acquisition.

Delay When using a trigger, the default setting is for the acquisition to begin immediately after the trigger pulse or level occurs. This default can be modified by using the Delay option in the Trigger Setup dialog. This feature allows an acquisition to begin a specified period after the trigger level is reached. To start an acquisition one second after a switch closes, set the trigger to external and enter 1.00 in the box next to Delay. The default scale for Delay is seconds, meaning that the acquisition will begin a specified number of seconds after the trigger has been initiated. The scale of the delay can be changed from seconds to samples, milliseconds, or minutes.

NOTE: Delay option not available in MP36R hardware.

Pretrigger During normal triggered acquisitions, data is collected only after the trigger has been activated (or after some delay). For some applications, it is useful to collect data on events that occur just prior to the trigger event. As an example, if an acquisition was set to begin when a device (such as a tone generator or flash) sends an output pulse, it might also be important to collect information on the subject's state just before the stimulus.

Pretrigger functionality is not supported in all acquisition modes (MP160/150 > Set Up Data Acquisition > Length/Rate): **NOTE:** Pretrigger option is not available in MP36R hardware.



Mode	Source: EXTERNAL	Source: CH #
Disk	Pretrigger supported	Pretrigger supported
Memory	Pretrigger supported	Pretrigger supported
MP160/150	Pretrigger supported	not available
Averaging	not available	not available

When the Pretrigger function is enabled, start an acquisition by clicking the Start button. When the internal memory in the data acquisition hardware is full, the hardware will start replacing the oldest data with the newest data (similar to the record last feature). This process continues until the trigger event occurs. Following the trigger, the hardware will collect data until the total length is reached. The acquisition now contains data from both before and after the trigger.

The amount of data collected before the trigger event is determined by the value in the box next to the Pretrigger popup menu. As with Delay, scaling can be set in terms of samples, milliseconds, seconds, or minutes. The duration of the Pretrigger may also be adjusted using the scroll box to the right of the Pretrigger dialog.

When Pretrigger is selected, it is important to note…

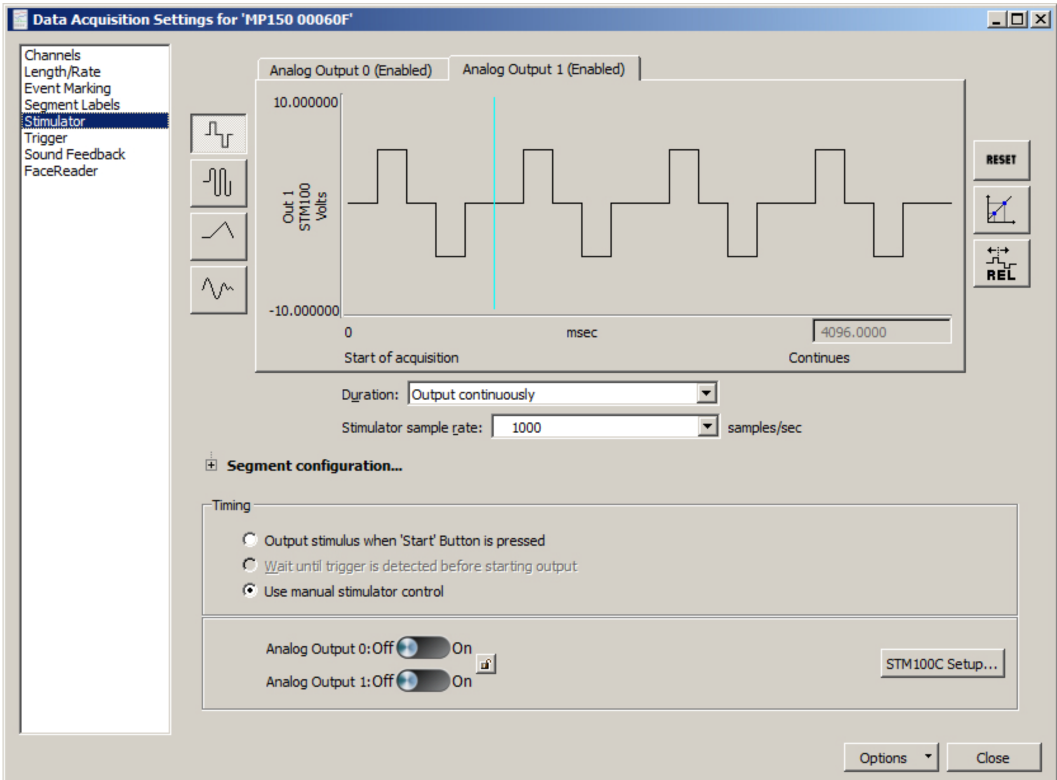
- The total length of the acquisition includes the duration of the Pretrigger. If the acquisition length is set to 120 seconds and the Pretrigger is set to 20 seconds, only 100 seconds of data will be collected after the trigger event occurs.
- Since the total length of the acquisition includes the duration of the Pretrigger, the duration of the Pretrigger may not exceed the length of the acquisition.

Hysteresis window (MP160 hardware only)

This feature helps compensate for potentially noisy input signals that may occur when Analog channels are used as the triggering source. The window field is editable, allowing a user-defined hysteresis threshold to be entered. The window units will match the units reflected in the Analog triggering source channel. Hysteresis does not apply to Digital triggering. This option will not be available in the Trigger setup window if External is selected.

Chapter 9 Set Up Stimulator

Note This chapter refers to stimulator setup for MP160 and MP150 hardware only. For MP36R, see the next chapter, 'Output Control.'



Although data acquisition is the primary function of the MP System, Acq*Knowledge* supports output of a signal through one or two analog channels while data is being acquired. This type of signal output is configured in the Stimulator setup window.

Four types of signals can be output:

Square waveforms—page 211	Ramp waveforms—212
Tone waveforms—212	Arbitrary waveforms—214

Each of these waveform types can be set to repeat signal output either Once or Continuously, and parameters can be set to either Relative or Absolute time scales.

To set the type of waveform to be output, select MP160/150 > Set Up Data Acquisition > Stimulator. Like the standard graph window, the Stimulator setup window plots time on the horizontal axis and amplitude on the vertical axis.

Use the Stimulator window to create and shape waveforms for output. Adjust the Stimulator Sample Rate (described below) to further control the parameters of the Stimulator Output design.

For any waveform (or stimulus) to be output, the following parameters must be specified; the type of stimulus, the "shape" of the signal, the output channel to be used, and how many times the stimulus should be output.

All the above parameters are set up from within the Stimulator Setup dialog. Regardless of the type of waveform selected, stimulus signals will normally be output when an acquisition is initiated, either as a result of clicking the "Start" button, using the "manual stimulator control" or via a trigger being activated.

Stimulator Sample Rate

A powerful feature intrinsic to the MP160 or MP150 unit is the ability to set a stimulation signal output rate that varies from the acquisition rate, thus permitting considerable flexibility for a variety of physiological applications. For a full explanation of MP160/150 Stimulator sample rates, see page 215.

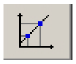
Use the "Stimulation sample rate" pull-down menu to select a unique sample rate for the stimulator.

➡ *See also*: Application Note AH162 - Using the Stimulation Features of the MP System.

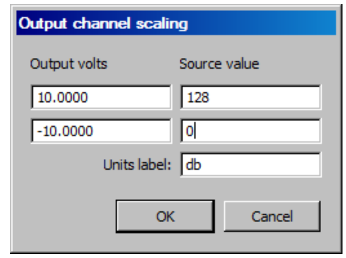
Stimulator Parameters

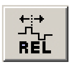
The Stimulator parameters are set by using the buttons in the right pane of the setup window.

Reset Refresh the display; use after the time scale has been adjusted.

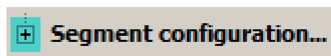
Scaling  Scaling button—Rescale stimulus signals to units other than Volts according to the Change Scaling Parameters.

This type of rescaling does not change the amplification of the signal, it is useful for recalibrating the output signal to more meaningful units. In the example shown here, an output signal of +10 Volts is rescaled to +128 dB, while an output signal of –10 Volts is rescaled to reflect 0 dB.

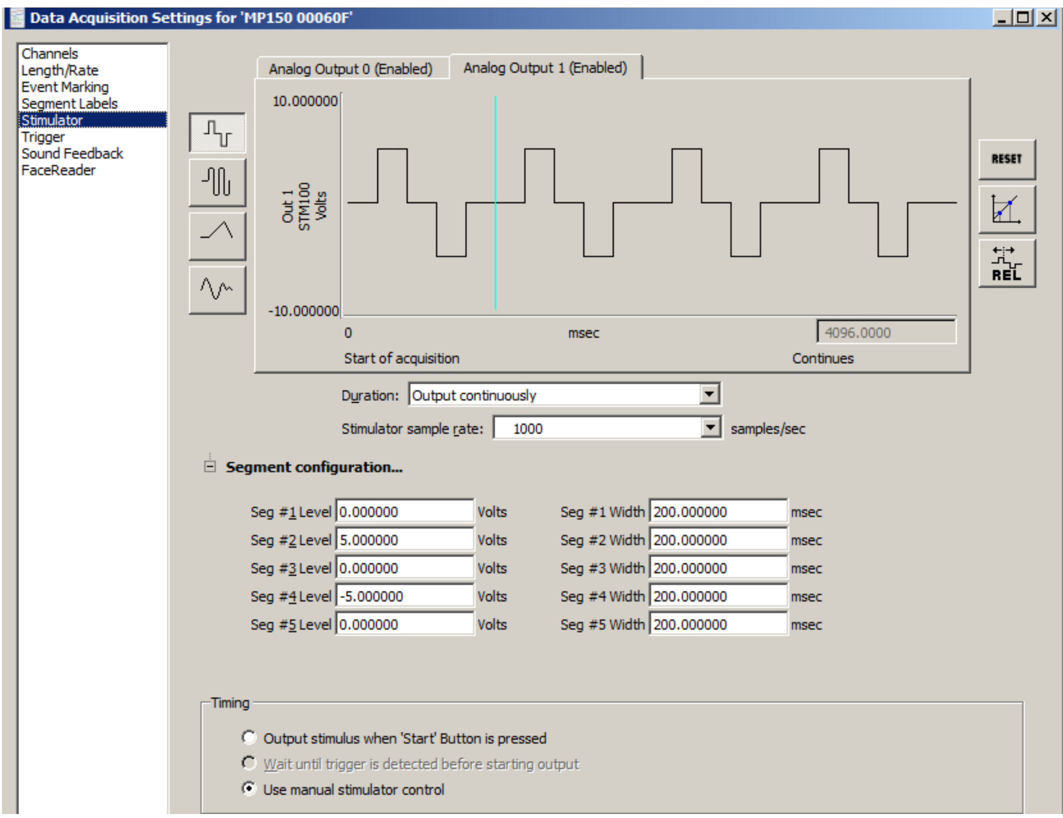


Relative  Set the duration of each segment of the output waveform in Seg # Width. In the sample dialog shown below left, a 5000 msec output is created by entering individual segment widths: 500 + 400 + 250 +200 + 3650 = 5000 msec.

Note The segment level fields are hidden by default and must be expanded by clicking the Segment Configuration "+" button (below).



For details about stimulator segment and width configuration, see page 211.



Output

Analog Output 0/Analog Output 1: Signals can be output on one or two analog output channels. The output channels are listed as A0 and A1 and correspond to Analog Output 0 and Analog Output 1 on the AMI100D/HLT100C (MP160) or UIM100C (MP150) module.

For MP160/AMI100D or HLT100C: Use a CBL100 3.5 mm cable with two CBL122 RJ11 adapters to connect Analog Outputs A0 or A1 to Analog Channels 1 or 2.

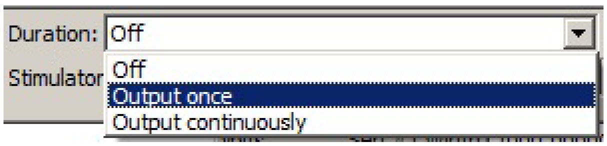
For MP150/UMI100C: Use a CBL100 3.5 mm cable to connect Analog Outputs A0 or A1 to Analog Channels 1 or 2.

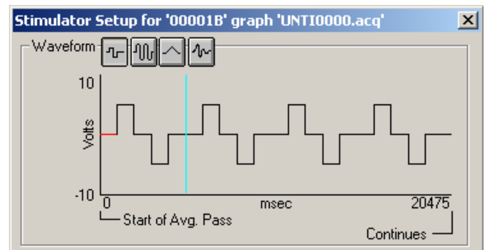
- For dual stimulation and independent control, connect an output device to A0 and A1.
- See *Analog Output for MP160/150 Users* notes on page 209.

The maximum resolution of a stimulus signal output through an analog channel is 22 µsec; this means that the shortest segment in the stimulus signal must be at least 22 µsec in duration.

Duration

Set independently for A0 and A1.



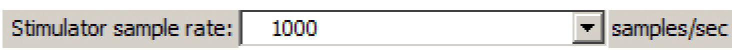


Off: Turn Output OFF (no stimulus signal output).

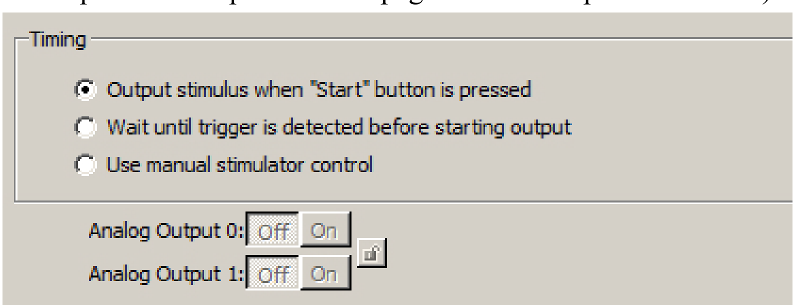
Output once: Output the stimulus signal once.

Output continuously: Output the stimulus signal for the duration of the acquisition (forever).

When Output continuously is selected, a vertical line is generated at the end of the first section of the waveform in the stimulator window to indicate where the first output signal ends and the second begins. The line can be dragged left or right like a vertical segment in a stimulus waveform to control the duration of the waveform as it is continuously output. Maximum continuous waveform output is 20 kHz.



Use to choose the Stimulator sample rate for the generated signal. (The Stimulator sample rate is independent of the acquisition sample rate. See page 215 for sample rate details.)



Control timing of output by aligning it with the Start button, waiting until a trigger is initiated before generating the signal, or manually toggle the selected stimulator on or off. Click the “lock” button to synchronize both stimulator outputs to the On/Off buttons.

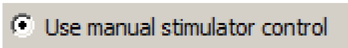
Note “Wait until trigger” option is only active if Triggering is enabled in the “MP160/150 > Set Up Data Acquisition > Trigger” menu.

Trigger

When a trigger option is selected (in the Trigger Setup window), Acq*Knowledge* allows selection of additional options with respect to when the signal is output. By default, the stimulus signal will be output when the Start button is clicked. When a trigger is enabled, however, there’s an option of either outputting the signal when the Start button is clicked or when the trigger is initiated. The trigger option is added to the stimulator window when a trigger is enabled in the Trigger setup dialog (described on page 203).

Manual Stimulator Control

When an MP160/150 unit is being used, the manual stimulator controls at the bottom of the Stimulator Setup dialog can be used to start and stop stimulators independently of the acquisition. If changes are made to the stimulus wave while a stimulator is running, the stimulator will need to be turned off and then back on to apply the changes to the settings.



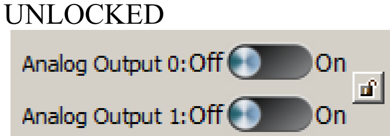
The manual stimulator controls cannot be used if the MP160/150 is set to acquire in averaging mode.

- The stimulator output will start simultaneously with the acquisition.
- The On/Off buttons will start and stop the stimulator output.

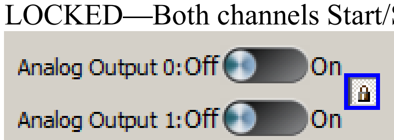
If Dual Stimulator settings are active, “Start with” applies to both stimulators.

A “lock” between the two sets of controls can be used to turn both stimulators on or off at the same time. This lock is useful for two-channel stimuli delivery, such as stereo sound.

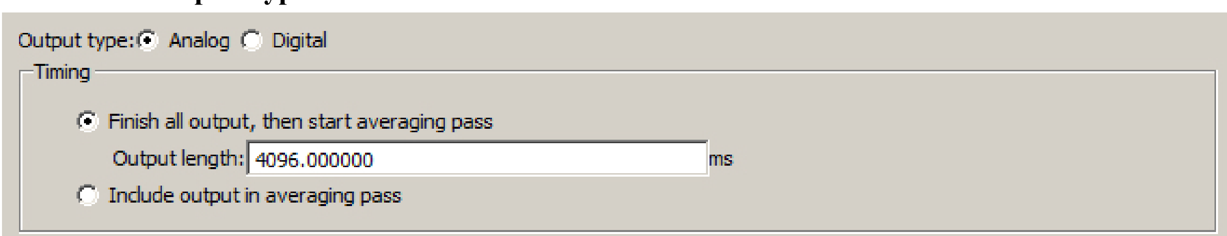
UNLOCKED



LOCKED—Both channels Start/Stop together



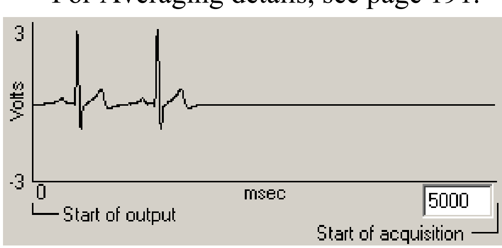
Stimulator Output Type



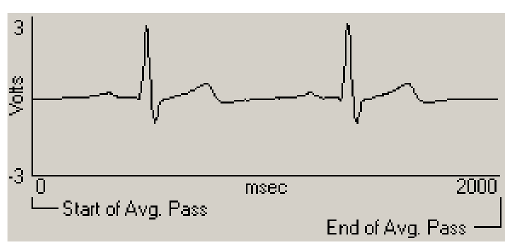
If an **averaging** acquisition is selected in the MP hardware setup, the timing can be set to delay the averaging pass until after the signal is generated, or to include the signal output in the averaging pass. Note that the signals cannot exceed the duration of the averaging pass.

The “Digital” setting will generate a true digital pulse (0 Volts and +5 Volts) prior to the averaging pass on digital I/O Channel 15.

- For Averaging details, see page 191.



Finish all output, then start averaging pass



Include output in averaging pass

Analog Output for MP160 and MP150 Users

The two MP160/150 Analog Output channels can independently output static or dynamic values:

- Static output: Use “Manual Control” (page 265) to set the output level for each channel in the range -10V to +10V. (MP menu > Manual Control, **OR** the Manual Control dialog can be opened directly from the Stimulator window by clicking the “STM100C Setup” button at the lower right of the screen.)
- Dynamic output: Use “Stimulator Setup” (page 205) to define the output level and pattern.

The MP160/150 will automatically use the “Manual Control” value if:

- No acquisition is in progress OR
- Acquisition is in progress but the Stimulator is disabled via the “Setup Stimulator” dialog.

The MP160/150 will only use the “Stimulator Setup” value if:

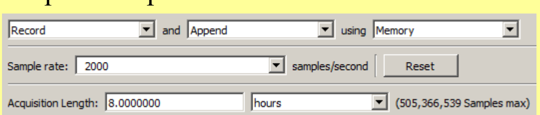
- Acquisition is in progress (or before Averaging pass) AND
- Stimulator is enabled via the “Stimulator Setup” dialog.

When the stimulator is in use:

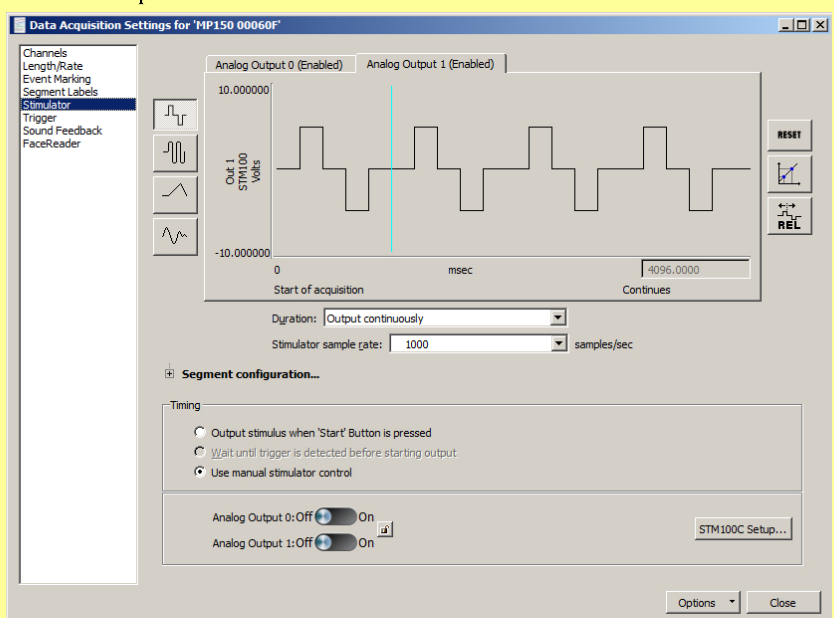
1. Any Stimulator Output starts (from before Time = 0) with the value established for “Manual Control.”
2. If Segment # Width = 0 the stimulator ignores the associated Segment # Level.
3. If the stimulator is in 1x mode, after the output waveform is sent, the value of the last segment is fixed until acquisition stops.
4. When acquisition stops, the stimulator resets to the “Manual Control” value.

The following dialogs and output illustrations demonstrate how the “Manual Control” value influences Analog Output for the Stimulator when an MP160/150 is used:

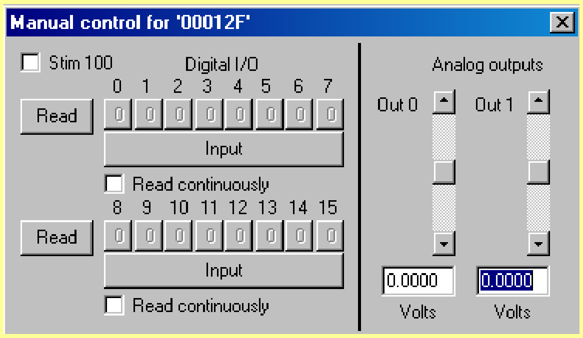
Acquisition parameters:



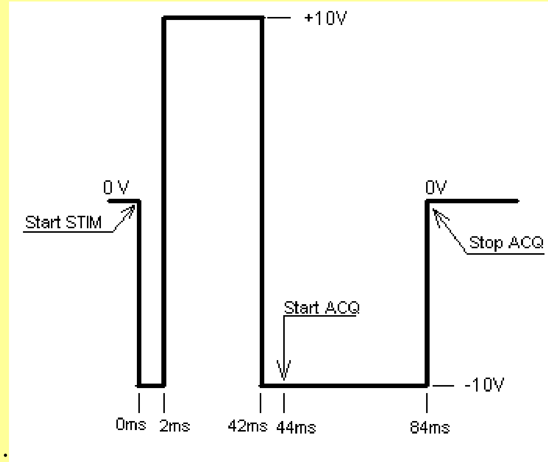
Stimulator parameters:



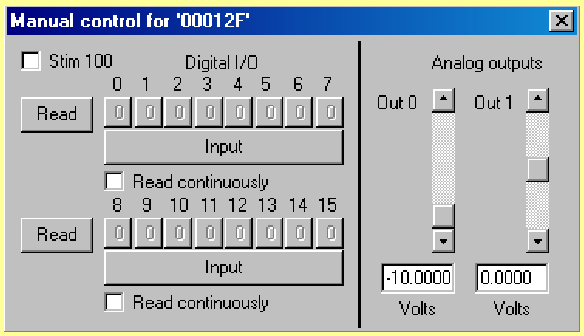
Manual Control list box:

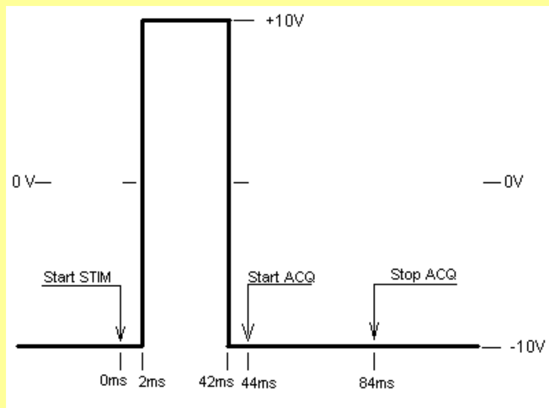


Stimulator Output pattern (using MP160/150)



:

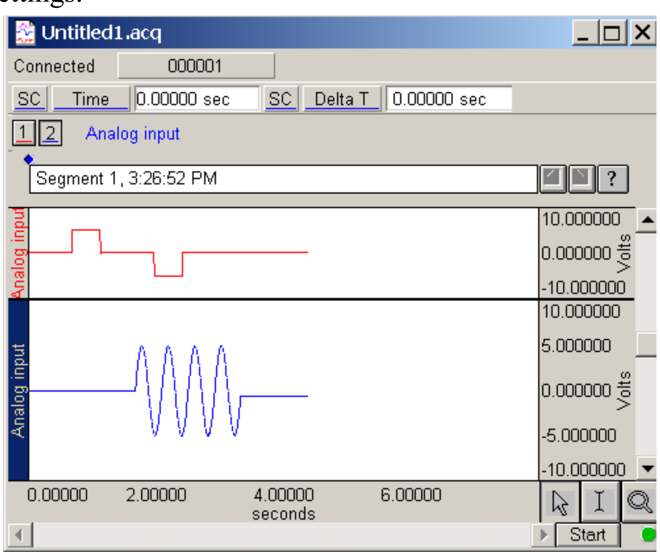




For details on Manual Control, see page 265.

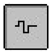
Dual Stimulation

For independent control of two stimuli (such as sound and electrical output), set stimulator functions for Output to A0 and A1 for each MP160/150 unit. Click the tab for each output at the top of the Stimulator Setup dialog and complete independent settings.

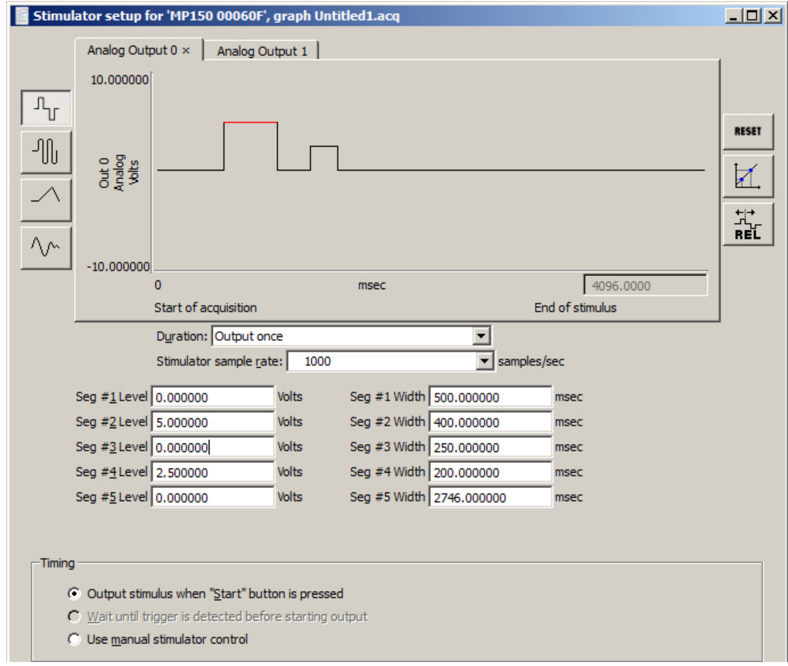


- For additional stimulus paradigms, add MP160/150 units (see Multiple Hardware, page 190).

Square waves

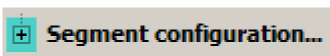


Square waveforms are useful for generating pulse waveforms, which can be used as stimuli or to trigger a stimulus-generating device (such as a flash device or a tone generator).



To output a square wave, choose the "Output Once" in the "Duration" section. A rectangular wave should be visible in the window. The shape of the can be controlled by manipulating the wave's various segments. A square wave has five segments, and Acq*Knowledge* allows flexible configuration of the level (amplitude) and width (duration) of each segment.

NOTE: The segment level fields are hidden by default and must be expanded by clicking the Segment Configuration "+" button (below).



In a square wave, each of the editable segments is oriented horizontally, with vertical segments connecting the adjacent sections of the wave. The first segment of a pulse waveform is the segment that appears at the far left of the waveform section. By positioning the cursor on this segment of the waveform, observe that Segment #1 level (vertical offset) is 0 Volts, and the Segment #1 width is 500 msec. (See segment boxes in center of Stimulator window.

To adjust the level of a segment, either:

a) Enter the desired level in the Seg # Level box; or

b) Position the cursor on the first segment of the waveform and drag it up or down using the mouse (segment 2 is selected in the preceding dialog, and appears in red).

To change the duration of a segment, either:

a) Enter a value in the Seg # Width box at the bottom of the Stimulator Setup dialog; or

b) Position the cursor on the first *vertical* segment in the setup dialog, click the mouse button, and drag the vertical segment left or right. Moving the first vertical segment left shortens the duration of the first segment, whereas moving the first vertical segment right lengthens it.

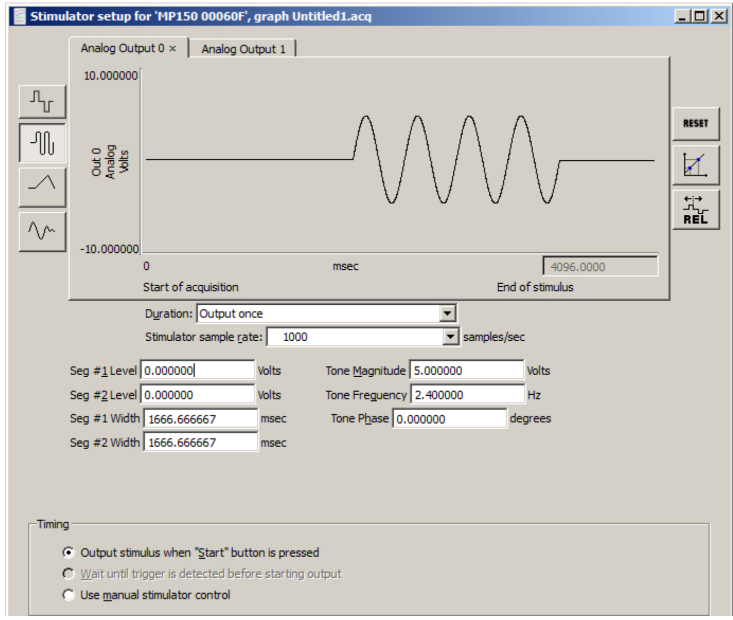
Each of the segments in the wave can be "edited" in this way.

Tone Stimuli

Tone waveforms allow for the creation of pure tone signals of any duration, magnitude, and frequency. This option outputs a pure sine wave, which is useful for audiological and stimulus response testing.

A tone waveform is comprised of two segments, with only the second segment being the actual tone itself. This allows for inclusion of a pre-signal delay (by setting the level for Segment #1 to 0 Volts and the duration to a desired value).

To set the duration of the tone, adjust the length of segment #2 (by changing the Seg #2 Width value box or by clicking and dragging the segments within the window). As shown, there is an additional (uneditable) section of the waveform *after* the second section. This segment returns the last value from segment two, and continues to output that signal level until the acquisition is terminated (if the stimulator is set to output once) or until another signal is output (if the MP System is set to output continuously).



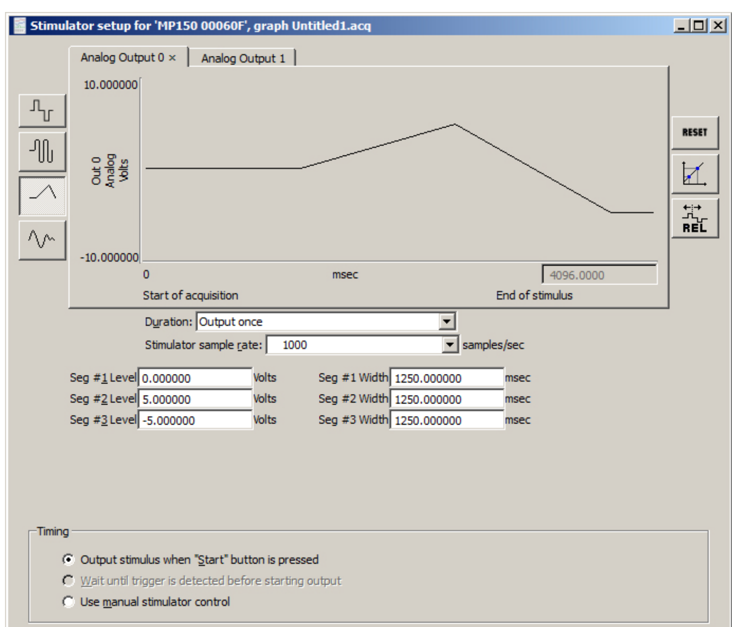
There are three additional parameters for Tone waveforms: frequency; magnitude; and tone phase.

- Tone frequency refers to the frequency of the second segment of the waveform. This can be set to any value, although the most common settings are between 20 Hz and 20,000 Hz.
- Magnitude refers to the peak-to-peak range of the signal, which can range from ± 0 to ± 10 Volts.
- Phase of the stimulus signal can be any value equal to or greater than 0 degrees. Phase settings of more than 359 degrees will be rescaled to fit the 0°-359° range. In other words, setting the phase to 360° or 720° has the same effect as setting the phase to zero degrees.

Ramp Waves

Ramp waveforms are useful for constructing a monotonically increasing or decreasing stimulus signal.

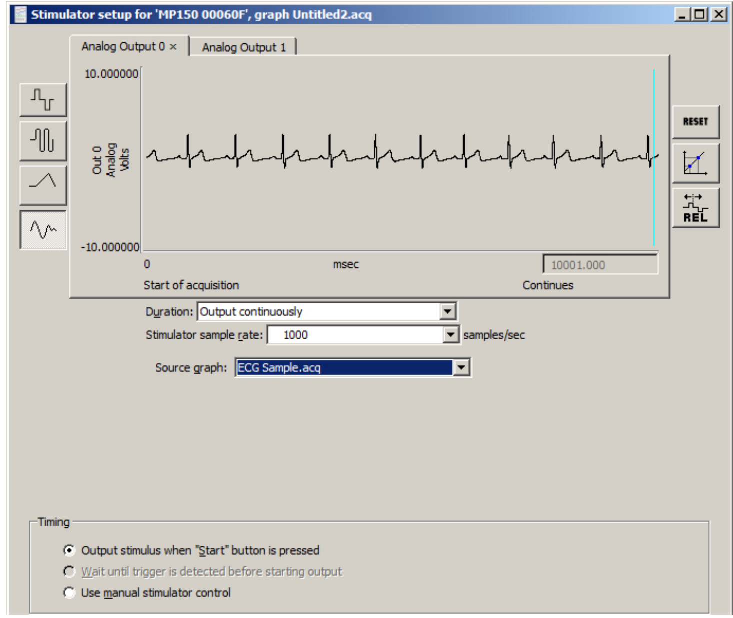
Ramp waves are comprised of three segments and the amplitude and duration can be set discretely for all three sections.



Arbitrary Waveform

The Arbitrary waveform option is used to set a waveform's shape and length using standard Acq*Knowledge* editing functions.

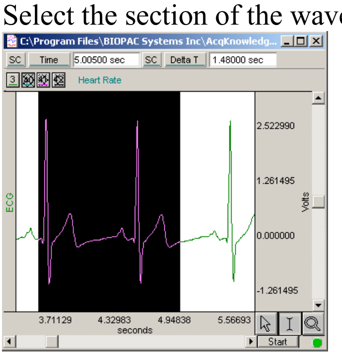
- The length of an arbitrary waveform is only limited by the available memory.
- Unlike the other types of waveforms, Arbitrary waveforms have no segments, so the "shape" of the waveform is determined by selecting an existing waveform and the only parameters that can be set are Scaling, Repeats, and Trigger.
- Maximum continuous output is 20 kHz.



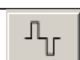
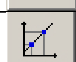
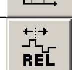
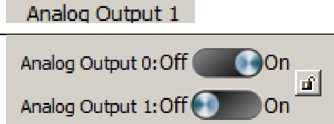
To create an arbitrary waveform:

A. Copy waveform segment

1. Open a waveform in a standard graph window.
2. Select the section of the waveform to be outputted.



Return to the Stimulator Setup dialog—the selected area will automatically be pasted into the dialog.

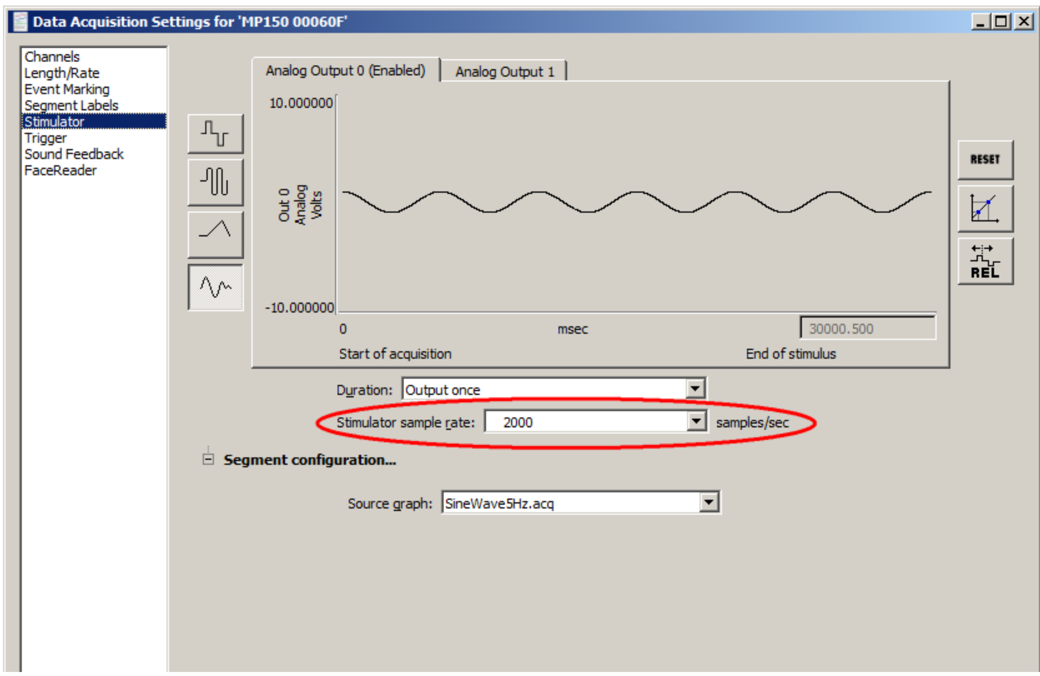
Stimulator Icons		
Waveforms:		Square wave
		Tone (sine) wave
		Ramp wave
		Arbitrary wave
Parameters:		Reset the display (use after adjusting the time scale)
		Scaling (rescale Stimulus signals to different units)
		Set time base to relative
Output:	Analog Output 0	Tab to output to Analog Output channel 0 (default)
	Analog Output 1	Tab to output to Analog Output channel 1
		Manually start and stop stimulator output by clicking the On/Off buttons. When the padlock is engaged, both stimulator outputs can be controlled simultaneously.
	STM100C Setup...	Use the STM100C Setup button for easy access to the Manual Control dialog for making adjustments to a connected STM100C Stimulator Module.

MP160/150 Stimulator Sample Rates

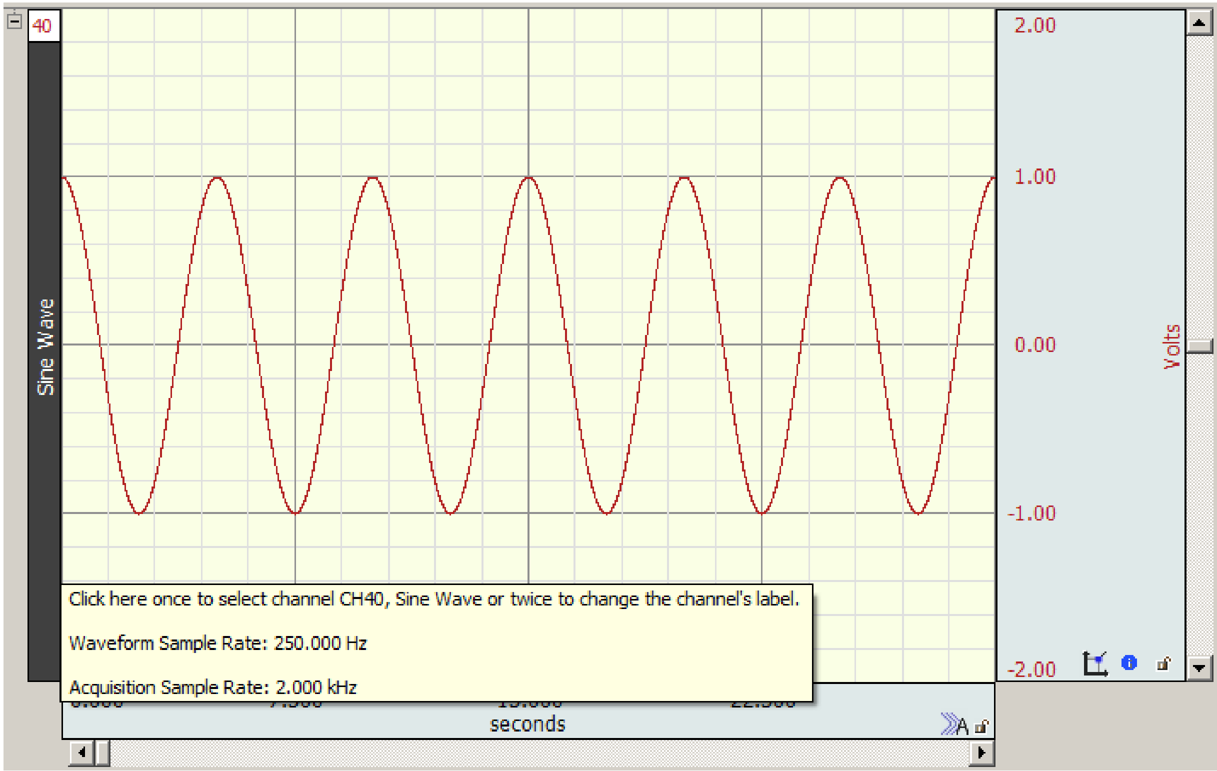
The MP160 or MP150 is the most common data acquisition device used with Acq*Knowledge*, and when combined with the AMI100D/HLT100C/UIM100C and STM100C modules, capable of outputting various waves at different rates, durations and types. As explained earlier in this chapter, there are four basic Stimulator signal types: **Square**, **Sine**, **Triangle** and **Arbitrary** waves. Square, Sine, and Triangle waves are limited to 4096 samples, which may be outputted once or continuously. 4096 samples also define the upper limit of a short burst wave. Arbitrary waves, like the other types, can be outputted once or continuously, but are not subject to the 4096 sample upper limit.

The Stimulator output sample rate may be the same, lower, or higher than the acquisition sample rate. The output signal can be redirected to an analog input channel.

The Stimulator output sample rate is configured in Acq*Knowledge* via a dropdown menu in the stimulator setup dialog box (the window is opened by choosing MP160/150 > Set Up Data Acquisition…" and choosing "Stimulator" in the left pane.

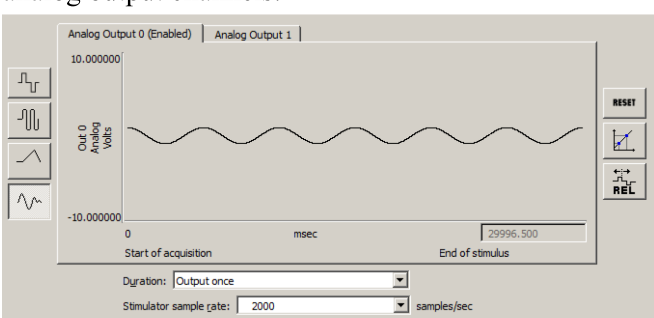


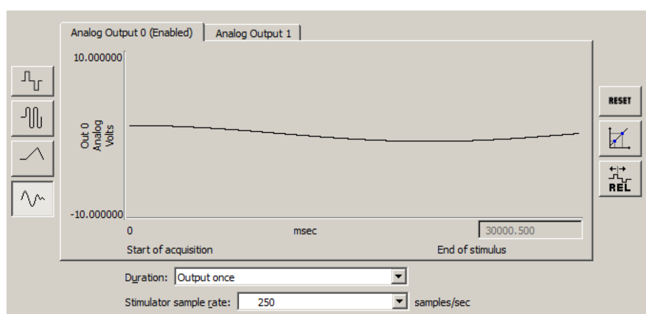
This rate specifies the frequency at which the analog output changes. This frequency has no necessary relationship to the sample rate of the source graph or the sample rate of the graph window associated with this data acquisition setup. By adjusting this frequency, the stimulator may be made to produce an output that varies more quickly, more slowly, or at exactly the same rate as that of the signal in the source graph. To have the timing match that of the source, set the stimulator sample rate equal to the graph sample rate of the source graph, even if the channel selected in the source graph has been downsampled relative to its graph sample rate. For example, here the source graph contains a 5 Hz sine wave in a channel with a waveform sample rate of 250 Hz in a window with a graph sample rate of 2000 Hz: (See following page.)



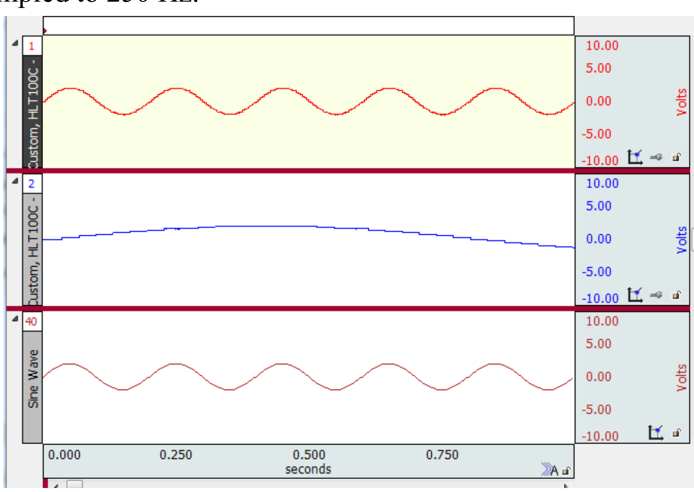
Sine wave acquired at 2000 Hz downsampled to 250 Hz

In another window, this graph window is used as the source for arbitrary waveforms from both of the two analog output channels:

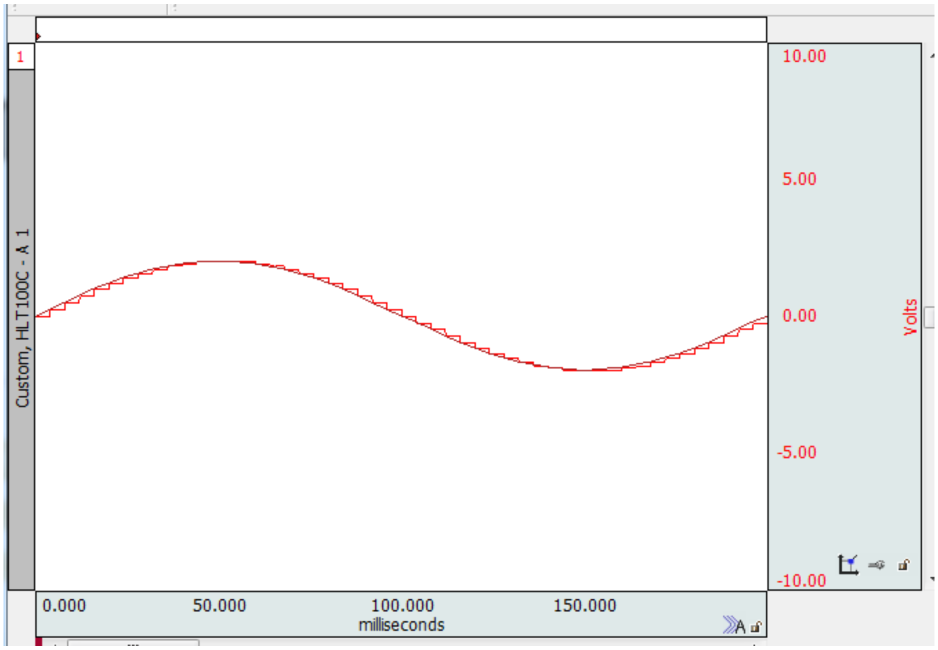




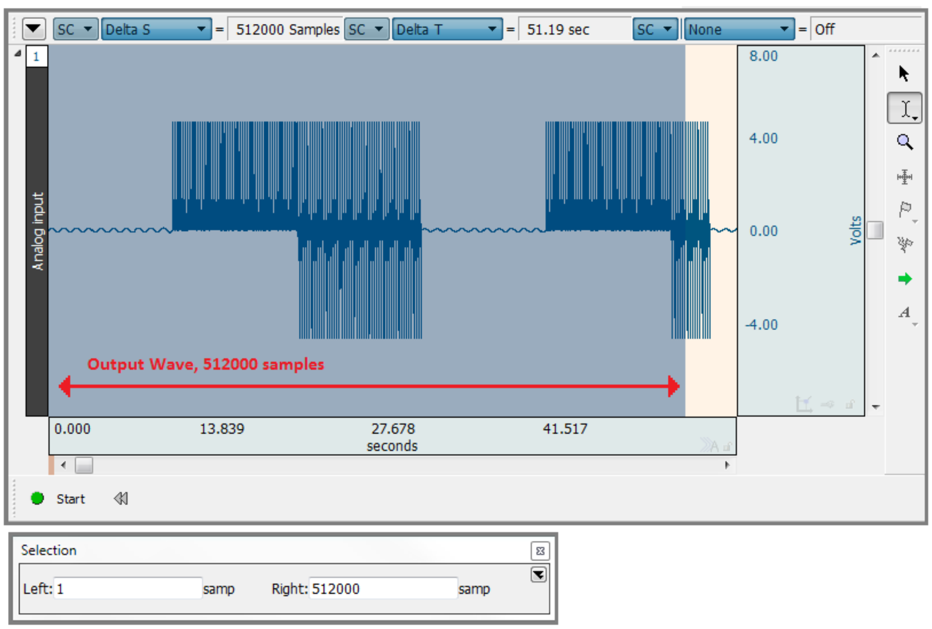
Using a pair of CBL100s, ANALOG OUTPUT 0 and ANALOG OUTPUT 1 were redirected to ANALOG CHANNELS 1 and 2 respectively. The graph sample rate for this acquisition was 2000 samples/second. The calculation channel used to create the sine wave in the source graph was also a part of this graph; this channel (Channel 40) was downsampled to 250 Hz.



Note that Channel 1, containing the recording of the output at 2000 samples/second, matches the timing of the original channel overall, but the original data have been upsampled to that sample rate with no interpolation to generate the output voltages. This is more easily seen by overlaying the two waveforms and zooming in:



Arbitrary wave sources are derived from any waveform within a saved data file or from a newly created waveform. Calculation channels, Transform and Edit operations may also be used to create unique waveforms.



Example source wave

The Expression calculation channel, Absolute value transformation and Edit Copy/Paste operations were used to create the example waveform shown above. The highlighted portion was used as the *source wave*.

The MP160/150 supports an aggregate (combined channel) sample rate of 400 K samples and has an internal memory of 512 K samples.

*Aggregate Sample Rate = # analog channels * Acquisition Sample Rate*

Any down sampling of channels is applied in Acq*Knowledge,* and does not affect the sampling rate generated in the MP160/150.

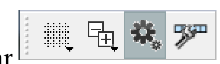
Up to 512,000 samples can be uploaded into the MP160/150 memory and then outputted as a stimulator signal. Longer source waves will upload the first 512,000 samples, and the remaining waveform data as memory becomes available.

The following components affect the limits for the stimulus output:

- Acquisition setup
  - mode
    - MP160/150 Memory
    - Save to disk or memory
  - sampling rate
- Stimulator setup
  - Duration
    - Output Once
    - Output Continuously
  - Stimulator sample rate
  - Analog Output: one or two analog output enabled
- Source graph/wave length
  - Short burst wave ≤ 4096
  - Long waves > 4096 and ≤ 512 K samples
    - Within the limits of the MP160/150 internal memory
  - Longer waves > 512 K samples

There are two basic Acq*Knowledge* acquisition modes, "Save to MP160/150 Memory" and "Save to Memory/Disk." On-line Averaging also uses the MP160/150 memory.

Save to MP160/150 Memory: This acquisition mode was designed for short burst signals at high acquisition sample rates with short duration. While longer acquisition can be acquired in this mode, the system may be slow to respond. Depending on the computer resources, it may take several seconds for the screen to update. Should this become an issue, adjust the CPU allocation in the Acq*Knowledge* Preferences. In the Preferences, select "Performance" and move the slider to the right toward *Better data transfer for high speed acquisition.*

Acq*Knowledge* Preferences are accessed from the Main Toolbar  or via Display > Preferences.

Analog Output Upper Limits Summary

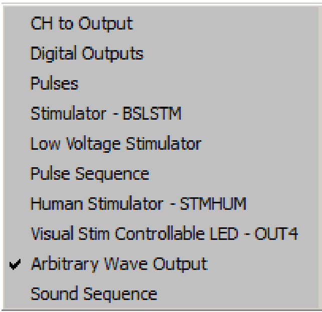
The upper limits for short burst, long, and longer waves are provided below.

Note: At high or maximum aggregate acquisition sample rates, the display may become sluggish and data may take several seconds to be displayed. Additional user actions may overwhelm the system.

	Short Burst Wave (≤ 4096 samples)	**Long Wave (> 4096 samples but ≤ 512 K samples)**	**Longer Waves (≤ 512 K samples)**
Stimulator Sample Rate:	100 K max (sample rate not adjustable for averaging)	100 K max	20 K max
Acquisition Modes:	Save to MP160/150 Memory Save to Averaging	Save to MP160/150 Memory Save to Memory or Disk	
Source Output Maximum per Analog Output:	4096 samples	512 K samples (256 K if dual stimulators are used via outputs A0 and A1)	
Maximum Aggregate Acquisition Sample Rate:	400 K		

Chapter 10 Output Control

Note Output Control chapter refers to MP36R hardware only.
For MP160 or MP150, see the previous chapter, 'Set Up Stimulator.'



The MP36R hardware can output pulses or analog voltages via the **Analog Out** port; this port is also used to connect to BIOPAC's external stimulators. The MP36R has an additional **I/O Port** which is used to output digital (TTL Level) signals.

Parameters for output signals are set via **Output Control**. Access to a specific Output Control is via the **MP36R > Output Control** submenu.

There are three basic Output Control categories:

- Pulse – Pulses, Stimulator-BSLSTM, Low Voltage Stimulator and Human Stimulator-STMHUM
- Pulse trains – Pulse Sequence, Sound Sequence and Visual Stim Controllable LED-OUT4
- Other – CH to Output, Digital Outputs, Arbitrary Wave Output

There are a total of ten Output Controls for the MP36R:

Output Control	See…	**MP36R** Functionality
CH# to Output	page 221	Direct analog CH1-4 to output listen to signals
Digital Outputs	page 223	Control 8 digital outputs
Pulses	page 186	Use with third-party devices; software can control pulse width and repetition.
Stimulator - BSLSTM	page 224	Use with BSL Stimulator
Low Voltage Stimulator	page 224	MP36R: Use OUT3 adapter for MP36R built-in low voltage stimulator. Software can control pulse amplitude, width and repetition (-10 to +10 V)
Pulse Sequence	page 188	Direct analog CH1-4 or digital D1-8 output. Allows for output of customized pulse trains.
Human Stimulator – STMHUM	page 225	Hand-held stimulator, allowing the subject to control the stimulus delivery. Configurable from 1-100 V.
Visual Controllable LED – OUT4	page 230	Direct analog CH1-4 or digital D1-8 output. Allows for output of customized pulse trains to an LED transducer for visual stimulus studies (OUT4).
Arbitrary Wave Output	page 231	Arbitrary wave output is very similar to the stimulator in the MP160/150, allowing for generation of square, sine or ramp signals, or arbitrary signals from another open graph window.
Sound Sequence	page 230	Outputs customized sounds assignable to a user configurable pulse train.

To open an Output Control, select it from the **MP 36R > Output Control** submenu. A checkmark appears next to the submenu selection and an **Output Control** panel is displayed, bordered in red in the active data window. To close an Output Control, select from the menu again (toggles between display and hide) or right-click in the open control panel and choose **Close**.

Only one Output Control panel per graph may be open at any time. Switching between different data files may display different output control panels, which operate differently.

Because some output devices can be used for stimulation on humans and can achieve voltages up to 100 Volts, built-in software logic makes output control as safe as possible. See page 245 for safety notes regarding human subjects. The following applies to all Output Controls.

The output will not operate unless its software control panel is open.

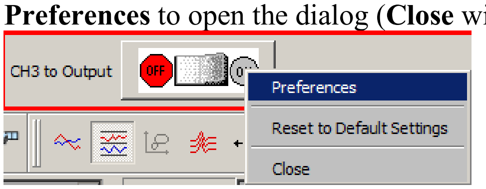
When an Output Control panel is closed, or the Acq*Knowledge* application is closed, MP36R output goes to 0 Volts, preventing the output device from sending pulses.

When an Output Control panel is opened, output is always OFF until activated by a click of the ON/OFF switch in the control panel or, if parameters allow, a click of the Start button in the data acquisition window. (Exceptions are the Digital Outputs Control when set to the preference “Set each output immediately.”)

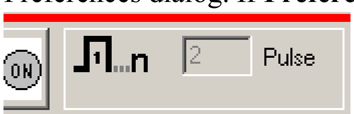
If desired, custom Output preference parameters can be saved as a preset for a current graph (file preset) or for all graphs (global preset) by using the “Save Settings” button in the Output Preferences window. A saved Output preference can be selected from the Output Settings pop-up menu in the Output Control’s panel.

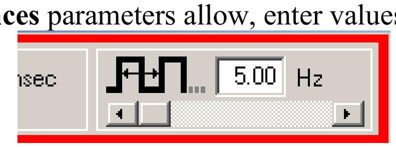
Output Control **Preferences** dialogs establish the parameters for output. Preferences dialogs are only available when the corresponding Output Control panel is open and active.

To generate the **Preferences** dialog:
Open an Output Control panel and then right-click over it to generate a pop-up menu. Choose **Preferences** to open the dialog (**Close** will close the control panel).



If a control panel entry box is grayed, its values may be already be established or limited by settings in the Preferences dialog. If **Preferences** parameters allow, enter values directly in the **Output Control** panel.





Key into the entry boxes and then enter the value by pressing the **Enter** key.

Use the **Tab** key or mouse to move to another entry box.

Click the **OK** button if in the preference dialog.

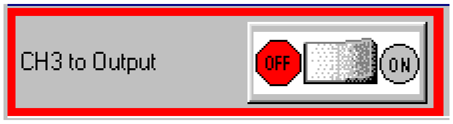
Values entered into a control panel or its Preferences dialog that are outside the specifications of the output device, or outside the limits defined by the Preferences dialog, may change automatically to reflect either the closest value to that requested that the hardware can achieve, or the closest increment defined by the limits in Preferences.

For example, if a Pulse width of 5 ms is entered into the Pulses Output Control panel entry box, but Preferences defines a range limit of .5 to 2 ms for Pulse width, the system will automatically change the new entry to 2 ms.

Saving Panel settings:

Output Control panel settings will be retained until a file is closed or saved. If a file is closed but not saved, settings will be lost (defaults established); if a file is saved, panel settings will be saved.

CH# to Output



The CH# to Output Output Control redirects an analog input signal to the **Analog Out** port on the back of the MP36R UNIT. The signal from the assigned channel will continue to be record and plot data.

This Output Control is used commonly when attaching headphones to the MP36R unit to listen to signals coming in on an analog input channel; for example listing to the Electromyogram.

To display this control panel:

Choose MP 36R > Output Control > CH# to Output to open the control panel.

MP36R users may use analog input CH1-CH4. Channel 3 is the default setting. If another channel N has been designated, the menu will read “CH<N >.”

Use the control panel **ON/OFF Switch** to start and stop output. OFF grounds the output so no signal (or sound) should be present.

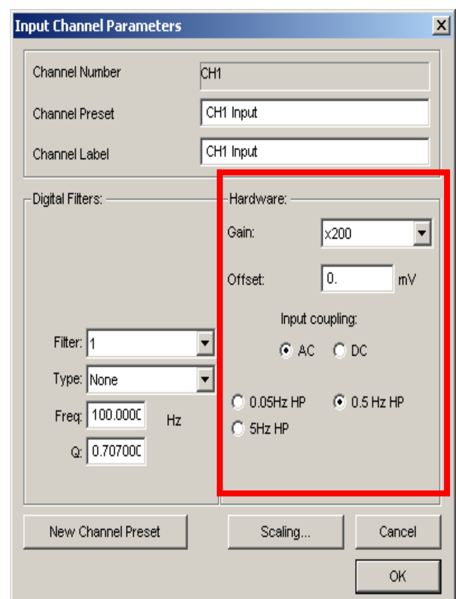
Set **Preferences** to designate which channel to redirect to output.

Open the Preferences dialog by right-clicking the control panel.

Use the pull-down menu to select the desired channel CH 1-4 to use for the output.

Click OK to set the output channel and return to the control panel.

Note Only the Hardware settings (Gain, Offset, Input Coupling) from the Input Channel Parameters dialog (MP36R > Set Up Data Acquisition > Channels > Setup) will be applied since output is established prior to the processing of Digital Filters.



See **MP36R Input > Output Scaling** values on the next page.

MP36R Input > Output Scaling

The MP36R hardware can pipe signals from any channel input to the output using the "CHX to Output" control panel in the Acq*Knowledge* software—due to the difference between the input and output range, there will be a change in signal level (scaling). The output range depends on the output pin used as shown in the following table.

Output Pin (Analog Out port)	**Pin Description**	**Output Range** (Volts)
Pin 1	Headphones, A.C. Coupled	-2.048 to +2.048
Pin 2	Low Voltage Stimulator, D.C. Coupled	-10 to +10

The input range is gain-dependent. The table below shows the scaling (multiplying) factors to use for each gain setting.

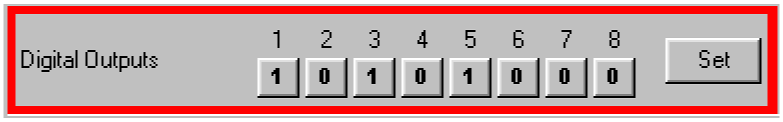
Gain	**Input Range** +- millivolts	**Output Scale**—*accurate to ±10%*** ***Factor 1*** **Pin 1** (Headphone out)	***Factor 2*** **Pin 2** (Low Voltage Stimulator)
x5	± 2 V	1.024	5
x10	± 1 V	2.048	10
x20	± 500 mV	4.095	20
x50	± 200 mV	10.238	50
x100	± 100 mV	20.475	100
x200	± 50 mV	40.950	200
x500	± 20 mV	102.375	500
x1,000	± 10 mV	204.750	1,000
x2,000	± 5 mV	409.500	2,000
x5,000	± 2 mV	1023.750	5,000
x10.000	± 1 mV	2047.500	10,000
x20,000	± 0.5 mV	4095.000	20,000
x50,000	± 0.2 mV	10238.000	50,000

Notes

***** 1: To properly measure the output signal, at least a 2K Ohm load is necessary.

****** 2. Input to Output scaling is accurate to within 10%.

Digital Outputs Control



The Digital Output Control manages the signal output for each of the eight digital lines via the **I/O Port** located on the back of the MP36R. Digital lines are used to control external devices.

The digital output uses standard TTL levels which correspond to the control panel setting as follows:

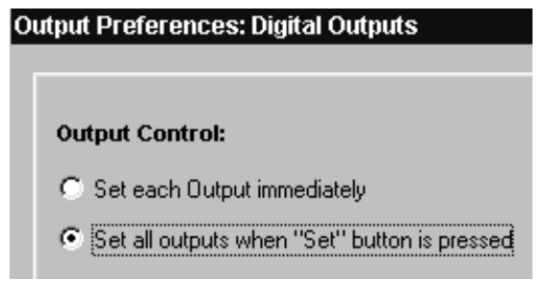
Control Panel setting	Output Voltage level (Volts)
0	0
1	+5

To display this control panel:

Choose **MP36R > Output Control > Digital Outputs** to open the Digital Outputs Control panel

Click each digital output line to set its digital state to 0 (off) or 1 (on).

To set **Preferences** for Digital Outputs, open the Preferences dialog by right-clicking the control panel.

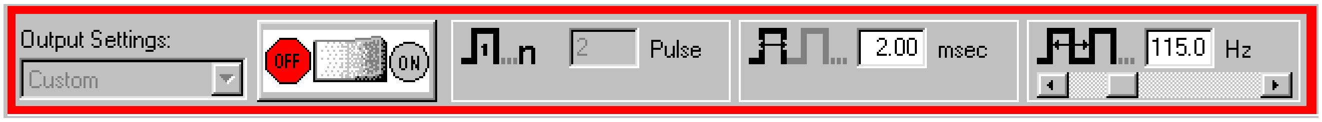


Select from the following two options:

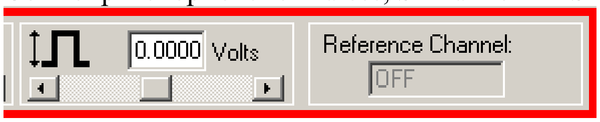
Set each output immediately (default) allows the state of each digital output line to be toggled between 0 and 1, and changes the state **immediately**. In this mode, no **Set** button is available in the control panel. Output for each line is set upon clicking its toggle button.

Set all outputs when Set button is pressed allows the state of each digital output line to be toggled, but the states will not physically be changed until the **Set** button is clicked on the control panel. In this mode, a **Set** button is available in the control panel. When the **Set** button is clicked, all eight digital lines will update simultaneously.

Pulses Output Control
Stimulator – BSLSTM Output Control
Stimulator – Low Voltage Output Control
Stimulator Human Stimulator (STMHUM) Output Control



Control panel options for Pulses, Stimulator – BSLSTM and Stimulator – Low Voltage



Additional control panel options for **Low Voltage Stimulator**

A variety of pulse output options are available. Exercise caution when using any of the options with human subjects—see the **Safety Note** on page 245.

Pulses Output Control

Select this Output Control for general pulse output, or when synchronizing to 3rd-party devices.

Use for reaction time measurements, where a subject listens with headphones for a series of "clicks" (pulses) and responds as quickly as possible with a button press. Determine reaction times by calculating the time between the start of the pulses and the responses.

Use with the **BIOPAC STP30W** Stimulus Presentation System (SuperLab) to measure responses to visual or auditory stimuli. To perform sophisticated evoked response averaging tests (e.g. P300), pair triggers with different visual or auditory stimuli.

Use to trigger another device (automatically send a pulse from the MP36R UNIT when acquisition starts).

Use to control a 3rd-party stimulator. BIOPAC recommends use of the BIOPAC BSLSTM Stimulator with the MP UNIT and BIOPAC software. If using the BSLSTM Stimulator, use the **Stimulator - BSLSTM Output Control** instead of this Pulses Output Control.

Stimulator – BSLSTM

Select this Output Control when using the Biopac Student Lab stimulator (BSLSTM)

Use with stimulation electrode HSTM01 for safe stimulation of human subjects (0 – 100 Volts), as well as lower voltage (0 - +10 Volt) general-purpose stimulation, such is used with amphibian muscle or nerve preparations.

Set up note Placing the BSLSTMA/B unit too close to MP36R hardware can result in data distortion of the BSLSTMA/B pulse width signal; distortion is more apparent at higher sampling rates.

- NEVER set the BSLSTMA/B atop MP36R hardware
- Position the BSLSTMA/B away from the MP36R hardware to reduce the signal distortion

Low Voltage Stimulator

Select this Output Control for low-voltage (-10 - +10 Volt), direct drive stimulation via MP36RAnalog Out port (with or without OUT3 BNC adapter).

Use with stimulator electrode HSTM01 for safe, stimulation of human subjects (0 – 100 Volts), as well as lower voltage (0 - +10 Volt) general-purpose stimulation, such is used with amphibian muscle or nerve preparations.

Outputs through a BNC connector so it can be used with most stimulation cables (such as those that terminate in a needle probe).

Stimulator Human Stimulator – STMHUM

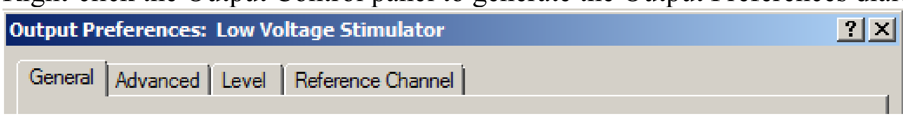
Select this Output Control to conduct stimulation studies that enable subjects to control the stimulus delivery.

This hand-held stimulator connects directly to the MP36 Analog Out port and has a red button for delivering the stimulus signal. The electrodes on the bottom of the unit are placed directly onto the subject. The STMHUM functions much like the BSLSTM but with no additional hardware required. The voltage range is 0 – 100 volts and can be limited or locked to a user defined level in the STMHUM Output Control panel, which resembles that of the Low Voltage Stimulator.

To use one of these control panels:

Choose MP 36R > Output Control and then select Pulses, Stimulator – BSLSTM, Low Voltage Stimulator, or Human Stimulator (STMHUM).

Right-click the Output Control panel to generate the Output Preferences dialog.



Set the Preferences.

General: ON/OFF, Number of pulses, Event options — see page 237

Advanced: Pulse width, Pulse repetition (rate) and Verify Transducer (STMHUM) — see page 240

Level (Low Voltage Stimulator and STMHUM only): Pulse level — see page 243

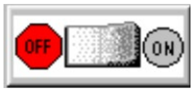
Reference Channel (Low Voltage Stimulator, Pulse Sequence and STMHUM only): The Reference Channel is the channel on which the pulse is outputted, and configurable as Analog channels CH1-CH4, or Digital channels D1-D8.

Once configured, Preferences may be saved using the **Save Settings** command, activated by pressing the saved settings from the pop-up menu in the control panel (see page 236).

Confirm the settings in the control panel. Adjust as desired within the parameters established in Preferences.

Entry limits: Settings entered into the Preferences dialog may establish, or limit, the values in the Output Control panel entry boxes. Enter pulse settings directly into the control panel only if the Preference settings are not locked to a specified value. A grayed or disabled entry box indicates that the values are locked.

Initiate the pulse sequence as defined in Preferences (see page 237).

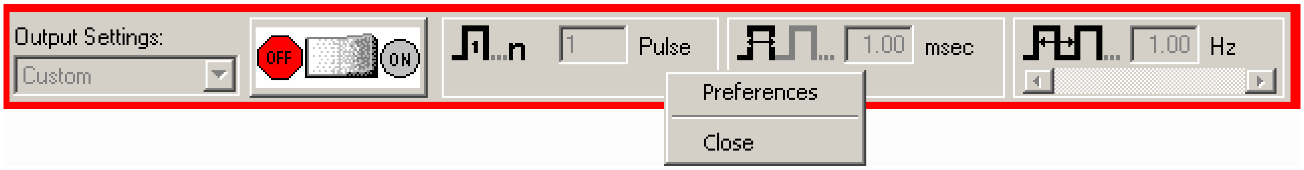


ON/OFF Button in Output Control Panel uses the switch in the Control panel.

Recording uses the **Start /Stop** button in the data acquisition window.

To close an Output Control panel:

Right-click anywhere in the Output Control panel to generate a pop-up menu and then choose **Close**, or select it (or another output control) from the MP36R > Output Control submenu.

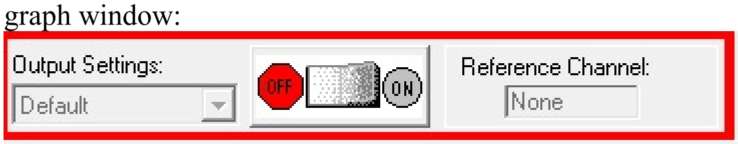


Pulse Sequence Output Control

This Output Control allows sequences of pulse configurations and delays to be sent to the MP36R unit, making it possible to create more complex stimulus setups.

NOTE: Use the OUT3 BNC adapter to output pulses to a third-party device.

Enabling the pulse sequence output control option will display the following control panel at the top of the graph window:



Pulse sequence configuration is performed in the Preferences dialog of this output control panel. (Accessible via right-click on panel shown above.) When a pulse train element is selected in the configuration, the controls will become visible in the right hand portion of the preferences dialog. The configuration makes use of three basic building blocks:

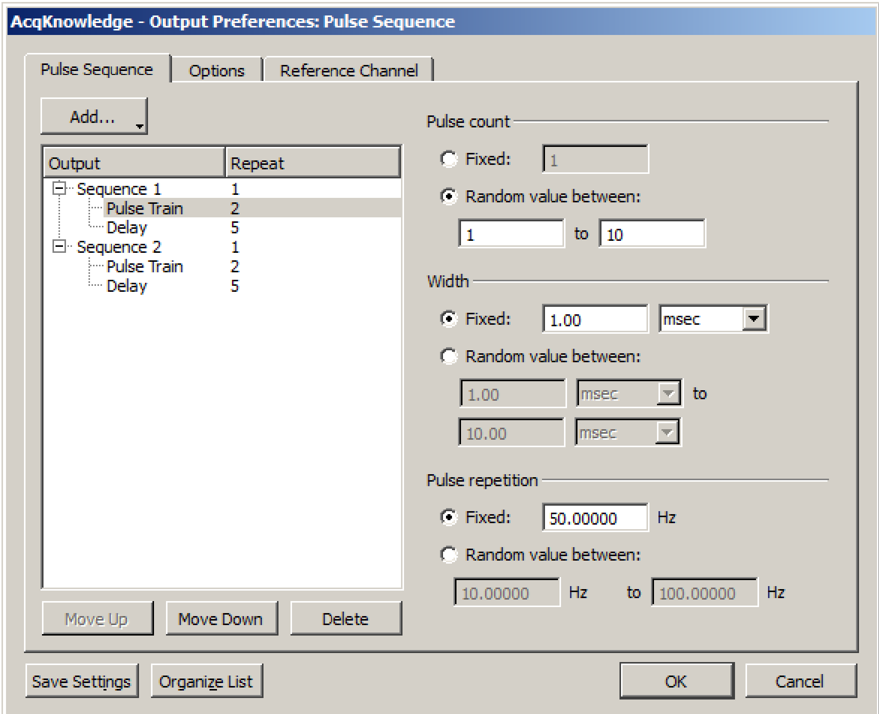
A *sequence* consisting of a number of delay and pulse train elements. The final configuration consists of one or more sequences that are outputted in order. Normally the entire configuration is outputted. There is a special operational mode on 'Start with Recording' that will take only the indexed sequence matching the current recording segment.

A *pulse train element* consists of Pulse count, Width and Pulse repetition, These elements can be fixed or randomly generated.

A *delay element* that allows for the introduction of time during which no pulses will be generated.

Each one of these building blocks also has a "repeat" count associated with it that will perform the action a set number of times. (Adjust by selecting the desired 'Repeat' and inputting a new value) Individual sequences, pulse trains and delays can be added, deleted, repeated and reordered as desired. In the right pane of the Preference dialog (shown below), fixed or random pulse counts, widths and repetitions can be configured and combined. As in other Output Controls, custom settings can be saved and organized in a list view. (See below for additional setup dialogs)

For a full explanation of preferences and tabs common to all Output Control panels, see the "Pulse Definition" section on page 235 and the "Output Control" section on page 235.



Preferences available in Pulse Sequence tab

Add: Displays pop-up menu for adding Sequences, Pulse Trains or Delays.

Output: Displays the configured sequences and sequence elements for the current or saved session.

Repeat: Editable field for setting the number of times the pulse train or pulse train element is repeated

Pulse count: Fixed – a set number of pulses is generated per sequence.

Random – set a random number of pulses to be generated per sequence.

Width: Fixed – each pulse width will be of a set duration, in units of microseconds, milliseconds, or seconds.

Random – sets the pulse width duration to fall between two set time ranges.

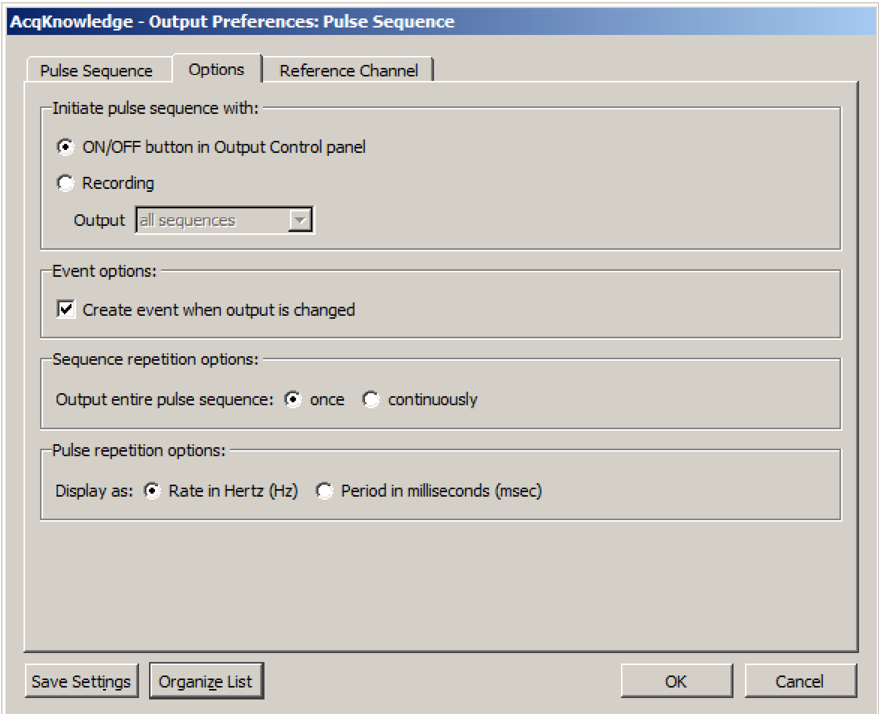
Pulse repetition: Fixed – sets a fixed interval between the start of one pulse to the start of the next pulse

Random – sets a random interval between two set values for the start of one pulse to the start of the next pulse.

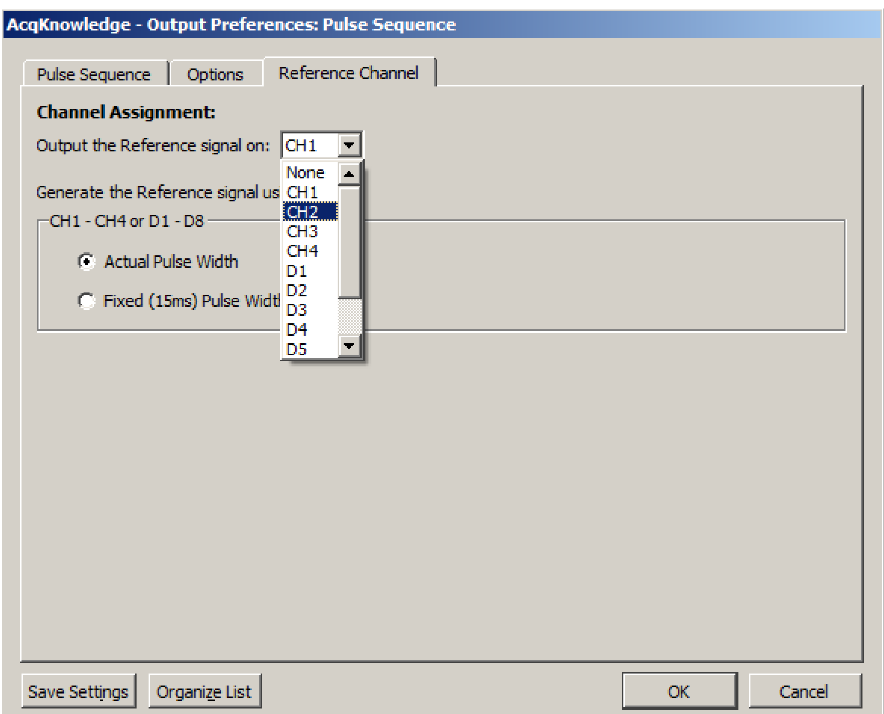
Move Up/Down Delete: Selectively reorders or deletes the various pulse train elements.

Save Settings: Saves modified settings as a custom preset for the current graph, or for all graphs.

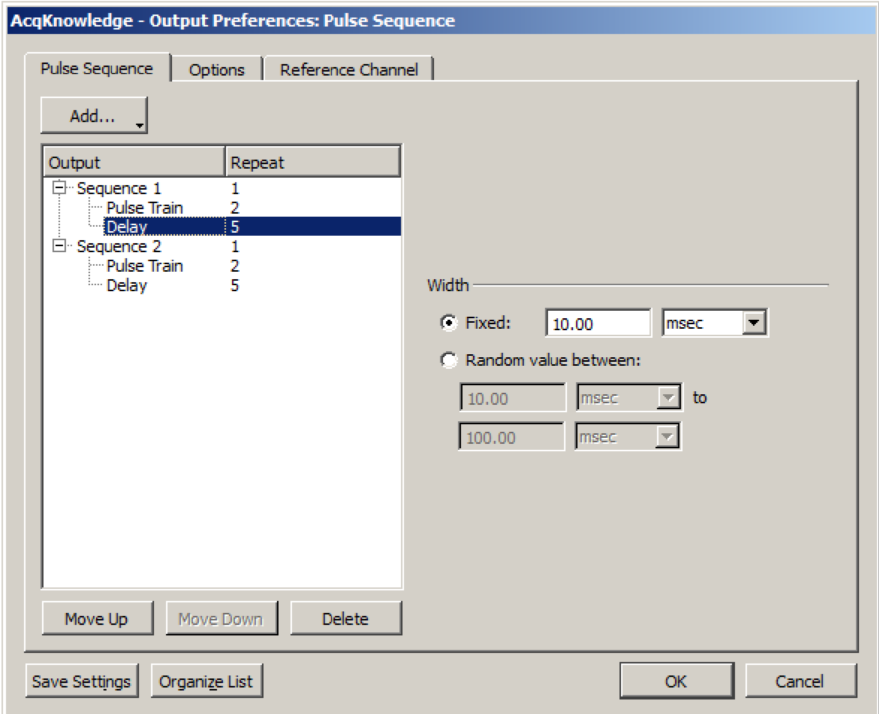
Organize List: Orders custom presets into a list and categorizes the custom presets for the current file or globally across the application.



Preferences available in Options tab

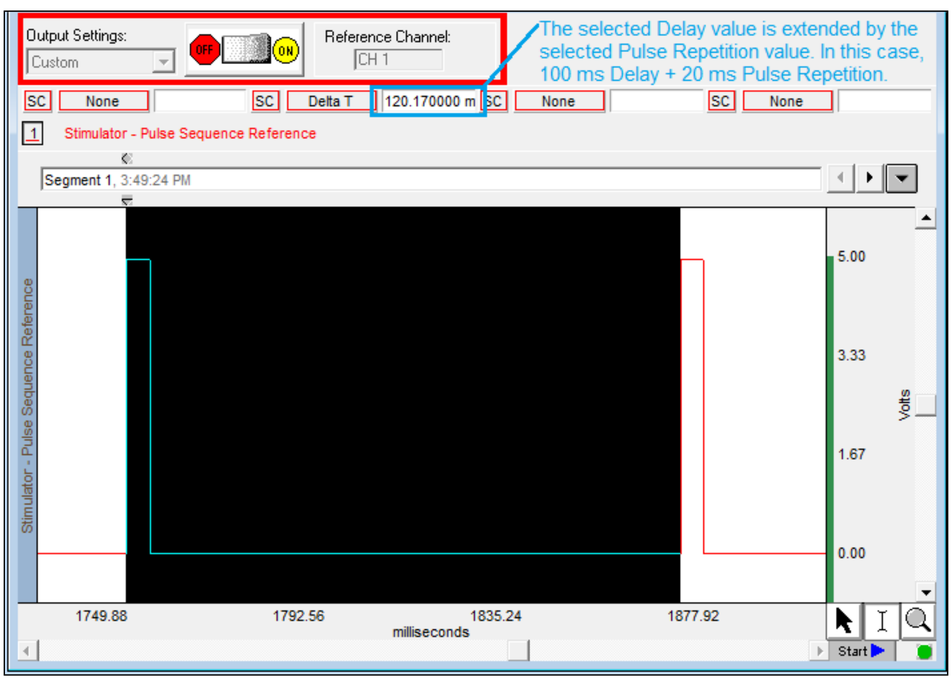


Preferences available in Reference Channel tab



Delay Preferences

About Delay between Pulse Trains:
The amount of actual Delay between pulse trains will vary from the set value depending upon the pulse repetition value that is used. In the example sequence below, a Delay of 100 milliseconds between pulse trains has been set up, combined with a pulse repetition rate of 20 milliseconds. Because the pulse repetition rate is applied before the Delay occurs, the actual Delay between pulse trains in this case will be 120 milliseconds. If it is critical that a Delay reflect an exact value, it is advisable to subtract the selected pulse repetition value when setting up the Delay parameters.

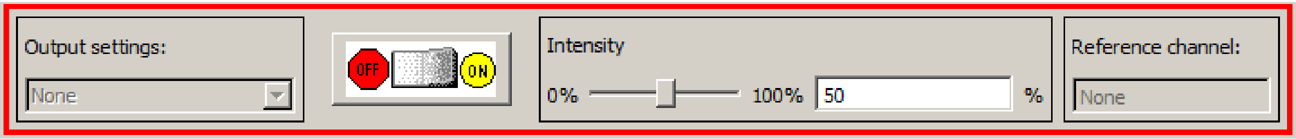


Delay between pulse trains

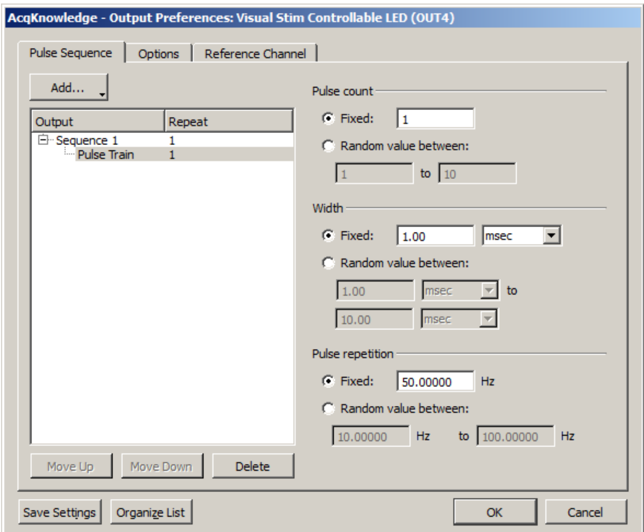
Visual Stim Controllable LED – OUT4 Output Control

This Output Control is used to set up parameters for the OUT4 LED transducer used for conducting visual stimulus studies, in which flashes of light of varying intensities and intervals are presented to a subject. The OUT4 LED transducer is connected directly to the MP36 Analog Out port.

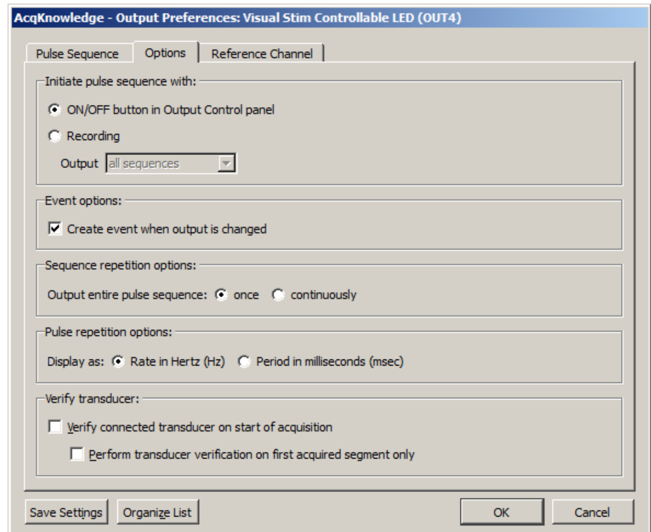
To use this Output Control choose **MP Unit > Output Control > Visual Stim Controllable LED**.



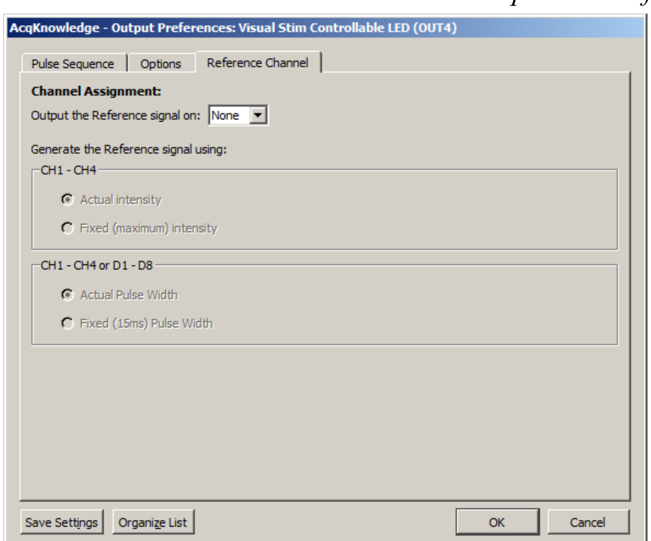
The Visual Stim Controllable LED Output Control panel is identical to the Pulse Sequence control panel, but with the addition of an intensity control for controlling the LED brightness level. The preferences operate identically to those of the Pulse Sequence Output Control covered in the previous section.



Pulse Sequence Tab for Visual Stim Controllable LED



Options Tab for Visual Stim Controllable LED



Reference Channel Tab for Visual Stim Controllable LED

For specifics on the Visual Stim LED preferences set up, see the Pulse Sequence Output Control section on page 226.

Arbitrary Wave Output

Acq*Knowledge* with MP36R supports signal output through one analog channel while data is being acquired. This is configured by using the Arbitrary Wave Output option. In general, the Arbitrary Wave Output is used in conjunction with an OUT3 Low Voltage Stimulator connected to the Analog Out port (rear panel of MP36R).

Four types of signals can be output:

Square waveforms—page 211	Ramp waveforms—212
Tone waveforms—212	Arbitrary waveforms—214

Each of these waveform types can be set to repeat signal output either Once or Continuously, and parameters can be set to either Relative or Absolute time scales.

Like the standard graph window, the Stimulator setup window plots time on the horizontal axis and amplitude on the vertical axis.

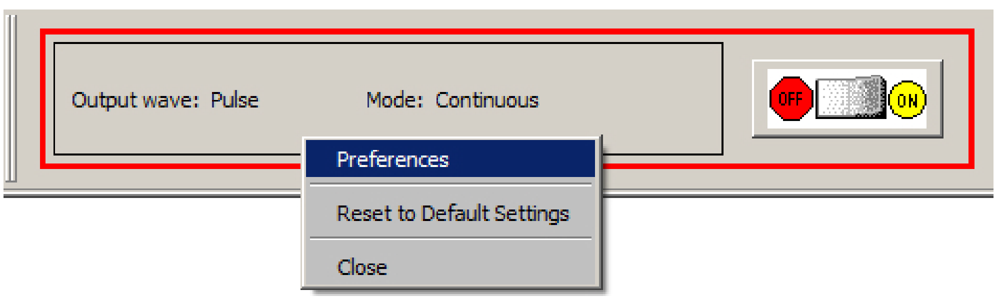
Use the Stimulator window (see following page) to create and shape waveforms for output. Adjust the Stimulator Sample Rate to further control the parameters of the Stimulator Output design.

For any waveform (or stimulus) to be output, the following parameters must be specified; the type of stimulus, the “shape” of the signal, the output channel to be used, and how many times the stimulus should be output.

The above parameters are set up from within the Stimulator Setup dialog. Regardless of the type of waveform selected, stimulus signals will normally be by clicking the Acq*Knowledge* graph’s “Start” button or by using the On/Off Output Control panel button.

To set up the Arbitrary Wave Output:

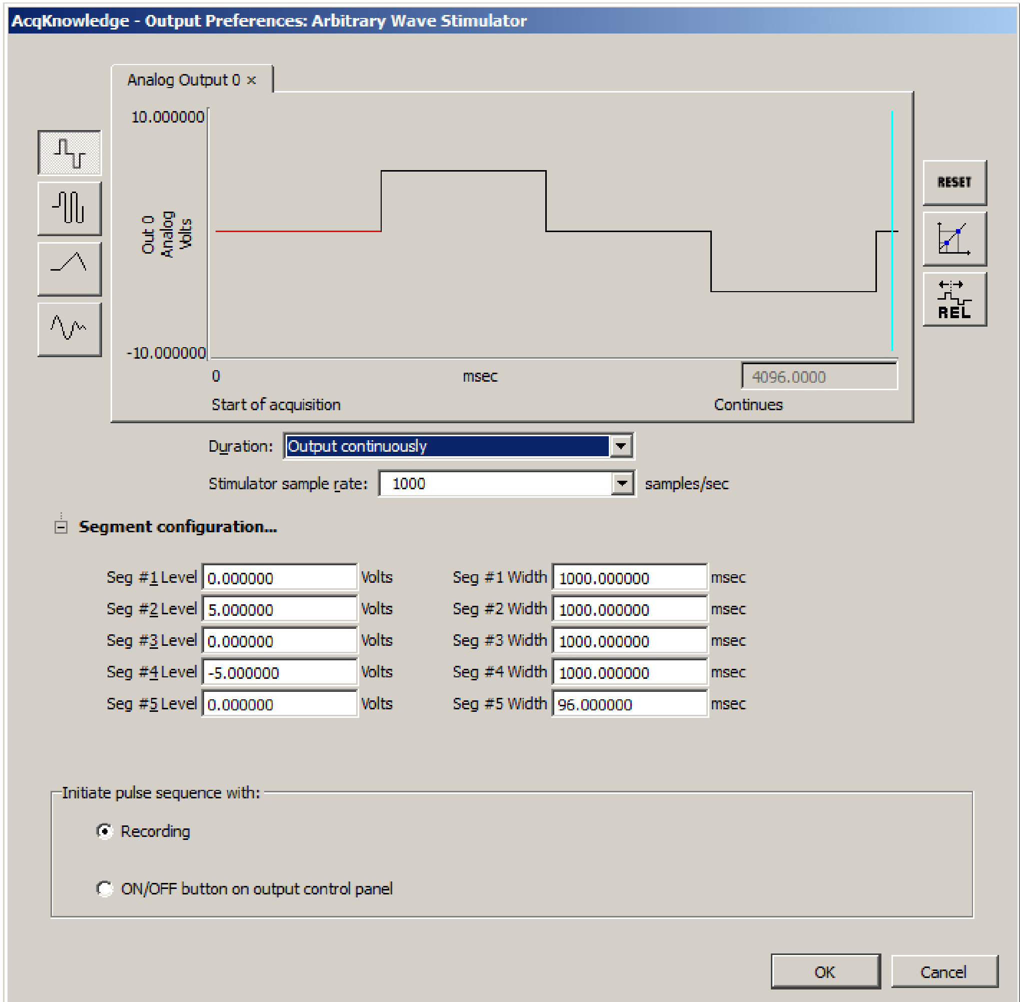
1. Select MP36R > Output Control > Arbitrary Wave Output.
2. Right click the Arbitrary Wave Output Control panel and choose “Preferences” to launch the Stimulator setup window.

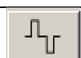
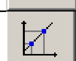
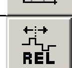
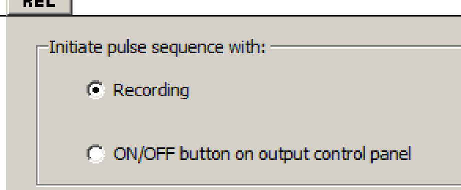


3. Set the desired waveform type and stimulator options in the Stimulator window.

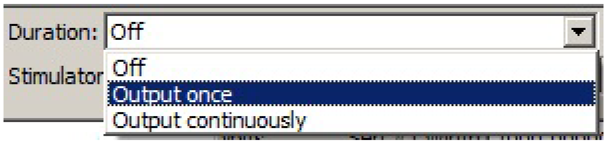
The MP36R Stimulator setup window (see following page) is nearly identical to the MP160/150 setup window detailed in the previous Stimulator chapter (page 205, with the following exceptions:

- The signal output is limited to one analog channel (vs. two in MP160/150 hardware).
- The pulse sequence is initiated by starting the acquisition or by toggling the On/Off button on the Output Control panel (vs. the Timing or Trigger controls in MP160/150 hardware).
- Stimulator averaging output is not supported in MP36R hardware.



Stimulator Icons		
Waveforms:		Square wave
		Tone (sine) wave
		Ramp wave
		Arbitrary wave
Parameters:		Reset the display (use after adjusting the time scale)
		Scaling (rescale Stimulus signals to different units)
		Set time base to relative
Output:		Sets Stimulator to be active when "Start" button is clicked OR when toggled via the ON/OFF button on the Arbitrary Wave Output control panel.

Duration



Off: Turn Output OFF (no stimulus signal output).

Output once: Output the stimulus signal once.

Output continuously: Output the stimulus signal for the duration of the acquisition (forever).

When Output continuously is selected, a vertical line is generated at the end of the first section of the waveform in the stimulator window to indicate where the first output signal ends and the second begins. The line can be dragged left or right like a vertical segment in a stimulus waveform to control the duration of the waveform as it is continuously output. Maximum continuous waveform output is 20 kHz.

Stimulator Sample Rate

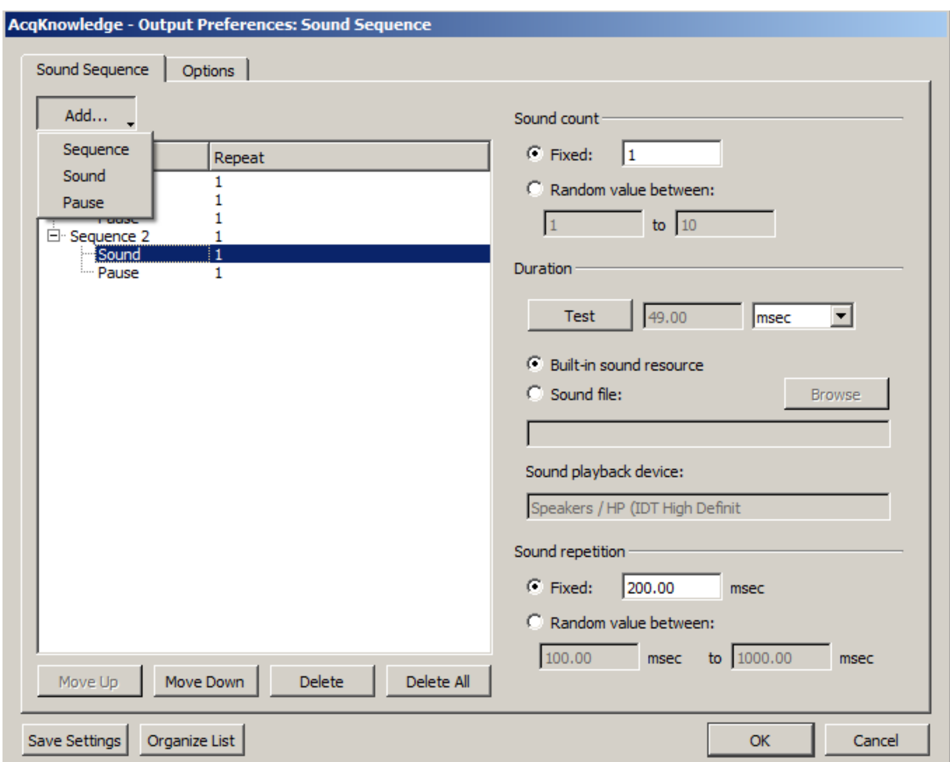
Use to select the Stimulator sample rate for the generated signal. (The Stimulator sample rate is independent of the acquisition sample rate. See page 215 for sample rate details.)

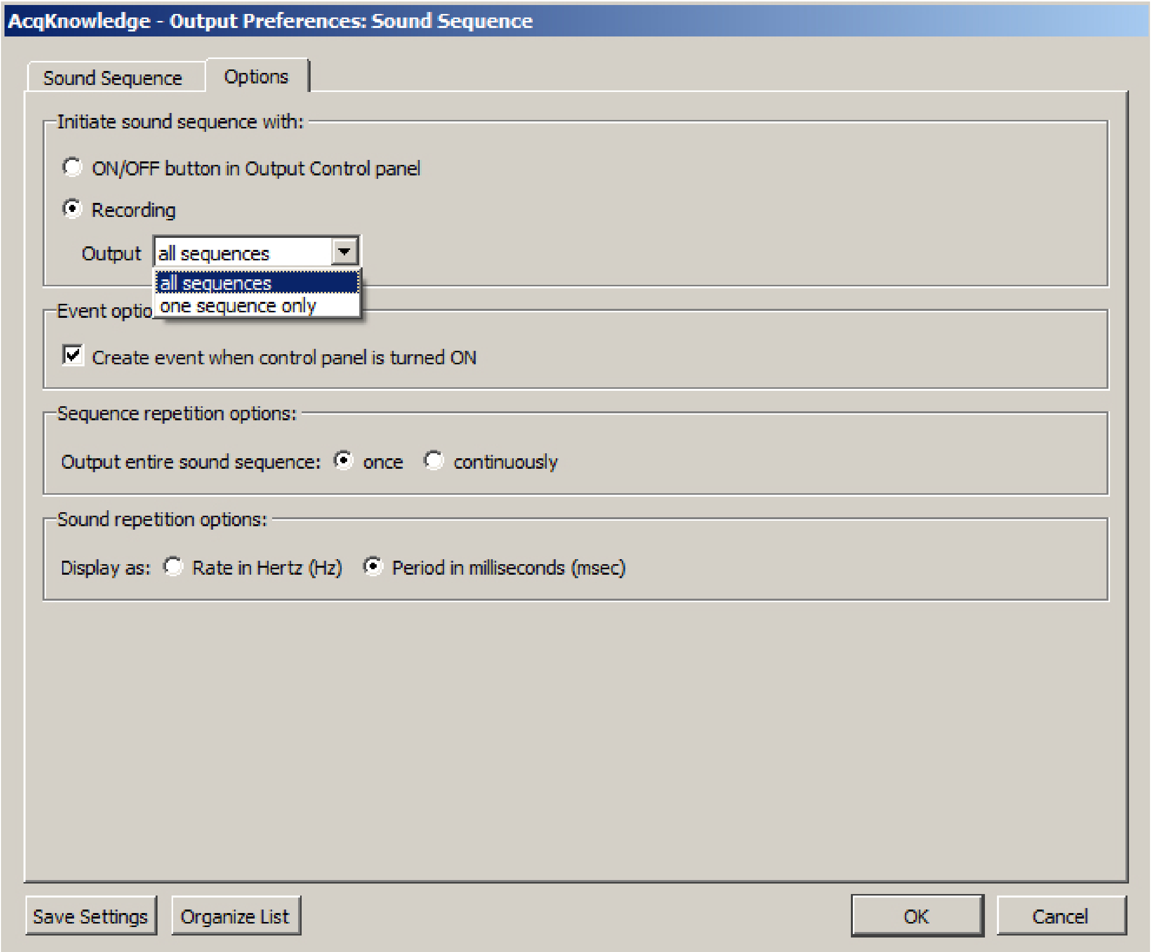
For more details on all other MP36R Stimulator parameters and functionality, see the previous MP160/150 **Stimulator** chapter on page 205.

➡ *See also*: Application Note AH162 - Using the Stimulation Features of the MP System.

Sound Sequence Output Control

Sound Sequence Output Control offers users the option of configuring and customizing sounds to be outputted for aural stimulus experiments. The control panel and Preferences dialogs used for Sound Sequence closely resembles that of Pulse Sequence. (Substitute "Sound" for "Pulse" and "Pause" for "Delay.") The built-in sound resource (a default "click") may be used, or any other file in *.WAV format can be substituted via the "Sound file" and "Browse" button. The "Duration" and "Sound repetition" values are dependent upon the duration of the sound file selected for output. The "Test" button will output an audio sample of the selected sound resource.



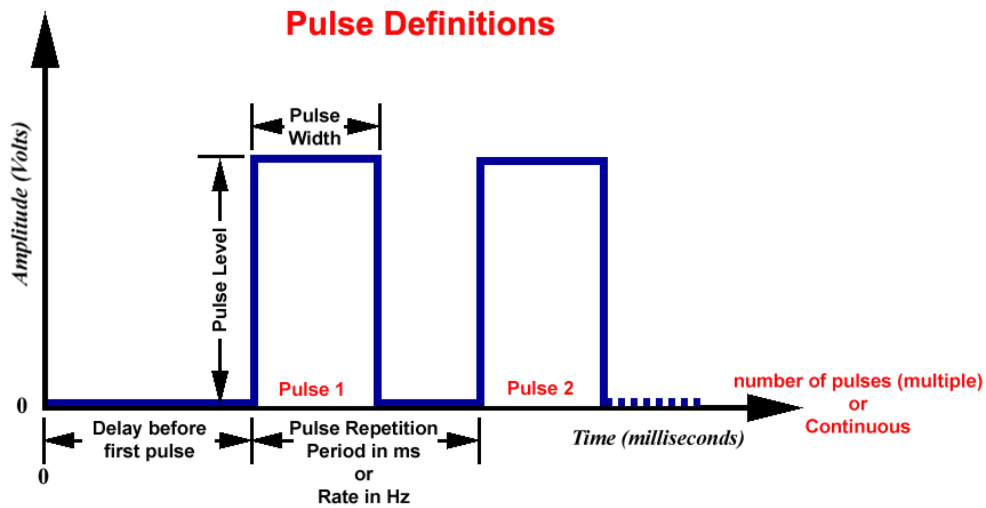


The option *all sequences* means that each configured sound sequence (regardless of number) will be outputted within the same segment. If "Once" is selected in the "Output entire pulse sequence" option, a configured sequence will be heard one time only. If "Continuously" is selected, the first Sound Sequence will be repeated after the last one has completed, looping the pattern repeatedly until the recording is stopped.

The option *one sequence only* means that each sound sequence will be outputted on a segment-by segment-basis only. For example, if one Sound Sequence is configured, it will only be heard during the first recording segment, but not during the second recording segment). If two Sound Sequences are set up, the first one will be heard during the first segment and the second one during the following segment. If no additional Sound Sequences have been configured, nothing will be heard during the third segments and beyond. (Exception: If "Save Once" acquisition mode is used, the Sound Sequence will be repeated when the recording is overwritten during subsequent passes).

Pulse Definitions

The following terms are used in the Output Control panels, Preferences, and guidelines for Pulses, Stimulator – BSLSTM, Low Voltage Stimulator and Human Stimulator-STMHUM.



Delay before first Pulse	Initial delay from start of acquisition to start of first pulse.
Number of pulses	Number of successive pulses that will be sent out at the specified Pulse Width, Repetition and Level. Set for Single (1), Multiple, or Continuous (Cont).
Pulse Level	Amplitude of the pulse, expressed in Volts. *Note*: The output of the BSLSTM is 0 Volts when the pulse is not active.
Pulse Repetition *Also called —* Events per second Pulse frequency Pulse sequence Pulse train Repetition rate Sample train	Can be expressed as **Period** (ms) or **Rate** (Hz). *Period:* Time between pulses; measured in milliseconds from the start of one pulse to the start of the next pulse. *Rate:* Number of pulses that occur in a one-second interval; measured in Hertz. **Rate** relates to **Period** as: Rate (Hz) = 1000 / Period (ms)
Pulse Width	Time that the pulse is in the non-zero or active state.

Output Control Panel Descriptions

The Output Control panels for Pulses, Stimulator – BSLSTM, Low Voltage Stimulator and Human Stimulator-STMHUM work in conjunction with Preferences to control pulse output. Control panel functions are detailed here:

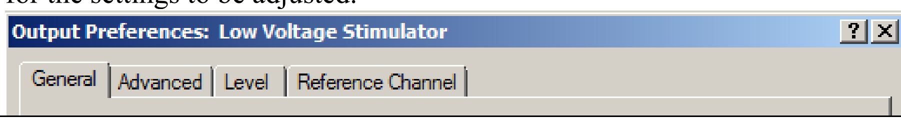
OUTPUT CONTROL PANELS	
General Notes	Pulse parameters can interact with each other. For example, the pulse repetition period cannot be set to a value less than the pulse width.

OUTPUT CONTROL PANELS

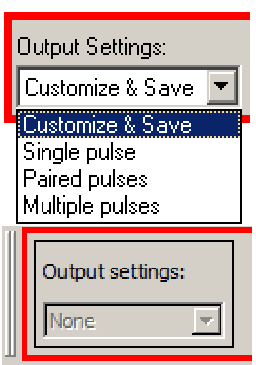
In order to simplify the interaction, the Pulse width entry overrides other entries as required; it is the priority parameter.
For example, if the pulse width is changed such that it exceeds the pulse repetition period, the pulse repetition period will be automatically adjusted to accommodate the new pulse width entry. If, however, the pulse repetition period is changed such that it is less than the pulse width, the repetition period will be changed, upon attempted entry, to the closest value that can be achieved without changing the pulse width.
Entries are checked and rounded (not truncated) as necessary to meet limitations of the hardware or the Preferences.
When a file is opened, the output device will not turn ON automatically. A user must manually press either the "Record" button or the "Start" button.
The exceptions are the "Voltage Output" control panel and the "Digital Outputs" control panel if "Set each Output immediately" is selected; these settings will output values immediately.
Output control settings are "local," which means that they are stored at the data file level, not the program level. Use the save as graph template (File > Save As) option to use existing Preferences in new data files.
If a file is saved with an Output Control panel visible and then closed, the panel will be visible when that file is re-opened.

Preferences

Right-click a control panel to generate the Preferences dialog, and then select a tab for the settings to be adjusted.



Output Settings



Displays the name of the current Preferences setting. The pull-down menu lists the names of all output Preferences saved using the **Save Settings** button (see page 236).
The pull-down menu is not accessible when an output pulse train is in progress.
If no settings configurations have yet been saved when the Output Control panel is first opened and no parameters are changed, the Output Settings box displays "Default."

When output settings are saved, the Output Settings box displays the name of the last selected setting. Use **Organize List** to change the display order of the menu, rename, or delete items (see page 237).
When a saved setting is selected from the pull-down menu, the Output Control panel and all Preferences dialog options will be updated.

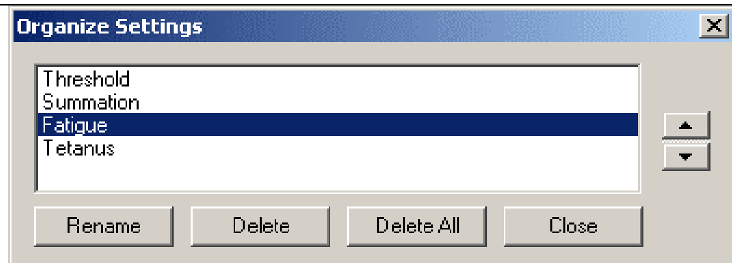
For Reference Channel—Low Voltage Stimulator; Human Stimulator; Visual Stim Controllable LED (OUT4) and Pulse Sequence only. All Output Settings must use the same reference channel assignment; other parameters can be unique for each setting.

OUTPUT CONTROL PANELS

Once configured, Preferences may be saved using the **Save Settings** button at the bottom of the Preferences dialog. **Save Settings** generates a dialog to name and save a defined configuration of Stimulator output settings. Saved configurations are accessible via the Output Settings pull-down menu in the Output Control panel. When a setting is selected from the menu, all current output parameters are updated to reflect the saved settings.

Multiple configurations can be saved as long as each has a unique name; the Save button will be inactive if the entered name is not unique.

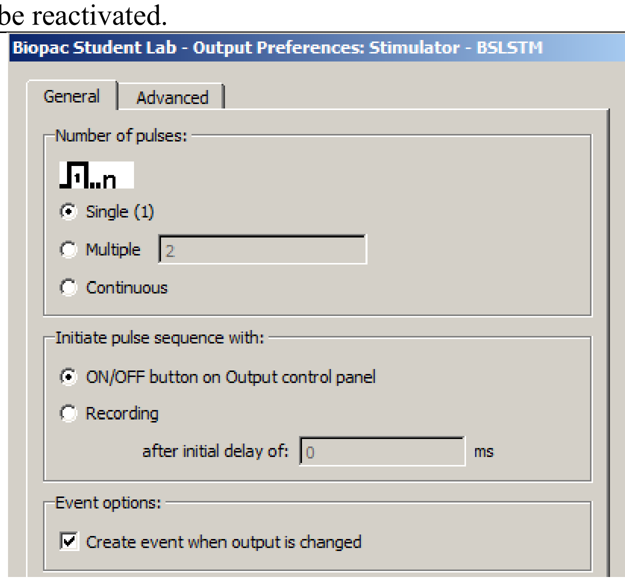
Settings can be saved locally (to a specific file) or globally. The data file or template file holds the output parameters as established when the file was saved plus any other named configurations of Output Settings.



Use the **Organize List** button at the bottom of the Preferences dialog to order, rename or delete saved Preferences settings. The up or down arrows are only available if two or more settings have been saved. Select a setting and then click the up and down arrows to set the position, or choose rename or delete. Selecting “Delete All,” removes all saved settings will be deleted and the default options will be reactivated.

General Tab

The General tab is available when using Pulses, Low Voltage Stimulator, Stimulator-BSLSTM and Human Stimulator-STMHUM.



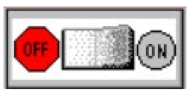
<table>
<tr>
<td>Number of Pulses

</td>
<td>Indicates the number of pulses to be output. When the Output Control panel is closed, the pulse output will be immediately stopped.

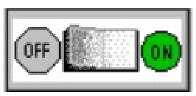
Single will establish a single pulse for outputting. All pulse repetition options, entry boxes and scroll bars in both the control panel and preferences windows will be disabled (grayed).
Multiple will establish a specific number of pulses for outputting. The selection activates an box where 1-254 pulses can be entered. When this option is selected, the Pulse Repetition scroll bar is activated in the Output Control panel.

Continuous will establish a continuous pulse train for outputting. When this option is selected, the Pulse Repetition scroll bar is activated in the Output Control panel.

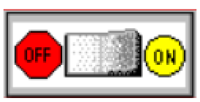
If “Initiate pulse sequence with ON/OFF button in Output control panel” is set, the pulse sequence will be stopped prior to acquisition and will have to be manually turned back on after the recording.</td>
</tr>
<tr>
<td>Initiate pulse sequence with…

ON/OFF Button


OFF (red)



ON (green)



AUTOMATIC START (yellow)</td>
<td>Controls the start and stop of pulses. Changes to Pulse Width and Repetition Rate can be made in the Output Control panel entry boxes during a pulse sequence, and during a recording, if all other Preferences parameters allow it. Any change in the pulse output will occur immediately. This allows the stimulator output to be changed “on the fly.”

When “Initiate pulse sequence with ON/OFF button” is selected:
The ON/OFF button controls pulse output independent of the acquisition status.
OFF is always available.
The ON/OFF button reflects the current output state, with one exception: if the pulse sequence lasts less than 0.5 seconds, the button will remain in the “ON” state for at least 0.5 seconds to indicate that the ON state occurred.
When the Number of Pulses selected is Multiple, ON/OFF acts as a momentary switch. Press the ON (green) button to start pulses;
it will automatically turn OFF (red) at the end of the specified pulse train.

The switch defaults to OFF. Saving a data file or saving as a Graph Template will save all stimulator preferences <u>except</u> the status of the pulse switch, which will always be saved in the OFF position.</td>
</tr>
<tr>
<td>Recording


Start button

Stop button</td>
<td>When “Initiate pulse sequence with Recording” is selected:
If the preference setting “Initiate pulse sequence with: ON/OFF button” is active, the control panel changes will take effect immediately. If settings are changed during a pulse train, changes do not take effect until the next time the stimulator starts.
Pulse output turns ON and OFF corresponding to the Start and Stop of the recording.

When in this mode, and not recording, the ON button will display as yellow, indicating that pulse output will automatically begin at the “Start” of the recording.

Pulse outputting can be turned OFF during a recording, but it cannot be turned back ON until the end of the recording.

When a Repeat sequence is running, pressing the OFF button will turn OFF the output <u>for the entire recording sequence</u> and the button will display as OFF until after the last sequence, when the switch will display as yellow ON (automatic start) indicating that pulse output will begin again at the “Start” of the next recording sequence. It is not possible to turn pulse outputting back ON during a repeated recording sequence.</td>
</tr>
</table>

When the acquisition stops, all stimulator pulses will cease, regardless of the Output Control panel settings.

The pulse output will stop concurrent with the end of the acquisition, even if the specified pulse output is not completed before the acquisition ends. When a new acquisition is started, the pulse output will start from the beginning.

In this mode, no changes can be made in the Output Control panel until the recording stops. Changes made after recording stops will take effect when a new recording is started.

When a pulse is sent out, the event label and indicator arrow will be generated (if the event preference is turned ON and events are displayed).

After initial delay

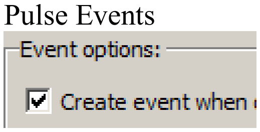
(Applicable to Pulses, Stimulator - BSLSTM, Low Voltage Stimulator and Human Stimulator-STMHUM only)

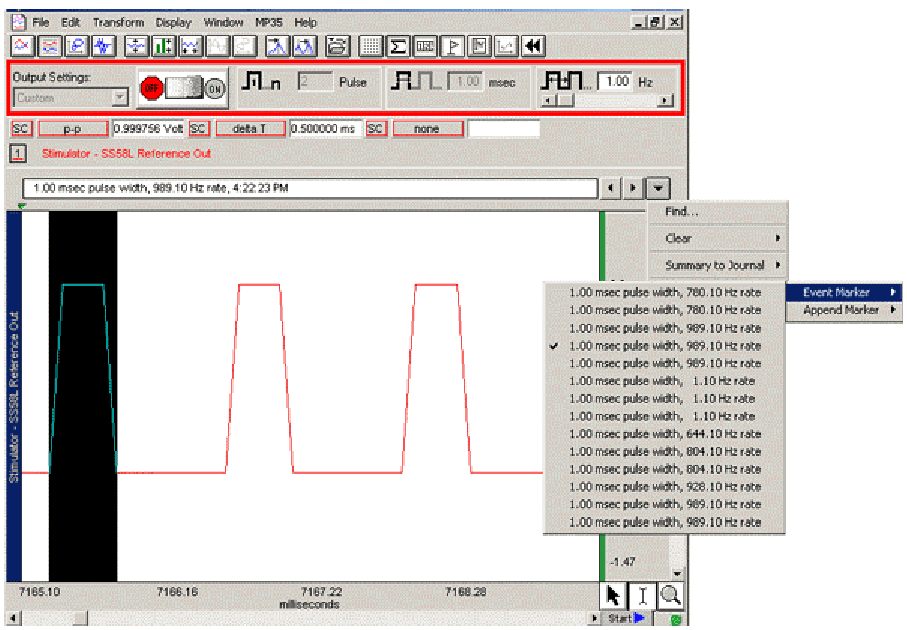
After initial delay of … is enabled only when "Initiate pulse sequence with **Recording**" is chosen. Specify a delay interval from the start of recording to the start of the first pulse. This is useful for viewing data prior to the stimulus pulse. The BIOPAC output device determines the delay range.

INITIAL PULSE DELAY	MP36R or BSLSTM	
Range	0 - 100 milliseconds	0 or .5 - 100 milliseconds*
Resolution	10 microseconds	1.953 microseconds

*Entries greater than 0 milliseconds must be at least 0.5 milliseconds.

Pulse Events



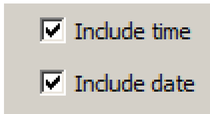


An advantage of using the Acq*Knowledge* software for output signals is that information regarding the pulse is automatically recorded along with the data. The amplitude reflects the output pulse level.

- Events can be automatically inserted and labeled for each Reference pulse or change in pulse train. The label will contain the Pulse width and Pulse rate (and system time stamp if selected).
- Events reflect setting changes made during an acquisition.
- All output pulse information is automatically recorded and archived with the saved data.

Set the event option by clicking in the box to "Create event when output is changed."

Set the "Include time/date" option in the global Preferences (MP36R > Set Up Data Acquisition > Event Marking)



The event label accurately captures pulse data, but the event arrow may not always line up exactly with the leading edge of the pulse; this typically is not a problem because the recording will include the actual stimulus pulse which can be used for timing measurements. Depending on the acquisition Sample Rate, the leading edge of the pulse in the recording may not correspond to the exact time the pulse was sent—it may be off by as much as one sample period. If the event precision is critical for the recording, increase the Sample Rate.

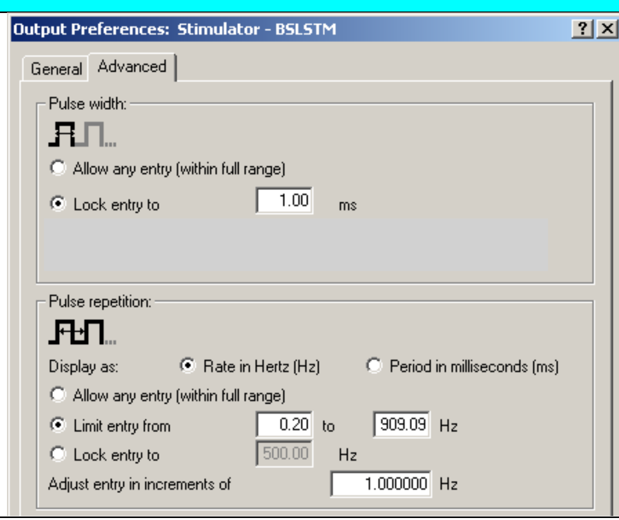
To display events, use the toolbar icon or Display > Show > Events.

The **Range** switch on the front of the **BSLSTM** stimulator should be set to 10 V or 100 V prior to recording and should not be changed during recording; if using a Preset, the corresponding Preset should also be selected prior to recording. The pulse level can then be determined by moving the decimal to the right or left depending on how the range was switched.

ADVANCED TAB (OUTPUT PREFERENCES)

Advanced Tab

(Applicable only to Pulses, Stimulator - BSLSTM, Low Voltage Stimulator and Human Stimulator-STMHUM)



Pulse Width

Indicates the Pulse Width setting, which determines the maximum Pulse Rate frequency. The Pulse Width value is limited by the Preference setting.

The entry is activated when the value is changed and the Tab or Enter key is pressed; it does not require a stimulator restart to take effect.

The Pulse width entry overrides other entries as required.

An entry may be automatically changed if any of the following conditions apply, in which case the closest possible value will be selected:

It falls outside the allowable range.

It is rounded to .01 millisecond increments (MP36R resolution).

Width has been limited by the **Pulse Width: Limit Entry** settings of Preferences.

Allow any entry

Pulse width is limited to the output capabilities of the BIOPAC MP36R unit. This option allows any entry within the allowable range specified below:

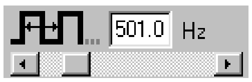
PULSE WIDTH RANGE MP36R hardware

Range	.050 – 100 milliseconds
Resolution	10 microseconds

Lock entry to

This entry locks the width to a single, specified value (within the allowable range). No other value can be entered.

Pulse Repetition



Indicates the Pulse Repetition period (Hz or ms).

The **Pulse period** must be greater than the **Pulse width**. See "TBPMIN" in the Output Preference > Advanced Tab Limits table on the next page.

The full range of acceptable Pulse Rate values is from **.2** to **6,667 Hz (MP36R).**

The <u>maximum</u> Pulse rate (PRPMAX) depends on the Pulse width setting:

Pulse width 100 ms → maximum Pulse rate = **9 Hz**

Pulse width .020 ms → maximum Pulse rate = **3333 Hz**

The formula for pulse width vs. pulse repetition is *PRPMIN = PW + TBPMIN*

Where: PRPMIN = the MINimum Pulse Repetition Period allowed.
PW = Pulse Width setting
TBPMIN = MINinum Time (in ms) between successive pulses for the output device (see device specifications)

If "Limit changes from ___ to ____" is selected in Advanced preferences, then PRPMAX will be determined by the formula above or the specified limit, whichever is greater.

An entry may be automatically changed:

- If it falls outside the allowable range.
- To round it to .01 Hz increments (resolution of system).
- To make it at least 0.1 millisecond greater than the Pulse width.
- By the Pulse Repetition Rate: Limit entry Preference.
- By the Pulse Repetition: Adjust entry increments Preference.

Any pulse width value can be manually entered, but when using the scroll bar or arrows, entries will be constrained by the "Adjust entry increments" Preference setting.

Pulse Repetition Scroll Bar

The Pulse Repetition **Scroll Bar** adjusts rate or period by the increment of change and limits established in Preferences. With each click of the scroll bar arrows, the rate will be increase by the specified increment.

When "Initiate pulse sequence with **ON/OFF button in Control Panel"** is selected, changes take effect upon release of the scroll box as long as the stimulator is running.

The scroll bar is disabled when Number of Pulses is set to "Single" or Pulse Repetition is set to Lock Entry to..."

Display as

Pulse repetition can be displayed as

Pulse Rate (expressed in Hz), or

Pulse Period (inverse of Pulse Rate, expressed in milliseconds).

Pulse Repetition Rate relates to the Pulse Repetition Period as:

Pulse Rate (Hz) = 1000 / Pulse Period (milliseconds)

	The "Display as" **units** selection is also used for: Pulse repetition entries in the control panel. Scroll bar increments. The Pulse Repetition Rate: Limit entry Preference. The Pulse Repetition: Lock entry Preference. The Pulse Repetition: Adjust entry increments Preference. When units are changed from Rate in Hertz (Hz) or Period in milliseconds (ms), the limits of the Pulse Repetition range will be converted by the formula: Period increment in ms = Round to nearest whole number [Period Range * (Rate increment in Hz /Rate Range in Hz)] For example, if the Range was 1Hz to 10 Hz with an adjustment increment of 1Hz, the proportional calculation would be Period increment = 900 ms (1Hz / 9 Hz) = 100 ms
Allow any entry	Pulse width is limited to support the output capabilities of the BIOPAC output device. See Output Preference > Advanced Tab Limits table for allowable range.
Limit entry	Establishes minimum and maximum values that can be manually entered or changed with the scroll bar.
Lock entry	Locks the Repetition to a single, specified value (within the allowable range). No other value can be entered in the control panel.
Adjust entry	Controls the scroll bar or scroll arrow increment; does not apply to manual entry.

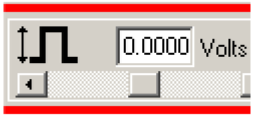
Advanced Tab Limits	Pulses		BSLSTM	
Pulse width				
Range (ms):	.050 – 100	.049 – 100	.050 – 100	.049 – 100
Resolution (ms):	.010	.001953	.010	.001953
Pulse Repetition				
Rate range (Hz):	.2 – 16,667	.2 – 10,204	.2 - 2,000	.2 – 2,004
Period range (ms):	.060 – 5,000	.098 - 5,000	.500 – 5,000	.499 – 5,000
TBPMIN Minimum time between Pulses (ms):	.010	.049	.450	.450
Resolution (ms):	.010	.001953	.010	.001953
Initial Pulse Delay				
Time range (ms):	0 – 100	0 or .5 - 100	0 – 100	0 or .5 - 100
Resolution (ms):	.010	.001953	.010	.001953

LEVEL TAB (OUTPUT PREFERENCES)

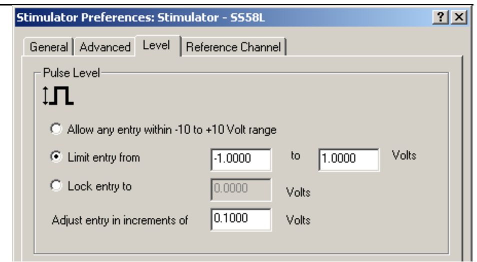
About Level	Low Voltage Stimulator and Human Stimulator-STMHUM allows the software to specify the pulse amplitude. The amplitude can be set to any value within the limits of the stimulator; the range is -10 to +10 Volts for the Low Voltage Stimulator and 0-+100 V for the Human Stimulator-STMHUM

Pulse Level

Low Voltage only



The **Level entry box** allows the user to manually enter any value within the limits of the system or within the limits of the Preference settings from the Level tab.

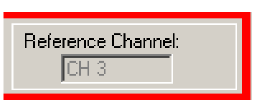


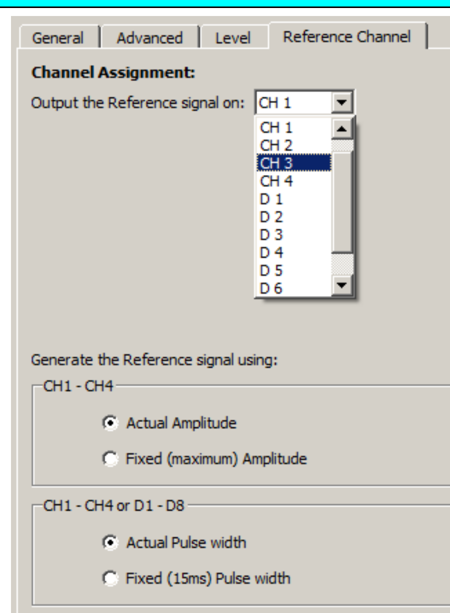
The Level entry box will be inactive (grayed) if:
The Level preference "Lock entry to" is active.
If "Initiate pulse sequence with Recording" is active (from the General tab) and a pulse sequence is in progress or "wait for trigger" is in progress.
Use the entry box or the scroll bar to set the Pulse level. When a value is entered which is out of range, the value will be rounded to the closest value obtainable after the "Enter" or "Tab" key is pressed.
If "Initiate pulse sequence with ON/OFF button in control panel" is active (from the General tab), then values entered during a pulse sequence will take place immediately.
If "Initiate pulse sequence with Recording" is active (from the General tab), any entry made between acquisitions will take place on the next "Start" of acquisition.

Allow any entry	The level is limited to the output capabilities of the stimulator. This option allows any entry within that range.
Limit entry	This entry reduces the range within the limits of the stimulator's output capabilities.
Lock entry	This entry locks the level to a single specified value.
Adjust entry	This setting affects the scroll bar or scroll arrow increment only; it does not apply to manual entry. The smallest increment is 5 mV, as limited by the MP36R. The specified increment is used to round manual entries to the closest obtainable value.

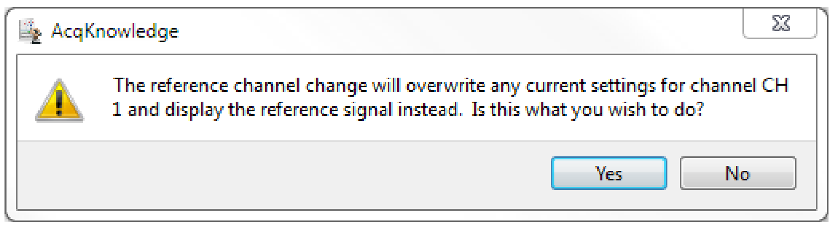
REFERENCE CHANNEL TAB (OUTPUT PREFERENCES)

Reference Channel





This option allows monitoring of the output signal on one of the analog or digital

	input channels without making any physical connections. This is an internal, hardware/firmware, feature that recreates the output signal and allows recording in “real time.” The assigned reference channel will override any “real” input signal. The reference signal is not the real signal, but is a very accurate “estimate” of the real signal. The pulse timing accuracy will be within 100 microseconds. If an analog input channel is used as the reference channel, the pulse level will be accurate within 5%. If the stimulation encounters a load that reduces or distorts the pulse output, the reference signal will not reflect this amplitude distortion. If a digital input channel is used as the reference channel, only a digital representation of the pulse will be generated; 0 to 5 volts.
Channel Assignment	Use the pull-down menu to choose which analog or digital input channel will be used as the output reference channel. When a new reference channel is assigned, a warning will be displayed indicating this setting will overwrite the existing Channel Setup parameters for the selected channel.  For example, if CH1 is set up for ECG data and then selected as the Reference Channel, the ECG parameters will be replaced. If another channel is then selected, CH1 will be reestablished with the default analog input parameters, and the ECG settings would need to be recreated via presets or manual entry. The reference Channel label should read: “(Selected Output) - Reference Out.” When an Analog Input Channel is assigned as the Reference channel, that channel (as viewed from MP36R > Set Up Data Acquisition > Channels) will be in a locked mode and the Preset pull-down menu will be disabled. The assigned reference channel will be inactive for “real” inputs until the Reference Channel Preference is changed to “None” or another channel. Once the control panel with an assigned Reference channel is closed, the data Acquisition Settings > Channels will automatically update to the default settings.
Generate using	Specifies how the Reference signal should be shown. If using **analog** input from CH1 - CH4, the selectable options are actual or fixed (max) amplitude and actual pulse or fixed pulse width. Fixed pulse widths are useful when the pulse width is much smaller than the sample interval (1/sample rate) is used. For example, Frog muscle stimulation uses a 1 ms pulse width and a sample rate of 2000 samples/second to capture the muscle response. At this sample rate, the stimulus pulse cannot be reliably recorded. By using the fixed width of 15 ms, the pulse should be recorded. If using **digital** input from D1 - D8, select actual or fixed (15ms) pulse width.

Usage Guidelines & Setup Summary for BSLSTM Output Control

HUMAN SUBJECT SAFETY

- Before using the stimulator on human subjects, it is very important to limit the energy the stimulator outputs. For optimal safety:
- Before powering on the BSLSTM stimulator, set the voltage level to zero by rotating the LEVEL knob on the front of the BSLSTM fully counterclockwise.
- Use BIOPAC HSTM Series Probes. These probes MUST be used in order to limit the energy the stimulator can output.
- Never create an electrical path across the heart.
- Never use on subjects with pacemakers.
- Read this manual and the BSL Hardware Guide to become familiar with Stimulator operation.

1. Connect the BSLSTM Stimulator to the MP36R and power on both units. (For instructions on how to connect the BSLSTM to the MP36R Acquisition Unit, refer to the *BSL or MP Hardware Guides*.)
2. Connect the Stimulator Trigger cable to the Analog Out port of the back of the MP36R hardware.
3. Connect the Stimulator Reference Output cable to an Input Channel on the front of the MP36R hardware. This channel will be set up in Step 8 below as the Stimulator Reference Channel.
4. The **Reference pulse** has a fixed Pulse width of 15 milliseconds, so chosen so that the Sample Rate of the recording may be as low as 100 samples/second and still capture the Reference pulse.
5. Before powering on the BSLSTM stimulator, set the voltage level to zero by rotating the LEVEL knob on the front of the BSLSTM counterclockwise all the way to the left.
6. Open a new data acquisition graph.
7. Confirm that **Events** are activated. Events are activated by default. If not activated for a given recording, choose **Display > Show > Events**.
8. Set up the **Stimulator Reference Channel**. This is the Analog Input Channel on the front of the MP36R that receives the Stimulator Reference Output cable from the back of the BSLSTM. Remember, the reference channel is generated from the stimulator and not the software.
9. Choose MP36R > Set Up Data Acquisition > Channels. This will generate a Set up Channels dialog.
10. Select the **Acquire**, **Plot** and **Enable** options for the analog channel to use as the Stimulator Reference Channel.
11. Click **Presets** and scroll to select “Stimulator (0-10V)” or “Stimulator (0-100V)” to match the Range switch setting on front of the BSLSTM.
12. Click **Setup** to view or change the analog channel parameters. Review the BSLSTM Stimulator section (page 224) and Analog Channel Setup section (page 138) before modifying channel/preset parameters.
13. Set the Gain and other input parameters as desired.
14. Click OK to accept the parameters.
15. Close the Set up Channels window.
16. Adjust the voltage output of the stimulator by using the **Level** control on the front of the BSLSTM.
17. Rotate the **Level** knob clockwise to increase and counterclockwise to decrease, reading the voltage in the BSLSTM’s digital display.

Stimulator Safety Features

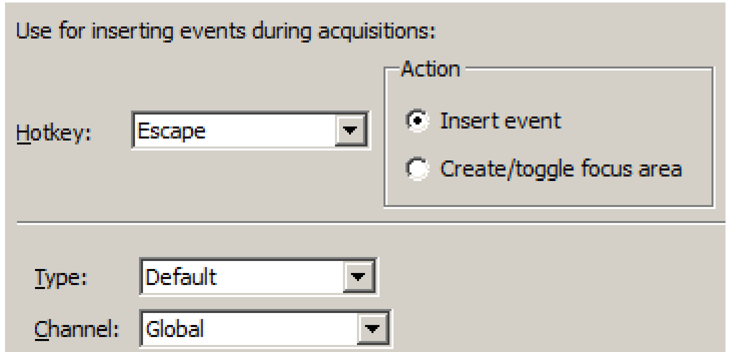
The stimulator cannot operate unless its Output Control panel is open.

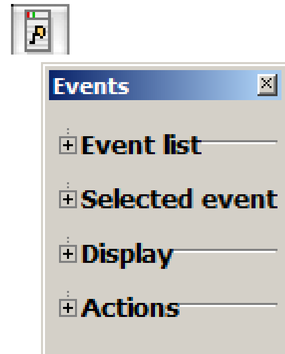
The Pulse ON/OFF Switch on the Stimulator Output Control panel must be OFF in order to open and configure Stimulator Preferences.

If the Stimulator Output Control panel (or the Acq*Knowledge* application) is closed in the middle of a pulse train while the stimulator is running, the stimulator will shut down and the pulses will stop.
If another data acquisition window is activated, the stimulator will stop and remain OFF unless restarted using the parameters associated with the new data window. The only exception is that if the stimulator is ON and the data window corresponding to current stimulator parameters is acquiring data, then the stimulator will continue to run until the end of the acquisition.

Chapter 11 Set Up Event Marking

Events (Markers)





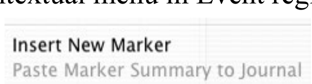
Event Toolbar Event Insertion Event Control

Event (Marker) Overview

For detailed analysis, it can be useful for waveforms to have extra information associated with them. This information might include waveform boundaries from ECG analyzers, spike classifications from a spike sorter, heartbeat classifications, or even detailed user notes. Acq*Knowledge* 4 uses "event" functionality to store and manage this information.

An event is a piece of information associated with a specific time in a waveform. An event can capture points of interest within a file (i.e. subject moved, dose added) or on a particular channel (i.e. T-wave onset). Once events are marked in the file, Acq*Knowledge* can use the event information for analysis, including measurement (page 263) and cycle detection (page 374).

- An event has the following pieces of information associated with it:
  - Event type
  - Sample location: the time position in hardware samples where the event is defined.
  - Channel: the channel for which the event is relevant.
    - Some events, such as the time of the start of an appended segment, may be relevant to all of the channels of a graph—these are "Global" events.
  - Label: a string of text that can be entered either automatically or by the user to provide more information about an event. Labels can be fixed or sequential in order.
- Different event types can be entered automatically or manually. These different event types allow events to be filtered and also support analysis routines that key off of these events.
    - Event insertion tool
    - Set up Event Marking (see page 250) to manually insert events during acquisitions
    - Copy/paste measurements and Copy/paste wave data operations can insert events at the selection boundaries; choose "Mark with events" under Preferences (see page 248)
    - Cycle Detector Output Events option (see page 374)
    - Contextual menu in Event region

    - Specialized Analysis (see page 403) to automatically insert events according to complex analysis algorithms

Event Toolbar

The event toolbar displays the visible events in the graph and provides a quick editing area for event descriptions. The right button toggles visibility of the Event Palette for detailed control (see page 251). The palette will "refresh" when events change the event configuration, such as horizontal scrolling, scale changes, changes in the selected event via clicking in the graph window, editing of the event label by using the event bar, transformations that define new events for the graph, waveform editing operations, and additions of new events by clicking the event bar at the top of the graph window. The right/left arrow buttons are for navigating through events. If events are placed in the waveform, the arrow navigation will locate events in the selected channel only.

Event Tooltips

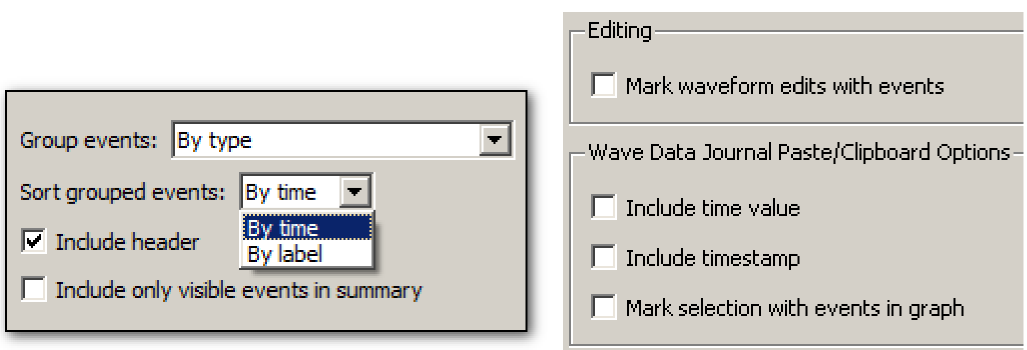
If events are being displayed within the plotting area and tooltips are enabled, a tooltip will be associated with every event in the plotting area. The tooltip includes the event type description, the user-defined label (if present), the time location of the event, and the amplitude of the waveform at the event location. While this information can be drawn directly on the graph, event tooltips assist in browsing event information when the screen becomes too crowded and there is not enough room to display all of the times, amplitudes, and labels.

Event tooltips are displayed under the event icon.

- If the event is being plotted directly on the waveform, this will be the point on the waveform associated with the event.
- If there is an indicator and the event icon is at the top of the indicator, the tooltip will be anchored at the top of the indicator.
- If the events are being plotted at the top of each track, the tooltip is anchored at the top of the plotting area directly underneath the event icon.

Event tooltips will not be displayed if tooltips are disabled, if events are only being displayed in the events bar at the top of the screen, if X/Y mode is in use, or if events are not currently visible.

Preferences for Events



Preferences > Event Summary and Waveform

Use the "Event Summary" section of the Preferences dialog to set options for pasting summaries of events into the journal.

- Group events

Sorted by type	sorted by event type descriptions first
Sorted by channel	grouped based upon where they are defined (Global events appear first, followed by groups for each individual channel).

- Sort Grouped events

Sorted by time	sorted in order by increasing time
Sorted by label	sorted alphabetically by label

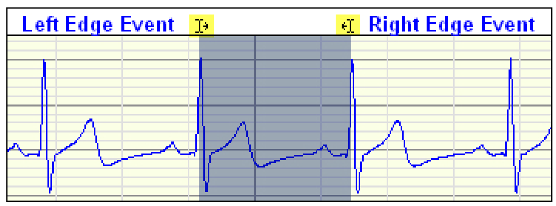
- Include only events visible on the screen

  Determine if the summary is generated for all of the events that are in a graph, or only for those events that are currently visible on the screen. If there are thousands of events in a file, this feature allows the list to be pared down to those of interest.

Event summary options will be saved with the graph if the graph has a graph journal, and can be pasted into the journal using "Summary in Journal" Event Palette Actions command (see page 255).

Other event preferences are available under Preferences > Waveforms

- **Mark waveform edits with events**
- **Mark selection with events in graph**—enabling this preference automatically brackets the edges of selected data areas with "selection begin" and "selection end" events when measurements or waveform data are pasted to the Journal. (This option is also available under Preferences > Measurements.)



"Selection Begin" and "Selection End" events

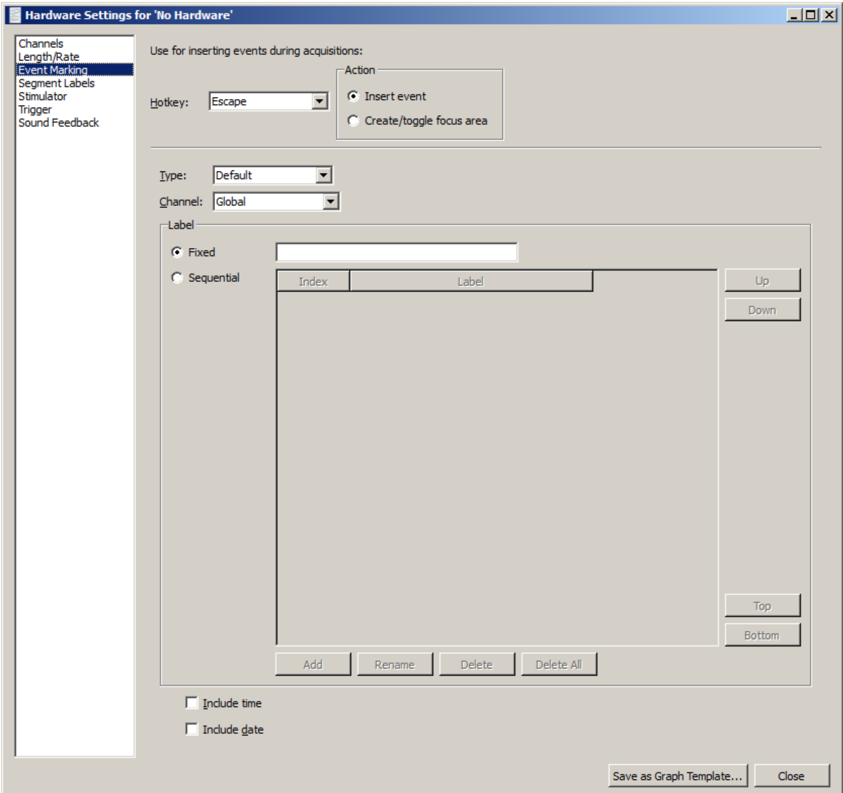
"Selection begin" and "selection end" events may also be applied manually by selecting an area of data and choosing the "Mark Selection" button in the Selection Palette.

- **Include time value**— include the time value (relative to start = 0) for the paste.
- **Include timestamp**—Include time and date stamps for when the paste occurred; this timestamp will match any timestamp pasted into the journal. When selected, any selection events added to the graph will have their labels set to match the timestamp.
- **Auto-paste results in independent journal** (Preferences > Journal)—Selection events and time stamp events can be automatically inserted to an independent Journal.

Combine these options to retain enough information to reproduce measurement results and correlate measurement results with specific areas of the graph; this helps verify the accuracy of measurement results made through manually constructed graph selections.

Any change to these settings will be retained within a saved graph file and will become the default for newly constructed graphs.

Event Marking Setup Options



Events of different types can be inserted during acquisition, regardless of whether events are visible in the graph. When a *hotkey* is pressed during acquisition, an event will be inserted into the graph at the end of the most recently acquired data. Each hotkey can have a different configuration, adjustable through a dialog accessible via the “Hardware > Set Up Data Acquisition > Event Marking...” menu item.

Hotkey — Assign Escape or F1 through F9. When a different hotkey is chosen, the other controls of the dialog change to reflect the configuration of the new hotkey.

Action — Choose whether the Hotkey assignment creates an event or a focus area.

Event type — Lists the standard hierarchical menu of available event types; Types are detailed on page 256. Choosing a new type from the pull-down menu will change the type of event inserted when the hotkey is pressed during acquisitions.

Channel — Contains a “Global” entry and all of the channels (analog, digital, or calculation) set to “Acquire” in Set Up Channels.

- “Global” will define global events drawn in the event bar above the graph data
- Choosing a new channel from this menu will cause events to be inserted on the appropriate channel of the graph when the hotkey is pressed.

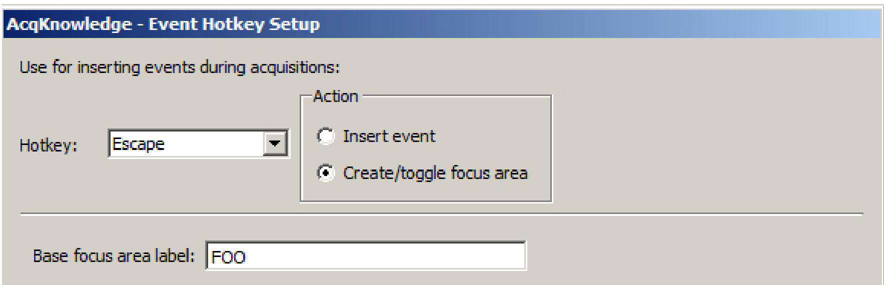
Label — Edit field for label text and toggle optional inclusion of time stamp and/or date stamp. Stamps correspond to the time of the system clock when the key was pressed, that is, the time of the event insertion in “real clock time.”

- Fixed - Provides a fixed label from text entered into the label field to the right. This label is used every time the assigned hotkey is pressed.
- Sequential - Labels for events will iterate sequentially through the entries in the table index when the assigned hotkey(s) is pressed. The area under ‘Label’ is editable for entering text.

Additional Hotkey Setup Controls	Function
Add	Adds an editable label field to the list.
Rename	Allows renaming of the existing segment label.
Delete	Deletes a selected custom label.
Delete All	Deletes all custom labels.
Up	Incrementally moves a selected label up the list.
Down	Incrementally moves a label down the list.
Top	Moves a selected label to the top of the list.
Bottom	Moves a selected label to the bottom of the list.
Include time	Adds timestamp to labels when checked
Include date	Adds current date to labels when checked

Create/Toggle Focus Area Action

Selecting the ‘Create/Toggle Focus Area’ action presents a similar setup dialog, but dictates that hotkeys setups will be assigned to defining Focus Areas instead of inserting events.



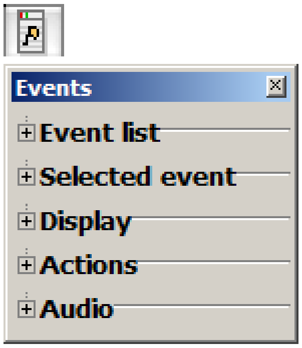
When this option is chosen, pressing an associated hotkey during a recording will initiate a focus area in the graph. Toggling the same hotkey will conclude the focus area. The focus area will appear highlighted and outlined in the graph following the second (termination) keystroke. As with events, multiple hotkeys and labels can be assigned.

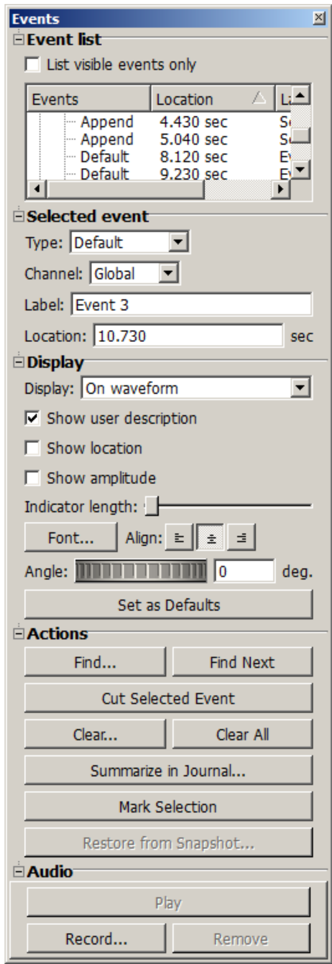
Example for setting up a Focus Area Hotkey:

1. Choose the desired hotkey from the Hotkey list.
2. Under Action, select ‘Create/toggle focus area.’
3. Assign the focus area a label by typing it into the ‘Base focus area label’ field.
4. If additional focus area hotkey assignments are desired, choose another hotkey from the list, and repeat steps 2 and 3.
5. When focus area hotkey assignments are completed, click OK.

- If the same hotkey combination is repeated to create subsequent focus areas, the base focus area label will remain the same but with incrementing numbers appended to the title.
- If a different hotkey combination is used for subsequent focus areas, unique base focus area names will be used as assigned.
- Starting a focus area assigned to one hotkey and then starting another focus area assigned to a different hotkey will terminate the original focus area and start a new one.
- Focus areas can be created and toggled while a recording is in progress.
- Focus areas can be shown/hidden by choosing the Show/Hide toolbar function (right) and checking or unchecking the “Focus Areas” option. 

Event Palette



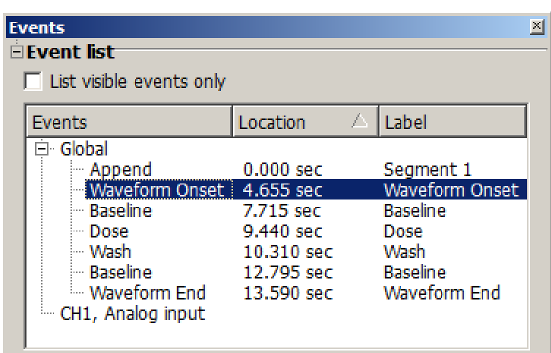


The event palette is a floating window that provides a quick summary of events for the top most graph and can used to examine, search, and modify events. Events can be extracted in a time range for a specific event type and specific channels.

There is only one visible event palette for the entire application. The palette consists of four sections: event list, selected event, display, and event actions. Each section can be shown or hidden by toggling the disclosure button next to its title.

- ➲ Event List, see page 252.
- ➲ Selected event, see page 253.
- ➲ Display, see page 253
- ➲ Actions, see page 255.
    - o See the Event Journal Summary enhancements.

Event List



The event list provides an expandable, scrollable, hierarchical view of the events in the topmost graph. Events are grouped by their channel on the top level.

The event list has three columns of information:

- Events: the readable type for each event
- Location (Time): the time location for each event
- Label: the user defined description for the event.

Sort the contents in ascending or descending order on each column by clicking the column header. Events and Description will sort in standard alphabetical order, Location will sort based on the horizontal axis location of each event.

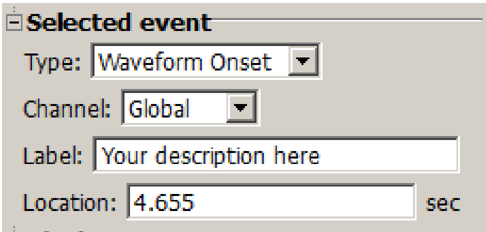
Select a single event from the event list by clicking on a single event. The event will be selected in the graph window and made visible if it is not currently displayed.

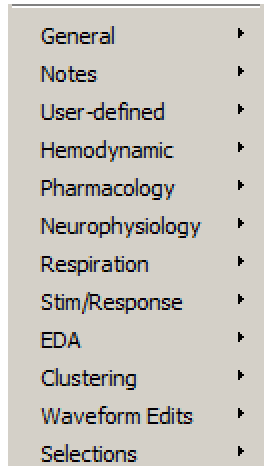
List visible events only toggles the checkbox to switch between the two display modes.

- When enabled, the event list will display only those events that are being displayed on the plotted portions of the graph. As the user navigates through the graph with the scrollbars, horizontal scale, or other means of changing the amount of visible data, the event list will continually refresh to contain the new set of visible events.

- When disabled, the event list will display all of the events for the entire graph. This can allow for easier navigation through graphs with hundreds of events, such as PhysioBank files.

Selected Event





Event type options are detailed on page 256.

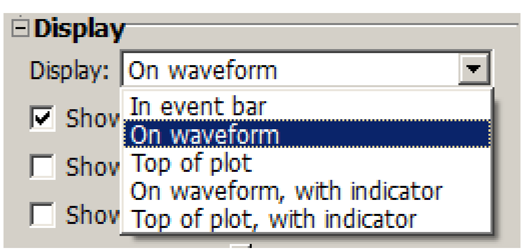
When a single event is selected, the type, channel (or "General" for global events), user-defined label, and location of the event will be filled in and can be edited. The controls can display information about only one event at a time; if no event is selected, the controls will be grayed out.

Event Location

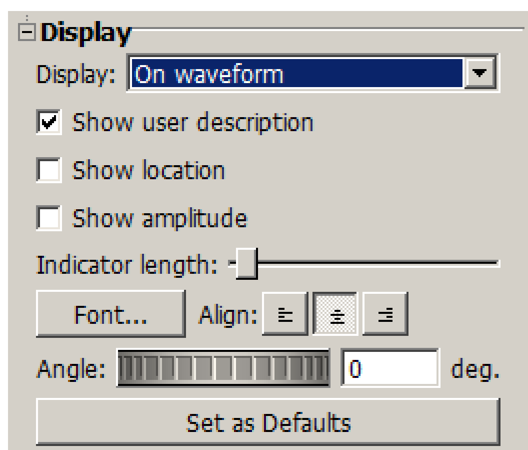
"Location defines the position where the selected event occurs, relative to the first sample in the file. To change the location of an event, change the position entered in the Location box. Precision matches the horizontal axis setting.

Events (with the exception of Append events) may be repositioned if desired. Alt-click (Windows) or Option+click (Mac) over the event icon and hold down the mouse button. Then simply drag the event to the desired location on the event bar and release the mouse button.

Display



Event display location

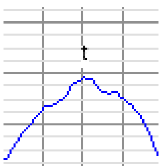
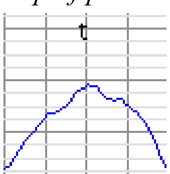
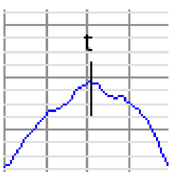
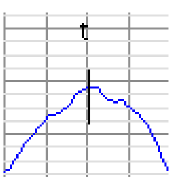


Event display detail

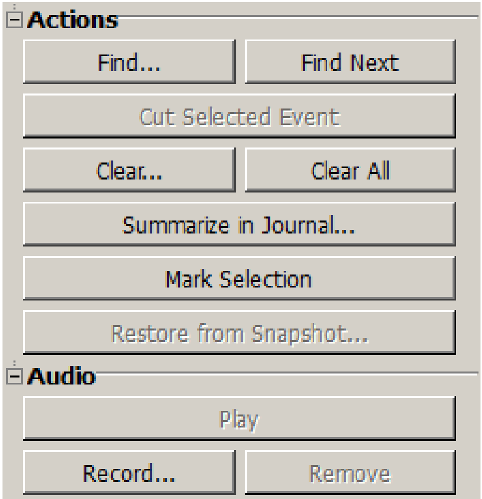
Display controls determine the location and detail of events to be drawn in the frontmost graph.

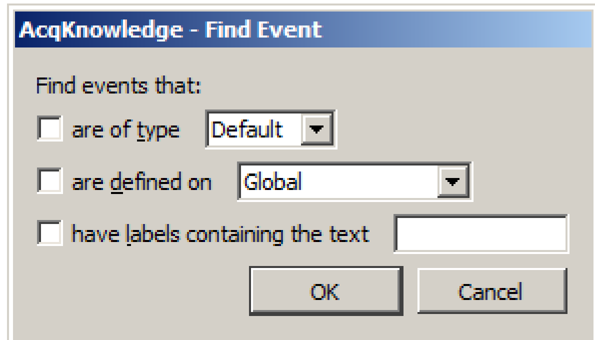
- Location—Choose one of the five display methods (described on page 254).
- Detail—the three checkboxes to establish how much information to include with events.
- Indicator length—Set the slider to shorten or lengthen the indicator line. This option is only active if the display mode is "On waveform, with indicator" or "At top, with indicator."
- Font – Align – Selects font style and alignment of Event labels.

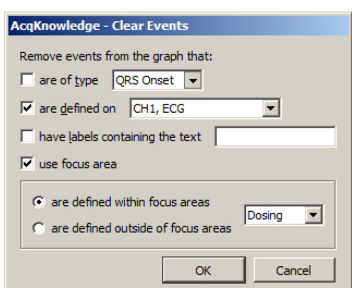
- Angle – Determines the angle in degrees that the Event text can be displayed in the graph. Value can be positive or negative.
- Set as Defaults – Saves any modified event palette settings as the default for newly inserted events and subsequent graphs. Applying this option has no effect on previously existing events.

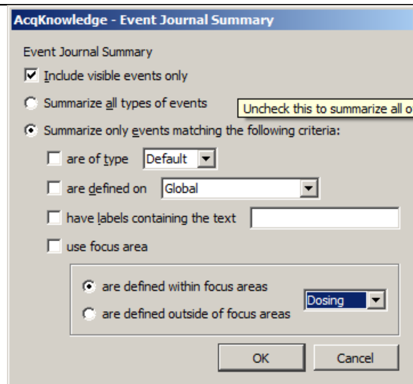
Location & Display	Description
In event bar 	Event icons are displayed in the global events bar located on top of the plot area in the graph window. This does not allow for distinguishing what channel a specific event belongs to. ▪ To select the event, click the icon in the events bar.
On waveform 	Event icons are displayed above or below the actual sample in the source channel corresponding to the location of the event. ▪ To select the event, click the event icon on top of the waveform.
Top of plot 	Event icons are displayed at the top of the channel track, either on top of the grid or in a channel-specific events bar. ▪ To select the event, click the icon at the top of the channel track.
On waveform, with indicators 	Event icons are displayed above the data with a vertical line of configurable length running through the data sample of the source channel at the event's location. ▪ To select the event, click the event icon or the indicator line.
Top of plot, with indicators 	Event icons are displayed at the top of the channel track with a vertical line of configurable length running through the data sample of the source channel at the event's location. ▪ To select the event, click the event icon or the indicator line.
Detail	When an event is being plotted within a graph, either on the top of a channel or floating above the data, the event's location, description, and amplitude of the waveform at that location can optionally be displayed along with the event icon. Plotting of additional information can be used for graphical annotations on the data and for clarifying event location for hardcopy or presentation.

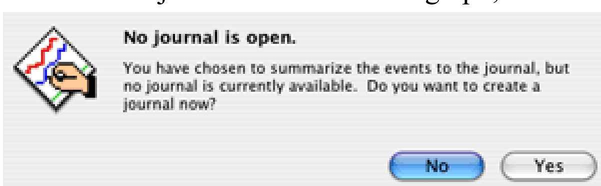
Actions

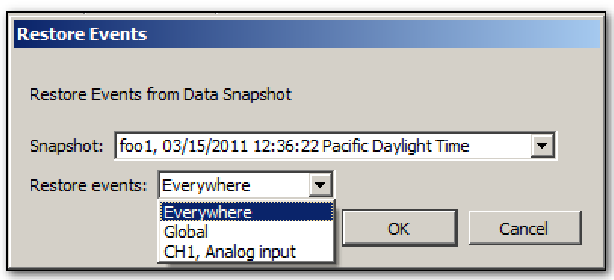




Actions Button	*Description*
Find	It is easy to create many more events then one can easily scroll through and locate in a list. Find controls the automatic location of events based on established search criteria. Click the Find button to generate the Event search criteria dialog, and then combine or restrict information to define desired events: event type, specific channel location, or label search. Click “Find First” to search for the first event in the graph that matches the criteria. If found, the event will be selected and made visible in the graph window.
Find Next	Finds the next single event that matches the established search criteria until no remaining events match the search criteria.
Cut Selected Event	Active only when an event is selected, removes the selected event from the graph.
Clear *Clear all*	Generates a search criteria dialog (similar to the Find dialog) and removes all matching events from the graph. There is also an option to clear events defined within a focus area without affecting the remaining events, or to clear events defined outside of a focus area while leaving events within the focus area intact. 
Summarize in Journal	Displays a dialog with controls that affect which events are included in the summary. Events can be filtered by visibility on the screen. Creates a textual summary of all of the events in the journal. ▪ See “Event Preferences” on page 248 for more information about modifications to the traditional events summary.

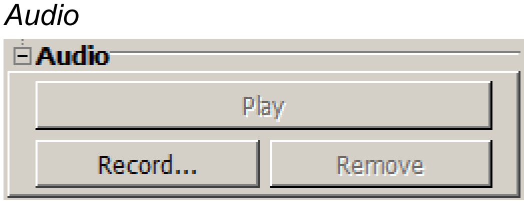
<table>
<tr>
<td>Event Journal Summary Enhancements</td>
<td>


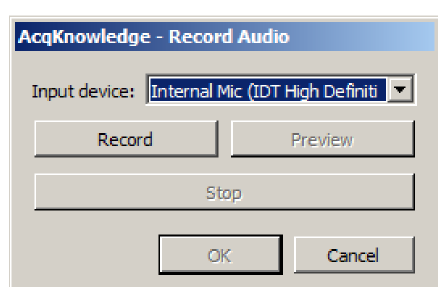
Events to be included in the summary can be filtered using the same criteria as Find... in the Event Palette. By adding the ability to summarize only events matching specific criteria, textual reports of arrhythmias or other infrequently occurring events of interest can be generated with ease. Events defined within or outside of focus areas can also be included or excluded from the summary.
When “Summarize in Journal” is clicked on the event palette, a dialog will be displayed with controls that affect which events are included in the summary.
If there is no journal for the current graph, the following prompt will appear.


</td>
</tr>
<tr>
<td>Mark Selection</td>
<td>Defines two new Global events in the graph at the precise time locations of the currently selected area (the highlighted wave data section). If there is no selection in the graph, this button has no effect. The events that are inserted will have the “Selection Begin” and “Selection End” event types.</td>
</tr>
<tr>
<td>Restore from Snapshot</td>
<td>


Enables deleted events to be restored from events present in a Data Snapshot. This option becomes active only if a Data Snapshot of the main graph is displayed. The following prompt will be displayed when Restore from Snapshot is selected. For information on Data Snapshots, see page 54.
</td>
</tr>
</table>

Audio



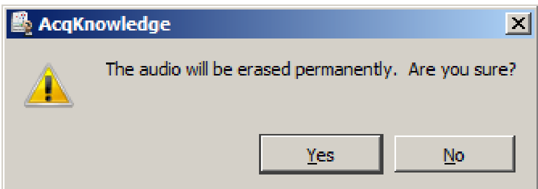


This option allows audio (such as verbal observations) to be recorded and linked to selected events in the event list. The controls are very simple to use, and the audio is recorded via computer microphone or selected audio capture device.

To set up a recording, select an event in the Event list and click “Record.” This opens the “Record Audio” setup dialog (see right).

Record Audio buttons	*Description*
Input device:	Select the onboard audio capture device to be used for the recording. Use the default or select another from the list of supported devices.
Record	Click to start the recording.
Stop	Click to end the recording.
Preview	Listen to the recording before linking it to an event. If recording is acceptable, click OK. To repeat recording, click Record again.

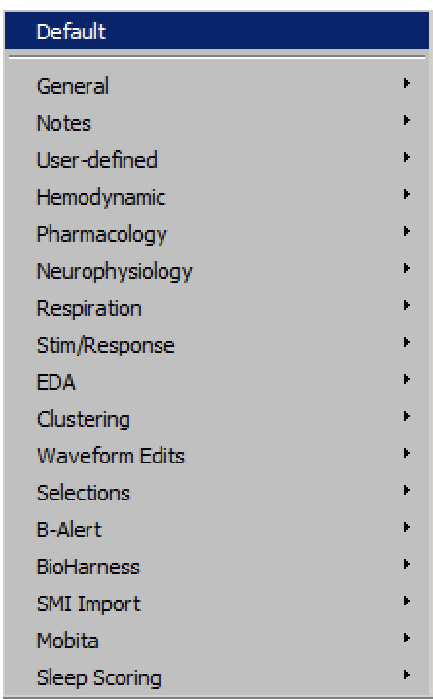
Once a recording is accepted, it can be played back by clicking "Play" in the Audio controls or by selecting the audio-linked event in the Event list. Selecting the linked event in the graph's event bar will also play the recording. Recordings can be erased by clicking the "Remove" button. One a recording is removed, it cannot be recalled.



Event Type Options

Event Types are pre-defined options for assigning event information. The Event Type is for marking purposes only and does not imply any analysis has or will occur for the event (unless Specialized Analysis was performed, see page 403).

Once Event Types are defined, some analysis functions can be automated, including measurement (page 263) and cycle detection (page 374).

Event classifications: 	*Event classifications* group similar event types together into a logical category. Event classifications present event types in a hierarchical fashion and allow other event classifications to be contained within them. For example, the "Hemodynamic" event classification includes a "Beats" sub-class with pre-ventricular contraction and escape beat event types.
Event type	Classification
Global	This is the same as 'untyped' markers from Acq*Knowledge* 3.6 or earlier. Unrecognized event types will be classified as global events.

Append	Automatically inserted by the program on append operations. Custom Append labels can be created in Hardware > Set Up Segment Labels. (See page 274.)
Notes	Annotation event to add notes on the data.
User-defined	Hotkey insertion for user-specific events; 9 types can be inserted via the keyboard during acquisition.
Pharmacology	Basic pharmacological events: baseline, washing, and dosing.
Waveform Edits	Automatically inserted by the program on cut or paste operations in a graph file. The description consists of the edit operation performed and a timestamp. Insertion of waveform edit events is off by default, but can be turned on for GLP purposes.
Selections	Used to mark boundaries of selected areas.

Classification	Pre-defined Event Type Options	
Default	"Esc" key inserts global event.	
General	Waveform onset or end Change in signal quality or rhythm Stimulator begin/end Recovery	Maximum and minimum Reset Communication lost User Alarm Audio Note
Hemodynamic > Beats	Normal Paced Fusion of paced and normal contraction Unclassifiable contraction Left bundle branch block Right bundle branch block Bundle branch block Atrial premature Aberrated atrial premature	Nodal premature Supraventricular premature Premature ventricular R-on-T premature ventricular Fusion of ventricular and normal Atrial escape Nodal escape Supraventricular escape Ventricular escape
Hemodynamic > Blood Pressure	Systole Diastole	End Systolic pressure End Diastolic pressure
Hemodynamic > ECG Complexes	QRS onset, peak, and end T-wave onset, peak, and end P-wave onset, peak, and end Q-wave peak S-wave peak	U-wave peak PQ junction J-point ST segment change T-wave change
Hemodynamic > Impedance	A-point B-point C-point	O-point X-point Y-point
Hemodynamic > Monophasic AP	Plateau	Upstroke
Hemodynamic > Other	Start of ventricular flutter Ventricular flutter wave End of ventricular flutter	Pacemaker artifact Isolated QRS-like artifact Non-conducted P wave

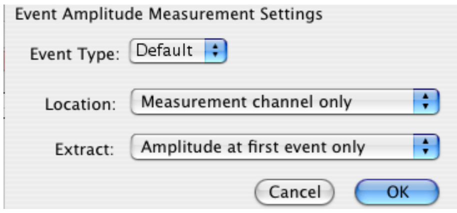
Notes	Arrow—short, medium, or long Flag	Star
Pharmacology	Baseline Dose	Wash
Neurophysiology	Spike Episode Begin	Spike Episode End
Respiration	Inspire Start Apnea Start	Inspire End
Stim/Response	Stimulus Delivery	Response
EDA	Skin Conductance Response	Specific SCR
Clustering	Cluster 1-9 End Cluster Training Set	Cluster n Outlier
User-defined	User Type 1-9	
Classification	Pre-defined Event Type Options	
Waveform Edits	Cut Paste begin	Paste end
Selections	Selection begin	Selection end
B-Alert	Start of Eye Blink Artifact Start of Excursion Artifact Start of Saturation Artifact Start of Spike Artifact Start of EMG Artifact Workload – EMG Start Workload – Invalid PSD Start Dummy Data Start Misaligned Data	End of Eye Blink Artifact End of Excursion Artifact End of Saturation Artifact End of Spike Artifact End of EMG Artifact Workload – EMG End Workload – Invalid PSD End Dummy Data End
BioHarness	Button Pressed	
SMI Import	Left eye hit object SMI stimulus image has been presented to the subject	Right eye hit object
Sleep Scoring	Wake Onset REM Onset Sleep Stage 1 Onset Sleep Stage 2 Onset Sleep Stage 3 Onset Sleep Stage 4 Onset Unscored Onset Sleep Spindle Onset	Wake End REM End Sleep Stage 1 End Sleep Stage 2 End Sleep Stage 3 End Sleep Stage 4 Ebd Unscored End Sleep Spindle End

Event Measurements

Measurements are a quick way to extract information from a graph. Three measurements extract information from events. When combined with the Cycle/Peak Detector (page 374), they are also powerful data reduction tools. These event measurements can provide quick summaries of event information, compute mean intervals between event types, and detail other operations.

- evt_ampl Event Amplitude Measurement (see below)
- evt_count Event Count Measurement (see page 261)
- evt_loc Event Location Measurement (see page 261)

Event Amplitude Measurement



evt_amp – Extracts measurement results where events are defined. Note that the amplitude is always taken from the measurement channel, which may be different from the channel on which the events are defined. Useful for extracting information such as the average T wave height within the selected interval. The measurement result is displayed without units (matching Value and other amplitude events).

Select Event Amplitude or click the measurement info button to generate the settings dialog.

Event Type Determines the type of events that will be processed; Types are detailed on page 256.

Location Determines where the processed events need to be defined. The menu options are:

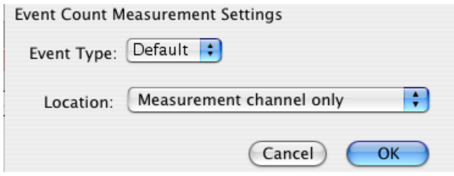
- Measurement channel only—Only extracts amplitude values for events that are defined on the channel specified in the measurement channel pull-down menu. Global events and other channel events are *not* included.
- Global events only—Only extracts amplitude values for events that are defined as global events appearing in the events bar; changing the measurement channel will not affect the measurement result. Channel events are *not* included.
- Anywhere—Extracts amplitude values for events defined on any channel and also global events; changing the measurement channel will not affect the result

Extract Determines what processing will be performed on the amplitude values extracted from events that match the Type and Location settings. The processing options are:

- Amplitude at first event only—The value of the measurement channel at the time of the first matching event in the selected area.
- Amplitude at last event only—The value of the measurement channel at the time of the final matching event in the selected area.
- Sum of amplitudes at all events—Computes the sum of the value of the measurement channel from each matching event within the selected area.
- Mean amplitude from all events—Computes the average amplitude value of the measurement channel from all of the event locations within the selected area.
- Minimum amplitude from all event —Computes the minimum amplitude value of the measurement channel from all of the event locations within the selected area.
- Maximum amplitude from all events—Computes the maximum amplitude value of the measurement channel from all of the event locations within the selected area.
- Median value of amplitude from all events—Computes the median of the set of measurement channel amplitudes at all events.
- Peak to peak interval of the set of amplitudes from all events—Takes the peak-to-peak difference from the set of measurement amplitudes at all events (max - min).
- Standard deviation of amplitudes from all events—Computes the standard deviation of the set of measurement channel amplitudes at all events.

If there are no matching events of the selected type in the selection, the measurement result will be zero.

Event Count Measurement



evt_count – evaluates the number of events within the selected area. The measurement result is unitless.

Select Event Count or click the measurement info button to generate the settings dialog.

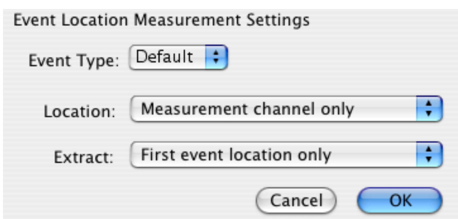
Event Type Determines the type of events that will be counted; Types are detailed on page 256.

Location Determines where the counted events need to be defined: the pull-down menu options are:

- Measurement channel only—Only includes events that are defined on the channel specified in the measurement channel pull-down menu; global events and other channel events are *not* included.
- Global events only—Only includes events that are defined as global events appearing in the events bar; channel events are *not* included. Changing the measurement channel will not affect the measurement result.
- Anywhere—Includes events defined on any channel and also global events. Changing the measurement channel will not affect the measurement result.

If there are no matching events of the selected type in the selection, the measurement result will be zero.

Event Location Measurement



evt_loc – extracts information about the times of events. The measurement result will take on the units of the horizontal axis; if specific units were set for time or frequency via Preferences, those units will be used.

Select Event Location or click the measurement info button to generate the settings dialog.

Event Type Determines the type of events that will be processed; Types are detailed on page 256.

Location Determines where the processed events need to be defined. The menu options are:

- Measurement channel only—Only extracts the time of events that are defined on the channel specified in the measurement channel pull-down menu; global events and other channel events are *not* included.
- Global events only—Only extracts the time of events that are defined as global events appearing in the events bar; channel events are *not* included. Changing the measurement channel will not affect the measurement result.
- Anywhere—Extracts the time of events defined on any channel and also global events. Changing the measurement channel will not affect the measurement result

Extract Determines what will be extracted from events that match the Type and Location settings:

- First event location only—The measurement will equal the time at which the first matching event in the selected area is defined.
- Last event location only—The measurement will equal the time at which the final event within the selected area is defined.
- Sum of all event locations—The times at which all matching events are defined are added together to produce the measurement result. This sum of times can be combined with Event Count measurements to compute average intervals over the selected area.

If there are no matching events of the selected type in the selection, the measurement result will be zero.

Printing Events

When a graph is printed and events are displayed onscreen for the graph, event icons will print as they are displayed. Event icons will be scaled, depending on the printer's DPI, to be proportional to the vertical scale plotted on the screen. If events are located at linearly interpolated positions, event icons will be dimmed on the printout (see the Variable Sample Rate section).

Event display setting	*Printed result*
	
Global events	Global events are drawn above and outside of the data plotting rectangle in the printout. If the event labels are close together, their alignment will be staggered to show separate lines of label text.
In event bar	All events are drawn above the data area of the printout. Only labels may be drawn with the events.
Top of plot *or* Top of plot, with indicator	Channel-specific events are drawn at the top edge of their channel’s track. No indicator lines are drawn. Depending on the display settings of the graph, the event label, amplitude of waveform at the event location, and Time of the event may be printed *below* the event icon
On waveform *or* On waveform, with indicator	Channel-specific events are drawn immediately above the position of the waveform sample at their location and will appear to be printed immediately above the data of the waveform. No indicator lines are drawn. The vertical printing position of an event icon will be identical for “On waveform” and “On waveform, with indicator” displays. Depending on the display settings of the graph, the event label, amplitude of the waveform at the event location, and time of the event may be printed *above* the event icon.

“Draw vertical divider at event locations” option in the Print Setup dialog.

- Enabled: draws a dashed vertical line at the precise time location of each event. Vertical divider lines for the event type will extend

Global	Through all channels of data
In event bar	Through all channels of data
Top of plot	From the top to the bottom of the relevant channel track
On waveform	From the top to the bottom of the relevant channel track

- Disabled: prints only the event icon, label, amplitude, and time. No indicator lines will be printed for the event display. The vertical divider can be used in place of indicator line drawing.

Events and Waveform Editing

Waveform editing will adjust event locations for channel-specific events. Waveform editing will never alter the time values for Global events (not associated with any specific channel, such as append events).

Copy When a portion of a waveform is copied the channel events will also be copied to the clipboard.

Cut When a portion of a waveform is cut, events within that selected area will be removed and channel events to the right of the removed area will be shifted to the left.

- If waveform editing event insertion is active, a waveform edit event will be inserted at the location of the edit operation indicating a “Cut” operation in its description.

Paste When the waveform is pasted from the clipboard, the channel events will appear at their same locations and any channel events to the right of the end of the pasted segment will be shifted by the length of the pasted segment.

- If waveform event insertion is active, a waveform event marker will be inserted at the beginning and at the end of the pasted segment.

Constructing Graph Selections from Events

Graph selections can be defined from events (in addition to the I-beam tool).

1. Click the first event to select it.
2. Hold down the Control key (Windows) or Command key (Mac) and click the second event. A selected area will be created in the data between the two events.

Event Plotting and Variable Sampling Rate

Event positions are defined in terms of the hardware sampling rate. The Variable Sampling Rate feature can generate waveforms with a sampling rate lower than the hardware sampling rate. Through explicit event definition, waveform downsampling, or other operations, events on a downsampled channel may not align with an actual waveform sample, but rather occur at a hardware sample position in between the waveform samples. These events will be drawn using linear interpolation when applicable, and only if the waveform is being drawn in line plot mode. In step plot and dot plot modes, regular event drawing routines are used, with the vertical position and amplitude of the nearest waveform sample to the event's left.

When an event is to be drawn on an intermediate position on a waveform, the linearly interpolated value is calculated for the hardware sample location. The interpolated value is derived from the closest waveform sample to the left and to the right. The vertical position on the waveform of the event and indicator line will match the vertical position of the linearly interpolated sample amplitude. This will place it immediately above the line connecting the two waveform samples on screen.

If an event is being drawn using linear interpolation

- Event icons will be dimmed, regardless of their display position (on waveform or top of the plot).
- Indicator lines will be drawn on the waveform at a linearly interpolated position and the indicator line will be a gray dashed line instead of a solid black line. (Indicator lines are never printed.)
- Amplitude labels, if included with the event, will correspond to the linearly interpolated amplitude at the event location and the linearly interpolated amplitude will be drawn in *italicized text*.

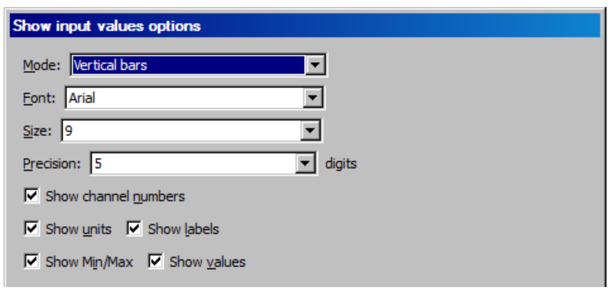
  Watch the Acq*Knowledge* Event Marking tutorial video for a detailed explanation of this feature.

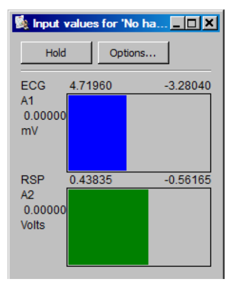
Chapter 12 Other Hardware Menu Commands

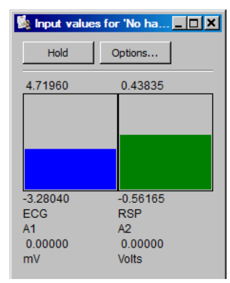
This chapter covers the following MP hardware menu items not appearing in other chapters:

Show Input Values	Display channel data values in real time in a color bar graph format.
Show Manual Control (MP160/150 only)	Monitor and/or output pulses through the digital input/output.
Show Gauge	Displays onscreen blood pressure gauge or stopwatch.
MP160/150 Info	Displays configuration and firmware information for the MP160 or MP150 hardware.
BioNomadix Logger options	Only applicable when BioNomadix Logger hardware is used. Contact BIOPAC for information about the Logger.
Autoplot – Scrolling – Sweep – Warn on Overwrite options	Data display options during acquisition.
Organize Channel Presets	Rename, delete, reorder or configure channel presets.
Set Up Linked Acquisitions	Record data simultaneously from multiple hardware devices.
Manage Hardware Connections	Connect, disconnect or switch supported hardware types.

Show Input Values







The Show Input Values option displays channel values in real time in an easy-to-read bar graph format. This allows values to be displayed prior to or following an acquisition.

The Input Values display can be set to numeric, horizontal or vertical bar graph format, and can be resized and moved to any position on the screen. To set the display mode, use the “Mode” menu generated via the “Options” button.

Note The Input Values window only displays values for channels that were Set Up with the “Values” box checked (see page 119 for more information).

Hold Regardless of the display options selected, the display can be “frozen” at any point in time by clicking the Hold button. Clicking this icon will hold the values at their level(s) when the icon was pressed. The window will remain frozen until the icon is clicked again. Once the values are “unfrozen,” the values will return to the standard real time display mode.

Options **Mode** controls the format of the values display.

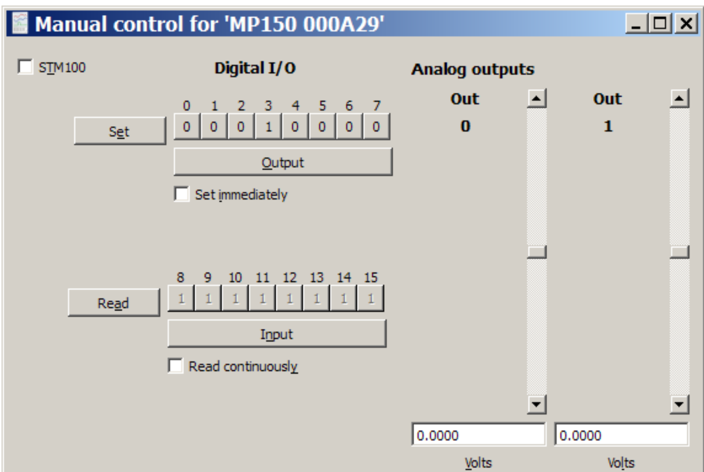
- Numeric Values—displays the voltages of the appropriate channels numerically.
- Bars: Horizontal bars or Vertical bars—the range of values of the bar graphs corresponds to the range for that channel in the graph window. To see the bar “bounce” less for a particular channel in the graph window, increase the units per division.
- **Font** and **Size** determine text display from fonts installed on the computer.

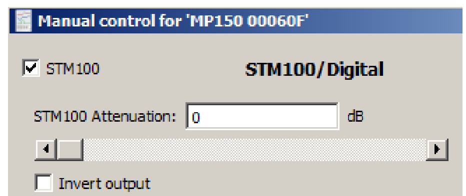
Precision controls *the total number of digits* displayed.

Show controls the amount and type of information displayed regarding each channel. Click the box next to each option to activate or deactivate it.

- **Channel Numbers** will display the channel numbers (A1 for the first analog channel, for example).
- **Units** will display the units for each channel (as indicated in the main graph window).
- **Labels** will display the channel labels (ECG 1, Respiration, etc.) along with the input values. This feature is especially useful when values from multiple channels are being displayed simultaneously.
- **Min/Max** will display the range of values associated with the data. This range corresponds to the upper and lower display limits for each channel as it appears in the graph window.
- **Values** will display number values along with the horizontal or vertical bar chart.

Manual Control (MP160 and MP150 only)





STM100 option

The Manual Control dialog allows the monitoring and/or outputting of pulses through the digital input/output (I/O) channels. The Manual Control is also used manually set the magnitude of the signal on either of the analog output channels. The digital outputs in Manual Control cannot be used to trigger an online Averaging acquisition.

Stimulator Usage Note

Use Manual Control to specify the stimulation output level

a. If the wide range of waveform output options available in the Stimulator Setup dialog cannot match the desired specifications.
b. For pre-stimulation and post-stimulation.

See page 209 for important Analog Output details.

The 16 digital channels are sectioned off into two blocks, with the first block consisting of I/O channels 0 through 7, and the second block consists of I/O 8 through 15.

- All the channels within a given block are programmed together and can be set as either inputs or outputs.
- The two blocks can be set independently.
  - For example, one block can be set to input data and the other to output data, or one block is inactive and the other block reads or outputs data.

To read incoming values for a given block of digital channels, click the Input button below the row of channels to have the input values displayed. This enables a block of digital channels to receive incoming data. To read the values for the entire block simultaneously, click the Read button to the left of the channel boxes for that block. Since these are digital channels, the values on the individual channel boxes will toggle between 0 and 1.

When Read Continuously is enabled (below the Input button), the values will be read in real time. When unchecked, the displayed values correspond to the values for that block of channels as of the last time the Read button was depressed. This mode provides much the same information as the Show Input Values mode.

To output values for a given channel, the block containing that channel must first be enabled to output data. To do this, click the bar below the channel boxes so the button reads “Output.” The individual channels within that block can then be reprogrammed. These channels will toggle between 0 and 1, with a 0 corresponding to zero Volts and a 1 corresponding to + 5 Volts. To output a digital 1 on I/O channel 3, the dialog would be setup as shown above.

The function buttons toggle as follows:

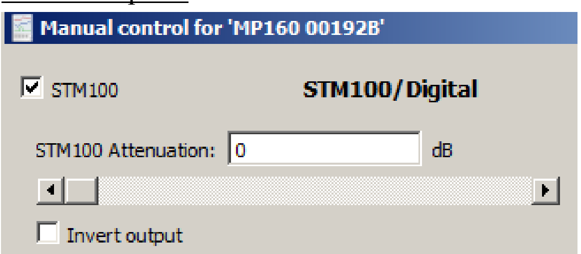
Input toggles to Output	When Input is selected, the checkbox is “Read continuously.”
Set toggles to Read	When Output is selected, the checkbox is “Set immediately.”

To output a signal on Channel 3, click the Set button to the left of the channel box. If the Set immediately box is checked, the signal will be output when the channel button is clicked.

IMPORTANT

Potential use conflicts can arise between the parameters set in the Manual Control window and those set for digital channels in the Set Up Channels window.

STM100 option



STM100 option

When the STM100C stimulator module is connected to an MP160 or MP150 System, the output level can be controlled via the STM100 option of the Manual Control dialog.

Attenuation	Attenuate the output signal by a given number of decibels (dB) for controlled stimulus applications. To output a signal with no attenuation, simply set the “Stim 100 Attenuation“ to 0 dB.
	Manually outputting a value on a digital channel can stop an acquisition if data is being collected at very high speeds (greater than 10,000 samples per second aggregate).
Invert output	Check this box to invert the polarity of the signal output through the STM100C.
	This function can also be achieved by flipping the polarity switch on the STM100C from positive (POS) to negative (NEG).

For more information on the STM100C stimulator output module, see the *MP Hardware Guide.pdf*.

Set Up Linked Acquisitions

This hardware (MP or other) menu option allows acquisitions to be recorded simultaneously from multiple hardware devices types into separate graphs. (For example, acquisitions can be simultaneously linked to two MP160/MP150, two MP36R units or an MP160/MP150 and a B-Alert unit.) The linked acquisitions can optionally be merged into a single graph for easy analysis.

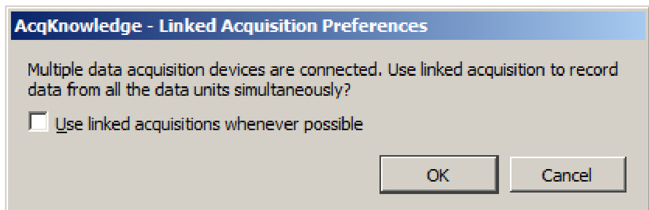
NOTE: Linked acquisitions are supported in the following hardware combinations only:

- MP160/MP150 to other MP160/MP150 hardware devices
- MP160/MP150 to B-Alert hardware devices
- MP36R to other MP36R hardware devices

Other hardware devices such as BioHarness are not supported, nor are linked acquisitions supported between different hardware types, (such as MP160 to MP36R).

In order to use linked acquisitions, a minimum of two graphs must be connected to different hardware units. If two or more graphs are connected to the same hardware unit, linked acquisition sessions are not supported.

If multiple data acquisition devices are connected and global linked acquisition settings have not been set up in Acq*Knowledge* Preferences, the following dialog will appear upon application launch:



Selecting “Use linked acquisitions whenever possible” will set a global preference to use linked acquisitions whenever multiple hardware devices are detected and offer additional preference settings. These settings can also be reset or changed at any time in Display > Preferences > Hardware. (See page 270.)

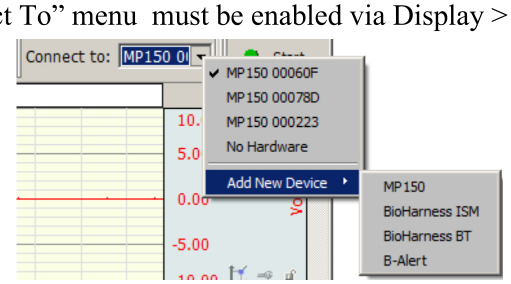
Choosing “Cancel” will still allow the setup of linked acquisitions, but this operation must be performed manually in Acq*Knowledge*.

Configuring New or Open Graphs for Linked Acquisitions

As stated above, Linked Acquisitions are supported only when two or more graphs are open, and only when two or more hardware devices are connected. Linked acquisitions can also be configured while Acq*Knowledge* is running, and graphs/devices added as desired.

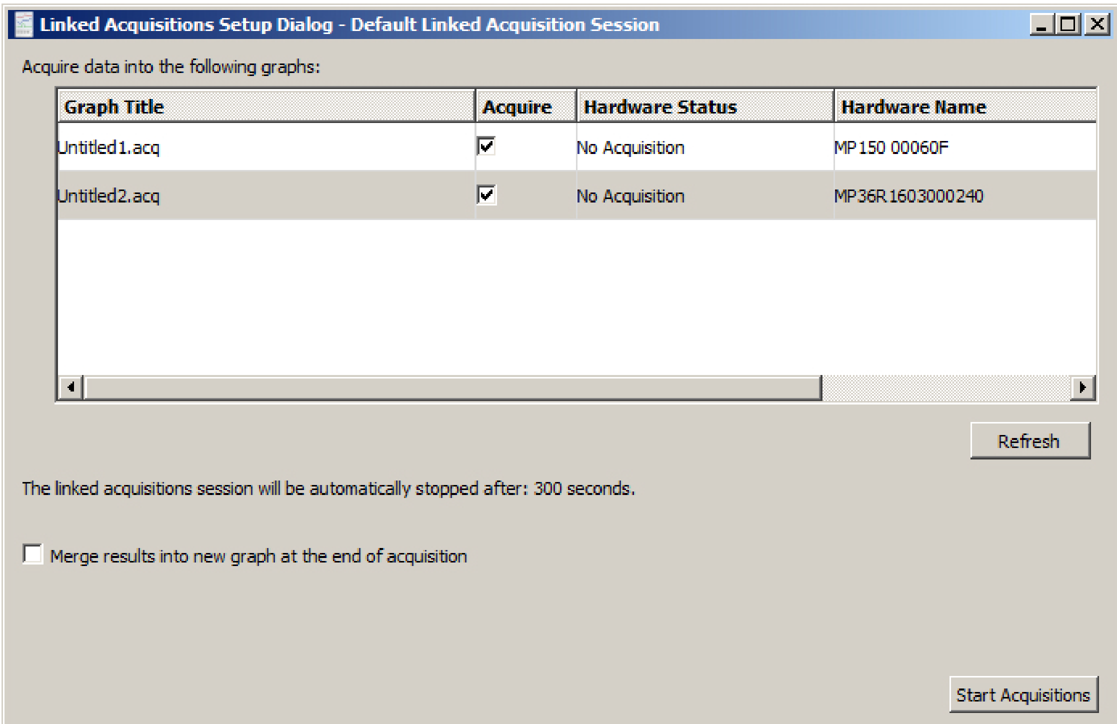
- If multiple data acquisition devices are connected and powered on, these devices will be listed in a pop-up menu in the initial Acq*Knowledge* startup window.
- Choosing “All Devices” automatically creates a separate graph for each connected device. This acts as a shortcut for setting up graphs for linked acquisitions.

Adding or changing hardware types with Acq*Knowledge* running: To add or change the hardware device for graphs that are already open, click the “**Connect to:**” pop-up menu and select or add a new device from the menu. (To be visible, the “Connect To” menu must be enabled via Display > Show > Hardware.)



The linked acquisition can output recorded data into the separate graphs, or optionally, merge the data into one graph. If the latter option is chosen, data from the separate graphs will be contained in separate labeled channels within the merged graph.

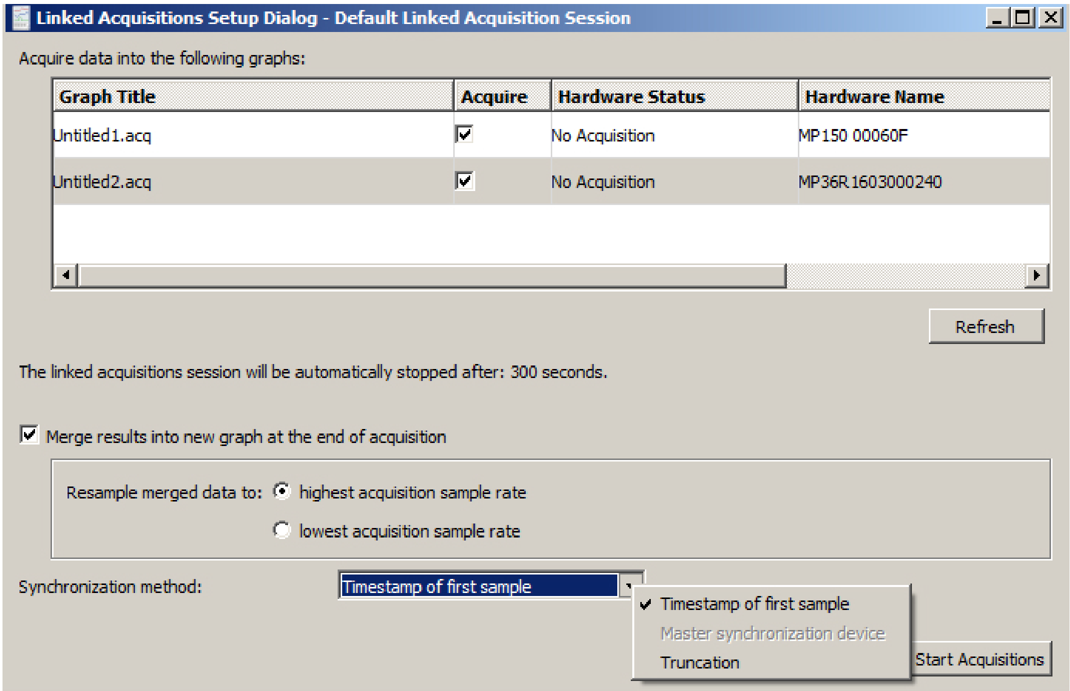
To access Linked Acquisitions setup, select **MP menu > Set Up Linked Acquisitions** to open the following window. Any open graphs are displayed in the “Acquire data into the following graphs” pane.



Top Column	Description
Graph Title	Displays the titles of the available graphs.
Acquire	Includes or excludes graphs from linked acquisition.
Hardware Status	Shows current status of hardware. (“No Acquisition” or “Acquiring Data.”)
Hardware Name	Identifies hardware device linked to graph.
Refresh button	Applies any settings that were changed (acquisition setup, etc.)

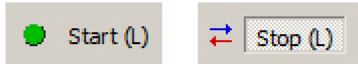
“**The linked acquisitions session will be automatically stopped after:**” This indicator displays the selected length of the shortest-duration graph in the group. Multiple graphs set to different durations will default to the length of shortest duration graph.

If the “**Merge results into new graph at end of acquisition**” option is checked, additional options become available. Please refer to the table on the following page for details about these options.



Functions	**Description**
Merge results into new graph at the end of acquisition	Outputs data collected from multiple recordings into one graph. **NOTE:** If the global preference is set to "Use linked acquisitions whenever possible," this option will not be available. (See following page for "Linked Acquisitions Preferences.")
Resample merged data to: highest acquisition sample rate (also available in the Hardware Preferences)	The merged graph data is upsampled to the highest selected sample rate among the linked graphs.(Example, if one graph is being acquired at 500 s/s and the other 2000 s/s, the 500 s/s graph will be upsampled to 2000 s/s.)
Resample merged data to: lowest acquisition sample rate (also available in the Hardware Preferences)	The merged graph data is downsampled to the lowest selected sample rate among the linked graphs. .(Example, if one graph is being acquired at 500 s/s and the other 2000 s/s, the 2000 s/s graph will be downsampled to 500 s/s.)
Synchronization method:	Offers various options for synchronizing the linked acquisitions.
"Timestamp of first sample" – Compares all timestamps, detects the one with the latest time, and then cuts the beginning section of the data in each channel. **"Master Synchronization Device"** – Used for pairing and synchronizing data obtained during linked MP160/150 and B-Alert acquisitions. This is the only option where the Master Sync Device radio button is active. This option requires the use of a BIOPAC CBLX10 cable to link the MP160/150 hardware with the B-Alert X10 headset. This cable allows for the injection of signals used to align data recordings between the two independent units. (See the MP Hardware Guide for more details on the CBLX10.) "**Truncated"** method – Searches for the shortest acquisition length and uses this parameter to calculate how much data will be removed from the beginning of longer acquisitions. This is the least precise of the three synchronization methods.	
Start Acquisition button	Starts the recording for all selected graphs.

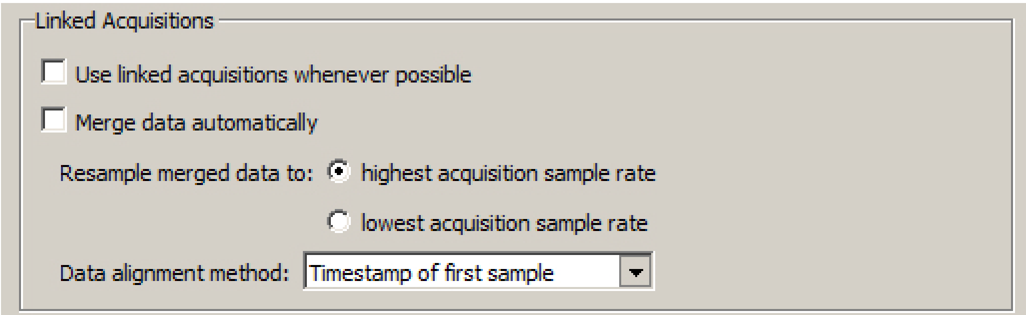
Graph Start/Stop button behavior: After linked acquisitions setup, Start/Stop buttons for all graphs display an "(L)" to the right of the button. Linked graphs can be simultaneously started and stopped by toggling the Start/Stop button of any graph. To Start/Stop linked graphs separately, hold down the Ctrl+Alt/Option keys while clicking the button.



Alternatively, the linked acquisitions setup dialog can be opened via the MP menu > Set Up Data Acquisition > Length/Rate window. (Note the **"Setup Linked Acquisitions"** button in this window.)

Linked Acquisitions Preferences

Global preferences for linked acquisitions can be accessed and set up via **Display > Preferences > Hardware.**



Tile floating graph windows automatically on start of linked acquisitions

This preference arranges linked acquisition graphs vertically when a recording is started.

Use linked acquisitions whenever possible: Use this option to automatically set up linked acquisitions if multiple hardware and multiple graphs are detected.

NOTE: If the global preference is set to "Use linked acquisitions whenever possible," the "Merge results into new graph at the end of acquisition" Setup Dialog option not be available.

Merge data automatically: Automatically merges data from multiple acquisitions into a single graph using the Resample and Data alignment options selected in the Preferences. Note that if this option is selected, recording modes are limited to Save Once to Memory or Save Once to Disk modes.

If these preferences are not selected, linked acquisitions must be set up manually in the linked acquisitions dialog (MP menu > Set Up Linked Acquisitions).

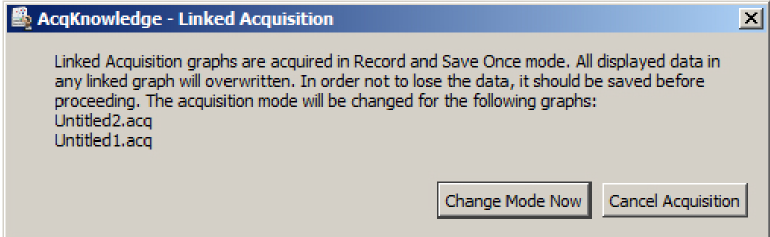
For complete Hardware Preferences information, see page 512.

Limitations on Linked Acquisitions synchronization methods

Synchronization Mode	Description	Criteria
Any method	Minimum number of selected graphs	2
	Minimum number of analog channels	1
	Minimum length of acquisition when B-Alert device is used	12 sec.
Master Synchronization Device method	Allowed hardware types	MP160/150 and B-Alert only
	Minimum sample rate on first channel of B-Alert hardware	256 s/s

Incompatible Acquisition Mode Warning

If an incompatible acquisition mode is used for any graph (such as append mode), the following dialog will appear:



Choosing "Change Mode Now" reverts graphs to a compatible acquisition mode. Selecting "Cancel" will exit the linked acquisition and leave acquisition modes unchanged.

The sample rates can vary between the linked acquisition graphs, but all

Limitations on Linked Acquisition Recording Modes:

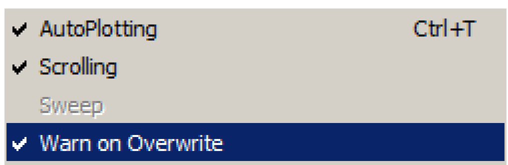
If the "Merge data automatically" option is selected in the Linked Acquisitions Preferences, recordings are limited to Save Once to Memory or Save Once to Disk mode.

Additional acquisition modes Append, Autosave, and Auto-repeat modes **are** supported in linked acquisitions if the "Merge data automatically" option is not selected.

Linked Acquisitions and "Warn on Overwrite" dialog:

Compatible record modes for linked acquisitions are Save Once to Memory or Save Once to Disk. Rerunning acquisitions in these modes normally results in a warning that data will be overwritten.

If data output is not being merged into one graph, the warning will be displayed. The warning can be suppressed in this circumstance by deselecting the "Warn on Overwrite" option in the hardware menus. (MP36R or MP160/150, etc.)



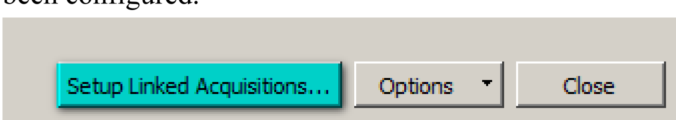
However, if the "Merge results into new graph" option is selected, the "Warn on Overwrite" dialog will *not* be displayed.

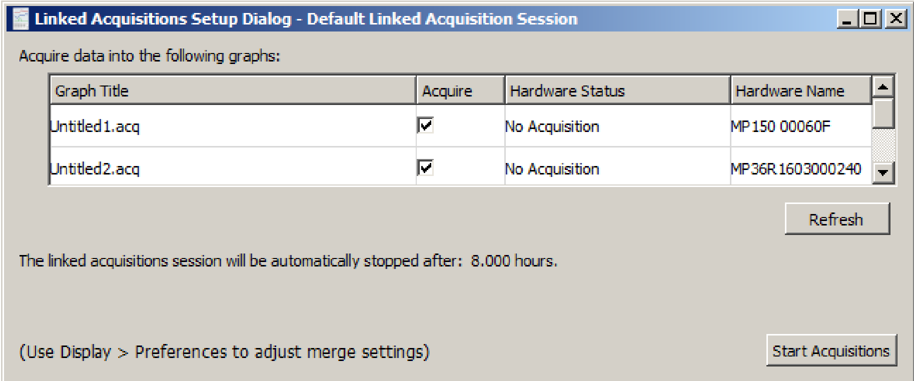
Linked Acquisitions and wireless connections: In general, if the computer is trying to use multiple network cards at the same time with an MP160/150, the MP160/150 either needs to be on the primary network, or additional network cards must be disabled, or network bridging must be enabled in the Windows system settings. When self assigning IP addresses, the MP160/150 may also choose a new IP address each time it is power cycled, which will prompt for reconnection.

Linked Acquisitions shortcut button in Data Acquisition Settings screen:

If Linked Acquisitions are configured, a "Setup Linked Acquisitions" button will appear at the bottom right of the Data Acquisitions Settings screen (MP menu > Set Up Data Acquisition) regardless of which option is selected in the left pane (Channels, Length/Rate, etc.). This button provides a shortcut to the Linked Acquisitions Setup dialog.

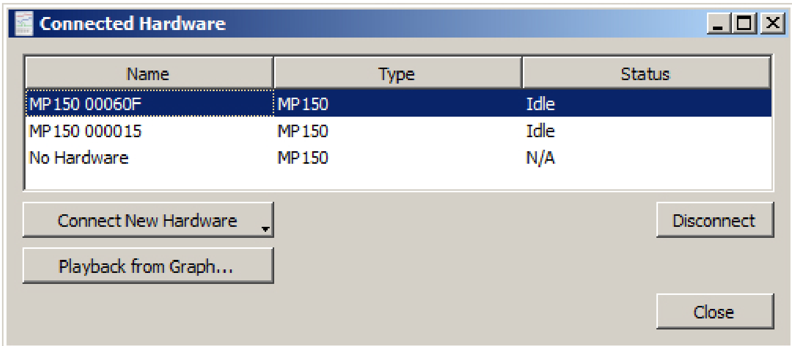
NOTE: The "Setup Linked Acquisitions" button is hidden in this view if a linked acquisition session has not been configured.

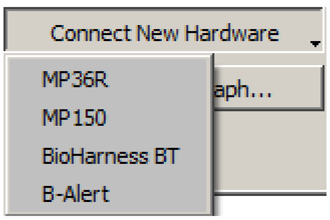


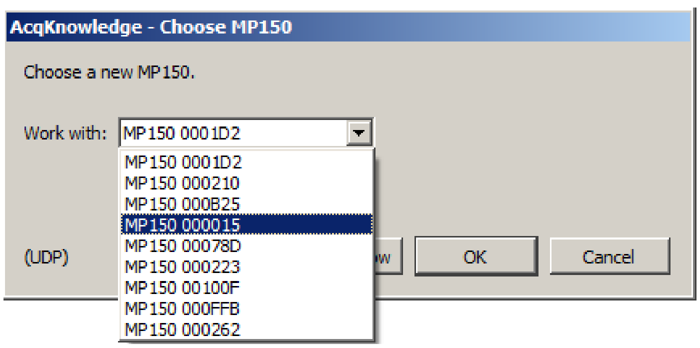


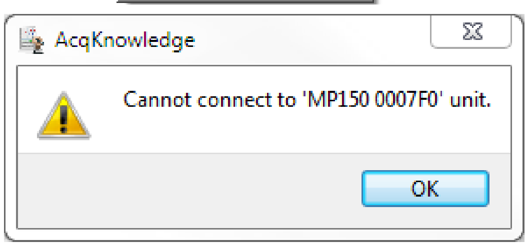
Watch the Acq*Knowledge* Linked Acquisitions video tutorial for a detailed explanation of this feature.

Manage Hardware Connections









The Manage Hardware Connections option enables easy connection and disconnection of new hardware and allows switching from a particular hardware unit (or hardware type) to another. It's even possible to have multiple Acq*Knowledge* graphs running on different hardware types at the same time. The following controls are available:

Connect New Hardware

Choosing 'Connect New Hardware' opens a popup menu for selecting and adding additional hardware units. Once a new hardware unit added, it will be available for use in the application, and will appear in the connected hardware list. (The example at left shows the selection of additional MP units on a local area network.)

The 'Choose MP160/150' pull-down menu lists all MP160/150 units that are powered ON and sitting on the same local area network. The software pings the selected MP160/150 unit and if available, the unit is added to the list. If the unit is busy or otherwise unavailable, a "Cannot connect to MP160/150" prompt such as the example below left is displayed.

Disconnect

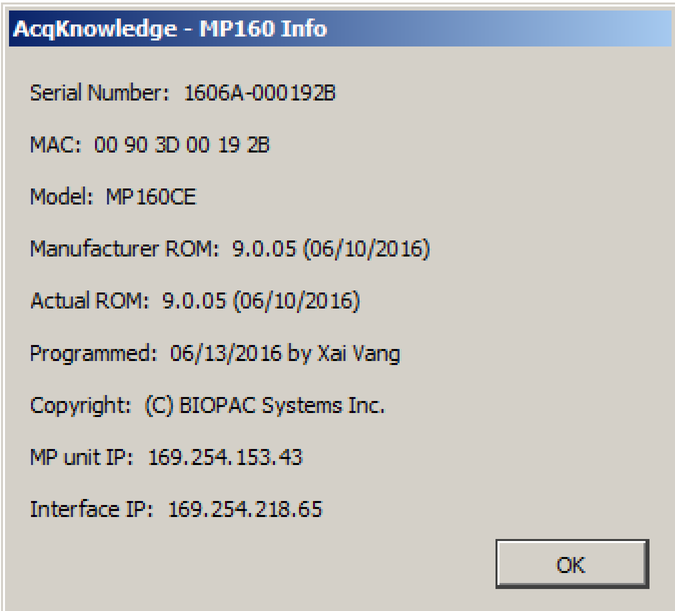
Use to disconnect from any available hardware in the list.

Playback from Graph

Launches the "Open for Playback" dialog. For more information on Playback Mode, see page 41.

MP160 or MP150 Info

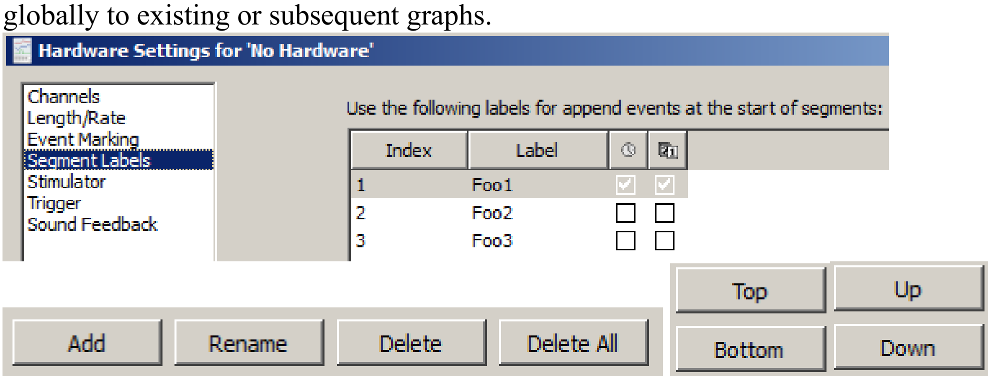
Select MP160/150 Info from the MP160/150 menu to generate a dialog with information about the software and firmware versions being used by Acq*Knowledge*:



Note: For information about Acq*Knowledge* software, click Help > About Acq*Knowledge*.

Segment Labels

Selecting Set Up Segment Labels from Hardware > SetUp Data Acquisition > Segment Labels launches a setup dialog enabling assignment of user-defined labels to append event segments. The Segment Label options are applied to the active graph only. The selected settings will be saved with the graph, but will not be applied globally to existing or subsequent graphs.

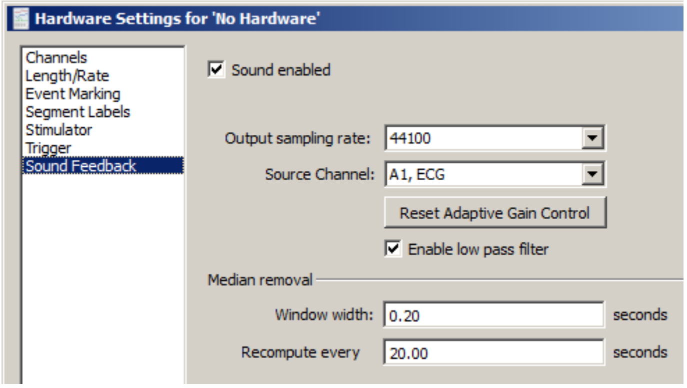


- Add — Adds a segment number to index. Segment text can be edited under ‘Label.’
- Rename — Used to rename an existing segment label.
- Delete — Deletes a selected segment from Index.
- Delete All — Deletes all segments from Index.
- Top/Bottom — Moves selected segment to top or bottom of Index.
- Up/Down — Incrementally moves a selected segment up or down the Index.

Enabling checkboxes below the  icons adds time/date stamps to the segment label.

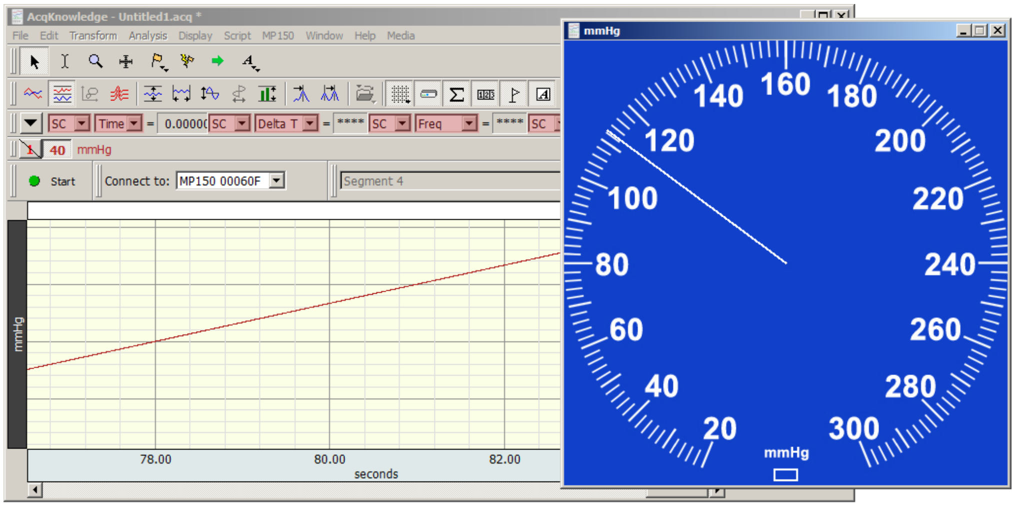
Sound Feedback

Sound Feedback enables data to be redirected to the computer's default audio output in real time. This feature can be used to monitor waveform data as sound through the computer speakers or headphones.



SOUND FEEDBACK CONTROLS	FUNCTIONS
Sound enabled	Turns sound feedback of data on and off.
Output Sampling Rate	Selects from available sampling rates of the default audio device.
Source Channel	Selects the analog, digital or calculation channel from which the audio will be acquired.
Reset Adaptive Gain Control	Resets gain control to adapt to the current level of the signal. Use after sound feedback has started to re-adjust the level after accidental spikes or large artifacts.
Enable low pass filter	Applies a low pass filter at the Nyquist frequency (50% of the acquisition sampling rate). This IIR filter can help smooth out transition artifacts due to upsampling of data to the audio sampling rate. (Enabled by default)
Median removal controls (Window width, Recomputate)	Removes baseline offset from the output signal.
Window width	Sets width of median removal window (in seconds). Must be a positive value.
Recompute every	Provides the time duration (in seconds) after which the median of the data is regenerated from the raw source data. Must be a positive value.

Gauge



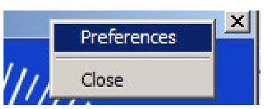
The Gauge is accessed via Hardware > Show Gauge. The optional "Gauge" display shows one channel of data in a gauge/dial indicator format.

The Gauge displays as a separate window, viewed simultaneously with graph and other windows.

The Gauge window:

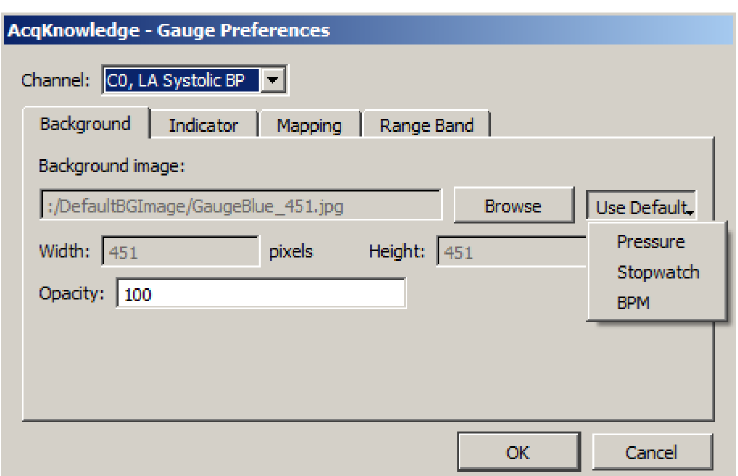
- Will display one channel of data: (analog or calculation)
- Updates and displays simultaneously with the graph window. For analog channels only, the display will update when the recording is stopped, but at a slower rate than when the recording is running.
- Can update during and in between acquisitions for all hardware devices; display may be updated at a rate slower than the sample rate and may display a value that represents the average of several samples.
- The background image (BMP, JPG or TIFF), indicator origin, range, length, thickness and color are all user-configurable. An optional range band overlay can also be enabled.
- Selectable gauge bitmaps include Blood Pressure Cuff, BPM or Stopwatch
- All window preferences as well as the window visibility, size and position will be saved with the file.
- Window sizing is "fixed" to the size of the background image, meaning it will have a 1 to 1 correspondence with the monitor pixels

Gauge Preferences



Gauge Preferences are accessed by right-clicking over the gauge and using the contextual menu. There are four tabs for setting the various Gauge parameters.

Background is the default tab presented in Gauge Preferences and contains options for setting the Background image.



Channel Provides a pop-up menu for assigning any one of the ENABLED analog or calculation channels.

Background Image Displays the path and file name of the current background image. The default image is a blue blood pressure gauge sized at 451 x 451 pixels.

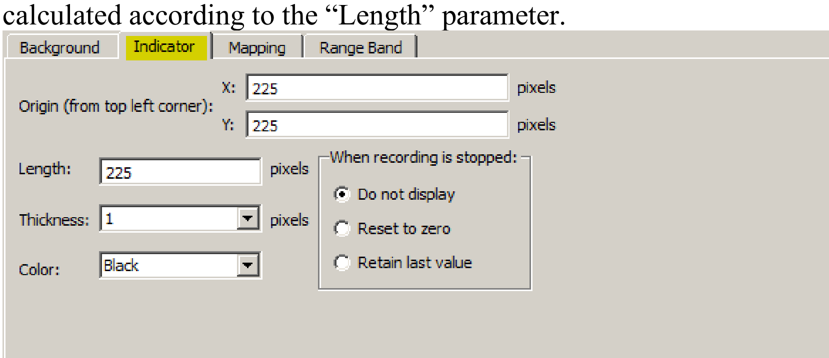
Browse Allows alternative background images in different directories to be used in place of the default gauges. The Browse location will default to the file path used by the currently selected background image. To change the background image, click the “Browse” button and locate the desired file. After the background image is specified, the pixel **Width** and **Height** will be updated. The **Width** and **Height** fields are not editable.

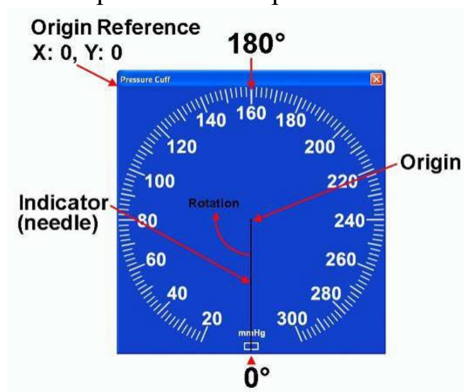
Use Default Displays a menu of available default background images. **(Pressure, Stopwatch and BPM**).

Opacity Changes the transparency of the gauge image.

Indicator

The “indicator” or “needle” is a simple line vector drawn from an assigned center point to an endpoint calculated according to the “Length” parameter.





Origin Center point of the indicator line referenced from the top left of the image (not the top left of the window) meaning neither the frame of window nor the title bar is included. The “X” parameter specifies the horizontal distance in pixels and the “Y” parameter the vertical distance. “X” cannot exceed the Width of the background image and “Y” cannot exceed the image Height. The *default* values are: Origin: X: Width/2, Y: Height/2. **Note that the pixel count starts at “0” so a 225 pixel square image will have its center point at 112 pixels.**

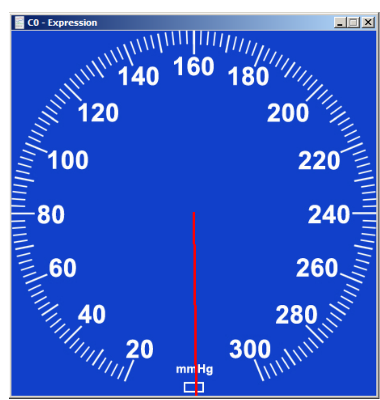
Length Specifies indicator span in pixels starting from the “Origin.” Default is the smallest of the Length or Width dimensions divided by 2.

Thickness Specifies the indicator width in pixels, with a selectable range between 1 and 10. The default is 1 pixel.

Color Specifies color of the indicator “needle” as Black (default) or White.

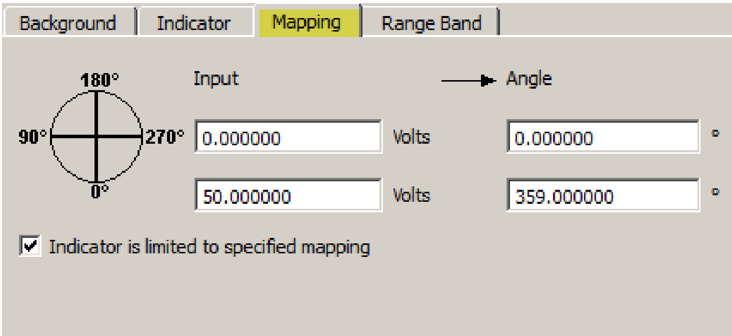
When recording is stopped

If the source channel is a Calculation channel, no gauge updating will occur when the recording is stopped. Under this circumstance, the “When recording is stopped” options become available. This allows the user to specify whether the indicator should not be displayed, should be reset to zero, or should retain the last value.



Mapping

For setting up two point mapping: Input to Angle.



Input Defines the input values in the scaled units. The units shown in the example are volts, but would reflect the units of the source channel (mmHg, psi, etc.). The Input mapping of the upper scale value is set to a default of 50 of the source channel unit type.

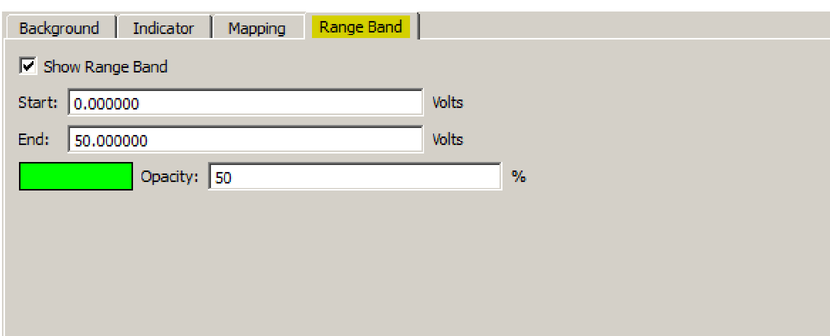
Angle Any angle can be entered, but 0, 360, 720, etc degrees means that the indicator will always be pointing straight down.

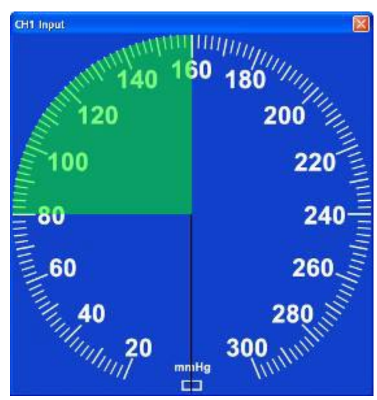
When assigning mapping angles: Because the indicator "needle" must rotate clockwise, the first value should be the lower angle. The first value also defines the indicator's starting angle but does not to need to be 0 degrees. For example, the Stopwatch Gauge's starting angle should be 180 degrees (pointing straight up). If half-circle gauges are used, the starting angle may be 90 degrees.

Indicator is limited to specific mapping

If this option is enabled, and the indicator needle reaches its mapped upper limit, it will stop rotating and turn red. If this preference is not selected, the needle will not change color if the defined mapping limits are exceeded and the needle will just continue in a clockwise rotation.

Range Band (Default OFF)
Use the Range Band as an optional feature to highlight a specified area of the Gauge View.





Start/End Defines a "pie" shape (defined by Mapping values) sourced from Gauge center and superimposed over the background image.

Color Clicking on the color bar will bring up a color palette, which allows any color to be selected. The default color is green.

Opacity Used to adjust the transparency of the Range Band. 100% means the background image will be fully obscured behind the range band, and 0% means the Range Band itself will not be visible. The default setting is 50%.

Segment Timer "Stopwatch" option

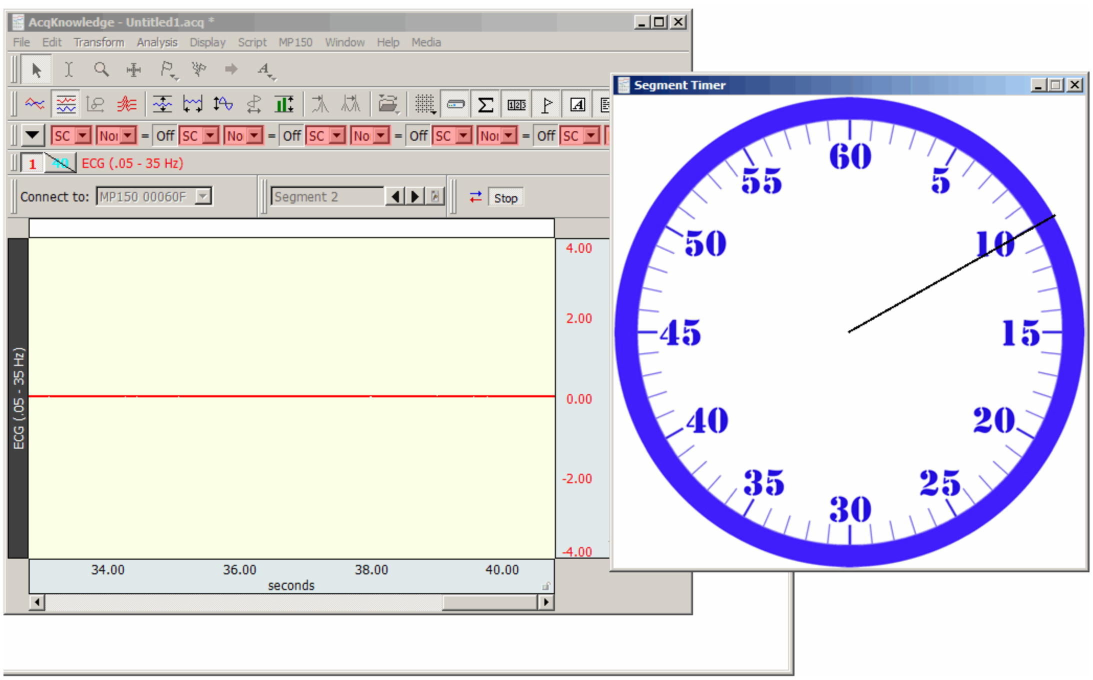
In addition to the standard Gauge described above, the Segment Timer Gauge option offers an analog "Stopwatch" view of an acquisition in progress. As the recording progresses, a circular onscreen stopwatch gauge displays the elapsed time with a sweep-second indicator. All customizable parameters shown above for the default Gauge view are applicable to the Stopwatch view. A custom mapping for the Stopwatch view can be created, or use the pre-configured "Segment Timer Gauge" graph template in the Sample Data folder.

Using the Segment Timer graph template – open the sample template in the following directory:

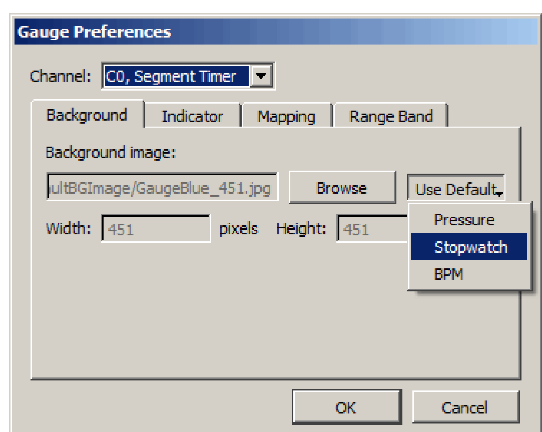
Main drive\Program Data\Biopac Systems, Inc\Acq*Knowledge* 5\Sample Data\Segment Timer Gauge.gtl

Clicking 'Start' will show the Stopwatch in progress. The template is setup to record ECG Lead II on CH 1 and is tied to a new Segment Timer calculation channel. However, no connections are needed to verify the segment timer and the template can be customized as desired. To change parameters, choose Preferences from right contextual menu with mouse positioned over the gauge window.

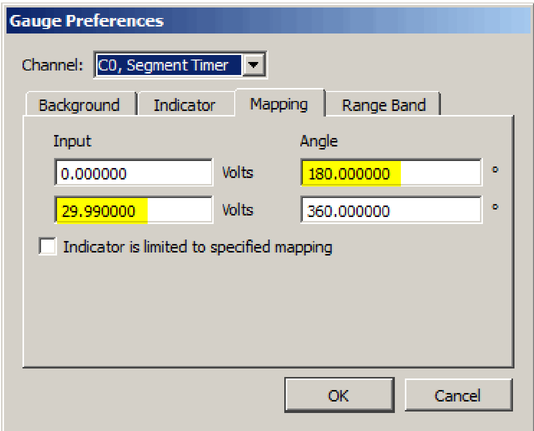
When the recording is stopped, timer indicator will also stop. When the next recording segment begins, the segment timer will reset to 0. (This default can be changed in the Gauge Preferences).



To configure a new Segment Timer Stopwatch view:



1. Set up desired acquisition parameters and channels.
2. Hardware menu > Set Up Data Acquisition > Channels > Calculation tab and choose the Segment Timer preset.
3. Hardware menu > Show Gauge and open Preferences by right-clicking the contextual menu over the Gauge window.
4. In the Gauge Preferences, choose "C0 – Segment Timer" for the Channel and "Stopwatch", as shown on right.
5. Choose the "Mapping" tab, enter the following Input to Angle mapping values and click **OK**:



6. Start the acquisition. Note the Stopwatch view will accurately reflect the time scale of the recording in progress.

Autoplotting, Scrolling and Sweep Display Modes

Checking or unchecking the Autoplotting, Scrolling and Sweep options controls how data is displayed on the screen during an acquisition. By default, Acq*Knowledge* displays the most recently collected data first, and if more than one screen of data is to be collected, then the time scale will "scroll" so that the newest data is always on the right edge of the screen.

When Scrolling is disabled and Autoplotting is enabled, the screen will be cleared when the data reaches the right edge of the screen, and plotting is redrawn from the left.

When both Scroll and Autoplot are unchecked, the incoming data will be plotted until the screen is full. Once the screen is full, data will continue to be collected, but only the first screen is displayed. By default, the hardware will display the first eight seconds of the data record, but this can be reset manually by changing the horizontal scale. To toggle Autoplot ON or OFF in the middle of an acquisition:

- select Ctrl+T (Windows) or Command+T (Mac OS) on the keyboard, or
- Choose the MP menu and enable or disable "Autoplotting"

Sweep display mode is similar to an oscilloscope sweep display in which data is plotted left to right, but old data remains visible on the screen while new data is incoming. This type of display is also seen in some clinical devices. Sweep mode can be toggled from the hardware menu during acquisition and is data view independent. Sweep mode is available in Scope, Chart, Stacked Plot, and Split View modes, and the sweep state is saved in graph files and templates.

In order for Sweep display to function:

- Autoplotting must be enabled
- Scrolling must be disabled
- Sweep must be enabled

In this configuration the old data remains visible while incoming data is in the form of a black vertical line "sweeping" across the old data from left to right. The old data and horizontal time scale are redrawn once the line sweeps across its axis.

"Sweep" mode cursor

Manual, Autoscrolling and Sweep options can also be accessed via the 

, 

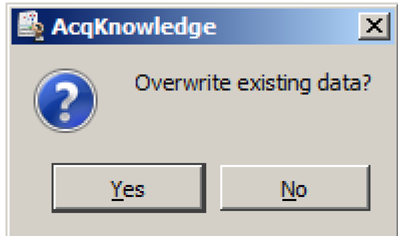
, or 

button in the lower right region of the horizontal axis region. For full details on this tool, see Autoscroll Horizontal Axis Controls on page 52.

Limitations: Sweep mode is temporarily disabled when scale modifications affecting the vertical or horizontal scale are applied. This includes: autoscaling, show all data, adaptive scaling, zoom, window resizing, end of acquisition. Sweep mode is not supported in XY mode.

Warn on Overwrite

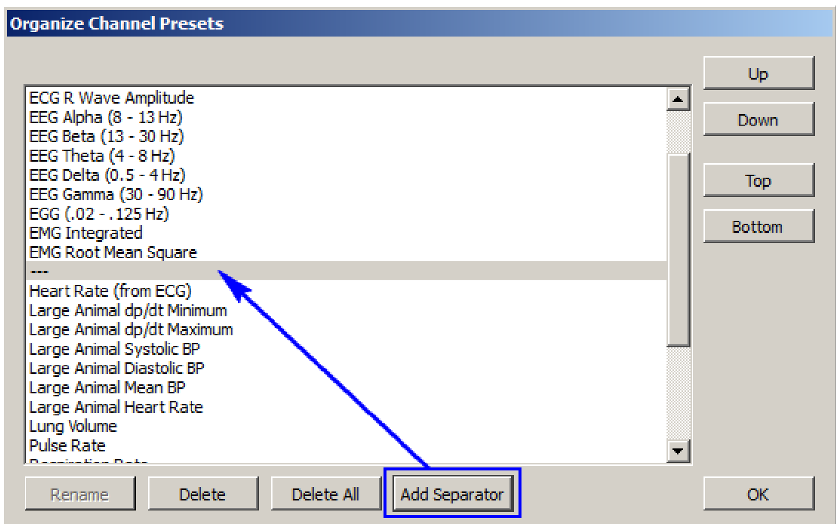
Selecting the "Warn on overwrite" option from the Hardware menu will generate a prompt each time a new acquisition is started:



After clicking "Yes," Acq*Knowledge* will erase the current file and overwrite it with a new acquisition. If the current file needs to be saved, click "No" and open a new file.

This prompt will appear at the beginning of each acquisition when the hardware is in Save Once with repeats mode. "Warn on Overwrite" can be disabled by deselecting this option under the Hardware menu.

Organize Channel Presets



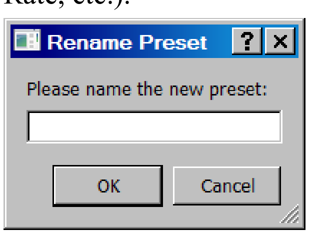
The Organize Channel Presets option controls the channel presets (established or custom) in the Hardware > Set Up Channels dialog. Presets can be renamed, rearranged or deleted. This option can be used to place the most frequently selected Presets at the top of the menu or group related Presets, such as established ECG Presets. Click a "Preset" description to select it, and then use the buttons to organize the Presets.

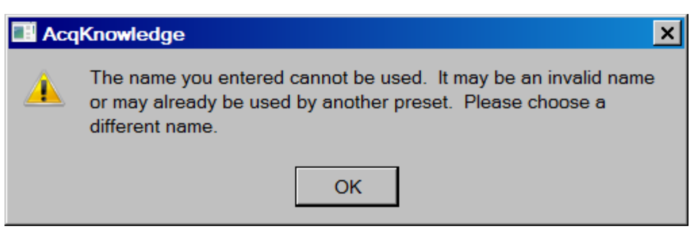
Up and **Down** buttons move the selection one space at a time.

Top and **Bottom** buttons jump to the start or end of the list.

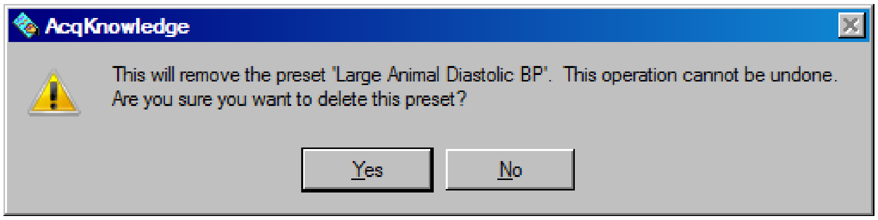
Rename a Preset by typing in a new title and clicking OK.

Titles currently used by a Preset or any name that matches a Calculation type cannot be used. (Integrate, Rate, etc.).





Delete a Preset by selecting that option. The Default Analog Input preset cannot be deleted. When deleting a Preset, a confirmation dialog will appear because this is an irreversible action.



Add Separator adds a new Separator entry to the Preset list and is useful for dividing different Preset types. If a Preset is currently selected in the list, the Separator will be added below it. (See diagram above) If no preset is selected, the separator will be added to the end of the list. Separators can be rearranged or deleted in the same manner as Presets.

The default location for Preset files is Computer > Local Disk > ProgramData > BIOPAC Systems, Inc > Acq*Knowledge* 5 > Presets.

Exit Playback Mode

This option is enabled when Open File for Playback (see page 41) has been selected. Select to resume acquisition functionality (change Playback menu to Hardware menu, Replay button to Start button).

Part C—Analysis Functions

OVERVIEW

This part describes how to analyze data; in most cases, analysis is performed after the data has been collected. This involves creating, managing, and saving files, as well as editing data, performing mathematical transformations, and displaying data in various ways. Many of the functions covered here are also discussed in *Part A—Getting Started*. Features that can be computed during an acquisition (primarily transformations and calculations) are discussed in *Part B—Acquisition Functions*.

For general information about sections of the graph window, and to become familiar with the "look and feel" of Acq*Knowledge*, turn to the *Editing and Analysis Features* chapter. Descriptions of functions can be found in the chapters describing each menu. All of the commands discussed here can be found under the File, Edit, Transform, or Display menu items.

Menu	See…	Type of Commands
File	Page 286	General file management commands, including opening, saving, and closing files. Export data files.
Edit	Page 317	Cut, copy, and paste between and within files. Export data files.
Transform	Page 328	Operations that primarily modify the data in the graph.
Analysis	Page 361	Operations that primarily derive data and measurements from the graph.
Specialized Analysis	Page 403	A courtesy copy of the new *Specialized Analysis* package with automation and scoring routines is included under the Analysis menu.
Display	Page 486	Control how data appears on the screen either during or after an acquisition.
Media	Page 521	Capture and Playback controls to synchronize video/audio with data.

Toolbars

Many of the most commonly used features in Acq*Knowledge* can easily be executed with a mouse click. The toolbar contains shortcuts for some of the most frequently used Acq*Knowledge* commands; icons are grayed out when they are not applicable. Custom toolbars can be created by clicking the Customize Toolbars icon. 
Click Display > Show > to view the toolbar options. Check a toolbar option to activate it.

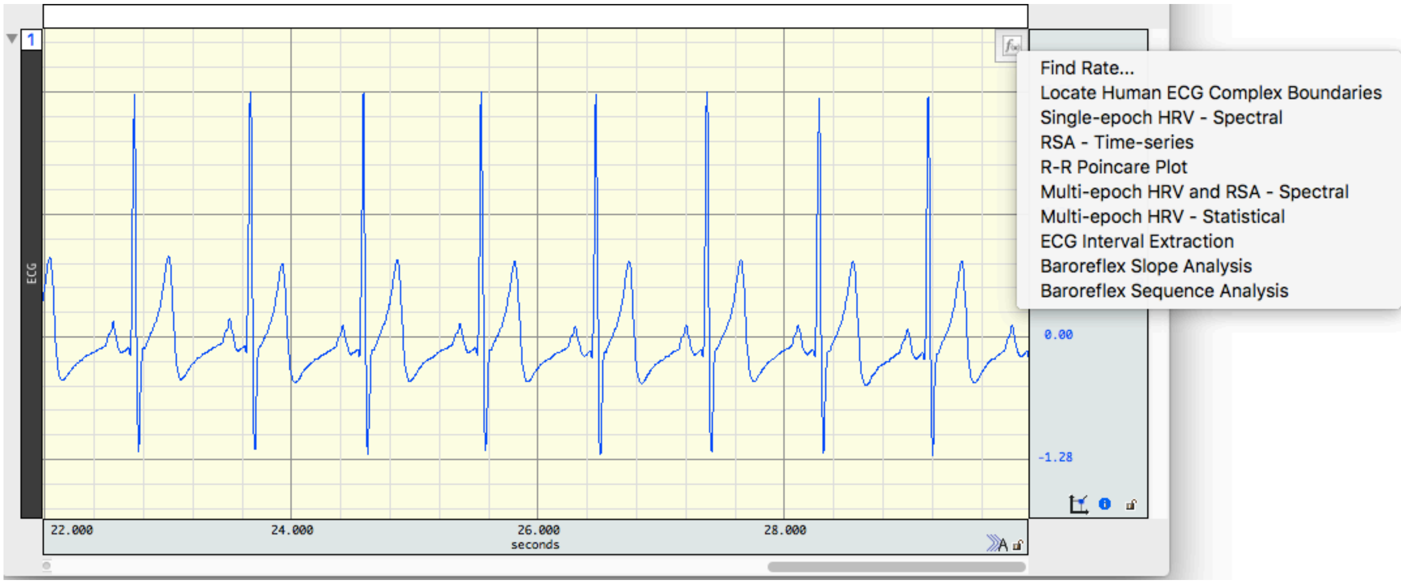
See page 60 for Toolbar icon definitions.

Shortcuts

Keyboard shortcuts are detailed on page 69.

Mouse shortcuts are detailed on page 73, including contextual menus.

Analysis Shortcuts

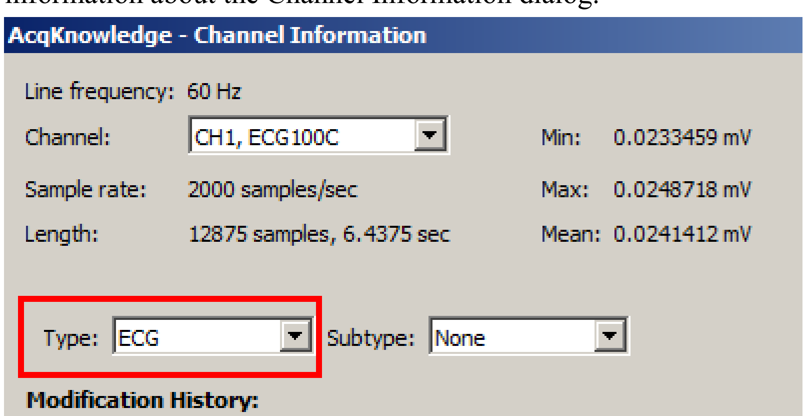


In Acq*Knowledge* 5.0.2 and higher, Analysis Shortcut buttons are available within individual graph channels. Analysis Shortcuts offer quick access to common Specialized Analysis* options. Clicking the shortcut presents a pop-up menu containing analysis options relevant to the signal type present in the selected graph channel.

This feature is helpful for avoiding the confusion of having to scroll through a lot of unrelated Analysis menu items when wishing to apply a transformation.

The Analysis Shortcut appears as a small button in the upper right corner of the graph channel . In order for this button to become active, one of the following configurations is necessary:

- A specific signal type must be configured in the Acq*Knowledge* Module Setup (MP160/150 menu > Set Up Data Acquisition > Channels > Add New Module) and data acquired under those parameters.
- If using MP36R hardware, a specific preset signal type must be configured (MP36R > Set Up Data Acquisition > Channels > Presets or MP36R > Channels > Setup > Advanced > Signal Types) and data acquired under those parameters.
- Or post-acquisition, a specific signal type (ECG, EMG, etc.) can be assigned in the Channel Information dialog. This will activate an Analysis Shortcut corresponding to the assigned signal type.
    1. Choose Display > Channel Info…(or right click in a graph channel and choose “Channel Info” from the contextual menu.)
    2. Choose the appropriate signal from the “Type:” pop-up menu. See page 504 for more information about the Channel Information dialog.

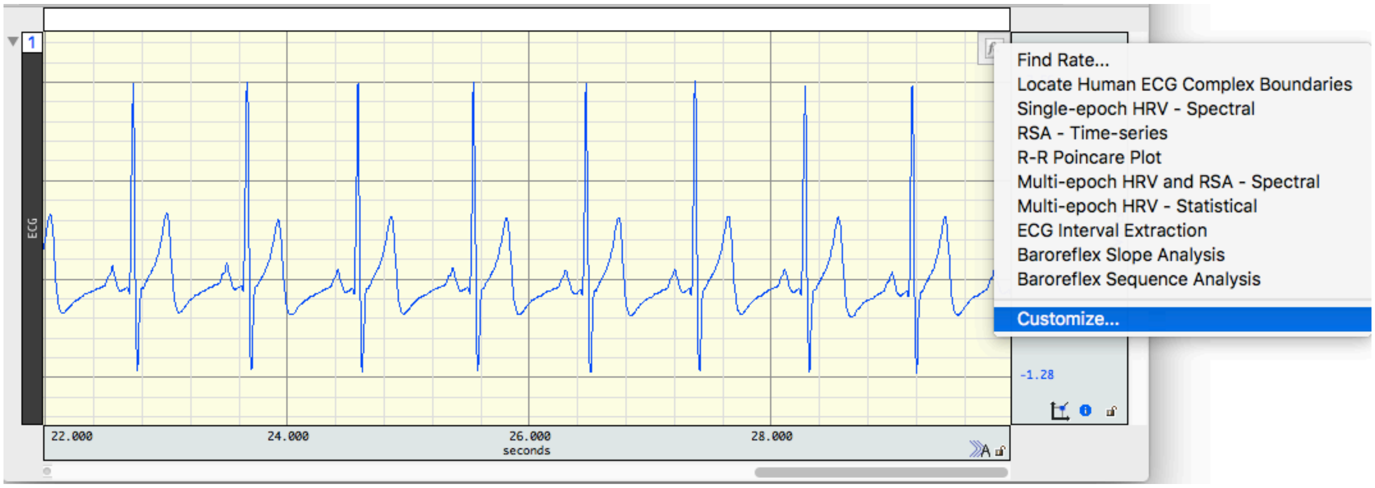


*See page 403 for complete Specialized Analysis information.

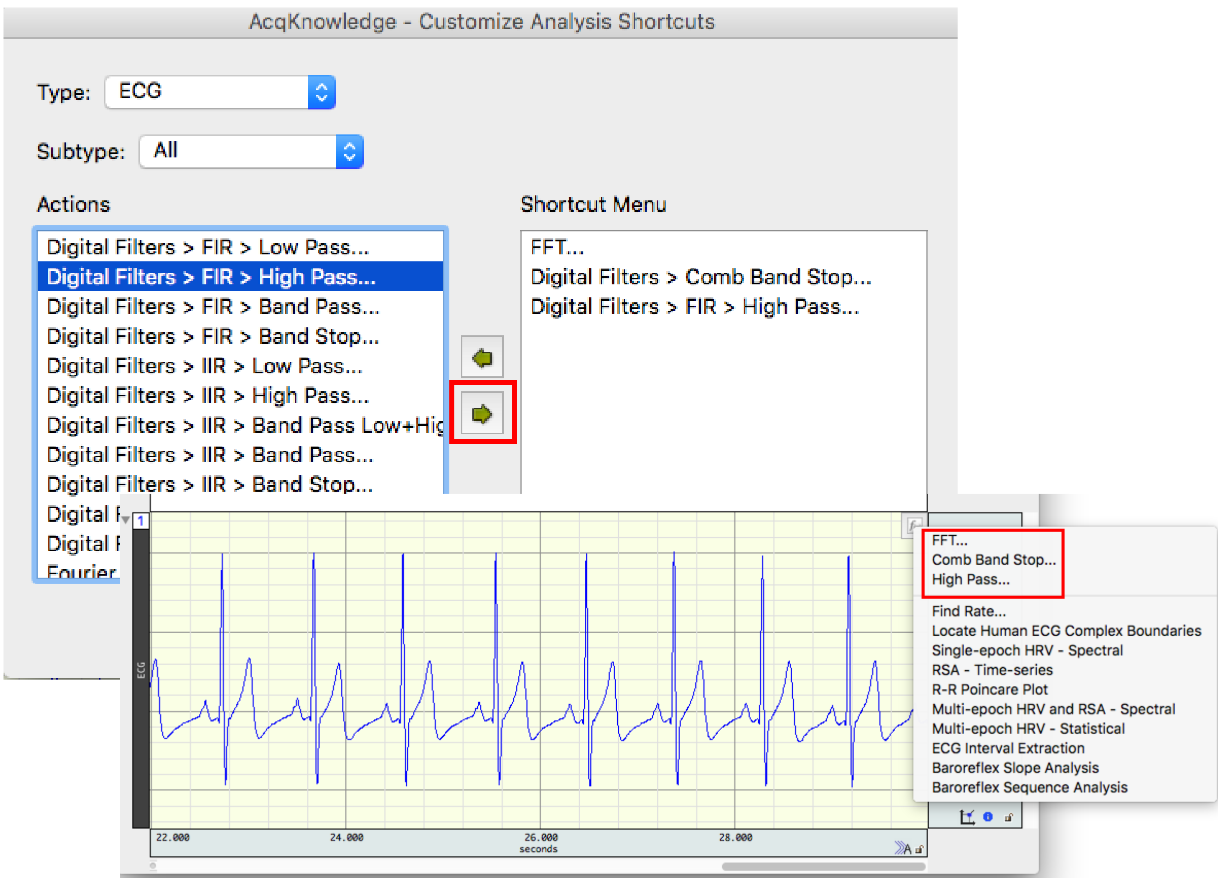
Creating Custom Analysis Shortcuts

Custom transformations and analysis routines can be added. To add a custom item:

1. Right click the Analysis Shortcut button and choose “Customize.” (The “Customize” item will only appear if the button is right clicked.)



2. Choose an option from the “Actions” list and click the right-pointing green arrow to add the item to the shortcut. (Any number of custom items can be added.) Click OK.

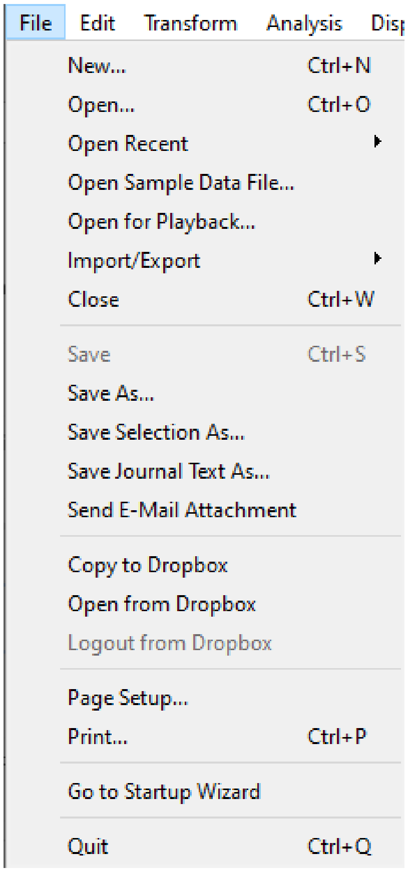


3. Custom shortcut items will be present in the graph’s Analysis Shortcut list for the selected signal type. (ECG for the above example.) Items can be removed via the “Clear” button or by selecting an item and clicking the left-pointing green arrow.

   TIP: Using the Alt or Option key in combination with the left-pointing green arrow will remove all shortcut items.

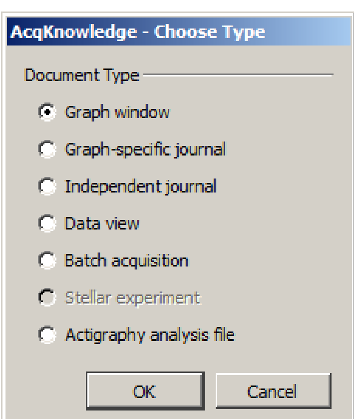
Chapter 13 File Menu Commands

Overview



Most of the items in the File menu are standard menu items and follow the standard Windows conventions or Macintosh conventions. By default, all files are created and saved in the Acq*Knowledge* file format, a proprietary format used to store binary data. Data can be read in from either text files or Acq*Knowledge* files, and can be saved in text, graphic, or binary format. As a rule, storing data in the Acq*Knowledge* format saves information in the most compact format possible and takes up less disk space than other file formats. In most cases, graph windows and data will be saved in the Acq*Knowledge* format.

New



Graph Window

When a new graph window is created, the window parameters can be modified, including horizontal scale, vertical scale, window size and position. These settings take effect once an acquisition begins.

New > Graph-specific Journal

Creates a graph-specific journal; see page 53 for details.

New > Independent Journal

Creates an independent journal; see page 53 for details.

New > Data View

Creates a new Data View for the active (frontmost) graph and names the window “Data View of ‘Filename’.” For Data View details, see page 43.

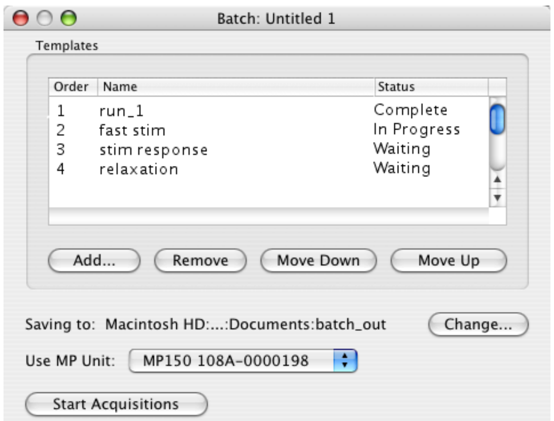
New > Batch Acquisition

Use the Batch Acquisition feature to configure advanced experimental setups and acquire data from a sequence of templates. Each template in the Batch may have different acquisition settings, channel configurations, and stimulator setups. Use a Batch for long duration experiments with hardware setting changes across segments, to automate routines, or to run multiple experiments on the same experimental setup in succession.

- For example, if an experiment has a preparatory period, a stimulus period, and a response period, three graph templates could be batched:
  - A template to acquire for the length of the preparatory period
  - A second template with a stimulator configured for the stimulus period
  - A third template to acquire the response period without stimulation

All three templates could be added in sequence to a single Batch Acquisition, which would then acquire all of the data for all three templates with a single start.

To create a new batch, choose File > New > Batch Acquisition to generate the Batch dialog.



The Templates controls at the top allows the addition, removal, or re-ordering of templates.

- Double click a template in the list to open the output graph from the most recent acquisition.
- Batch acquisition cannot combine acquisitions that do not end, so the acquisition storage mode for template files cannot be set to "Save last," "Autosave" or "Repeat forever."

Status

N/A	No status is available for the template, no batch acquisition has been performed.
In Progress	Data is currently being acquired for the template.
Waiting	A batch acquisition is in progress but has not yet reached the step where the template is used.
Complete	Data acquisition for the template has been finished successfully and has been saved to disk at the batch output location.
Error	A batch acquisition was aborted manually or due to communication errors. The data for the template may not have been saved or may be unreliable.

Batch Errors

Misconfigured templates and misconfigured averaging templates may generate the Adjust Length/Adjust Latency/Abort Acq warning prior to the start of acquisition. Clicking "Abort" will halt the batch acquisition. Misconfigured templates may result in those rare cases where data was acquired into a graph template with a different hardware configuration prior to saving the template to disk.

Saving to:

Use the "Change" button to specify the directory where the acquisition output should be saved.

Use MP Unit:

Specify the MP unit that should be used for the Batch Acquisition.

This menu lists all of the available hardware units. Entire menu dimmed out while batch acquisitions are in progress.

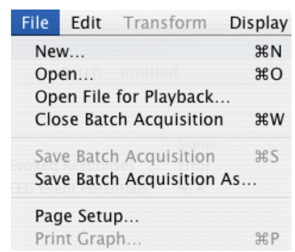
Start/Stop Acquisitions

Toggles to starts and stop batch acquisitions; dimmed when the specified MP unit is being used to acquire data unless it is a batch acquisition that is in progress. Batch acquisitions may be terminated by using either a control in the batch user interface or by clicking the “Stop” button in the graph window actively acquiring data for the current template of the batch. During the execution of an individual template acquisition, errors may occur that abnormally terminate that acquisition (i.e., communications errors with the MP unit, errors in calculation channel, disk errors, etc.). When the acquisition in progress is terminated due to an error, the batch acquisition will be halted as well.

- If a batch acquisition is aborted early, the batch output directory will contain the full result graphs for all of the templates that were previously completed successfully. It will also contain a partial graph file for the template that was being used at the time the acquisition was aborted. Templates that were not used will not have any associated graph files.

Resume

When a batch acquisition is terminated prematurely, the acquisition may be restarted from the first template in the sequence or from where it was stopped (e.g. the template with the error status).



Batch Acquisitions can be saved for use at a later time using File > Save Batch Acquisition As. Batch Acquisition files retain all of the settings for their individual templates and can be used even if the original templates used to configure the batch no longer exist or have been moved. Each template is acquired and saved into an output graph file that can be opened at a later point in time to examine the results.

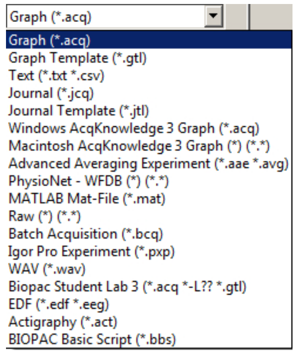
To open a Batch Acquisition, use File > Open and select type “Batch Acquisition.”

When a batch acquisition is started, the templates will acquire data in the order indicated from the specified MP unit. Files are saved before the next acquisition is started.

- If the batch acquisition completes successfully, the batch output directory will contain all of the graph files that were created during the acquisition. Each output graph is saved into a user-specified directory and is titled “Batch *n* - template name” where *n* is the order in the acquisition sequence.

Open

The File > Open command generates the standard file open menu, and supports a variety of different file formats from the popup menu at the bottom of the dialog.



Multiple files

To open multiple files in a single dialog, hold the Control/Command key down and select multiple files. To open consecutive multiple files in a single dialog, select the first file, hold the Shift key down and select multiple files. Acq*Knowledge* can only recognize one Journal file at a time, so multiple selection is disabled when the file type is set to Journal or Journal Template.

Graph The default file formats (*.acq) is referred to as "Acq*Knowledge*" files. The Acq*Knowledge* file format is the standard way of displaying waveforms in Acq*Knowledge*. These files are stored in a compact format that retains information about how the data was collected (i.e., for how long and at what rate) and takes relatively little time to read in (compared to text files, for instance). Acq*Knowledge* files are editable and can be modified and saved, or exported to other formats using the Save as command. Format options for the graph file include

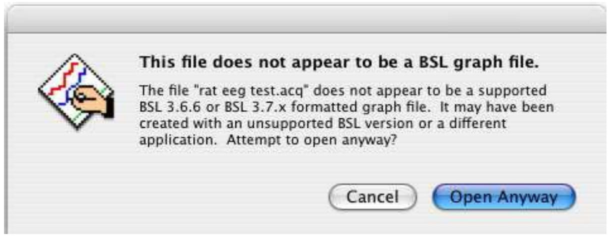
- **Graph**—Acq*Knowledge* 5
- **Windows Acq*Knowledge* 3 Graph**—previous release format
- **Macintosh Acq*Knowledge* 3**—previous release format
- **Biopac Student Lab *PRO* Graph**—import files created using the Biopac Student Lab *PRO* software; to open BSL Lesson files (.ldd), manually add the extension ".acq" to the end of the file.
  BSL File Import Notes

  BIOPAC produces two different software lines, the Acq*Knowledge* software for research and the BSL software for higher education. These two applications use different file formats, making it difficult to analyze data recorded in one with the other.

  Acq*Knowledge* can directly import data files that were created in Biopac Student Lab *PRO*. This allows data acquired with an MP36, MP35 or MP30 to be analyzed using the advanced analysis routines of Acq*Knowledge*.

  Hardware and calculation channel settings are also imported. This allows for the migration of some BSL *PRO* templates to Acq*Knowledge*. Only basic analog, digital, and calculation channels can be acquired; templates that use any of the BSLSTM or other output options are not supported.

  Importing is limited to graph files created with BSL 3.6.6 or higher. It is not possible to import files created with earlier versions of BSL. To import from earlier BSL versions, those files must first be opened with BSL 3.6.6 or higher and re-saved to disk to update the file format. The updated files can then be imported directly into Acq*Knowledge*.



When saving files, Acq*Knowledge* must save using the Acq*Knowledge* graph file format or another available export format. It is not possible to open Acq*Knowledge* graph files with BSL Lessons or BSL *PRO*.

Template Graph Template files (*.GTL)

This powerful feature allows for creation of a template file with predefined experiment parameters. Simply click "Start" to run the experiment.

The Graph Template option will save a copy of a master file and retains all settings for future acquisitions. Graph template files open to previously saved setup parameters (as established under the Hardware menu) primary graph window size.

This feature can be especially useful for recreating protocols in the laboratory. Set up an experiment, save it as a Graph template, then simply open the Graph template file and click the Start button to acquire data under the same settings.

When a Graph template file is opened:

NOTE

a) The graph window will not contain any data. (Since no data is saved in the template, arbitrary waveform output setups, which require a source date file, will not function in a template.)
b) The Journal window will contain all text entered and saved with the template—this is a handy way to place instructions or information about the experiment.

Acq*Knowledge* "***Quick Start***" (*.gtl graph template) files are available for over 40 applications. Just open the graph template file to establish appropriate settings for the selected application, and click Start. ***Quick Start*** files were installed to the Sample Data folder and can be used to establish the settings required for a particular application or as a good starting point for customized applications.

Text *.TXT*. Text files are a convenient way of transferring information between applications, and most spreadsheet and statistics programs are capable of importing or exporting data in a text file format. Acq*Knowledge* assumes that the text file contains numeric data laid out in columns and rows, and that there is some delimiter between each column. It also assumes that each column represents a distinct variable or channel of data. Normally, the values in each row represent the state of each variable at different points in time. When a text file is opened, the numeric values will be plotted as waveform data in a standard graph window. Each column of data is read in as a separate channel.

If non-numeric values are encountered, a dialog will appear warning that data will not be imported properly. In order for data to import correctly, the text file must consist entirely of numbers and the separators (tab, comma, or spaces) between them.

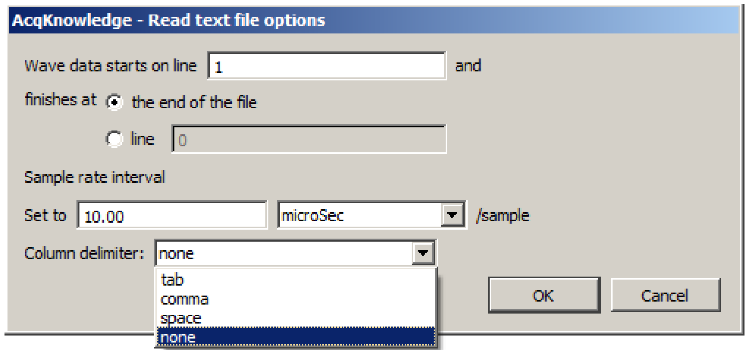
Journal **.JCQ*—Opens an independent journal; see page 53 for details.

Open the journal file from the File Menu (File > Open > Journal); right-clicking or double-clicking a saved Journal file will open a blank application window.

Jrnl Temp **.JTL*—Opens a journal template; see page 53 for details.

Options

When the Files of type: Text option is selected, an Options button is activated. Clicking on this button generates another dialog with options for controlling the amount and type of data to be read in, as well as the time scale for data display.



Wave data starts on line

To control how much data is read in, enter a value in the read line box at the top of the dialog. This tells Acq*Knowledge* which row contains the first data point in the series. By default, this is set to 1, although it may be necessary to set it to another value since some applications (usually spreadsheets) generate a "header," or text information at the top of a file. It's also possible to read in a limited amount of data by entering a value in the box to the right of the line radio button. This value indicates the last line to be read in as data. By default, text files will be read in starting at line one and data will continue being read in until the end of the file is reached.

Interval

To control the horizontal scale (usually time) for the text file after it is displayed in the graph window, change the Interval between sample points, which can be expressed either in terms of time or frequency. The interval between samples is equal to the reciprocal of the sampling rate; Interval = 1/(Sample Rate). For example, if data was collected at 50 samples per second, there is an interval between sample points of 0.02 seconds. Acq*Knowledge* would then assume that there is a 0.02 second "gap" between the data point in row two and the data point in row three (and all subsequent pairs of adjacent rows). Likewise, with a data file that spans 10 seconds and has 100 rows of data, the interval between sample points will be 0.01 seconds.

Most files contain time domain data, although some applications generate frequency domain data (the results of a spectral analysis, for example). The principle here is the same as with time data, that there is some interval between different frequencies. If a text file contains 20 sample points covering the range between 0 and 60 Hz, then the interval would be set to 3Hz per sample.

Column Delimiter

This setting tells Acq*Knowledge* what characters indicate a "gap" between two columns. This can be set to tab, comma, or space. All text files must have some sort of column delimiter, unless there is only one channel of data present.

- Tab delimited text files —the most common type— have a tab between each column for every row of data. These files are most often generated by spreadsheets and similar packages.
- Comma delimited files place a comma between each column of data for each row, much the same way as a tab delimited file. Statistics programs such as BMDP and SAS frequently create these types of files.

- Space delimited files are also commonly created by statistics packages, and place some number of spaces (usually two) between each column of data for every row which contains information.
- None. If uncertain which delimiter to use, select “none” and Acq*Knowledge* will automatically select a delimiter.

When either tab or comma is selected, Acq*Knowledge* will read in a new column each time it sees a delimiter, even if there are no numeric values between delimiters. For example, the following text file will read in three channels of data, although the channels will be of different lengths.

```
0.301424, 0.276737, 0.045015
0.338723, 0.808811, 0.542627
0.354271, 0.506313, 0.715995
0.001325, 0.762115
946207, 0.894992
0.926409,
```

Sample text file

The first channel will contain six data points, the first being 0.301424 and the last value being 0.926409. The next channel will contain three data points, starting with 0.276737 and continuing through 0.506313. The software considers that there is no other data values for channel two. The third channel starts with the entry 0.045015 and the last data point for this channel is 0.894992. There are only five data points in the last channel.

PhysioNet PhysioBank is a public service of PhysioNet and offers downloadable archives of gigabytes of “standard” data for cardiac arrhythmias, gait analysis, and other types of physiological signals. Acq*Knowledge* can use PhysioBank data directly and can be integrated with other software tools that understand this interchange format.

A PhysioBank file is usually comprised of several files, including a header file (usually “*.hea”), and all of the files must be located in the same directory for the PhysioBank record to open successfully. Open using the header file.

Opening a PhysioNet file will import data and annotations into a new graph window. If “atruth” annotations exist, they will be translated into appropriate events on the appropriate channel. All annotation types are retained except LEARN annotations, which are treated as UNKNOWN.

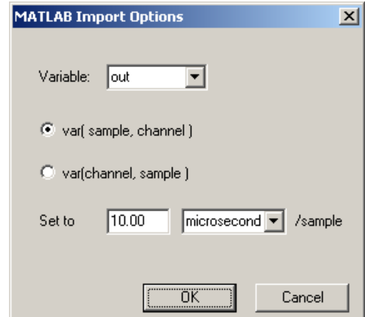
MAT MATLAB® format Acq*Knowledge* can open files created as a MATLAB work space.

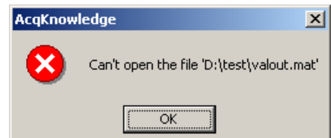
- Available only in the Windows® release of AcqKnowledge: import MATLAB® version 6 files containing specific workspace variables (see below). In MATLAB®, add "-v6" to the command line when saving files in order to store workspace variables in version 6 format.
- Interoperability with earlier versions of MATLAB is not guaranteed.

Uses the “MAT-file” binary format to load numerical and textual information. If the MAT-file is properly formatted with the following arrays, Acq*Knowledge* will reconstruct the graph with appropriate sampling rate, channel labels, units, and data:

data units labels isi isi_units start_sample

- MATLAB files open with no Start button.
- If the MAT file is missing any of the expected variables or contains extra variables, only one two-dimensional array variable can be imported into a graph. A MATLAB Import Options dialog will be generated. Choose which variable data is stored in, what dimension maps to samples, channel indices, and sample rate, and then click OK to open the file.
- If Acq*Knowledge* can't recognize the file format, an error prompt will be generated and a blank graph window will be opened.





Raw This low-level data exchange option interprets all data at a single sample rate; variable sample rates are not supported. All of the data will be unscaled when opening (importing) files. That is, a value of 0 will be imported as a zero voltage. Scaling will need to be manually applied to the data. Options to open (import) raw data:

Data type:	32-bit or 64-bit IEEE floating point format or 8-, 16-, and 32-bit integer formatted data
# of channels:	Enter the number of channels stored in the data file as a positive integer less than or equal to 60.
Layout:	*Packed sequential*: All of the data for an individual file is located in a single block of the file and multiple channels follow one another. *Interleaved*: Data is grouped into a single "frame" for each sample location with one data element for each channel, so data for a particular channel is spread throughout the file (similar to Linear PCM audio file format).
Endian:	Little and big endian byte ordering, matching the data formats of x86 and PowerPC/Sparc, respectively. Set to big for Mac-Power PC generated raw files (default), or to little for Mac-Intel generated or Windows-generated raw files.
Set to *x*/sample:	Specify the *inter sample interval* of data in the file, which will be translated into an appropriate sampling rate. The edit field will accept an arbitrary floating point number. The units menu contains µsec, msec, sec, MHz, kHz, Hz. The edit field will be dynamically converted to match the units selection; no conversion will be used when switching between frequency and time.

Batch Batch files (*bcq) is the format used for a saved Batch acquisition setup. All previous configurations are saved in this file, so a Batch experiment can be rerun without having to repeat the setup. When a saved Batch file is opened, the batch setup window appears with previous graph templates intact. From here, the setup can modified and saved under the same or a different name.

Igor Pro Igor Pro Experiments (compatible with Igor Pro 3.1, 4.0, and 5.0).

The waves contained in an Igor Pro packed experiment can be opened (imported) in Acq*Knowledge* provided that the packed experiment files comply with the following:

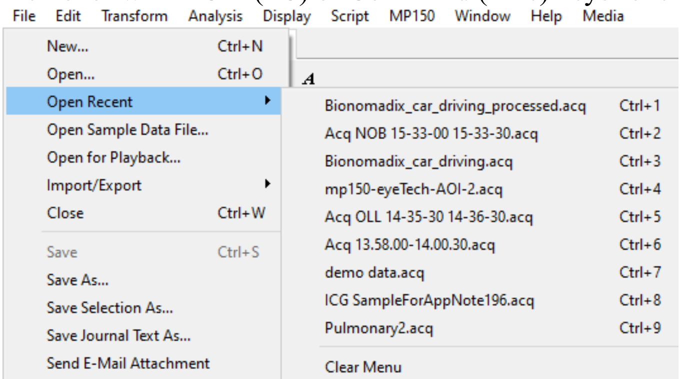
- no text waves
- no complex waves
- all waves in Version 2 or Version 5 format (Igor defaults)
- all waves one-dimensional (vectors)
- all waves multiples of the same fundamental inter sample interval

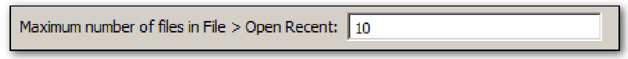
If the wave has an associated wave note, it will be used as the channel label.

WAV	WAV files containing 60 channels or less can be imported. When this format is chosen, the list of available files will be filtered such that only files ending in the".wav" extension or having the "WAVE" type are shown. When a WAV file is selected, it will be analyzed to determine if it is compatible with the Acq*Knowledge* application. If the file is compatible, a new graph window will be created displaying the data contents of the WAV file. • Each channel will be numbered "Channel *n*" where *n* is an increasing digit. These channels will be unitless in amplitude. • All of the data will be converted into the 64 bit floating point format for storage in memory and in the ACQ formatted files on disk. • The horizontal axis of this graph will be set to time and the sampling rate set to match the rate as specified in the WAV file headers. • This graph will be marked as an imported graph into which data cannot be acquired. • This will dim the start button and any appropriate hardware menu entries that would be used to access the invalid hardware settings.
EDF	Opens files with .eeg and .edf extensions saved in European Data Format (EDF). Data is imported entirely into memory in a newly created graph window titled after the filename, similar to other file import routines. All scaling factors will be applied to the data as it is imported, and it will be converted to double precision floating point format. Since EDF format includes data that is not used by Acq*Knowledge*, only the following items are imported: • channel data • channel labels • units • sampling rate (taken from maximum sample rate of all channels) All other information stored in the EDF file will be discarded when the file is imported. Only 60 channels of data can be imported from an EDF file. Channels will be imported starting with the graph file index 1. If there is a 60th channel, it will be placed into the channel with index 0. If an EDF file contains more than 60 channels, only the first 60 channels will be imported and a prompt will advise that not all of the channels could be imported.
ACT	Opens actigraphy files generated from analysis of existing accelerometer data files related to sleep studies and wake/sleep activity. Actigraphy licensed functionality is required for this file format to be active. For information on Actigraphy, see page 589.
BBS	Opens Biopac Basic Scripting files. Biopac Basic Scripting licensed functionality is a scripting language development option for Acq*Knowledge.* For more details, see page 533.

Open Recent

The File > Open Recent command generates a list of recently used files. These files can be opened directly from the list or with a Ctrl (PC) or Command (Mac) keystroke combination.





The listed files appear in the order they were opened, with the most recently-opened file appearing at the top. Default number of files appearing in the list can be modified in the Preferences. (Display > Preferences > Other or Main Toolbar)

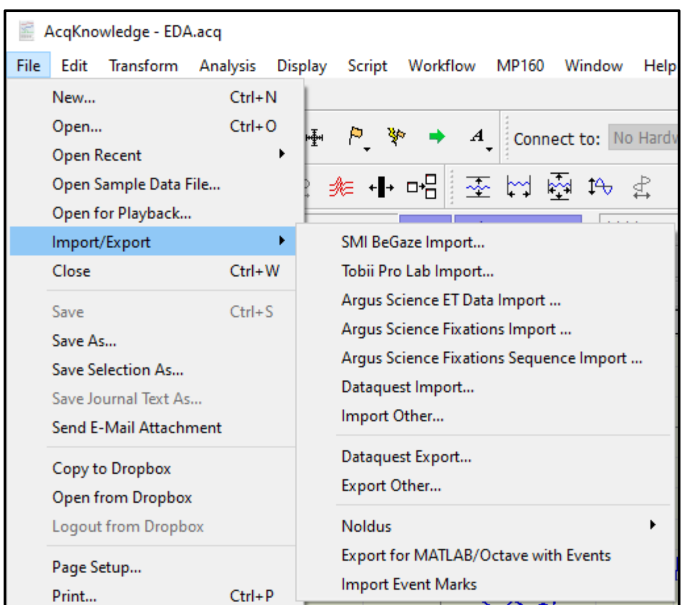
Open Sample Data File

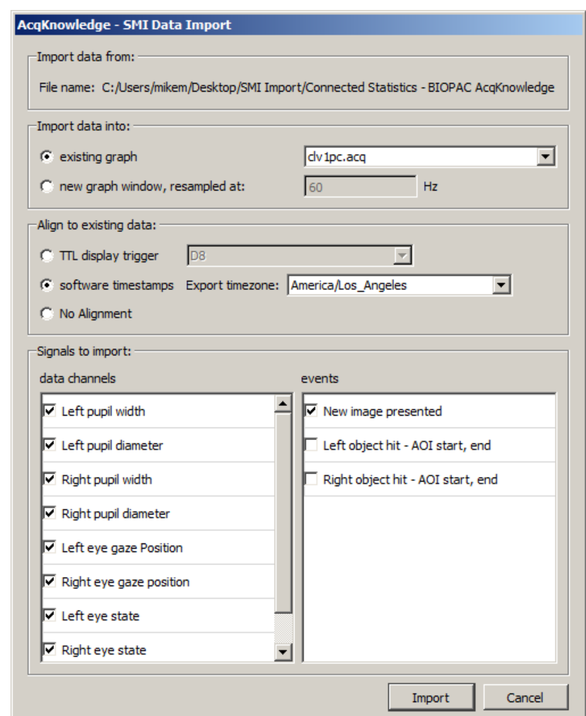
Allows easy access to Acq*Knowledge* Sample Data files, eliminating the need to navigate to them manually.

Open for Playback

The File > Open for Playback command generates a standard file open dialog; see page 41 for Playback details.

Import/Export





This option allows for importing of data from third-party programs into an Acq*Knowledge* graph. The following formats are available for import:

SMI BeGaze Import—Imports SensoMotoric Instruments BeGaze software's eye tracking data and aligns the data with other physiological signals recorded in Acq*Knowledge*. In order to use the SMI BeGaze Import feature in Acq*Knowledge*, the BeGaze eye tracking data must first be exported to a text file format readable by Acq*Knowledge*. (BeGaze software offers text file export of the eye position, pupil width measurements, analyzed data and eye tracking events.) BeGaze eye tracking data can then be imported into an existing Acq*Knowledge* graph, a new graph, or aligned to existing data.

To use TTL display trigger synchronization, the digital output line from the SMI hardware must be connected to the hardware unit used for recording record data, and digital channels must be enabled during data acquisition. The time of the first image presentation within the BeGaze data will be placed at the first positive peak within the digital signal.

The software's timestamp alignment will extract the recording time from the BeGaze data and align it with the internal Acq*Knowledge* timestamps. For more details about timestamp alignment, see page 296.

When importing and aligning data to an existing graph, physiological data must be recorded into a single segment. Data recorded as multiple appended segments will not be properly aligned.

BeGaze exports may contain only a subset of the recorded and analyzed data. Signals not present in the export file will be removed from the 'Signals to import' checkbox options.

Importing SMI Begaze Data into Acq*Knowledge*

Use this feature to import eye tracking data from SMI BeGaze software into Acq*Knowledge*:

1. In Begaze software, export the eye tracking data to *.txt format and save the file.
2. Launch a new graph in Acq*Knowledge* or open an existing graph for BeGaze data import.
3. In Acq*Knowledge*, choose "File > SMI BeGaze Import" and navigate to the *.txt file exported in Step 1 and click "Open." This will launch the SMI Data Import setup screen.
4. Under "Import data into:" choose the Acq*Knowledge* destination graph for SMI Begaze data import.
5. Choose the desired alignment option (digital trigger signal, timestamps from Aqc*Knowledge* and SMI data, or no alignment.)
6. Select the eye tracking signals and SMI events to import and click "Import."

The selected SMI signals and events will be placed into the Acq*Knowledge* graph at the appropriate locations. Eye tracking video created in the BeGaze software can be also be exported to Acq*Knowledge* and synchronized with the graph data by using the "Sync SMI Video" feature under the Acq*Knowledge* Media menu. The video synchronization is accomplished by extracting timestamp information from the exported BeGaze file.

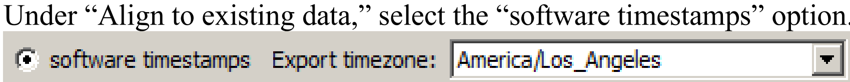
- Watch the Acq*Knowledge* SMI BeGaze import and synchronization video tutorial for a detailed demonstration of this feature.

Using the Software Timestamps Option to Align Data

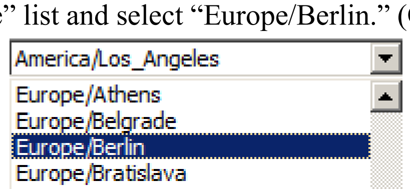
If the existing Acq*Knowledge* graph and SMI *.txt file selected for import were recorded in different time zones, selecting the "software timestamps" option helps compensate for the time zone disparity and aligns the data accordingly. In order for the timestamp alignments to be accurate, it is essential to know the time zone the SMI *.txt file was recorded in. (The "export time zone" default setting is determined by the clock time/date properties of the Acq*Knowledge* computer.) However, if the SMI eye tracking data was exported from another computer in a different time zone, changing the "export time zone" parameter to match that time zone will help properly align the imported data with the current time zone of the Acq*Knowledge* graph. This is best illustrated in the following example.

In this example, the exported SMI BeGaze eye tracking data selected for import into Acq*Knowledge* was recorded in the "Europe/Berlin" time zone, while the Acq*Knowledge* graph was recorded in the "America/Los Angeles" time zone. To synchronize both files timestamps to the current time zone:

1. Follow Steps 1-4 from above ("Importing SMI BeGaze Data").
2. Under "Align to existing data," select the "software timestamps" option.



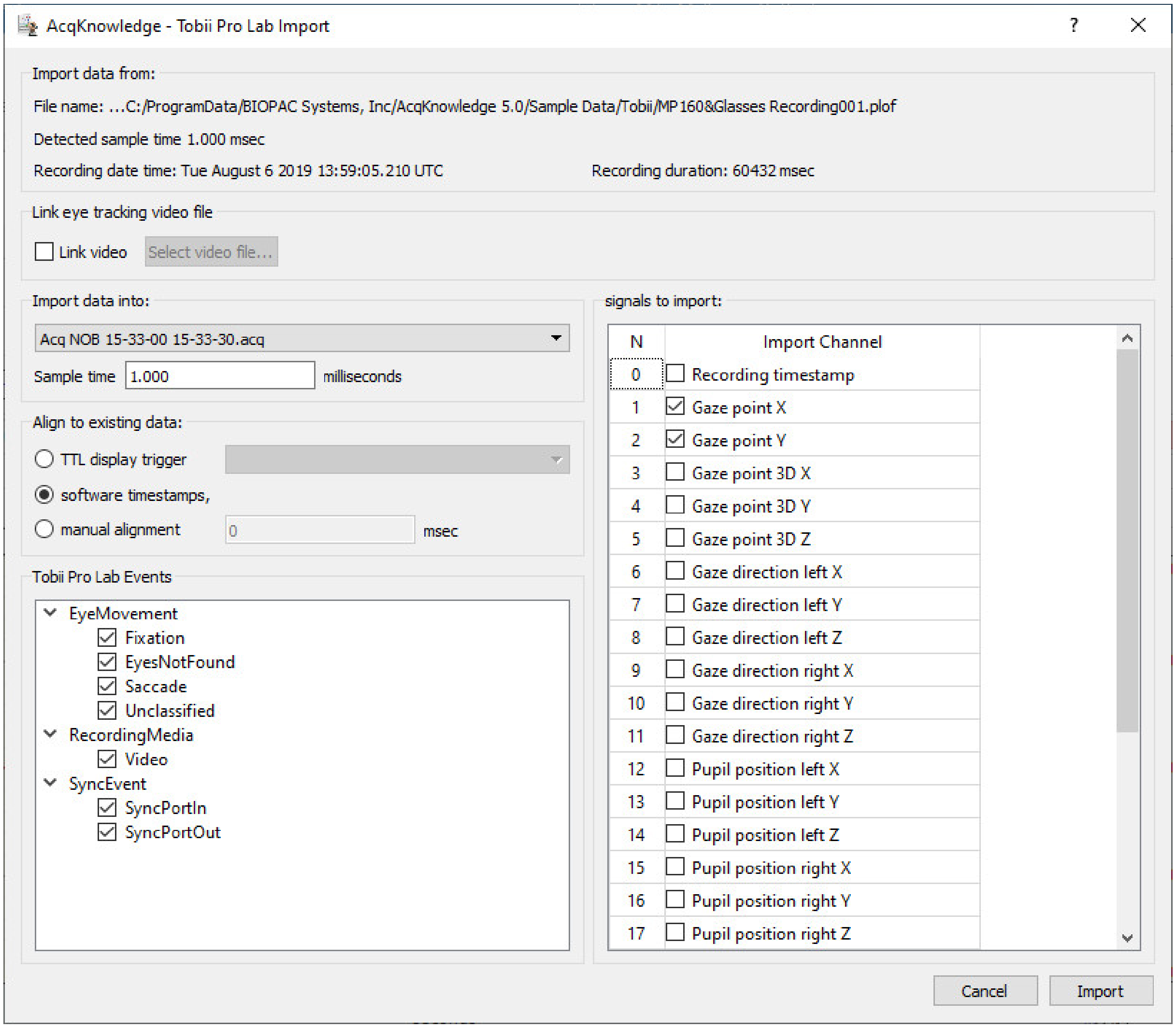
3. Scroll down the "Export time zone" list and select "Europe/Berlin." (Or an applicable time zone.)



4. Click "Import."

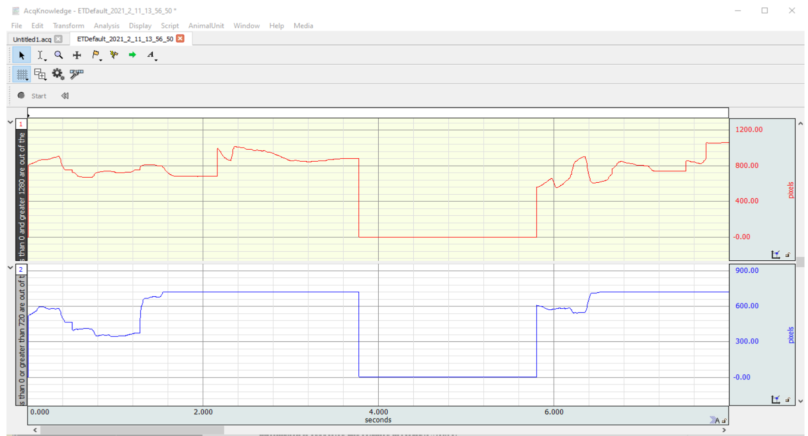
If the Acq*Knowledge* graph and the SMI BeGaze file selected for import were recorded/exported in the same time zone, it is not necessary to use the "software timestamps" alignment option. In this instance, choose the "No alignment" option.

Tobii Pro Lab Import

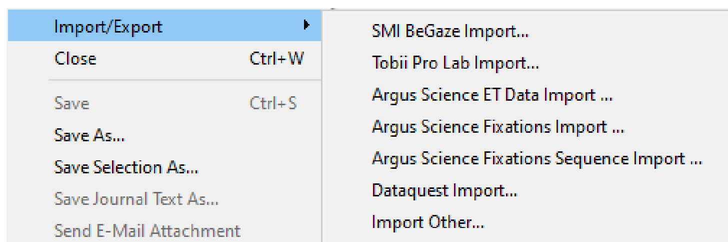


Tobii Pro Lab is eye tracking software integrated with Tobii eye tracking hardware products, such as Tobii Pro 2 eye tracking glasses. Acq*Knowledge* supports the import of Tobii Pro files (*.plof and *.tplde) into a new or existing Acq*Knowledge* graph. To import Tobii data, choose File > Import/Export > Tobii Lab Pro Import, navigate to the Tobii data file, and click "Import." After Tobii data is imported, the Acq*Knowledge* screen shown above will appear. Use these controls to customize the Tobii eye tracking data for import into an Acq*Knowledge* graph.

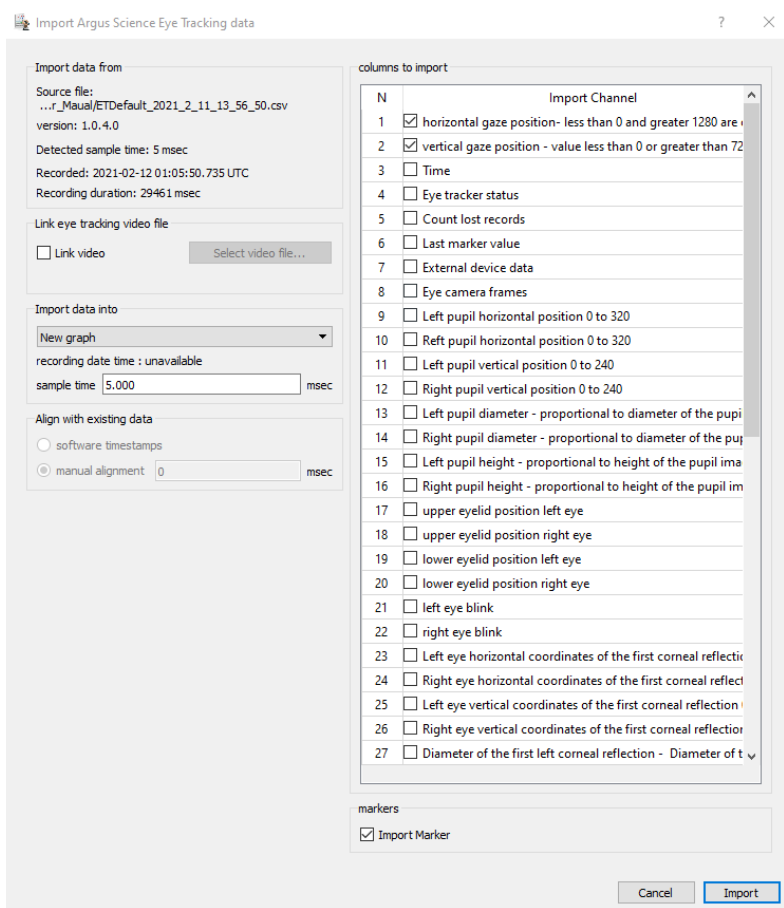
Argus Science/ETVision Import



Argus Science eye tracking software is known as ETAnalysis and supports ETVision glasses. Acq*Knowledge* supports the import of Argus ET Data (*.csv), Fixations(*.xml), and Fixations Sequence (*.xml). To import Argus Science data, choose File > Import/Export and select from the three Argus Science options.



Recorded videos of eye tracking can be linked by enabling “Link Video” under the **Link eye tracking video file** section and selecting a video file. Experimenters can also configure whether this data goes into an existing Acq*Knowledge* graph or a new graph, adjust sample time, and align with existing data in an existing graph. This import function displays a prompt to select specific columns to import. These columns will autofill with specific channels of data that were recorded during data acquisition, but can be added to the graph as needed.

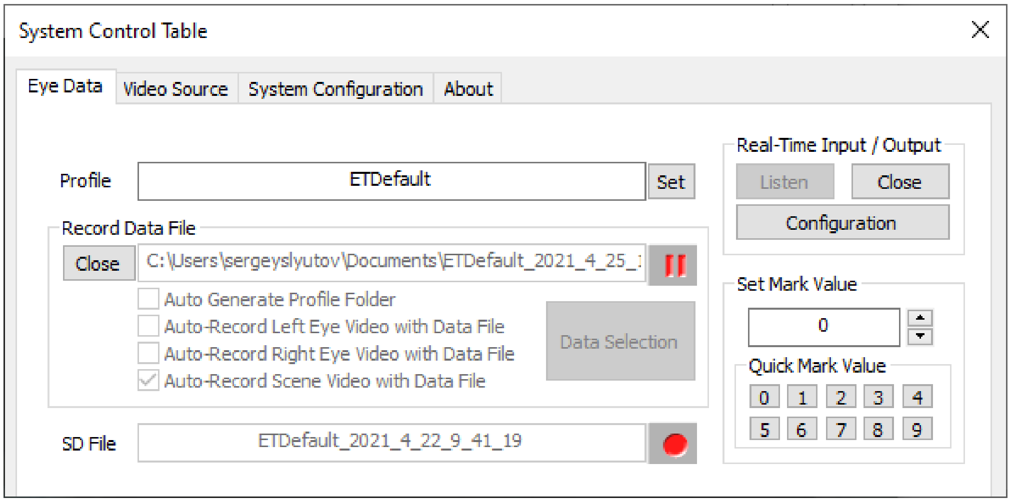


Click “Import” to open an Acq*Knowledge* graph with the selected graph presets and ET data or Fixation/Fixation Sequence data.

To synchronize automatically with Acq*Knowledge*, ETVision can record data directly to *.csv files during a session with ETVGlasses. Follow the subsequent steps for automatic synchronization.

1. Start ETVision and connect to ETVGlasses. Video from the scene and eye tracking cameras should play in real time if the glasses are connected
2. Open the System Control Table
3. Navigate to the Eye Data tab.
4. Click “Data Selection”.
5. Select the channels to be recorded. Close the “Data Selection” dialog.
6. In the Eye Data tab, check the checkbox “Auto-Record Scene Video with Data File”. This option records the video stream and selects the cameras used in the presentation.
7. Navigate to “Record Data File” and select “File.”
8. When prompted, save the *.csv and *.wmv files to a specified location.

9. In the Eye Data tab, clicking the  red circle will cause ETVision to begin recording data into *.csv and *wmv files for data and video/media, respectively. Clicking record saves the current time as a timestamp in the *.csv file. This timestamp is used for synchronization with other data when importing into Acq*Knowledge*.
10. Start Acq*Knowledge*. and create a graph.
11. Start data acquisition in Acq*Knowledge*.
12. Click the record icon in the Eye Data Tab in ETVision.



13. When the experiment is complete, stop the Acq*Knowledge* data acquisition and the recording in ETVision.
14. In Acq*Knowledge*, navigate to File > Import/Export -> Argus Science ETData Import.
15. Select the *.csv files saved from the ETVision recording for the import.
16. Click “Link Video” if attaching the video is desired. Select the *.wmv file and click “Link”.
17. Select software timestamp under “Align with existing data”.
18. Import is always applied to the first segment of data in the target graph.

    Note: Data timestamps can be found from the “Import Argus Science Eye Tracking data” menu for all *.acq and *.csv data sources. Use this information before running the import to verify the selected files are correct. The time is presented in UTC time zone. ETVision writes the date & time corresponding to the moment the application began writing data to the *.csv file. This time will correspond to the “software timestamp” option for aligning with existing data.

20. Select the desired channel and click “Import”. The import is always applied to the first segment of data in the target graph.
21. If the “Autoscale” button is clicked on the graph, data will be arranged for a more convenient presentation.

    Note: ETGlasses *must* be used as the data source during recording in ETVision in order to allow automated synchronization based on timestamps.

For additional information about Argus eye tracking glasses, see Chapter 34.

Dataquest Import

Dataquest ART is a data acquisition software package from Data Sciences International (DSI). This package is used with a variety of devices including implantable telemetry units. The File > Dataquest Import option allows data acquired from ART files to be directly extracted into Acq*Knowledge*. The following Dataquest file information is supported and retained in Acq*Knowledge*:

- Data accuracy
- Retention of animal IDs

- Import of either waveforms or parameters
- Provides choice of animal subjects to be imported

Dataquest File Description

Unlike graph files, Dataquest ART saves data as multiple files in a single directory. Each file may be either a continuous recording or consist of multiple segments.

A recording may contain multiple animals/subjects. Each animal/subject is given an animal ID. This animal ID forms the basename of all of the various Dataquest data files.

Two primary types of data are recording for each animal: waveforms and parameters. Waveforms are the semi-continuous raw data recorded from transmitters during the segment. For multi-channel recordings, each channel may have an independent sampling rate and the sampling rate may vary within an individual channel for an individual experiment, but the duration and recording frequency are identical across all channels and animals. Parameters are derived measurements such as heart rates, mean pressure, and other values derived from the raw data. The user's protocol may dictate which type of data will be useful in the analysis, but many DSI customers perform further data reduction on the parameters instead of working with the raw data.

Dataquest splits waveforms and parameters up into separate files. Specific ID parameters are stored into a sequence of files named "ID.P##" where ## is a continual incrementing sequence of alphanumerics 0-9A-Z. Each individual waveform is stored into a series of files named "ID.C##." C is a single character indicating the channel number 0-9A-F, for up to 16 channels. ## is a continual incrementing sequence of alphanumerics 0-9A-Z, similarly to parameter files.

Each individual parameter or waveform file may contain data from multiple segments. A new file is created once the size of a particular storage file reaches a user-specified limit. The total number of files, therefore, does not necessarily equal the number of segments.

The data for each specific segment in the file also contains a timestamp indicating the calendar time of the beginning of the segment.

Creating Graphs from Dataquest Data

Although related, waveforms and parameters are very different types of data. Acq*Knowledge* primarily stores and analyzes continuous signals. As parameters are not continuous signals, they are not easily combinable with waveforms in a single graph. Therefore, parameters and waveform data are imported differently.

Waveform Graphs

Waveform graphs are imported with waveform data within individual channels. Dataquest waveforms may have different sampling rates for each individual waveform and potentially varied sampling rates within an individual waveform. The imported graph's sampling rate will be set to the highest sampling rate of all segments of the file.

If a file contains multiple animal units, the animals can be selectively imported. By default all animal units are imported into a single graph.

Each data segment is separated by an append marker to allow the use of Find Cycle across discontinuous data segments. The append marker label corresponds to the segment timestamp of the in the local time zone.

For each animal with ID, the individual channels are imported with labels as "ID – label" if the DSI file contains a label for the channel. If there is no label is found, it will be labeled with its index "ID – Channel C" where C is the index from the beginning of the specific DSI file extension.

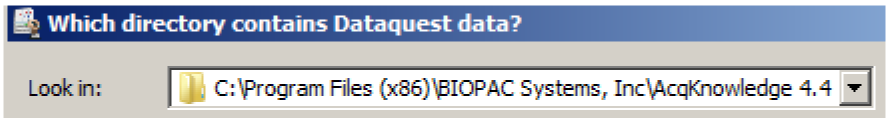
Parameter Graphs

Parameters are stored by Dataquest as one set of numbers per segment. Parameter graphs are imported using the same approach as rate detector XY output graphs. The graph will be set up as an arbitrary horizontal axis labeled “segment index.” Each parameter will be imported into a single graph channel, with the channel named “ID – Param,” “ID” replaced with the animal ID, and “Param” replaced with the name of the parameter as read from the Dataquest DSI file. The parameters are then imported as data points.

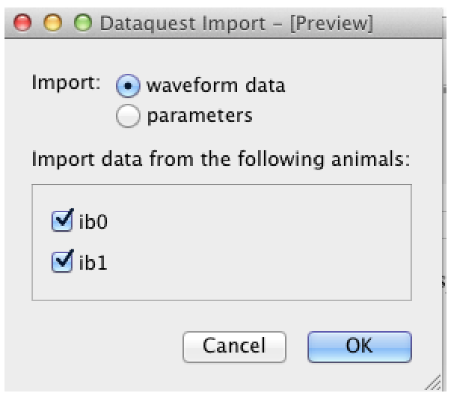
Only subsets of animals may be chosen; all parameters will be imported for the chosen animals. Users wanting a subset of parameters may optionally erase or hide graph channels after the data is imported.

To Import Dataquest files into Acq*Knowledge*:

1. Choose “File > Dataquest Import.”



2. Navigate to the Datquest file and click “Choose.”
3. Make the desired selection in the Dataquest Import dialog and click OK.



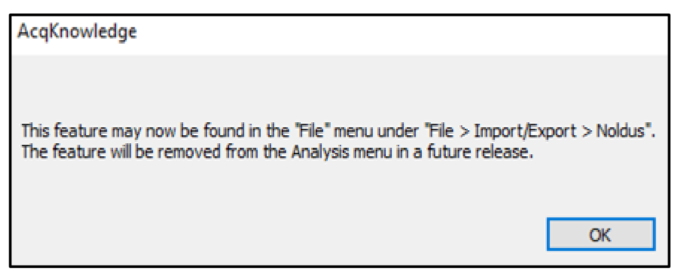
Dataquest Export

Opens a destination directory to export files to Dataquest format.

Noldus

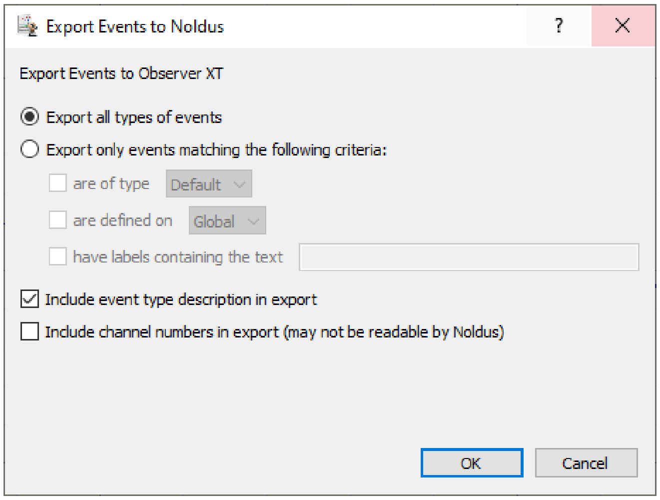
Acq*Knowledge* supports import and export of event mark information in Noldus The Observer XT format. The Observer XT is a popular behavioral analysis software package and the Acq*Knowledge* The Observer XT feature allows behavioral markers to be imported from The Observer XT into Acq*Knowledge* and Acq*Knowledge* marker information to be exported into The Observer XT-compatible files.

NOTE: Since Acq*Knowledge* 5.0.8, this function has moved from the **Analysis** menu to the **File** menu. While the option still appears under the tab Analysis > Noldus, choosing these options opens the following dialog box.



Under the “File” menu navigate to File > Import/Export > Noldus. The following options are available:

Export Events to The Observer XT



Acq*Knowledge* events can be exported to The Observer XT by "all types" or based upon selective criteria.

Check boxes allow the inclusion of event type descriptions in the exported file as well as channel numbers in the export file.

NOTE: Channel number information is not readable by The Observer XT. This feature was added to the event mark export function so that exported information can completely characterize the event marks as they appear in the Acq*Knowledge* graph window. This box should not be checked when files are being created specifically to be read in by The Observer XT.

Import Markers from The Observer XT

The Import markers feature will read The Observer XT file data and define the events in the active Acq*Knowledge* graph. For each range of behavior, a pair of global markers will be added with labels correlating to the behavior type as well as the start of and end of the behavior.

Import FaceReader Data

Launches a File Open dialog for importing data from tab-delimited FaceReader export files (*.txt format).

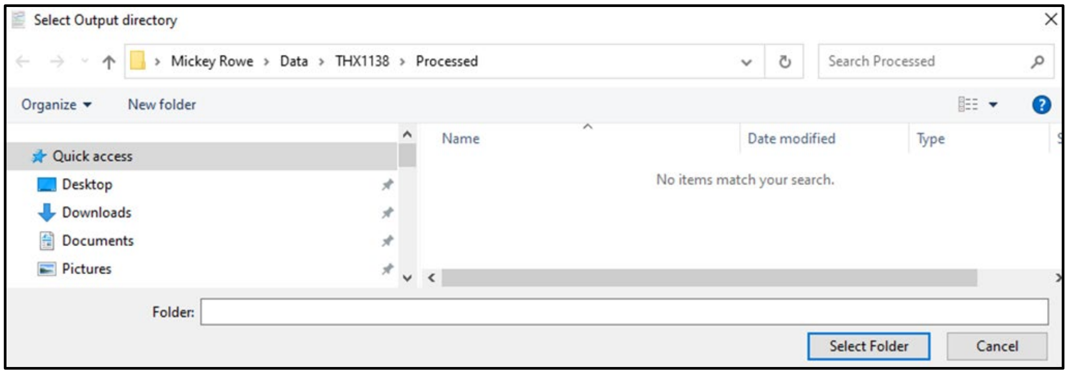
- Watch the Acq*Knowledge* Noldus The Observer XT import and export video tutorial for a detailed demonstration of this feature.

Export for MATLAB/Octave with Events

This feature allows users to generate data and associated event marker files that can be read in MATLAB or its free equivalent, Octave. Exporting an Acq*Knowledge* graph file with this function generates two files. (NOTE: Since MATLAB file export is currently unavailable in Acq*Knowledge* for Mac, the .mat file is not created when the function is run on that platform). The first is a MATLAB (.mat) data file with the same name as the original Acq*Knowledge* file (the .acq file extension is replaced by ".mat"). There are exceptions to this rule when there are spaces or special characters in the file name*. The second is an event marker file with the addition of "Markers.m" to the original graph file name. For example, using this function will convert an Acq*Knowledge* file called "EDA.acq" to two MATLAB-compatible files called "EDA.mat" and "EDAMarkers.m."

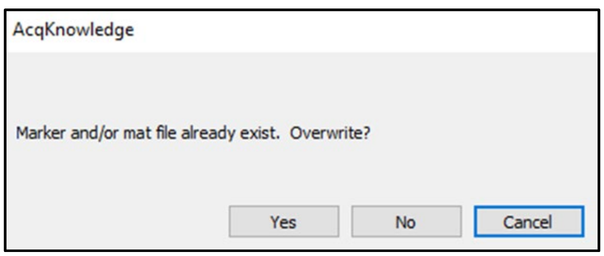
Generating and Saving Files

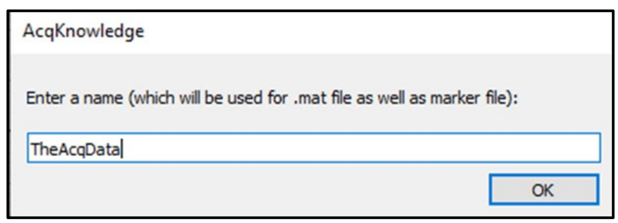
With a graph file open, go to File > Import/Export > Export for MATLAB/Octave with Events. A "Select Output Directory" dialog box will open (see below) and the user will be able to choose the folder where the .mat and .m files will be saved.



Once the files are successfully saved, Acq*Knowledge* will display the dialog box "Marker and .mat files written!" Click **OK** to close the dialog.

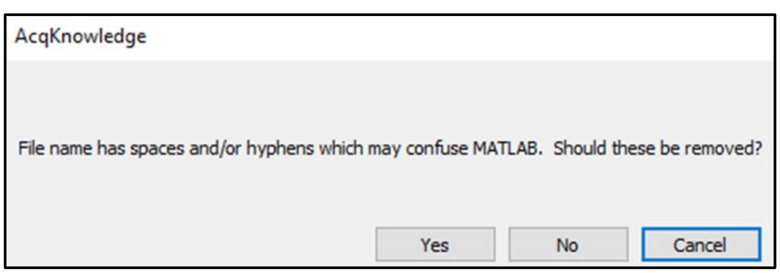
If another file exists with the same name, a dialog will appear stating "Marker and/or .mat file already exists. Overwrite?" If using a Mac, the message will exclude references to the .mat file. Click **Yes** to overwrite the existing file. If the user clicks **No**, they will be given the option to rename the new files.





***Note Regarding .m Marker File Names and MATLAB**

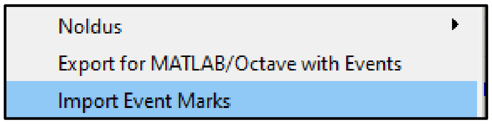
The .m files each contain a function. To import the event mark information into MATLAB/Octave, this function should be called from the command line or a script in MATLAB/Octave. To prevent MATLAB/Octave from interpreting a space as the end of the function name or a hyphen as a minus sign, the script will optionally remove such characters from the names before saving the files. If a file name contains spaces or hyphens, the following dialog will appear.



Clicking **Cancel** closes the dialog box and stops the execution of the script. Clicking **Yes** removes any spaces or hyphens from the graph window name before using it as the base name for the two files to be saved. Clicking **No** will cause the graph title to be used as the base name for the two files exactly as is (users may wish to manually edit names later).

Import Event Marks

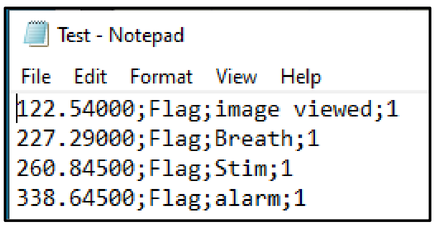
This feature allows users to create a list of event descriptions, labels, and times that can be read into Acq*Knowledge* from a text file (.txt) to efficiently insert multiple event marks at once. Select **Import Event Marks** from the **Import/Export** pull-down menu.



Selecting this option will open the "Open Event Mark File" navigation window. Navigate to the text file (.txt) containing the event mark information to be imported. Select the file and click **Open**.

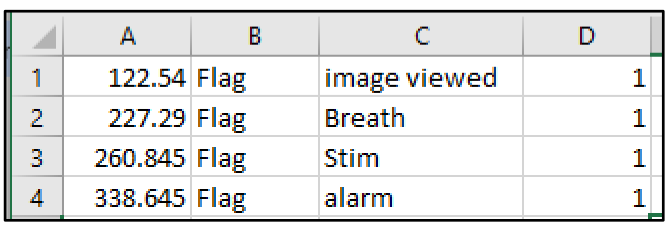
Import File Format

Event marks in the import .txt file should be formatted with each of the data categories separated by a semicolon as follows: time (in seconds); event type description; label; channel number (-1 for Global). See example below.



This function accepts files created by the Export Events to The Observer XT function and will make use of all information, including channel information included in such files.

Users may also wish to create event mark text files using a spreadsheet. To do this, sort the data for time, event type, label, and channel into columns as illustrated below and save the file as text file (.txt) with semicolon delimiters.

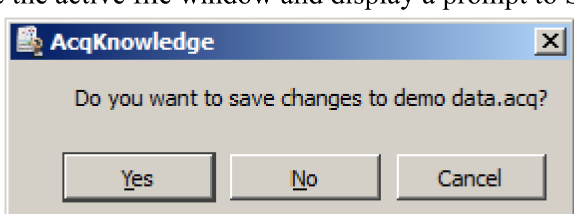


	A	B	C	D
1	122.54	Flag	image viewed	1
2	227.29	Flag	Breath	1
3	260.845	Flag	Stim	1
4	338.645	Flag	alarm	1

The import function adds event marks to a graph file without removing existing event marks. If the user needs to re-import event marks into an existing graph file, the user should first clear any existing event marks that may be duplicated when they are re-imported.

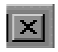
Close

This File menu command will close the active file window and display a prompt to Save.



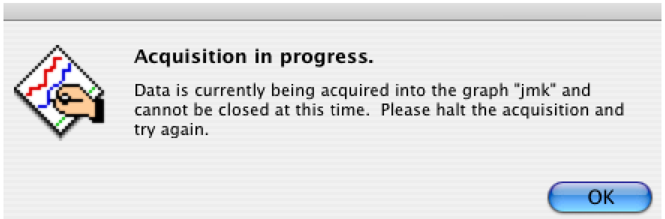
TIP: To close multiple graph files at the same time, hold down the Alt/Option key while closing a file. All graphs must be saved in order to use this keyboard shortcut.

Close without saving

- *Windows*—click the  in the upper right corner of the file window
- *Mac OS*—click the  in the upper left corner of the file window

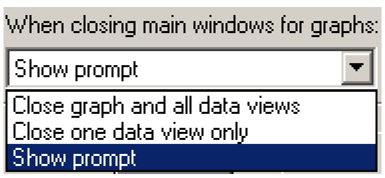
Click “No” to the Save Changes prompt.

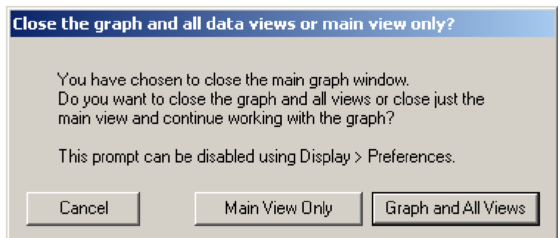
Close during acquisition



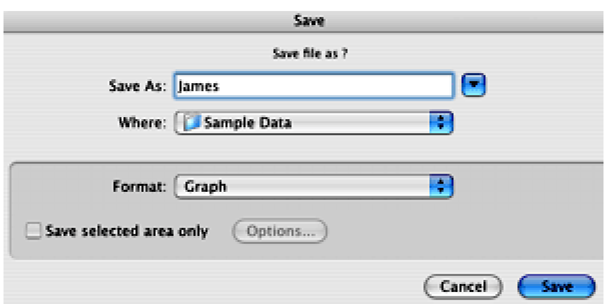
Close multiple data views

Set the level of close functionality under Display > Preferences > Other or Main Toolbar.





Save



This menu command will save any changes made to a file. If more than one file is open, this command applies only to the active window. For untitled files, a name file prompt will be displayed. The file will remain open after the save is complete, allowing for continued work on the file.

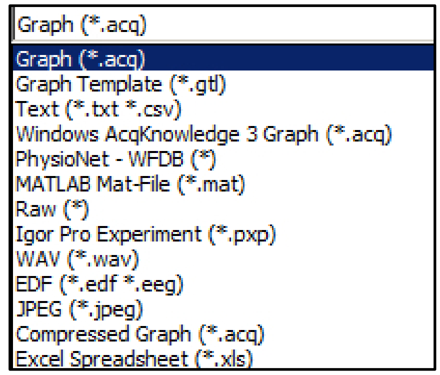
- The Save menu is dynamic and corresponds to the type of file to be saved, i.e., Save Graph, Save Journal.

Files should be less than 2 GB, except Acq*Knowledge* 3.9 “Graph” files on the Mac, which can be larger if not compressed. Data files greater than 2 GB can be opened, but edit, transformation and analysis operation cannot be performed.

To save data in another format (such as a text file), use File > Save As.

Save As

Choosing File > Save As produces a standard dialog that allows saving of data in a variety of formats and to any location. As with all dialogs, use this to save a file to a different file name or directory than the default settings.



Graph Acq*Knowledge* format

The default file format for the File > Save as command is to save files as an Acq*Knowledge* 5 file, which is designed to be as compact as possible. These files can only be opened by Acq*Knowledge* 4, but data can be exported to other formats once it has been read in.

- To save in the previous release format, choose **Windows Acq*Knowledge* 3 Graph**. When a file is saved in Acq*Knowledge* 3 format, the following calculation channel types will revert to Integrate: Band Stop Comb Filter, Adaptive Filter, FLC, WFLC, CWFLC, Rescale and Metachannels.

File Compatibility

Windows Acq*Knowledge* cannot save as Macintosh Acq*Knowledge* files.

Macintosh Acq*Knowledge* 3.9 and above can save as “Graph (Windows)” files, but it saves in Windows Acq*Knowledge* 3.7.1 format. In this earlier format, all data is retained, but new Windows Acq*Knowledge* features (like dual stimulation, data views, embedded archives, etc.) are lost along with any settings specific to Macintosh Acq*Knowledge* (like events, adaptive scaling settings, etc.).

- Macintosh Acq*Knowledge* 3.9 and above can save PC-compatible Graph (*.acq) and Graph Template (*.gtl) files. Variable sampling rate information and hardware settings are retained, and Journals can be read from and written to PC files. Choose the format “Graph (Windows)” to create PC-compatible files.

GTL Graph Template

This feature can be especially useful for recreating protocols in the laboratory. Set Up an experiment and save it as a Graph template, then simply open the Graph template file and click the Start button to acquire data under the same settings.

TIP: Check the existing ***Quick Start*** template files listed on page 290 before creating or saving a new template. With over 40 templates provided, one might be a close match to the settings required for a particular application or to use as a good starting point for customized applications.

The Save As Graph template option saves the setup parameters established under the hardware menu and retains the size of the primary graph window. In general, the minimum file size for graph templates is 700 K-800 K; file size may increase as setup options are enabled.

When a file is saved as a Graph Template:

a) No graph data will be saved.

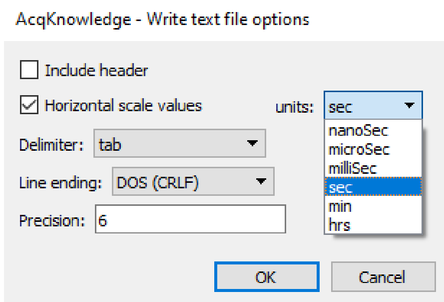
NOTE

- Since no data is saved in the template, arbitrary waveform output setups, which require a source date file, will not function in a template.
- It’s necessary to select Save / Save as and select “File of type .ACQ” to save the graph data.

b) Journal text will be preserved. Any entered text will be saved to the Journal window and stored with the template—this is a handy way to place instructions or information about the experiment for future reference.

Text

TXT Saves graph data in text format. When Save As Text is selected, an Options button is generated. Clicking on this button generates a Save Options dialog that allows control over how much data is saved and the format it is saved in.



Include header

When the first box is checked, a "header" is included at the top of the text file that contains information about the sampling rate, number of channels, date created, and other information relating to the data. This information is frequently useful, but some programs will attempt to read in the header information as data, which could result in nonsensical results. Including the header is recommended as it can always be edited out later using a text editor or the journal.

Horizontal Scale

Enabling this checkbox will include the horizontal scale (usually time) values in the text file, along with the data to be saved. This allows time series plots to be produced in other applications, as well as correlating events to time indexes in graphing and statistical packages. Since a separate row is generated for each sample point, To exceed the limitations of programs if data is collected at a fast sampling rate (many spreadsheet programs are limited to about 16,000 rows). It's recommended to consult the section on resampling data after an acquisition is completed (page 355).

Effective in Acq*Knowledge* 5.0.6, horizontal time scale units are now selectable when saving or exporting graphs as text or comma-delimited files. Time units' options are: hours, minutes, seconds, microseconds, and nanoseconds. For frequency graphs (such as FFT), horizontal units are exported as millihertz, hertz or kilohertz.

Delimiter

When data is saved as a text file, each channel of data is saved as a separate column, with the number values for each data point saved in rows. Use the pop-up menu to select the delimiter to separate the columns of data in the text file. By default, a tab is placed between each column for every row of data; this format is called a tab-delimited text file and almost all applications will read in tab-delimited text files. Data can also be saved in a comma-delimited format or a space-delimited format.

Line ending

Use to create text files that are compatible with Classic Mac OS applications (Mac), Unix-compatible applications (Unix), or PC-compatible applications (DOS).

Precision

Use to define the number of significant digits used for the horizontal scale when pasting wave data. Very high sampling rates may require more than the default value of 6 digits to accurately resolve the inter-sample interval.

PhysioNet This format requires that the WFDB library is present on the computer. PhysioBank is a public service of PhysioNet and offers downloadable archives of gigabytes of "standard" data for cardiac arrhythmias, gait analysis, and other types of physiological signals. Acq*Knowledge* can use PhysioBank data directly and can be integrated with other software tools that understand this interchange format.

Saving a file in PhysioNet (WFDB) format will export the entire contents of the graph to a PhysioBank record. The record will consist of multiple files, all in the location specified for export. There will be a header file (*.hea) and a single data file for each channel of the graph (starting with "d" and ending with the base name of the header file). The files must not be separated for a successful move or copy.

<u>Export Limitations</u>

Precision Some precision may be lost due to differences in binary representation between Acq*Knowledge* and PhysioBank formats.

Events Events will not be exported to the PhysioNet format.

Channels Only 32 channels of data can be exported from a graph (the max allowed in a PhysioBank file).

Rate When exporting a graph that uses variable sampling rates, all channels in the exported file will be downsampled to the lowest waveform sampling rate of the source graph.

***.MAT MATLAB** MATLAB® format. Uses the "MAT-file" binary format to save numerical and textual information as Filename.mat.

- Available only in the Windows® release of Acq*Knowledge*: create MATLAB® version 6 files which should be readable by any version of MATLAB® released later than November 2000.
- Interoperability with earlier versions of MATLAB is not guaranteed.

The following variables will be in the workspace when the file is opened in MATLAB.

data	Contains the data of the graph in floating point format, for all of the channels of the array. The first dimension of this array is the amount of data in each channel, the second dimension increments with each channel. Therefore, each column contains a full channel of data that can be accessed in MATLAB via data (1:length, [channel number]).
units	This string array contains the textual representation of the units of the samples stored in data, with one element per channel of data.
labels	This string array contains the labels of each of the channels, with one element per channel.
isi	This floating point array of one element gives the number of units of a single inter sample interval of the data.
isi_units	This single string array provides a units string for a single unit of isi. Time data will always be "ms," frequency data will always be "kHz," and other values will be represented by an Arbitrary horizontal axis type in an ACQ graph.
start_sample	Contains the time offset of the index 0 sample of data in isi units. This will be 0 for many graphs, but if only a selected area of a graph was exported into the MAT file, the start_sample will contain the offset from the original data corresponding to the start of the data array in the MAT file.

Raw Options to save (export) data for low-level data exchange are:

Data type: 32-bit or 64-bit IEEE floating point

Layout: *Packed sequential*: All of the data for an individual file is located in a single block of the file and multiple channels follow one another.

Interleaved: Data is grouped into a single "frame" for each sample location with one data element for each channel, so data for a particular channel is spread throughout the file (similar to Linear PCM audio file format).

Endian: Little and big endian byte ordering match x86 and PowerPC/Sparc data formats, respectively. To exchange with Windows applications or Mac-Intel, set to little endian; to exchange with standard Mac applications, set to big endian.

<u>Raw Data Export Limitations</u>

Formats Raw export only allows data to be saved in 32-bit and 64-bit IEEE floating point format.

Rates All files will be interpreted at a single sample rate; variable sample rates are not supported. If a graph with variable sampling rates is exported, channel data for downloaded channels will be padded to match the highest waveform sampling rate.

Length If channels have unequal lengths, the overall file length will match the longest channel. Shorter channels will be padded at the end using their final sample value so that all channels contained in exported files will be equal in length.

Scaling When integer-valued analog channels are exported from Acq*Knowledge* to raw files, all relevant scaling and offset will be applied—the data in the file will appear the same as if the channel had been internally converted to floating point format before export.

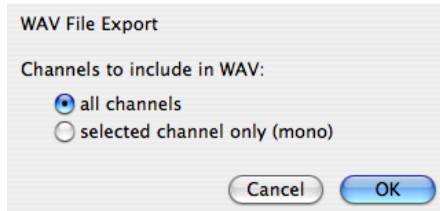
If the value of a channel is outside the maximum/minimum value that a chosen export data type can represent, the value will be clipped accordingly. (Acq*Knowledge* uses a 64-bit data type, so this should only be a problem if exporting to 32-bit floating point values.)

Igor Pro Igor Pro Experiment format.
An Acq*Knowledge* graph will be saved (exported) to a single packed experiment file, with each channel saved into a separate Igor wave that preserves the channel label, waveform sampling rate, and unit information. Vertical units will be stored as data units, and horizontal units will be stored dimension units; extended units are supported. The scaling of each wave will be adjusted to match the waveform sampling rate. All data will be stored in 64-bit floating point format in a one-dimensional wave. The waves will be named incrementally from "wave0" and the channel label will be stored in the wave note field. Files will have the type/creator pair "IgsU/IGRO" and a ."pxp" extension will be added to the file name for compatibility with Igor Pro for Windows™.

WAV This option saves the graph data into a WAV audio file for exchange with other applications. The ."wav" extension will automatically be added if the save as filename does not end with it.
The "Selected area only" checkbox will be active for WAV export. When checked, only the highlighted area will be exported to the WAV file. The final sample of this range is not included in the export, mirroring the other file export routines of Acq*Knowledge*.
All exported WAV files use the 64 bit floating point format. This format preserves full operational precision. Most audio applications should be able to support floating point WAV files. Exported data will not be normalized when it is exported.
Any normalization to audio ranges should be performed prior to exporting the data.
WAV files are normally either one or two channels (e.g. mono or stereo).
Acq*Knowledge* graph files, however, usually contain more than two channels.

Although they can contain more than two channels, most audio applications may not be able to recognize these multiple channel files.

- If a graph file contains only one or two channels of data, a WAV file will automatically be created without further interaction.
  - Graphs with a single channel will result in mono WAV files.
  - Graphs with two channels will result in stereo WAV files.
- If a graph contains more than two channels, the user will be presented with the following choice:



  - **all channels**—create a multiple-channel WAV file with one channel per channel of data in the graph. While this WAV file may be easily opened by some applications, it may not be fully compatible with audio applications and other applications expecting two channels or less.
  - **selected channel only**—create a single channel mono WAV file using only the data of the selected channel. This will be the selected channel in chart mode, the active channel in scope mode, or the vertical channel in X/Y mode. This single channel export may be useful for exporting audio channels that are recorded along with physiological data, such as heart sounds, audio stimuli, and the like.

After a WAV file is exported, the WAV file will not be reopened; the open graph will be left unmodified. To view the exported file, import the WAV file.

EDF Saves file in European Data Format (EDF). The saved file will automatically have an .edf extension added onto it if the user did not include it. Users will be able to save either the entire graph or only a selected portion of data.

Acq*Knowledge* does not retain sufficient information to accurately complete an EDF header. When exporting, the following default values will be used:

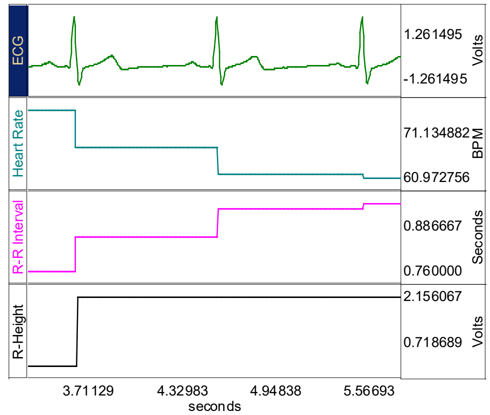
EDF Header Element	***Default***
subject ID	Empty*
recording ID	Empty*
recording date	Set to the modification date of the graph file on disk. If no graph file is on disk, the current date of the first Append event mark is used.
recording time	Set to the modification time of the graph file on disk. If no graph file is on disk, the current time of the first Append event mark is used.
transducer description	Empty*
filter description	Empty*
	* Empty: indicates that the field will be left blank

All other fields will be filled with corresponding information from the graph, including channel titles, sampling rates, channel units, and scaling factors. Variable sampling rate information will be preserved as it can be expressed in the EDF format.

EDF is used by many applications and online recording databases to store information, particularly EEG recordings.
EDF is an open file format originally developed for sleep studies. It stores continuous time recordings of data in a binary format.
Since its original proposal, EDF has been adopted by a number of open source and commercial tools as a supported data file format.

Usage has also expanded beyond sleep studies into other types of recording.

JPG



Acq*Knowledge* also supports formats for saving graphical information. Most drawing, page layout, and word processing programs can read .JPG files. This is particularly useful for writing reports. A. JPG file can be opened in any standard drawing program and can then be embellished or used to highlight any particular phenomena of interest.

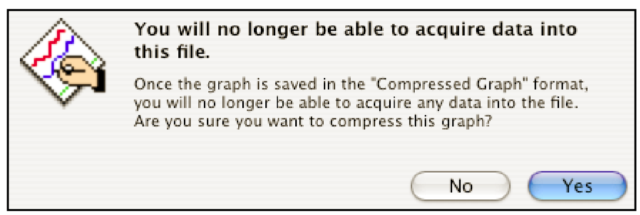
When data is saved as a graphic, only the current screen data is saved. For example, for a data file that spans eight hours but displays only two minutes of data onscreen, only the two minutes of data will be converted to a graphic file. Since Acq*Knowledge* uses information about the computer screen in creating the graphic file, the default resolution of the file will be the same as the window. Most word processors and graphics packages allow for some way to resize and scale graphics.

Compressed Saves a compressed Acq*Knowledge* formatted file. The degree of compression varies based on data characteristics, but will generally achieve about 60% compression. Saving small files (less than 200K) may have little effect. Using a sample file as an example:

ECGdata.acq	166 KB
ECGdata_Compressed.acq	38 KB

Compressed graphs no longer allow data acquisition and will open with no Start button.

A warning prompt will be generated when attempting to compress a graph in which data can be acquired (Start button active):

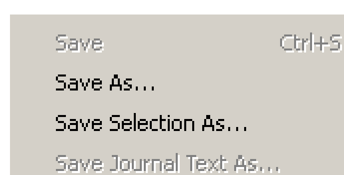


Excel Spread-sheet Excel Spreadsheet Export—Graph data can be saved directly to an Excel spreadsheet by using the Excel Spreadsheet format in File > Save As. Each channel will be placed into its own column of the spreadsheet. Also available for File > Save Journal Text As, Find All Cycles journal, and Specialized Analysis tools.

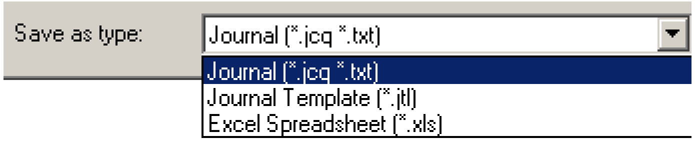
Note The Excel spreadsheet option requires Excel or a compatible spreadsheet application that can read Excel files (OOo, Symphony, etc.). If Analysis results are exported to an Excel spreadsheet, and a compatible application is not available, results will open as a text document the data and nonsense characters.

Save Selection As

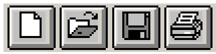
To save only the data that has been selected with the I-beam tool, choose File > **Save Selection As**; this option saves the selected area to another file and does not affect the currently open file. Specify file name and file type and click Save.



Save Journal Text As



Choosing File > Save Journal generates a save dialog to save the journal text as a separate file. Specify file name and file type and then click Save.

Journal 

Text (.TXT) format*—Saves an independent journal; see page 53 for details.

Jrnl Temp *.JTL format*—Saves a journal template; see page 53 for details.

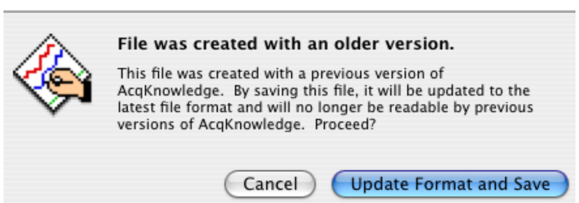
Excel Spread-sheet *Excel Spreadsheet File (*.XLS)*—Journal text can be exported directly into an Excel spreadsheet by using the File > Save Journal Text As with the Excel Spreadsheet format. Each line of text in the journal will be saved as a single row with tabs separating columns. A selected portion of a journal can also be written to a spreadsheet. This export allows for textual data reduction results to be easily exported into a spreadsheet to allow for further analysis.

- Also available for File > Save As, Find All Cycles journal, and, for Specialized Analysis tools.

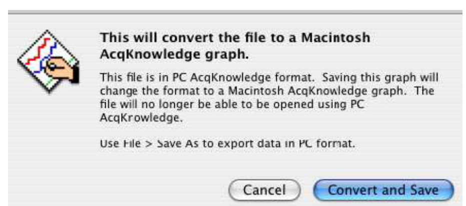
Note The Excel spreadsheet option requires Excel or a compatible spreadsheet application that can read Excel files (OOo, Symphony, etc.). If Analysis results are exported to an Excel spreadsheet, and a compatible application is not available, results will open as a text document the data and nonsense characters.

File Format prompts

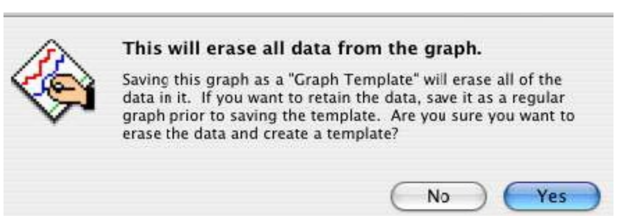
When a file open or save function requires a format change for compatibility or alters file content, a prompt will be generated to require the user to confirm the option to update format or convert and save.



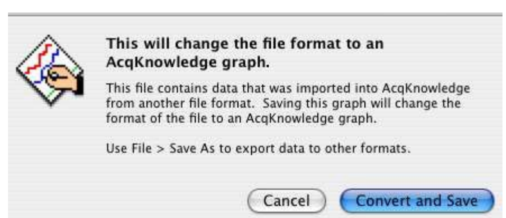
Created with a previous version of Acq*Knowledge*



Windows PC Acq*Knowledge* format



Saving as a "Graph Template" will erase all data



Imported from another file format

Send Email Attachment

Use this feature to create an email attachment containing an image of the active Acq*Knowledge* graph, along with the journal contents.

When using this feature:

- The default email program will launch, along with a 'compose new email' window.
- An Open Document (*.odt) text file containing an image of the currently opened graph and associated journal text will be copied to the attachment field. The formatting and images present in the journal should be preserved.
- Further details can be typed into the body of the email prior to sending.

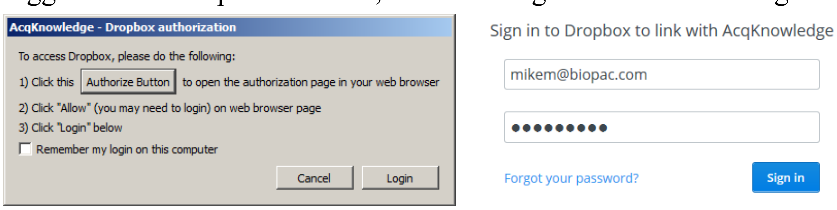
In order to open the attachment, the email recipient must have a word processing application compatible with *.odt file format, such as OpenOffice, NeoOffice or Microsoft Word™.

Copy to Dropbox – Open from Dropbox

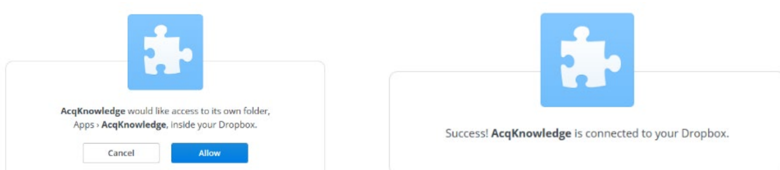
The Dropbox options allow for copying or opening Acq*Knowledge* data files to or from a Dropbox account directly from within the Acq*Knowledge* application. This is useful for storing files online where they may be accessed from any computer. In order to use this feature, access to an active Dropbox account is necessary. To create a Dropbox account, go to www.dropbox.com.

To set up Acq*Knowledge* to use Dropbox:

1. File > Copy to Dropbox. If Dropbox is being used for the first time in Acq*Knowledge*, or if not logged in to a Dropbox account, the following authorization dialog will appear.



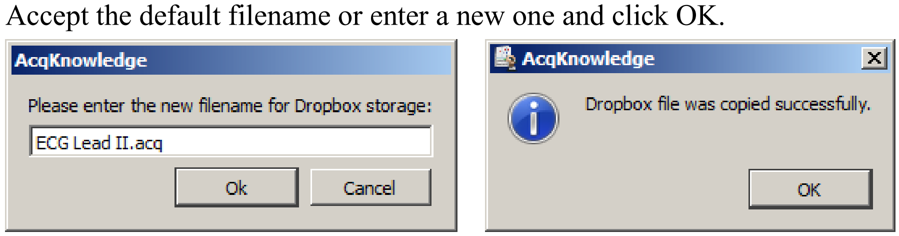
2. Click the "Authorize Button" and sign in to the Dropbox account.



3. Click "Allow" to grant Acq*Knowledge* permission to create a new Dropbox folder (above left).
4. A confirmation dialog will appear indicating Acq*Knowledge* is successfully connected to Dropbox (above right). Close or minimize the browser window.
5. Dismiss the Step 1 Dropbox authorization dialog by clicking "Login." While logged in to the Dropbox account, this setup procedure will not need to be repeated.

To Copy files to Dropbox:

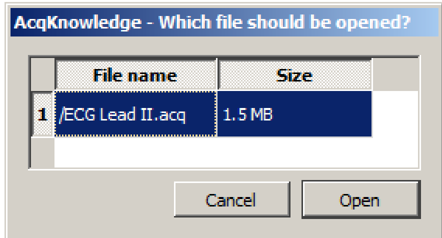
1. File > Copy to Dropbox.
2. Accept the default filename or enter a new one and click OK.



3. A confirmation dialog will appear indicating the file is stored on Dropbox.

To open files stored on Dropbox:

1. File > Open from Dropbox.
2. Select the desired file from the list of stored Acq*Knowledge* files and click "Open."



NOTES:

- If Dropbox is being used for the first time in Acq*Knowledge*, or if not logged in to a Dropbox account, the authorization dialog shown on the previous page will appear before allowing access to a stored file.
- More than one file can be opened from the list, but must be selected individually. Multiple selections are not supported.
- To log out of Dropbox from Acq*Knowledge*, choose File > Logout from Dropbox.

Page setup

Choosing File > Page Setup produces a standard printer setup dialog that allows setup for any available printers. All options in this dialog function as described in the system manual. There are also options for configuring printing adjustments with respect to fonts, image orientation, and graphics presentation.

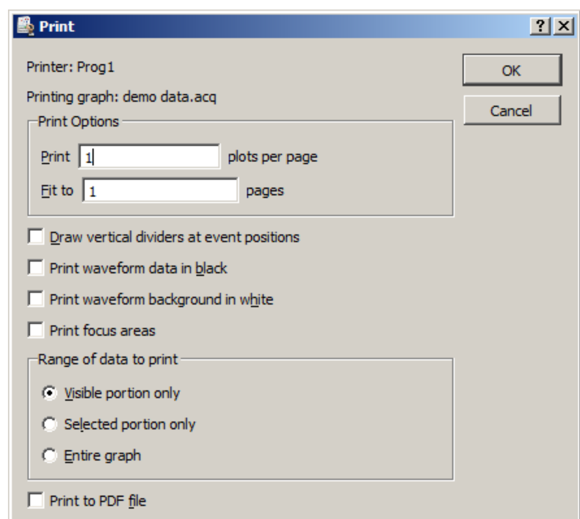
Print

The File > Print menu that Acq*Knowledge* uses is similar to the standard computer print dialog; however, there are additional options available

The Print menu is dynamic and corresponds to the type of file being printed, i.e. Print Graph, Print Journal.

Click Print for more options.

Note: In Mac OS, the option to create a PDF file appears in the initial Print dialog.



- Print Options
  - **Plots per page**—Control how many plots appear per page when the file is printed. Printing more than one plot per page has the effect of "snaking" graphs on a page much the same way text appears in a newspaper. For example, if this option was selected so that two plots were printed per page, Acq*Knowledge* would divide the amount of data to be printed on that page into two graphs—one graph printing at the top of the page, the second graph printing at the bottom of the page. This option allows records to be printed on considerably fewer pages than standard printouts, and is most effective when only a few channels of data are being printed.
  - **Fit to pages**—Print the contents of a window across multiple pages. When a record is printed over multiple pages, the amount of data on the screen (the amount of data to be printed) is divided by the number of pages entered in the dialog. The graph on the screen is then printed across the number of pages specified in the Total pages box at the bottom of the File > Print dialog. These two options apply only to graph windows, and do not apply to Journals.
- **Draw vertical dividers at event positions**—Adds visible borders at points where events occur.
- **Print waveform data in black**—Waveforms will appear black when printed, regardless of selected colors in graph channels.
- **Print waveform background in white**—Prints white background, regardless of selected background colors in graph channels.
- **Print focus areas**—Turns focus areas on or off for the printout.
- Range Options—determine the range of data that will be included in the printout
  - **Visible portion only** synchronizes the range of data in the printout to match the range of data that is visible on the screen.
  - **Selected portion only** prints only the data that is selected in the graph. This option is disabled if there is no selection in the graph. When working with Journals, it is easy to generate large amounts of text content in the window. Only a portion of this information may actually be of interest and this feature allows for only portions of the text to be printed. If there is no selected text, the entire journal or modification log will be printed regardless of this setting.
  - **Entire graph** prints all of the data contained in the graph from zero to the maximum length channel.
- **Print to PDF file**—generate a PDF file.

Go to Startup Wizard

Closes graphs and exits to the Startup Wizard. This is useful if multiple graphs are open and circumvents the need to close each one individually via the close (X) button or File > Close.

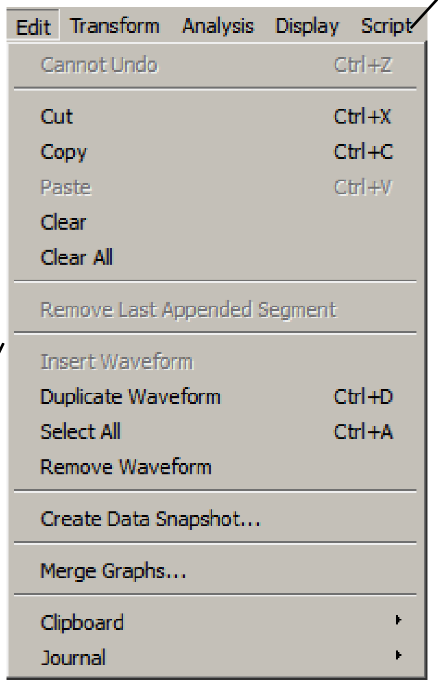
Quit

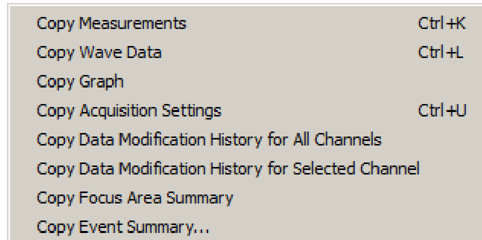
Select Quit from the File menu to entirely exit Acq*Knowledge* software; a prompt will appear to save any open graph files that have been modified.

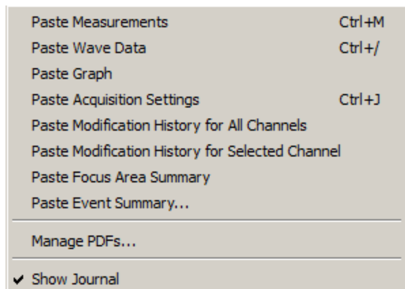
Mac OS only—Use Quit under the Acq*Knowledge* menu (page 518) to exit the software.

Chapter 14 Edit Menu Commands

Overview







One of the most useful features in Acq*Knowledge* is the ability to edit and work with data by cutting and copying sections from one window to another. In this sense, Acq*Knowledge* can manipulate data much as a word processing program handles blocks of text. To select an area of interest in the Acq*Knowledge* data for further study, use the I-beam selection tool to highlight an area.  This selection tool is used for a variety of purposes including cutting and pasting waveform data, making measurements and determining which portion of a waveform to save as text values. To select this tool, click its icon on the toolbar. Notice that the cursor changes into the familiar "I-beam" cursor when moved within the graph area. Click the mouse and drag to select a portion of the waveform.

IMPORTANT

When multiple waveforms are present, the highlighted area appears to include all of the waveforms, but most modifications and transformations apply only to the selected channel.

Once a section of a waveform has been selected, functions such as editing, transformations, saving data to the journal, saving as text, and using the measurement functions can be performed on the selected area. The cursor always selects at least one sample point; when there is no defined area, a single sample point will be selected, and the cursor will blink. Highlight a larger area by positioning the cursor over the first point of interest, hold down the mouse button, and drag the cursor either left or right to highlight an area. Modify the selected area by placing the cursor anywhere on the graph, then holding down the shift key and clicking the mouse. This feature is useful for fine-tuning the selected area. To fine tune, first coarsely select an area. After zooming in (with the zoom tool) on either edge, then use the shift key to precisely align the edges of the selected area.

Acq*Knowledge* also allows the selection of an area spanning multiple screens. To do this, first select an area that contains the leading edge of the graph portion of interest. Next, use the horizontal scroll bar to scroll to the end of the area of interest. Then place the mouse near the area of interest and click the button while holding down the shift key. While still depressing the mouse button, move the cursor to the exact position desired.

By using the selection tool to select areas of the waveform, the Cut, Copy, Paste and Clear functions are designed to work in much the same manner as any text editor. These functions operate only on the selected area.

Edit menu functionality during acquisition

The following Edit menu functions cannot be performed during acquisition: Undo, Cut, Clear, Clear All, Paste, Insert Waveform, Duplicate waveform, and Remove Waveform.

Undo / Can't undo

The Undo command allows for restoration of data that was unintentionally deleted or modified. Undo applies to editing commands and transformations (such as digital filtering and mathematical operations).

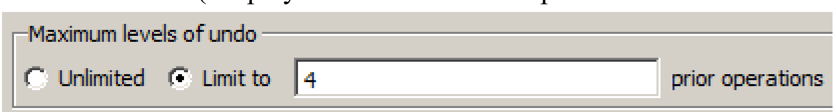
There are some important exceptions to the Undo command.

First, neither Edit > Clear all nor Edit > Remove waveform can be undone. It is a good idea to make backup files before performing any editing, especially when using these commands.

Second, changes in the display options (i.e., changing the horizontal scale or changing the color of a waveform) cannot be undone, since they are easier to manipulate and less drastic than cutting data out of a waveform. If the screen scale (or other display parameters) is modified, it is possible to undo this modification.

> TIP: If a waveform is removed of if a "Clear All operation is applied accidentally, one way to recover the data is to close the file without saving the changes. The data file can now be reopened and changes made since it was last saved will not be retained.

Perform multiple levels of undo on a per graph basis. The most recent operation is undone first followed by the previous operation until the maximum number of Undo operations are reached. The maximum number is set in Application Preferences (Display > Preferences > Graph > Maximum levels of undo) .



NOTE: Specialized Analysis (page 403) scripts are complex and undo may not function for all steps.

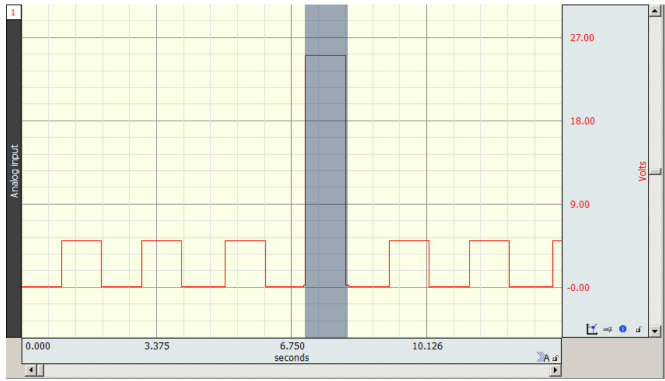
Cut

When Edit > Cut is selected, the selected portion of the active graph channel removed and copied to a clipboard, where it is available for pasting into other windows.

Cut cannot be performed during acquisition.

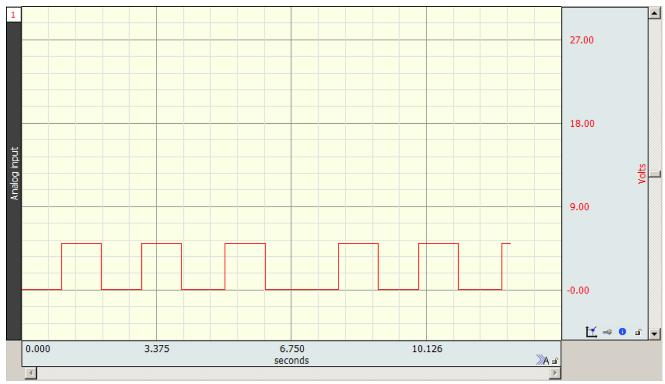
- When a selected area is removed from a waveform, the data will shift left to "fill in" the deleted area. So, if ten sample points are deleted, all data after the selected area will be shifted over ten sample points. Since this alters the relationship of events to the time base, it's recommended to consider alternatives to cutting sections of data—such as using smoothing, digital filtering, or the connect endpoints functions to transform the section of data.

Area selected using the editing tool →



Same data with selected area Cut out →

Note that the data after the selected area has shifted backward in time.



Copy

Choosing Edit > Copy will copy the selected area of the active graph channel to the clipboard without modifying the text/waveform on the screen.

- Once the area has been copied, it can be inserted in another window of the same type using the Edit > Paste command or, for waveforms, the Edit > Insert waveform command.
- To copy a waveform to another channel in the same graph window, choose the Edit > Duplicate waveform command.
- Edit > Copy applies only to a selected area of graph data. To copy and entire graph, use Edit > Clipboard > Copy Graph (see page 323.)

Paste

The Edit > Paste command will take the contents of the clipboard and paste it into the currently selected area of the active window of the same type.

- If no area is selected, the data is pasted at the beginning of the waveform in a Graph window or the end of the text a Journal window.
- Paste cannot be performed during an acquisition.

Clear

The Edit > Clear command works much the same way as the Cut command, with the key difference being that data is not copied to the clipboard. This function deletes the selected area from the selected channel only. If the entire waveform is selected (as with the Edit > Select all command), the clear command will delete all the waveform data and leave an empty channel.

Clear may move or alter memory and cannot be performed during acquisition.

- As with the cut command, the clear function operates on only one channel, and when a portion of the waveform is deleted, the remaining data will shift left. If multiple channels of data are present, one channel will be “shorter” than the others.
- To remove a selected area of data from multiple channels, use the Edit > Clear all command.

Clear all

Choosing Edit > Clear all will delete the selected area from *all* channels. This is similar to the clear function in that data is removed and is not copied to the clipboard. The Clear all command, however, removes a section of data from all waveforms, whereas the clear command applies only to the selected channel.

Clear All may move or alter memory and cannot be performed during acquisition.

- When Edit > Select all is chosen prior to performing the Clear all function, all waveform data for all channels will be deleted.
- The Edit > Undo command does not work for Clear all.

Select All

When Select all is chosen from the Edit menu, the entire selected channel becomes highlighted. For almost all commands, when a waveform is selected using Select all, subsequent operations apply to the selected channel only.

- The exception is when Edit > Clear all is chosen after Edit > Select all. When this occurs, all data from all waveforms will be deleted.

Insert Waveform

The Edit > Insert waveform command is useful for copying a waveform (or a section of a waveform) within the same or another graph. However, within the same graph, Duplicate waveform is simpler. To do this, first select the area to be copied using the cursor and the Edit > Copy command. Next open the graph window to insert the waveform into.

Select the new graph and choose Edit > Insert waveform. A new (empty) channel will then be created and the data copied into the empty channel.

- Insert waveform cannot be performed during acquisition.
- This command cannot be undone directly, although selecting the inserted channel and choosing Remove waveform from the Edit menu effectively undoes this operation.

Duplicate waveform

Choosing Edit > Duplicate waveform will create a new channel in a graph window and copy an entire waveform (or a selected area) to the new channel. When a portion of the waveform is selected, only the highlighted area will be duplicated.

Duplicate waveform may move or alter memory and cannot be performed during acquisition.

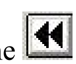
- To duplicate the entire waveform, choose Edit > Select all and then select Duplicate from the Edit menu or click the right mouse button and select Duplicate from the pull-down menu.

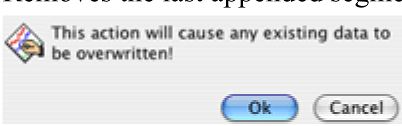
Remove waveform

Deletes the entire selected waveform, regardless of what other options are selected. Remove waveform may move or alter memory and cannot be performed during acquisition.

- The Edit > Undo command does not work for Remove waveform.

Remove last appended segment

Removes the last appended segment. Equivalent to the  Rewind toolbar icon.



- Edit > Undo does not work for Remove last appended segment.

Create data snapshot

The Snapshot options store “snapshots” of the original acquired data at specific stages along with the full graph file. Use snapshots for analysis or reporting to compare results to original waveforms or intermediate stages of analysis. This is essentially an embedded archive; it is not a backup tool.

IMPORTANT: Archive functions do not create a new file—they are not backup functions.
Original data is copied and pasted to the end of the original file.
This feature cannot be used to recover lost or damaged graph files.

See page 54 for Snapshot details.

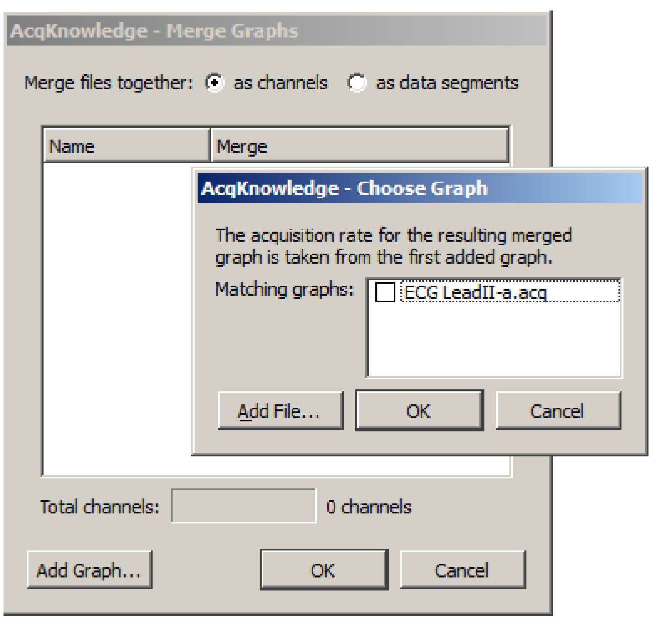
Merge Graphs

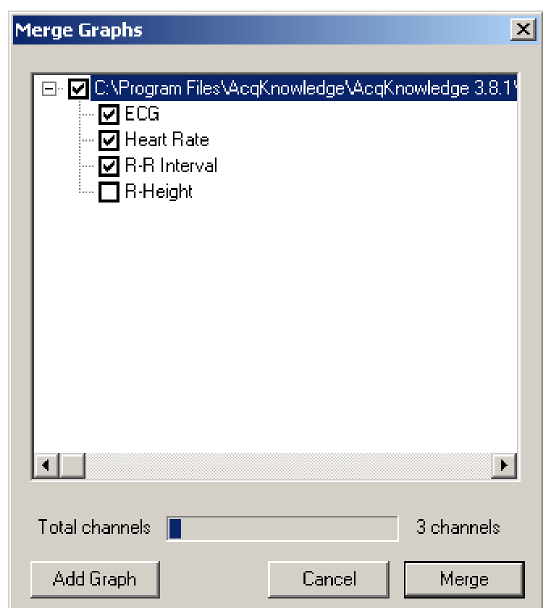
Combine multiple graph files into a single file for performing cross-file analysis and storage. Use merge with the multiple-hardware capabilities to produce single graph files containing multiple streams of data from an individual subject.

Use Merge Graphs to combine data from multiple graph files acquired with the same acquisition rate into one merged graph file.

Note Merge Graphs requires Acq*Knowledge* to allocate additional memory and then load the data into memory; when this operation is executed on large data files, the application may crash—on Windows OS, the resulting file size of a merge should be less than 2 GB; data files greater than 2 GB can be opened, but edit, transformation and analysis operation cannot be performed.

1. Select Edit > Merge Graphs to generate the Merge Graphs dialog.
2. Click Add Graph to generate the Choose Graph dialog.
3. Choose a file to add to the merge.
   - "Add" the "Matching graph" listed (this pull-down menu includes all open files with the same acquisition rate)
   - "Add File…" to browse and select a file that is not already open
4. Adjust the selection for individual channels if desired.
   - Click the "+" to list individual channels in the graph file.
   - Toggle the checkbox to add or remove the associated channel/graph file.
   - File names cannot be deleted from the list, but they can be removed from the merge.
5. Repeat as desired for multiple files.
6. Click Merge and wait (the status can be checked in the Total Channels bar).
7. Save the merged file.

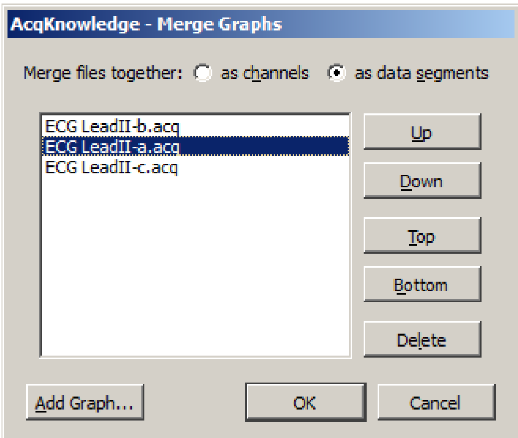




Merging graphs as data segments

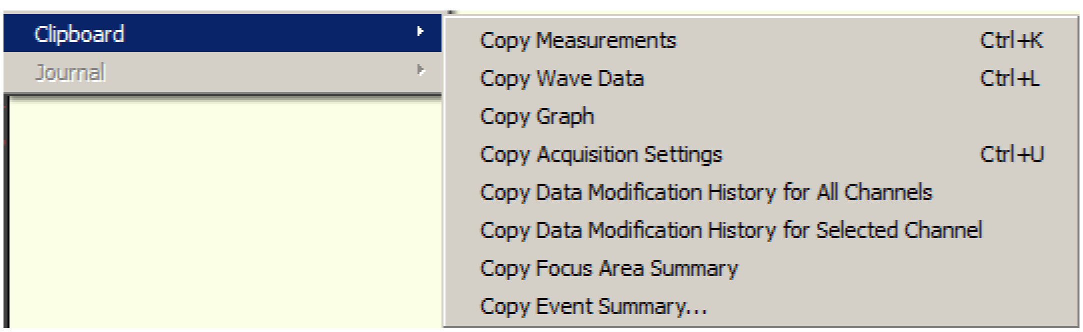
Individual graphs may also be merged into a single channel as appended segments. This can be useful for concatenating data types that don't support append mode, or when importing data from software that outputs each session as a self-contained graph file.

To merge separate files into sequential segments, check the Merge Graphs "as data segments" option and select the data files as shown in steps 1-7 above. The same limitations exist for appended graphs as do for graphs merged into individual channels. (All selected graphs must share the same sample rates and channel configurations.)



Additional navigation controls become available when merging graphs as appended segments. This allows reordering of the data segments into the sequence desired for the merged file. By default, the first graph added to the list will be displayed as data segment 1, but this can be modified by selecting any appended graph and moving it up or down the list via the "Up", "Down", "Top", "Bottom", or "Delete" navigation buttons.

Clipboard



All of the clipboard commands involve copying data from Acq*Knowledge* to the standard Windows clipboard, where the contents of the clipboard are made available for other applications. Transferring data to the clipboard allows data to be copied from Acq*Knowledge* to other applications even after closing the graph window and/or quitting Acq*Knowledge*.

Data can be copied to the clipboard in two formats:

Text/Alphanumeric	Copy Measurement and Copy Wave Data save information to the clipboard in text/numeric format.
Graphic format	Copy Graph transfers the image in the window to the clipboard.

➢ Copy Measurements

Copies the contents of all visible measurement popup menus, along with the values associated with these windows. Once the measurements have been copied, they can be pasted into any application that allows paste functions, including word processors, drawing packages, and page layout programs. A sample of measurements pasted from Acq*Knowledge* into a text document follows:

BPM = 85.714 BPM   delta T = 0.700 sec   p-p = 0.8170 Volts

- Copy Wave Data

  Copies the data (in numeric form) for all channels from the Acq*Knowledge* graph into the clipboard. When an area is selected, only the data in the highlighted area will be copied to the clipboard. As with the copy measurement command, once the data is stored in the clipboard, it can be pasted into virtually any application.

  When multiple channels of data are copied to the clipboard, the data is stored in columns and rows, with data from each channel stored in a separate column. For a four-channel record, four columns of data will be copied to the clipboard. As with a text file, Acq*Knowledge* will insert a delimiter between each column of data. The default delimiter is a tab; the delimiter can be changed to either a space or tab in the File > Save as Options dialog. See page 290 for more detailed instructions on how to set the column delimiter. Transferring data through the clipboard performs essentially the same function as saving data as a text file (using the File > Save As command), with the obvious exception that transferring data through the clipboard does not save data to disk.

- Copy graph

  Copies the graph window as it appears on the screen to the clipboard, where it is stored in graphic format. The graphic can be placed into a number of different types of documents, including word processors, drawing programs, and page layout programs. The JPEG graphic format are common to almost all applications, and images saved in these formats can be edited in most graphics packages and many word processors.

  Using the copy graph function is similar to saving a graph window as a JPEG (using the File > Save As command), except that using the file save command writes a file to disk, whereas transferring data through the clipboard does not save a file.

- Copy Acquisition Settings

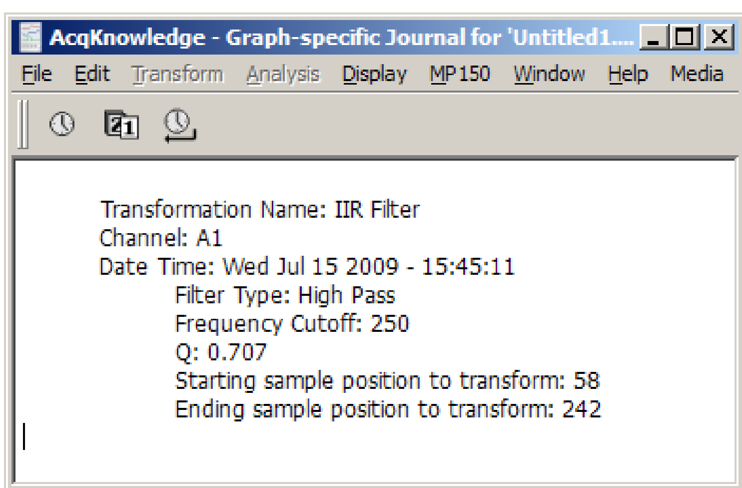
  Creates a textual summary of the current acquisition settings and sends it to the clipboard, where it can be pasted into the journal via Edit > Journal > Paste Acquisition settings, or pasted to another program.

  The summary includes sampling rates, channel configuration, calculation channel settings, triggering options, averaging options, and if any stimulator is active. This is useful for retaining records for acquisition parameters (and for technical support, if necessary). Use this feature to keep a textual record or printout of the hardware unit configuration along with the data.

- Copy Data Modification History…

  Copies the transformation history for all channels or a selected channel to the clipboard. Modification history includes the transformation name, channel (analog, calculation, or digital), date & time, and relevant transformation parameters, including starting and ending sample position.

  Use Edit > Paste to move it from the clipboard to an active Journal window or other word processing application.



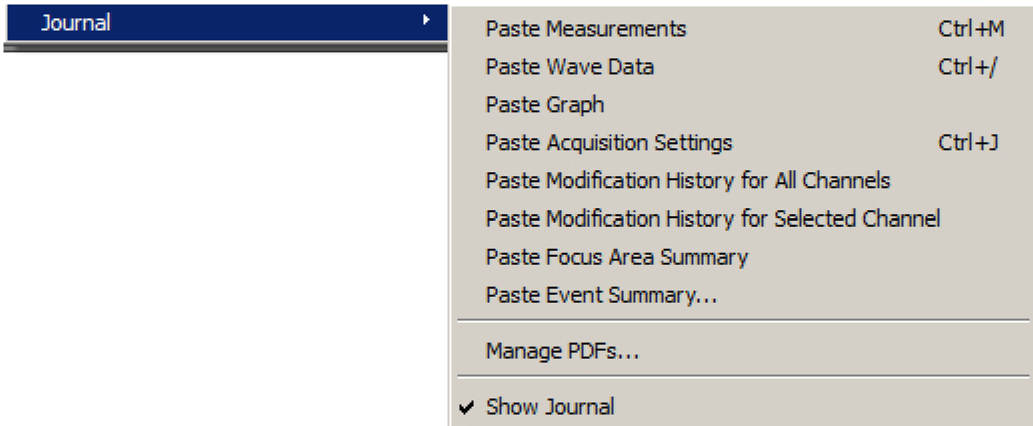
- ➢ Copy Focus Area Summary

Copies the starting and ending position of the focus area in horizontal axis units. Summary includes focus area label.

- ➢ Copy Event Summary

Copies events to the clipboard as selected in the Event Summary setup dialog.

Journal



The Edit > Journal sub-menu options are similar to those found in the Edit > Clipboard menu. The key difference is that data (whether measurements or raw data) is pasted directly into the journal rather than copied to the clipboard.

- ➢ Paste Measurements

Choosing Paste Measurements from the Edit > Journal menu will cause all visible measurement windows to be pasted into the journal. Each time this is selected, the measurements and values are pasted into the journal using the precision specified in the Display > Preferences dialog. Additional measurement rows and degrees of precision can be added in the Preferences (see page 504).

Paste Measurement shortcuts:

- Keyboard: Ctrl + M
- Mouse: Right-click in the Journal and choose “Paste Measurement”

- ➢ Paste Wave Data

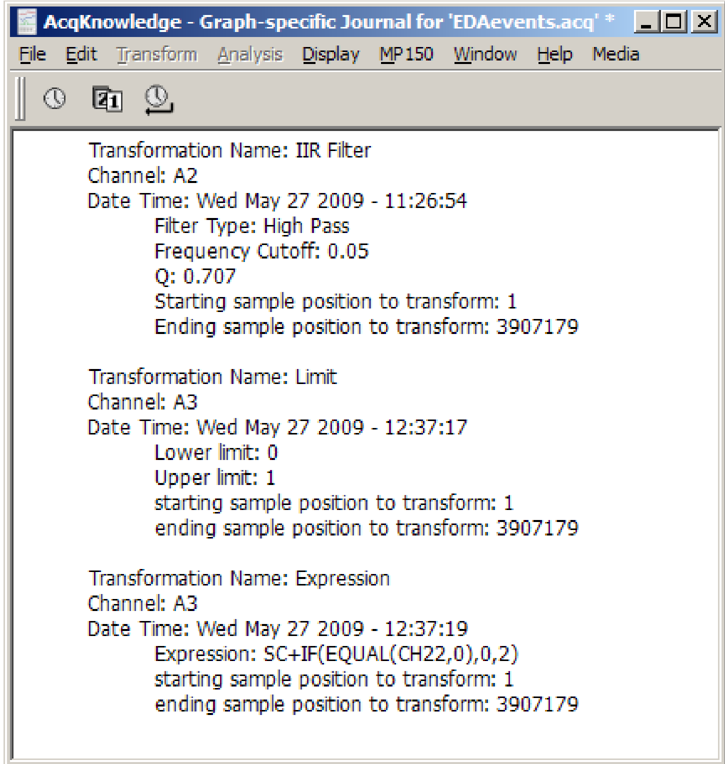
Converts the selected area of the waveform to numeric format and paste it into the journal in standard text file format. As with the copy wave data command (in the Edit > Clipboard submenu) this will paste the selected area from all channels, not just the selected channel, and will place a delimiter between the columns when two or more channels are being pasted to the journal. By default, tab characters are used to separate columns but can also be changed to comma or space delimiters in the File > Save As > Options dialog. See the Save As section on page 305 for more information on how to change the column delimiter.

- ➢ Paste Acquisition Settings

Pastes the acquisition settings to the journal as they were copied via Edit > Journal > Copy Acquisition settings.

- ➢ Paste Modification History…

Use after Copy Data Modification History… to paste the transformation history from the clipboard for all channels or for the selected channel to an active Journal window or other word processing application. Modification history includes the transformation name, channel (analog, calc, or digital), date & time, and relevant transformation parameters, including starting and ending sample position.



- Paste Focus Area Summary

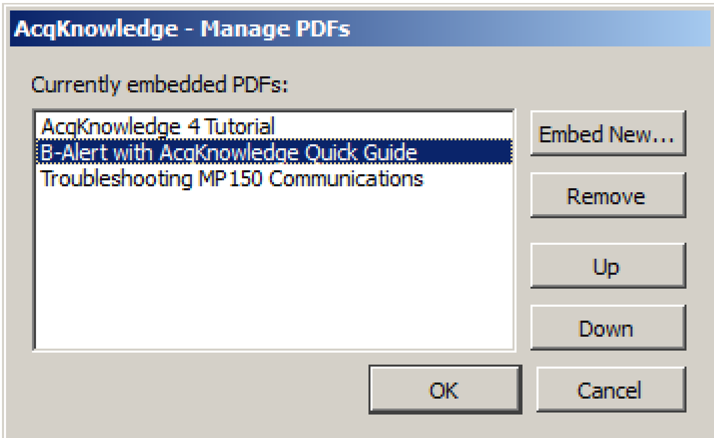
  Pastes the focus area summary to the journal as copied via Edit > Journal > Copy Focus Area Summary.

- Paste Event Summary

  Pastes the event summary to the journal as copied via Edit > Journal > Copy Event Summary.

➢ Manage PDFs

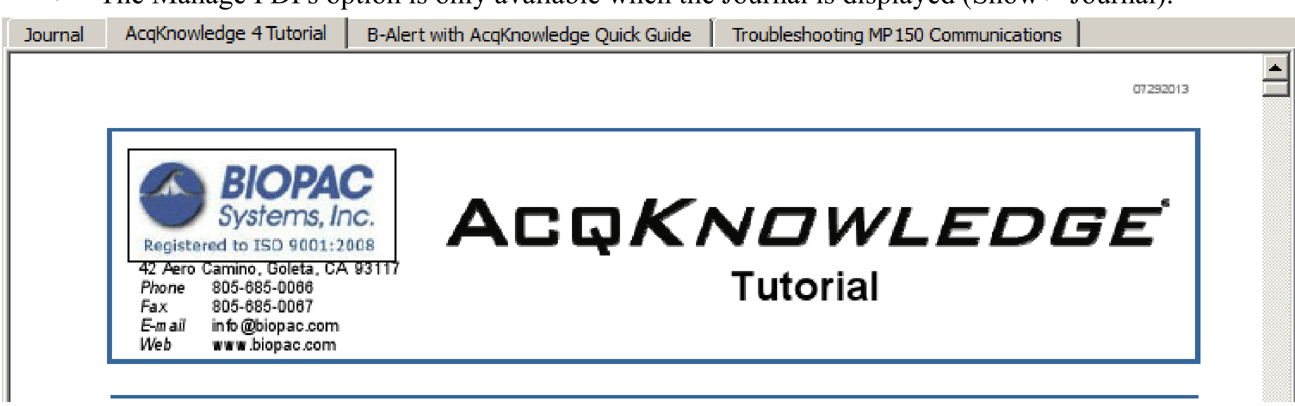
Use this option to select and import (embed) PDF files into the Journal as tabbed windows. Multiple PDFs may be imported and each PDF appears under its own tab heading. Choose Edit > Journal > Manage PDFs, or right-click in the Journal and choose Manage PDFs. The following dialog will appear:



Control	Description
Embed New	Launches a “File > Open” dialog for navigating to the directory containing the PDFs to be embedded.
Remove	Removes a PDF from the list. (The actual PDF is not deleted.)
Up	Moves the selected PDF up the list and determines its tab order in the Journal.
Down	Moves the selected PDF down the list and determines its tab order in the Journal.
OK	Imports the embedded PDFs into the Journal

After embedding PDFs into the Journal, toggle between them by clicking the tabs. Clicking the Journal tab will activate the Journal window. Saved Journal content is not affected by embedded PDFs.

- The Journal formatting tools are not available when a PDF is actively displayed.
- The Manage PDFs option is only available when the Journal is displayed (Show > Journal).

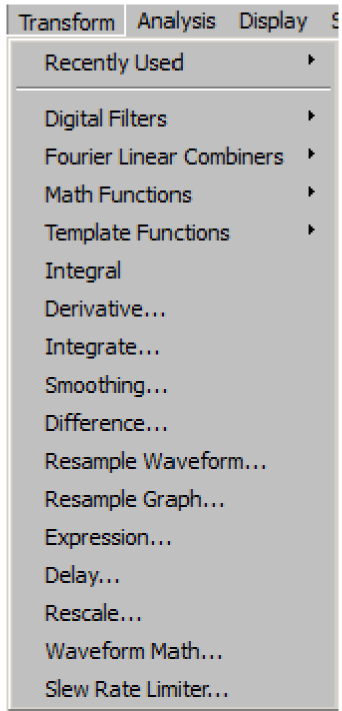


➢ Show Journal

Toggle to display/hide the Journal window.

Chapter 15 Transform Menu Commands

Overview

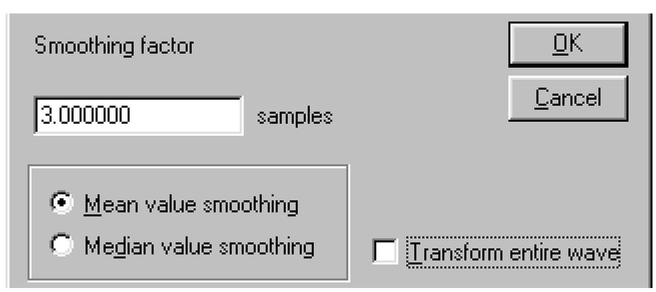


The Transform menu contains operations that primarily modify the data in the graph.

Acq*Knowledge* provides a number of options for post-acquisition analysis and transformations. These transformations perform a range of operations on the data, from digital filtering and Fourier analysis to math functions. All of these options can be found under the Transform menu, and are disabled while an acquisition is in progress. Unless otherwise noted, all transformations described here apply to the selected channel only. Some options (such as the expression and math functions) allow users to specify a channel (or channels) to be transformed.

It is important to remember that Acq*Knowledge* is always selecting at least one point, and the cursor will flash whenever only one point is selected. Some of the transformation functions (e.g., math function, waveform math) can operate on a single sample point, and will transform a single sample point when only one is selected.

There are two ways to apply a transformation to an entire waveform.



a) For transformations that generate a dialog, check the “transform entire waveform” box (usually located toward the bottom of each dialog). This will transform the entire waveform, regardless of whether a single point, area, or the entire waveform is selected.

b) For transformations that do not generate a dialog, use the Edit > Select all command prior to selecting the transformation. This will transform the entire waveform for all of the transformation functions.

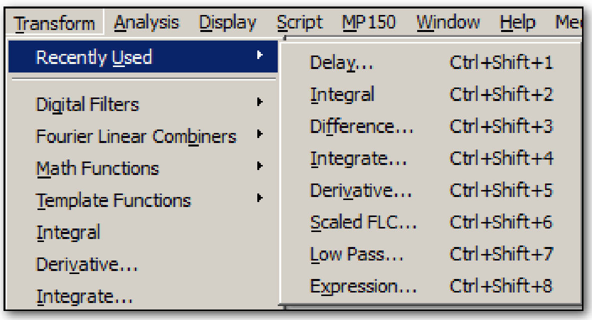
- Edit > Select All is not necessary when only a single point is selected prior to selecting the transformation because Acq*Knowledge* will automatically apply the transformation to the entire waveform since it is not possible to perform these transformations on a single point.

Recently Used Transformations

The Transform > Recently Used submenu allows quick access to a user's most recently used transformations and analysis commands. The Recently Used submenu also appears at the top of the Transform submenu available from the context menus of waveforms.

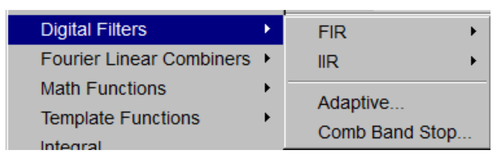
The submenu lists a default of five of the most recently used transformations, with the most recently executed at the top of the menu. To adjust the number of recent transformations displayed, select Display > Preferences.

The recently used transformation listing is saved and restored across subsequent launches of Acq*Knowledge*. It also is application wide: Executing a transformation in any graph will add that transformation onto the recently used list. The recently used list is independent for each user account.



The recently used transformations can also be launched by the keystroke combinations appearing in the menu.

Digital Filters



FIR filters are linear phase filters, which mean that there is no phase distortion between the original signal and filtered waveforms.

IIR filters are not phase linear filters but are much more efficient than FIR filters in processing data. The IIR filters are useful for approximating the results of standard biquadric filters of the form:

$$(as^2 + bs + c) / (xs^2 + ys + z)$$

These types of filters are commonly implemented in electronic analog circuitry. IIR filters are also used for online filtering (discussed on page 165).

- See Appendix B for more information about the differences between these types of filters.

Adaptive filtering is a signal processing technique that processes two different signals in relation to one another. Adaptive filtering creates efficient high-quality filters with a minimal number of terms, which can be very useful in blocking mains interferences or other known periodic disturbances; see page 335 for details.

Comb Band Stop filters remove a fundamental frequency and its overharmonics (e.g., integer multiples of the base frequency) from a signal and are useful for removing noise.

TIP: Use **Filter Multiple Channels at Once** to selectively apply FIR, IIR, or Comb Band Stop filters to a single channel or multiple channels at the same time. Filters can be applied to any signal type. See page 421 for additional details.

To understand how digital filters work, it is important to understand the nature of analog signals and their frequency components. All analog signals are comprised of signals of various frequencies. A commonly used analogy is that of the color spectra. Just as white light is made up of a variety of colors that have different wavelengths (frequencies), physiological signals are comprised of specific signals with unique frequency signatures.

For example, an electroencephalogram (EEG) recording is comprised of several different types of signals, each of which has a different frequency signature. Alpha waves (one of the most studied EEG signals) have a frequency range of about 8 Hz to 13 Hz. This means that alpha waves go through a complete cycle (from peak to peak or trough to trough) anywhere from eight to 13 times a second.

There are, of course, signals that have other frequency signatures in EEG data. Most types of physiological data have a number of different frequency signatures present in the overall signal. In addition, frequency components besides the signal(s) of interest are often present. In the U.S., it is not uncommon for 60 Hz electrical noise to be acquired along with physiological signals (in other countries, AC interference is present at either 60 Hz or 50 Hz).

Use digital filtering to retain only the frequency components of interest and remove other data (whether it is "noise" or merely physiological signals outside the range of interest).

It is important to note that the way in which data is filtered depends in large part on the sampling rate at which the original data was acquired. For instance, if data was collected at 50 samples per second (50 Hz), it is not possible to filter out 60 Hz signals.

In fact, data must be sampled at a rate equal to at least twice the frequency of the signal to be removed. So, if data is to be collected and the information between 80 Hz and 120 Hz is to be removed, the data must be sampled at 120 Hz*2, or 240 samples per second (or faster). Also, each channel of data is filtered separately, so removing one type of data from one channel will not affect any other channels.

Digital filters can be divided into four general classes:

low pass band pass high pass band stop

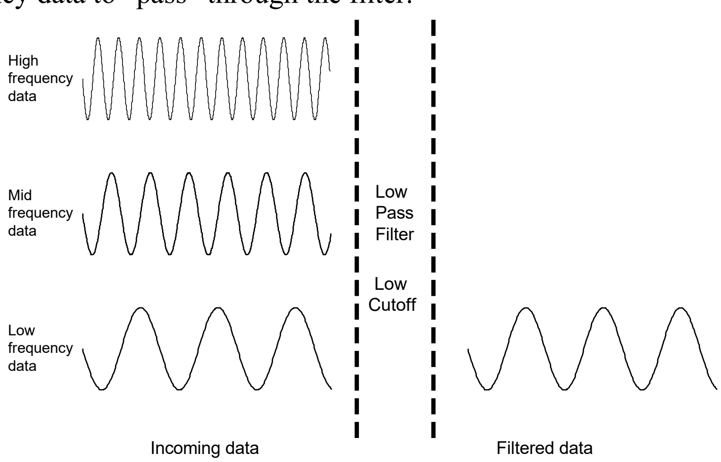
Descriptions of these four classes of filters follow, with visual examples of how these filters work. In each of the four examples, a single channel of data containing frequency components in three ranges (low frequency, mid-range, and high frequency) is acquired.

- Low frequency data, by definition, has slowly changing values, much like respiration patterns or core temperature variations.
- High frequency data, compared to low frequency data, is noticeably more "spiked," much like an EMG signal. The high frequency wave repeats itself about five times in the time it takes the low frequency wave to repeat once.
- Mid-range data falls somewhere in between these two extremes.

In the examples that follow, one possible way that these data could have been collected is if respiration were measured, but the measurement was contaminated with high-frequency muscle movement and mid-frequency signal coming from AC interference. The data is then passed through a filter, where some of the frequency components are removed.

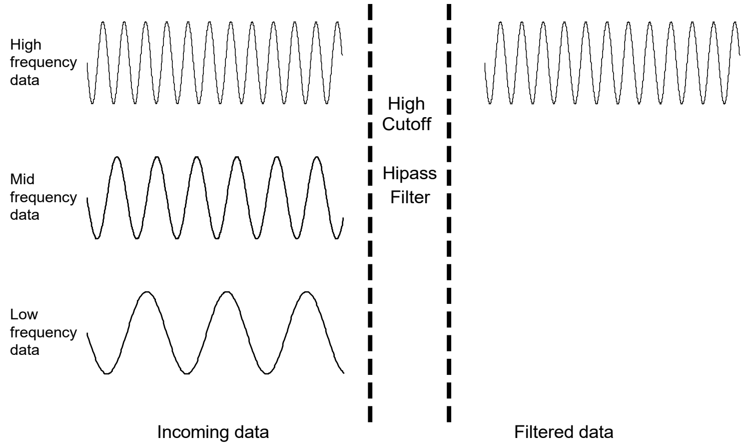
Low pass filtering

In the example below, a low pass filter attenuates the data above a given threshold, allowing only lower frequency data to "pass" through the filter.



High pass filtering

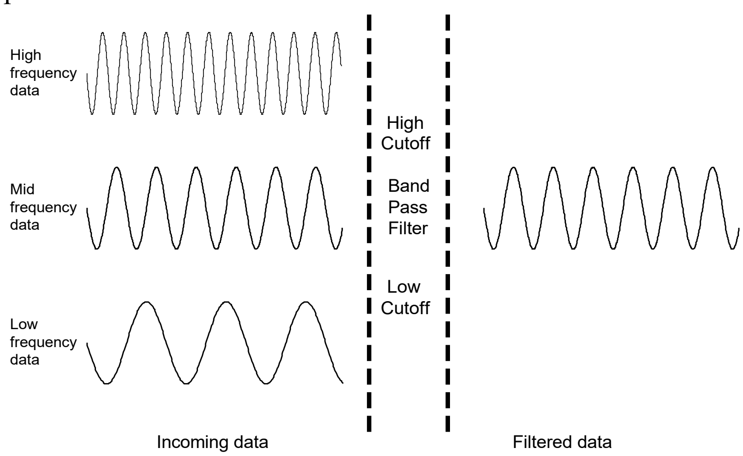
In the example below, a high pass filter removes the low and middle range data, but allows the high frequency data to pass through the filter.



Whereas the low pass and high pass filters retain data either above or below a given threshold, the next two types of filters work with a range, or band, of data.

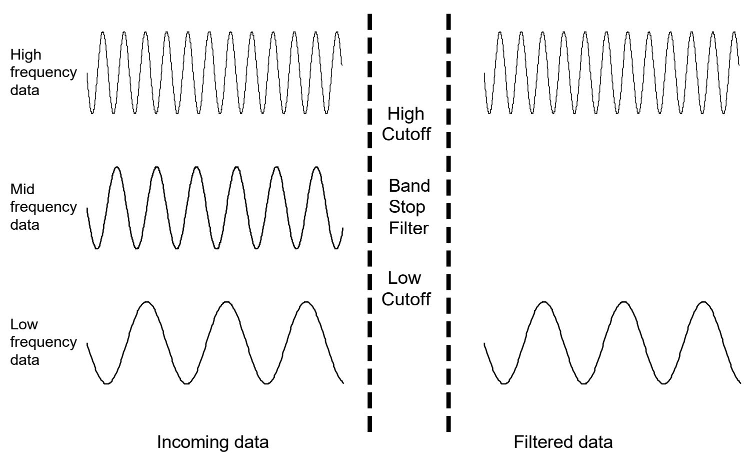
Band pass filter

The band pass filter, allows only the data within the specified range to pass through the filter. A band pass filter is useful for retaining only specific waves from an EEG record. For example, to retain alpha waves, set the filter to only pass data between 8 Hz and 13 Hz.

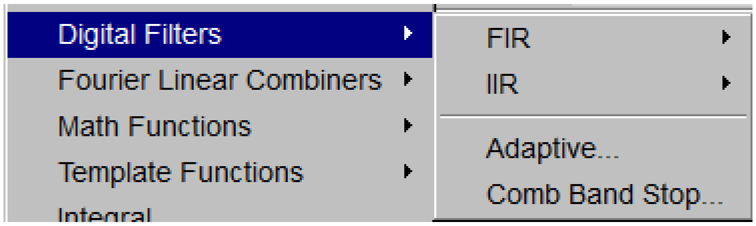


Band stop filter

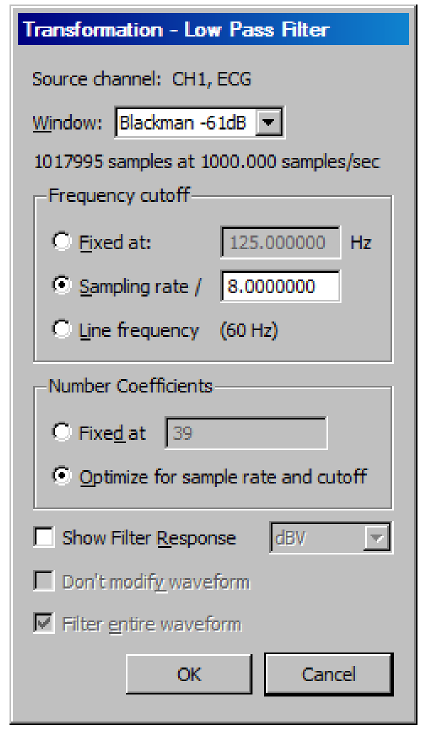
The band stop filter allows data to pass above and below the specified range. This type of filter is typically applied to remove extraneous 60 Hz or 50 Hz noise from a data record.



FIR Filters



Digital filter dialog



When selecting an FIR filter type, the corresponding Digital Filter dialog will appear, allowing a number of different filtering options to se selected.

1. Window. The Window popup menu presents a variety of filtering algorithms. The filter default is set to a “Blackman” type. These different Windows (described in detail in Appendix B on page 692) allow fine tuning of the filter response.
2. Cutoff Frequency (Hz) (or threshold). Enter a fixed value or set to a fraction of the sampling rate or to line frequency.

   Sampling rate—frequency is set to a fraction of the sampling rate and automatically updates when the sample rate is modified.

   Line frequency—frequency is set to the line frequency at which the data was recorded.

   Fixed at —Fixed value guidelines are as follows:

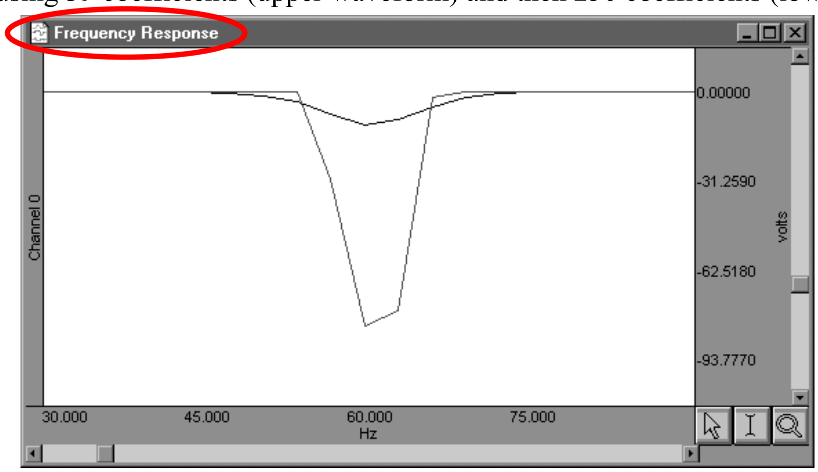
   - *Low Pass Filter*—data with frequency components below the cutoff will pass through the filter, whereas frequency components above the threshold will be removed. For low pass filters, the default cutoff frequency is the waveform sampling rate divided by eight and can be set to any value between 0.000001Hz and 0.5 times the sampling rate.
   - *High Pass Filter*—data with frequency components above the cutoff will pass through the filter, whereas frequency components below the threshold will be removed. For high pass filters, the default threshold is the waveform sampling rate divided by four and can be set to any value between 0.000001Hz and 0.5 times the sampling rate.
   - *Band-type Filters*—a low threshold and a high threshold must be specified to define the band of data (the frequency range) that is either passed or stopped, depending on whether it is a Band Pass or Band Stop filter. In either case, the default for the low threshold is the waveform sampling rate divided by eight and the default for the high threshold is the waveform sampling rate divided by four. The threshold settings can take on any value from 0.000001Hz and 0.5 times the sampling rate, but the two thresholds cannot be set to the same value and the high threshold must be greater than the low threshold.
3. Number of Coefficients. Enter a fixed value or enable the optimize option.
   - Fixed at—This determines how well the filter will match the desired cutoff frequency (or range). The minimum number of coefficients is 3 and the maximum must be less than the total number of sample points in the selected area. The software will truncate the maximum number of coefficients to the highest odd number less than the total.
   - Optimize for sample rate and cutoff—the number of coefficients is set as four times the sampling rate divided by the cutoff frequency of the filter. Optimize does not necessarily produce the best quality filter, but it takes less time.

   The recommended number of coefficients is

   4 x (waveform sampling rate/lowest frequency cutoff for the filter)

For every filter except the band pass, the lowest frequency cutoff is equal to the specified cutoff frequency for the filter; for the band pass filter, the lowest frequency cutoff is the low frequency cutoff setting. Filters that use a small number of coefficients tend to be less accurate than filters that use a large number of coefficients. Larger coefficients increase filter accuracy, but also increase the processing time required to filter the data.

To see how changing the number of coefficients affects the way data is filtered, it can be useful to examine the filter response patterns. In the example below, data was collected at 500 Hz and the band stop filter was designed to remove 60 Hz noise using a low cutoff of 55Hz and a high cutoff of 65Hz. The same data was band stop filtered using 39 coefficients (upper waveform) and then 250 coefficients (lower waveform).

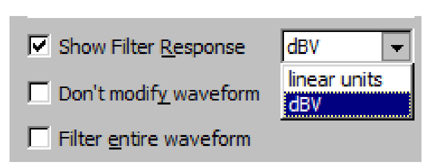


Along the horizontal axis, the units are scaled in terms of frequency, with lower frequencies at the left of the screen. The values along the vertical axis are scaled in terms of dB/V and indicate the extent to which various frequencies have been attenuated.

In both filter response waveforms, there is a downward-pointing spike that is centered on 60 Hz. The baseline of the filter response corresponds to a value of approximately 0 on the vertical axis, indicating that the signals significantly above or below 60 Hz were not attenuated to any measurable extent. Observe that the filter does not chop the data at either 55 Hz or 65 Hz, but gradually attenuates the data as it approaches 60 Hz.

For example, the upper waveform in the filter response plot represents data that was filtered using a value of 39 coefficients. The slope is relatively shallow when compared to the lower waveform, which represents a filter response performed with 250 coefficients. Although the filter that used 250 coefficients took slightly longer to transform the data, the filter response pattern indicates that the data around 60 Hz is attenuated to a greater degree. Also, the 250-coefficient filter started to attenuate data considerably closer to the 55 Hz and 65 Hz cutoffs, whereas the default filter began to attenuate data below 55 Hz and above 65 Hz.

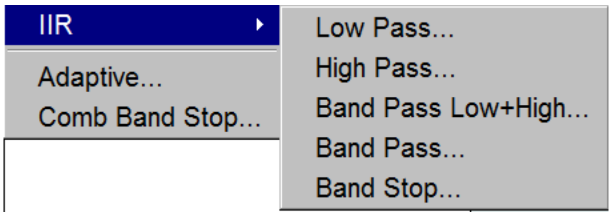
> TIP: A good rule of thumb is to use a number of coefficients greater than or equal to two times the sampling rate divided by the lowest cutoff frequency specified. For example, if running a low pass filter at 1 Hz on data sampled at 100 Hz, choose at least (2 x 100/1) or 200 coefficients in the filter. Additional coefficients will improve the response.

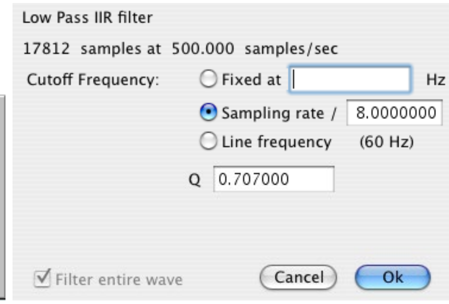


4. Show Filter Response. When checked, this option generates a plot of the filter response in a new window, labeled “Frequency Response” (see example above).
   - Units: Select linear units or dBV.
5. Don’t modify waveform. This option is useful in conjunction with the “Show Filter Response” option. When both boxes are checked, Acq*Knowledge* will produce a plot showing the filter response, but will not modify the waveform. This allows for repeatedly specifying different filter options (without modifying the waveform) until the desired frequency response is achieved.
6. Filter entire wave. If this option is checked, Acq*Knowledge* will filter the entire wave and replace the original. To keep the original, duplicate it prior to filtering.

IIR Filters

To access the IIR filter dialog, click the Transform menu, scroll to select Digital Filters, drag right to IIR and drag right again for the filter options. For all filter types, the software will limit the frequency setting so it cannot exceed one-half the channel sampling rate. For real-time filter options, see page 165.





Low Pass and High pass
: Pass data that falls below or above the specified standard. The Low Pass default is waveform sample rate/8; the High pass default is waveform sample rate/4.

Band Pass (low + high)
: Pass a variable range of data. Specify a low frequency cutoff and a high frequency cutoff to define the range or "band" of data that will pass through the filter; frequencies outside this range are attenuated. For the Band Pass Low + High filter, the low default is waveform sample rate/8 and the high default is waveform sample rate/4.

- This filter is best suited for applications where a fairly broad range of data is to be passed through the filter. For example, apply to EEG data to retain only alpha wave activity.

Band Pass (single freq)
: Requires only a single frequency setting, which specifies the center frequency of the band to be passed through the filter. The "width" of the band is determined by the Q setting of the filter (discussed in detail below). Larger Q values result in narrower bandwidths, whereas smaller Q values are associated with a wider band of data that will be passed through the filter. This filter has a bandwidth equal to Fo/Q, so the bandwidth of this filter centered on 50 Hz (with the default Q=5) would be 10 Hz. Although functionally equivalent to the Band Pass (low + high) filter, this filter is most effective when passing a single frequency or narrow band of data, and to attenuate data around this center frequency. The Band Pass (single frequency) default is waveform sample rate/8.

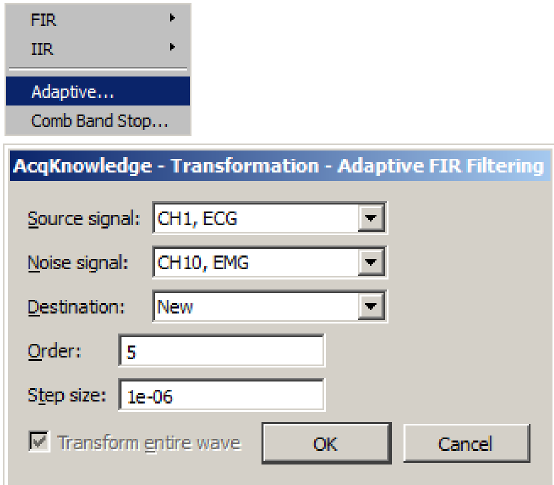
Band Stop (single freq)
: Defines a range (or band) of data and attenuates data within that band (the opposite function of a band pass). This filter is implemented in much the same way as the standard Band Pass, whereby a center frequency is defined and the Q value determines the width of the band of frequencies that will be attenuated. The Band Stop (single frequency) default is waveform sample rate/8.

Q coefficient
: The online filters are implemented as IIR (Infinite Impulse Response) filters, which have a variable Q coefficient. The Q value entered in the filter setup box determines, in part, the frequency response of the filter. This value ranges from zero to infinity, and the "optimal" (critically damped) value is 0.707 for the Low Pass, High pass and Band Pass filters. A Q of .707 for any of these filters will result in a second order Butterworth response. The Q is set to a default of 5.000 for the single frequency Band Pass and Band stop filters. For more details about the Q setting, see the Appendix.

Sampling rate
: Sets the Frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.

Line frequency
: Sets the Frequency to the line frequency at which the data was recorded.

Adaptive Filtering



Adaptive filtering is a signal processing technique that processes two different signals in relation to one another and can be used for noise estimation, noise reduction, general-purpose filtering, and signal separation. Adaptive filtering creates efficient high-quality filters with a minimal number of terms, which can be very useful in blocking mains interferences or other known periodic disturbances.

- Useful for noise filtering where it is possible to acquire a signal that is correlated to the noise (similar to the way noise-cancelling headphones detect and remove outside noise). Applications include removing EMG from ECG or EOG from EEG.

➲ See the Adaptive Filtering Calculation Channel on page 180.

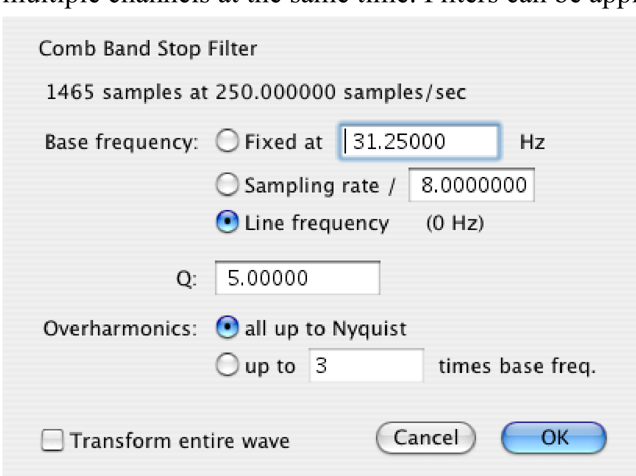
The weights within an adaptive filter are modified on a step-by-step basis. Acq*Knowledge* uses the N-tap FIR adaptive filter, with coefficients updated using least means squares (gradient) feedback.

Source signal	The source channel will be replaced by the adaptive filter results.
Noise signal	The noise channel is the signal that is correlated with the noise to be eliminated from the Source; it is not modified by adaptive filtering.
	Source and Noise channels must have the same sampling rate.
Order	Specify a positive integer for the number of terms to be used in the internal FIR filter.
Step size	Provides *mu*, the rate of adaptation of the coefficients within the FIR filter.

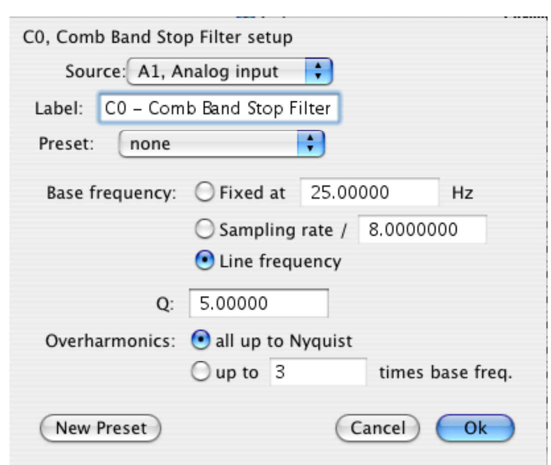
Comb Band Stop Filter

Comb Band Stop filters out a fundamental frequency and its overharmonics (integer multiples of the base). Resonance, aliasing, and other effects may generate interference at multiples of a base frequency. The Comb Band Stop filter combines all the required filters instead of requiring a separate filter for each interfering overharmonic.

Use **Filter Multiple Channels at Once** to selectively apply Comb Band Stop filters to a single channel or multiple channels at the same time. Filters can be applied to any signal type. See page 421 for additional details.



Transformation Dialog



Calculation Channel Dialog

Comb Band Stop filters remove a fundamental frequency and its overharmonics (e.g., integer multiples of the base frequency) from a signal and are useful for removing noise. Acq*Knowledge* approximates a Comb Band Stop filter by cascading a series of IIR Band Stop filters and is limited to removing frequencies and overharmonics. The number of filters used can be fixed at a particular number (e.g., limiting the number of harmonics to filter out) or configured to automatically remove all possible harmonics for any given sampling rate.

- Mac OS — Use the "Comb Band Stop Filter" Automator action to integrate Comb Band Stop filters into Workflows.

For a given base frequency ω and quality factor Q, the comb filter approximation will be given by the set of following formulas:

$$y = \left(F_{\omega} \circ F_{2\omega} \circ F_{3\omega} \cdots \circ F_{k\omega}\right)(x)$$

where $F\omega$ represents a standard two-tap IIR band stop filter for the frequency ω with coefficients computed using the quality factor Q.

The number of overharmonics of the base frequency to be removed is given by the integer value k. The maximum allowable number of overharmonics may be automatically determined given the sampling frequency f_s:

$$k_{\max} = \left\lfloor \frac{f_s}{2\omega} \right\rfloor$$

This limits the maximum overharmonic frequency to be less than the Nyquist of the sampling frequency.

After the first comb filter is performed, the most recently used settings for the comb filter will be displayed, (except for “Transform entire wave,” which will be reset each time the dialog is opened).

Textual export will include the source channel, base frequency, quality factor, and number of harmonics.

Comb Band Stop Filter Dialog

number of samples	Width of the selection.
@ samples/sec	Waveform sampling rate of the source channel. • The channel sampling rate of the calculation channel can not exceed the channel sampling rate of the source channel. Downsampling will be applied to the source channel prior to comb filter processing, if required, and all Nyquist frequency restrictions will be determined from the calculation channel sampling rate.
Frequency	Fixed—The comb filter will remove this base frequency and integer multiples of this frequency. • Must be positive and less than the Nyquist frequency (half the sampling rate). Sampling rate—Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified. Line frequency—Uses the line frequency at which the data was recorded.
Q	Quality factor used when computing the coefficients of the IIR notch filters. • Must be positive.
all up to Nyquist	Removes all integer multiples of the base frequency. This will include all multiples of the base frequency that are less than the Nyquist frequency.

Harmonics	Removes the base frequency and integer multiples of the base frequency up to and including the multiple contained in the edit field • Must be an integer greater than 0 and must not exceed k max • The final multiple must be less than the Nyquist frequency. If it is not, the input will need to be corrected before the comb filter can be applied.
OK	If the settings are valid, executes the comb filter transformation. Verification of certain calculation channel parameters does not occur until the start of acquisition as sampling rates may be changed after calculation channels are configured. Prior to the start of acquisition, the following will be checked: • source channel to ensure it is still being acquired. • base frequency of the comb filter to ensure it is less than the Nyquist frequency of the channel sampling rate. • if the user has manually specified that a fixed number of overharmonics should be used, the number of overharmonics to ensure the highest used overharmonic does not exceed the Nyquist frequency of the channel sampling rate. If any of the parameters are invalid, a prompt will be displayed indicating which settings are incorrect and must be fixed for the acquisition to be started.
Cancel	Quits without modifying any data.
Source	All enabled analog, digital, and lower-index calculation channels.
Label	When the calculation type of a channel is changed to comb filter, the title of the channel will be replaced with the default label “C*n* –Filter” where *n* is the index of the calculation channel. • Must be 40 characters or less.
Preset	Displays the title of any Calculation Preset currently applied to the calculation channel.

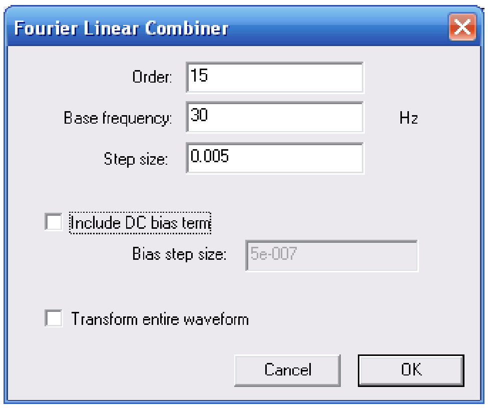
Fourier Linear Combiners

Transform > Fourier Linear Combiners:

➲ See FLC Calculation Channel options on page 179.

➲ See FLC references on page 339.

Fourier Linear Combiners are linear combinations of adaptable sinusoidal functions that are particularly well suited to processing cyclic data. Sine and cosine harmonics of a *base frequency* are summed together and the *order* is the fixed number of harmonics used in the model. *Step size* provides mu, the gain factor used to adjust the weights of the harmonics at each processing step. Step sizes must be much less than 1 for the system to converge. As step sizes decrease, relaxation time lengthens. The FLC model is adjusted based on the source data using least means square (LMS) feedback and the *bias* compensates for DC offset.



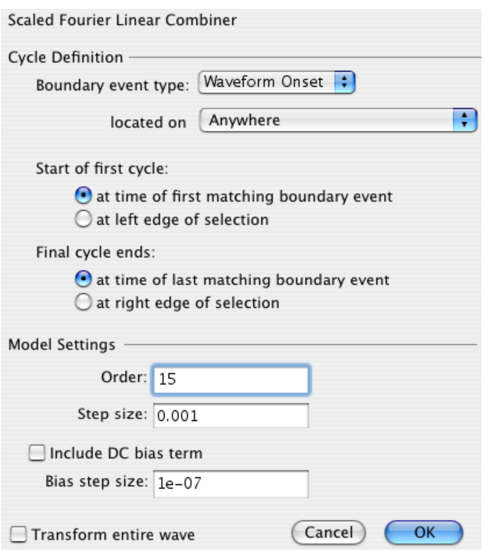
Basic FLC

Simple summation of fixed numbers of sines and cosines; uses harmonics of a fixed frequency and adjusts weighting coefficients of the mixture.

Operates on a single channel at a time.

Well suited for extracting data of a known frequency band from a signal with a stable frequency.

- Use as an adaptive noise filter to remove non-periodic and semi-periodic noise uncorrelated to the base harmonic frequency.



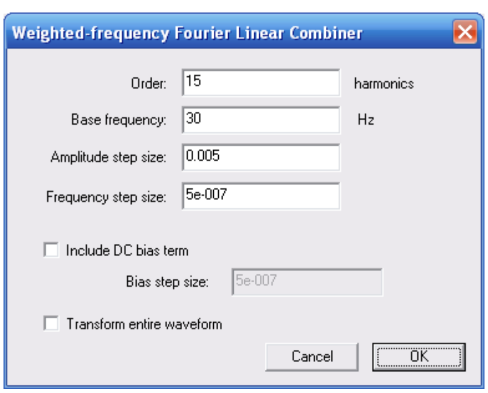
Scaled FLC

Fundamental harmonic frequency can vary on a cycle-to-cycle basis. The frequency remains fixed within a single cycle and must be known before processing.

Scales the harmonics used in each cycle based on cycle boundary events (defined through the Cycle Detector, ECG Analysis, or manually). Events from one signal can be used to drive analysis of another signal.

Well suited for signals with detectable boundaries, such as ECG.

- Use to extract information that is tightly coupled to other cyclic signals, such as extracting ICG based upon *Knowledge* of the RR cycles of the ECG.



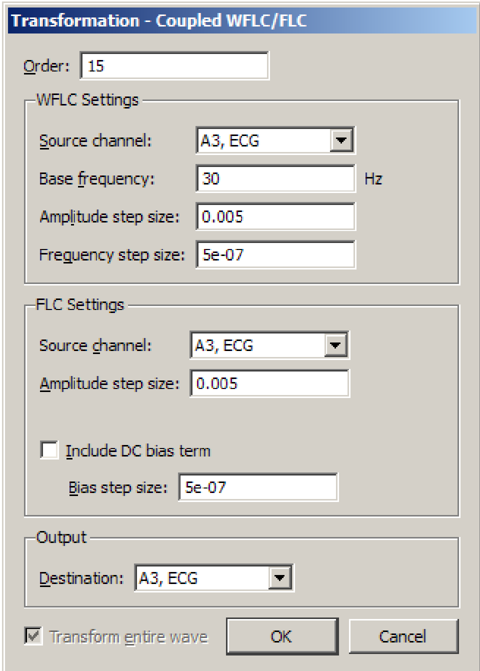
Weighted-Frequency FLC

Base frequency of the harmonics is variable; adapts the frequency in response to the input signal using LMS feedback; the frequencies are similarly adjusted to the amplitudes.

Operates on a single channel at a time.

Well suited for modeling periodic signals of an unknown and potentially varying frequency and/or amplitude.

- No cycle boundaries or frequencies need to be pre-determined.



Coupled WFLC/FLC

Runs a WFLC on the signal to determine the harmonic frequency and then runs the result through an FLC using the computed harmonic. The second FLC can be run on the same or a different channel.

The transformation will occur in the channel designated as " Output."

Well suited for real-time extraction of information from one signal based upon the frequencies contained in another signal.

- Use to remove movement noise from ECG.
- Unique configurations can be established with two input signals, one for frequency and one for amplitude.

FLC References

The basic Fourier linear combiner (FLC) is described by Vaz and Thakor.

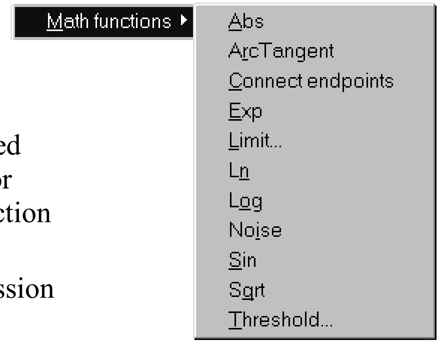
- Christopher A. Vaz, and Nitish V. Thakor, "Adaptive Fourier Estimation of Time-Varying Evoked Potentials," *IEEE Trans. Biomed. Eng.*, VolBME-36, pp. 448-455.

The weighted-frequency Fourier linear combiner (WFLC) and the coupled weighted-frequency Fourier linear combiner (CWFLC) are described by Riviere, Rader, and Thakor.

- Cameron N. Riviere, R. Scott Rader, and Nitish V. Thakor, "Adaptive Canceling of Physiological Tremor for Improved Precision in Microsurgery," *IEEE Trans. Biomed. Eng.*, Vol BME-45, pp. 839-846.

The scaled Fourier Linear Combiner (SFLC) is described by Barros, Yoshizawa, and Yasuda.

- Allan Kardec Barros, Makoto Yoshizawa, and Yoshifumi Yasuda, "Filtering Noncorrelated Noise in Impedance Cardiography," *IEEE Trans. Biomed. Eng.*, Vol BME-42, pp. 324-327.

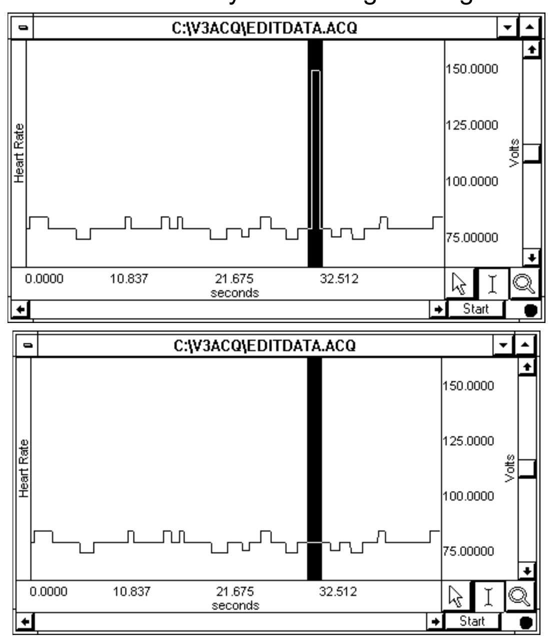


Math Functions

Acq*Knowledge* supports a wide range of mathematical and computational transformations after an acquisition has been completed. Unless otherwise noted, each of these functions applies only to the selected area of the selected channel. If no area is selected (i.e., a single data point is selected), the cursor will blink and Acq*Knowledge* will transform the entire wave. If a math function attempts to divide by zero, a zero will be returned.

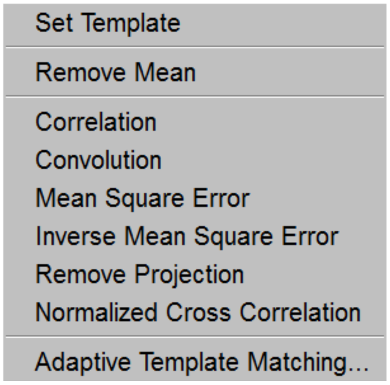
For complex transformations involving multiple functions, using the Expression transformation is recommended (see page 356 for details).

The following table describes the commands available in the Transform > Math functions menu:

Transform > Math	Explanation of Command
Abs (Absolute Value)	Computes the absolute value of the data. All negative data values are made positive, with no change in magnitude. This function can be used to rectify data.
Atan (Arc Tangent)	Returns the arc tangent of each data point in radians. This rescales the data such that the range is from $-\pi/2$ to $\pi/2$.
Connect endpoints (Connect the endpoints)	Draws a line from the first selected sample point to the last selected sample point and interpolates the values on this line to replace the original data. The *connect endpoints* function is useful for removing artifacts in the data or in generating waveforms. In the example below, the "noise spike" in the data is an undesired measurement artifact that should be removed. The Cut operation will remove data, but the subsequent data will be shifted to the left. Connect endpoint preserves the time series of data on the horizontal axis by connecting the edges of the selected area..  *Area selected before (top) and after (bottom) connect endpoints function*
Exp (Exponential)	Computes the function e^x, where x is the waveform data and e is 2.718281828. This is the base of the natural logarithms.

Limit (Limit data values)	“Clips” data outside the range specified by the set of boundaries in the limit dialog. This operation prompts the user for an upper and lower limit. Any data values outside these limits will be clipped. To limit only one boundary (high or low), set one edge to the desire level and the second boundary beyond the Max/Min value of the data within the selected area. For example to set all negative values to zero and leave the positive values unchanged: set the lower limit to zero and the upper limit to a value greater than max for the selected area.
Ln (Natural Logarithm)	Computes the natural logarithm of the selected section. The inverse of this function is the exponential function, *Exp*.
Log (Base 10 Logarithm)	Computes the base 10 logarithm of the selected section. In order to perform the inverse of this function, which would be 10^x, use the Waveform Math power operator with the constant k=10 as the first operand and the waveform data as the second operand.
Noise	Converts the selected section into random data values between –1.0 and +1.0. This is mainly useful for creating stimulus signals and other waveforms.
Sin (Sine)	Calculates the sine of the selected section. The data is assumed to be in radians.
Sqrt (Square Root)	Takes the square root (√) of each data point in the selected section.
Threshold (Threshold data values).	Transforms all data points above the threshold to +1 units, and converts all values below the lower threshold to 0 units. Once the data crosses a threshold it will continue to be set to +1 for the upper cutoff and 0 for the lower cutoff, until it crosses the opposite threshold. The most common application of this function is to serve as a simple peak detector, the results of which can be used in rate or phase calculations. Threshold Algorithm Assume a domain variable with t_{start} being an integer, a real-valued signal y(t) defined for all t, and two real valued levels y_{low} and y_{max} satisfying the relation . Define the threshold function thresh(t) function such that:

Template Functions



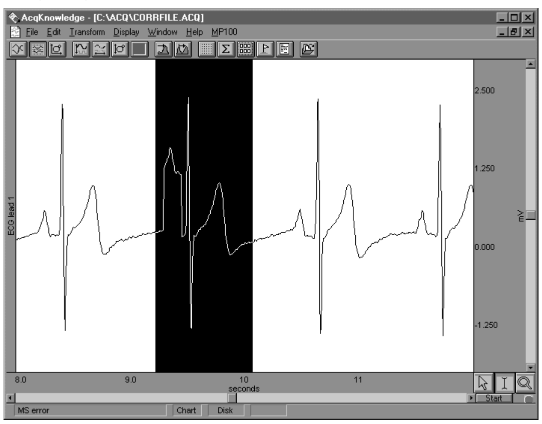
The Template Functions are useful for comparing waveforms. Technically, the template functions provide correlation, convolution, mean square error, inverse mean square error, remove projection, normalized cross correlation transformations of a template waveform against another waveform. To activate the full template menu, select an area and then select set template.

Set Template

Use the following ECG waveform as an example and contains an abnormality. After detecting an abnormality, this operation can help detect if there are other (similar) abnormalities in the recording. To do that, it's necessary to select the pattern to search for, and then compare that pattern to other data sets in the file.

Selecting a section of a wave to be used as a template:

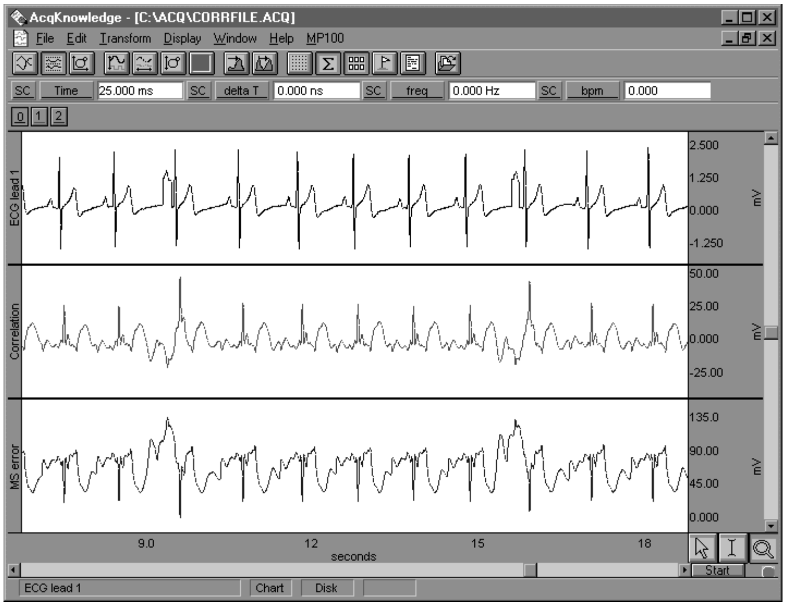
1) Highlight the section to be used as a pattern.



2) Click the Transform menu and choose Set template from the Template functions submenu. This copies the selected portion into a buffer for subsequent template functions
3) Select the waveform and position the cursor at the beginning of the data.
4) Choose Correlation from the Template functions submenu. The center waveform in the graph below shows the result of the correlation.

Note the higher amplitude peaks where the template data more closely matches the waveform. The lower waveform illustrates the mean square error function, which is similar to the correlation function.

This indicates that there are two abnormal beats in the waveform. The first one appears at about 3 seconds and is the one used as a template; the second one appears at about 11 seconds.



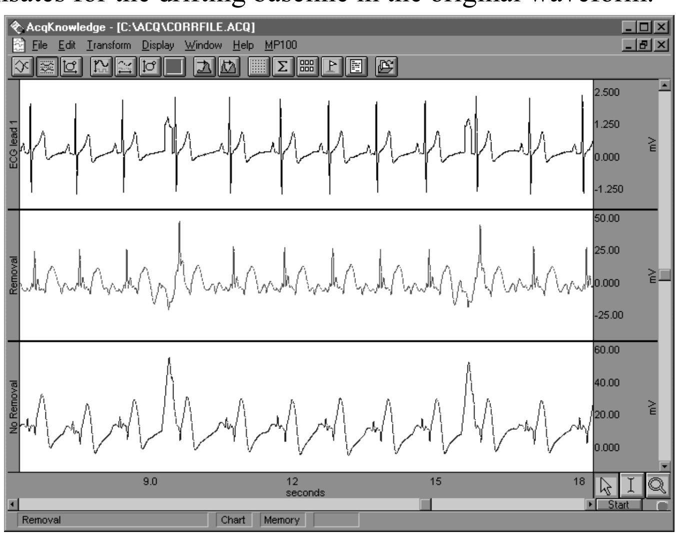
Result of correlation and mean square error functions

5) Use the zoom tool to inspect the abnormalities more closely.

Remove mean

A drifting baseline can be problematic when comparing waveforms. The effectiveness of a comparison of a template or waveform with a slowly drifting baseline will be increased by applying the Remove mean template function. The remove mean option causes the mean amplitude value of the template and the compared section of the waveform to be subtracted from each other before the sections are compared. This way, a large baseline offset will have very little effect on the comparison. This option is toggled every time it is selected and is enabled when a check mark is present.

For example, the following graph shows the original waveform at the top, the correlated waveform with mean removal in the middle, and the same correlation without mean removal at the bottom. Note how the mean removal effectively compensates for the drifting baseline in the original waveform.



Correlation with and without mean removal

Template algorithms

The template functions are: correlation, convolution, mean square error, inverse mean square error, normalize cross correlation, remove projection and adaptive template matching.

a) Correlation is a simple multiplication and sum operation. The template is first positioned at the cursor position in the waveform to be correlated. Each point in the template waveform is multiplied by the corresponding point in the data waveform (the waveform to be correlated) and summed to produce the resulting data point. The template is then moved one data sample forward and the operation is repeated to produce the next resulting data point. The resulting data points replace the waveform to be correlated.

The correlation function algorithm can be expressed by the following formula, where $f_{output}(n)$ is the resulting data point, $f_{template}(k)$ is the template waveform data points, and K is the number of data points in the template:

$$f_{output}(n) = \sum_{k=1}^{K} f_{template}(k) * f_{waveform}(n)$$

b) Convolution is identical to the correlation function except that the template waveform is reversed during the operation. This function is not generally useful by itself, but can be used as a building block for more sophisticated transformations. The convolution function algorithm can be expressed by the following formula, where $f_{output}(n)$ is the resulting data point, $f_{template}(k)$ is the template waveform data points, and N is the number of data points in the template:

$$f_{output}(n) = \sum_{k=-N/2}^{N/2-1} f_{template}(-k) * f_{waveform}(n+k)$$

c) Mean square error positions the template at the cursor position in the waveform to be compared. Each point in the template waveform is subtracted from the corresponding point in the waveform to be compared. The result is squared and summed to produce the resulting data point. The template is then moved one data sample forward and the operation is repeated to produce the next resulting data point. The resulting data points replace the waveform.

The mean square error function tends to amplify the error (or difference) between the template and the waveform, which makes it useful when looking for an extremely close match rather than a general comparison. When a match is found, the mean square error algorithm returns a value close to zero.

The mean square error function algorithm can be expressed by the following formula, where $f_{output}(n)$ is the resulting data point, $f_{template}(k)$ is the template waveform data points, and K is the number of data points in the template:

$$f_{output}(n) = \sum_{k=1}^{K} [f_{template}(k) - f_{waveform}(n)]^2$$

d) Inverse Mean square error simply inverts the result of the mean square error algorithm. Accordingly, when this algorithm finds a match between the template and the data, the algorithm returns the inverse of a value close to zero and, typically, a large positive spike will occur at the point of the match.

e) Remove Projection Template removes the projection of a reference signal from another part of a signal (whereas the other template functions revolve around the comparison of a portion of a signal against a reference signal).

Remove Projection treats the template in memory as a vector. The projection of the selected area onto the template is computed as a vector dot product. This projection is then removed from the source data. After a remove projection transformation, the remaining data consists of the part of the signal that is the most unrelated to the template.

Remove Projection can be useful for emphasizing signal differences. For example, it may be useful for exploring differences in an arrhythmia in comparison to a normal reference beat. It may also be useful as a denoising building block by removing the projection of a signal against idealized noise in the template.

The number of samples in the template should match the number of samples in the selected area of source data.

- Dot product is undefined for vectors of mismatched dimensions.
- If the template is longer than the selected source data, the template will be shortened (for that single transformation; it will be restored afterward) so its length matches the selection width.
- If the selection is longer than the template, any data occurring after the end of the template will not be transformed.

To create a Remove Projection template:

1. Highlight the portion of data to be used as the reference signal.
2. Transform > Template > Set Template.
3. Highlight the portion of the data to be analyzed.
4. Transform > Template > Remove Projection.

f) Normalized cross-correlation (NCC) is useful when searching for variations in the signal. Regular cross-correlation (Transform > Template > Correlation) can exhibit large amplitude spikes when the energy of a signal varies greatly or amplitudes change suddenly, causing jumps that are not necessarily indicative of a match with the template. Normalized cross-correlation is a statistical method that can help resolve these issues by applying normalization to both the template and signal being searched. This reduces the effect of amplitude variation in the result, making normalized cross-correlation useful for template matching purposes.

This transformation computes the windowed normalized cross-correlation, and results in a value between -1 to 1, which indicates the linear fit of the data set. Normalized cross correlation is defined as:

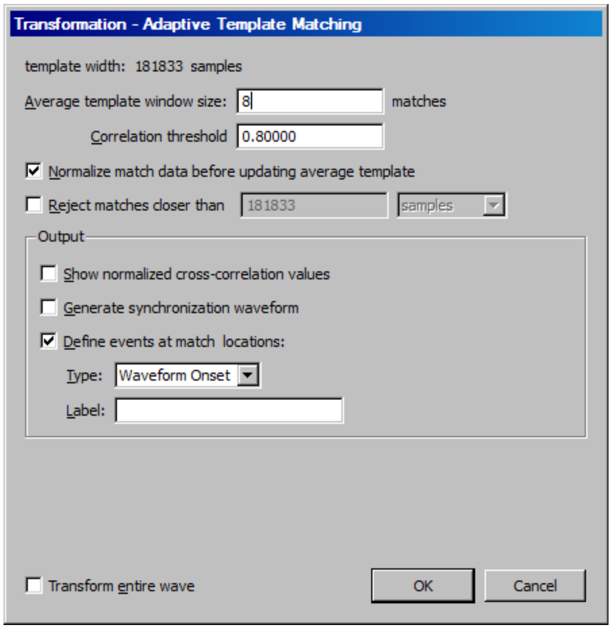
$$\gamma = \frac{\sum_{i=0}^{L}(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum_{i=0}^{L}(x_i - \overline{x})^2 \sum_{i=0}^{L}(y_i - \overline{y})^2}}$$

where x = template
y = signal
L = length
$\overline{f}$ = mean value of the signal f

At the end of the transformation, the source data will be replaced with the sliding NCC values. Data outside the selected area will be left unmodified. If the selected area is zero width when the transformation is to be executed, the entire waveform will be transformed.

If selection is shorter than the template, the missing data at the right end of the selected area will be filled with zero padding until it matches the length of the template. This padding occurs in memory and will not affect the source data in the graph. The same zero padding is used when computing NCC at the end of every selected area when the template is running off the end of the data. This zero padding should trend the NCC to zero at the right edge of the transformed area, in most cases.

Adaptive Template Matching



Many different types of physiological analysis involve locating repetitive features within a signal. These may occur at regular intervals or may occur sporadically. Sometimes the areas of interest may be intermingled with other results, such as occasional heartbeat arrhythmias occurring in a long-term ECG recording. Template matching is one frequently used approach for locating areas of waveforms that exhibit certain characteristics. An example selection is specified as the input template. Then, using cross correlation or related methods, the areas of an arbitrary wave that most strongly match the example can be located.

Adaptive Template Matching allows the template to vary during execution to incorporate changes to the morphology of signal attributes. The adaptation consists of a moving average of a number of the most recent matching attributes. A template match will be defined as a peak in the windowed normalized cross correlation of the adapting template with the signal.

Normalized cross correlation helps to eliminate artifact due to baseline shift and changes in overall power and amplitude. This heuristic is sensitive to waveform morphology instead of amplitude.

Template width

The number of samples in the template that will be used as the initial template for the transformation, as set using Transform > Template Functions > Set Template.

Note One template is shared globally by all graphs and data views in Acq*Knowledge*.

Average template window size

Input positive integers only. Provides the number of previous matches to be used for constructing the average template estimate.

Correlation threshold

Floating point input in the range -1 to 1. Provides the threshold used for peak detection on the normalized cross correlation signal. Corresponds to r in the algorithm description.

Normalize matching data before updating average template

Toggle check box. When enabled, the reference set normalization algorithm option is used. This performs mean subtraction and unit magnitude normalization to every member of the reference set prior to constructing the average template. This option can help to compensate for unintentional weighting of the windowed average template towards larger amplitude data.

Reject matches closer than

When checked, the minimum match interval algorithm option is used. This rejects matches that are too close together and can compensate for degeneration of the algorithm into continual matching due to signal self similarity. The edit field contains the minimum width that must separate valid matches. The width must always be a positive number. The popup menu specifies the units of the separation interval. Its contents are dependent on the horizontal axis type:

Time (seconds & HH:MM:SS)	Frequency	Arbitrary
samples	samples	samples
milliseconds	Hz	arbitrary units
seconds		
minutes		
hours		

Output

Show normalized cross correlation values provides access to the sequence of correlation values that is examined by the heuristic for potential matches. Viewing the normalized cross correlation signal can provide feedback that is useful for proper threshold selection and for detecting whether the heuristic has fallen into one of its degenerate cases (e.g. NCC signal hovering around the threshold for extended periods of time). When checked, a new channel will be added into the graph containing the normalized cross-correlation values computed by the algorithm. The channel will be labeled “NCC Values.”

Generate synchronization waveform allows for the generation of spike trains. The value of the wave in the graph will be zero by default. At each sample position where a match with the average template is triggered, the wave value will be set to one. A single sample position set to 1 indicates a single valid match. This synchronization wave can be used in conjunction with the cycle detector to perform further data reduction, input to the rate detector for computing match frequencies, and other analysis.

Define events at match locations output allows placement of an event on the waveform being analyzed at the location of each valid match. The event output can allow adaptive template matching to be used to construct classifiers that provide event locations for further data reduction with the cycle detector.

- *Type*—Used to choose the type of event that will be defined at match locations. Displays the standard hierarchical menu list of event types.
- *Label*—Label to be given to events defined at match locations.

Transform entire wave

When checked, the entire waveform will be analyzed. When unchecked, only the selected area will be transformed.

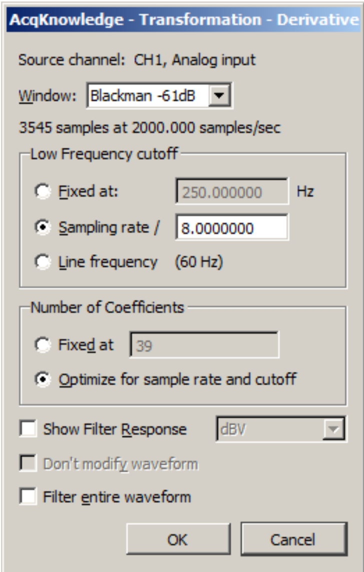
Integral

Integral is essentially a running summation of the data. Each point of the integral is equal to the sum of all the points up to that point in time, exclusive of the endpoints, which are weighted by half. The exact formula is below, where f( ) is the data values and ΔTs is the horizontal sampling interval (reciprocal of the sample rate):

$$f_{output}(n) = \sum_{k=1}^{n-1} f_{input}(k) + [[f_{input}(n-1) + f_{input}(n)]/2] * \Delta Ts$$

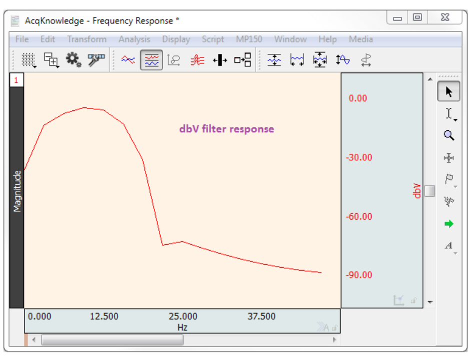
The units will be (amplitude units • horizontal units). The integral function can be used to compute the area under the curve in a continuous fashion. For instance, in data acquired by an accelerometer, the integral of the data would be the velocity, and the integral of the velocity would be the distance. As with all transformations, this function can be applied to either a selected area or to the entire waveform.

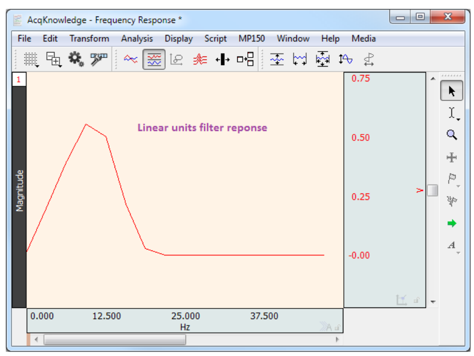
Derivative



Derivative calculates the derivative of the selected area of a waveform. Since high frequency components return nonsensical results in a derivative, a low pass filtering function is included in the Derivative function (see page 330 for more information on low pass filters). Derivative is based on an FIR filter implementation.

The Filter Response for a Derivative transformation will be displayed in linear units or in dbV. The Derivative FIR filter frequency response will appear as a linearly increasing magnitude up to the point of the specified cutoff frequency, at which point, the filter magnitude will drop off sharply.





Derivative may provide better results than Difference; if high frequency noise is present in the signal.

Cutoff Frequency — The value entered in the cutoff frequency box should be roughly equivalent to the highest frequency component of interest present in the time series data. The default cutoff frequency is 0.125 times the waveform sampling rate.

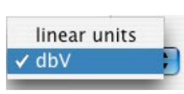
Sampling rate—Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.

Line frequency—Uses the line frequency at which the data was recorded.

# of Coefficients — Fixed—The default number of coefficients is (4 x waveform sampling rate)/Cutoff Frequency. As the number of coefficients (Q) increases, the Derivative becomes more accurate. Fixed can produce better filters but may take longer to execute.

Optimize for sample rate and cutoff—Estimate the number of coefficients as four times the sampling rate divided by the cutoff frequency of the filter. Optimize does not necessarily produce the best quality filter, but takes less time.

Units — Select linear units or dbV.



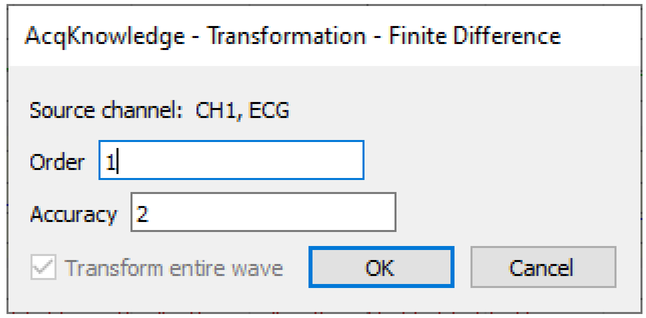
TIP: A good rule of thumb is to use a number of coefficients greater than or equal to two times the sampling rate divided by the lowest cutoff frequency specified. For example, if running a low pass filter at 1Hz on data sampled at 100 Hz, choose at least (2 x 100/1) or 200 coefficients in the filter. Additional coefficients will improve the response.

Finite Difference

The Finite Difference transformation applies an algorithm that performs numerical approximation of higher order derivatives. The finite difference is used to approximate derivatives in numerical methods, such as solving differential equations and boundary value problems. It can be scaled to approximate derivatives over intervals with larger numbers of samples and to approximate partial derivatives for multivariate systems.

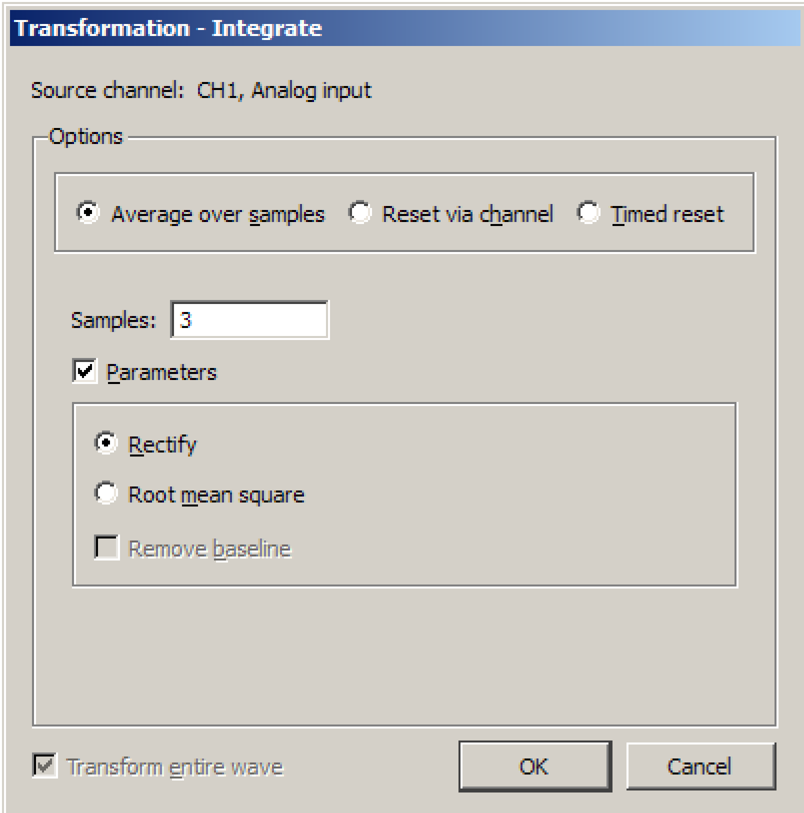
Each finite difference consists of both the **Order** of the derivative to be estimated and an **Accuracy** parameter. The accuracy setting allows additional samples outside of the minimal number of samples required for a specific order to be included in the calculation. This may be used to adjust the approximation.

The Finite Difference transformation is included with Acq*Knowledge*'s built-in transformations.



1. With a graph (.acq) file open, select the channel on which to perform the transformation.
2. Select **Finite Difference** from the **Transform** menu.
3. This will open the Finite Difference Transformation dialog box.
4. **Order** sets the order of the derivative that should be estimated.
5. **Accuracy** sets the number of extra samples to include in the finite difference. This number must be at least 2. Accuracy numbers are rounded to even numbers, so any odd entry here will automatically be converted to an even number.
6. Click OK to apply the transformation and close the dialog box.

Integrate



The Integrate transformation operates the same as the Integrate calculation—see page 153, except it does not have a Max Cycle option, which is not relevant post-acquisition, and Reset via channel with mean subtraction enabled functions differently online and offline.

Root mean square is implemented as:

Sqrt(sum(x^2)/(n))

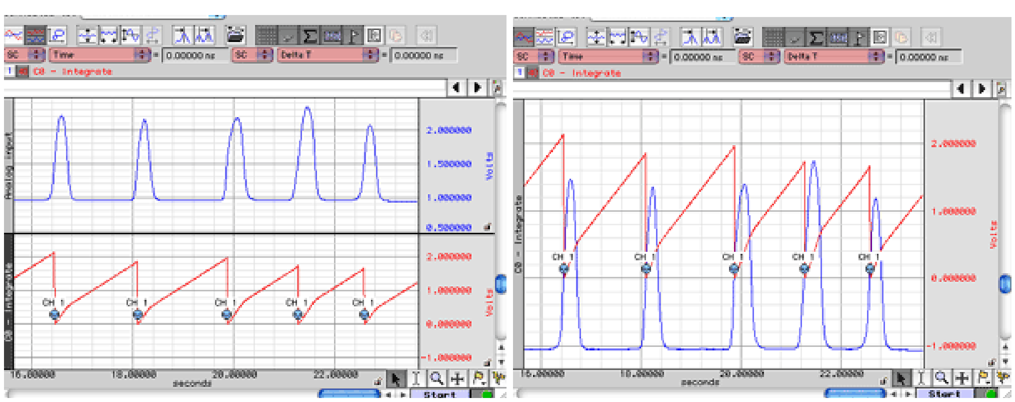
Reset

Online Mean subtraction causes the online version to be delayed by the mean cycle length. It waits for that period of time to pass so it can determine a mean value for the initial cycle, and it then tries to re-compute this mean for each cycle. If the resets are too short or too long, the window expires and the processing halts again until a new mean can be recomputed. Online processing may reset from threshold crossing in the control channel or window expiration when it loses mean tracking.

Offline Since all the data is available, the mean is computed from the data in the channel and doesn't delay the signal. Also, since it isn't doing windowed means, there are no window expiration events that are inserted. Offline processing may reset from threshold crossing in the control channel.

Output Reset

Enable the checkbox option to create an Event at each signal reset.

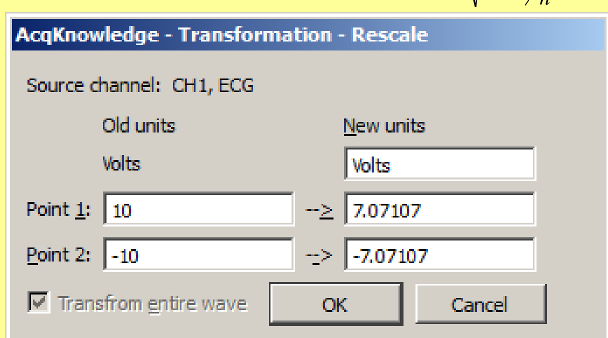


The Integrate formula is the same in the calculation (online, real-time) mode and the transformation (off-line, post-processing) mode; it varies only based on the parameters selected.

Notes

- For the first points, value of index *"i"* will be *less than or equal to zero;* it means that for summation the result will only contain values beginning with $f(x_1)$.
  - For the first point for summation: $f(x_{-1}), f(x_0), f(x_1)$.
    $f(x_{-1})$ and $f(x_0)$ - don't exist, resulting in: $f(x_1)$.
  - For the second point for summation : $f(x_0), f(x_1), f(x_2)$.
    $f(x_0)$ - doesn't exist, resulting in: $f(x_1)+f(x_2)$.
- The Integrate formula is implemented as a Standard Deviation formula (see mathworld.wolffram.com > Wolfram Research > equation 5 at http://mathworld.wolfram.com/StandardDeviation.html.
- The Root Mean Square formula is identical to the Standard Deviation formula, but without mean removal; this is the *n-1* definition.
  - For an explanation of *n-1* versus *n* in the formula, see notes in: http://duramecho.com/Misc/WhyMinusOneInSd.html
  - For a window size *n*, to convert from the *n-1* definition to the *n* definition, use $\sqrt{(n-1)/n}$
- The formulas to calculate RMS are optimal for data with a zero mean (typical for biopotential data). Data with a non-zero mean can be rescaled with the Transform option Rescale. Choose Transform > Rescale, and then enter the following parameters:

Input value (Scale) value	Map
10	7.07107
-10	-7.07107



1. Via samples, no extra parameters selected

$$F(x_j) = \sum_{i=j-s+1}^{j} f(x_i) * \Delta x$$

Where:
i - index for source values (***the real range is 1..j);
j - index for destination values (1..n);
n - number of samples;
x_i, x_j - values of points at horizontal axis;
$f(x_i)$ - values of points of a curve;
$F(x_j)$ - integrated values of points of a curve;
s – number of samples to average across;
$\Delta x = \dfrac{x_n - x_1}{n-1}$ - horizontal sample interval;
x_n, x_1 - values at horizontal axis at the endpoints of selected area.

2. Via samples, rectify

$$F(x_j) = \sum_{i=j-s+1}^{j} ABS(f(x_i)) * \Delta x$$

Where:
i - index for source values (***the real range is 1..j);
j - index for destination values (1..n);
n - number of samples;
x_i, x_j - values of points at horizontal axis;
$f(x_i)$- values of points of a curve;
$F(x_j)$- integrated values of points of a curve;
s - number of samples to average across;
$\Delta x = \frac{x_n - x_1}{n-1}$ - horizontal sample interval;
x_n, x_1 - values at horizontal axis at the endpoints of selected area.

3. Via Samples, root mean square (RMS)

$$F(x_j) = \sqrt{\frac{\sum_{i=j-s+1}^{j} (f(x_i))^2}{s-1}}$$

Where:
i - index for source values (***the real range is 1..j);
j - index for destination values (1..n);
n - number of samples;
x_i, x_j - values of points at horizontal axis;
$f(x_i)$- values of points of a curve;
$F(x_j)$- integrated values of points of a curve;
s - number of samples to average across.

4. Via samples, root mean square, remove baseline

$$F(x_j) = \sqrt{\frac{\sum_{i=j-s+1}^{j} \left[f(x_i) - \frac{\sum_{m=j-s+1}^{j} f(x_m)}{k} \right]^2}{s-1}}$$

Where:
i and m- indexes for source values (***the real range is 1..j);
j - index for destination values (1..n);
n - number of samples;
x_i, x_j - values of points at horizontal axis;
$f(x_i)$- values of points of a curve;
$F(x_j)$- integrate values of points of a curve;
s - number of samples to average across.
k - coefficient: for the first few points that have index j < s k=j,
for the other points with j > =s k=s

Integrate Timed Reset Formulas

Given an input signal x with sampling rate f_s expressed in Hertz to be reset every m samples, the timed reset integrate output O is given by the following recursive formulas indexed in terms of samples evaluated with data starting at a starting sample position j:

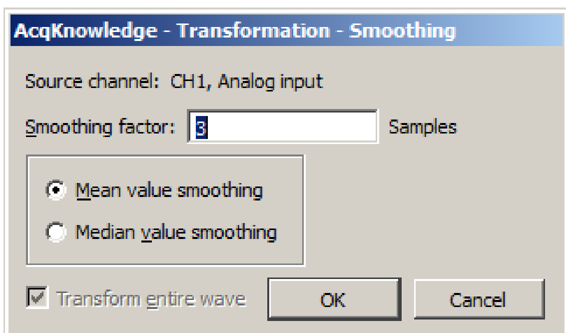
$$O_n = \begin{cases} 0 iff((n = j) \vee ((n - j) mod m = 0)) \\ x(n-1) * \frac{1}{2 * f_s} + O_{n-1} iff((n > j) \wedge ((n - j) mod m \neq 0)) \end{cases}$$

The default scaling factor applied to the signal x matches the rescaling applied by the integrate reset via channel processing. When acquiring the first segment of data into a graph, j is set to 0. For subsequent segments, j is set to the index of the first sample of new data acquired into the graph.

If rectification is enabled, the formula will be changed to take the absolute value of the source prior to the integration:

$$O_n = \begin{cases} 0 iff((n = j) \vee ((n - j) mod m = 0)) \\ |x(n-1)| * \frac{1}{2 * f_s} + O_{n-1} iff((n > j) \wedge ((n - j) mod m \neq 0)) \end{cases}$$

Smoothing



The smoothing function is a transformation that computes the moving average of a series of data points and replaces each value with the mean or median value of the moving average "window." This has the same effect as a crude low pass filter, the advantage being that there is less change to shape and amplitude of the original waveform.

Samples — Acq*Knowledge* allows the user to set the width of the moving average window (the number of sample points used to compute the mean) to any value larger than three. By default, this is set to three samples, meaning that Acq*Knowledge* will compute the average of three adjacent samples and replace the value of each sample with the mean or median before moving on to the next sample. For data acquired at relatively high sampling rates, it is recommended to set the smoothing factor to a higher value, since smoothing three sample points when data is collected at 1000 Hz will only average across three milliseconds of data, and will typically do little to filter out noise. To set the size of the window, enter a value in the Transform > Smoothing dialog.

This function is most effective on data with slowly changing values (e.g., respiration, heart rate, GSR) when there is noise apparent in the data record.

Mean value — Mean value smoothing is the default and should be uses when noise appears in a Gaussian distribution around the mean of the signal. The Mean value smoothing formula is shown below, where "m" is the number of points in the window and "n" is the sample number:

$$f_{output}(n) = \sum_{k=n-(m/2)}^{k=n+[m-1)/2]} f_{input}(k) / m$$

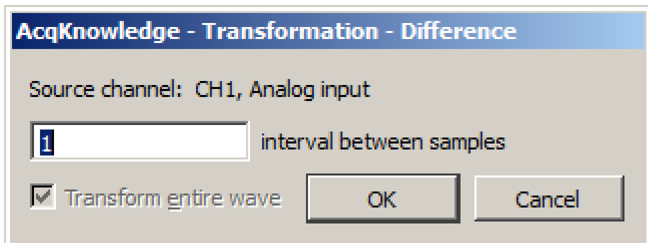
Median value Use Median value smoothing if some data points appear completely aberrant and seem to be "wild flyers" in the data set.

The Median value smoothing formula is shown below, where "m" is the number of points in the window and "n" is the sample number:

$$f_{output}(n) = \text{median}\,(n - [m/2]; n + [m/2])$$

Watch the [Acq*Knowledge* Smoothing video tutorial] for a detailed demonstration of this feature.

Difference



The Difference function measures the difference (in amplitude) of two sample points separated by an arbitrary number of intervals. The difference is then divided by the total interval between the first selected sample and the last selected sample.

When the difference transformation is selected, a difference interval dialog will be generated and the number of intervals between samples can be entered (default of 1).

For data with no high frequency components, a 1-interval difference transformation approximates a differentiator.

The formula for the difference transformation is shown below, where "m" is the number of intervals difference, [ ] rounds the integer down, "n" is the sample number, and ΔTs is the horizontal sampling interval:

$$f_{output}(n) = \frac{f_{input}(n + [m/2]) - f_{input}(n - [(m+1)/2])}{(\Delta Ts * m)}$$

Example for boundary values when m = 3:

$$f_{output}(0) = (f_{input}(1) - f_{input}(0)) \,/\, (\Delta Ts * m)$$
$$f_{output}(1) = (f_{input}(2) - f_{input}(0)) \,/\, (\Delta Ts * m)$$
$$f_{output}(2) = (f_{input}(3) - f_{input}(0)) \,/\, (\Delta Ts * m)$$

If an odd number is entered (K = odd):

$$f_{output}(K) = (f_{input}(K+1) - f_{input}(K - 2)) \,/\, (\Delta Ts * m)$$

If an even number is entered (K = even):

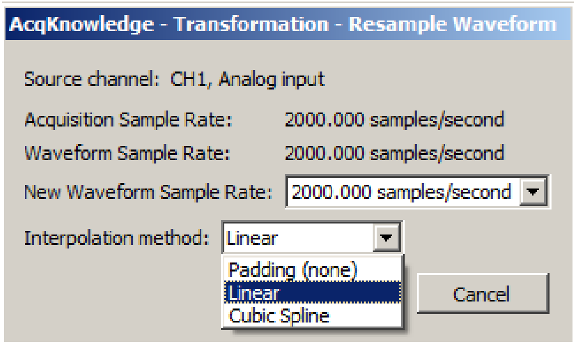
$$f_{output}(K) = (f_{input}(K+2) - f_{input}(K - 2)) \,/\, (\Delta Ts * m)$$

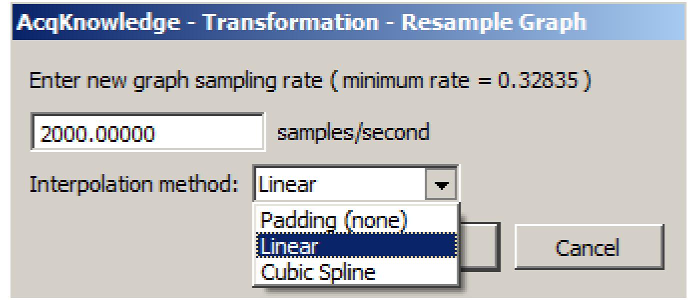
Note: The online (real-time) Difference calculation is calculated differently because projected values are not available. The online Difference formula is:

$$f_{output}(n) = f_{input}(n - m) - f_{input}(n) \,/\, (\Delta Ts * m)$$

Using the default difference setting of 1 interval will produce a "ΔP/ΔT" waveform when the transformation is applied to a blood pressure or similar waveform.

Resample





Variable sampling rate and the flexible acquisition speeds of hardware units can create data sets that are at different sampling rates. For some types of data analysis, the data must be resampled to a common sampling rate. Acq*Knowledge* has resampling facilities with Transform > Resample Graph; Transform > Resample Waveform, and Pasting between graph windows of different sample rates when the “Interpolate pastings between graphs” Preference is enabled (via Display > Preferences, page 511).

Acq*Knowledge* provides three interpolation methods for resampling data. Any changes made to the interpolated pastings between windows Preference and the interpolation method used in the Preferences dialog will be retained across launches of the software.

Padding—Padding will use the closest original value of the waveform to the left of the new sample position for the value, constructing a padded square save as the data is resampled. Padding is desirable when it is imperative no new data or data approximations get introduced into an analysis.

Linear—Linear interpolation is the default; previous software versions generated any missing data via linear interpolation. This method uses the sample points of the old waveform as the endpoints of a line. Missing data points are approximated from points lying on this linear segment.

Cubic spline—Cubic spline interpolation will construct a spline for the entire data set and use the values of this spline as the new waveform values. A natural fit spline is used that keeps zero second derivative at the endpoints of the fit. Cubic splines are useful when the analysis requires data with a smooth derivative.

Resample Graph

Apply an arbitrary, user-defined sample rate to all waveforms present in a file.

- This option will adjust as needed the channel sampling rate as well as the acquisition sampling rate.

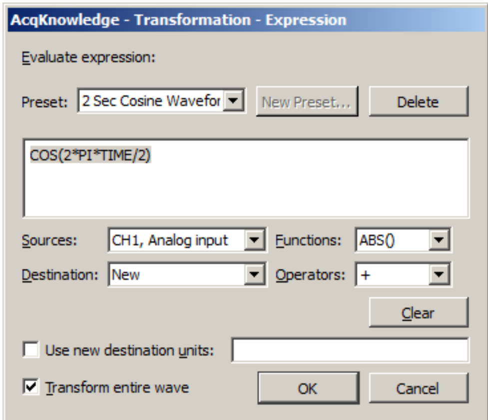
Resample Waveform

- For Resample Waveform, the highest rate that can be entered is the Acquisition Sample Rate.

Resamples the active channel to a different rate. Resampling data maintains the same time scale but changes the number of samples per second. This option can be used to increase the number of sample points per interval (usually samples per second). When this is applied, Acq*Knowledge* will interpolate between sample points to adjust to the new rate. This will add data points, although not necessarily more information.

- Resampling to a lower sampling rate will “compress” a data file and information will be lost.
  - For example, a 4-channel data file sampled at 250 samples per second for 15 minutes requires about 1.8 MB of disk space. If these channels are resampled to 100 samples per second, the size of the file on disk is about 720 KB, a considerable reduction.
- The highest rate a channel can be resampled to is the file acquisition rate (Hardware menu > Set Up Acquisition).
- If data is resampled to a lower rate and then resampled again at a higher rate, the waveform will maintain the resolution of the lower sampling rate, only with more data points.

Expression



See the tables on page 171 for descriptions of sources, operators and functions for the Expression dialog.

The post-acquisition Expression transformation is available for performing computations more complex than available with the Math and Function calculations. The post-acquisition version of the Expression transformation includes all the same features as the online version described on page 167. The Expression transformation will symbolically evaluate complex equations involving multiple channels and multiple operations. Unlike the Math and Function calculations, which can only operate on one or two channels at a time, the Expression transformation can combine data from analog or digital channels, as well as calculation channels with a lower channel number. Also, computations performed by the Expression transformation eliminate the need for "chaining" multiple channels together to produce a single output channel.

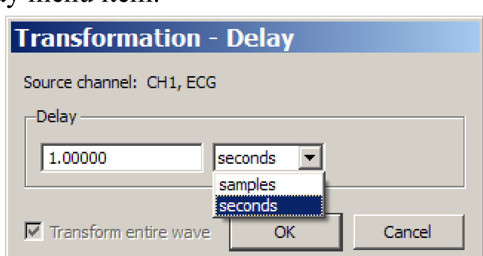
To have Acq*Knowledge* solve an expression and save the result to a new channel, choose Transform > Expression. For each expression, specify a source channel (or channels), the function(s) to be performed, any operators to be used, and a destination for the result. The components of each expression can be entered either by selecting them from the pop-up menus (sources, functions, destination, and operators), or by typing mathematical commands directly into the expression box.

Any expression can be assigned a specific name and saved as a custom preset. A pop-up menu of recently used expressions is also available in the Preset menu, along with a pre-loaded list of commonly used expressions.

The Expression transformation can reference past and future points.

Delay

The Delay transformation allows the addition of time delays in postprocessing (similar to the Delay calculation channel that can be used to add time delays to signals). The time delay can be added by introducing zero-valued samples at the start of the area to be delayed. The length of the waveform will remain the same; an amount of data at the beginning of the wave prior to the delay will be lost, with the length equal to the delay. To set up a delay, choose the Transform > Delay menu item.



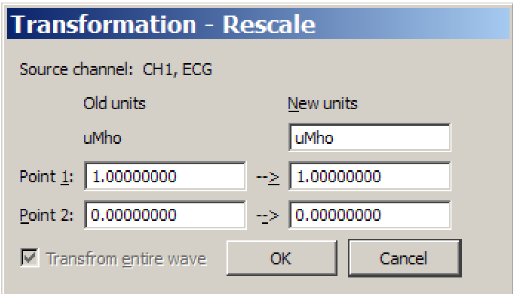
When inputting the delay amount, the units can be changed between **seconds** and **samples**.

- **Delay by samples** is applied according to the acquisition sampling rate, not the channel sampling rate.

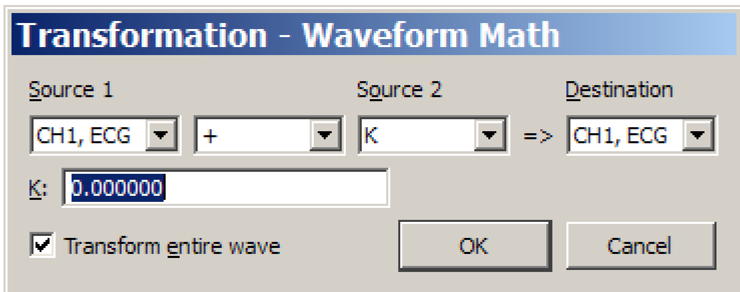
The Automator action allows Delay to be used in Automator workflows. See page 23.

Rescale

The Rescale transformation operates identically to the Rescale calculation—see page 181.



Waveform Math

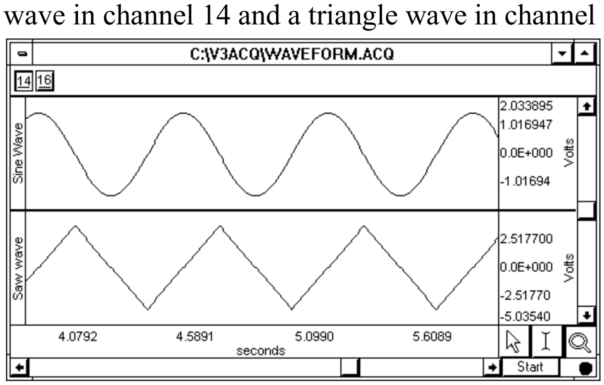


The Transform > Waveform Math operation allows arithmetic manipulation of waveforms. Waveforms can be added together, subtracted, multiplied, divided or raised to a power. These operations can be performed using either two waveforms or one waveform and an arbitrarily defined constant. Operate on the entire waveform by choosing Transform entire wave, or operate on portions of the waveform that have been selected using the cursor tool. If there is no selected area, only one sample point (the one selected by the cursor) will be transformed.

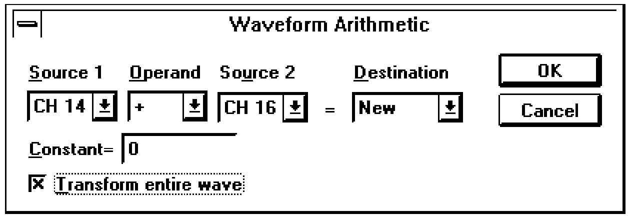
All of the main components of a waveform math calculation can be selected from pop-up menus in the Waveform Arithmetic dialog.

Source	The channels to be used in the transformation are referred to as source channels (Source 1 and Source 2), and can be combined using any of the operators in the pop-up menu. Source channels allows for selection any of the existing channels in the current window, or a constant (defined by K).
Constant	The "Constant =" entry box is activated when a Source is set to "K, Constant."
Operand	The pop-up menu allows selection of addition, subtraction, multiplication, division or power functions.
Destination	Save the results to an existing channel or create a new channel. Choose an existing channel from the pop-up menu or select the "New" option, which will create a new channel (using the next available channel).

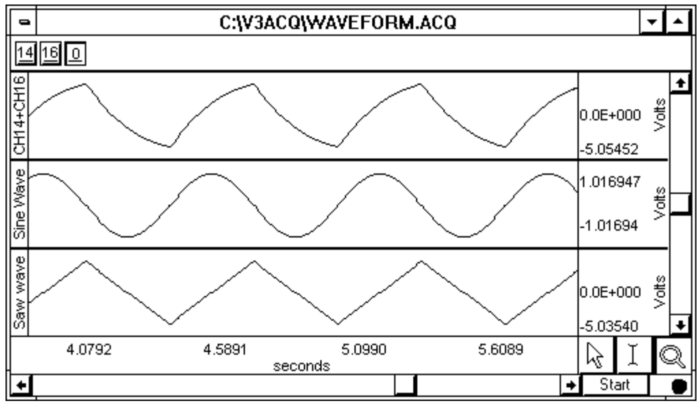
Waveform math can be used many ways. As one example, two waveforms can be added together. The following screen shows a sine wave in channel 14 and a triangle wave in channel 16.



To add these two waves, select Transform > Waveform Math and set source 1 to channel 14, the operator to addition “+”, source 2 to channel 16, and destination to New as shown here:

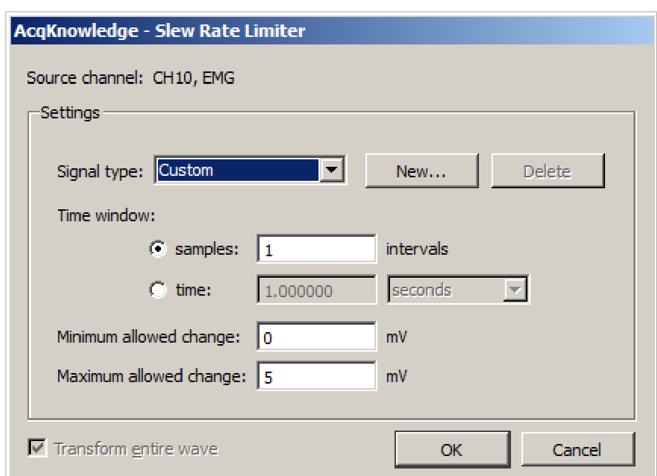


Click OK to perform the transformation. The following screen shows the sum of CH14 and CH16 on a new channel.



NOTE: If two waveforms of unequal length are selected as sources, the length of the resulting waveform will be equal to that of the shortest one. Likewise, if one of the source waveforms extends only into a portion of the selected area, the resultant waveform will only be as long as the shortest source portion. If waveform math is performed on a selected area and output to an existing waveform that does not extend into the selected area, the resultant waveform is appended to the destination waveform.

Slew Rate Limiter



The Slew Rate Limiter transformation is used for denoising and removing motion artifact during and after recording. The allowable amount of motion artifact over a given time/sample window can be precisely adjusted from a minimum allowable change to a maximum allowable change, thereby eliminating artifacts that exceed the selected amplitude range within a given time period.

Tailor the range for a given type of artifact by modifying the Time window and Minimum/Maximum allowed change parameters. Parameters for various levels of artifact detection can be permanently stored by clicking “New…” and saving the signal type as a custom preset.

To apply the slew rate limiter transformation in Acq*Knowledge*:

1. Select the desired source channel in the data.

2. Transform > Slew Rate Limiter.
3. Select the time window using a sample interval or a time value.
4. Set the desired minimum allowed change value.
5. Set the desired maximum allowed change value.
6. Click OK.

Any artifact that falls outside the boundaries of the maximum/minimum allowed change setting will be eliminated from the data.

See also: Slew Rate Limiter online calculation channel on page 182.

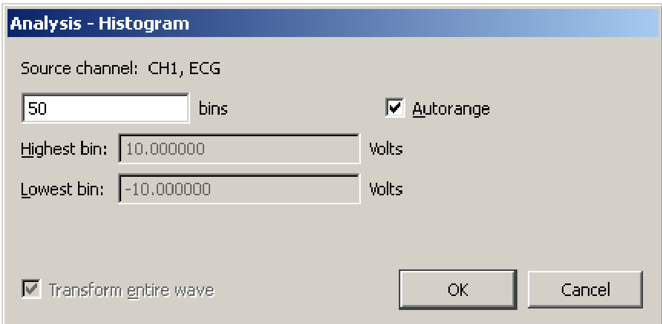
- Watch the Acq*Knowledge* Slew Rate Limiter video tutorial for a detailed demonstration of this feature.

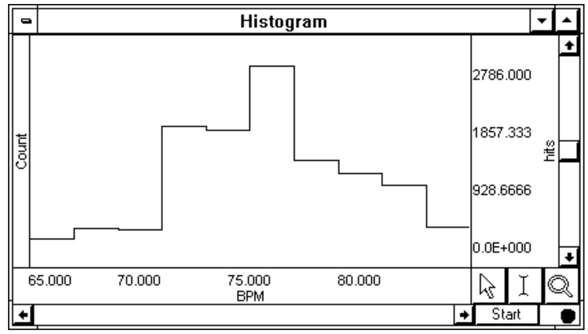
Chapter 16 Analysis Menu Commands

Overview

The Analysis menu contains operations that derive data and measurements from the graph—plus a courtesy copy of the Specialized Analysis package with classifiers and automation routines.

Histogram





The Histogram function produces a histogram plot of the selected area. When a histogram is created, the sample points are sorted into “bins” along the horizontal axis that contain ranges of amplitude values. These bins divide the range of amplitude values into equal intervals (by default, ten bins) and the individual sample points are sorted into the appropriate bin based on their amplitude value.

For instance, if a waveform had a range from 65 BPM to 85 BPM, the lowest bin would contain all data points with a value from 65 BPM to 67 BPM. The second lowest bin would hold all data points between 67 BPM and 69 BPM, and so on, until the tenth bin was created. Acq*Knowledge* then counts the number of “hits” (the number of data points) in each bin and plots this number on the vertical axis.

Analysis > Histogram Options:

bins Determines how many bins the data will be divided into; the default is ten bins.

Autorange Fits all the data selected into a bin; the bin sizes are determined by the extent of the data and the desired number of lines. Automatically sets the center of the lowest bin equal to the minimum value of the waveform (or the selected area, if a section is highlighted), and centers the highest bin on the maximum value of the waveform (or selected area, if any).

Disable to fix the bin sizes and enter values for Highest Bin and Lowest Bin.

After clicking OK, a histogram plot will be generated in a new window. By default, Acq*Knowledge* displays the frequency of occurrence for each bin on the vertical axis. To calculate the cumulative frequency, select the entire histogram waveform and choose Integrate from the Transform menu.

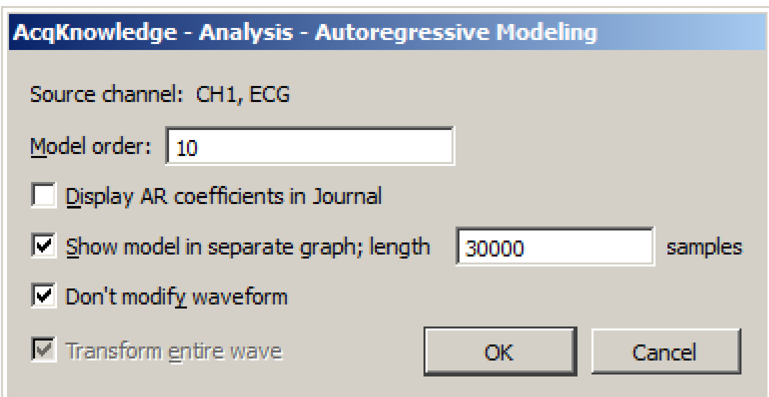
Since the histogram function sorts sample points into a relatively small number of categories, the histogram window is likely to display a large number of “hits” in each bin, especially if data was collected at a relatively fast sampling rate. If this is the case, it’s recommended to resample the data at a lower rate (using the Transform > Resample function). The caveat to this is that resampling the data may cause a bias, unless the data was filtered to remove all frequency components that are more than 0.5 the resampling rate.

Autoregressive Modeling

About autoregressive modeling

Autoregressive modeling is linear mathematical modeling algorithm well suited to operation on discrete series of data. Using autoregressive models of physiological data, it is possible to perform advanced time series analysis, compression, denoising, arrhythmia detection, and waveform classification. Its ability to be used to extrapolate spectral features from waveforms at low sampling rates makes autoregressive modeling quite useful for electrogastrogram analysis (see page 408).

AR modeling has a large number of applications in physiological signal analysis. These applications derive from its ability to approximate data through a more compact representation in AR coefficients. Other applications leverage AR modeling's ability to generate additional data for a signal with roughly the same characteristics. Specialized applications exist for ECG, EEG, and EGG in addition to general purpose analysis procedures.



AR Time-Frequency Analysis is on page 366.

Autoregressive modeling estimates the parameters of a fixed-order autoregressive model, representing a model output value as a linear sum of previous input values. AR modeling may replace the source data with the model of equivalent length. The output length is equal to the source data, unless specified.

Output can also paste model parameters as tabular text to a journal. If “Don’t modify waveform” and “Show model in separate graph” are both enabled, a new graph window will be generated to display the specified number of samples resulting from the best-fit autoregressive model.

Nonlinear Modeling

About nonlinear modeling

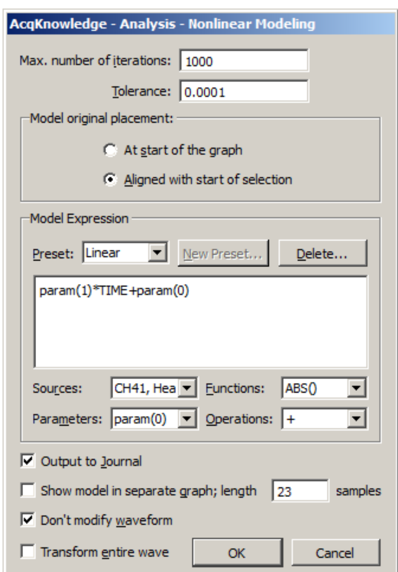
Modeling is used in physiological data to assess how well data conforms to a theoretical model. This is used to express a sampled signal in a continuous form and to perform data reduction. The nonlinear modeling features in Acq*Knowledge* support more advanced physiological analysis than is possible with the linear regression measurement, which is a rudimentary single order linear model.

Nonlinear modeling is the process of finding the best fit of a mathematical function to an arbitrary data set. Fitting the function—or model—to the data consists of choosing a set of function parameters that minimize error between the actual data points and the values generated from the model function. Nonlinear modeling functions can be arbitrarily complex. When the model is close to the shape of the data, the fits between different data sets may be good indicators of subtle variations in the data.

Most general-purpose methods of performing modeling are iterative and require an estimator for the function. A commonly used estimator is the least means squares (LMS) estimator. Nonlinear models can be estimated from data by combining LMS estimators with multidimensional function minimization algorithms.

Applications in hemodynamics

Many pressure and ECG signals exhibit regular morphologies. Fitting data to models that share these characteristics helps emphasize subtle differences in waveforms though variations in their model parameters. Nonlinear modeling is one of the most accepted methods for computing indexes for the relaxation period of left ventricular pressure. Cardiac researchers have used the time constant "tau" in various studies on cardiac function and abnormalities. Tau is determined by one of the parameters to an exponential model of the trailing end of the pressure signal. Studies have indicated that tau can be a good indicator of cardiac dysfunction, but reliable methods for its calculation have proven difficult and the effort is ongoing. The generic modeling abilities in Acq*Knowledge* allow researchers to analyze data using the tau constant and potentially develop robust algorithms for its calculation.



See the NLM measurement on page 110

Nonlinear modeling (also called "arbitrary curve fitting") determines the "best fit" of an arbitrary function to source data; the function is called a *model*.

A model must match underlying trends in the data to produce meaningful results. Also, to properly interpret the value of the best fit coefficients and any further derived results, users must consider the limitations of the simplex search method, which include: estimation only; not guaranteed to terminate; not guaranteed to find the exact solution; may get stuck in local minima.

Nonlinear modeling generates a new display and replaces source data with a model of equal (unless specified) length and also pastes model parameters as text to a journal. The sampling rate and axis units match the source graph.

Max Iterations

Indicates the number of iterations after which the simplex search will be terminated if no convergence has been achieved.

Tolerance

Provides the tolerance used for termination of the algorithm. If the estimator decreases in two consecutive steps by less than this tolerance, the simplex search will halt.

Model Origin Placement

Controls where the zero point of the model is placed. Selection-relative placement is useful when comparing different sections of the same channel of data by looking for variations in their best fit model parameters. If channel data is used as part of the Model Expression the location from where the channel data is extracted will not be translated; regardless of the model origin setting, the channel data will be used from the selected area only.

Model Expressions

These model expressions use the same expression format as other parts the program, such as the Expression calculation channel. See the function tables starting on page 171 for details on Sources, Functions, and Operators.

Preset

The following presets for the most common types of models are included. Users can extend presets or create custom models if these presets are too general to achieve exact fits with simplex search. Presets are stored at Computer > Local Disk > ProgramData > BIOPAC Systems, Inc > Acq*Knowledge* 5.x > Presets.

Preset	Description	Expression
Cubic	3rd order polynomial.	param(3)*(TIME^3)+param(2)*(TIME^2)+param(1)*TIME+param(0)
Gaussian	Standard Gaussian model; useful for peak fitting.	param(0)*EXP(-((TIME-param(1))/param(2))^2
Linear	Basic linear fit of the data.	param(1)*TIME+param(0)
Logarithmic	Logarithmic growth and decay; useful for initial rapid growth/decay followed by gradual decline/increase.	param(0)*LOG(TIME-param(1))+param(2)
Logistic	Logistic LVP relaxation model; T_L given by a(1).	param(0)/(1+EXP(-TIME/param(1)))+param(2)
Monoexponential	Exponential LVP relaxation model; T_e given by a(1).	param(0)*EXP(-TIME/param(1))+param(2)
Power Series	Useful for a wide variety of data, e.g. reactant analysis.	param(0)+param(1)*(TIME^param(2))
Quadratic	2nd order polynomial.	param(2)*(TIME^2)+param(1)*TIME+param(0)
Weibull Distribution	Commonly used in reliability analysis.	param(0)*param(1)*TIME^(param(1)-1)*EXP(-param(0) *TIME^param(1))

Sources

All channels except the active can be used as sources with the Model Expression.

Parameters

Parameters are represented by *param(n)* where *n* is an integer index starting from zero. For example, in the linear model param(0)*x+param(1), *param(0)* can be interpreted as the "a" in "ax+b and *param(1)* can be interpreted as the "b" in "ax+b."

Output to Journal displays the result of the modeling as text in the journal. **Note**: If this option is unchecked and "Show model in separate graph" is selected, the separate graph's Journal will contain the model parameters. The Output to Journal option applies only to the Journal of the original source graph.

Show model in separate graph generates a separate graph to display the best fit model.

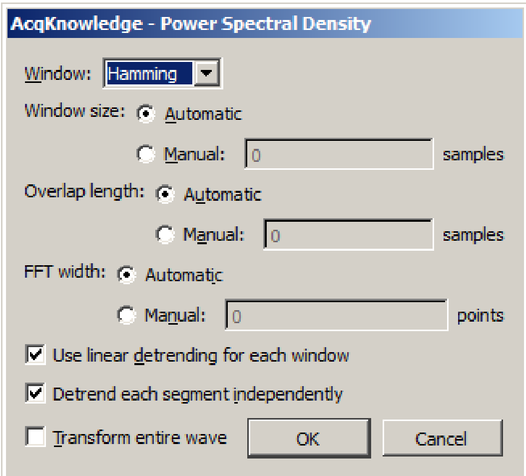
Length specifies the length of the separate model graph in samples.

Don't modify waveform suppresses replacement of the selected source data.

- If the model fitting does not complete successfully, the original data will be preserved regardless of the state of this selection.

Transform entire wave fits the entire data of the selected waveform to the model, with model origin at start of graph.

Power Spectral Density



The Power Spectral Density (PSD) function extracts the power present at different frequencies within a signal and is useful for EMG analysis. The PSD transformation approximates the same result as squaring the linear FFT magnitude. PSD is not available when the horizontal units of the source graph are set to Frequency.

Acq*Knowledge* uses the Welsh periodogram to average signal time-sliced portions of the signal and reduce noise effect, and generates a two dimensional graph displaying the wattage of a particular frequency component in a signal. Windowing options are Hanning, Hamming, or Blackman. The graph is plotted as horizontal frequency vs. vertical (units)^2/Hz, where *units* are the vertical axis units of the source data.

Window

Used to change the window that is applied to each segment of the source data prior to computing the PSD to be included in the average. Includes the following options:

Hamming Hanning Blackman

Window size

The specified number of samples must be a power of two. Note that the window function is applied to the entire window width of the data; using a subset of the windowed data will not include the final portion of the windowed data.

- If the FFT size is less than the window size, only a subset of the windowed sample data will be used.

Automatic — If selected, the window size is selected automatically depending on the size of the source data. For a data length of *n* samples, choosing this radio button will use the window size:

$$L = \frac{n}{4.5}$$

Manual — If selected, the window size will be input manually by the user in the associated edit field. The window size must be greater than three and must be less than the length of the data selection. Users will be warned on invalid window sizes when attempting to click OK.

Overlap length

After each individual FFT, the window of source samples is shifted over by a certain amount to compute the next FFT, so there is an overlap of source samples in successive windows of source for the next FFT in the average.

Automatic — If selected, the number of samples to overlap successive windows will be computed automatically. Given a window length *L* computed according to the window width choices, choosing this radio button will use an overlap number of samples:

$$\frac{L}{2}$$

Manual — If selected, the number of samples to overlap successive windows of source data. Overlapping reduces windowing artifacts The overlap length must be positive and must be less than the window size. Users will be warned on invalid overlap lengths when attempting to click OK.

FFT width	Automatic	If selected, the number of points to use for each individual FFT will be computed automatically. Given a window length *L* computing according to the window width choices, the number of points in the FFT will be set to: $$N_{fft} = \left\{ \begin{matrix} 256, L < 256 \\ 2^{\left\lceil \frac{\log(L)}{\log(2)} \right\rceil}, L \geq 256 \end{matrix} \right\}$$ ▪ The number of points in the FFT is set to 256 if the window width is less than 256. Otherwise the length is set to the next power of two higher than the window width.
	Manual	If selected, the number of points in the FFT will be specified manually in the edit box to the right of the radio. The number of points in the FFT will be required to be a positive power of two. It is recommended that the FFT length be set larger than the window size. If longer than the window size, zero point padding is used. Users will be warned on invalid FFT number of points when attempting to click OK. If the user inputs a number of points for the FFT that is shorter than the window width, a confirmation dialog will be displayed to the user warning that the windowing is shorter than the requested FFT width and asked if they want to continue.

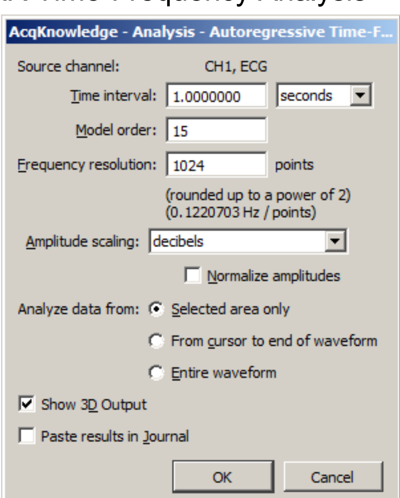
Use linear detrending for each window — When enabled, linear regression detrending is applied for each individual segment prior to the FFT computation. When disabled, windowing only is applied.

Detrend each segment independently — *This option is only available when "Use linear detrending" is enabled.* When this option is enabled, detrending is applied independently for each segment; when disabled, detrending from the previous segment will be incorporated into the next segment.

Transform entire wave — When enabled, the entire waveform is delayed. When unchecked, only the selected area is delayed.

- If there is no selection in the graph, the checkbox is enabled and dimmed.
- As the selection changes in the graph with the selection palette, the state of this checkbox is updated.

AR Time-Frequency Analysis



The AR Time-Frequency transformation can be used to examine changes in the spectral density of a signal using enhanced frequency resolution from derived AR models. Examining frequency changes over time can be a useful tool for arrhythmia detection and rough classification of waveforms.

Autoregressive spectrum time-frequency analysis divides a waveform into equal-length time segments, calculates an AR model (see page 365) for each individual time segment, and then computes a power spectrum from the model. (To perform raw data time-frequency analysis, use the Cycle/Peak detector with the FFT 3D output option.)

Time interval—Enter a positive floating point value to specify the segment width; the source signal is split into fixed length segments of this width and a frequency spectrum is generated for each segment from a model of its data.

Model order—Enter a positive integer to specify the order of the AR model that is constructed on an interval by interval basis.

Frequency resolution—Enter a positive integer to indicate the number of points contained in the FFT of an individual time segment; it will be rounded to the closest power of 2 when analysis is performed.

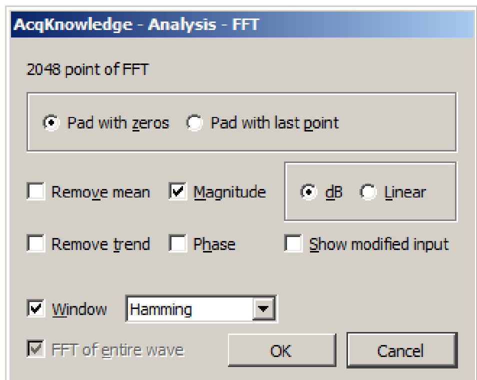
Amplitude scaling—"Normalize amplitudes" scales amplitudes such that the maximum peak-peak distance is equal across time intervals.

Show 3D Output—Constructs a 3D surface plot of the time-frequency analysis with amplitude vs. frequency vs. time.

NOTE: The controls for viewing and manipulating the Autoregressive Time-Frequency 3D Output are identical to those used in the **Find Cycle 3D Surface View** described on page 383. Refer to that section for full descriptions of of the 3D Output view angles, X, Y, and Z-axis range, plot resizing, and additional settings such as font size and color.

Paste results to journal—Inserts a series of tab-delimited tables representing the frequency distributions on a cycle-by-cycle basis into the Journal.

FFT Fast Fourier Transformation



The FFT algorithm requires that the data length be an exact power of two (i.e., 256 points, 512 points, 1024 points, and so on).

The Fast Fourier Transformation (FFT) is an algorithm that produces a description of time series data in terms of its frequency components. This is related to the *frequency spectrum*. The FFT displays the magnitude and phase of the time series data selected and displays only the DC and positive frequency components; the FFT does not display negative frequency components. To reconstruct a signal from additive sines or cosines, it's necessary to include both the positive and negative frequency components. Since it's not physically possible to generate a negative frequency signal, the amplitude of the corresponding positive frequency component must be doubled.

The output from an FFT appears in a graph window with magnitude (vertical axis) plotted against various frequencies (horizontal axis). A large component for a given frequency appears as a positive (upward-pointing) peak. The range of frequencies plotted is from 0 Hz to 1/2 the sampling frequency. Thus, if data was collected at 200 samples per seconds, Acq*Knowledge* will plot the frequency components from 0 Hz to 100 Hz.

Fourier analysis can yield important information about the frequency components in a data set, and can be useful in making determinations regarding appropriate data cleaning techniques (e.g., digital filtering). The FFT algorithm assumes that data is an infinitely repeating periodic signal with the end points wrapping around. Thus, to the extent that the amplitude of the first point differs from the last point, the resulting frequency spectrum is likely to be distorted as result of this start point to end point discontinuity. This can be overcome by "windowing" the data during the transformation. For more information on the windowing feature, see the window section that follows.

The FFT transformation cannot be performed in real time (i.e., during an acquisition). To emulate an online spectral analysis, use online filters and the Input Values window. See page 264 for more information about real-time frequency information.

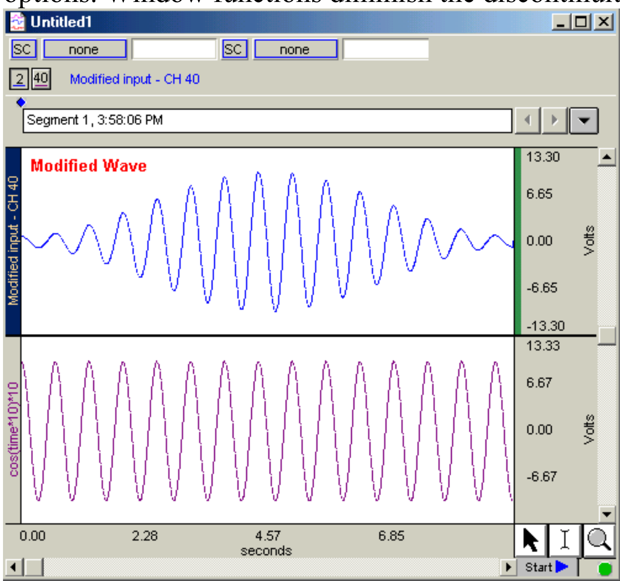
Pad — If a section of data is selected that is not a power of two, Acq*Knowledge* will always “pad” data up to the next power of two, filling in the remaining data point with either:

Pad with zeros: a zero

Pad with last point: the last data point in the selected area

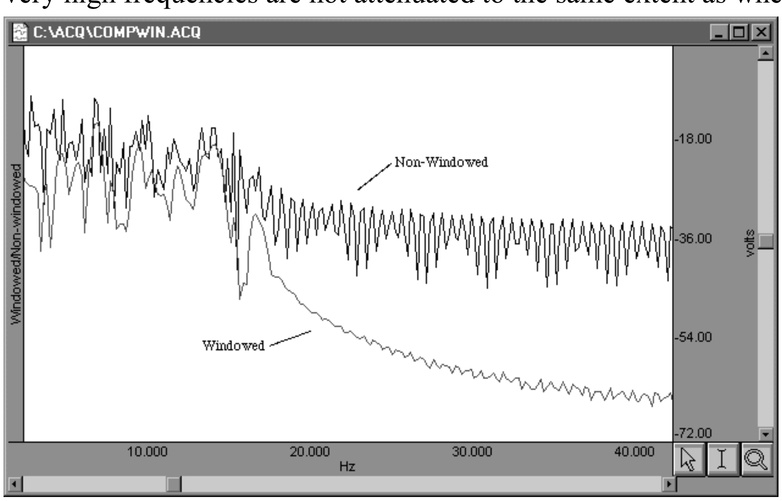
In other words, if 511 data points are selected, Acq*Knowledge* will use a modified version of the waveform as input. The modified waveform will have 512 points, and the last point in the modified wave will be either a zero or equal to the 511th point of the original data.

Show Mod. — To view the modified waveform being used as input for the FFT, check the Show modified input box. Whenever possible, it is best to use an input waveform (select an area) that is an exact power of two. The waveform is modified by applying the windowing and padding options. Window functions diminish the discontinuities that occur at either end of the wave.



Window — The FFT algorithm treats the data as an infinitely repeating signal with a period equal to the length of the waveform. Therefore, if the endpoint values are unequal, the resulting frequency spectrum will show larger than expected high frequency components due to the discontinuity. Windowing these data minimizes this phenomenon. For example, to apply a window transformation to a sine wave whose endpoints do not match up, check the box next to Window and choose a type of window from the pop-up menu. Each of the windows has slightly different characteristics, although in practice each provides similar results within measurement error.

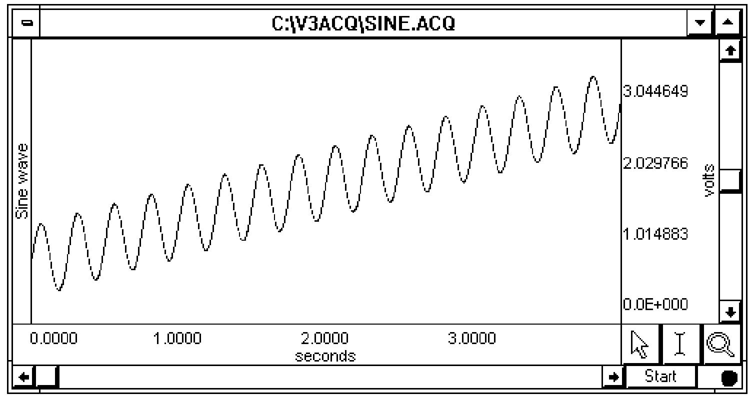
As shown below, the frequency spectra of the windowed and non-windowed data differ significantly when the endpoints are unequal. When data are not windowed, the very low and very high frequencies are not attenuated to the same extent as when windowed.

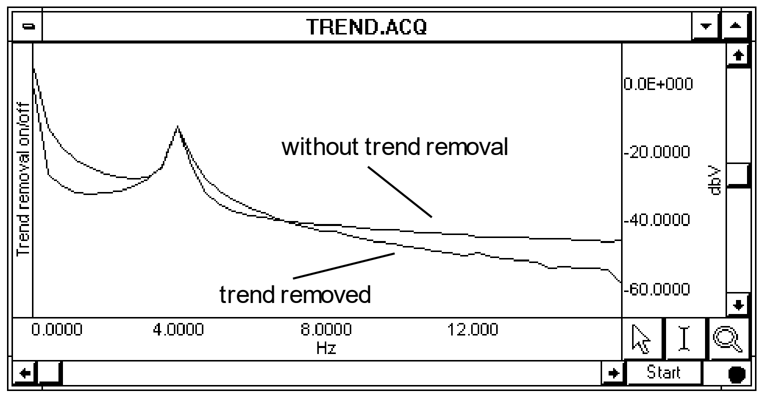


Remove Trend Sometimes, data contains a positive or negative trend that can cause extraneous frequency components to "leak" into the frequency spectrum. This can be prevented by selecting remove trend when performing the FFT. This effectively draws a line through the endpoints, and subtracts the trend from the waveform.

For example, the following sine wave has an upward trend through the data (positive trend component). The lower graph shows FFTs of the skewed sine wave data with and without the trend removed.

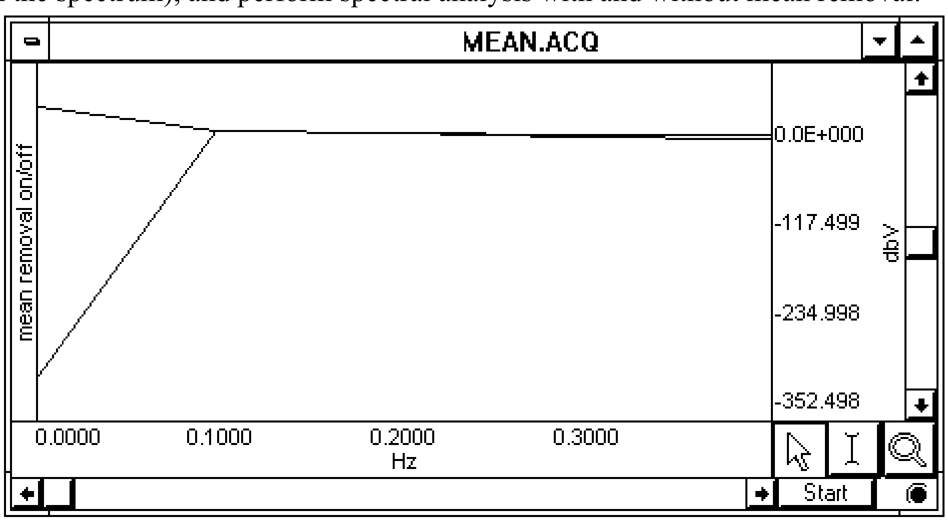
Note that the spectrum of the data without the trend removal has gradually decreasing frequency components, while the data with the trend removed has far fewer frequency components except for the single spike due to the sine wave.





Remove Mean Remove mean calculates the mean of all the points in the selected area and then subtracts it from the waveform. This is generally useful for windowing a waveform that has a large DC offset.

As an example, start with a sine wave with a 10-volt DC offset (with a little noise added to broaden the spectrum), and perform spectral analysis with and without mean removal:



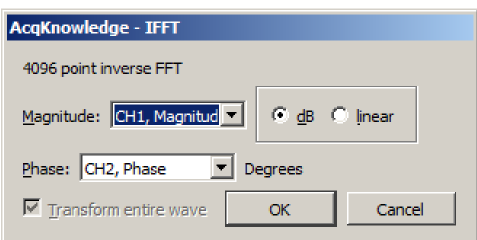
Note the large spectral components at the beginning of the top plot, without mean removal. This is due to the offset of the original data. The bottom plot is with mean removal.

Since the offset of the waveform is often an artifact of the way it was generated, the remove mean option provides a more accurate indication of the true spectral components. This is especially true for applications where low frequency components are of interest. If the data has a large DC offset and the data is to be windowed, generally a more meaningful spectrum will result if the mean is removed prior to windowing.

Linear — By default, the FFT output is described in terms of frequency along the horizontal axis and dBV on the vertical axis. The Bell scale (from which dB are derived) is logarithmic, and in some cases it may be useful to have the output scaled in linear units. To do this, click the button next to linear and check OK. The other options in the dialog work as they normally do when the dB scaling option is selected. The relationship between log and linear units is: $dBV_{out} = 20 \log$ VIN.

Phase — The standard FFT produces a plot with frequency on the horizontal axis and either dB/V or linear units (usually Volts) on the vertical axis. In some cases, it may be useful to obtain phase plots of the waveform (as opposed to the default magnitude plots). Phase plots display frequency along the horizontal axis, and the phase of the waveform (scaled in degrees) on the vertical axis. This option functions apart from the magnitude option—either can be checked independently. If both are selected, separate magnitude plot and a phase plots will be produced.

Inverse FFT



The Transform > IFFT menu option is generated after an FFT is performed. An Inverse FFT (Transform > IFFT) converts spectral values back to a time series waveform to reverse the FFT transformation. Any modifications to the original data (such as windowing or padding) will be shown in the resulting time series data.

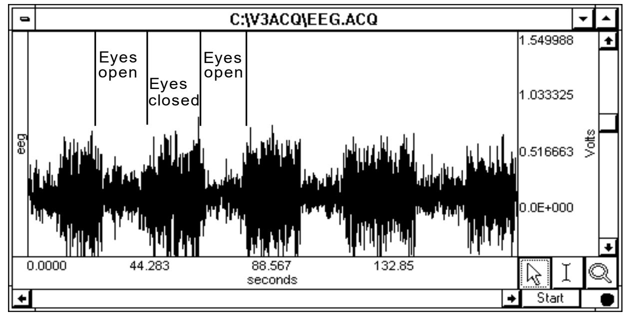
To obtain a meaningful IFFT result, the FFT graph must contain at least one magnitude channel and at least one phase channel. With the window open, choose IFFT from the Transform menu to generate the Inverse FFT dialog.

To accurately recreate the time series waveform

1. Select the source channels for the inverse FFT in the Magnitude and Phase pull-down menus.
2. Select whether to express Magnitude in linear units or dB logarithmic units (decibels). To determine this setting, check the vertical axis units of the magnitude channel; this should correspond to the Magnitude scaling choice that was used when performing the forward FFT.
   - The Phase waveform must be in degrees.
3. Click OK to perform the IFFT.
   - The result is generated in a new time domain window, labeled "IFFT of Spectral…"

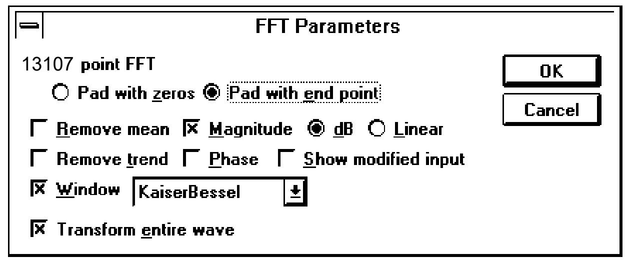
The following FFT example uses an electroencephalogram (EEG) signal acquired when the subject alternated between eyes open and eyes closed. Typical results suggest that higher levels of alpha activity (activity with frequency components between 8Hz and 13Hz) are to be expected when a subject's eyes are closed.

1. The raw data, prior to FFT, is shown here:



2. Select Transform > FFT from the menu.

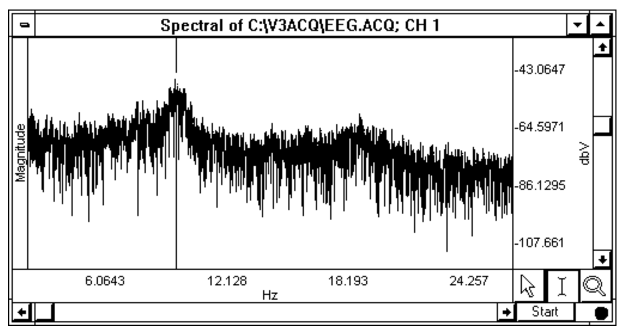
   The FFT Parameters dialog will be generated; in this example, the Window function chosen is Kaiser Bessel:



3. Click OK.

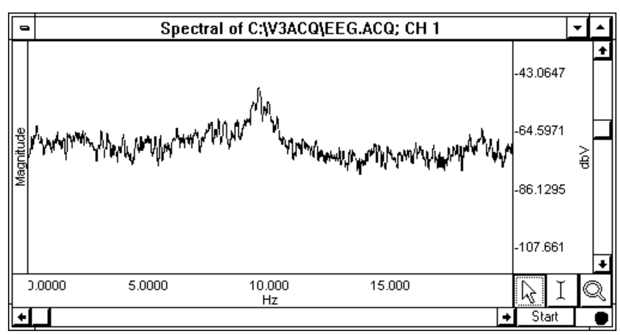
   A frequency domain window (a graph window which places frequency along the horizontal axis rather than time) will be created and displayed, showing the spectrum of the input data.

   The window is named "Spectral of (the original window name)" and ends with the channel number, as shown here:



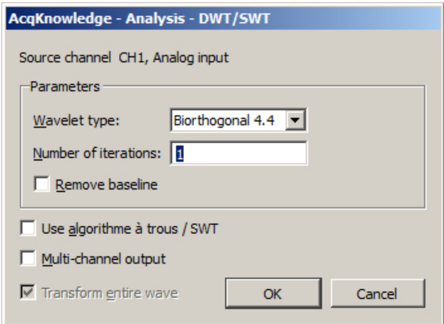
   The resulting magnitude value for each component is equal to the peak value of the sine wave contributing to that component. The entire pattern of frequency components is known as the frequency spectrum of the data. The somewhat erratic appearance of the spectrum is usually due to small-scale variations in the original waveform.

4. *Optional*—This "noise" can be removed by applying a smoothing transformation to the FFT output. In the graph shown, there is a pronounced frequency component centered on 8Hz, which corresponds to the alpha wave frequency band (8Hz—13Hz). The frequency spectrum (0-20 Hz shown) used 20-point smoothing.



Watch the Acq*Knowledge* FFT video tutorial for a detailed demonstration of this feature.

DWT/SWT



About Wavelet Transformation

Wavelet transforms are similar to Fourier transforms. Instead of projecting a signal in a space of sines and cosines, wavelet transforms project a signal into a space comprised of orthogonal functions called *wavelets*. Discontinuities are more obvious in wavelet transforms than in sines and cosine analysis, making wavelet transforms a better choice for decomposing a signal to its fundamental form. Wavelet transforms can be used for noise reduction and filtering, extracting features from signals that are not apparent in time or frequency domains, and predicting signal qualities from a small number of data points.

Discrete wavelet transformations (DWT) break a source signal into high-frequency and low-frequency components. Use for ECG and EEG analysis. DWT creates a new graph with wavelet coefficients on the horizontal axis and the amplitude for each coefficient on the vertical axis, pastes acquisition settings to the graph journal, and places an event at each boundary between the high- and low-frequency components produced at each iteration.

Wavelet type	Specify Biorthogonal 4.4, Symlet 4, Coiflet 6, Daubechies 8 or Spline 3.
Number of iterations	Specify the number of transforms to execute.

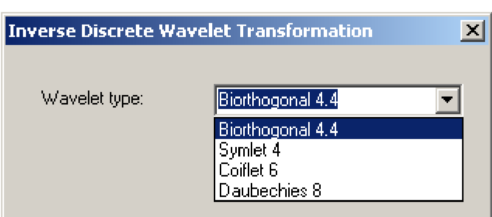
Stationary wavelet transformations (SWT) differ from DWT in that the "stationary" transformation retains all coefficients at each processing level, so each level's output is equivalent to the length of the input signal. At each output level, the low and high pass filters are upsampled by inserting 2k−1 zeros between each wavelet filter coefficient. This method retains information unnecessary for reconstruction of the original signal but produces output that may be more useful for identifying and enhancing specific characteristics of the original signal.

To enable the SWT option, check the "**Use algorithme à trous / SWT**" box. Like the DWT transformation, the SWT output will appear in a new graph.

Multi-channel output: This option places a copy of the original source data in the first channel of the output graph. Coefficients for each level are inserted as subsequent channels of the graph labeled "*dn*" with *n* replaced by the level of decomposition. The final channel is prefixed with an "*h*" indicating the high-pass coefficients left over from the final run.

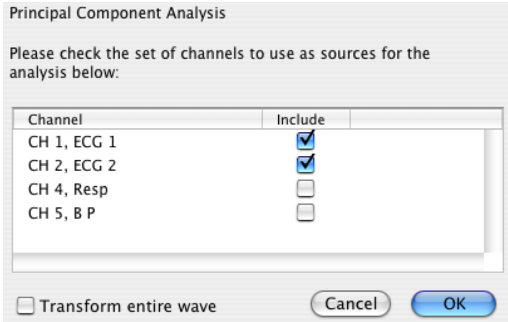
If either the multiple channel or the SWT options are used, the Inverse DWT cannot be used to reconstruct the original data. To reconstruct the original data, apply regular DWT with single channel output.

Inverse DWT



Operational on the result of a DWT. Projects data from wavelet space to time space. For correct recomposition of the source data, the wavelet type specified for the IDWT must match the wavelet type used for the DWT. Amplitudes of the wavelet coefficients may be changed, but an IDWT will fail if the horizontal units, events at DWT iteration level boundaries, or file length have been modified. **Note:** Spline 3 DWT is not supported in Inverse DWT.

Principal Component Analysis



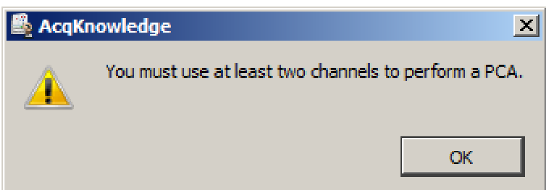
About Principal Component Analysis

Principal Component Analysis decomposes source signals into a new signal space (constructs an orthogonal set of vectors). PCA is useful as a feature extraction and data reduction tool.

Changes in the values of the mixing matrix may be indicative of changes in underlying signal morphologies that other methods cannot easily detect.

For example, PCA is useful for EEG analysis; where it can reduce 32 channels to the fundamental elements of signals.

Acq*Knowledge* uses a mean-adjusted covariance matrix method to generate a new PCA graph with each component in a separate channel. The coordinates of the new space are the eigenvalues extracted from the matrix defined by the source data and are called “Principal components.” The extracted eigenvectors are the “mixing matrix.” Sine and cosine are orthogonal signals. The principal components are numbered in order of decreasing eigenvalues, which implies that the first principal component contains the majority of the variation of the source signals. Results are also pasted in to the journal, including the eigenvalue magnitudes and the eigenvector matrix. To determine the percentage contribution of each component, review the eigenvalue magnitudes. Select two or more channels—all of the selected channels must have the same sampling rate. If at least two channels are not selected, the following message will appear:

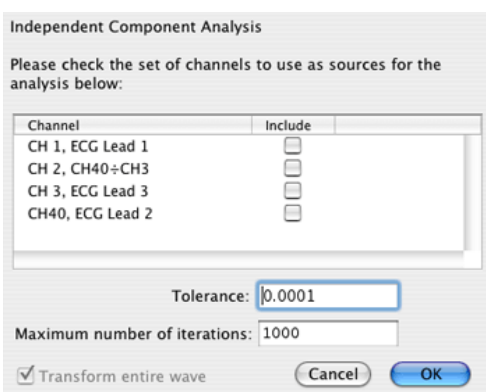


Inverse PCA

Available only for graphs produced by PCA. Reconstructs the source signals based on the components and mixing matrix of the PCA graph. The graph is reconstructed in a new window, with a list of the components used pasted to the journal.

➲ For noise reduction, use only the strongest principal components to reconstruct the source signals.

Independent Component Analysis



About Independent Component Analysis

Independent Component Analysis is useful for signal separation, denoising, and advanced EEG analysis to remove noise signals or locate approximate regions of active processing centers in the brain. ICA is a form of statistical blind separation that attempts to separate mixed (overlapped) signals based on the assumption that they are statistically independent.

- For example, if two microphones in a room record one person reciting Shakespeare and another person playing the banjo, the recordings will capture both the speaker and the banjo. After performing ICA on the two recordings, one result will have only the speaker and the other will have only the banjo.

Acq*Knowledge* uses the FastICA algorithm to generate a new ICA graph with each component in a separate channel.

For more information on the FastICA algorithm, see this link.

Select two or more channels—all of the selected channels must have the same sampling rate.

Specify tolerance and number of iterations.

ICA limitations to consider for application and interpretation:

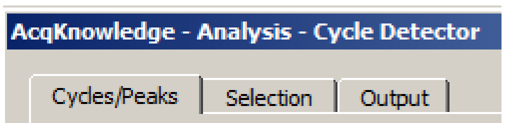
1. The number of mixed sources must be equal to the number of independent components (as in the example where two microphones captured two sound types).
2. Sources must be statistically independent; highly-correlated signals cannot be effectively separated.
3. Sources must have non-Gaussian probability distribution. It is not possible to separate out components like white noise through ICA.
4. Signal mixing must be a constant, linear process. Any type of non-linear signal propagation cannot be expressed in linear combinations of sources, the underlying assumption of ICA.
5. The component sources must be stationary (that is, point sources).

Inverse ICA

Available only for graphs produced by ICA. Reconstructs mixed signals based on the components and mixing matrix of the ICA graph. The statistical nature of the algorithm implies that it cannot perfectly reconstruct original source data—it estimates the most probable set of source signals. The graph is reconstructed in a new window, with a list of the components used pasted to the journal.

Find Cycle (Peak Detector)

Watch the six-part Acq*Knowledge* Find Cycle video tutorial for a detailed demonstration of this feature.



The Find Cycle/Peak Detector setup dialog is accessed by choosing Analysis > Find Cycle, or using the Ctrl+F keystroke.

Overview

The advanced Cycle/Peak Detector combines with the powerful Event Marking System. Use it to perform amplitude, time, or event-based measurements. New output options for measurements, averaging, events, clustering (K-means), and 3D surface (cycle data, histogram, FFT, and DWT).

The Find Cycle detector uses three tabbed settings panels to define and automate cycle/peak detection:

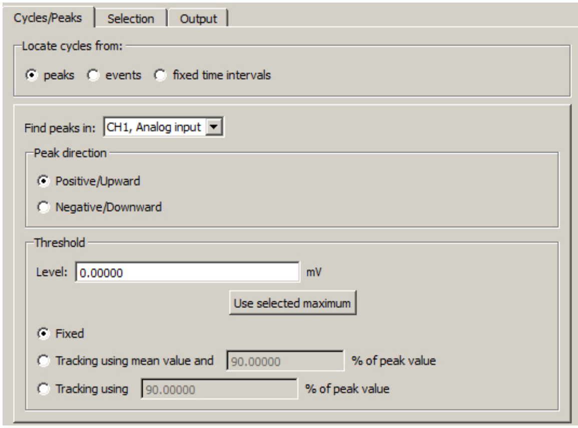
Cycles/Peaks Selection Output

Cycle detector settings are graph-independent, which means that find cycle/peak operations can be performed in multiple graphs without needing to re-enter graph-specific settings for each run. By using multiple data views, different find cycle/peak operation can be performed on the same set of data without losing settings between “Find Next Cycle/Peak” operations.

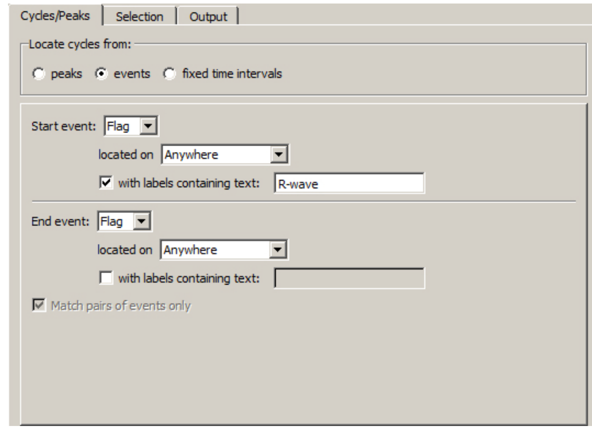
When the Cycle/Peak Detector is first opened for a graph, the dialog will be filled with the values from the last successfully executed find Cycle/Peak operation. Subsequently, changes to the settings will be applied only to that graph.

TIP When running the cycle detector multiple times and needing to put the edge back at the beginning of the waveform for the next pass, use the keyboard shortcuts Home, End, Page Up, and Page Down to quickly change edge location (see page 69).

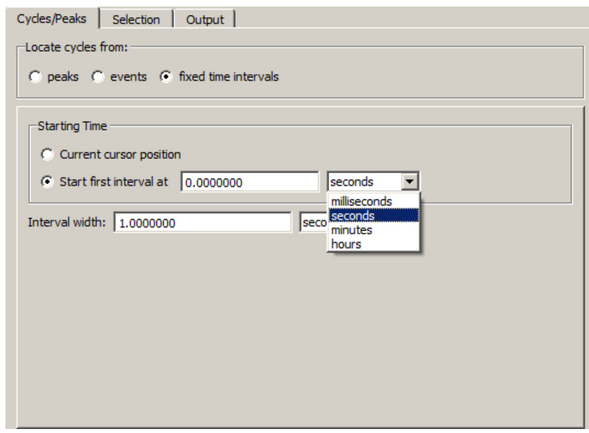
Cycles/Peaks tab



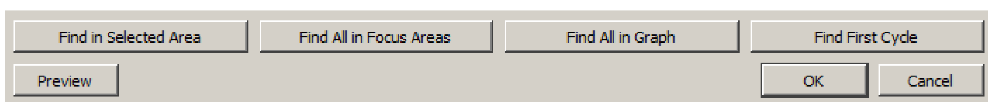
Peaks



Events



Fixed Interval



Find Cycle controls available at bottom of dialog

Find Next Cycle

When selected from the Analysis menu (or Ctrl+E), both edges will move one peak to the right while staying above the threshold.

Find All Cycles in Graph

When selected from the Analysis menu, Find Cycle setup dialog or selecting Ctrl+R, the software will find all cycles/peaks through the end of the file. If the data file is very large, it may take some time to find all the cycles since Acq*Knowledge* loads data from disk while it scans for the cycles.

Find in Selected Area

When selected from the Analysis menu or in the Find Cycle setup dialog, only cycles within a selected area will be detected, all others will be ignored.

Find All Cycles in Focus Areas

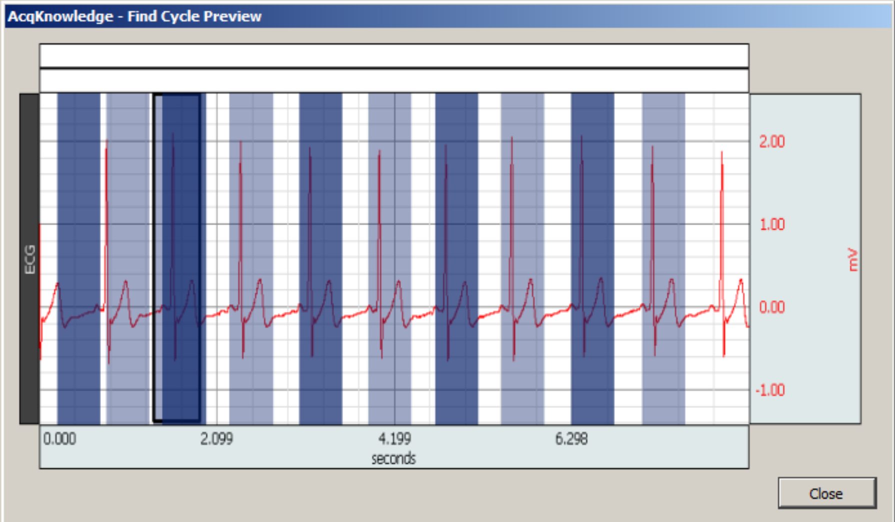
If the graph contains defined focus areas, this option will limit cycle detection to focus areas only. If no focus areas are defined, this option will not be available. This is selectable via the Analysis menu or in the Find Cycle setup dialog.

Find First Cycle

Use this option to apply changes to the Find Cycle setup and locate the first cycle. This is selectable via the Analysis menu or in the Find Cycle setup dialog.

Preview (Selection tab)

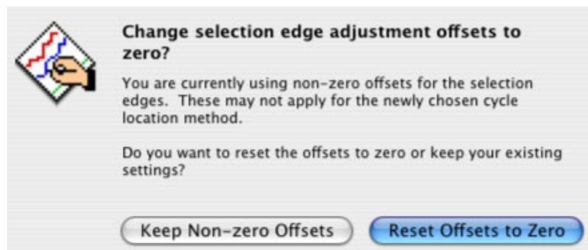
When selected, a preview of the selected Find Cycle operation is displayed prior to applying the settings.



Find Cycle definitions

The Cycles/Peaks tab offers three general methods for establishing cycle parameters:

- Peaks: Data driven maximum and minimum (see page 379)
- Events (see page 379)
- User-defined fixed time intervals (see page 380)



When the cycle location mode is switched on the “Cycles/Peaks” tab, the edge selection offsets will be checked. If they are non-zero, a prompt will appear, warning that that the edge adjustment offsets may not apply for the new cycle location mode. The user can reset the offsets to zero (default) or retain the (non-zero) settings used in the previous cycle location mode.

Peaks

Peak direction Positive/Upward – searches for positive voltage spikes in the signal.

Negative/Downward – searches for negative voltage spikes in the signal.

Level *Important usage note*—Level is not set automatically when the Cycle/Peak detector is generated. (Automatic Level is used in previous versions of Acq*Knowledge* for Mac and current version for Windows.)

Use selected... To optimize the threshold detection level for the selected area of data in the graph, click the "Use selected maximum/minimum" button underneath the level. When changing the source channel or peak direction, also use this button to re-compute the recommended level based upon the new settings. The recommended level is "Tracking using % of peak value" (see below) using a percentage factor of 75%.

Threshold Fixed—Keeps the threshold voltage level constant.

Tracking The Tracking threshold mode modifies the threshold after it finds a peak, depending upon the value of the new peak, and will compensate for a slowly drifting baseline.

Hints regarding the use of Tracking Threshold Options

- If data has a very consistent cyclical nature, either Tracking Option will work.
- If data has spurious positive or negative peak values present, the Means Reference Tracking Option is a better choice.
- If data has an erratic baseline, but consistently sized, positive and negative peaks, the Peaks Reference Tracking Option is a better choice.

Tracking using mean value and % of peak value—Adjusts the threshold voltage level after each peak, based on the average of the last cycle's data and the specified percentage of the current peak voltage. The Means reference option will determine the Mean Value of all the data, from peak to peak. This Mean Value establishes a variable reference upon which the tracking threshold operates. The software determines the new threshold (NT) as follows:

For Positive Peaks

NT = Mean Value + (Positive Peak Value - Mean Value) x (% factor)

For Negative Peaks

NT = Mean Value - (Mean Value - Negative Peak Value) x (% factor)

Tracking using % of peak value—Adjusts the threshold voltage level dynamically based on the specified percentage of the value of the most currently found peak. The Peaks reference option will determine the Positive Peak Value and Negative Peak Value of all the data, from peak to peak. The Positive and Negative Peak Values establish a variable reference upon which the tracking threshold operates. The software determines the new threshold (NT) as follows:

For Positive Peaks

NT = Neg. Peak Value + (Pos. Peak Value—Neg. Peak Value) x (% factor)

For Negative Peaks

NT = Pos. Peak Value - (Pos. Peak Value—Neg. Peak Value) x (% factor)

Events

Event-based cycle location are used to extract information from events or define events based upon Find Cycle output. Either one or two events may be used to define a cycle.

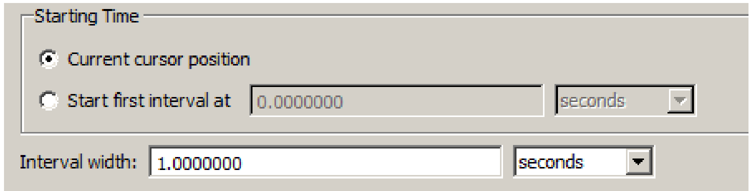
Start / End	Define the event; any of the predefined event types can be explicitly matched. To use only one event to define each cycle select the exact same event type for both "Start event" and End event," and see the "Match Pairs" discussion below.
Match pairs	"Match pairs of events only" may be unchecked only when the Start event and End event are identical. Under this condition, if the box is checked, two such events are used to define one cycle. If the box is unchecked, then each event defines a cycle by itself. This is useful for adjusting a selection relative to an event, such as locating the first second prior to each event of a specific type. This option makes it possible to hit time periods for each event since each cycle consumes two events.
Located on	Specify the channel when the event must be defined, either its actual channel or "Global" for events not associated with any channel. Select "Anywhere" to search for events of specific types across channels.
With Labels optional	Toggle the "With labels containing text" checkbox to set this option. When checked, the matching event's label must contain the text in the edit box to the right of the checkbox. ▪ The text search is not case sensitive. The search must be non-empty for cycles to be located properly. When unchecked, the matching event can have any label, including none.

The Cycle detector uses the following algorithm to search for cycles in the graph:

1. From the starting point, find the first event matching the criteria of the Start event. This will be defined as the *left event*. If no event matches the Start criteria, no more cycles are in the file.
2. If the Start event criteria match the Ending event criteria and zero width cycles are allowed (e.g. "Match pairs of events only" is unchecked), define the right event as identical to the left event and go to step 5.
3. From the location of the left event, find the closest event matching the criteria of the End event. This will be defined as the *right event*. If no event matches the End criteria, no more cycles are present in the graph.
4. Within the time region between the left and right events, search for any events that match the Start criteria. If such an event occurs, redefine the left event to be this matching event and repeat the step. If no event is located, then the closest pair of events has been located.
   - This step is useful for working with data that has missing portions of the sequence, as can come out of some classifiers. For example, if two event types A and B are used as the endpoints, a sequence of three events AAB will match the last two events as the cycle. This is logical in the case of physiological data where, if B should occur periodically in the signal, AA is an indicator of an abnormality or missed classification.
5. Set the selected area to the time interval whose endpoints are the left and right events.
6. Perform selection adjustment and output as indicated by the settings on the "Selection" and "Output" tabs.
7. If "Find All Cycles" is being performed, return to step 1 and use the ending event location as the new starting point to find any remaining cycles in the graph.

Fixed Interval

Fixed interval-based cycle detection is based upon cycles found in consecutive time intervals of a fixed width. The time width is user defined and the starting point of the cycle detection can be placed at the current location of the cursor, or to begin at an exact point of time in the graph.



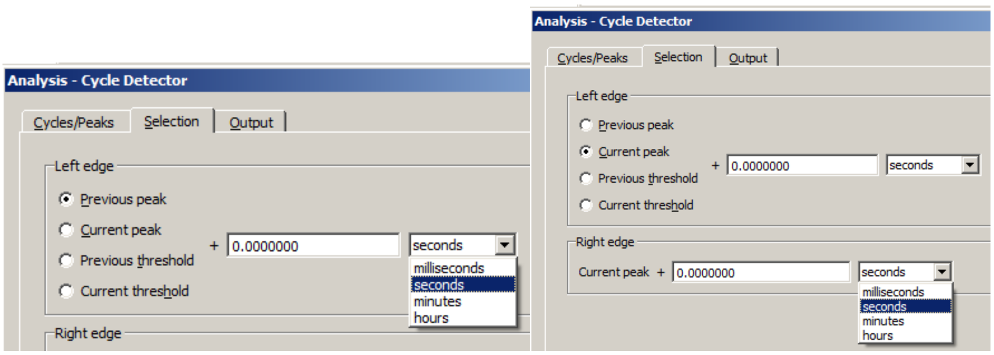
The time units for starting the first interval and setting the interval width can be selected in milliseconds, seconds, minutes or hours.

Selection tab

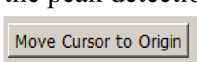
Use the Selection tab to adjust the range of data that will be analyzed to generate any output. By default, the data range is set to be the entire cycle as located by the settings on the Cycle/Peak tab, but it can be adjusted to analyze only specific portions of the cycle.

The controls on the Selection tab vary based on the settings on the Cycle/Peak tab

Peak When the Cycles/Peaks location method is “Peaks,” the Selection can be adjusted based on the times of the peaks in the data or the times of the threshold crossings prior to the peaks.

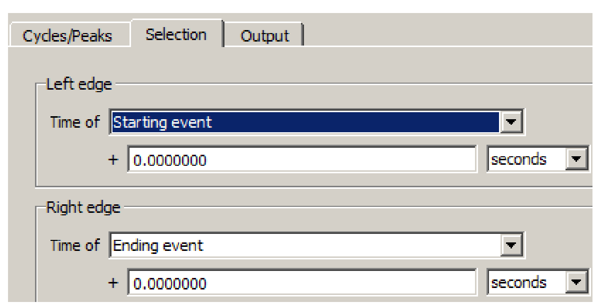


To perform analysis on the entire data within each cycle, the selection should be from the “previous peak” to the “current peak.” To examine fixed-width time windows located at each peak, use the “current peak” to “current peak” settings and adjust the two time offsets accordingly. Note that the settings must place the left edge earlier in time than the right edge for the peak detection to succeed properly.



“Move Cursor To Origin” (at bottom left of screen) sets the graph data selection back to the first sample. Use this to reset the cursor in order to find all of the data in the graph.

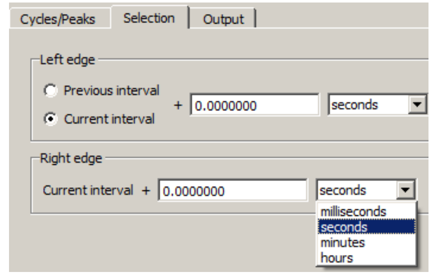
Event When the Cycles/Peaks location method is “Events,” the Selection can be adjusted based on the locations of the events that define the boundaries of a cycle.



For a specific cycle, the starting event will be the event at the left boundary of the cycle and the ending event will be the event at the right boundary of the cycle. The starting event will never be located after the ending event in time.

To analyze data over each entire cycle, use the “starting event” to “ending event” setting. To examine fixed-width time windows occurring within each cycle, set the left edge and the right edge to the same event (e.g. “starting event” to “starting event” for time windows at the beginning of each cycle) and adjust the offsets accordingly. Note that the settings must place the left edge earlier in time than the right edge for the peak detection to succeed properly.

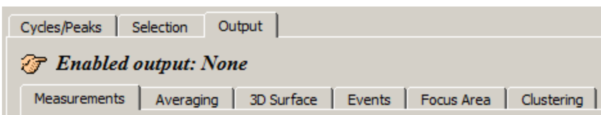
Fixed When the Cycles/Peaks location method is “Fixed time intervals,” the Selection can be adjusted based on the endpoints of the time interval.



To analyze the data over each entire interval, use the “previous interval” to “current interval” setting.

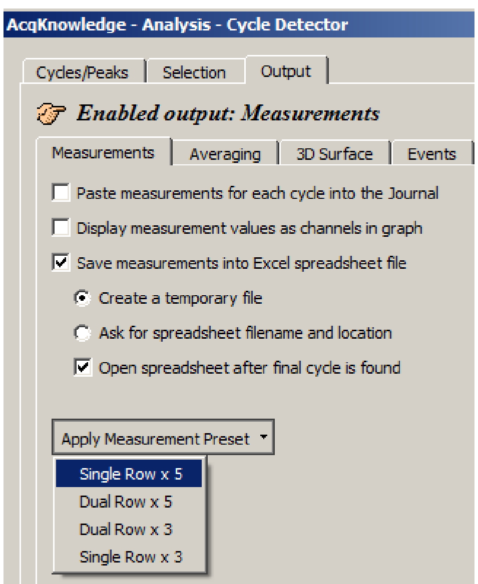
To examine fixed-width time windows within each interval or only a sub-portion of each interval, use the “current interval” to “current interval” setting and adjust the time offsets accordingly. Note that the inputted settings must place the left edge earlier in time than the right edge for the peak detection to succeed properly.

Output tab



The Cycle/Peak Detector includes six Output options, which can be independently enabled: Measurements, Averaging, 3D Surface, Events, Focus Area and Clustering. The selected output, if any, is listed at the top of the Output tab as Enabled output.

Output Measurements

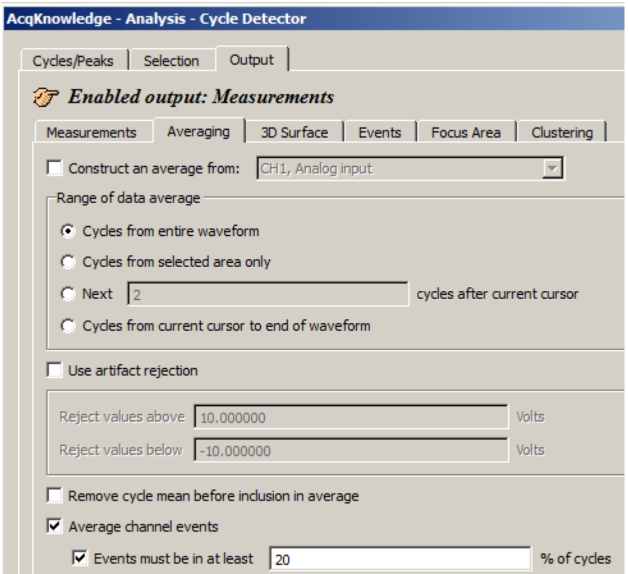


Toggle each checkbox to enable/disable the option:

- Paste measurements for each cycle to the Journal.
- Plot measurement results; display measurement values as channels in graph.
- Save measurements to Excel spreadsheet file, plus output options. In order for spreadsheet output to be generated, a “Find All Cycles” operation is required.
- Apply Measurement Preset – this option replaces the current measurement configuration with any of these selectable presets.

NOTE: If the horizontal axis is in world time (HH:MM:ss), any time measurement exported to Excel will be reported in standard time units, such as seconds or minutes.

Output: Averaging—Offline



Use Averaging Output" to perform offline ensemble averaging of source data or ensemble averaging of event locations. Specify the channel where the cycles/peaks are to be located in the "Cycles/Peaks" tab and specify the channel whose data should be ensemble averaged in the "Average" controls on the "Output" tab.

Toggle the "Average channel events checkbox near the bottom of the tab to turn event averaging on and off.

Offline averaging can produce average locations of events within the defined cycle along with the average data. When a cycle is found, any events in that cycle will be noted. Events that are on the channel of data being averaged will be examined for inclusion in the average.

Index For each individual cycle, each event will be given an index starting at 0 and increasing to one less than the number of occurrences of that event type within the cycle. The time offset for each event from the start of its cycle will be averaged along with the offset for events with the same index from all other cycles. When the graph of the averaged data is produced, these average time offsets from the start of the cycle will be used to define new events for the averaged data. If the events and averaging interval were correlated with the data, the average event offset will produce a reasonable representation of the appropriate event locations for the averaged cycle.

- Average events reflect the accuracy of classifiers and the consistency of data used to locate each cycle.

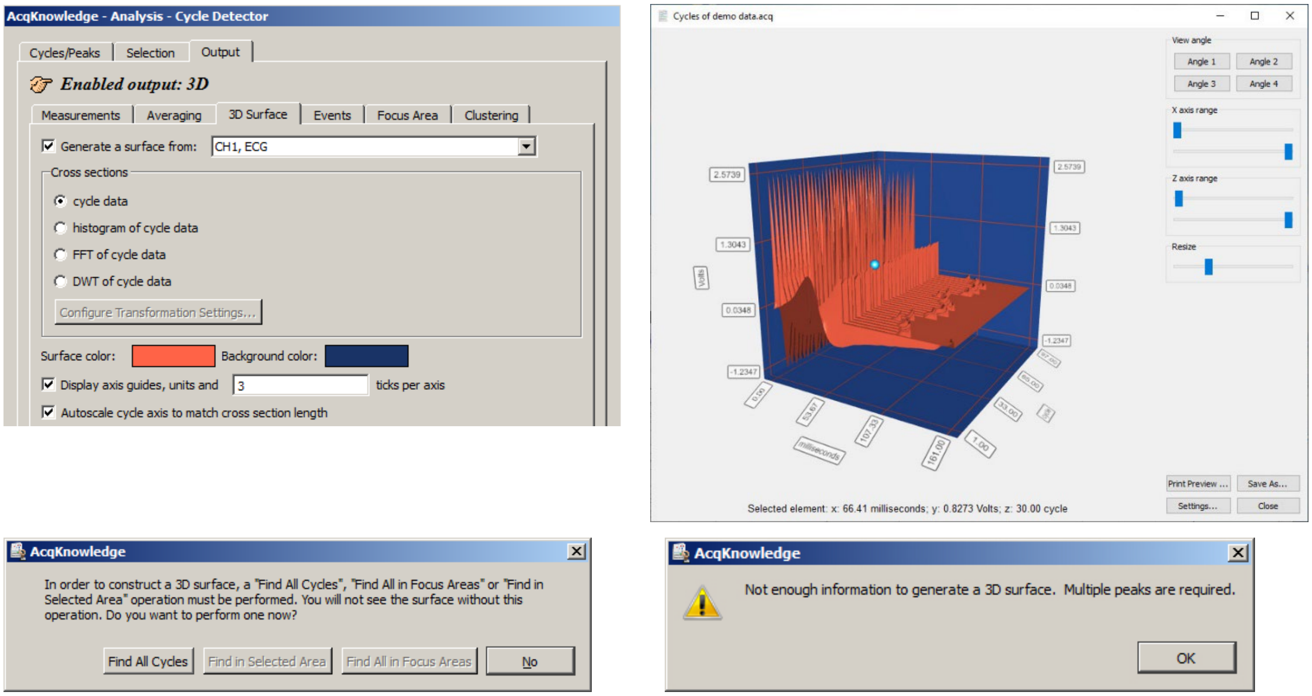
Label Each event is labeled with the number of cycles contained in the event. Differences in the event sequence can cause spurious events to be inserted. The label helps in manual inspection for events that were only in one or two cycles.

Rejection Toggle the "Events must be in…" checkbox to turn rejection on and off, and specify a percentage for the relative number of cycles an event must appear in to be considered valid.

Remove… When mean removal is enabled, the mean value of the data within each cycle is subtracted prior to including it in the overall signal average. This mean removal option is useful for:

- Extracting signals that are "riding" on top of other signals with high DC offset (e.g., MRI artifact on top of skin temperature)
- Compensating for baseline drift where there are not enough cycles present in the data for the baseline variation to completely cancel itself out.

Output 3D Surface



3D Surface Output options, 3D Surface image, and dialogs displayed if output options are not set properly

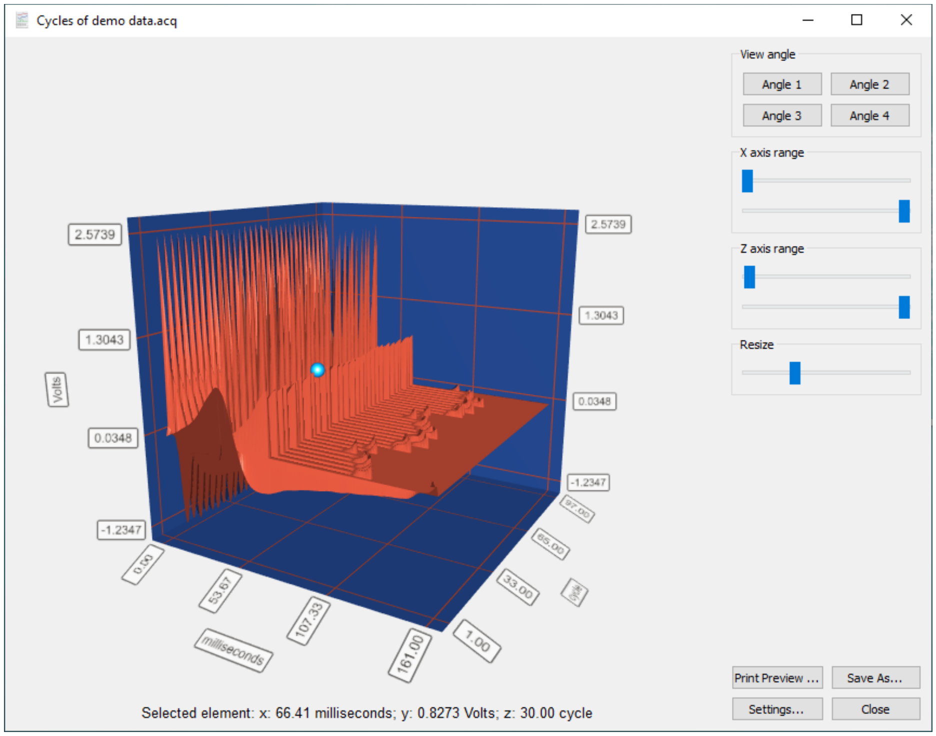
Toggle the “Generate a surface” checkbox at the top of the 3D tab to turn Surface Output on and off.

1) Choose a channel to generate a 3D surface from.
2) Confirm or establish the cycle period of interest on the channel.
   - Use the *Cycles/Peaks* tab and the *Selection* tab to adjust the threshold and edge positions for the cycle period for 3D output.
3) Choose a cross-section output format for the cycle data: cycle data, histogram, FFT, or DWT.
   - For histogram, FFT, or DWT, click “Configure Transformation” to change the settings.
4) Select surface and background colors.
5) Set axis options.
6) Click OK.

Use the “View angle,” “x-axis range,” “z-axis range,” and “Zoom in/out” controls to manipulate the 3D surface image view. The x-axis and y-axis units will dynamically update as the image is re-oriented. See the following page for details about these controls.

3D Output Example Compare ECG cycles in 3D Output. The following example shows how to Acq*Knowledge* will generate a 3D image using each cross section of ECG.

a) Cycles/Peaks tab: set the threshold level to identify each R-wave.
b) Selection tab: set the edge to
   Current Peak
   Left edge -.5 seconds
   Right edge .5 seconds
c) On the Output tab
   Enable 3D Output
   Specify the channel to generate a surface from.
   Choose “cycle data” for the cross-section format.
   Click Find All Cycles.



3D Surface Controls:

View angle: Controls position of 3D Surface image using four available preset angles. Allows quick access to the various angles.

- Angle 1: Applies view angle of -30/15 degrees
- Angle 2: Applies view angle of -120/15 degrees
- Angle 3: Applies view angle of 60/15 degrees
- Angle 4: Applies view angle of 150/15 degrees

x-axis range: Adjusts minimum and maximum range of the vertical axis.

- Left slider = minimum range
- Right slider = maximum range

z-axis range: Adjusts minimum and maximum range of the horizontal axis.

- Left slider = minimum range
- Right slider = maximum range

Zoom in/out: Move the scrollbar to the left to zoom **out** and to the right to zoom **in** on the 3D Surface image.

Click **Print Preview**… to access controls for printing the 3D surface image.

Click **Save As**… to save the displayed image in *.jpg, *.png, or *.bmp format.

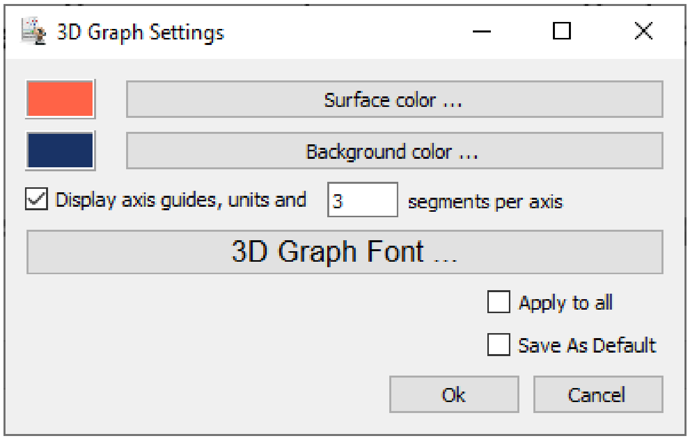
Click **Settings…** to access options for setting/changing the surface/background colors, font style/size, and display of the axis guides, units and visible segment. See details about these settings on the following page.

Click **Close** to exit the 3D Surface view.

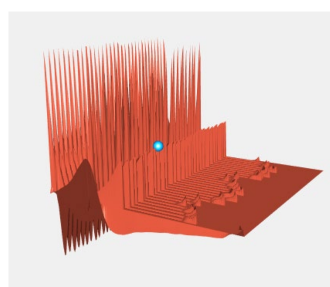
Using the mouse to rotate the image: Right-click the 3D Surface image and hold to rotate the image vertically or horizontally. Maximum vertical rotation: 90 degrees. Maximum horizontal rotation: Unlimited.

Selecting a sample: To select a single sample, place the mouse cursor over the 3D Surface and click the left mouse button. The sample selected by the mouse cursor will be highlighted with a blue sphere , after which the focus will switch to the graph containing the Find Cycle data. The blue sphere will be positioned at the selected sample and the elements of the selected sample will display below the 3D surface image.

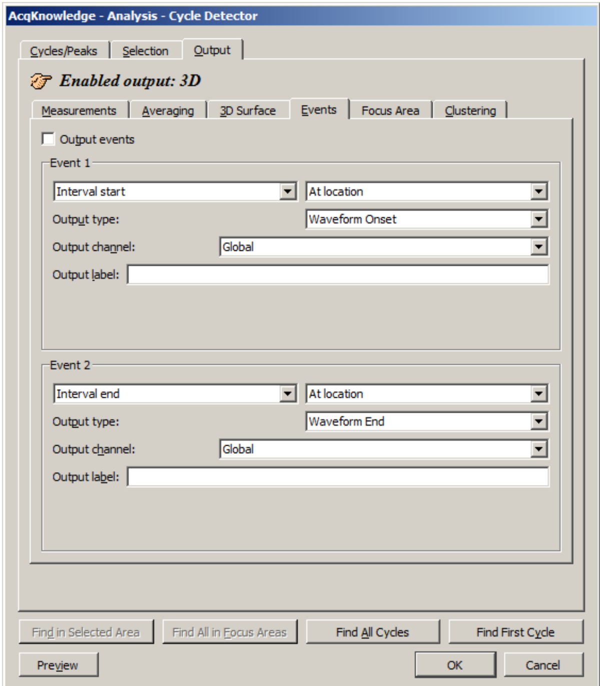
3D Surface Settings:



The following 3D Surface settings are available:

Surface color…	Opens a colorwell for selecting the color of the 3D Surface view.
Background color…	Opens a colorwell for selecting the contasting background for the 3D surface
Display axis guides, units and segments per axis checkbox	Shows or hides of the following elements: • Axis guides: background division gridlines for 3D Surface view • Volt and millisecond units • Segments per axis is the gridline display. The number of visible gridlines to display can also be set here. If the "Display axis guides…" box is unchecked, the 3D surface will appear as follows: 
Apply to all…	Applies to the selected settings to all current 3D Surface views but does not change the default setting for subsequent views.
Save as default…	Saves the selected settings as the default for all current and subsequent 3D Surface views.

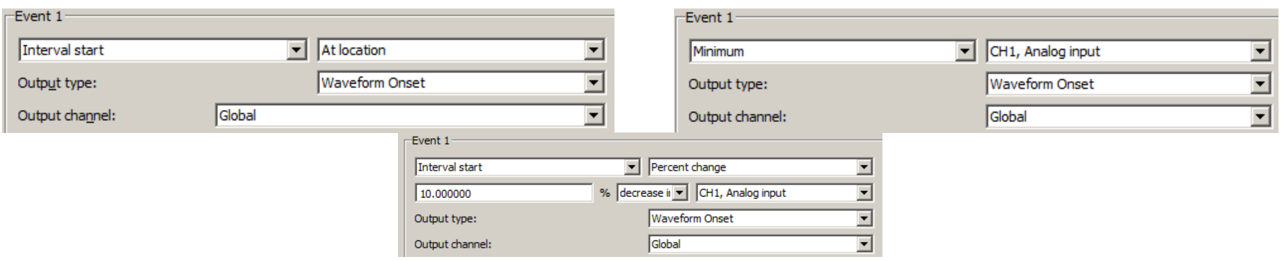
Output Events



Toggle the "Output events" checkbox at the top of the Events tab to turn Event Output on and off.

The Cycle/Peak Detector Output mode can define events at specific locations; a maximum of two events per cycle can be inserted with Event Output. After the Cycle Detector has located a cycle and adjusted the selection, the data within that cycle can be analyzed and used to create new events in the graph (data-driven or time specific).

Event definition



Insertion method & channel selection

Brief definitions follow, see the Event Location table on page 387 for details:

To place the event directly at the specified interval (start or end). See Interval Adjustment on page 386.

Percent change looks for a crossing based on a percentage of the value of the signal at the corresponding edge and places the event when a signal increases or decreases in value from the edge.

% peak to peak change looks for a point where the signal's value has changed by a percentage of the maximum peak-to-peak amplitude distance over the selected area and places the event when a signal increases or decreases in value from the edge

Minimum place events at the minimum of a specific channel's data within the selection.

Maximum place events at the minimum of a specific channel's data within the selection.

The channel whose data should be examined is specified in the pull-down menu directly to the right of the insertion method pull-down menu:

Output type

For each insertion method, the "Output type" pull-down menu adjusts the event type of the inserted event.

Output channel

Sets the channel where the event is inserted, either "Global" for defining global events or specific channels.

- None—disables any insertion for that event and all of the other controls will be hidden except the insertion method pull-down menu.
- Interval start / Interval end—a pull-down menu is displayed to be used to change between the different offset methods
- Minimum / Maximum

Output label

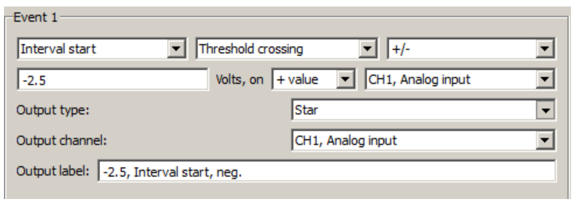
Use this edit field to type in specific label text. Each event that is inserted will have its label set to this text. By default, it is empty (inserted events will not be labeled).

Interval Adjustment

When an "At location" method is used, options will be generated to fine-tune event placement relative to the Interval end or Interval start of the selection.

Offset

Underneath the insertion method pull-down menu, a set of controls will be added, allowing the user to specify the percentage, choose whether to search for an increase or decrease, and choose the channel whose signal should be examined.



When the offset method is "Threshold crossing," the event will be placed when the signal on a channel crosses a threshold.

There are a number of possible ways to configure the threshold crossing:

- Fixed—The edit field may contain a specific voltage level for the threshold. In this configuration, an event will be placed if the value of the channel specified in the next pull-down menu crosses this fixed voltage value.
- + value—The edit field may specify an offset from the value of the channel at an interval start or end. The threshold voltage level is the value of the chosen source channel plus the offset from the edit field. To specify a threshold lower than the value of the channel at the interval start or end, choose the – value option. Mean and percentage of peak-to-peak + or – options are available as well.

Direction of crossing

The direction of the crossing can be specified.

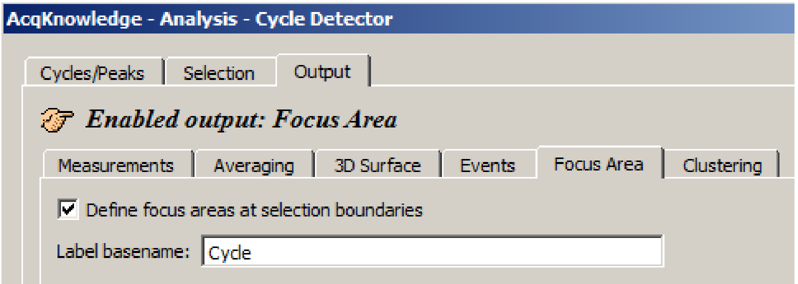
- + (positive crossing)—the signal must approach the threshold from below and cross to above the threshold before an event is inserted.
- \- (negative crossing)—the signal must approach the threshold from above and cross to below the threshold before an event is inserted.
- ± (mixed threshold)—an event will be inserted at the first positive or negative crossing that is encountered.

Event Location Table

Insertion Method	*Location Process*
Interval, at location	Place an event at the left or right boundary of the selected area, as specified.
Interval +/- percent offset	Given a particular channel, place an event at the specified time within the selection when the signal increases or decreases by a specific percentage. Interval start + Place at the time closest to the left boundary of the selection. The percentage is calculated from the value of the signal at the left boundary of the selected area. Interval end - Place at the time closest to the right boundary of the selection. The distance between the event and the right edge of the selection will have an amplitude difference equal to the indicated percentage of the right edge's value. If the signal does not increase or decrease by that percentage within the selection, no event will be inserted.
Interval +/- percent peak to peak offset	Given a particular channel, place an event at the specified time within the selection when the signal increases or decreases by a specific percentage of the peak to peak delta of the selected area. Interval start + Place at the time closest to the left boundary of the selection. The percentage is calculated from the result of subtracting the minimum value of the signal over the selected interval from its maximum. Interval end - Place at the time closest to the right boundary. The distance between the event and the interval end of the selection will have an amplitude difference equal to the indicated percentage of the minimum value of the signal over the selected interval subtracted from its maximum. If the signal does not increase or decrease by that percentage within the selection, no event will be inserted.
Interval +/- threshold crossing	Starting at the specified boundary of the selection, determine a threshold value. This threshold voltage may be: ▪ fixed voltage level ▪ value of signal at the specified interval + offset ▪ mean value in selected area + offset Interval start + Search for the first location where the signal on a particular channel crosses the threshold. Interval end - Examining data from right to left, search for the rightmost location where the signal on a particular channel crosses the threshold. If the direction of the threshold crossing matches the user specified direction, then an event is inserted. If it does not, then the next threshold crossing is located and the process repeats. If the threshold is never crossed within the selected area in the user-specified direction, no event is inserted.
Minimum	The event will be placed at the time location corresponding to a specific channel's minimum value within the selected area.
Maximum	The event will be placed at the time location corresponding to a specific channel's maximum value within the selected area.

Output Focus Area

Use this tool to define and highlight focus areas within the graph and include them in the Find Cycle output.

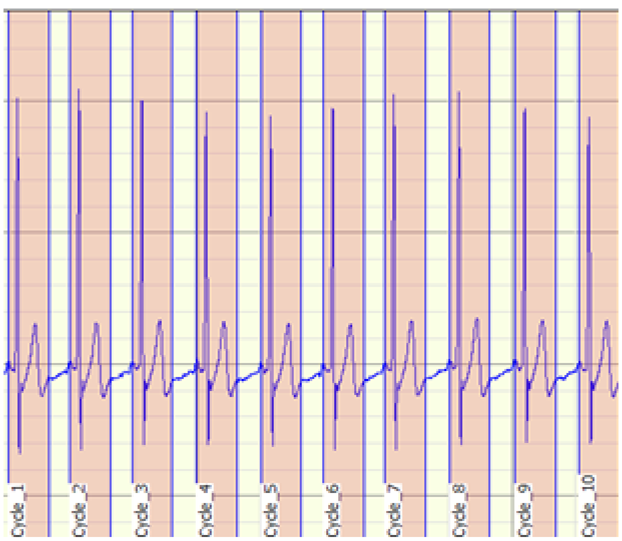


Define focus areas at selection boundaries

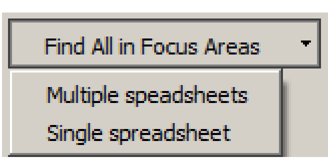
When checked, focus area output is enabled. Focus area selection boundaries will be defined as determined in the Find Cycle selection setup.

Label basename

Use to assign a name or label to the cycles located in the focus area. The defined basename will appear in the focus area section of the graph, along with incremented numbers for each subsequent cycle. (See below)



Find Cycle data derived from multiple focus areas can also be exported to either a single spreadsheet, or multiple spreadsheets. If the “Multiple” option is selected, each defined focus area will have data exported to a separate spreadsheet. (i.e., three focus areas will output three spreadsheets.)



Output: Clustering

Clustering is the process of taking a set of data points and partitioning them into a fixed number of groups called clusters. Each cluster represents data points that may share some type of commonality. This can be used to assign each data point to a class of similar points. Clustering can be used for hemodynamic analysis and is one of the basic analysis tools used for spike analysis in neurophysiology.

Algorithm Overview

K-means clustering is an iterative algorithm that begins with a data set of real-valued points in an n-dimensional space. Given this data set, one then specifies how many clusters are present. The k-means clustering algorithm attempts to find the location at the center of each of these clusters. Essentially, this algorithm partitions the data set into k groups such that the sum of the differences between the centers of each group and its remaining members is minimized.

A basic algorithm description is:

A. Given a total of k clusters, choose k potential cluster centers.

B. Assign each member of the data set to a cluster according to the closest potential cluster center using a Euclidean distance function (sum-of-squares).

C. Adjust the location of the potential center for each cluster to a more optimal value. The most basic method is to assign the new center to match the mean value of all of the members of the set.

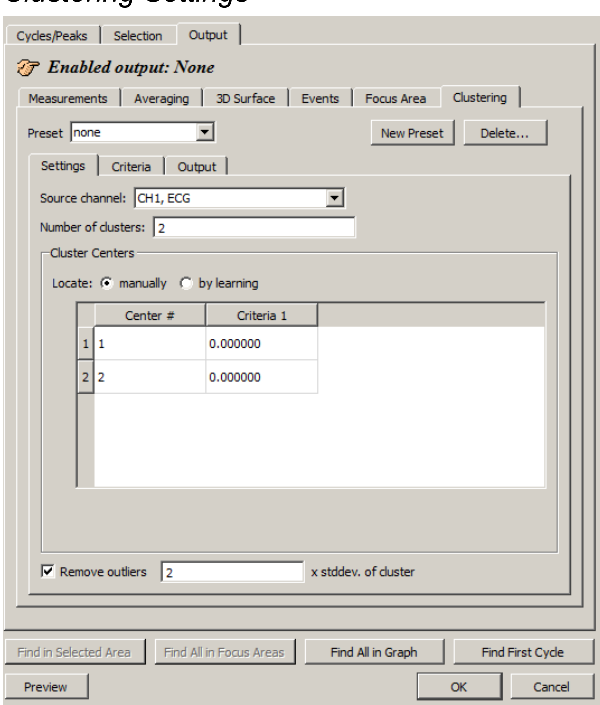
D. Determine if the set of clusters and centers is satisfactory. If not, go to step 2 and repeat the clustering process.

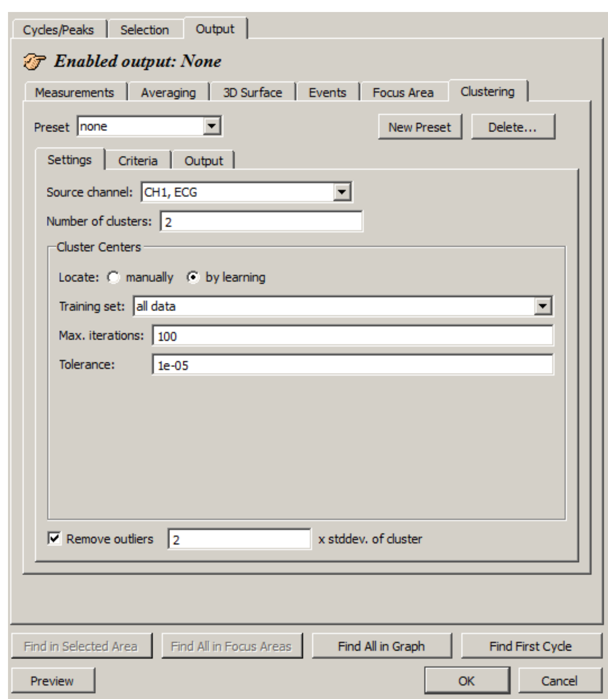
There are many different variations on what constitutes satisfactory ending conditions. The most ideal stopping criteria are when the cluster assignments no longer change with successive iterations. When there is no change in the centers, the solution perfectly minimizes the Euclidean distance sum for each cluster, unique up to variations in ordering of the dimensions. In practice, determining the perfect clustering of a data set is computationally intensive and may require some time to process. Approximations of perfect clustering are quicker to compute and usually produce sufficiently accurate results.

A waveform segment is reduced to a single data point by extracting numerical quantities known as *features*. *Feature clustering* is a very common data reduction method in use by clustering-based spike sorting software. Each feature is a single real-valued number extracted from the data. Examples of features are: maximum amplitude in waveform segment, minimum, time to maximum, time to minimum, peak to peak distance, sum of all values, maximum slope of peak.

A commonly used clustering analysis starts with two features. The features are then calculated for each waveform segment and presented on a scatter plot, allowing the user to visually determine how many clusters may be present. A k-means clustering analysis is then run on these data points to determine the center of the clusters in feature space. With the center known, each waveform segment is then assigned to a cluster depending on the values of its features.

Clustering Settings





Number of clusters

After features have been extracted, data points constructed from the feature are split up into a number of groups. Enter the number of clusters into which the data is to be partitioned.

Locate Cluster Centers

Clustering has a good potential to form the basis for classifiers to score physiological data. The cluster centers can be located by keeping the centers fixed and manually setting the cluster centers (above left) or by automatic learning, which dynamically locates the cluster centers based upon a training set of all data, a subset of data based upon a percentage, or based upon a selected event in the data.

Manually

The manual method allows the centers of each cluster to be manually typed in and edited. Instead of running a full k-means algorithm to locate centers, the k-means algorithm will simply run through the data set and assign each element to the closest cluster center and apply any outlier detection.

This simplistic clustering will allow centers as computed from a previous run to be used in subsequent clustering. Using manually specified centers is necessary to provide consistency when clustering data that may occur in different experiments or different graph files. The use of manual centers allows for the clustering implementation to be used as a classifier to compare new data sets to clusters as determined from either ideal or previously scored data sets.

By Learning

The learning method will use the full k-means clustering algorithm as described above. This consists of choosing candidate centers, computing mean distances, adjusting the candidate center positions, and repeating until termination conditions are met.

The data set used to compute the center positions can either be the full data set, a subset of the data or an event within the data set.

Training Set Definition

The training set is the set of data that is used during the iterative portion of the clustering algorithm that learns the potential center of each cluster. Training sets are only used for learned centers. There are three ways to specify a training set for use in clustering:

- Use all the source data when searching for the centers.
- Allow the training set to be a specific percentage of the total source data set with members of the training set chosen at random.
- Manually identify the training set with events located in the data.

Partial clustering refers to running the k-means clustering algorithm on only a subset of the source data. There are a number of reasons to perform partial clustering. One is computational efficiency. K-means clustering can be a time intensive procedure, as each iteration of the algorithm must recompute all of the distances to reclassify the entire data set. By performing partial clustering, it is possible to reduce the complexity of the k-means clustering step by limiting the amount of source data that needs to be processed in each step. This may be acceptable in situations where perfect partitions are not required.

Another use of partial clustering is to construct a *classifier*. A classifier is some method for assigning a particular data point to a specific class. To construct a classifier using k-means clustering a k-means algorithm is run on a training set that has known desirable data properties for splitting data into a number of classes. Once the centers of this training set are known, they can be used to perform another clustering analysis on a set of unknown data and determine how well that data exhibits the properties of the training set.

Max. iterations

This field is used for entering the maximum number of iterations the k-means algorithm is run. If the specified number of iterations is reached, processing will halt and centers will not be located.

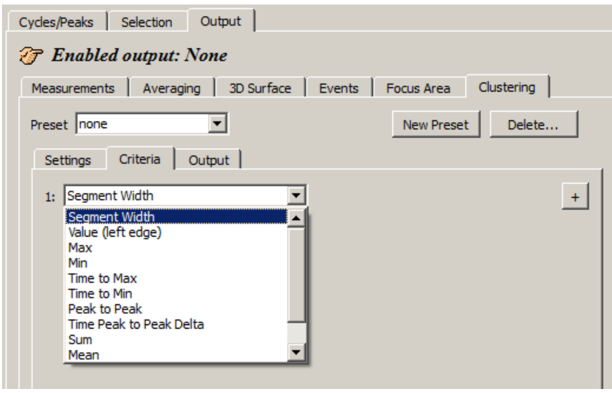
Tolerance

This value represents the minimum distance allowed for center adjustment. If the centers move by less than this value in subsequent learning steps, they will be considered stable and clustering will commence.

Remove Outliers

The clustering analysis allows for optional removal of outliers, or spurious data points. When enabled, each cluster is assigned a boundary. After each data point has been assigned to the cluster, the standard deviation of the distance of each point from the center of the cluster is computed. When outlier rejection is enabled, any data point that is farther away from the center than a specific number of standard deviations will be removed from the cluster. Enabling outlier removal retains only the points in a cluster that have the strongest association with each other.

Clustering Criteria



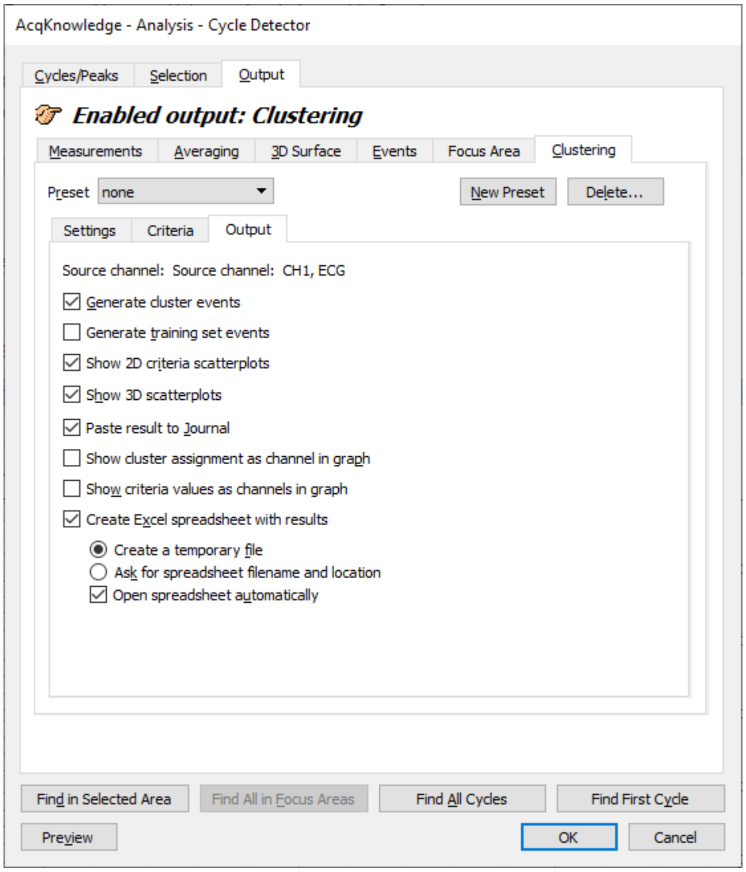
For a particular segment of a waveform, features are extracted based upon user-specified criteria.

Segment Width	Peak to Peak
Value (left edge)	Time peak to Peak Delta
Max	Sum
Min	Median
Time to Max	Mean
Time to Min	Measurement Result

Multiple segments are located using the Find Cycle/Peak functionality. After the criteria have been computed for each segment, clustering is then performed. This allows segments to be partitioned based upon their features. For example, "Segment Width" criteria can be used to partition ECG cycles into two clusters of shorter segments and longer segments.

The criteria Segment Widths are reported in milliseconds, as are the other time-based criteria (Time to Max; Time to Min; and Time Peak-to-Peak Delta). If the measurements are fixed to units of milliseconds, then K-Mean Criteria results will match measurement magnitude results. Clustering is defined with a hard left to right directionality for all measurements. Therefore, Delta T will have opposite signs than the same measurement pasted with Find Peak.

Clustering Output



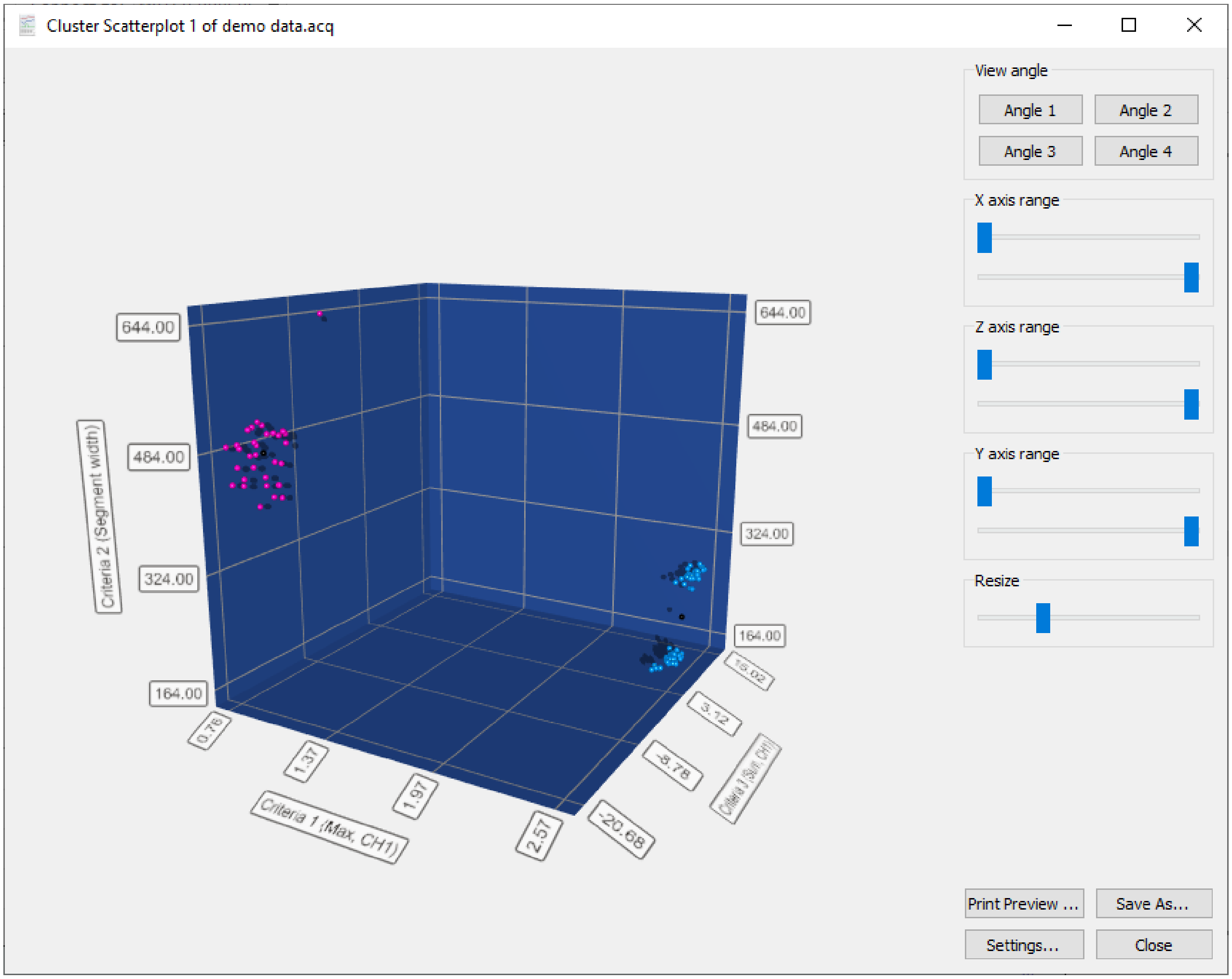
The output of a clustering analysis can be presented in multiple ways, including events, waveforms in the graph, textual tables, and visual scatterplots. These outputs allow for visual examination of the clustering results for anomalies and provide a foundation for further data reduction using other Acq*Knowledge* tools. By examining waveform data in a reduced feature space, it may be possible to construct clustering configurations that allow for separation of neuron action potentials into different classes, detection of heart arrhythmias, and other classification tasks.

One of the traditional methods of presenting results of a k-means analysis is through scatterplots.
Scatterplots are dot plots with a single dot per waveform segment run through the k-means clustering algorithm. They provide good visual references that can be used to estimate the potential number of clusters present in data and to compare the distinguishing abilities of different sets of criteria.

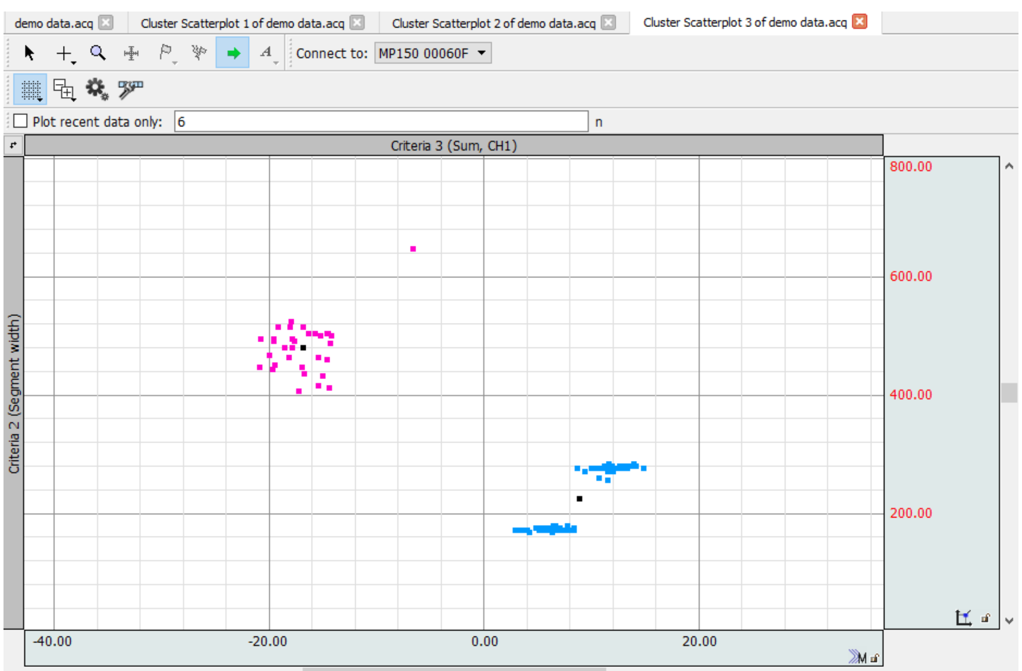
The scatterplot can be extended into three dimensions to provide feedback on relations between three criteria at the same time. With each criterion assigned to one of the three coordinate axes, a small sphere centered around the criteria values for a waveform segment can be constructed. Displaying the spheres for all data points would create the 3D scatterplot.

To generate 3D criteria scatterplots, select at least three criteria. There is also an option to change the 3D scatterplot background color and export results to an Excel spreadsheet. (See example scatterplots on following page).

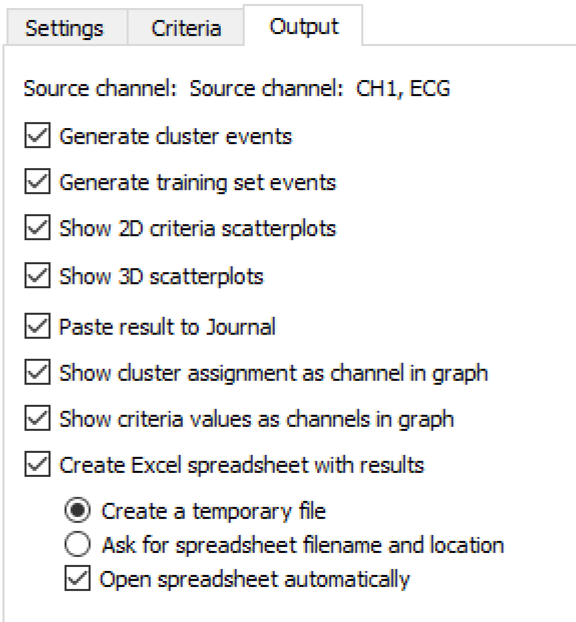
NOTE: The controls for viewing and manipulating the Find Cycle 3D scatterplot are identical to those used in the **Find Cycle 3D Surface View** described on page 383. Refer to that section for full descriptions of of the 3D Scatterplot view angles, X, Y, and Z-axis range, plot resizing, and additional settings such as font size and color.



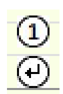
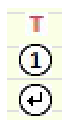
Find Cycle 3D Scatterplot



Find Cycle 2D Scatterplot

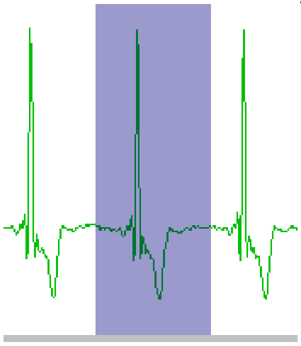


Additional Clustering Output Controls

Generate cluster events	Adds detected cluster events to graph display. 
Generate training set events	Adds detected training events to graph display. The *training set* is the set of data used during the center search portion of the clustering algorithm. 
Show 2D criteria scatterplots	Creates 2D cluster scatterplot graphs, one per criteria selected.
Show 3D criteria scatterplots	Creates 3D cluster scatterplot of Find Cycle operation.
Paste result to Journal	Creates Journal view of scatterplot criteria
Show cluster assignment as channel in graph	Adds cluster index to graph as a separate channel.
Show criteria values as channels in graph	Creates separate channels in graph showing criteria changes over time.
Create Excel spreadsheet with results	Outputs clustering results to temporary or permanent spreadsheet format.

The following example details how to detect the positive spike in the QRS complex—a typical use of the Find Cycle (peak detection) function.

1. Select the area around a typical peak.

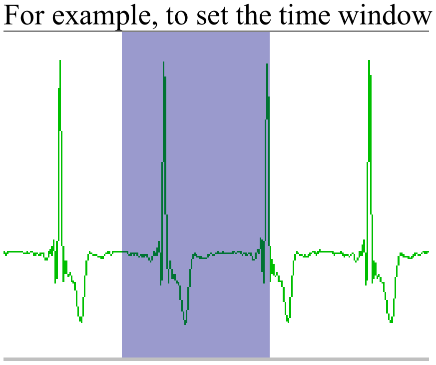


2. Select Find Cycle (Locate cycles from peaks).
3. Enable "Use selected maximum" on the Cycles/Peaks tab to automatically set an appropriate threshold value based on the amplitude of the cycle detector.
4. Click the Output tab and choose the desired option(s), such as paste measurement controls to update the journal with the measurement values from the new peak.
5. Click a Find button.
   - Find first cycle – the edge will blink at the first cycle point
     - To manually move through the file, click Find next
     - Or, select an area and choose Find all
     - Or, place the edge in the data and Find all will detect cycles from that point forward.
   - Find All Cycles will find all cycles from the beginning of the selected area to the end of the waveform.
   - Find in Selected Area will only find cycles in the selected area.
   - Find in Focus Area will only find cycles in focus areas.

To use an offset

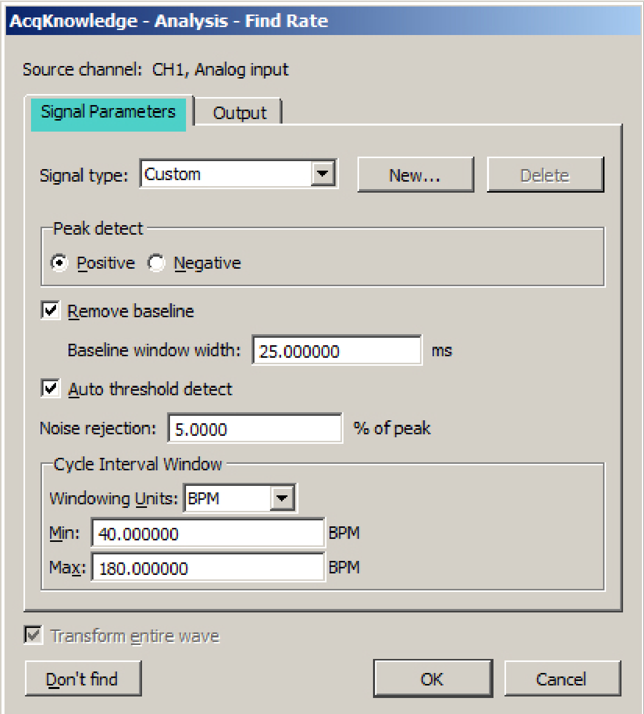
Use the Selection controls to set a time window around the selected cycle; previous peak controls the left edge, Current peak has options to control the left and right edges.

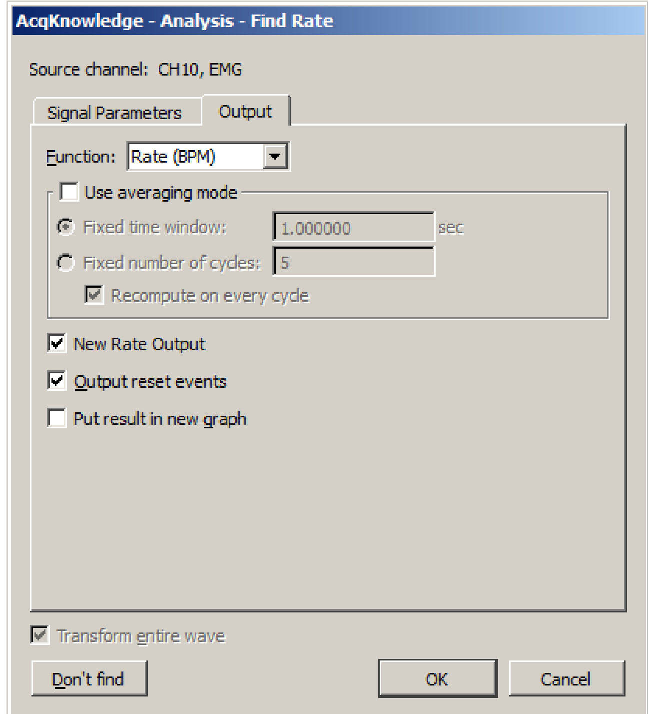
1. Use steps 1-4 above.
2. Click the Selection tab.
3. Set the desired edge values.
   - For example, to set the time window 0.5 seconds *prior* to the previous peak.



To control the left and right edges, select current peak and enter the appropriate time window to define an interval around the cycle.

Find Rate





The Rate Detector is critical to Acq*Knowledge*'s ability to extract information from physiological data that has a degree of periodicity. Physiological data that can be investigated using the Acq*Knowledge* Rate Detector includes:

- ECG (e.g. Heart Rate or Inter-Beat-Interval recording)
- Blood Pressure (e.g. Systolic, Diastolic, Mean, dP/dt Max, dP/dt Min)
- Respiration (Respiration Rate measurement)
- EMG (Zero Crossing or Mean Frequency analysis)

The Find Rate function computes rate calculations (including BPM) for data that has already been collected. Although this function uses the same algorithm as the online rate detector (which uses a Calculation channel), it can be advantageous to perform rate calculations after the data has been acquired. One benefit is that off-line rate computations do not require that a separate channel (i.e., a Calculation channel) be acquired. Since the number of acquired channels is reduced, other data can be collected and/or data can be sampled at a higher rate.

Rate detector settings are graph-independent, which means that find rate operations can be performed in multiple graphs without needing to re-enter graph-specific settings for each run. By using multiple data views, different find rate operations can be performed on the same set of data without losing settings between "Find Rate" operations. When the Rate Detector is first opened for a graph, the dialog will be filled with the values from the last successfully executed Find Rate operation. Subsequently, changes to the settings will be applied only to that graph.

Modes of Operation

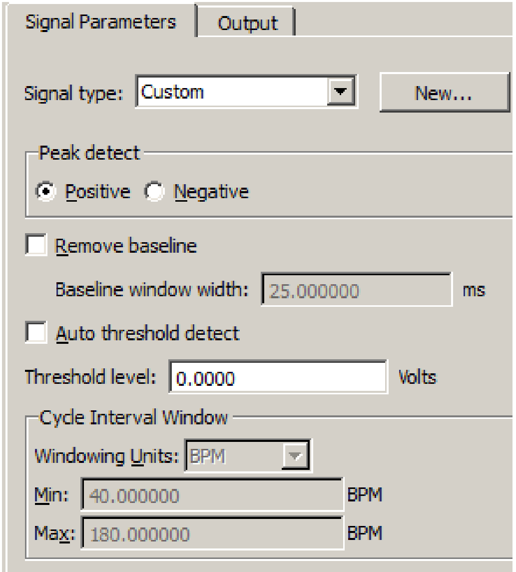
The Rate Detector incorporates a significant amount of flexibility to optimize performance when extracting data from periodic physiological waveforms. There are three basic modes of operation for the Rate Detector:

1) Fixed threshold detect mode
2) Auto threshold detect mode (enables Noise rejection)
3) Remove baseline and Auto threshold detect mode

Generally, it's best to use the simplest Rate Detector mode suitable for a particular application. If the simplest mode doesn't work, add layers of sophistication, one at a time. For example:

If the Fixed threshold mode can't or will not work, use the Auto threshold detect mode.

If the Auto threshold detect mode is similarly unavailable, adjust the Noise rejection or add the Remove baseline option.



1) Fixed threshold detect mode:

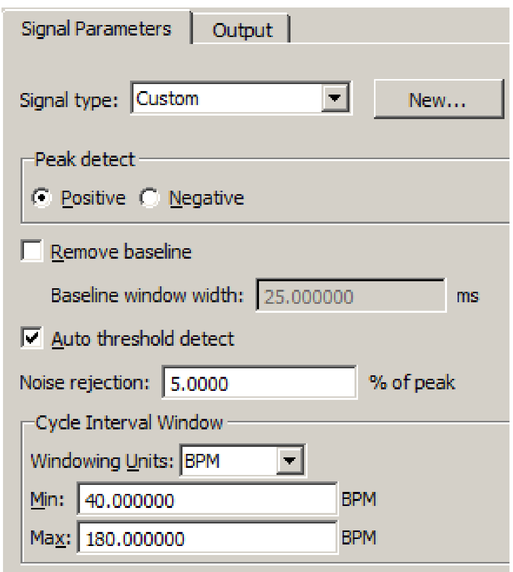
Fixed threshold detect mode is the simplest mode of operation for the Rate Detector. As shown here, the Threshold Level has been set to 0.00 Volts. If the waveform crosses 0 Volts, the Detector will begin to look for Positive or Negative peaks (based on the Peak detect setting).

Not available in Fixed mode:

Noise rejection

Baseline window width

Windowing options



2) Auto threshold detect mode:

Auto threshold detect mode is a more advanced and flexible mode of operation for the Rate Detector. In this case, the Rate Detector will create a variable threshold defined as:

Positive peak search

0.75 • (Old Peak Maximum - Old Peak Minimum)

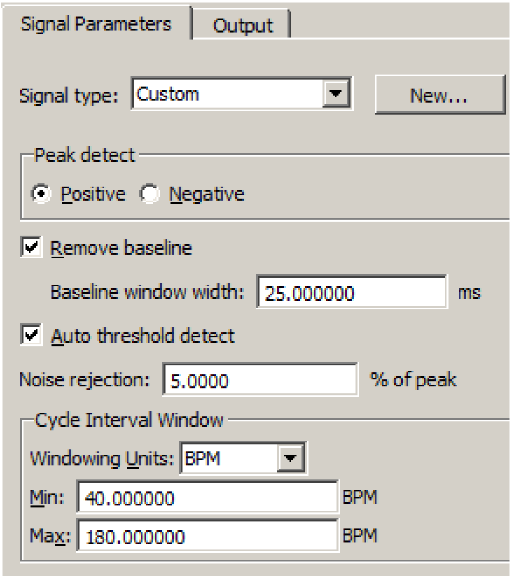
Negative peak search

0.25 • (Old Peak Maximum - Old Peak Minimum)

Furthermore, the Rate Detector will construct a moving file of data points defined by 1.5 times the number of samples that can be placed in the largest rate window size (defined by the Window settings). If the Rate Detector loses sync (no trigger event inside the window), the threshold is changed to the mean value of the moving file of data points. This operation permits successful recovery in the event of spurious waveform data values.

The Noise rejection setting creates Hysteresis around the variable threshold. The Hysteresis level is defined as:

Hysteresis = Noise rejection (%) • (Old Peak Maximum - Old Peak Minimum)



3) Remove baseline and Auto threshold detect mode:

Remove baseline and Auto threshold detect mode is an advanced and flexible mode of operation for the Rate Detector. Primarily, the Rate Detector performs an automatic (and hidden) moving difference function on the waveform data. The difference function is performed over a variable number of samples defined by:

# of points = (baseline window width / 1000) * Sampling Rate

This difference waveform is then passed through the variable threshold:

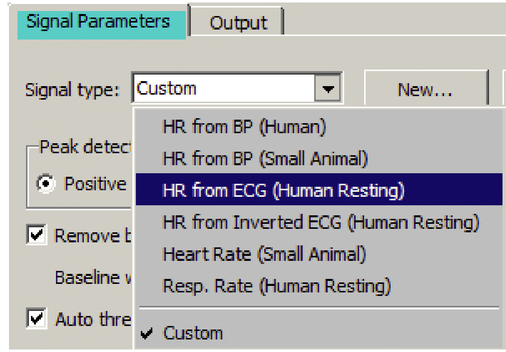
Positive peak search = 0.75 • (Old Peak Maximum - Old Peak Min)

Negative peak search = 0.25 • (Old Peak Max - Old Peak Min)

Furthermore, the Rate Detector will construct a moving file of data points defined by 1.5 times the number of samples that can be placed in the largest rate window size (defined by the Window settings). If the Rate Detector loses sync (no trigger event inside the window), the threshold is changed to the mean value of the moving file of data points. This operation permits successful recovery in the event of spurious waveform data values.

FIND RATE OPERATIONAL SUGGESTIONS	
Option	Waveform Characteristics
Fixed threshold option	• Waveform data has clearly defined positive or negative peaks (like respiratory or air flow data), which are consistently higher (in magnitude) than the rest of the waveform. • waveform data has clearly defined zero-crossings (such as EMG), and it's necessary to determine the rate of these crossings
Auto threshold detect option	• Waveform data has a moving baseline, but the peaks are otherwise larger in magnitude than other parts of the waveform (blood pressure). *It may be necessary to adjust the Noise rejection (Hysteresis) to optimize performance.*
Remove baseline *and* Auto threshold detect options	• Waveform data has high narrow peaks (like most ECG leads), which may or may not be larger in magnitude than other (slow moving) parts of the waveform. *It may be necessary to adjust the Noise rejection (Hysteresis) to optimize performance.*

Signal type



The Signal type menu contains parameters for specific human and animal waveform morphologies. All pre-defined and custom signal types are common to both calculation channel Rate (online) and analysis Rate (offline) dialogs. Signal type modifications affect settings in the Signal Parameters tab only, and do not affect the Output tab settings.

Select from six pre-configured signal types or click "New" to create, name and save custom setups. This allows quick access to frequently used Rate detection signals without the need to recreate modified settings. Custom Rate signal types may be added or deleted in the same manner that channel presets are in other areas of the Acq*Knowledge* application.

Peak detect

By default, the Peak Detector searches for Positive peaks (upward pointing, such as the R-wave of an ECG signal) to calculate the rate of a waveform. In some instances, however, it may be necessary to base the rate calculation on negative peaks (downward pointing). To do this, select Negative peak.

Remove baseline

The Remove baseline option applies a difference operation to preprocess the signal. This option is useful when signals have a slowly fluctuating baseline.

Auto threshold detect

When the Auto threshold detect box is selected in the Find Rate dialog, Acq*Knowledge* automatically computes the threshold value using an algorithm that accentuates peaks and uses information about the previous peak to estimate when and where the next peak is likely to occur. This threshold detector is typically more accurate than a simple absolute value rate calculation function, and is able to compute a rate from data with a drifting baseline and when noise is present in the signal. (For a detailed description of how the calculation is performed, contact BIOPAC Systems, Inc. for the complete Application Note.)

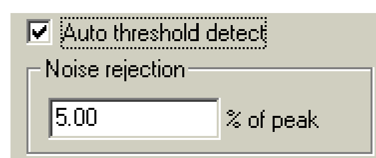
- When Auto threshold detect is enabled, the Noise rejection and Window options are enabled.

Threshold level

This option (activated when "Auto threshold detect" is *not* selected) allows a threshold level to be used for a simple absolute value rate calculation function.

- The Auto threshold detect option is typically more accurate.

Noise rejection

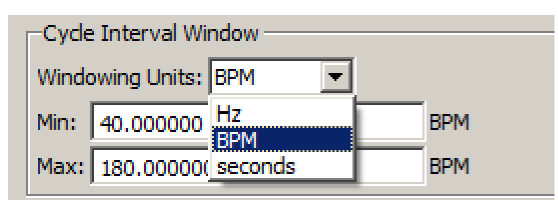


Noise rejection (activated when "Auto threshold detect" is enabled) constructs an interval around the threshold level. The size of the interval is equal to the value in the "Noise rejection" text box. Checking this option helps prevent noise "spikes" from being counted as peaks.

- The default is equal to 5% of the peak-to-peak range.

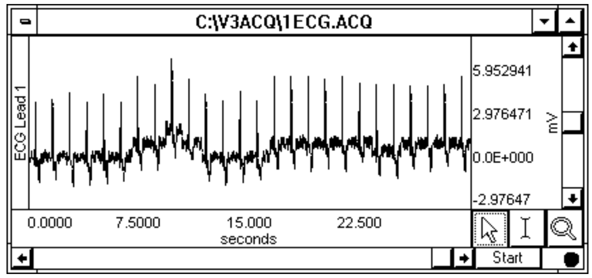
Cycle Interval Window

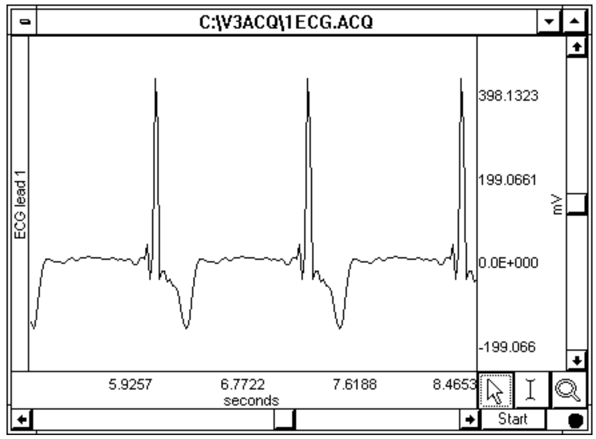
The Cycle Interval Window is used to specify an upper and lower limit for the Rate calculation. Window is activated when "Auto threshold detect" is enabled; the Windowing Units pull-down menu is only activated when the selected Function can have variable units. (Hertz, BPM or Seconds.)



Defaults: Min 40 BPM
Max 180 BPM

Setting the upper and lower bounds for the "window" tells Acq*Knowledge* when to start looking for a peak.





Acq*Knowledge* will try to locate a peak that matches the automatic threshold criteria within the specified window. If no peak is found, the area outside the envelope will be searched and the criteria (in terms of peak value) will be relaxed until the next peak is found.

For instance, once the first peak is found, Acq*Knowledge* will look for the next peak in an interval that corresponds to the range set by the upper and lower bounds of the window. The interval associated with the upper band of 180 BPM is 0.33 seconds (60 seconds ÷ 180 BPM), and the interval for the lower band is 1.5 seconds (1 minute ÷ 40 BPM). If a second peak is not found between .33 seconds and 1.5 seconds after the first peak, then Acq*Knowledge* will look in the area after 1.5 seconds for a "smaller" peak (i.e., one of lesser amplitude).

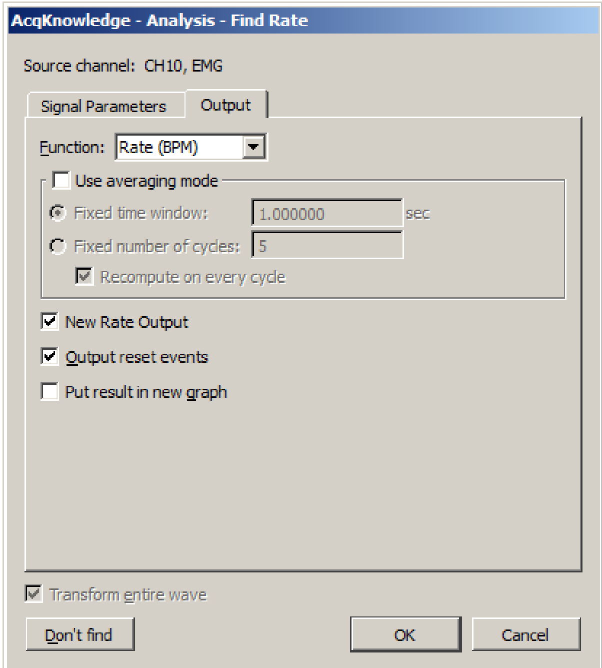
For those rate functions that require a window interval in seconds, it's recommended to enter numbers like .33 seconds and 1.5 seconds (which correspond to the BPM defaults of 40 and 180). These numbers will be suitable for detecting the heart rate of an average subject.

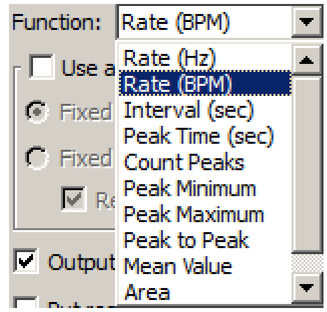
Window (Peak Interval)

A simple peak detector uses what is called a *threshold-crossing algorithm*, whereby each time the amplitude (vertical scale) value exceeds a given value, the peak detector "remembers" that point and begins searching for the next event where the channel crosses the threshold. The interval between the two occurrences is then computed and usually rescaled in terms of BPM or Hz. This is how the Acq*Knowledge* rate Calculation functions when all options are unchecked.

In the sample waveform shown here, the threshold was set to 390 mV to detect the peaks of the waveform and provide an accurate rate calculation. Since it only recognizes signals greater than 390 mV as a peak, this 390-mV threshold is referred to as an "absolute threshold." Most waveforms are not so well behaved, however, and artifact can be introduced as a result of movement, electrical interference, and so forth. Combined with actual variability in the signal of interest, this can result in "noise" being included with the signal, as well as baseline "drift" which can render absolute threshold algorithms useless.

Additional Find Rate Dialog Settings, Output Tab





Function

The Rate Detector Function menu lists a variety of calculations, which are discussed below.

Rate (Hz), Rate (BPM), Interval (sec)

The most commonly used function is the Rate (BPM) option, which calculates a rate in terms of beats per minute or BPM. Rate calculations can also be performed that return a rate value scaled in terms of frequency (Hz) or time interval (sec). When rate is reflected in terms of a time interval, the time difference (delta T) between the two peaks is returned. This is sometimes referred to as the *inter-beat interval* (IBI). The frequency calculation returns the rate in Hertz (Hz), which is computed by dividing 1 by delta T. These measurements are perfectly correlated with the BPM calculation, since BPM is equal to 60 times the frequency calculation, or 60 divided by delta T.

Peak time

Returns the time (in seconds) at which the peak occurred. Like the other Rate functions (e.g., BPM and Hz), the value of the last peak time will be plotted until a subsequent peak is detected. The resulting plot will resemble a monotonically increasing "staircase" plot.

Count peaks

Produces a plot of the number of peaks (on the vertical axis) vs. time on the horizontal axis. When used with the delta measurements (in the measurement windows), this is a convenient way to calculate how many peaks occur within a selected area.

Peak maximum/minimum

Tracks the maximum value of the peak (the ECG R-wave). This correlates to the systolic pressure in blood pressure readings. To search for minimum peak values, select negative from the Peak detect section of the dialog.

Peak-to-peak

Looks at the vertical difference between the maximum and minimum values of the waveform on a cyclical basis—useful when needing to determine the amplitude of the pulsatile signal.

Mean value

Computes the mean of a pulsatile signal on a cycle-by-cycle basis between two peaks; produces a staircase plot.

Area

This function computes the area of the signal between two peaks, on a cycle-by-cycle basis.

Sum (not shown)

This function extracts the sum of all amplitudes for each cycle.

Use Averaging Mode

Use this option to average the output of the selected function using values based upon a fixed time window or a fixed number of cycles. If the average is taken from a fixed number of cycles, there is an additional option to recompute on every cycle. When unchecked, the output will be reset after the selected number of cycles are detected and remain fixed until the next group cycles are detected. When checked, the output will start after the first cycle is detected and will then be refreshed on every cycle.

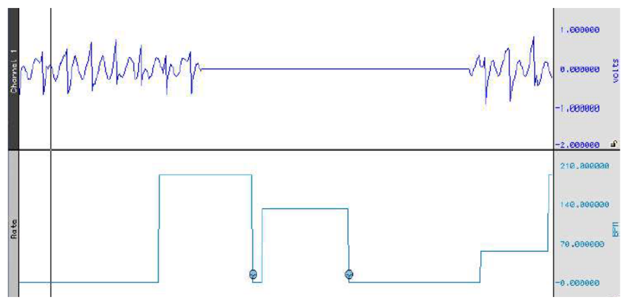
Output reset events

This option controls the definition of reset event insertion into the graph.

If no thresholds are found within the user-specified window width, the automatically detected threshold level will "reset" and tracking will start anew; the output of the rate detector function may also drop to zero. When "Output reset events" is enabled, a reset event will be added to the channel whenever the threshold is reset due to window expiration

- This helps distinguish zero-valued output due to window resetting and true zero-value output.

In the sample shown, the signal drops to zero during a period of analysis (e.g., due to lead clip falling off). Reset events indicate automatic threshold tracking was lost in this interval and the points where the search for a new level begins.



Put Result in New Graph

When this option is checked, the results from the find rate calculation are plotted in a new graph window with data displayed in X/Y format, with time on the horizontal axis. By default, this option is unchecked and the resulting transformation is placed in the lowest available channel of the current graph.

NOTE: When put into a new waveform or used as a calculation channel, the output rate function uses padding to generate a signal at a continuous sampling rate. The extracted value is used for padding until the next cycle is detected. This padding can cause unsuitable weighting for statistical analysis. For accurate statistical analysis with only one value for each cycle, use the offline rate detector "show output in new window" to produce a "value" waveform with one output point for each cycle. This output is suitable for export to Excel or other software for statistical analysis.

Find Rate of Entire Wave

When this option is checked, the rate (or other function from the Find rate command) will be calculated for the entire wave (other than the selected area, if any).

Don't Find

Saves dialog settings in order to close out of the dialog and select an area. When the dialog is reopened, the earlier settings will be retained, after which the OK button can be clicked to perform the Find Rate function. This is useful for setting parameters using an area of a waveform and then repositioning the cursor at another point in the record.

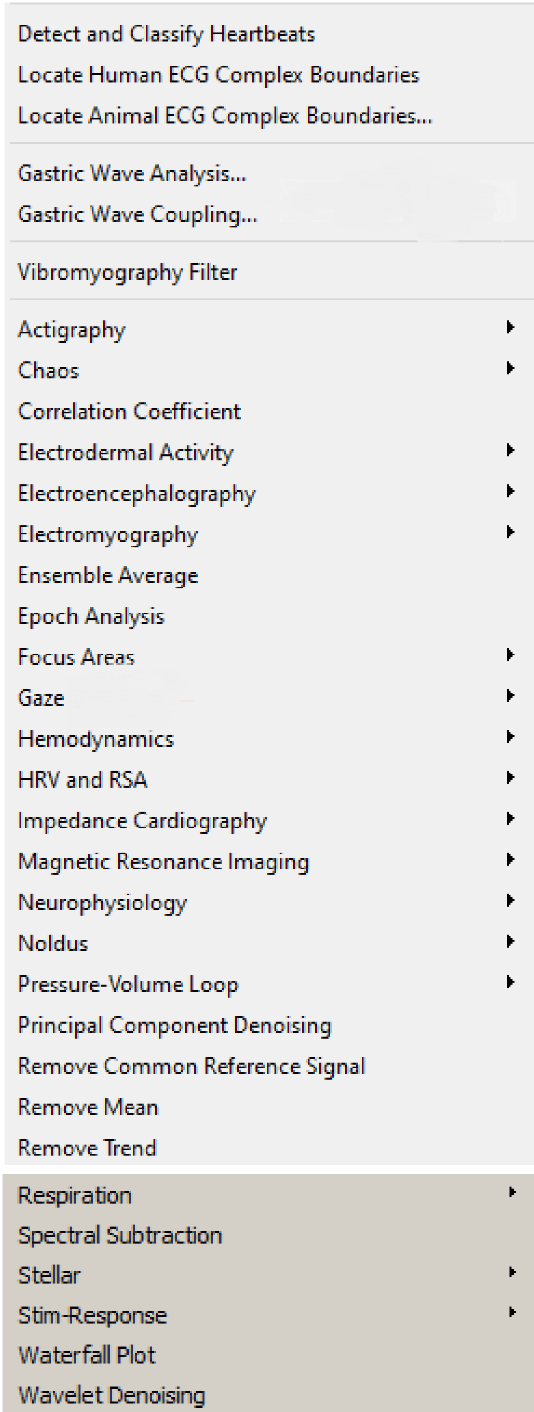
Specialized Analysis

The Specialized Analysis package includes tools to automate analysis to save hours (or days!) of processing time and standardize interpretation of results.

A courtesy copy of the Specialized Analysis package is installed under the Analysis menu with Acq*Knowledge*™ 4.

See the next chapter for full details.

Chapter 17 Specialized Analysis



The Specialized Analysis package includes comprehensive analysis tools to automate analysis to save hours (or days!) of processing time and standardize interpretation of results.

- Acq*Knowledge* 5 includes a courtesy copy of the Specialized Analysis Package under the Analysis menu.

Specialized Analysis provides extensive post-acquisition analysis options similar to modules from Mindware Technologies, PONEMAH Physiology Platform, EMKA Technologies, SA and other advanced analysis applications. If more analysis options, save the data as MATLAB, Igor Pro, PhysioNet, raw, or text format—or compress the file to reduce file size by about 60%.

Analyze data collected on Hardware Systems with Windows OS or Mac OS.

*See the **Analysis** menu on page 361 for other operations that derive data and measurements from the graph*:

Histogram
Autoregressive Modeling
Nonlinear Modeling
Power Spectral Density
AR Time-Freq Analysis
FFT
DWT
Principal Component Analysis
Independent Component Analysis
Find Cycle
Find Next Cycle
Find All Cycles in Focus Area
Find All Cycles
Find In Selected Area
Find Rate

The Specialized Analysis package includes the following Analysis Packages and Classifiers:

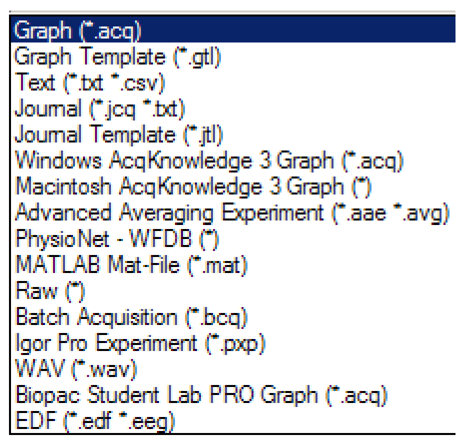
Analysis package—bundle of transformations created to assist with analysis in a specific area of research.

Classifier—special-purpose transformation that defines events at well-known points of interest on standard waveforms, such as the ECG wave boundary classifier and the QRS beat detector and arrhythmia detector.

- Detect and Classify Heartbeats
- Locate Human ECG Complex Boundaries
- Locate Animal ECG Complex Boundaries
- Gastric Wave Analysis
- Gastric Wave Coupling
- Chaos Analysis
  - Detrended Fluctuation Analysis
  - Optimal Embedding Dimension
  - Optimal Time Delay
  - Plot Attractor
- Correlation Coefficient
- Electrodermal Activity
  - Derive Phasic EDA from Tonic
  - Event-related EDA Analysis
  - Locate SCRs
  - Preferences: Output Display Format; Phasic EDA Construction Method: Smoothing Baseline Removal or High Pass Filter
- Electroencephalography
  - Compute Approximate Entropy
  - Delta Power Analysis
  - Derive Alpha-RMS
  - Derive EEG Frequency Bands
  - EEG Frequency Analysis
  - Remove EOG Artifacts
  - Seizure Analysis
  - Preferences: Output Display Format
- Electromyography
  - Derive Average Rectified EMG
  - Derive Integrated EMG
  - Derive Root Mean Square EMG
  - EMG Frequency & Power Analysis
  - Locate Muscle Activation
  - Preferences: Output Display Format
- Ensemble Average
- Epoch Analysis
- Focus Areas
  - Define Between Events
  - Define for Appended Segments
- Gaze
- Hemodynamics
  - Classifiers: ABP; LVP; MAP
  - Arterial Blood Pressure
  - Baroreflex Sequence Analysis (licensed feature)
  - Baroreflex Slope Analysis (licensed feature)
  - ECG Interval Extraction
  - Estimate Cardiac Output from ABP
  - Left Ventricular Blood Pressure
  - Monophasic Action Potential
  - Preferences: Output Display Format; LVEDP Location Method; dP/dt pk-pk %; MAP Plateau Location Method; dP/dt MAP pk-pk %
- HRV and RSA
  - Multi-epoch HRV – Statistical
  - Multi-epoch HRV and RSA – Spectral
  - R-R Poincaré Plot
  - RSA – Time-series
  - Single-epoch HRV – Spectral
- Impedance Cardiography
  - Body Surface Area
  - Ideal Body Weight
  - ICG Analysis
  - VEPT
  - PEP Pre-ejection Period
  - dZ(t)/dt Derive from Raw Z
  - dZ(t)/dt Classifier: B, C, X, Y, and O Points
  - dZ(t)/dt Remove Motion Artifacts
  - Preferences: Output Display Format; C-, B-, and X-Point Location; Stroke Volume Calculation Method; Body Measurement Units; Body Surface Area Method; Ideal Weight Estimation Method; dZ(t)/dt Max Method
- Magnetic Resonance Imaging
  - Artifact Frequency Removal
  - Signal Blanking
  - Artifact Projection Removal
  - Slew Rate Limiter
  - Median Filter Artifact Removal
- Neurophysiology
  - Amplitude Histograms
  - Classify Spikes
  - Average Action Potentials
  - Dwell Time Histograms
  - Generate Spike Trains
  - Locate Spike Episodes
  - Find Overlapping Spike Episodes
  - Set Episode Width and Offset
  - Preferences: Detect Spike; Default Episode Width; Default Episode Offset; Default # of Spike Classes
- Noldus
- Principal Component Denoising
- Remove Common Reference Signal
- Remove Mean
- Remove Trend
- Respiration
  - Compliance and Resistance
  - Penh Analysis
  - Pulmonary Airflow
- Spectral Subtraction
- Stim-Response
  - Digital Input to Stim Events Stim-Response Analysis
- Waterfall Plot
- Wavelet Denoising

Acq*Knowledge* File Portability

Use Specialized Analysis to analyze Acq*Knowledge* data files collected on Hardware Systems running on Windows/PC or Mac OS. Open/save the following file formats:



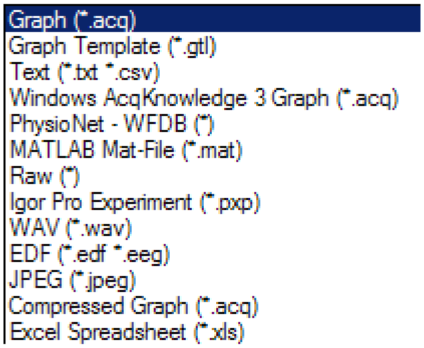
Opening files for Specialized Analysis

The default file formats (Graph and .ACQ) are referred to as "Acq*Knowledge*" files. The Acq*Knowledge* file format is the standard way of displaying waveforms in Acq*Knowledge*. These files are stored in a compact format that retains information about how the data was collected (i.e., for how long and at what rate) and takes relatively little time to read in (compared to text files, for instance). Acq*Knowledge* files are editable and can be modified and saved, or exported to other formats using the Save as command.

File Compatibility

- Mac Acq*Knowledge* 3.9and above can open and create PC-compatible Graph (*.acq) and Graph Template (*.gtl) files. Variable sampling rate information and hardware settings are retained, and Journals can be read from and written to PC files. Files must end on a multiple of the lowest channel sampling rate to be fully PC compatible.

Saving files after Specialized Analysis



Saving Files Acq*Knowledge* 4

The default file format for the File>Save as command is to save files as an Acq*Knowledge* file. Selecting Graph (MPWS) or .ACQ (MPWSW) from the popup menu in the Save As dialog will save a file as an Acq*Knowledge* file, which is designed to be as compact as possible. These files can only be opened by Acq*Knowledge*, but data can be exported to other formats.

File > Save Selection As allows saving a portion of the file. When this option is enabled, only data selected with the I-beam tool will be saved. This allows saving of the selected area to another file and does not affect the currently open file.

File Compatibility

Windows Acq*Knowledge* 3.9 and above files can be opened with Mac Acq*Knowledge* 3.9 and above, but some advanced features may not transfer.

- Mac Acq*Knowledge* 3.9 and above can save PC-compatible Graph (*.acq) and Graph Template (*.gtl) files. Variable sampling rate information and hardware settings are retained, and Journals can be read from and written to PC files. Choose the format "Graph (Windows)" to create PC-compatible files.

The Mac version does not save compressed PC files.

Files must end on a multiple of the lowest channel sampling rate to be fully PC compatible.

Excel Spreadsheet Export—The Specialized Analysis tools have been updated to automatically export their results to an Excel spreadsheet if desired. The spreadsheet contents mirror the tabular Journal text output. All the spreadsheets are saved as temporary files, so they need to be re-saved in order to be saved permanently.

- Also available for File > Save As, File > Save Journal Text As, and Find All Cycles journal.

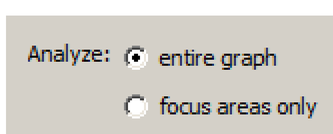
Note Specialized Analysis scripts are complex and undo may not function for all steps.

Some of the specialized algorithms are very complex and processor intensive, so they may take a long (even *very* long) time to return a result.

Most specialized analysis operations create additional channels in the graph, thus changing the underlying data in the source channel. In this instance, attempting to acquire appended data into the source channel of a graph that has had an analysis operation applied will result in a standard message: "You have modified or edited data in a way that prevents appending acquisition. You can replace the existing data or abort." This is normal for analysis operations that have modified the underlying graph data. Under this circumstance, all analysis operations will generate this message with the exception of the following:

- DWT/IDWT
- HRV
- ICA/IICA
- PCA/IPCA
- Detect and Classify Heartbeats
- Power Spectral Density
- Nonlinear Modeling

An option to perform analysis on the entire graph or on the focus areas only is presented in setup dialogs for most Specialized Analysis tools.



Detect and Classify Heartbeats

This robust QRS detector is tuned for human ECG Lead II signals. It locates QRS complexes and places an event near the center of each QRS complex to identify the type of heartbeat event:

- Normal: The beat was recognizable as a valid heartbeat falling in a human heartbeat rate.
- PVC: The beat was shorter than the beats around it and may be a pre-ventricular contraction. These events can be found in the "Hemodynamic > Beats" submenu of the event type listing.
- Unknown: The beat wasn't recognizable as a valid heartbeat. This may occur on the first beat prior to the QRS detector locking onto the signal. It may also occur if tracking is lost due to changes in signal quality.

The Cycle/Peak detector may be used with these events to perform further cardiac analysis.

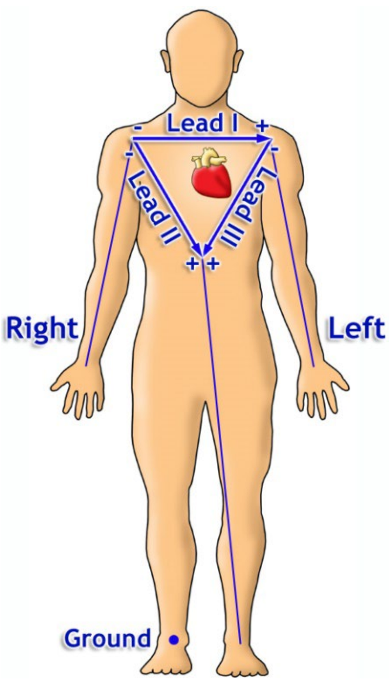
For information on the algorithm used in Detect and Classify Heartbeats, see page 485.

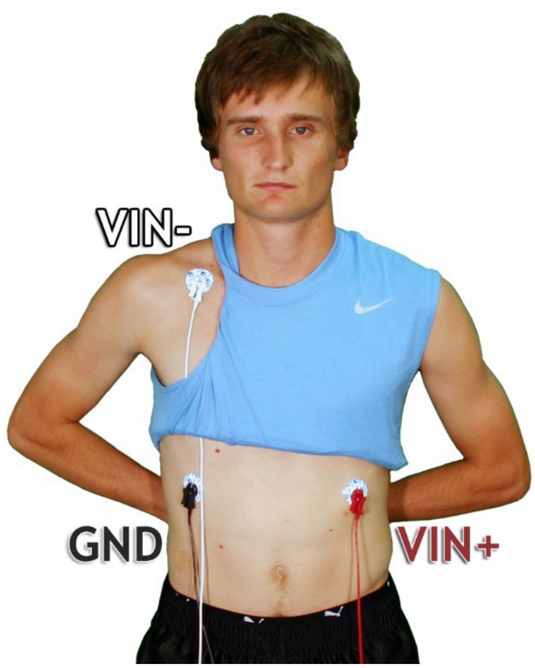
Watch the [Acq*Knowledge* Detect and Classify Heartbeats video tutorial] for a detailed demonstration of this feature.

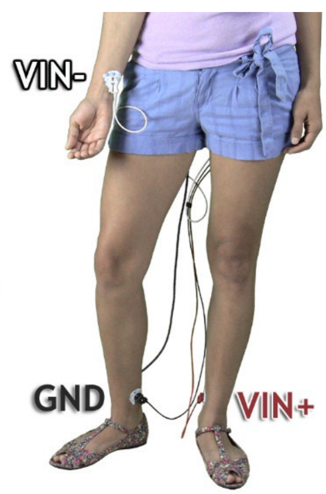
Locate Human ECG Complex Boundaries

IMPORTANT: The ECG Complex Boundaires algorithm requires an **ECG Lead II** waveform in order to yield accurate results. When using a Lead I / Lead III waveform as a data source, use the Acq*Knowledge* Find Cycle feature to output QRS peak events into the data before using ECG Complex Boundaries analysis.

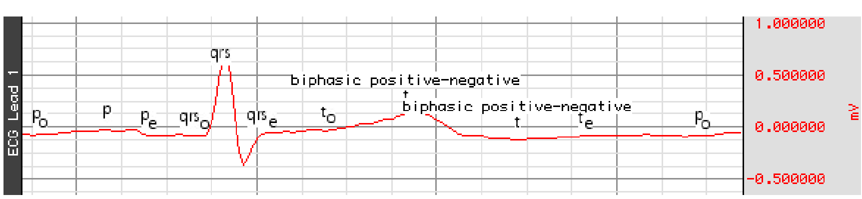
ECG Lead II configuration: Left Leg or lower left rib (RED = Vin+) and Right Arm or clavicle (WHITE = Vin-)







For detailed information about ECG Lead Configurations see BIOPAC [Application Note 109].



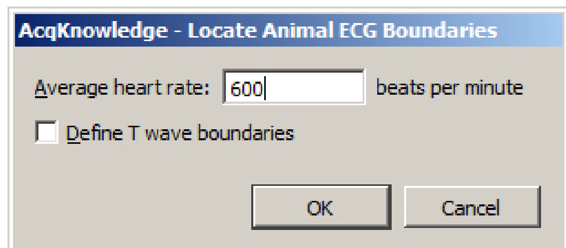
Locate Human ECG Complex Boundaries performs ECG waveform boundary detection for human ECG Lead II signals; ECG signals must be sampled at 5 kHz or below to be analyzed with this classifier. It will attempt to locate the boundaries of the QRS, T, and P wave and will define events for each individual complex. It will attempt to insert the following events; all of these complex boundaries can be found in the "Hemodynamic > ECG Complexes" submenu of the Event Type listing.

Wave	Type	Event Placement & Description
QRS	Onset	Before the beginning of the Q wave
	Peak	At the top of the R wave
	End	After the end of the S wave
T-wave	Onset	At the onset of T
	Peak	At the peak of the T wave *Note:* This may not be a positive peak if the T-wave is inverted. If the T-wave seems to be bi-phasic, two T-wave events will be inserted and the event description will indicate that the T-wave is bi-phasic.
	End	At the end of T
P-wave	Onset	At the onset of P
	Peak	At the top of the P wave *Note*: This may not be the absolute maximum, but rather the likely center of P.
	End	At the end of P

The Cycle/Peak detector may be used with these events to perform further cardiac analysis.

For information about the algorithm used in Locate Human ECG Complex Boundaries, see page 485.

Locate Animal ECG Complex Boundaries

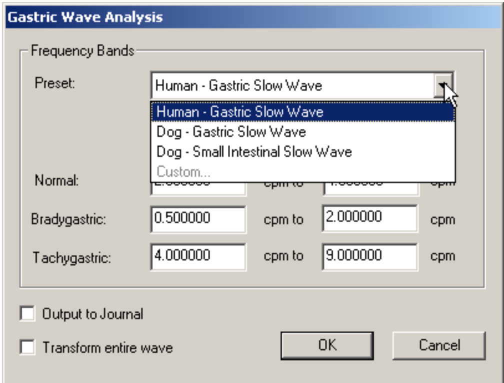


Locate Animal ECG Complex Boundaries optimizes the ECG waveform boundary detection for animal input. Smaller animals such as mice often lack a detectable T wave, so in the setup dialog the T wave boundaries are disabled by default. If appropriate to the experiment, T wave detection can be applied by enabling the "Define T wave boundaries" checkbox. The average heart rate can also be customized to reflect the normal range of a particular animal subject. (The default rate is 600 BPM.)

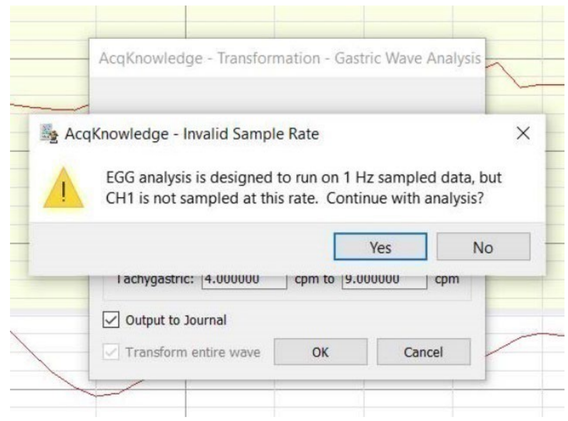
For information about the algorithm used in Locate Animal ECG Complex Boundaries, see page 484.

- See the Acq*Knowledge* Locate Animal ECG Complex Boundaries video tutorial for a detailed explanation of this feature.

Gastric Wave Analysis

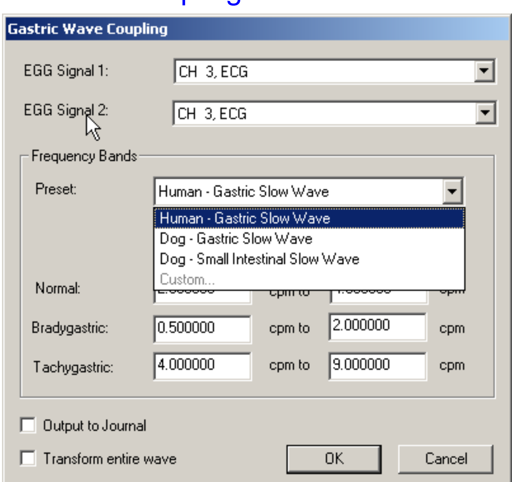


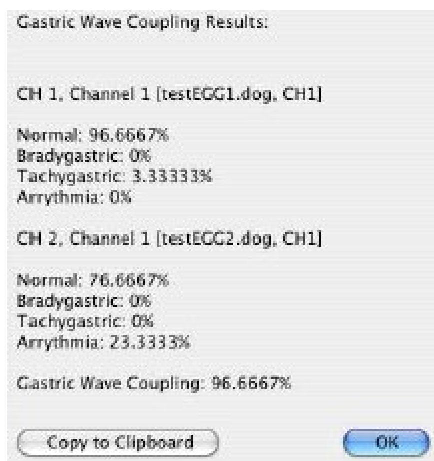
Gastric Wave Analysis uses autoregressive time-frequency analysis to determine the classifications of gastric waves present in an EGG signal. The single wave analysis determines the percentage of gastric waves that fall within the frequency bands corresponding to normal, bradygastric, and tachygastric waves. The analysis also indicates the percentage of waves that fall outside of these boundaries and are arrhythmias. The frequency bands are expressed in units of "contractions per minute" and may be adjusted by the user. Presets for commonly used subject and wave types are predefined; custom presets may be added.



Note: Analysis is optimized for a 1 Hz sampling rate. Gastric Wave analysis results are likely to be unreliable if not sampled on a 1 Hz waveform. Note the popup to the right if the user chooses to conduct analysis on a waveform sampled at a different rate.

Gastric Wave Coupling

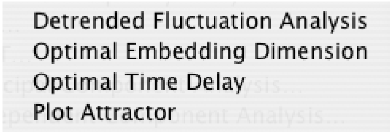




Gastric Wave Coupling takes two EGG signals and uses autoregressive techniques to classify the contractions in those signals according to user-configurable frequency bands (similar to single channel Gastric Wave Analysis). In addition to providing classification information for the two signals, Gastric Wave Coupling provides a measure of the percentage of coupling between the two signals—this measure that can be used to determine the amount of slow-wave propagation across the stomach.

See the Acq*Knowledge* Gastric Wave Analysis and Gastric Wave Coupling video tutorial for a detailed explanation of this feature.

Chaos Analysis



The "Chaos" analysis package assists the user in exploring the chaotic nature of data, including measurement selection and visualization of time domain attractors in the data.

Detrended Fluctuation Analysis

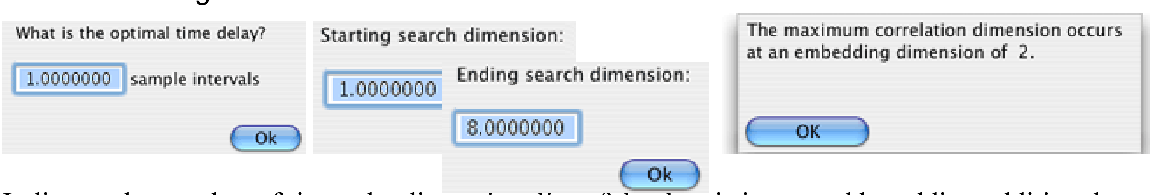
Modified root mean square analysis, useful for evaluating self-similarity in a long-term, non-stationary data series. Source data is mean-adjusted and then integrated. It is then split up into segments, each of length n. In each segment, via linear regression, the best fit least squares line is computed. For a particular value of *n* and a number of samples *N*, the characteristic fluctuation of the piecewise linear fit y_n. is defined as:

$$F(n)=\sqrt{\frac{1}{N}\sum_{k=1}^{N}[y(k)-y_n(k)]^2}$$

F(n) is evaluated over a user-specified range for the number of divisions. *n* will equal the total length divided by the number of divisions. A log-log plot of the interval width *n* in samples versus the corresponding value of *F(n)* will be created. If a linear relationship appears to exist in this graph, then the source signal displays some form of self-similarity. The slope of the line in this graph is related to the scaling exponent.

➲ For more information on Detrended Fluctuation Analysis, see http://www.physionet.org/physiotools/dfa/

Optimal Embedding Dimension

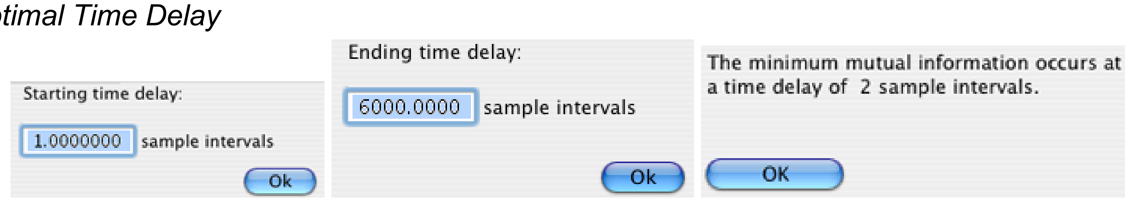


Indicates the number of times the dimensionality of the data is increased by adding additional copies of the data. Many of the fractal measurements take an embedding dimension parameter. Increasing the dimensionality of the data may improve the quality of the results. In general, embedding dimensions should always be less than 8.

After the most relevant time delay for the data has been selected, Optimal Embedding Dimension assists in choosing the embedding dimension that appears to give the most accurate results. The embedding dimension is chosen to be the earliest dimension in the search range where the fractal correlation dimension measure reaches a local maximum. This indicates the lowest dimension where the data has the potential to exhibit the most self-similarity.

- Since real data may not be fractal in nature, there may be no local maximum for the embedding dimension. In this case, it is not possible to determine the optimal dimension.

Optimal Time Delay

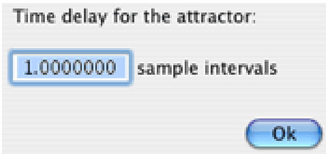


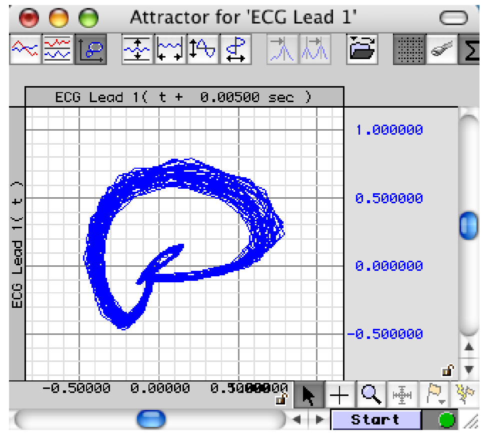
This algorithm assists in picking a time delay that is most relevant for the data. It locates the earliest time delay in the specified interval range where the mutual information measurement reaches a local minimum.

Optimizing the time delay in this fashion picks the shortest delay where the signal exhibits the most independence with respect to its time-delayed version.

The fractal dimension and other chaos-related measurements operate on a single channel of data. In the process of extracting these measures, a signal is compared with a time-delayed version of itself to examine the patterns in dynamics of the data. These measures take a fixed time delay setting. The Optimal Time Delay transformation can be used to choose the best value for the parameter.

Plot Attractor

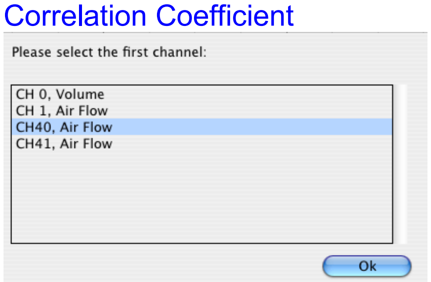


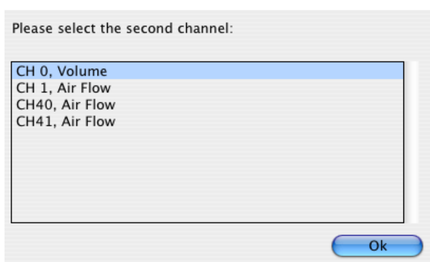


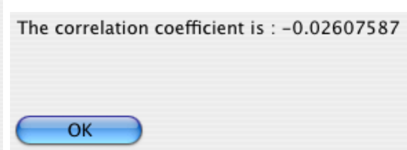
Assists in constructing X/Y plots for the attractors of time delayed data. By visually examining the shape of the attractor at a given time delay, To develop an intuitive sense for the underlying nature of the data and the dynamics of the system.

Plot Attractor functions on the active channel of the graph. It prompts the user for a time delay and then constructs a new graph window with an X/Y plot of the attractor of the original signal against the time delayed version of the signal. It does not perform any additional computation aside from assisting in the setup and configuration of the attractor plot.

Correlation Coefficient







The *correlation coefficient* is a statistical measure related to the degree of variance or covariance between two data series. Given two data series x and y of length n, the correlation coefficient r is given by the formula:

$$r = \frac{n\sum xy - \sum x \sum y}{\sqrt{\left[n\sum x^2 - \left(\sum x\right)^2\right]\left[n\sum y^2 - \left(\sum y\right)^2\right]}}$$

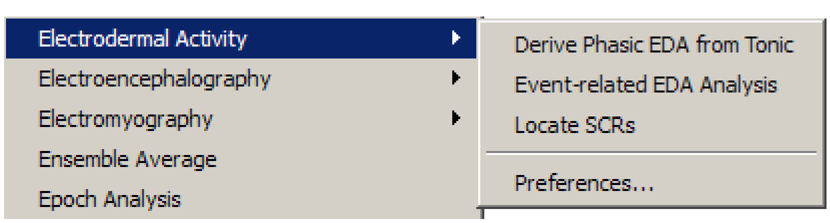
(see http://mathworld.wolfram.com/CorrelationCoefficient.html)

The square of the correlation coefficient can be used to determine the proportion of variance in common between the two signals. As the square gets closer to 1, the signals are a better statistical match for each other.

To derive the correlation coefficient, two channels of data are compared against each other.

- the channels must have the same length
- the channels must have the same waveform sampling rate
- all of the data of the entire graph for the two channels will be used to compute the correlation coefficient.

Electrodermal Activity



Overview

The **Electrodermal Activity** (EDA) analysis routines are separated into three menu options that transform the tonic EDA signal to create a phasic waveform, locate and score skin conductance responses, or perform a detailed event-related EDA analysis by combining event information from the Stim-Response: Digital Input to Stim Events routine (see page 479) to the event-related EDA Analysis routine. The Event-related routine will automatically derive the phasic waveform and locate SCRs.

The routines employ a scoring system that marks the waveform and the point of stimulus delivery. It's easy to manually adjust the automated scoring by relocating the event onset/peak/end before rerunning the analysis. The event-related analysis provides a variety of measures from the SCR data, including classification of specific and non-specific responses. The results are pasted into the journal file or Excel for further analysis.

Preferences must be established for each routine and can be adjusted at any time via the Preferences option (page 419). The time to complete the analysis routine will vary based on the number of SCR responses and the sample rate of the data.

Definitions

The prompts and results of the Electrodermal Activity analysis package use the following terminology and units:

μmho—the unit abbreviation for micromhos, used in channel labels and analysis results; micromho is equivalent to microsiemens.

EDA (Electrodermal Activity)—the general area of skin conductance signals. Sometimes referred to by the older term "galvanic skin response."

Tonic EDA—continuous data acquired from an EDA electrode that includes all baseline offset. Sometimes referred to as "skin conductance level." Averaging the tonic EDA over a specific period of time results in the average skin conductance level over an interval. Tonic EDA is recorded using BIOPAC equipment with the high pass filtering set to off (DC mode).

Phasic EDA—a continuous signal indicative of localized changes in the tonic EDA signal. Sometimes referred to as "continuous skin conductance response." Phasic EDA can be thought of as AC coupled tonic EDA. The EDA analysis package offers multiple ways of constructing phasic EDA including smoothing and high pass filtering. The EDA analysis package performs the majority of its analysis on tonic EDA signals, so if phasic EDA is being recorded directly it is recommended that a second channel be used to record tonic EDA.

Skin Conductance Response (SCR)—an individual localized change in the tonic EDA signal. An SCR may occur in response to a stimulus or may occur spontaneously. In general, there are multiple SCRs present in a tonic EDA signal and they can be detected as deflections from the localized baseline.

Reference

The Electrodermal Activity analysis package was developed to support the parameters established in:

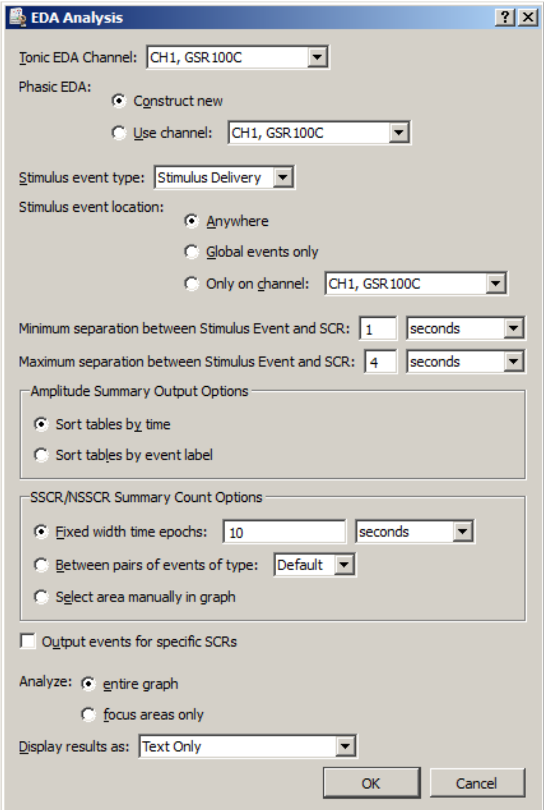
M. E. Dawson, A. M. Schell, and D. L. Filion. The electrodermal system. In J. T. Cacioppo, L. G. Tassinary, and G.B. Bernston, editors, Handbook of Psychophysiology: second edition, pages 200–223. Cambridge Press, Cambridge, 2000.

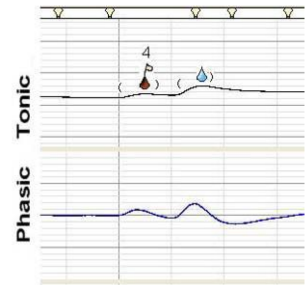
Derive Phasic EDA from Tonic

Given a tonic EDA signal, this transformation uses baseline smoothing or high pass filtering (the method currently set in Preferences) to construct a new Phasic EDA channel in the graph containing the estimate of the phasic EDA. This routine is automatically included in both the locate SCR and Event-related EDA routines.

Phasic EDA refers to a continuous signal indicative of localized changes in the tonic EDA signal. This data is sometimes referred to as "continuous skin conductance response." Phasic EDA can be thought of as AC coupled tonic EDA. The EDA Analysis Package offers multiple ways of constructing phasic EDA including smoothing and high pass filtering. The EDA Analysis Package performs the majority of its analysis on tonic EDA signals, so if phasic EDA is being recorded directly it is recommended that a second channel be used to record tonic EDA.

Event-related EDA Analysis





Sample EDA Analysis Output

All SCR events are marked on the tonic waveform as follows:

(*open paren.*	The point at which the phasic signal crosses the SCR threshold level established in EDA Preferences; see page 419
blue waterdrop	blue marks the peak response of a nonspecific, event-related SCR
red waterdrop	marks a specific SCR "SRR" with a flag numbered with the stimulus event type
) *close paren.*	The point at which the phasic signal crosses the zero threshold level

The Event-related EDA Analysis transformation routine assists in the extraction of EDA measures that are linked to specific stimuli. The stimulus event marks must be included in the file BEFORE using this analysis.

This analysis routine requires four elements:

1. Tonic and Phasic waveforms.

   Tonic EDA Channel: A Tonic EDA signal must be present in the graph.

   Phasic EDA:

   Construct new: Given a tonic EDA signal, a phasic EDA will be automatically constructed using baseline smoothing or high pass filtering (the method currently set in Preferences).

   Use Channel: If the graph contains a phasic waveform, select the appropriate channel.

2. Stimulus delivery events.

   Digital events with a common event type must be located BEFORE using this analysis.

   The Event-related EDA Analysis requires that an event be defined in the graph at the location of the delivery of each stimulus. This event may be defined using the Event Tool, hotkey insertion during acquisition, or any other method of defining events. All of the stimulus delivery locations to be extracted must have the same event type (e.g. "Flag"). To analyze multiple different event types, the transformation script must be executed multiple times.

   - If using E-Prime, SuperLab, or some other stimulus delivery system and have the digital events captured in the Acq*Knowledge* file, it's recommended to use the Stim-Response: Digital Input to Stim Events routine (see page 479). This routine will automatically classify and label the digital events for use by the Event-related EDA analysis.

   Stimulus event type: If using the Digital Input to Stim Events, select Stim/Response > Stimulus Delivery. Stimulus delivery events are located by event type or by specific channel of the graph.

   Stimulus event location: Specify the location as anywhere, global only, or on a specified channel. See the Events section for details.

3. Skin conductance responses.

   If the tonic EDA signal does not already have SCR events defined on it, SCR events will be automatically constructed on the channel using the Locate SCRs transformation routine.

4. Specified time window between the stimulus event and the skin conductance response.

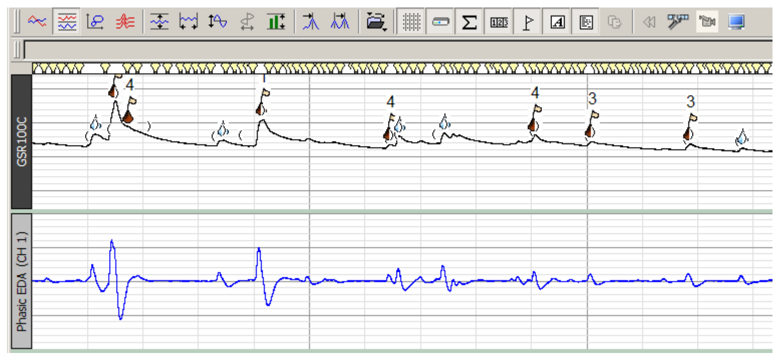
The transformation takes a maximum allowable separation window between the stimulus event and SCR response. Each stimulus delivery event is paired with the closest SCR event. SCRs that correspond to a stimulus delivery are known as specific SCRs (abbreviated "SRR"). SCRs generally occur within a certain timeframe after stimuli. The time window allows responses too close to stimuli to be rejected and classified as non-specific.

Minimum separation: specify in relation to the stimulus event (includes time unit options).

Maximum separation: specify in relation to the stimulus event (includes time unit options).

Given a response time window [res_{min}, res_{max}], for each stimulus delivery event at a time t, SCR onset events that are not presently matched as SRRs will be searched for in the window [$t + res_{min}$, $t + res_{max}$]. The SCR onset event within this window closest in time to [$t + res_{min}$] will be paired with the stimulus event and considered a SRR.

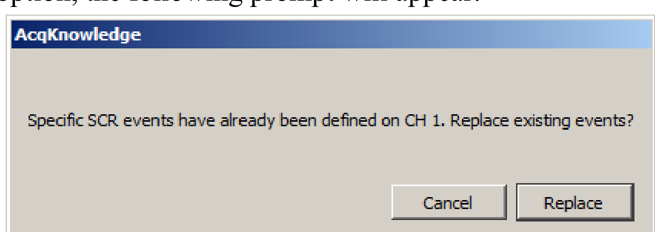
SRR are marked as a red waterdrop icon with a flag numbered with the corresponding stimulus event type when "Output events for specific SCRs" is enabled.



Each SRR will be matched to only one stimulus delivery event. If the closest SCR to a stimulus is farther away than this time interval, it is not assumed to be a response to the stimulus. It may be a response to a later stimulus or it may be a non-specific SCR that occurred spontaneously.

Output Events for Specific SCR

Enable this option to mark Specific skin conductance events as a red waterdrop icon with a flag numbered with the corresponding stimulus event type. If the EDA graph channel already contains Specific SCR events when applying the Output events option, the following prompt will appear:



Click "Replace" to remove and replace the existing Specific SCR events. Note that regular SCR (blue waterdrop) events are not affected by applying the Output events option. To manually adjust the position of the regular SCR events, select the SCR event by clicking it, open the Event palette, and edit the event time value in the Location field. Alternatively, SCR events can also be repositioned by selecting the event, pressing the Alt key and dragging to the desired position.

Event-related EDA Analysis Output Options

Enhancements provide more options for multiple stimulus event types and unmatched events, including:

- Labels and additional measures are available in the specific stimulus and SCR analysis table
- Text and Excel tables may be optionally sorted either by time or grouped by stimulus label
- A new table has been added listing stimulus events that were not paired with an SCR
- The SRR/NS.SRR Rate analysis, which counts frequencies of SCRs in specific time periods, may now be driven by time periods defined using pairs of events or a selection in the graph

- A table has been added listing amplitude/frequency percentage statistics for all matched and unmatched stimuli events (e.g., total stimulus count, percentage of stimuli that were pared with an SCR, etc.)
- Additional optional Specific-SCR events may be defined on the tonic EDA waveform at the positions of specific SCRs with labels matching the stimulus to which they were responses. This allows for further peak-detector based runs to perform additional data reduction.

Event Related EDA Event Types:

- Waveform Onset
- Waveform End
- Skin Conductance Response
- Specific SCR

Waveform Onset and Waveform End events are also available for other Specialized Analysis operations.

Amplitude Summary Output Options

For each specific SCR that is paired with a stimulus delivery event, the following measures are extracted in table format and can be sorted by **Time** or by **Event label**. If text output is enabled in EDA Preferences, the average value of SCL, Latency, SCR Amplitude, and SCR Rise Time will be included as the final row of the table.

Name	*Abbrev.*	*Description*	*Units*
Stimulus Delivery Time	Stim Time	The time within the recording where the stimulus delivery event was located.	seconds
Skin Conductance Level	SCL	Amplitude of the tonic EDA signal at the time when the stimulus was delivered.	μmho
Response Latency	Latency	Time separating the stimulus delivery from the onset time of the corresponding SCR. This latency will always be less than the maximum allowable latency specified as a parameter for the analysis.	seconds
SCR Amplitude	SCR Amplitude	Height of the corresponding SCR as determined by the change in the tonic EDA amplitude from the time of SCR onset to the maximum tonic EDA amplitude achieved during the SCR: $[EDA(t_{max}) - EDA(t_{onset})]$	μmho
SCR Rise Time	SCR Rise Time	Time taken for the tonic EDA to reach its maximum value within the SCR: $[t_{max} - t_{onset}]$	seconds
Absolute SCR Size	SCR Size	Contains the SCR Size, which is the absolute amplitude of the paired SCR event. This is the amplitude of the "SCR" event in the triplet. Formula: $EDA\ [t_{max}]$	μmho
SCR Onset Threshold	SCR Onset	Contains the absolute amplitude of the waveform onset event of the specific SCR. Formula: $EDA\ [t_{onset}]$	μmho
Stimulus event label	StimLabel	Contains the label of the stimulus delivery event.	N/A

The SCR Size and Onset Threshold values will be included for the textual table, graphical channel output, and in the Excel spreadsheet. The stimulus event label will be included only in the textual and Excel spreadsheet output; it is not possible to represent textual information in graph channels.

Sorting Options

The output table rows may appear in one of two orderings.

- "Sort tables by time" - Consecutive rows will be arranged in order of increasing time.
- "Sort tables by event label" - Case-sensitive lexicographical sort based on the StimLabel column; "AAAA" will be considered as unique from "aaaa" / "AaAa", etc.

SSCR/NSSCR Summary Count Options

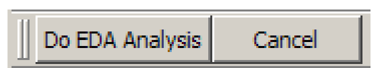
In addition to the above measures extracted for each specific SCR, the analysis performs rate extractions for specific and non-specific SCRs. By examining how the rate of SCR occurrences changes, long-term experimental trends can be investigated. This analysis is placed into a second set of waveforms (or a second table for text and Excel output).

Fixed width: fixed width window is specified as the "SCR count interval width" when performing the analysis. The entire recording is split up into fixed-width epochs of this granularity with the first epoch aligned at the start of the recording. For each fixed-width epoch, the following are extracted:

Name	*Abbrev.*	*Description*	*Units*
Epoch Start Time	Start Time	Time location in the recording of the start of the epoch being examined.	seconds
Specific SCR Rate	SRR	Frequency of the occurrences of specific SCRs within the epoch. Specific SCRs are those SCRs that were successfully matched to a corresponding stimulus delivery event.	Hz
Non-specific SCR Rate	NS.SRR	Frequency of the occurrences of non-specific SCRs within the epoch. These are SCRs that occur spontaneously and are not paired with any known stimulus.	Hz

Between event pairs: Select an event type from the pull-down menu. The software will locate the event markers at the beginning and end of the region of interest and perform the analysis between the two points This option is useful if the recording is broken into defined periods—such as baseline, event, and response—using the event hotkeys.

Manually selected area: Highlight the area where NSSCR/SSCR rates should be computed and then click "Do EDA Analysis" in the graph window.



Amplitude/Frequency Percent Summary

The "Stimulus Matching Summary" table for Textual and Spreadsheet output provides overall summaries for each unique event label for Stimulus Delivery events. The table has one line for each unique event label; the labels are numbers starting with 1.

This table provides an overall average for amplitude, magnitude and % Frequency for the specific SCR associated with Stimulus Delivery events. In this case, frequency is referring to the ratio of Stimulus Delivery events to the occurrence of specific SCRs.

Assume we have a set S of all Stimulus Delivery events of an identical label.

This will be split into two subsets: $S_{matched}$ consisting of all Stimulus Delivery events that have an associated SCR with them, and S_{ns} consisting of the non-specific stimulus events that do not have an associated SCR with them. Given these sets, the following definition holds:

$$S_{matched} \cup S_{ns} = S$$

For an individual event, define the SCR Amplitude function:

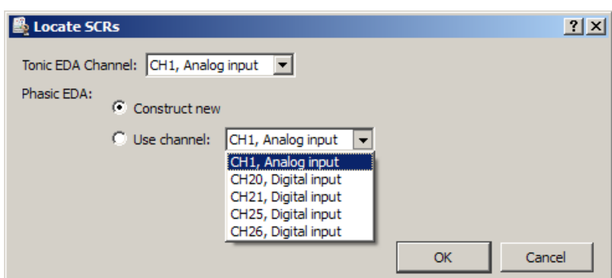
$$a(s) = |EDA(t_{max}) - EDA(t_{onset})|$$

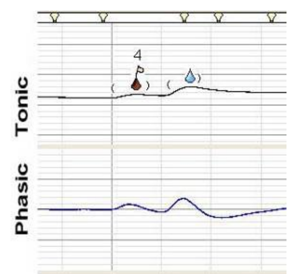
The following are the definitions of measures that will be included in the table:

Name	***Abbrev.***	***Description***	***Units***
Amplitude	Amplitude	Average value of the SCR amplitude of the specific SCR events. Defined by the following formula:	umho

Name	Abbrev.	Description	Units
		$$Amplitude = \frac{\sum_{s_i \in S_{matched}} a(s_i)}{\lvert S_{matched} \rvert}$$	
Magnitude	Magnitude	Weighted average of the SCR amplitude of the specific SCR events over the entire set of specific and non-specific events. Defined by the following formula: $$Magnitude = \frac{\sum_{s_i \in S_{matched}} a(s_i)}{\lvert S \rvert}$$	umho
Matched	Matched	Total number of specific SCRs associated with a Stimulus Delivery event. Defined by the following formula: $$Matched = \lvert S_{matched} \rvert$$	
Non-matched	Non-matched	Defined by the following formula: Non-matched = Stimulus Delivery $_{\text{Total count}}$ – Specific SCR $_{\text{Total count}}$	
Total	Total	Total count of Stimulus Delivery events. Defined by the following formula: $$Total = \lvert S \rvert$$	
Frequency (%)	Freq%	Percentage of stimulus events that were paired with an SCR. Defined by the following formula: $$Freq = \frac{\lvert S_{matched} \rvert}{\lvert S \rvert} * 100$$	
Label	Label	Textual label of the events that are included in *S*.	

Locate SCRs





The Locate SCRs routine will identify skin conductance response and score the waveform. This analysis is useful for analyzing spontaneously occurring skin conductance responses. The routine is automatically included in the Event-related EDA routine. All SCR events are marked on the tonic waveform as follows:

(	*open paren.*	The point at which the phasic signal crosses the SCR threshold level established in EDA Preferences; see page 419
	blue *waterdrop*	The peak response point of a nonspecific, event-related SCR
)	*close paren.*	The point at which the phasic signal crosses the zero threshold level

This transformation requires a tonic EDA signal. If a phasic EDA has already been constructed for this tonic EDA, it may be used; otherwise, the transformation will create a phasic EDA automatically according to the settings in the Preferences.

Given a tonic EDA, the Locate SCRs transformation defines an event for each skin conductive response in the tonic EDA. SCR location is a two stage process. First, all potential SCR occurrences are located on the signal. Second, all potential SCR occurrences that are not large enough are rejected.

Potential SCR occurrences are detected by performing thresholding positive peak detection on the phasic EDA signal (using H and P as set via Preferences):

1. Given a detection threshold H (expressed in μmho), search for a positive threshold crossing in the phasic EDA signal. This position is recorded as the start of the potential SCR.

2. Continue examining the phasic EDA until the first negative threshold crossing of 0 μmho occurs. This position is recorded as the end of the potential SCR.
3. Return to step 1 to continue searching for more potential SCRs.

After all of the potential SCRs have been located, the set of valid SCRs is constructed as follows:

1. Determine the overall maximum amplitude of the phasic EDA signal within all potential SCRs.
2. Given a percentage P, construct a threshold level T of P percent of the overall maximum phasic EDA signal value located in step 1.
3. Examine each potential SCR. Find the maximum phasic EDA. If $m < t$, discard the potential SCR. Mark the potential SCR as a valid SCR.

If the tonic EDA channel chosen for analysis already has SCR events defined on it, the SCR events will be replaced with the newly detected SCR events. No existing SCR events will be erased without a confirmation.

Once SCR events have been defined, they can be used in conjunction with the Cycle Detector for performing further data reduction. The “event count” measurement can be used to estimate SCR frequency during individual time ranges of the experiment.

Events on Tonic EDA

After valid SCRs are located using the algorithm above, events are inserted into the graph that can allow for further data analysis around the SCR positions. Three events are defined on the tonic EDA waveform for each individual valid SCR:

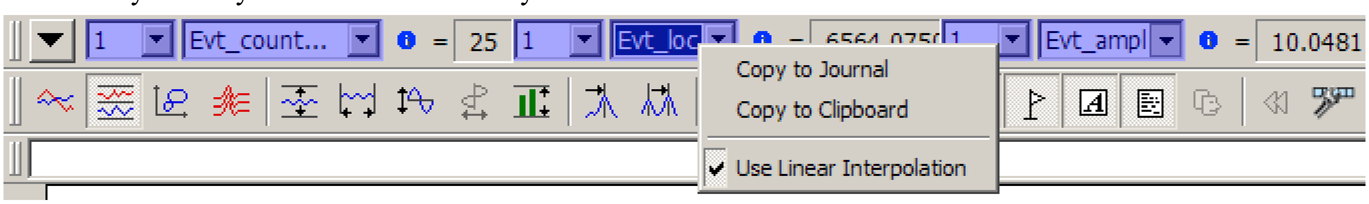
1. “General > Waveform onset” event at the SCR onset time. This is the point where the threshold H was crossed in the phasic EDA.
2. “EDA > Skin conductance response” event at the time where the tonic EDA reaches its maximum value within the SCR (max in time range).
3. “General > Waveform end” event at the ending SCR time. This is the point where the zero threshold was crossed in the phasic EDA.

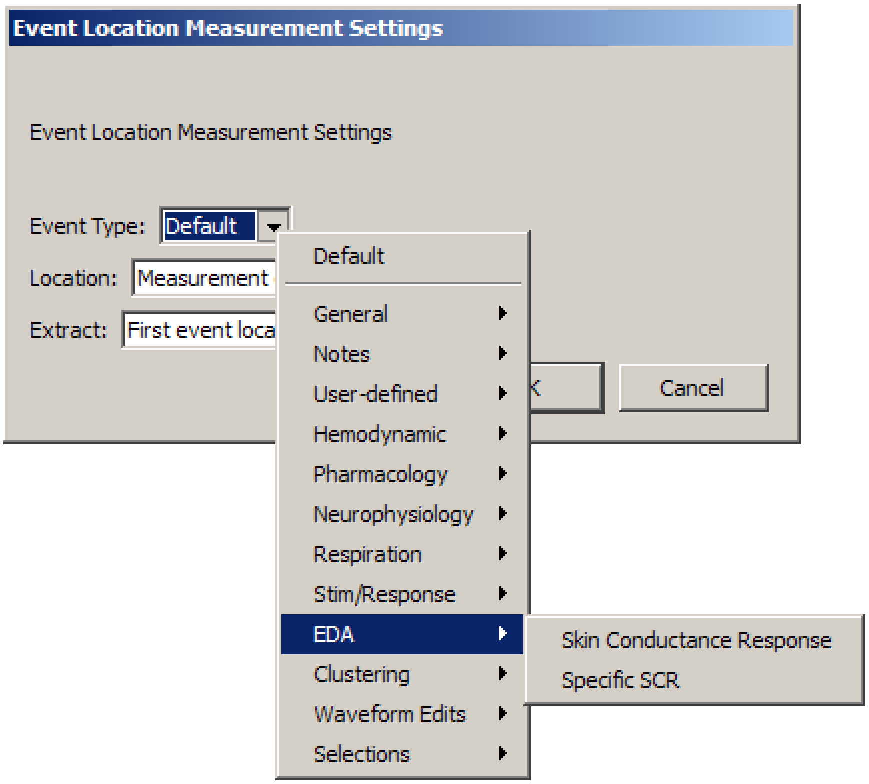
Events for SCRs will always occur as described above, in the order shown.

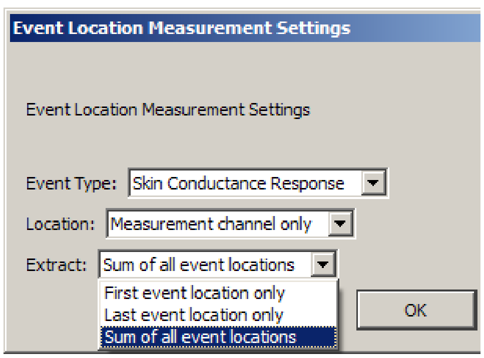
EDA Measurements

To perform Event-related EDA analysis, choose Analysis > Electrodermal Activity > Event-related EDA Analysis.

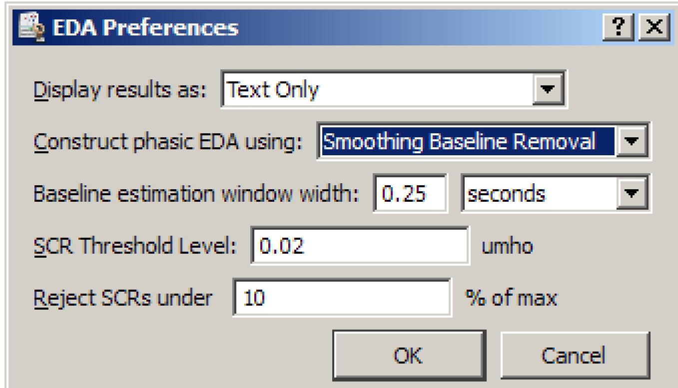
To take measurements from the skin conductance response analysis, set measurements for event count, event location and/or event frequency. Set the source channel as the Tonic EDA channel and select the location (measurement channel only, global events only, anywhere) and measurement parameters as desired. This method is useful for spontaneously occurring skin conductance response analyses. Take measurements over a manually selected area or use Find Cycle analysis to take automatically measurements over a user-defined time interval.




Event Location Measurement Settings
Event Location Measurement Settings
Event Type:
Default
Location:
Measurement
Extract:
First event loca
Cancel
Default
General
Notes
User-defined
Hemodynamic
Pharmacology
Neurophysiology
Respiration
Stim/Response
EDA
Clustering
Waveform Edits
Selections
Skin Conductance Response
Specific SCR

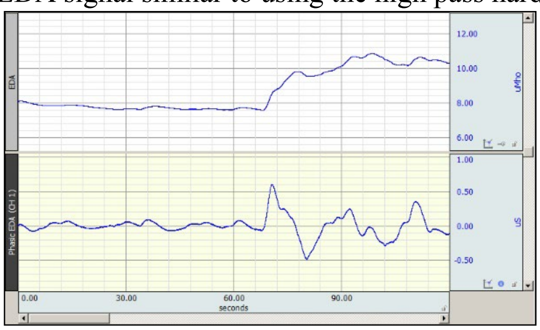

Event Location Measurement Settings
Event Location Measurement Settings
Event Type:
Skin Conductance Response
Location:
Measurement channel only
Extract:
Sum of all event locations
First event location only
Last event location only
Sum of all event locations
OK

EDA Preferences…

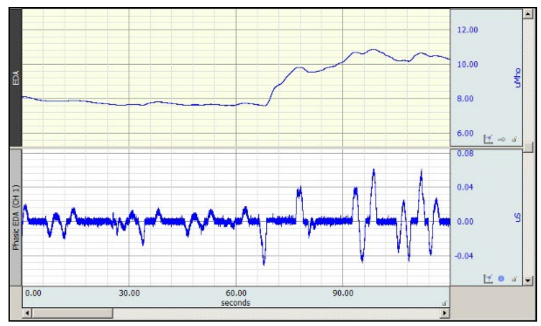


The following EDA Preferences can be configured and will be applied to all options in the analysis package:

- **Display results** as text, graph channels, or Excel
- **Construct Phasic EDA using** High pass Filtering or Smoothing Baseline Removal
  - High pass Filtering—High pass filtering constructs phasic EDA by applying a digital IIR high pass filter (f = 0.05 Hz, Q = 0.707) to the tonic EDA signal. This high pass filter essentially AC couples the tonic EDA signal similar to using the high pass hardware filter available on the GSR100C module.

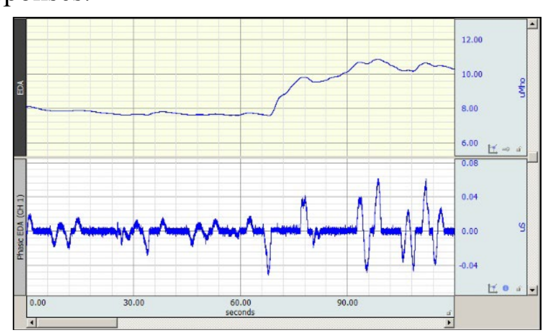


0.05 Hz High Pass Filter

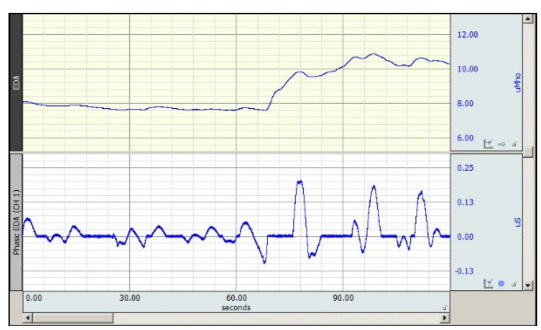


Smoothing Baseline Removal

  - Smoothing Baseline Removal—Smoothing baseline removal constructs phasic EDA by subtracting an estimate of the baseline conductance from the tonic EDA. Set the baseline estimation
- **Baseline estimation**: The estimate of the baseline is generated using median value smoothing. This is more computationally intensive than high pass filtering. Increasing the window will increase sensitivity and return more responses.



Baseline window set to 4 seconds

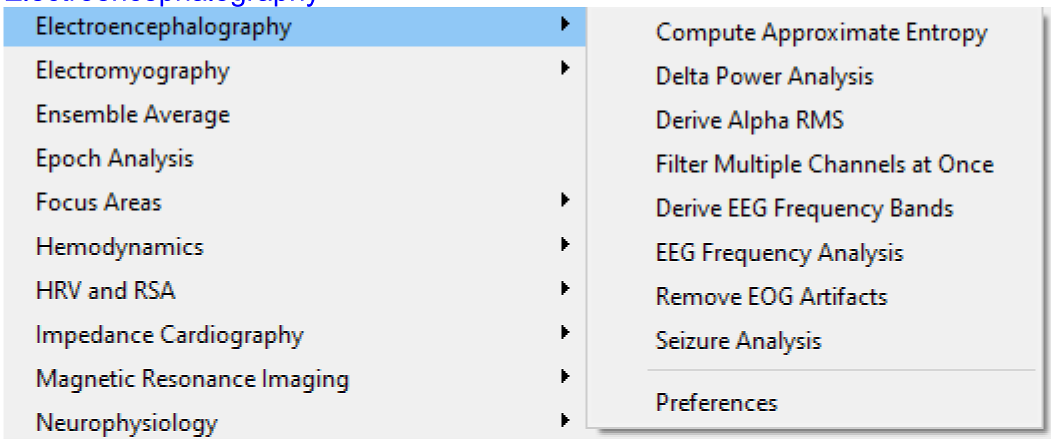


Baseline window set to 8 seconds

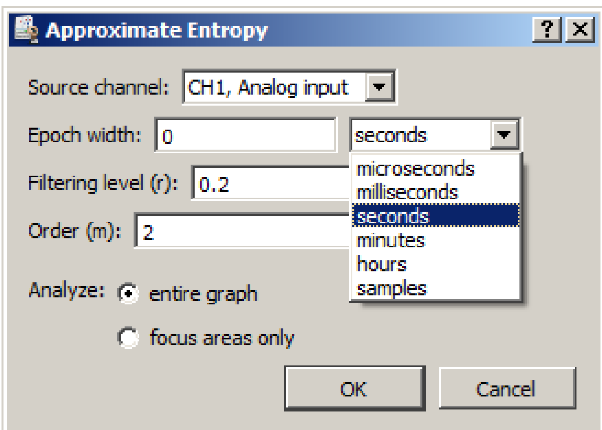
- **SCR detection parameters**: threshold detection level H and percentage P, see page 416.
  - The default values are H = 0.02 μmho, P = 10, where H is detection threshold and P is percentage
  - Setting H to 0 and P to 10% will approximate the SCR detection algorithm referenced in

    K. H. Kim, S. W. Bang and S. R. Kim, “Emotion recognition system using short-term monitoring of physiological signals,” Medical & Biological Engineering & Computing, vol. 42, pp. 419-427, 2004.
  - Setting P to 0% will retain all potential SCRs (none will be rejected in the second phase).

Electroencephalography



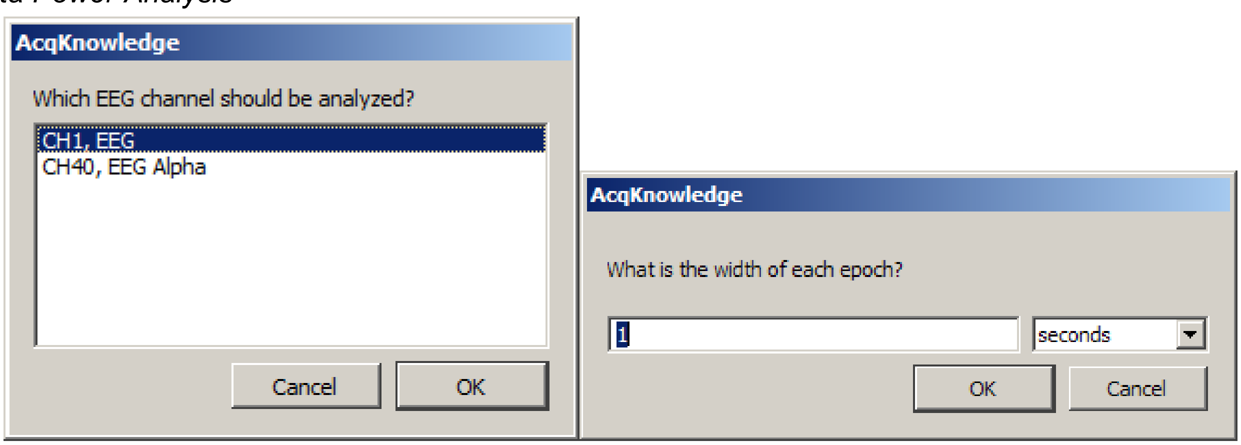
Compute Approximate Entropy



Approximate entropy is a statistical measure that attempts to quantify the predictability of a data sequence. A perfectly predictable data series (such as a pure sine wave) has approximate entropy of zero. Several studies are beginning to examine approximate entropy of EEG data and its relationship to external factors such as drugs and sleep states.

The Compute Approximate Entropy script divides an EEG signal into fixed-width epochs and computes the approximate entropy for each epoch. Derivation of the approximate entropy is a computationally intensive process and may take several minutes or hours to complete. To obtain only the sub-ranges of the EEG data, use the “focus areas only" option to restrict the approximate entropy computations to that data range only.

Delta Power Analysis

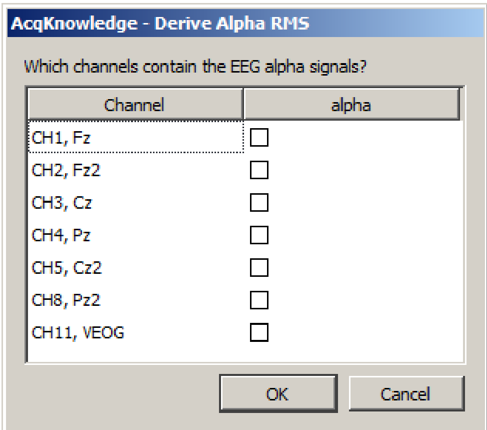


Delta power is the total power of the EEG signal that occurs within the delta frequency band as configured in the Preferences. Delta power has been examined in a number of various EEG studies as an indicator of sleep/wakefulness and other conditions. By examining changes in the delta power, it may be possible to correlate delta power with effects of external factors.

The Delta Power Analysis script divides an EEG channel into fixed-width epochs. For each epoch, the power spectral density is computed and the total power within the delta frequency band is derived from the PSD. This delta power value is then placed into the graph or into the journal as specified by the output preferences.

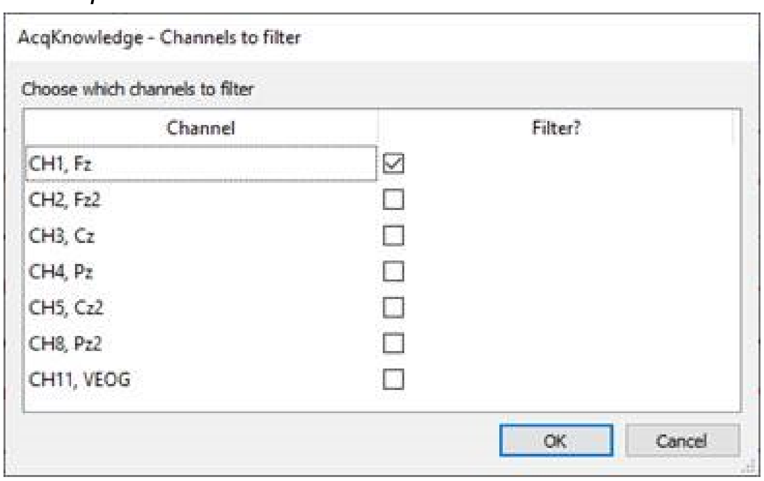
Delta power can be measured from either a filtered or unfiltered EEG channel.

Derive Alpha RMS



The Derive Alpha RMS script constructs an integrated RMS waveform from an alpha EEG signal (the alpha EEG signal can be constructed with Derive EEG Frequency Bands). Alpha RMS is the windowed root mean square value of the signal using a window width of 0.25 seconds. Individual channels are selectable for analysis.

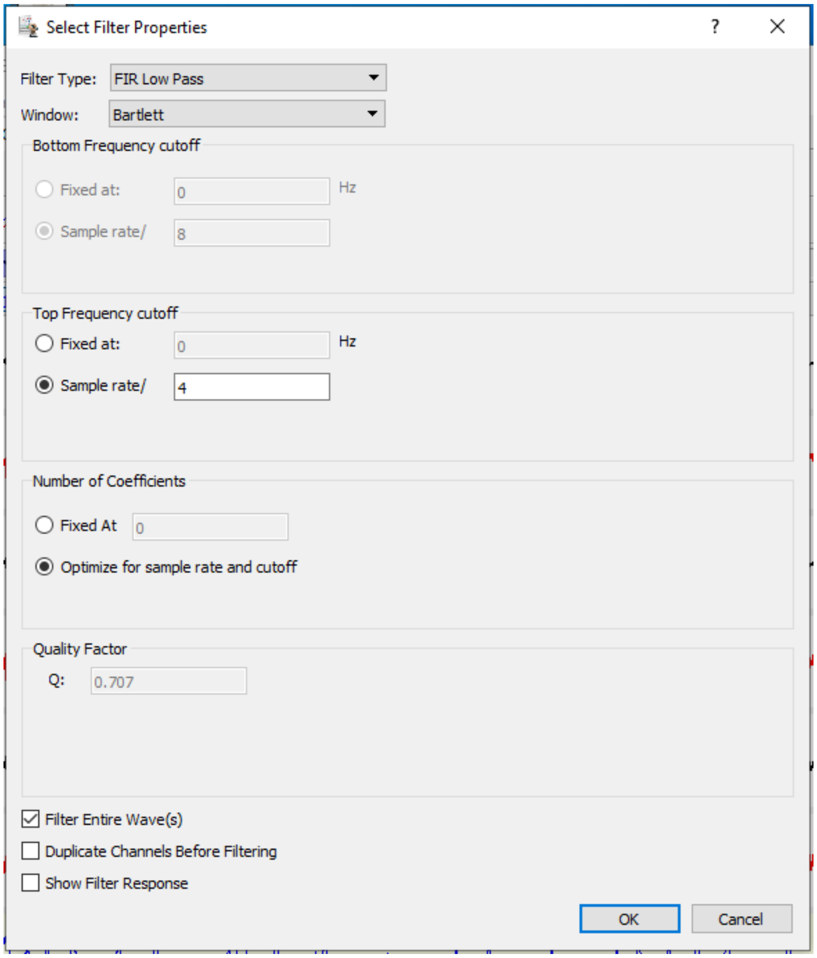
Filter Multiple Channels at Once



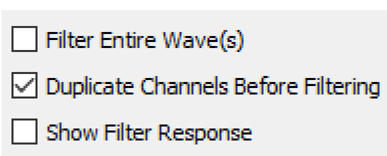
Filter Multiple Channels at Once allows FIR, IIR, or Comb Band Stop filters to be selectively applied to a single channel or multiple channels at the same time. Filters can be applied to any signal type and are particularly useful for EEG analysis. After selecting desired channels, clicking **OK** will open a new dialog box to specify how channel data should be filtered.

These filtering options shown below are very similar to options found in Transform > Digital Filters, except they are only applied to the channels selected on the previous screen. Different frequency parameters and default Q settings are enabled in this dialog box when specific filter types are chosen from the drop down menu at the top of this window.

If the Comb Band Stop filter is selected from the Filter Type dropdown, unlike in Transform > Digital Filters, the software will not permit a range of frequencies; the default option is all up to Nyquist.



The three checkboxes at the bottom of the above image are a new addition to this dialog box as well.

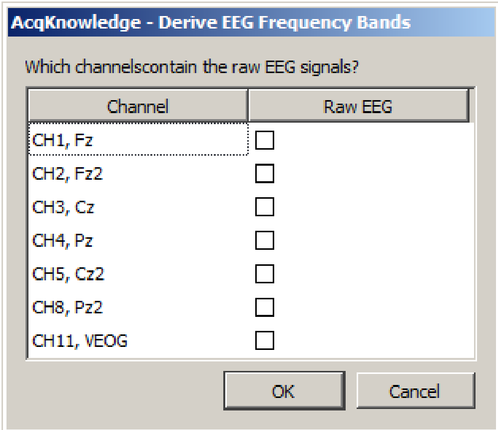


Filter Entire Wave(s) is equivalent to checking the Transform Entire Wave checkbox used by Transform > Digital Filters.

Duplicate Channels Before Filtering will make a copy of the channel data being recorded; and apply selected filter options to that copy to preserve the original input data and selected channels.

Show Filter Response is only available with certain filters, and will open a new graph window to plot how the filter is attenuating energy as a function of frequency. This graph only tracks one copy of the filter response, since the filter is applied to all channels of selected data.

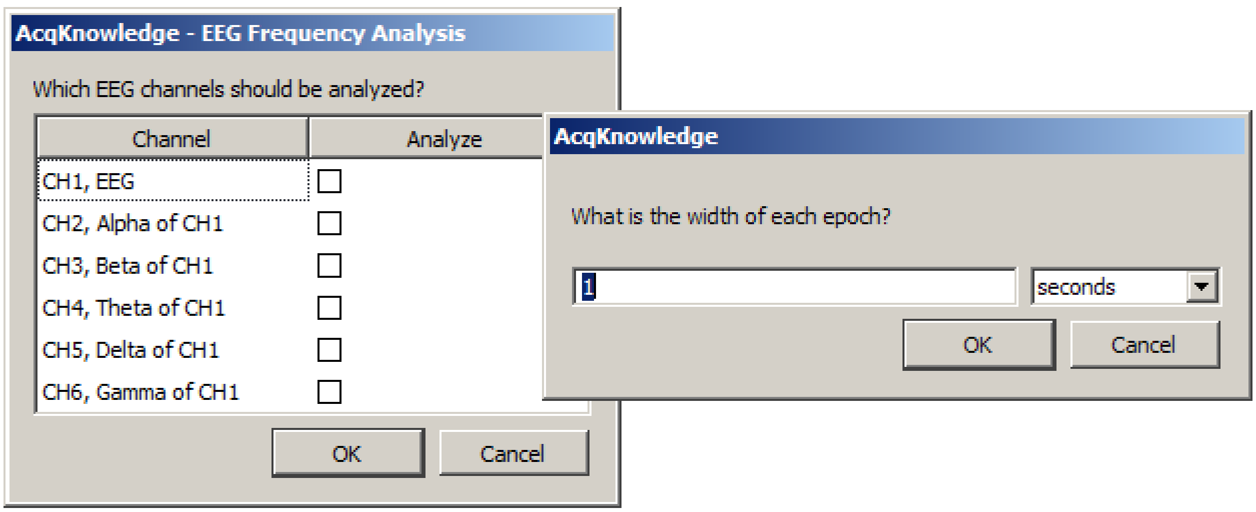
Derive EEG Frequency Bands



The Derive EEG Frequency Bands script applies filtering to an unfiltered EEG lead signal to generate the following five standard EEG bands: Alpha, Beta, Theta, Delta, and Gamma.

The frequencies for each band are specified n the analysis package preferences. Filtering is performed using the digital filter, IIR Band Pass Low+High.

EEG Frequency Analysis



EEG may be characterized in terms of frequency and the power within specific frequency bands. The EEG Frequency Analysis script performs various feature extractions from EEG signals using FFT and other techniques to examine the power within the EEG signals. This analysis may be performed for multiple EEG leads simultaneously, allowing for either analysis of multiple leads or analysis of multiple EEG alpha, beta, theta, or delta bands from a single raw lead.

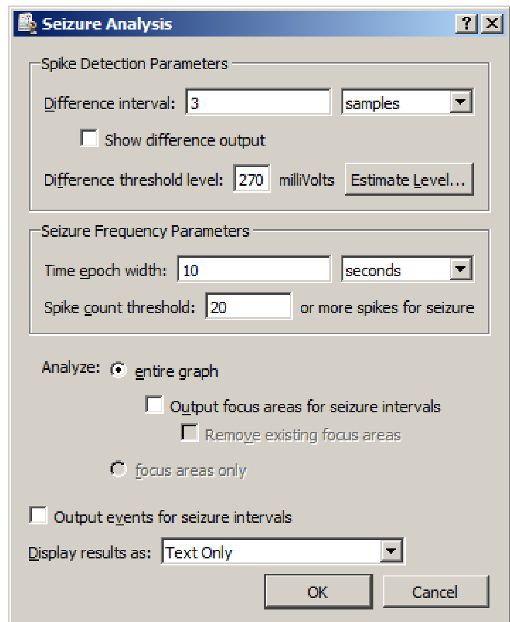
The EEG Frequency Analysis script divides the EEG signals into fixed-width time epochs. For each individual time epoch, Acq*Knowledge*'s Power Spectral Density function is used to estimate the power spectrum of that epoch using a Welch periodogram estimation method. From this PSD the following measures are extracted for each epoch:

Name	*Abbrev.*	*Description*	*Units*
Mean Power	MeanP	The average power of the power spectrum within the epoch. (Units Note: V will be replaced with the voltage units in which the EEG was recorded)	$\frac{V^2}{Hz}$
Median Frequency	MedianF	Frequency at which 50% of the total power within the epoch is reached.	Hz
Mean Frequency	MeanF	Frequency at which the average power within the epoch is reached.	Hz

Name	*Abbrev.*	*Description*	*Units*
Spectral Edge	Spectral Edge	Frequency below which a user-specified percentage of the total power within the epoch is reached. This percentage can be set using "Preferences" and defaults to 90%.	Hz
Peak Frequency	PeakF	Frequency at which the maximum power occurs during the epoch.	Hz

Watch the [Acq*Knowledge* EEG Frequency Analysis video tutorial] for a detailed demonstration of this feature.

Seizure Analysis



Seizure Analysis is designed to enhance functionality of the EPOCH® wireless EEG system commonly used for acquiring small animal signals. Long term EEG recording is often used for studying seizure activity. Unlike human EEG, EEG for non-anesthetized animals may contain a variety of superimposed artifacts resulting from random motion and scratching. Seizure Analysis offers a reliable means of differentiating actual seizure activity from other types of motion artifact.

The Seizure Analysis tool consists of a configurable difference interval, slope threshold, time epoch width and spike detector. Using the default values found in the figure above, seizure activity is defined as follows:

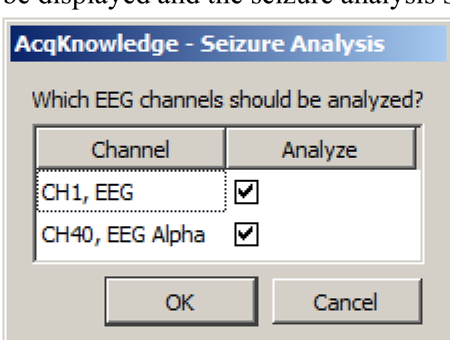
1. Perform a difference on the EEG data with a 16 ms window width. At this window width, normal EEG spikes in the signal have a roughly logarithmic distribution.
2. Identify maximum threshold for normal spike distribution, chosen at 270 microvolts on the difference signal.
3. Perform peak detection on the difference signal with the fixed chosen threshold. Spikes above this threshold are considered candidate epileptic spikes and marked with a check mark on the waveform.

After spikes are located seizures will be located using a spike frequency method:

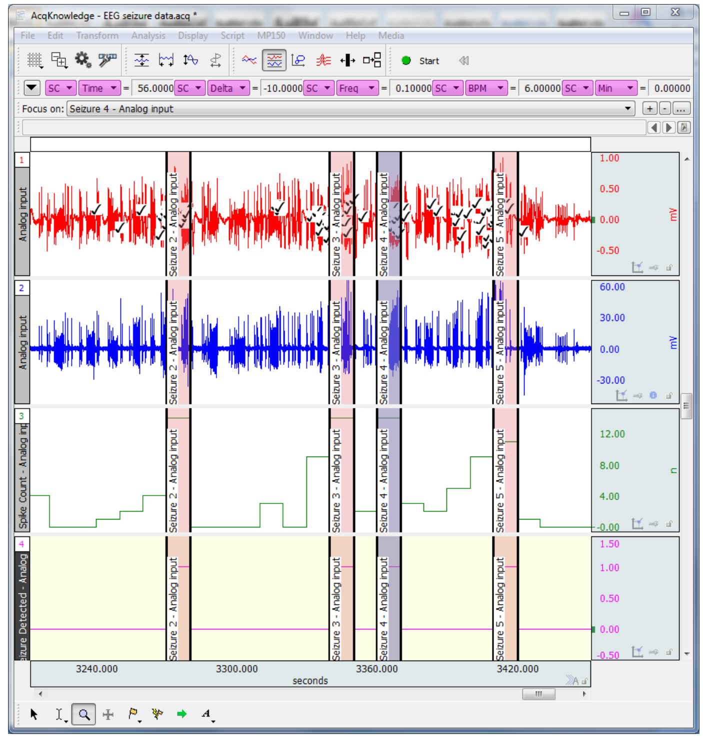
1. Split data up into 10 second periods.
2. Count the number of spikes in each period. If more than 20 spikes occur within the period, the period is marked as a seizure.

Using Seizure Analysis

1. Analysis > Electroencephalography > Seizure Analysis and set the EEG data results preferences if necessary. (See page 427)
2. If more than one EEG channel is to be analyzed, as is often the case with the EPOCH® EEG system, the following selection screen will appear. If there is only one channel of EEG data in the file, this screen will not be displayed and the seizure analysis screen depicted above will appear.



3. Set the desired parameters for seizure detection and click OK.



If the EEG Analysis Preferences are set to display results as graph channels, two new channels of data will be created. The first channel shows a tachogram of the number of epileptic spikes identified within the Time epoch. The second channel displays a square wave that runs from 0 to 1; a 1 indicates that an epoch matches the seizure threshold. In the default setting, 20 seizure spikes have to be identified within a 10 second epoch for the epoch to be classified as containing a seizure.

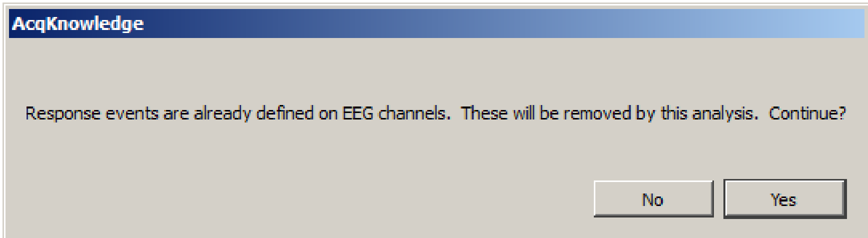
If the “Output focus areas for seizures” option is checked, a focus area is created for each epoch that contains a seizure. This option is useful for running additional analysis routines and taking measurements over just the areas of data that contain seizures.

Seizure Analysis Parameters

CONTROL	DESCRIPTION
Difference Interval	Alters the time window used to compute the difference for slope detection. Default value is 3 samples.
Show difference output	The difference interval used for spike detection will be displayed in the graph.
Difference threshold level	Adjusts the fixed threshold level used to locate peaks in the difference signal corresponding to EEG spikes associated with seizures. Default value is 270 microvolts.
Time epoch width	Adjusts the time width used for seizure detection. Default value is 10 seconds.
Spike count threshold	Sets the number of spikes that must be present in the specified time window (epoch) in order to be indentified as seizure activity.
Analyze: entire graph	The entire graph is scrutinized for potential seizure activity.
Output focus areas for seizures	In addition to normal output, the analysis will create focus areas in the graph at each identified seizure period.
Analyze: focus areas only	Only focus areas will be scrutinized for potential seizure activity.
Output events for seizure intervals	A pair of “waveform onset” and “waveform end” events will be created at boundaries of identified seizure areas.

Spike Event Output

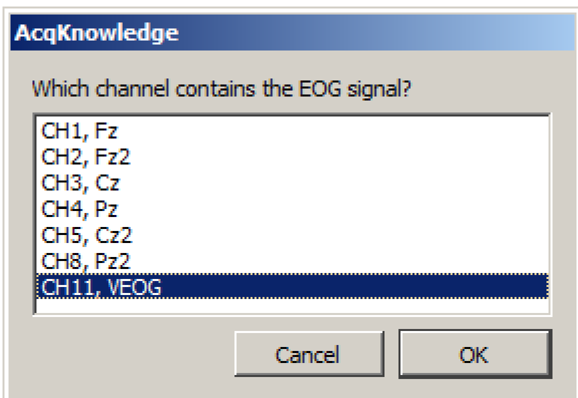
For all types of seizure analysis output, this analysis will leave Stim-Response events on the EEG channel wherever spikes are detected according to the analysis parameters. These events allow for visual verification of spike detector functionality. If any Response events are found on the EEG channels at the start of the analysis, then following dialog will be presented:

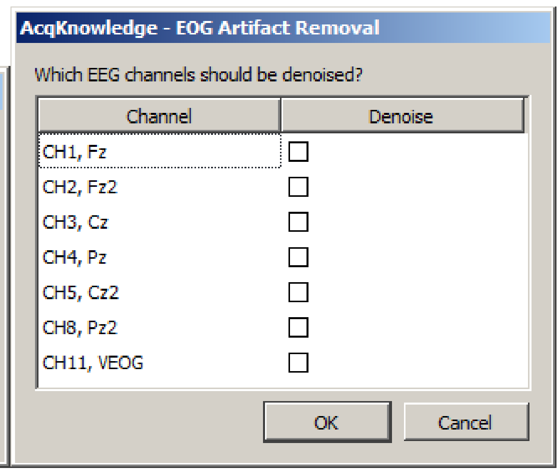


Clicking "Yes" removes the existing events. Only Response type events will be removed from the EEG channels; other types of events, or events on other channels will not be affected.

Watch the Acq*Knowledge* Seizure Analysis video tutorial for a detailed demonstration of this feature.

Remove EOG Artifacts





Some EEG recordings involve subjects performing various visual tasks such as reading or watching video. Under these conditions, EEG may be susceptible to interference from the much stronger EOG signal arising from eye motion, particularly if EEG is recorded from near the front of the skull. Remove EOG Artifacts helps remove EOG interference from the EEG signals, recovering the EEG data for use in further analysis.

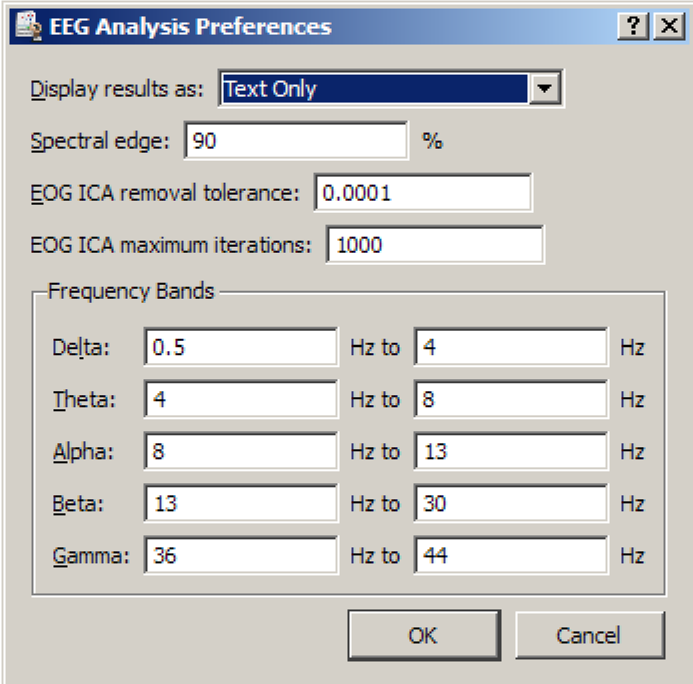
EOG removal is performed using a blind signal separation technique known as Independent Component Analysis. ICA is used to split up statistically independent signals that have been mixed together during recording. Since EOG is independent of EEG, ICA can be used to remove it.

In order to use Remove EOG Artifacts, a distinct EOG signal must be acquired in addition to the EEG signals. The EOG signal is required to identify the components correlated to eye motion.

EOG artifact removal functions better when it is performed on multiple EEG leads simultaneously. Better results may be obtained by including EEG leads that do not exhibit EOG interference since the increased number of leads allows for more fine-grained signal separation. Good results can be seen with as few as two EEG leads and one EOG lead. While this technique can be performed with a single EEG lead, the results will not be as dramatic.

Note ICA is a non-deterministic technique, so it may not be possible to automatically separate the signals for every EOG/EEG data set. For ICA to be successful, it may be necessary to fine-tune the parameters of the ICA search procedure to match the data, use a different electrode configuration, or use fewer or more leads.

Preferences…



Adjust the EOG ICA Tolerance level and the EOG ICA maximum number of iterations by accessing Transform > Specialized Analysis > Electroencephalography > Preferences. EOG ICA Tolerance is used as the termination condition of ICA signal separation. The EOG ICA maximum number of iterations is another termination condition of ICA signal separation and represents the maximum point at which the search is aborted. For more information on these settings, see the documentation for the Independent Component Analysis transformation.

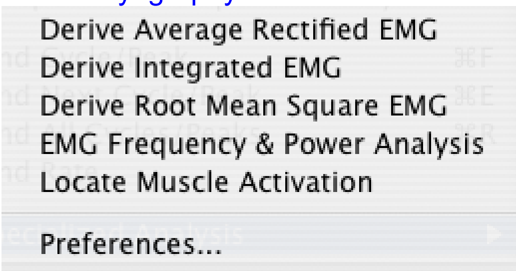
Because ICA is a statistical technique, any filtered data produced with Remove EOG Artifacts should be carefully verified against other information to ensure that the approximations produced via ICA represent information that is truly correlated to the expected ECG.

The spectral edge percentage indicates the cutoff percentage of the total power at which spectral edges will be placed. The default value is 90%.

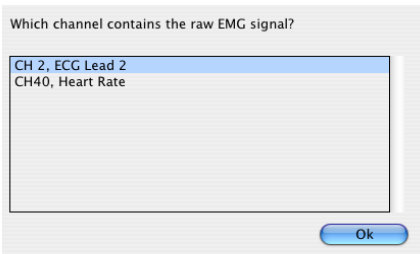
The frequency bands of alpha, beta, delta, and theta may be modified to match different analysis protocols. The default frequency ranges are:

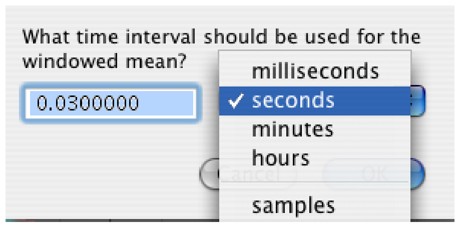
- Alpha—8 Hz-13 Hz
- Beta—13 Hz-30 Hz
- Delta—0.5 Hz-4 Hz
- Theta—4 Hz-8 Hz
- Gamma—36 Hz-44 Hz

Electromyography



Derive Average Rectified EMG



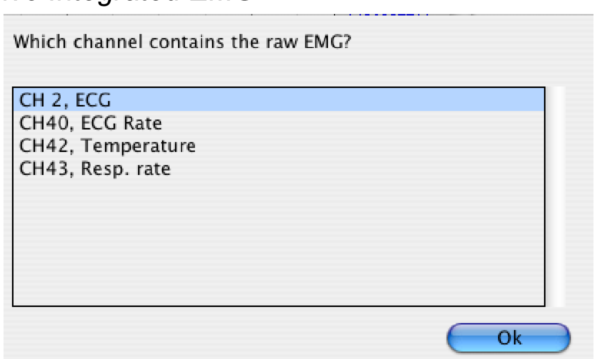


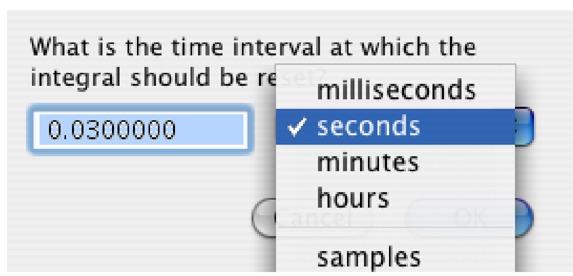
Average rectified value (ARV) is defined as a time windowed mean of the absolute value of the signal. ARV is one of the various processing methods used to construct derived signals from raw EMG data that can be useful for further analysis.

To perform ARV, a time window must be specified for the sliding mean. The default time window setting is 30 milliseconds, but this value can be adjusted depending on the desired amount of smoothing effects. It is advisable to closely examine results for time windows larger than 30 milliseconds as it is possible for delay to be introduced into the result.

The ARV is computed using the Integrate transformation with a Rectified Average over Samples configuration.

Derive Integrated EMG

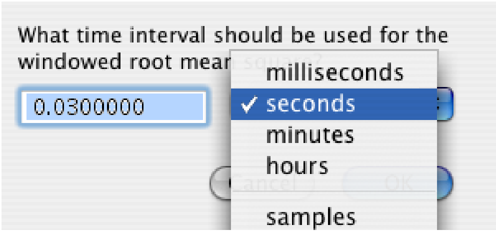




Integrated EMG (iEMG) is defined as the area under the curve of the rectified EMG signal, that is, the mathematical integral of the absolute value of the raw EMG signal. When the absolute value of the signal is taken, noise will make the mathematical integral have a constant increase. Integrated EMG splits up the signal into fixed-width timeslices and resets the integral at the start of each timeslice. To derive iEMG, the width of this timeslice must be specified. Similar to ARV, timeslices longer than 30 milliseconds may introduce delay into the result.

The integrated rectified EMG signal will appear like a “sawtooth” style wave. In addition to the true iEMG, this script will output a second waveform whose value is the maximum value of the iEMG signal in each timeslice. This Maximum iEMG is easier to interpret visually and approximates the envelope of the iEMG signal.

Derive Root Mean Square EMG



Root Mean Square EMG (RMS EMG) is defined as the time windowed RMS value of the raw EMG. RMS is one of a number of methods used to produce waveforms that are more easily analyzable than the noisy raw EMG.

To construct the windowed RMS signal, a time window must be specified for the sliding mean. The default time window setting is 30 milliseconds, but this value can be adjusted depending on the desired amount of smoothing effects in the RMS EMG. It is advisable to closely examine results for time windows larger than 30 milliseconds as it is possible for delay to be introduced into the result.

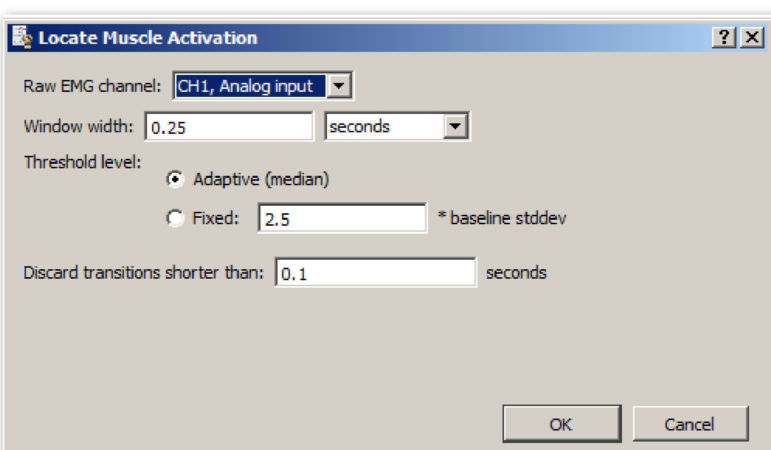
RMS EMG is computed using the Integrate transformation in a Root Mean Square Average over Samples configuration.

EMG Frequency and Power Analysis

Several frequency domain techniques may be used for data reduction of EMG signals. The EMG Frequency & Power Analysis script extracts several measures derived from the power spectrum of an EMG signal. The EMG signal is split up into a fixed number of time periods; within each window, the power spectrum is computed using the Power Spectral Density transformation. For each time period, the following measures are extracted:

Name	*Abbrev.*	*Description*	*Units*
Median Frequency	MedianF	Frequency at which 50% of the total power within the epoch is reached.	Hz
Mean Frequency	MeanF	Frequency at which the average power within the epoch is reached.	Hz
Peak Frequency	PeakF	Frequency at which the maximum power occurs during the epoch.	Hz
Mean Power	MeanP	The average power of the power spectrum within the epoch. (Units Note: V will be replaced with the voltage units in which the EMG was recorded)	$\frac{V^2}{Hz}$
Total Power	TotalP	The sum of the power at all frequencies of the power spectrum within the epoch. (Units Note: V will be replaced with the voltage units in which the EMG was recorded)	$\frac{V^2}{Hz}$

Locate Muscle Activation



When performing gait analysis, exercise physiology, or other research, identification of periods where the muscle is active can allow for correlation of external factors to muscle activity.

Locate Muscle Activation attempts to identify various periods of muscle activity using statistical methods. The transformation requires a raw, unfiltered surface EMG channel. It takes a window width of *w* seconds, by default 0.25 seconds. It is important that the first *w* seconds of the EMG signal be "background noise", that is, that the muscle being examined is relaxed for the first quarter second. This quarter-second period is used to estimate baseline parameters that affect the entire process.

Note The LMA analysis expects EMG to be an AC-coupled signal centered around zero without baseline offset. If the signal is centered below zero, then no muscle activations are located. The Remove Mean function from the Analysis menu can be used to center the signal around zero for most waveforms.

This transformation implements a variation of the Hodges and Bui detection algorithm as described in:

P. W. Hodges and B. H. Bui, "A comparison of computer-based methods for determination of onset of muscle contraction using electromyography," *Electroenceph. Clin. Neurophysiol.*, vol. 101, pp. 511-519, 1996.

The variation implemented is a threshold-based algorithm roughly consisting of the following steps:

1. Determine mean value μ_0 and resting standard deviation σ_0 of the first *w* seconds of the signal.
2. Construct a filtered ARV EMG signal, *z*. The window width *w* is used when constructing the ARV signal.
3. Extract the variance of the signal with respect to the noise with the formula
   $$g = \frac{z - \mu_0}{\sigma_0}$$
4. Using a threshold *h*, determine when the signal *g* lies below and above the threshold. Portions of time above the threshold are periods of muscle activity.
5. Discard any transitions across the threshold if they are shorter in duration than a user-specified time, *t*.

There are two methods of specifying the threshold *h*. An adaptive method examines the signal *g* and chooses the threshold to be the median of *g* over the entire waveform. Alternatively, the threshold can be specified manually. Using a manual threshold can be useful in adjusting the detection to better match specific EMG data. A suggested threshold is 2.5. By lowering the threshold, a larger quantity of data will be considered as muscle activity. By raising the threshold, a larger quantity of data will be considered to be noise.

The transition discard time *t* is specified in seconds. The default value of *t* is 0.1 seconds. If muscle activity is being inaccurately identified as inactivity for short periods within active times, try increasing the value of *t*. Do not set *t* to be greater than the smaller of either the shortest duration of a single muscle contraction or the shortest rest interval between consecutive muscle contractions.

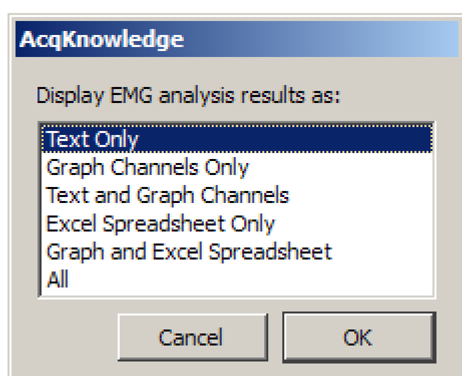
There are two outputs from the Locate Muscle Activation script.

- A new waveform, Muscle Active, will be added to the graph. The value of this wave will be zero when the muscle is at rest and one when the muscle is active. This wave can be used to quickly visually examine the record for periods of activity.
- Events are also generated on the raw EMG waveform. A Waveform Onset event is placed at each transition from inactive to active, and a corresponding Waveform End event is placed at each active-to-inactive transition. These events can be used in conjunction with the Cycle Detector to perform further data reduction based on muscle activity.

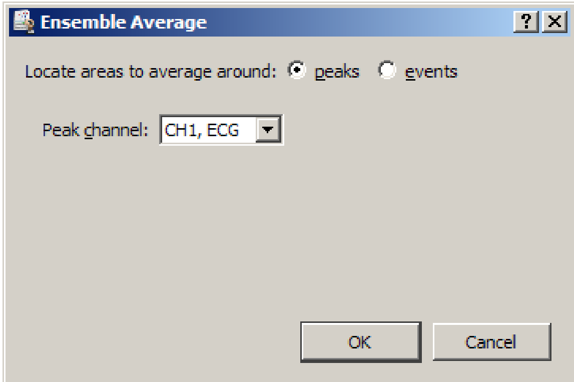
The detection of muscle activation onset and end from surface electrode EMG is an imprecise process. The output of this location should be visually examined for misidentification of activation periods that are too short, too long, overlapping, or missed.

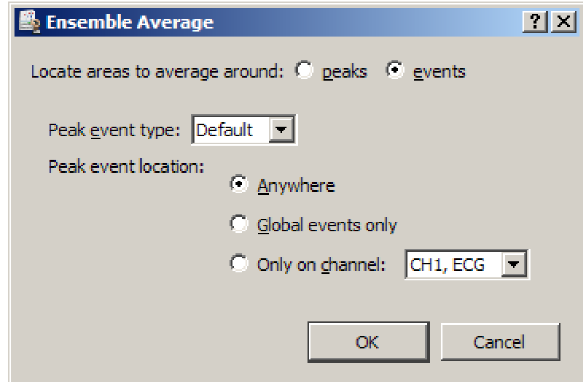
Preferences…

The Preferences allow the type of output to be chosen for displaying results: text, graph channels, or Excel.



Ensemble Average

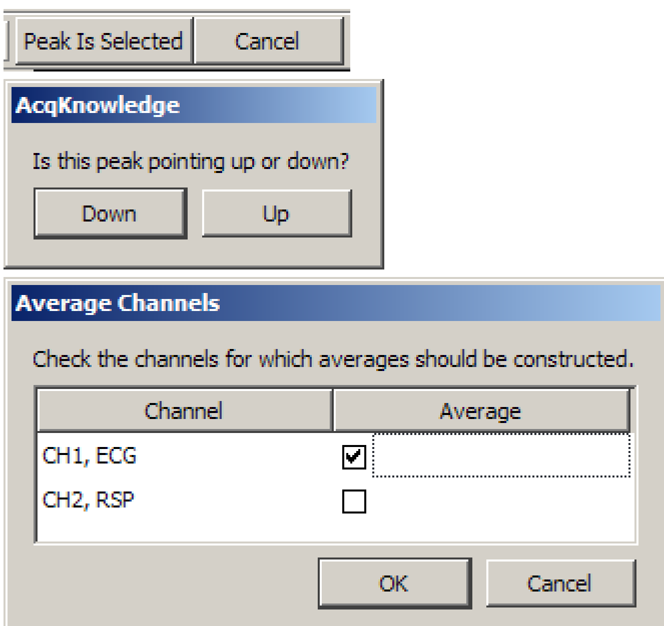


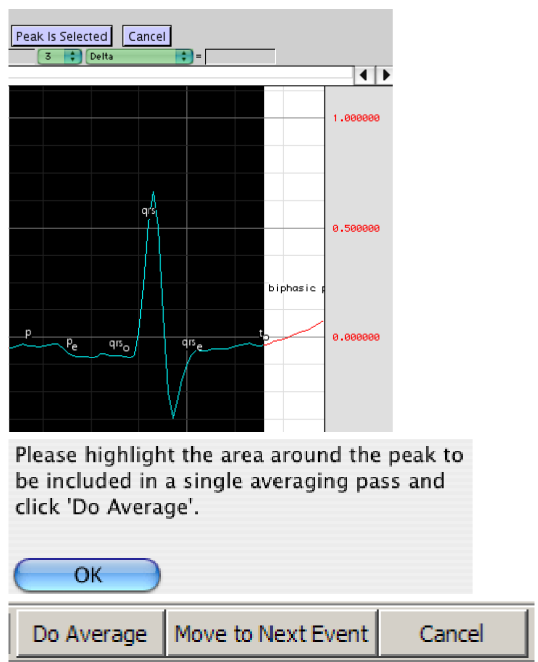


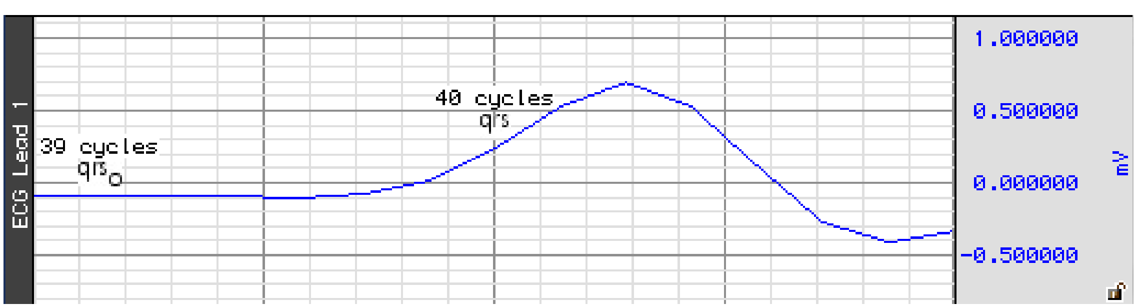
Ensemble Average assists in performing offline averaging. Offline averaging produces an average waveform from a number of cycles, also known as an *ensemble average*. Averages of multiple channels can be extracted simultaneously and be consolidated into a single graph window showing the results. Offline averaging is also available as a function within the Find Cycle feature.

This option provides two methods for locating individual members of the ensemble.

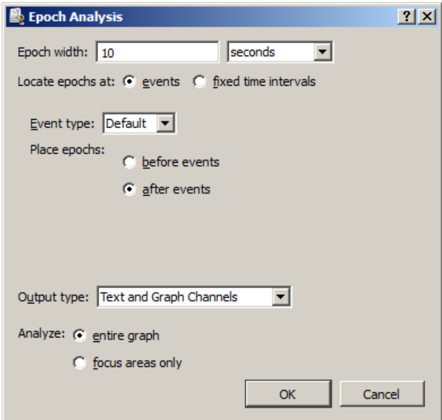
- **Peaks**: Data-driven peak detection with positive or negative peaks in the data. This method automatically derives appropriate threshold levels from a user-selected peak and is useful for constructing averages keyed to periodic signals with strong spikes, such as ECG.
- **Events:** Place members of the ensemble surrounding events in the waveform. Events must be previously defined by the user, either manually or through another automated process. This method is useful for constructing averages keyed to any types of events in a graph.

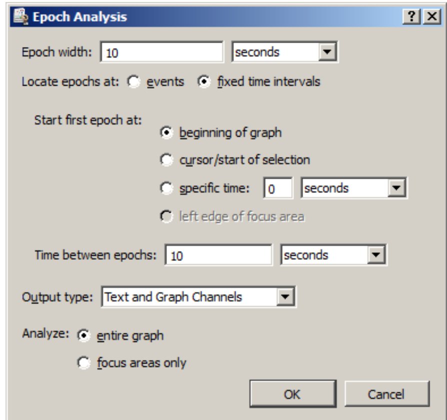




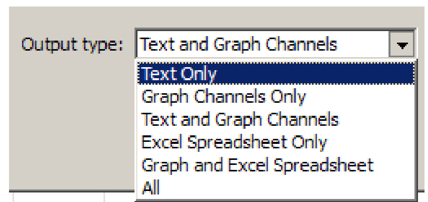


Epoch Analysis



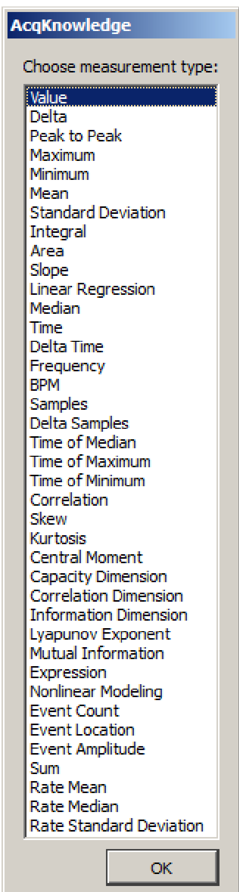


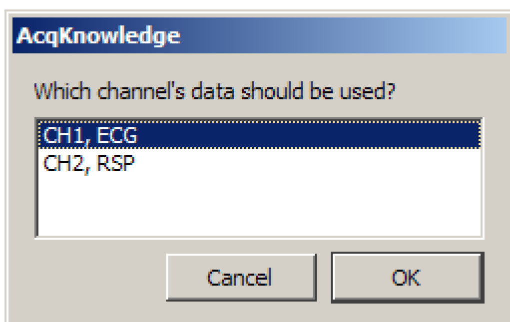
Extracts basic measures from fixed-width time segments of data. A fixed-width time segment of data is known as an *epoch*. The location of these fixed-width intervals can either be keyed off of locations of events in the graph or tied to regular time intervals (e.g., occurring at a constant frequency). All the standard Acq*Knowledge* measurements can be extracted on an epoch-by-epoch basis with the exception of Calculate.

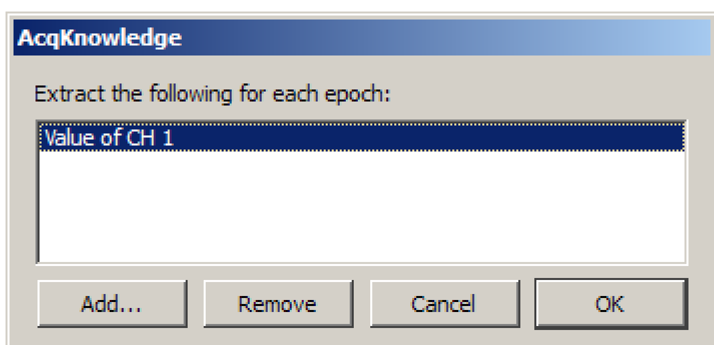


Epoch-by-epoch measurement results can be viewed either as channels of data in the graph, a textual summary, or on an Excel spreadsheet; textual summaries include a final row with an overall average of each extracted measurement.

Times output by Epoch Analysis are always expressed in seconds; all other units correspond to the current preferred measurement unit settings accessible under Display > Preferences.







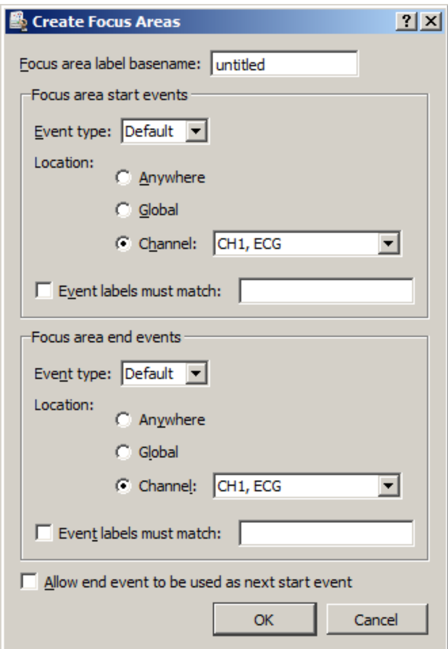
NOTE: The Expression measurement function MMT() is available in Epoch Analysis, but the results may not be reliable.

Focus Areas between Events and Segments

In addition to the standard focus area functionalities discussed on page 96, focus areas can also be used as an analysis tool to define areas of interest between certain event types or between appended segments.

Define Between Events

The parameters for defining focus areas using this method are highly customizable, and can be based upon specific event types or titles as well as various event locations in the graph. The following table explains the various focus area start and end event options.



Focus area label basename:

Use to assign a title for the focus areas. Successive focus areas will use the same title with the addition of incrementing numbers.

Event type:

Use to select the type of event for defining the focus area.

Location:

- **Anywhere**—all channel and global events are included in the event matching criteria.
- **Global**—when selected; only global events are included.
- **Channel**—when selected; only events in an individual channel are included. Select the desired channel from the combo box menu.

Event labels must match:

When checked, only events with labels matching the edit field text will be defined. When unchecked, all events of the selected type are matched, regardless of label.

Define for Appended Segments

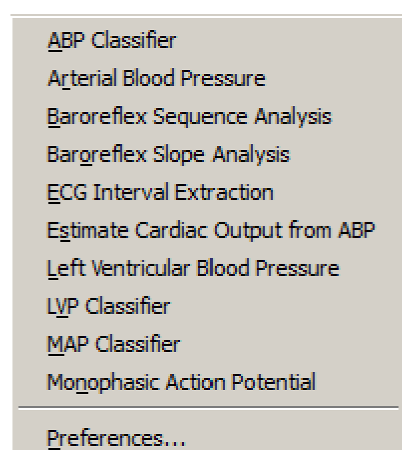
This method simply defines the time range between appended segments as focus areas. No configurable options exist for this feature within the Analysis menu.

Hemodynamic Analysis

Hemodynamics is the study of blood and circulation related data. This analysis package concerns itself with interpretation of ECG, blood pressure, and monophasic action potential data; ECG signals must be sampled at 5 kHz or below to be analyzed with this package.

IMPORTANT: These routines are designed specifically for human subjects and may not function well, or at all, on animal subjects, particularly small animals.

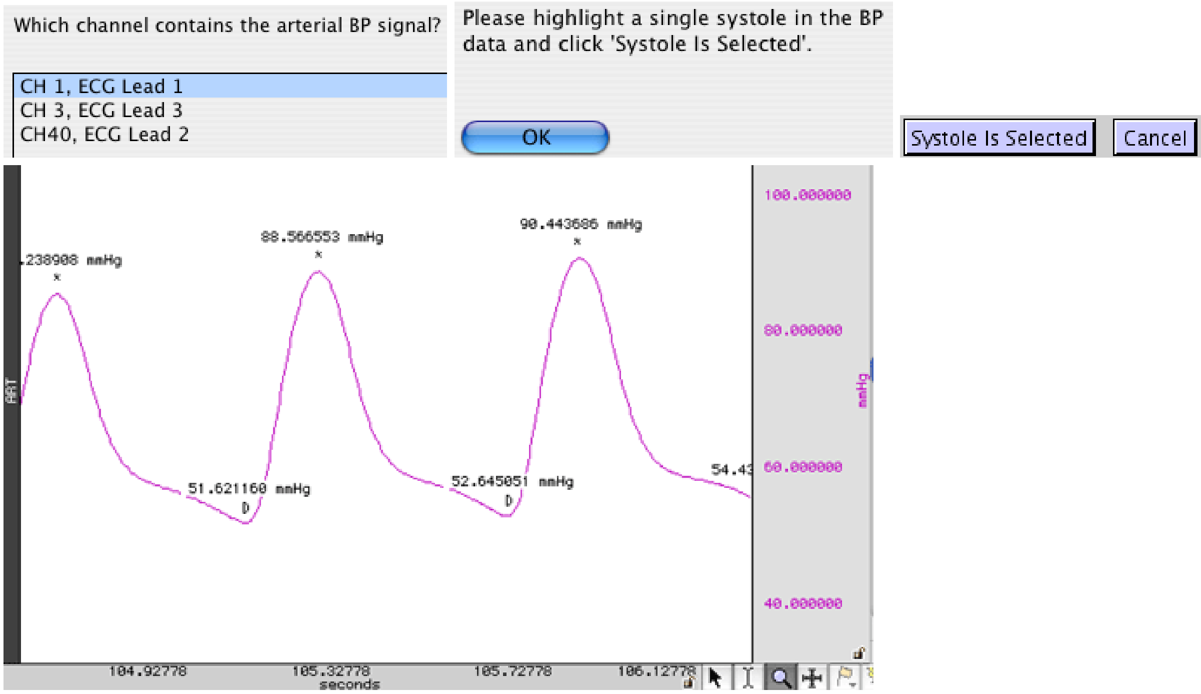
The Hemodynamic analysis package consists of:



a) ABP Classifier
b) Arterial Blood Pressure
c) Baroreflex Sequence Analysis (licensed feature, see page 585)
d) Baroreflex Slope Analysis (licensed feature, see page 585)
e) ECG Interval Extraction
f) Estimate Cardiac Output from ABP
g) Left Ventricular Blood Pressure
h) LVP Classifier
i) MAP Classifier
j) Monophasic Action Potential
k) Preferences

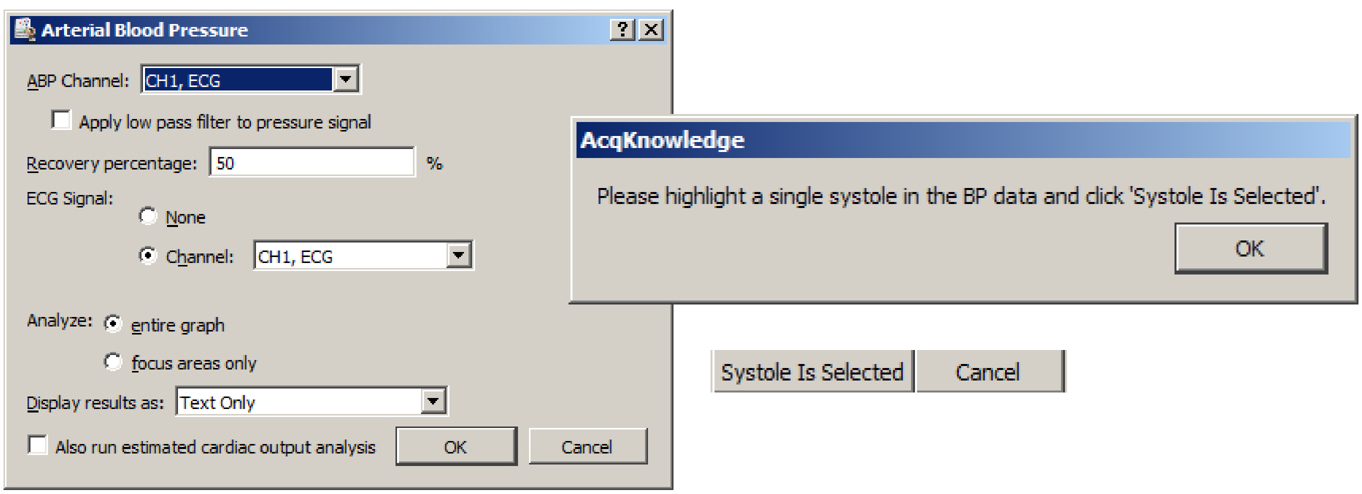
The time units reported by all of these transformations are in seconds unless otherwise noted.

ABP Classifier



Places systolic and diastolic events at appropriate locations on a continuous arterial blood pressure signal recording using either invasive means or a continuous noninvasive pressure monitoring system. The ABP classifier functions directly on the pressure data and may fail for signals that exhibit strong noise characteristics or large baseline drifts. Pre-filtering the signal may improve classification accuracy.

Arterial Blood Pressure



Extracts various cycle-by-cycle measures from arterial blood pressure (ABP) and ECG signals. It can function on an individual ABP signal or, when used in conjunction with an ECG Lead II signal, extract additional Q relative measurements.

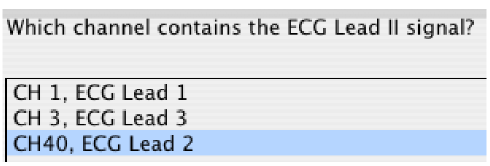
- If the ECG and ABP signals have not been classified when this analysis is performed, events for diastolic, systolic, and ECG boundaries will be inserted as necessary.
- If systolic, diastolic, and Q events are already present on the signals, however, they will be used.
- Enable the "Apply low pass filter to pressure signal" checkbox to reduce noise from the ABP signal. Using this filter applies a 60 Hz cutoff.
- Enable the "Also run estimated cardiac output analysis" to cascade cardiac output measures to the ABP result.

On a cycle-by-cycle basis, the arterial blood pressure analysis transformation extracts the following measures:

Name	Abbrev.	Description
Diastolic	-	Minimum pressure occurring during the cycle
Ejection time	ET	Time interval between the diastolic pressure and the minimum of dP/dt
Heart rate	HR	Heart rate in BPM as extracted from the diastolic-to-diastolic time interval for a given cycle
Maximum dP/dt	dP/dt max	Maximum amount of the change in the pressure during the cycle
Mean blood pressure	MBP	Mean blood pressure:
Minimum dP/dt	dP/dt min	Minimum amount of change in the pressure during the cycle
QA Interval	QA	Time interval between ECG Q wave and the diastolic pressure
Pulse Height	PH	Pulse height (a.k.a pulse pressure): Difference between max and min pressures within an individual cycle: P systolic − P diastolic
Recovery interval	%REC	Time required for the pressure signal to decrease by a user specified percentage of the pulse height
Systolic	-	Maximum pressure occurring during the cycle
Time to peak pressure	TTPK	Systolic upstroke time: Time interval between the diastolic and systolic pressures

When textual output is used, the average of all of these measures will be output as the last row of the table.

ECG Interval Extraction



Extracts cycle-by-cycle time and voltage measurements for various points and intervals between waveforms in the cycle on ECG Lead II signals. This interval extraction is based off of the waveform boundary locations with additional logic for defining explicit Q and S wave events. QRS peak events as output for boundary location are used as the R peak location.

- If the ECG signal was not classified before running the interval extraction analysis, it will be classified automatically.

This analysis extracts the following cycle-by-cycle measures:

Name	*Abbrev.*	*Description*
Corrected QT interval	QTC	QT time interval divided by the square root of the RR interval
Heart rate	HR	RR time interval expressed in BPM
P height	P-H	Amplitude at the peak of the P wave in a cycle
PRQ interval	PRQ	Time between the onset of the P wave to the Q wave
QRS width	QRS	Time between onset of the QRS complex and the end of the QRS complex. Equivalent to the time between onset of Q and end of S
QT interval	QT	Time between the beginning of the Q wave and the end of the T wave
R height	R-H	Amplitude of the R wave in a cycle
RR interval	RR-I	Time between consecutive R peaks in the waveform
ST interval	ST	Time between the S wave to the end of the T wave

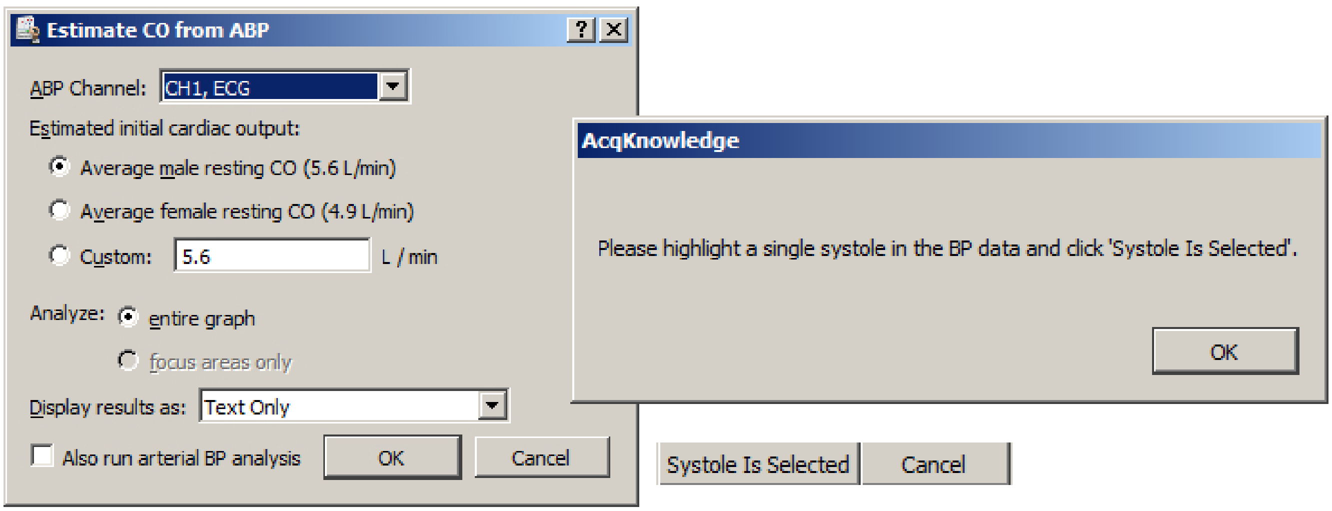
At the end of the text table output, the average of all of the cycles will be displayed. Additionally, both text and Excel output will indicate the number of cycles that did not have all three of the QRS, P, and T waves defined.

These are cycles where the classifier missed a boundary and are listed as "Bad cycles," which may happen due to noise or other artifacts in the signal.

Estimate Cardiac Output from ABP

This analysis algorithm, based on the universally recognized Liljestrand non-linear compliance formula, derives an estimate of cardiac output (CO) from an existing arterial blood pressure (ABP) signal. Using this method, it is possible to obtain an accurate measure of this data in a noninvasive fashion. For optimal results, the analysis must first be calibrated through the Estimate Cardiac Output from ABP setup dialog in which an initial resting cardiac output is selected. Adding smoothing or a low pass filter to the signal may further improve results.

1. Select the desired Hemodynamics > Preferences settings. (See page 440 for details.)
2. Hemodynamics > Estimate Cardiac Output from ABP.
3. Select the channel containing the blood pressure signal.
4. Choose an estimated calibration cardiac output level based upon typical male, female, or custom parameters.
5. Select the entire graph or desired focus areas for analysis and click OK.
6. Follow the "Highlight a systole in the BP data" prompt and click OK.
7. Click "Systole Is Selected" to begin the analysis.



If no systolic/diastolic events exist in the selected BP channel, they'll automatically be scored and added using the ABP classifier analysis script. Cardiac output results are presented in graph, text or spreadsheet format, depending on the desired extraction method set up in the Hemodynamics preferences.

Enable the "Also run arterial BP analysis" checkbox to cascade ABP measures to the cardiac output result.

For text and spreadsheet output, the following measures are extracted.

Name	Abbrev.	Units	Description
Start Time	--		The time at the beginning of each cycle.
Heart Rate	HR	BPM	Heart rate as extracted from blood pressure signal in BPM.
Estimated Cardiac Output	CO	L/m	Estimated cardiac output as computed using the estimated calibration constant and Liljestrand formula.
Estimated Stroke Volume	SV	L	CO/HR

For graph channel output, the following channels are added to the graph:

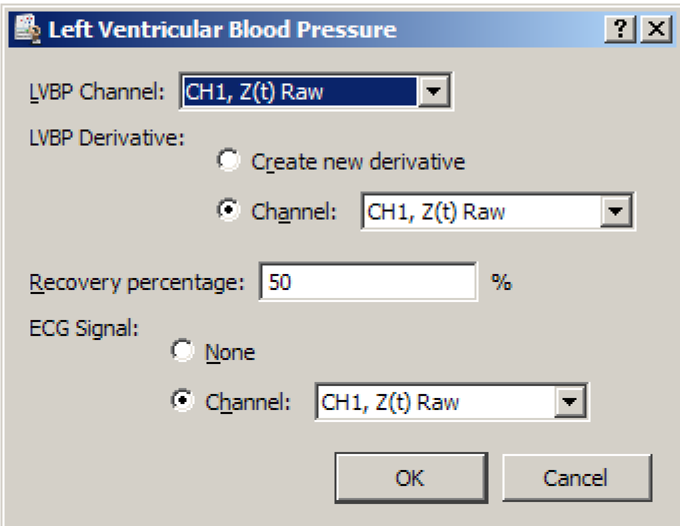
Channel Label	Units	Description
Heart Rate - ch	bpm	Heart rate as extracted from blood pressure signal in BPM (e.g., time duration of the cycle in seconds / 60).
Estimated CO - ch	L/m	Estimated cardiac output as computed using the estimated calibration constant and Liljestrand formula.

Channel Label	Units	Description
Estimated SV - ch	L	Estimated stroke volume. Equal to: CO / HR.

If focus areas only are being analyzed, a new set of three channels will be defined for each focus area.

Watch the Acq*Knowledge* Cardiac Output from ABP video tutorial for a detailed demonstration of this feature.

Left Ventricular Blood Pressure



Extracts various cycle-by-cycle cardiac measures of left ventricular blood pressure data, optionally in conjunction with an ECG Lead II signal. Examines the LVP signal, ECG, and derivative of the LVP signal.

- If the LVP and ECG signals have not been classified before this analysis is executed, they will be classified automatically.
- Derivatives of the LVP signal can be pre-existing or can be constructed automatically.
- If an ECG signal is not included, only pressure related measures will be extracted.

The analysis outputs the following information on a cycle-by-cycle basis and the textual output cites the average of all of these cycle-by-cycle measurements:

Name	*Abbrev.*	*Description*
Contractility index	CI	maximum value of dP/dt during the cycle divided by the pressure at that time location
Developed pressure	DP	Amplitude interval between end diastolic pressure and systolic pressure
dP/dt Max	-	Maximum change in pressure over the cycle
dP/dt Min	-	Minimum change in pressure over the cycle
End diastolic pressure	LVEDP	End diastolic pressure for the cycle. This is not necessarily the minimum pressure during the entire cycle. LVEDP is located on the LVP signal using the method set in the preferences.
Minimum pressure	MIN	Absolute minimum pressure occurring during the entire cycle. This is not necessarily equivalent to the end diastolic pressure
QA Interval	QA	Time interval between the Q wave of the ECG and the end diastolic pressure
Rate	-	heart rate in BPM as extracted from the time interval between consecutive end diastolic pressure locations
Recovery time	%REC	Time it takes for dP/dt to increase from the minimum dP/dt location to a user specified percentage of that minimum value
Systolic pressure	SYS	Maximum pressure occurring during the entire cycle
Tau	-	Monoexponential time relaxation constant tau computed on a cycle by cycle basis.

Name	*Abbrev.*	*Description*
		See "Computation of Tau" on page 438 for specifics.
Tension time index	TTI	Integral of the pressure between end diastolic and the time of minimum dP/dt

Computation of Tau

There are many different methodologies used to extract the time constant from LVP data. The time constant is extracted from a best fit parameter of a model to the trailing edge of LVP data on a cycle by cycle basis. This analysis uses a monoexponential model of zero asymptote for computing tau.

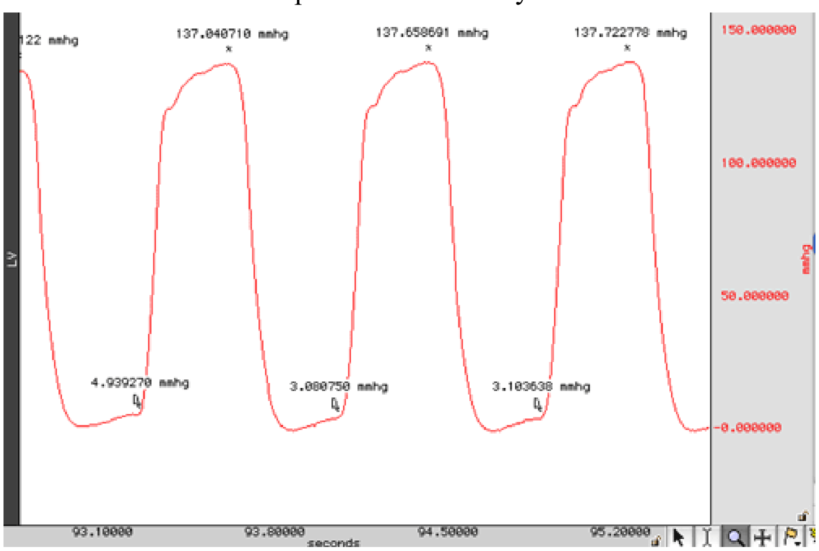
The relaxation period is defined as the range of data between the time of minimum dP/dt in the cycle to the point where the LVP pressure signal drops below the previous LVEDP level. Within this range, the following model is fitted to the data using the simplex search method:

$$P_0 e^{\frac{t}{\tau}}$$

where P_0 is the value of the LVP signal at the time of dP/dt minimum and t is the time coordinate shifted such that t is 0 at the time of dP/dt minimum. The best fit value from this model is used as the value of the relaxation time constant.

LVP Classifier

Operates on left ventricular blood pressure (LVP) data to define events at the systolic pressure and the left ventricular end diastolic pressure for each cycle.



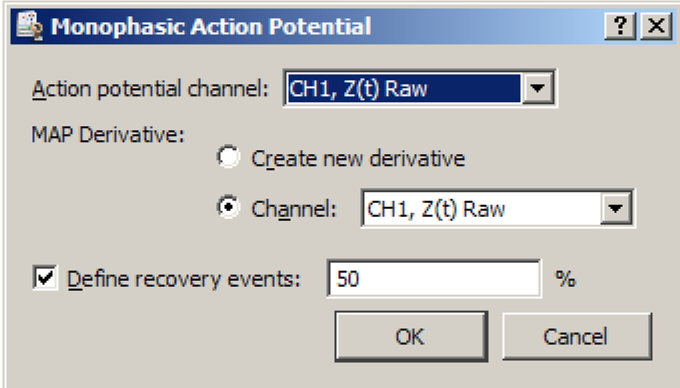
The location of these points is performed using filtered derivatives of the original LVP signal. Pre-filtering the signal (low pass of 50 Hz or less) or smoothing the signal before running the classifier may improve accuracy.

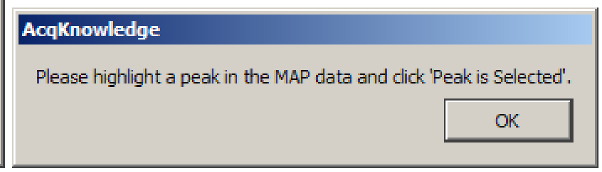
The LVP classifier locates LVEDP (left-ventricular end diastolic pressure) by examining the derivative of the pressure signal based upon the location method specified in Preferences:

- Adaptive threshold of 0 plus a percentage of the peak to peak change in pressure. The percentage is user-specified; the default is 1%. If the LVP signals do not have "flat" valleys, this percentage may need to be increased to fine-tune positioning of LVEDP.
- First zero crossings before contraction.

Watch the Acq*Knowledge* LVP classifier video tutorial for a detailed demonstration of this feature.

Monophasic Action Potential





Performs classification of MAP data acquired from a human or animal subject and extracts various cycle by cycle intervals. Locates upstroke, maximum, 100% recovery, and user-specified recovery points on the action potential.

- Classification is performed using the action potential with its smoothed derivative; pre-filtering noise with low pass filters may improve classification.
- If upstroke, maximum, and plateau events are already defined on the MAP signal, the classifier is not invoked and only recovery events are defined.

Plateau position

To better handle animal subjects and different potential morphologies, there are two methods for locating the plateau position in monophasic action potential data; use Preferences to set the method. Each method defines recovery percentage time locations depending on the signal between its maximum and the beginning of the plateau. The plateau is located by examining the derivative of the MAP immediately following its maximum value after an upstroke.

- The first method uses an adaptive threshold of zero plus a percentage of the peak to peak change in the derivative between the maximum and the first zero crossing after the maximum. If the signal remains above the upstroke voltage in this interval, a quick algorithm is used to locate 100% recovery and user-specified percentage levels.
- The default percentage is 0.1%, which will place the plateau position very close to the second zero crossing. This slight window around zero helps place plateau start events better for MAP data that has plateaus that continue increasing after their starting position.
- Searches for the second zero crossing after the maximum. If the signal drops below the voltage level of the upstroke in this interval, a different (slower) algorithm is used to ensure the recovery percentage is relative to the upstroke voltage and not the minimum occurring between the maximum and plateau.

The analysis outputs the following information on a cycle-by-cycle basis and the textual output cites the average of all of the cycle-by-cycle values:

Name	*Abbrev*	*Description*
100% recovery period	100% REC	Time interval from the upstroke for the signal to recover back to the upstroke voltage level
dV/dt maximum	dV Max	Maximum change in voltage over the cycle
dV/dt minimum	dV Min	Minimum change in voltage over the cycle
End diastolic voltage	EDV	The value of the signal at the beginning of the upstroke
Max voltage	MAX	The maximum value of the signal over a single cycle
Minimum voltage	MIN	The minimum value of the signal over a single cycle. This may be less than the upstroke voltage depending on the morphology of the action potential
Plateau voltage	PLAT	The value of the signal at the start of the plateau after the completion of the upstroke
Rate	-	This is the heart rate in BPM as extracted from the time interval between consecutive upstrokes
Stroke amplitude	AMP	Voltage interval between the plateau and the upstroke voltage
User recovery period	%REC	Time interval from the upstroke for the signal to recover a specific percentage of the interval between the upstroke and the maximum voltage between the upstroke and the plateau

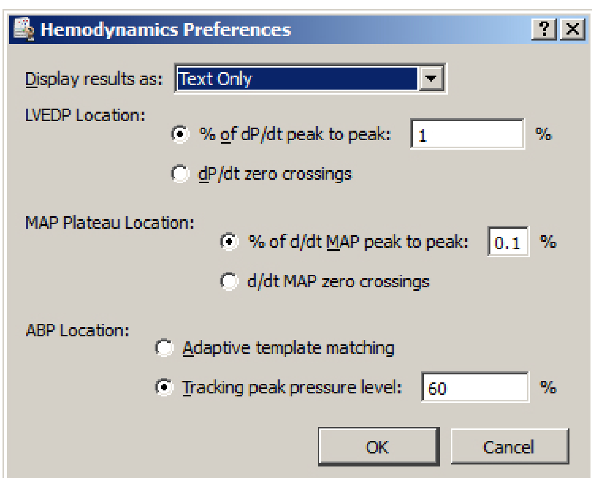
Watch the [Acq*Knowledge* Monophasic Action Potential video tutorial] for a detailed demonstration of this feature.

MAP Classifier

The classifier portion of Monophasic Action Potential only – defines upstroke, plateau, and percentage recovery events on MAP signals without performing the additional MAP data extraction.

The start of the plateau is located using either the second zero crossing of the derivative or a percentage of the cyclic peak-to-peak distance of the derivative. The plateau location method can be configured in Preferences.

Preferences



Display results as

Several of these transformations produce large amounts of cycle-by-cycle derived measures. Results can be displayed as a tab delimited table in the journal, as waveforms in the graph, as an Excel spreadsheet or various combinations. Results are displayed as text-only by default.

LVEDP location method – see page 438

- adaptive threshold of 0 plus a % of pk-pk change in pressure
- first zero crossings before contraction on the dP/dt signal

MAP Plateau location method – see page 439

- adaptive threshold of 0 plus a % of pk-pk change in the derivative between the max and the first 0 crossing after the max
- second zero crossing after the maximum

ABP Location method (Arterial Blood Pressure)

- **Adaptive template matching**

  This arterial blood pressure cycle location method uses adaptive template matching (see page 346). A single cycle is selected, systolic to systolic, which sets an example template. Subsequent blood pressure cycles are located by correlation to this template with the template adapting to the signal. This may function better if there is artifact in the pressure signal, however may not be as suitable for signals that have significant changes in heart rate. Location may also improve if a different cycle is chosen as the initial template. Adding smoothing or a low pass filter to the signal may improve results for Estimated Cardiac Output, ABP Classifier and Arterial Blood Pressure.

- **Tracking peak pressure level**

  The Tracking peak pressure level ABP location method is similar to the cycle detector's peak location method. This method sets a detection threshold from a selected systole and adjusts the threshold based on a customizable tracking percentage. The default tracking percentage is 60%. If the blood pressure signal is highly variable, this tracking percentage may need to be lowered. If the tracking percentage is set too high, blood pressure cycles may be missed.

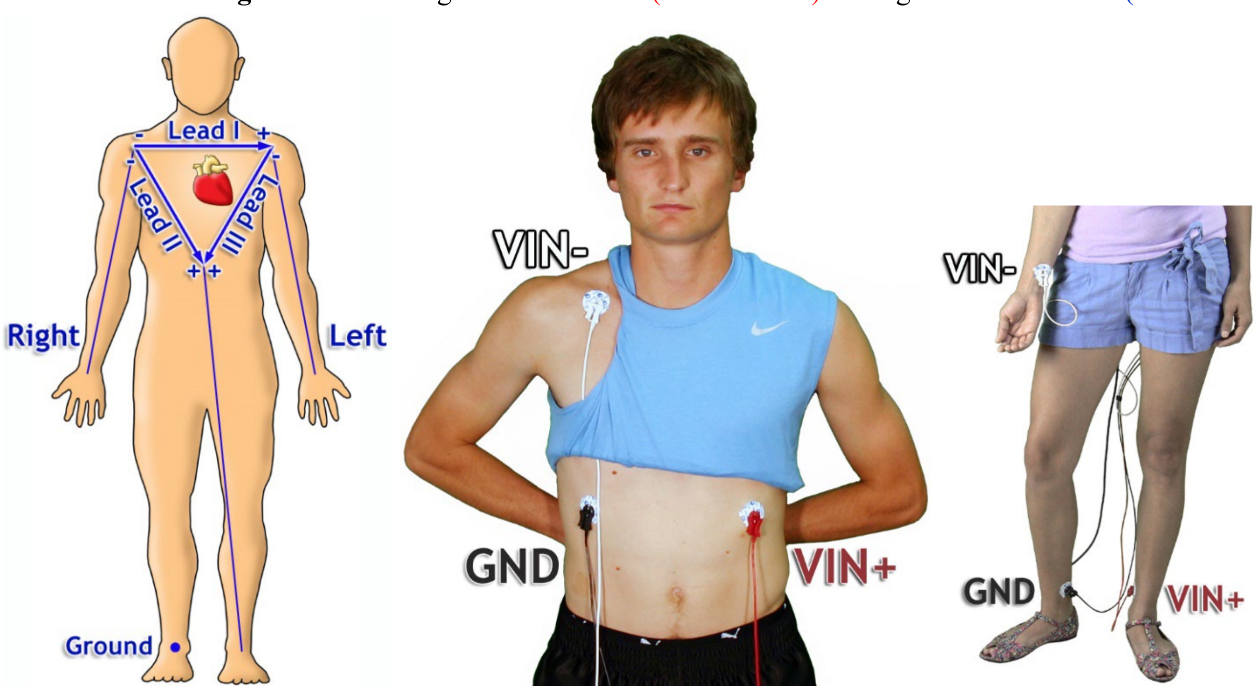
HRV and RSA Analysis

Acq*Knowledge* includes flexible options for extracting a wide range of heart rate variability (HRV) and respiratory sinus arrhythmia (RSA) measures. This analysis feature will:

- Extract HRV measures over user-defined areas of data, specifically fixed time trials (“epochs,”) events, and focus areas.
- Obtain RSA measures using frequency-based HRV.
- Automatically compute HRV using geometrical and statistical methods.

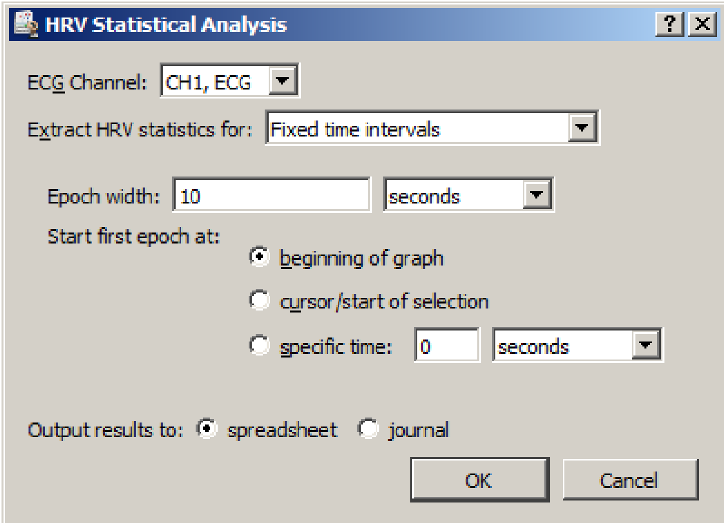
IMPORTANT: The HRV Statistical Analysis algorithm requires an **ECG Lead II** waveform in order to yield accurate results. When using a Lead I / Lead III waveform as a data source, use the Acq*Knowledge* Find Cycle Detector to output QRS peak events into the data before using Multi-epoch HRV Statistical Analysis. (See page 374 for information about the Find Cycle Detector.)

ECG Lead II configuration: Left leg or lower left rib (RED = Vin+) and right arm or clavicle (WHITE = Vin-)



For detailed information about ECG Lead Configurations see BIOPAC Application Note 109.

Multi-epoch HRV – Statistical



This analysis computes statistical measures of heart rate variability in user-specified time intervals. These measures (RMSSD, SDSD, and pNN50) can be extracted by fixed time intervals, time between event boundaries or focus areas. Output from the script is a spreadsheet containing these statistics and the time intervals over which they are computed. ECG complex events are also scored in the source graph. See Application Note 129 for a detailed explanation of HRV statistical analysis measures.

Acq*Knowledge* calculates HRV statistical measures RMSSD, pNN50, and SDSD as follows:

There are n+1 identified beats leading to n interbeat intervals leading to n-1 successive differences.

$$RMSSD = \sqrt{\sum_{i=1}^{i=n-1} [IBI(i+1) - IBI(i)]^2 \Big/ (n-1)}$$

$$= \sqrt{\textstyle\sum_{i=1}^{i=n-1} SD\ (i)^2/(n-1)}$$

where SD(i) (ith successive difference) is IBI(i+1) – IBI(i)

pNN50 = 100*(# of SDs with abs(SD) > 50 msec)/(# of SDs)

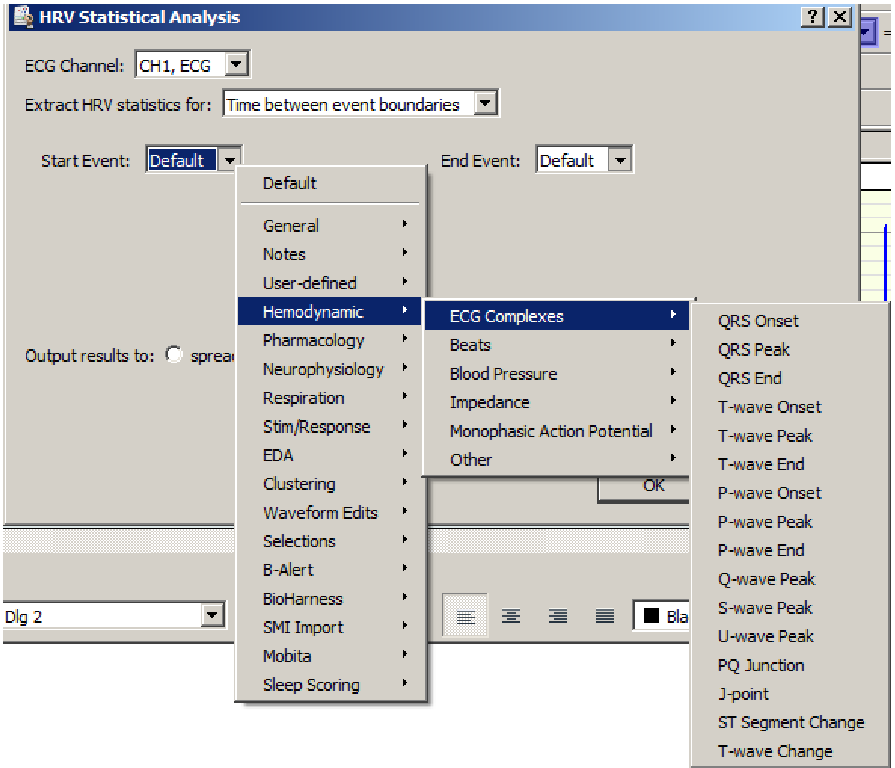
$$SDSD = \sqrt{\sum_{i=1}^{i=n-1} [SD(i) - \bar{SD}]^2/(n-1)}$$

$$where\ \bar{SD} = \textstyle\sum_{i=1}^{i=n-1} SD\ (i)/(n-1)$$

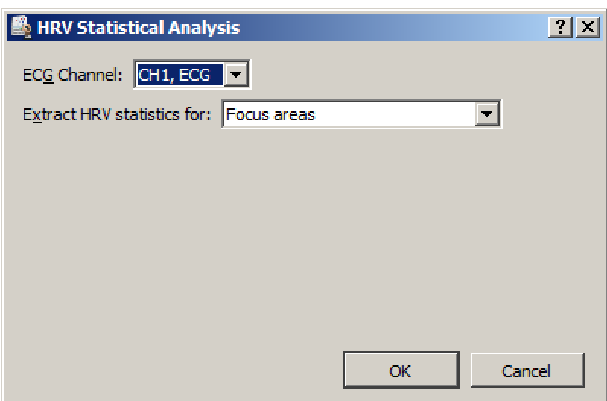
The following table describes options in the Multi-epoch HRV Statistical Analysis setup for the default Fixed time intervals setting:

Control	Description
ECG Channel:	Selects the channel to extract the statistics from. The ECG channel should be selected.
Extract HRV statistics for:	Select how the time ranges used for extracting statistics are applied. The options are Fixed time trials, Time between event boundaries and Focus areas.
Epoch width:	Indicates time duration and time units for each epoch. (Microseconds, milliseconds, seconds, minutes, hours, samples)
Start first epoch at:	Chooses location for starting first epoch. (Beginning of graph, current cursor location or a specific time point in the graph.)
Output results to:	Statistical Analysis results can be exported to a spreadsheet or pasted into the Journal

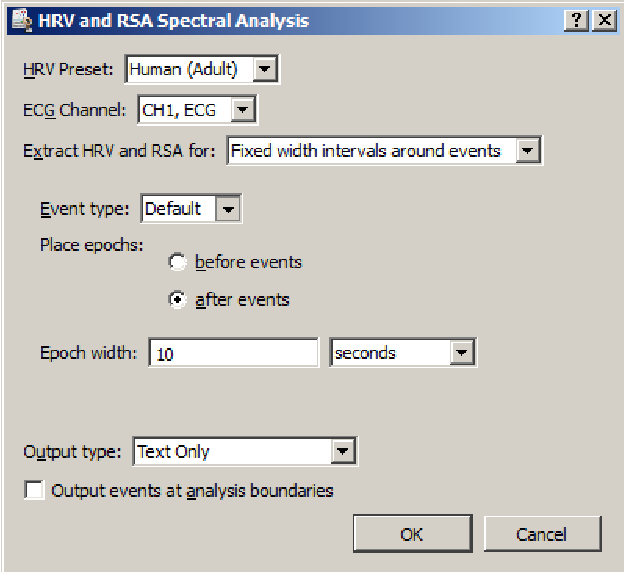
If the statistics are extracted using the “Time between event boundaries” criteria, starting and ending event types need to be selected and the selected event types must be present in the graph before performing the analysis.



If the statistics are extracted using the “Focus areas” criteria, defined focus areas must be present in the graph before performing the analysis.



Multi-epoch HRV and RSA – Spectral



This routine performs RSA and HRV analyses on specified time slices along an ECG waveform, whether by markers, fixed time intervals or focus areas. Then the HRV parameters of VLF, LF, are extracted, formed into a table, and written back into the journal or to an Excel spreadsheet. The following table describes the HRV and RSA Spectral Analysis options:

Control	**Description**
HRV Preset	Selects the heart rate variability preset to be used in the analysis. (This must first be pre-defined in the main HRV analysis dialog for conveying PSD, frequency bands, etc.) For more information, see Single-epoch HRV – Spectral.)
ECG Channel:	Selects the channel to extract the statistics from. The ECG Lead II channel should be selected here.
Extract HRV and RSA by:	Selects how the segments to be analyzed should be located. Available options are by: • Periodic time intervals – this option segments the data into fixed width epochs that occur at regular frequency intervals. It is equivalent to the “fixed time interval” option of epoch analysis. • Fixed-width intervals around events – “Fixed width intervals around events” is akin to the “at events” option of Epoch Analysis. It searches for individual events and analyzes a fixed interval of time with that event either as the beginning point or the endpoint of the time window. • Time between event boundaries – allows the segments to be located between two different individual events. The boundaries should ideally be two different types of events. If set to the same type a prompt will appear, asking whether the ending event of a pair should be immediately reused as the start of the next time interval. • Focus areas – this method extracts the HRV for each focus area defined within the graph. See below for specific setup descriptions for the above options.
Output type:	Select the analysis output format – Text, Excel, or both.
Output events at analysis boundaries:	Defines new markers at the time boundaries of each analyzed data segment. This is useful when performing validation of the analysis.

If **Periodic time intervals** are chosen, the following setup criteria are available:

- Epoch width: – sets the duration and time units for each epoch
- Start first epoch at: – choose location for starting first epoch. (Beginning of graph, current cursor location or a specific time point in the graph.)
- Time between epochs: – indicates the time separating one epoch to the start of to the next.

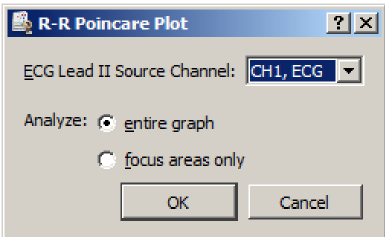
If **Fixed width intervals around events** is chosen, the following setup criteria are available:

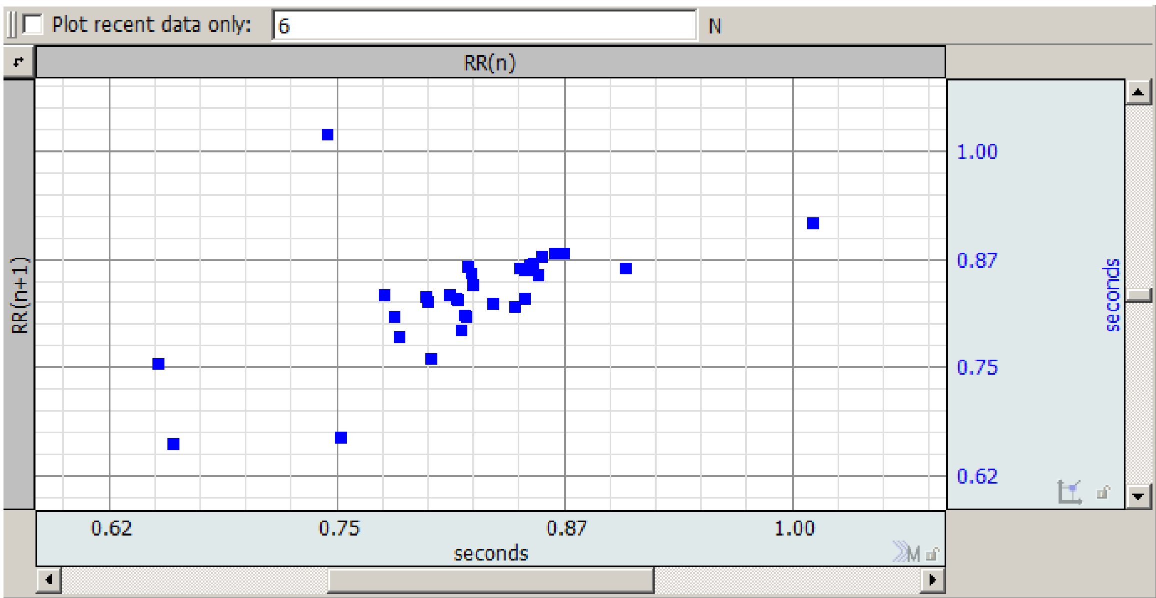
- Event type: – choose the specific type of event to be used in the analysis.
- Before events: – when selected, the event marks the end of the analysis time interval.
- After events: – when selected, the event marks the beginning of the analysis time interval.
- Epoch width: – sets the duration and time units for each epoch.

If **Time between event boundaries** is chosen, the following setup criteria are available:

- Start event: – select the starting event type at the beginning of each time segment.
- End event: – select the ending event type at the end of each time segment.

R-R Poincaré Plot





Poincaré plots are constructed from ECG Lead II data. A Poincaré plot is an XY plot with RR intervals in seconds on one axis and on the other axis the sequence delayed by one beat (RR vs. RR+1). This plot may be used to visually inspect for patterns in the sequence similar to an attractor plot. The RR intervals are measured in seconds.

This generates a new dot plot graph window in XY mode, no textual output is generated. Click the button to exchange the X and Y axis (flip the plot diagonally.) Use "Plot recent data only" to isolate a subset of the most recent data points. Enter the desired number of data points to be displayed and check the "Plot" box. Or, with the box checked, enter the desired value and hit the Enter (Return) key.

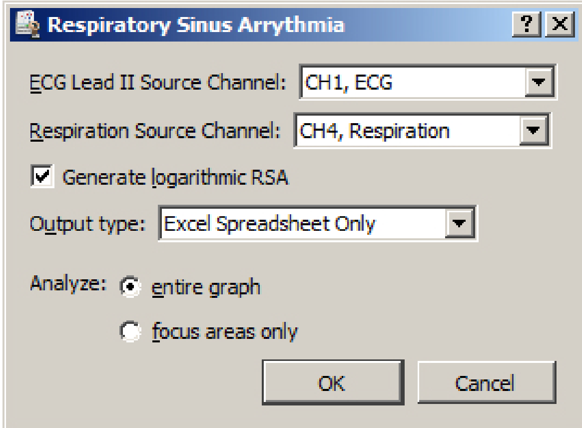
Applying the R-R Poincaré plot option also scores the ECG source graph with QRS events.

Beginning with Acq*Knowledge* 5.0.3, R-R Poincaré Plot analysis has been extended with SD1 and SD2 metrics. SD1 and SD2 are two standard Poincaré plot descriptors. SD2 is defined as the standard deviation of the projection of the Poincaré plot on the line of identity (y = x), and SD1 is the standard deviation of projection of the PP on the line perpendicular to the line of identity (y = − x)

This places SD1 and SD2 and their ratio into the output graph Journal and creates a data view with the values of x1 and x2.

To further reading about Poincaré, see Filtering Poincaré Plots by Jaroslaw Piskorski and Przemyslaw Guzik.

Respiratory Sinus Arrhythmia (RSA Time-series)



***IMPORTANT*—Respiration analysis assumes a bidirectional airflow signal that records both inhale and exhale. Unidirectional respiration signals cannot be analyzed at this time.**

Respiratory Sinus Arrhythmia is used to explore the connection between respiration and changes to heart rate. Variations in the heart rate can be directly correlated with vagal tone. The RSA index can be used to investigate changes in this connection during recording.

This RSA index is computed using the peak-valley method as outlined in:

> Grossman, P., van Beek, J., & Wientjes, C. (1990). A comparison of three quantification methods for estimation of respiratory sinus arrhythmia. *Psychophysiology*, 27, 702-714.

This method uses both a recorded ECG Lead II signal and a respiration signal. By using respiration information, this analysis method can provide breath-to-breath analysis that does not require parameter tweaking for individual subjects.

While designed for use with the RSP100C/TSD201 respiration module and transducer combination, it should be possible to use other estimates of respiration. The respiration signal is used to locate periods of inhalation and exhalation. Inhalation begins at valleys in the signal while expiration at peaks. Any respiration estimate that exhibits this morphology should be sufficient.

The RSA index outputted by this analysis is linearly scaled as per the recommendations in Grossman et. al. For comparison to other methods or studies using logarithmic scaling, Transform > Math Functions > Ln transformation can be used after analysis to convert results to logarithmic scaling.

In Acq*Knowledge* versions 4.4.1 and higher, selecting the “Generate logarithmic RSA” checkbox will automatically output the logarithmic result.

RSA results are triggered from the respiration cycle. The RSA analysis outputs the following measures:

Cycle Index of the respiration cycle in the analysis.

Time Location of the start of the respiration cycle on the time axis.

Min Period Minimum heart rate occurring during the inspiration window of the respiration cycle, expressed in milliseconds (IBI).

- If a respiration cycle is invalid, this measure will be set to 0.

Max Period Maximum heart rate occurring during the expiration window of the respiration cycle, expressed in milliseconds (IBI).

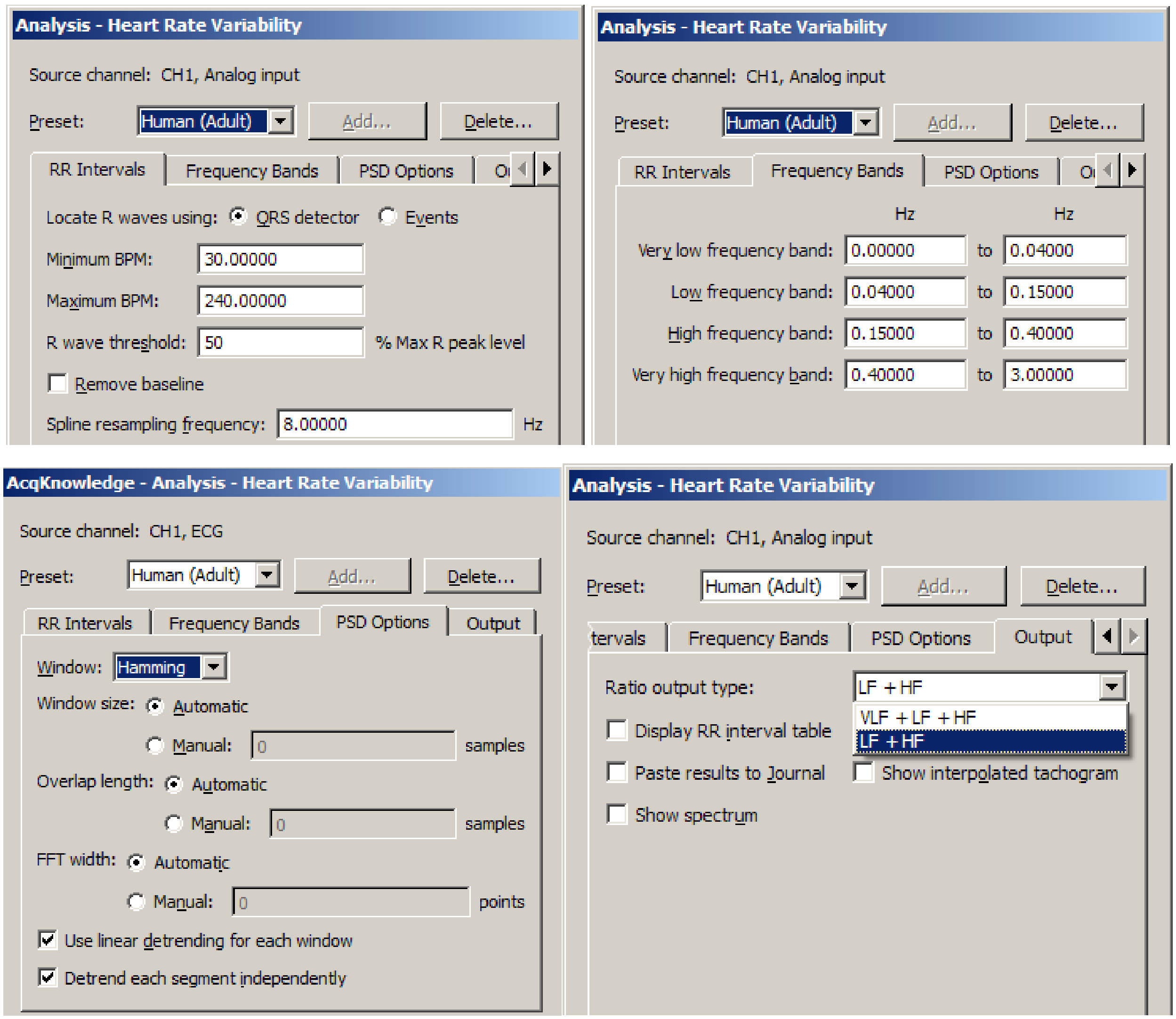
- If a respiration cycle is invalid, this measure will be set to 0.

RSA RSA index for the respiratory cycle, expressed in milliseconds. This is the max rate minus the min rate. This is output in linear scaling.

If a respiration cycle is invalid, this measure will be set to 0.

Single-epoch HRV – Spectral

Single-epoch HRV – Spectral (formerly referred to as Heart Rate Variability in Acq*Knowledge* versions 4.3.1 and earlier), is the examination of physiological rhythms that exist in the beat-to-beat interval of a cardiac signal. Single-epoch HRV assists in performing frequency domain analysis of human ECG Lead II data to extract standard HRV measures. The HRV algorithm in Acq*Knowledge* 3.9 and above conforms to the frequency domain algorithm guidelines as published by the European Heart Journal (1996) 17, 354-381.



Single-epoch HRV processing in Acq*Knowledge* consists of three stages:

1. The RR intervals are extracted for the ECG signal.
   - A modified Pan-Tompkins QRS detector is used.
2. The RR intervals are re-sampled to a continuous sampling rate in order to extract frequency information.
   - Cubic-spline interpolation is used to generate this continuous time-domain representation of the RR intervals.
3. The frequency information is extracted from the RR intervals and analyzed to produce standard ratios. Power sums are reported in units of sec^2.
   - A Welch periodogram is used to generate the Power Spectral Density (equivalent to Transform > Power Spectral Density).

The initial implementation of the HRV algorithm was primarily for use with long duration recordings. HRV algorithm improvements allow for further customizations to the algorithm:

- Windowing type for FFTs used to construct the PSD may be changed between Hamming, Hanning, and Blackman.
- Overall window length for segmenting source data for individual FFTs to include in PSD average may be modified .

- Length of the individual FFTs in the average can be manually specified.
- Scaling has been changed for PSDs, which are now scaled relative to the sampling frequency.
- Summary of power in individual frequency bands has been changed.
- Instead of a straight sum, an average power value is now reported.
- Power at endpoints is halved (e.g., divided by 2).
- Ratios of power in the different frequency bands may optionally include the very low frequency band in the total power estimate.
- The modifications to the HRV algorithms that affect its power spectrum estimation have also been applied to the PSD transformation.

After selecting Analysis > HRV and RSA > Single-epoch HRV – Spectral, choose the appropriate tab(s) and establish settings.

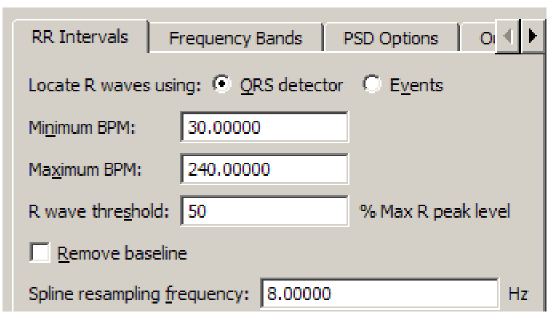
Preset controls, Transform entire wave checkbox, and OK/Cancel buttons apply across all of the tabs.

Preset—The preset menu can be used to save a variety of HRV settings, including: beat detection parameters, spline resampling frequency, and frequency band ranges. Choose a preset from the popup menu to apply its settings. To construct a new preset with the currently displayed settings, choose Add New Preset. A default preset for adult human subjects is supplied.

RR intervals

Select a method to locate R waves: QRS Detector or Events.

QRS detector

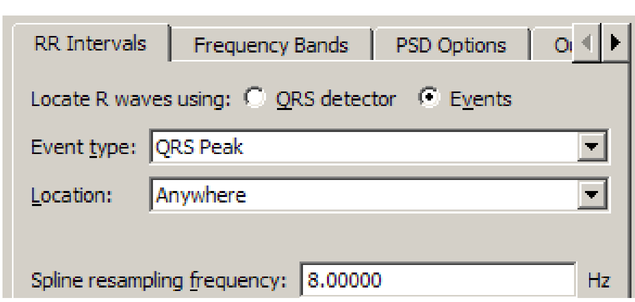


The heart rate variability implementation has a built-in QRS detector. The detector does not run on raw source data; it uses a modified Pan-Tompkins algorithm to normalize the ECG data to 1, whereby the peak amplitude of the highest R-wave represents 1. Use the tachogram output to examine the output of the QRS detector.

- *R wave threshold*—The detection threshold must be specified in terms of percentage of maximum R peak level; this helps to clarify the units in which this threshold is expressed. The default threshold level of .5 should place the threshold in the middle of the R-wave, which should function on a wide range of data sets. If the R-wave amplitude varies a lot, it might be necessary to adjust the threshold level.
    - R wave threshold is expressed in normalized units, which are in the range (-1, 1): positive for positive R wave peaks. The maximum voltage in the signal maps to 1.0 and the minimum voltage in the signal maps to -1.0.

      Pan J and Tompkins WJ. A Real-Time QRS Detection Algorithm. *IEEE Transactions on Biomedical Engineering* ***32***(3):230-236, 1985.

Events



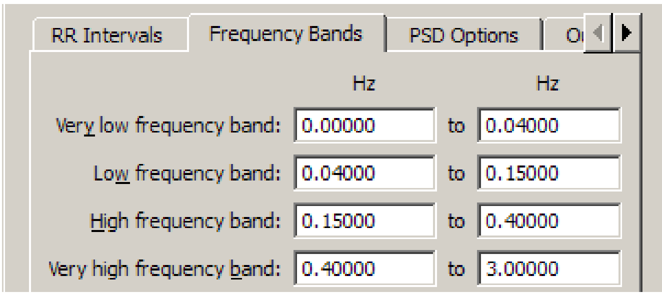
R-wave peaks will be located using events already in the graph of the channel of data to be analyzed. This assumes a single event is placed at each R-wave peak and that all of the R-peak events are of the same event type. When using events, the built-in QRS detector is not used; the exact positioning between the events on the channel is used to extract the RR intervals.

By using events, it is possible to use other QRS detectors within Acq*Knowledge* for performing HRV analysis. It is also possible to apply spectral HRV-style analysis to data in other domains as long as intervals can be reduced to events.

Spline resampling frequency

For highest accuracy, set to no less than twice the topmost frequency of the very high frequency band.

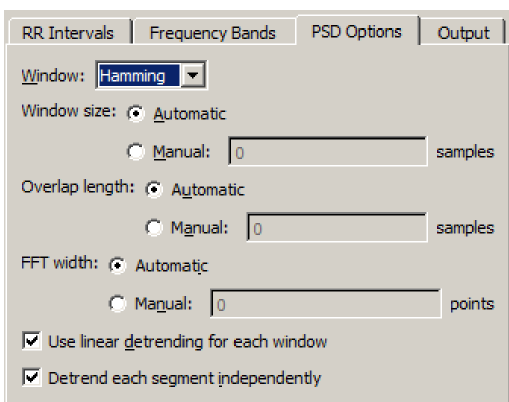
Frequency Bands



Enter the start and end of each specified frequency band to adjust the boundaries of the frequency analysis. They are preset to the frequency ranges recommended by the European Heart Journal (1996) 17, 354-381. Output of derived parameters is presented in a dialog and may also be pasted as text to the Journal.

- Very high frequency band, usually used in rat studies, is disabled if the spline resampling frequency is less than the upper bound of the very high frequency range.

PSD Options



PSD Options establish parameters for the power spectral density transformation used to compute the spectrum from the interpolated tachogram; the options contained in this tab mirror the controls of the Analysis > Power Spectral Density transformation detailed on page 365.

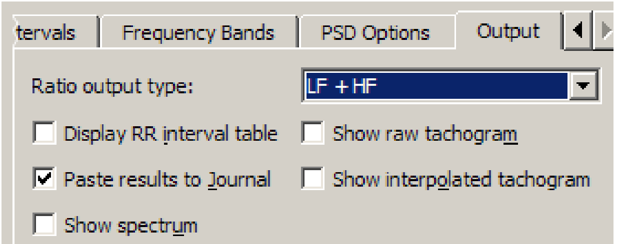
The use of linear detrending in each individual segment of source data prior to the windowed periodogram analysis can be enabled or disabled. When disabled, the algorithm may be tuned to correspond to implementations that do not apply linear trending, such as MATLAB, which uses windowing only. The same PSD options are available via Analysis > Power Spectral Density so users can regenerate the spectrum from either the raw or interpolated tachogram output as necessary.

After the user modifies the parameters for the PSD transformation, those parameters will become the new default values each time the dialog is displayed. When the application is relaunched, the default settings will be used (user changes are not persistent).

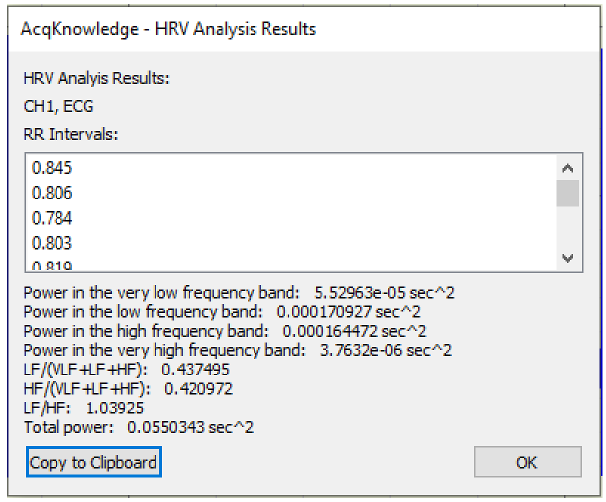
PSD Options

- The PSD output power values are scaled by the sampling rate: $PSD_{new} = \frac{PSD_{old}}{f_s}$
- Reporting a sum for a frequency range when computing the power in an individual band is as follows:
  - Given a frequency range f_{low}, f_{high} define the set S of all samples of the PSD where $S = \{PSD(f_{low}), \ldots, PSD(f_{high})\}$.
  - Define the sum of the power within the frequency range as follows: $s(f_{low}, f_{high}) = \left(\frac{S_1}{2} + \sum_{i=2}^{i=|S|-1} S_i + \frac{S_{|S|}}{2} \right) \times \frac{(f_{high} - f_{low})}{|S|-1}$.
  - This applies the scaling factor to a sum of the frequencies in the frequency range, with the magnitudes at the endpoints divided by 2.
- The ratios of power in different bands are automatically computed. When computing these ratios, power in the VLF band may be included or not depending on user preference. These are the ratios computed. Define $s_{vlf} = s(vlf_{low}, vlf_{high})$, $s_{lf} = s(lf_{low}, lf_{high})$, and $s_{hf} = s(hf_{low}, hf_{high})$. The VLF ratio is: $ratio_{vlf} = \frac{s_{vlf}}{s_{vlf} + s_{lf} + s_{hf}}$. The LF/(LF+HF) ratio is defined as: $ratio_{lf} = \frac{s_{lf}}{s_{vlf} + s_{lf} + s_{hf}}$. The HF/(VLF+LF+HF) ratio is defined as: $ratio_{hf} = \frac{s_{hf}}{s_{vlf} + s_{lf} + s_{hf}}$.

Output



Create standard result presentation graphs or assess performance of the HRV algorithm. Output options allow access to intermediate computation data for algorithm validation and/or measurements.



RR Interval table

- If the combined output formula is selected, the analysis output will contain an additional line of text: "VLF Ratio" with the corresponding percentage.

Spectrum

Displays the power spectrum density (PSD) estimation from which the PSD summations and and the ratios of power in the different frequency bands are computed.

Raw tachogram

Plots the raw R-R intervals found by the QRS detector. Perform statistical HRV measures on the R-R intervals without exporting the textual R-R table to excel.

Interpolated tachogram

Plots the resampled R-R intervals after cubic spline interpolation is applied and extracts the PSD from this data.

IMPORTANT—Recording good data is essential for performing HRV analysis. The protocol for data acquisition, filtering, artifact detection and correction in Application Note 233 results in great improvements in HRV analysis.

"Results reveal that even a single heart period artifact, occurring within a 2-min recording epoch, can lead to errors of estimate heart period variability that are considerably larger than typical effect sizes in psychophysiological studies." —Berntson & Stowell, 1998 "ECG Artifacts and Heart Period Variability: Don't Miss a Beat!" Psychophysiology, 35, 127-132; http://faculty.psy.ohio-state.edu/berntson/vita.ggb.pdf

- See **Application Note 233 Heart Rate Variability—Preparing Data for Analysis Using Acq*Knowledge* (online at www.biopac.com)**

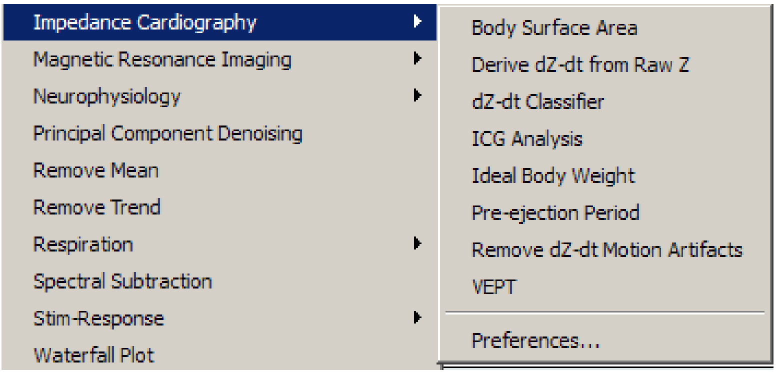
Watch the Acq*Knowledge* HRV Analysis video tutorial for a detailed demonstration of this feature.

The note explains how to optimize ECG R-R interval data for Heart Rate Variability studies by using a template matching approach. It also explains how to identify erroneous R-R interval values caused by signal artifact and shows methods for correcting the errors by using the tools in the Acq*Knowledge* software. The note explains how to:

A. Record good ECG data
B. Prepare data for the tachogram
   1. Filter the ECG data
   2. Transform the data using Template Correlation function
C. Create a tachogram
D. Identify problems with the tachogram data
E. Correct tachogram data

Impedance Cardiography Analysis

The Impedance Cardiography analysis package assists in the analysis of cardiac output and other hemodynamic parameters using noninvasive bioimpedance monitoring techniques; signals must be sampled at 5 kHz or below to be analyzed with this package. This analysis offers a variety of approaches for estimation of cardiac measures.



Body Surface Area

Determines the body surface area estimation in square meters for a subject of a given height and weight, using the formula set in Preferences. It can be used to calculate body surface area independent of any of the other analysis routines, which may be useful for validation purposes or other derived calculations.

Body Surface Area equation

Use the Preferences option to select an algorithm for estimating body surface area of a subject and deriving stroke volumes from impedance data.

Method	*Formula*
Boyd	$BSA = 0.0003207 \times Height(cm)^{0.3} \times Weight(g)^{0.7285-0.0188\log(Weight(g))}$
DuBois and DuBois	$BSA = 0.20247 \times Height(m)^{0.725} \times Weight(kg)^{0.425}$
Gehan and George	$BSA = 0.0235 \times Height(cm)^{0.42246} \times Weight(kg)^{0.51456}$
Haycock	$BSA = 0.024265 \times Height(cm)^{0.3964} \times Weight(kg)^{0.5378}$
Mosteller	$BSA = \sqrt{\dfrac{Height(cm) \times Weight(kg)}{3600}}$

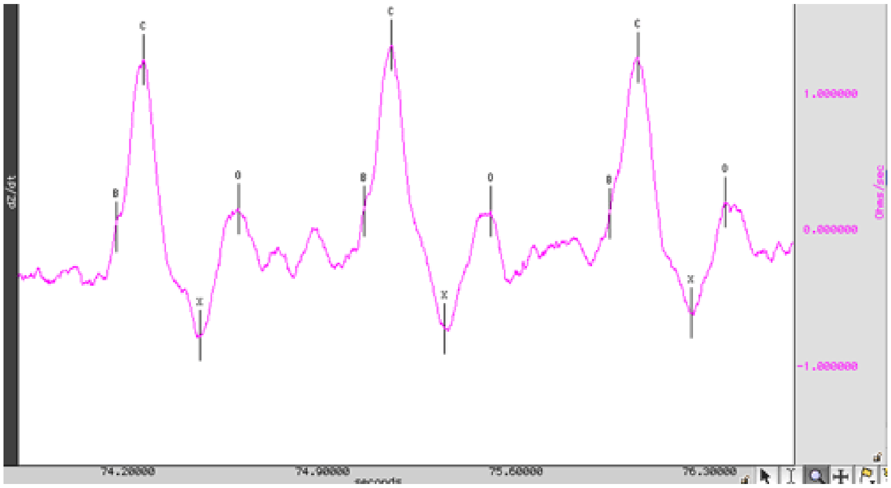
dZ(t)/dt Derive from Raw Z

This is a convenience utility for working with impedances recorded using the BIOPAC EBI100C amplifier or the raw impedance output of the BIOPAC NICO100C module. When computing derivatives from raw impedance signals from an EBI100C, this will apply appropriate filtering for a thoracic impedance signal and properly invert the derivative to match traditional dZ(t)/dt presentation.

Zo is the nominal, DC Baseline Component, of thoracic impedance (Z) measured by the NICO100C, EBI100C, BN-NICO or SS31L. The AC Component of Z is typically referred to as “dZ(t)/dt”, where the AC Component is defined as the changes in Z associated with the mechanical movement of blood associated with the beat of the heart. The DC Baseline Component of Z is typically referred to as “Zo”, where the DC Baseline Component is defined as the stable or slowly changing values of Z associated with variations in the overall thoracic impedance due to slow moving fluid shifts and changes in thoracic volume. In impedance cardiography, the overall Z waveform appears as a slowly varying “DC Baseline Component (Zo)” which has slight dips in its value, indicated by the “AC Component (dZ(t)/dt)” that are coincident with each heartbeat, as blood is periodically ejected from the heart.

dZ(t)/dt Classifier

Places events at common inflection points on a dZ(t)/dt waveform to derive other measures.



The classifier will attempt to locate the following points on the ICG signal:

- B point – opening of aortic valve (set location in Preferences)
- C point – Maximum left ventricle flow (set location in Preferences)
- X point – Closing of aortic valve (set location in Preferences)
- Y point – Closing of pulmonal valve
- O point – Widest opening of mitrial valve

The algorithm for locating these points on the ICG signal examines local minima and maxima in the dZ(t)/dt signal as well as values of its second derivative. Filtering is applied to the second derivative signal to improve accuracy.

- Pre-filtering the dZ(t)/dt signal may improve accuracy slightly.

In a particular cardiac cycle, if there is not enough definitive change in the ICG signal to locate a particular point, the point will be omitted. This may most commonly occur with the Y point since its inflection between X and O is subtle and may be lost.

The location routine, as with impedance cardiography measurements in general, is sensitive to motion artifacts. It is intended to function on signals acquired from subjects at or near perfect rest. Swings in the dZ(t)/dt signal may cause the classifier to fail. It is recommended that motion artifacts be removed before running the dZ(t)/dt classifier or any other ICG analysis tools that may invoke the classifier on an ICG signal. If artifacts are present within the signal, the template matching cycle location method will exhibit better behavior than the fixed threshold method. The choice between these two methods can be made with the Preferences option of the analysis package.

B-point Location—Use Preferences to set the dZ(t)/dt B-point location method.

There is no standard method generally accepted for programmatically locating B-points on an ICG waveform. The appropriate choice of B-point location method may depend on the data or on subjective preference. On average, all five methods will produce similar results for clean data. ICG Preferences has five options for B-point location:

- Second derivative classification – Given a C peak, it searches within a 150ms to 100ms time window before the C peak for the maximum of the second derivative of impedance ($\ddot{Z}$). The B point is placed at this maximum.
- Third derivative classification – Given a C peak, it searches for the maximum value of the third derivative of impedance ($\dddot{Z}$) within 300ms before the C peak. The B point is placed at this maximum.
- Cycle-by-cycle 'Isoelectric' crossings – Given a cycle defined by two C peaks, the mean of the dZ(t)/dt signal is computed over the cycle. The B point is then placed at the closest time to the right C peak that is still underneath this baseline zero level.

- R to C polynomial model - Location of B point based on locations of R and C points according to polynomial equation found in Lozano et al. (2007). Psychophysiology, 44:113-119.
- Min derivative in C-QRS interval – Start at C, move backwards in time 35 ms, start looking for minimum of derivative of dZ(t)/dt, stop at peak of QRS + 25 ms. Minimum dZ(t)/dt derivative in window (35-(R+25)) ms is B.

C-point Location—Use Preferences to set the dZ(t)/dt C-point location method.

In several of the ICG analysis scripts, the B, C, X, Y, and O points will need to be located on the dZ(t)/dt waveform. The starting point of this process is locating individual cycles on the dZ(t)/dt waveform to define the C points. Use Preferences to set the cycle location method:

- Template Matching – the user is expected to select a representative cycle of the dZ(t)/dt waveform. The entire cycle should be selected (e.g. visually to approximate a C-C interval, a X-X interval, etc.). The entire dZ(t)/dt signal is then correlated with that representative cycle, and individual cycles are picked out from locations of maximum correlation.
- Fixed Thresholding – the user is prompted to select one of the C peaks of the dZ(t)/dt waveform. The voltage level of this peak is then used to compute an Ohms/sec thresholding level. Peak detection is then run on the dZ(t)/dt waveform using that voltage level as the threshold.

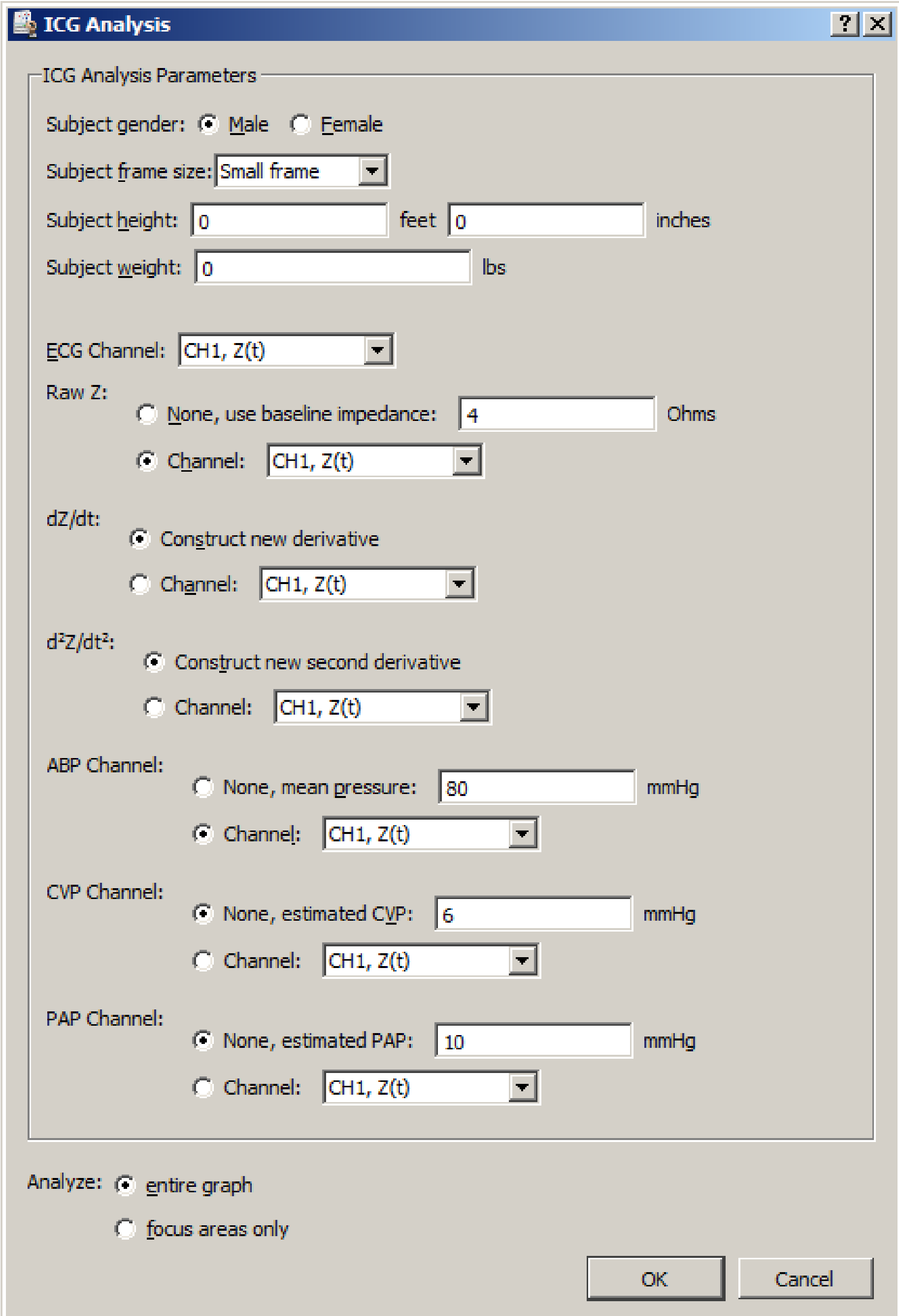
  Since ICG is subject to many artifacts such as respiration components and motion artifacts, the default method used is template matching. For extremely clean ICG signals, however, fixed thresholding can be used effectively as well and will provide a quicker analysis.
- Adaptive template matching – the user is prompted to select a representative cycle of the dZ(t)/dt waveform. This is used as a basis for an adaptive match to locate cycles. Adaptive template matching will adapt to changes in the dZ(t)/dt waveform as conditions change within the experiment. Two parameters may be set. The window size is the number of ICG cycles to use for estimating the next template. Smaller values will track changes more quickly; larger values will reduce interference from artifact. The correlation threshold is the value above which a match is found. It refers to the normalized cross correlation of dZ(t)/dt with the template and should be between 0 and 1. Values closer to 1 will require precise matches and skip artifacts. Values closer to 0 will use looser match constraints and may be required if the ICG is changing rapidly.

X-point Location

There are two methods that may be used to locate the X point of the ICG waveform at the closing of the aortic valve. The choice of appropriate X point location method is dependent on the electrode configuration that is used to acquire the ICG signals. In certain electrode configurations, the dZ(t)/dt minimum may actually occur closer to the A-wave complex than to X, making the first (and default) option of searching for the first turning point a more reliable solution. It's recommended to acquire a phonocardiogram in conjunction with ICG to help determine which method will be more accurate at locating X.

- Search for the first turning point in the dZ(t)/dt signal that occurs after the C point location and place X at the first positive zero crossing in the second derivative of impedance (d^2Z/dt^2).This is the default X point location method.
- Locate the X point at the minimum value of dZ(t)/dt over each cardiac cycle.
- Start at C, move forward in time 150 ms, start looking for minimum of dZ(t)/dt, stop at 275 ms. Minimum in window is X.

ICG Analysis



The ICG Analysis routines include 20 derived impedance and hemodynamic measures that correspond to various values that are generated by other industry-standard impedance cardiography analysis tools. Many users tend to be interested only in a subset of the various measures produced by the analysis (e.g. only heart rate and cardiac output); the extra measures can “clutter” the output and frustrate users who have to delete them manually.

The ICG Analysis output options feature adds a new step to the ICG Analysis where the user may toggle the output of individual measures on and off. This allows users to suppress generation of all output for a measure including the graph channels, column in the Excel spreadsheet, and column in the text output.

ICG Analysis performs a full impedance cardiography analysis on data, extracting intervals and derived cardiac measures. The minimal set of signals required to run this analysis is an ECG Lead II signal and either a raw impedance signal or a dZ(t)/dt signal.

- If a raw impedance signal is present from an EBI100C or NICO100C and no derivative has been constructed, the analysis will automatically construct the appropriate derivative and perform classification.

- If both a raw impedance and a dZ(t)/dt signal are present, the baseline impedance will be derived on a cycle-by-cycle basis to improve the accuracy of the analysis.
- If no raw impedance signal was acquired, a default fixed baseline impedance can be used.
- If a NICO100C amplifier is used, it is recommended that both the raw impedance and dZ(t)/dt signals be acquired to improve analysis accuracy.
- To automatically apply motion filtering to the dZ(t)/dt signal, use Preferences to enable Motion Filtering (see page 461).
- ICG Preferences must first be selected in order to generate the main ICG Analysis setup window.

In addition to the minimal set of signals, it is also possible to use arterial blood pressure, central venous pressure, and pulmonary arterial pressure signals to improve the quality of the algorithm results. If any of these signals are not present, default fixed estimated values can be substituted for the mean pressures instead of deriving pressures on a cycle-by-cycle basis.

ICG Analysis may potentially perform classification of both the dZ(t)/dt and the ECG Lead II signals. The various notes for understanding the limitations of these classifiers apply and should be understood to properly interpret failures in the analysis.

ICG Analysis will produce the following information on a cycle-by-cycle basis:

At the end of the textual table an average of all of the cycle-by-cycle values will be appended.

Name	*Abbv.*	*Description*	*Units*	*Formula*
Acceleration index	ACI	Maximum blood acceleration	1 / sec^2	
Cardiac index	CI	Normalized cardiac output	m^2 / min	
Cardiac output	CO	Volume of blood pumped each minute	l / min	
Heart rate	HR	Heart rate in BPM as computed from the RR interval.	BPM	
Left cardiac work	LCW	Work exerted by the left ventricle each minute	kg m	
Left cardiac work index	LCWI	Normalized left cardiac work	kg m / m^2	
Left ventricular ejection time	LVET	Time interval between B and X. Time interval between aortic valve open and close.	sec	*Not applicable*
Mean blood pressure	MBP	Mean blood pressure as measured on the arterial blood pressure signal, or fixed estimate if no ABP signal is present.	mmHg	
Mean central venous pressure	CVP	Mean central venous pressure over cycle, or default value if no CVP signal is present.	mmHg	*Not applicable*
Mean pulmonary arterial pressure	PAP	Mean value of the pulmonary arterial pressure of a cycle, or default value if no PAP signal is present.	mmHg	*Not applicable*

Name	*Abbv.*	*Description*	*Units*	*Formula*
Pre-ejection period	PEP	Time interval between the Q wave of the ECG and the B point of the ICG. Time interval between systole and aortic valve open.	sec	*Not applicable*
RR interval	RR-i	Time interval between R peaks in the waveform.	sec	*Not applicable*
Stroke index	SI	Normalized stroke volume	(ml / beat)/ m^2	
Stroke volume	SV	Volume of blood pumped by left ventricle in a single beat	ml / beat	Set equation in Preferences: Kubicek—Estimates SV from the derivative of the impedance signal and blood resistivity: Note $\frac{dZ}{dt}_{\max}$ may be either the absolute maximum or the BC delta in amplitude, as set in Preferences. ▪ Sramek—Estimates SV from the derivative of the impedance signal and the estimated volume of electrically participating fluid (VEPT): o In the ICG analysis routines, VEPT is estimated using a truncated cone model. ▪ Sramek-Bernstein—Estimates SV from the volume of electrically participating tissue scaled according to body habitus. The SV equation is: $SV = \frac{\delta(VEPT)}{Z_0} \times \frac{dZ}{dt}_{\max} \times LVET$ *where* $\delta(VEPT) = \frac{weight_{actual}}{weight_{ideal}} \times \frac{(0.17H)^3}{4.25}$ Ideal body weight is computed using the method set in the Preferences. To best match the original Sramek-Bernstein equation, use the Met Life Tables ideal body weight method.
Systemic vascular resistance	SVR	Afterload; arterial flow resistance	dynes sec / cm^5	

Name	Abbv.	Description	Units	Formula
Systemic vascular resistance index	SVRI	Normalized afterload	dynes sec m^2 / cm^5	
Systolic time ratio	STR	Ratio between electrical and mechanical systole	none	
Thoracic fluid content	TFC	Electrical conductivity of the chest cavity	1 / Ohms	
Thoracic fluid index	TFI	Mean value of the raw impedance over the cycle, or fixed baseline value if no raw impedance signal is present.	Ohms	*Not applicable*
Velocity index	VI	Maximum velocity of blood flow in the aorta.	1 / sec	Note $\frac{dZ}{dt}_{max}$ may be either the absolute maximum or the BC delta in amplitude, as set in Preferences.

Ideal Body Weight

Body Weight is derived from a person's height, gender, and (for the Met Life method) frame size. It describes the ideal weight based upon various estimates. Ideal body weight is subject to much interpretation, so a number of methods are provided. Ideal Body Weight results are always expressed in kilograms.

Use Preferences to set the Ideal Body Weight computation method; the selected method is also used for ICG Analysis.

Method	*Formula*
Devine	*Men* 50 kg + 2.3 kg per inch over 5 feet *Women* 45.5 kg + 2.3 kg per inch over 5 feet
Metropolitan Life Tables	The weight is taken from the standard Metropolitan Life tables, which are based on gender, height, and frame size. The Metropolitan Life tables specify weight ranges; the ideal body weight is computed as the average of the endpoints of each weight range. Ideal weights are based on height with shoes on and are only defined for heights between *Men* 5' 2"and 6' 4" *Women* 4' 10"and 6' 0"
Miller	*Men* 56.2 kg + 1.41 kg per inch over 5 feet *Women* 53.1 kg + 1.36 kg per inch over 5 feet
Robinson	*Men* 52 kg + 1.9 kg per inch over 5 feet *Women* 49 kg + 1.7 kg per inch over 5 feet

PEP Pre-ejection Period

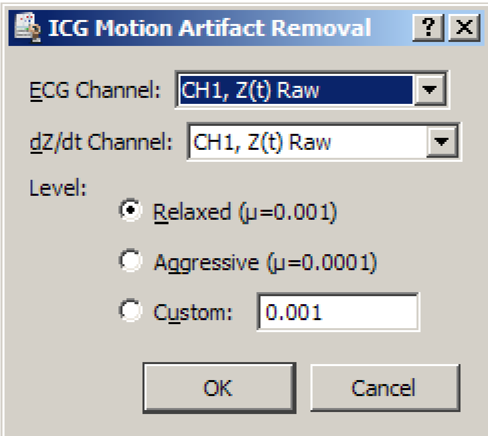
The pre-ejection period is the time interval between the electromechanical systole and the onset of ejection of blood from the left ventricle of the heart. This can be derived from standard ECG data and ICG data as the interval between the Q point on the ECG and the B point on the ICG. The Pre-ejection Period analysis tool helps extract PEP measurements from ECG Lead II and ICG data. PEP can also be computed using the full ICG Analysis tool on page 456.

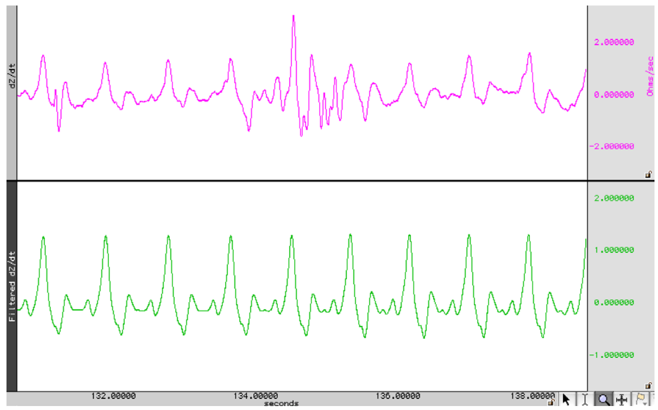
To use Pre-ejection Period analysis, both an ECG Lead II and an ICG (dZ(t)/dt) signal must be present. If either of these signals requires classification, the analysis will run the appropriate classifier to define the relevant events on the signals. To automatically apply motion filtering to dZ(t)/dt, use Preferences to enable Motion Filtering (see page 461).

PEP analysis will output the following information on a cycle-by-cycle basis and the final line of the textual output will be the average of all of the cycle measurements. All time unit output is in seconds unless otherwise noted.

Name	Abbrev.	Description
Heart rate	BPM	The heart rate for the cycle as indicated in BPM. Derived from the RR interval.
Pre-ejection period	PEP	Time interval between the Q wave of the ECG and the B point on the ICG for the cardiac cycle. If the PEP cannot be computed for a particular cycle, it will have the value "----" in the textual output or 0 in the graphical output.
RR interval	RR-i	Time interval between R peaks of a single cycle of cardiac data.

dZ(t)/dt Remove Motion Artifacts





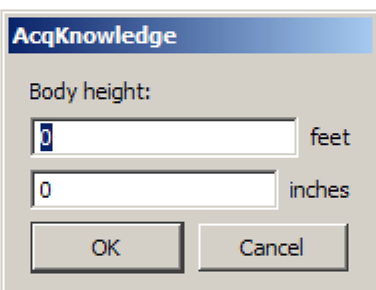
Applies SFLC motion artifact removal to a dZ(t)/dt signal. Uses cycle information from an ECG signal to construct a sinusoidal model of the ICG signal containing only components that are correlated to the heart rate.

IMPORTANT

Motion artifact removal will affect the amplitudes of the dZ(t)/dt signal, so results derived from a motion filtered dZ(t)/dt signal should be additionally verified for accuracy.

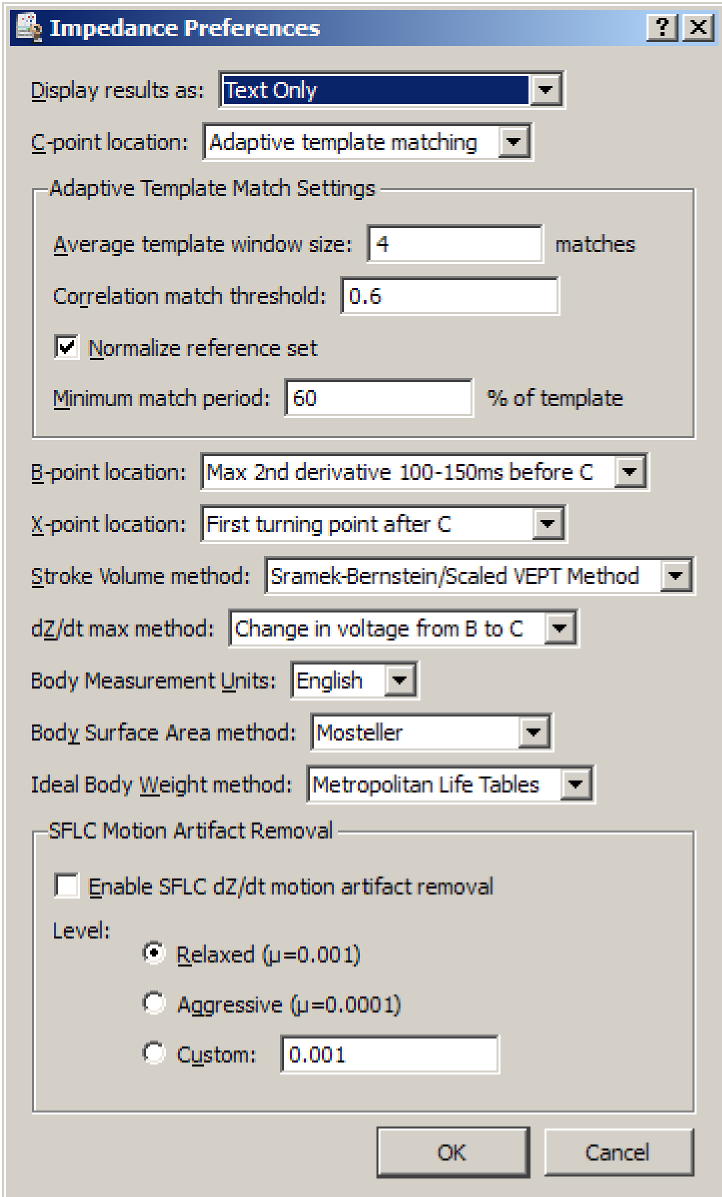
This tool performs the same type of filtering as the ICG Analysis and Pre-ejection Period tools when the Motion Filtering preference is enabled.

VEPT



Uses the truncated cone method to compute the volume of electrically participating tissue (VEPT) in cubic centimeters of a subject. At the prompt, enter the height of the subject in the units set under Preferences. This input can be used to calculate VEPT independent of other analysis routines, which may be useful for validation purposes or other derived calculations.

Preferences



Display results as

- Textual tables in the journal
- Channels of data inserted into the graph.

C-point location –see page 455

B-point location – see page 454

X-point location – see page 455

Stroke volume equation – see page 458

- Kubicek, or Sramek, or Sramek-Bernstein

dZ(t)/dt Max method – Baseline drift in ICG signals can introduce drift artifacts into stroke volume, cardiac output, and other measures that are sensitive to changes in dZ(t)/dt max. The Preferences offer two settings. "Max dZ(t)/dt in cardiac cycle" will extract the maximum amplitude of dZ(t)/dt as the max value. This is the traditional way of measuring dZ(t)/dt max. A second estimate option, "change in voltage from B to C" will take the amplitude delta between B and C as the estimate of dZ(t)/dt max. This will produce different stroke volume results, but is useful for removing motion artifact and improving consistency.

Body Measurement Units system for inputting

- English system: body height in feet and inches, distance between measuring electrodes in inches, and body weight in pounds
- Metric system: body height in meters and centimeters, distance between measuring electrodes in centimeters, and body weight in kilograms.

Body Surface Area equation – see page 453

- Boyd; DuBois and DuBois; Gehan and George; Haycock; or Mosteller

Ideal Body Weight method– see page 459

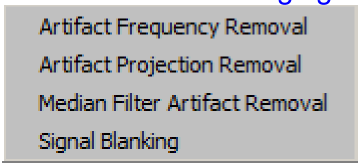
Motion Artifact Removal

The Pre-ejection Period and ICG Analysis transformations have the ability to optionally apply motion filtering automatically to the dZ(t)/dt signal. Motion filtering is performed using an SFLC keyed to the R waves of an ECG signal. The SFLC filtering approach is similar to performing cycle-by-cycle averaging of the dZ(t)/dt signal. This motion filtering approach may cause errors to be introduced in derived calculations, so any results with motion filtering turned on should be validated additionally.

Filter Magnitude Level – relaxed, aggressive, and custom.

- "Relaxed" uses a SFLC step size of .001. This allows the filter to adapt moderately quickly to changes in the dZ(t)/dt signal.
- "Aggressive" uses a SFLC setting of .0001. The filter will adapt less quickly to changes in the ICG signal, allowing better filtering out of motion artifacts at the expense of a lessened response to changes in underlying ICG morphology.
- "Custom" allows for an arbitrary SFLC step size. The step size must be greater then zero and much less than 1 for the filter to converge.

Magnetic Resonance Imaging



Magnetic resonance imaging, or MRI, is often used to study the brain and other organs in the body. As access increases to MRI machines, researchers are beginning to combine MRI with traditional physiological signal recording. The strong magnetic fields used by MRI equipment can cause profound artifacts in physiological recordings, which can make the analysis of physiological recordings acquired in an MRI difficult. Some artifacts are external interference while other artifacts can be caused by currents being induced in electrode leads or even in the body itself.

Artifact Location and Trigger Signals

Most of the MRI analysis options require information to identify the positions of various artifacts. Event positions can be used or a "trigger signal" waveform in the graph can be used to identify periods when the MRI is active. Some MRI machines have a TTL output that is synchronized with periods where the MRI is on.

- Whenever possible, this trigger signal should be acquired with the hardware unit along with the physiological data.

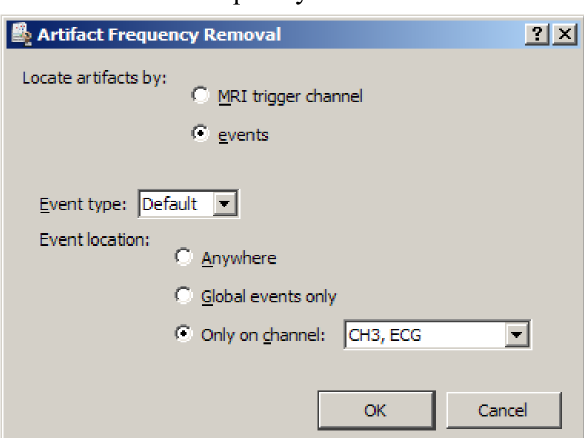
Trigger detection off of an MRI trigger signal waveform is performed using fixed level thresholding on the waveform data. The threshold level is set to be the minimum value of the entire trigger signal plus 1/10th of the peak-to-peak distance of the trigger signal. The threshold is kept data dependent to allow for artificial trigger signals to be derived from data if the MRI unit does not provide its own. The trigger signal may be acquired on either an analog or digital channel.

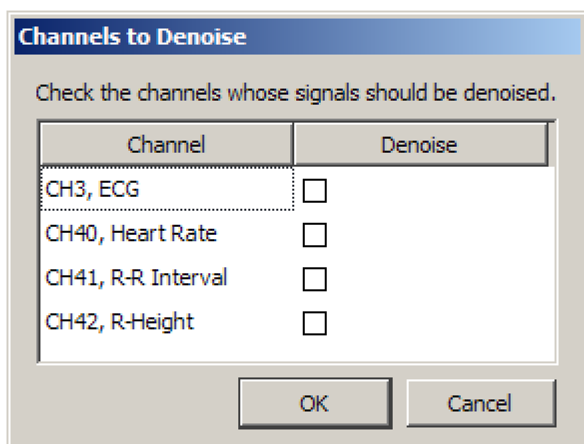
Event driven artifact location can be useful when trigger signals are not available from the MRI or are not recorded. A cycle detector analysis can be used to place events at the onset of each artifact, or these events may be placed manually. Event based detection is also useful for applying the procedures for artifacts that are not directly related to the MRI trigger signal, such as for removing the cardiac interference from EEG data caused by the magnetic field of the MRI machine.

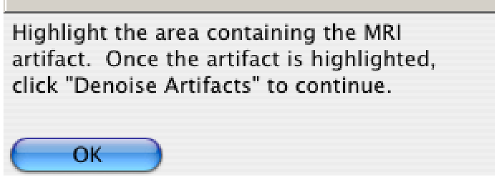
For more information on cycle detector analysis, see the Find Cycle section on page 374.

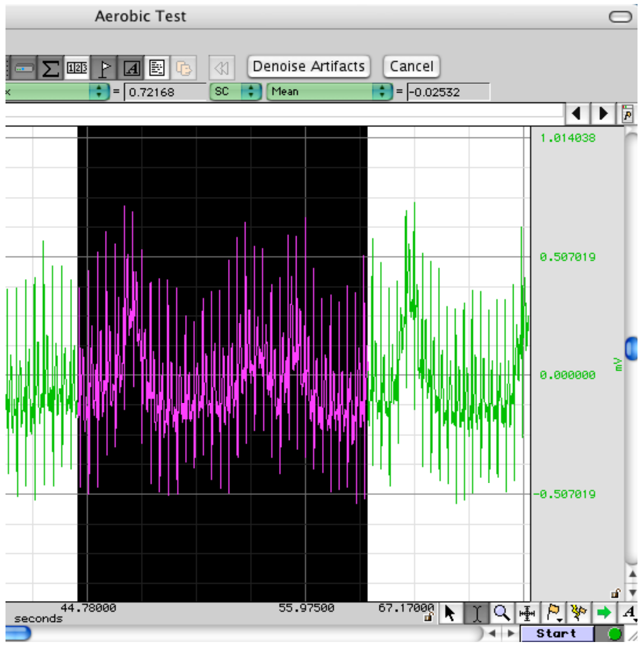
Artifact Frequency Removal

MRI > Artifact Frequency Removal









Two large sources of interference in MRI recordings are the current induced by the MRI magnetic field and the RF pulses used for triggering molecule alignment. While the overlap of this interference may be difficult to separate in the time domain, the MRI interference may have a distinctive signature in the frequency domain.

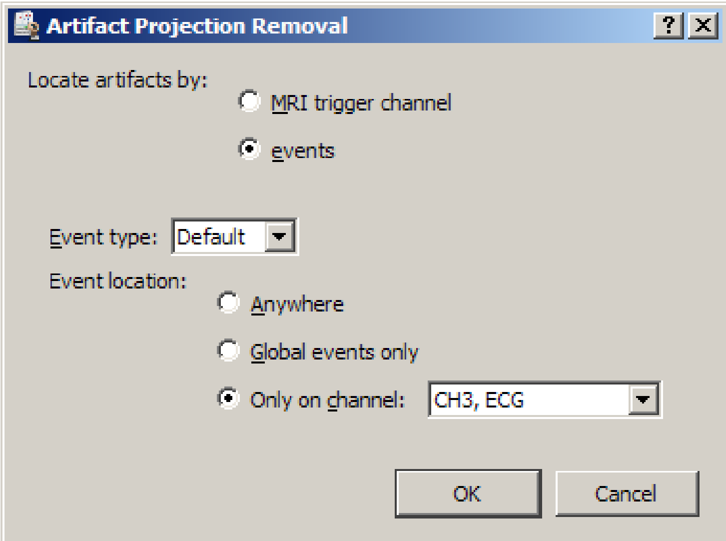
Artifact Frequency Removal is a frequency domain adaptation of the ensemble projection removal of the Artifact Projection Removal transformation. It attempts to cancel out MRI artifact by removing the frequencies most strongly associated with the MRI signal.

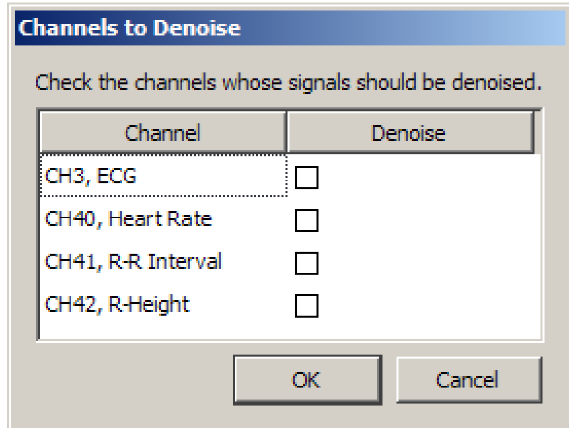
For each channel of data to be denoised, either the MRI trigger signal or event positions are used to locate periods of MRI activity for constructing an ensemble average. The FFT of this ensemble average is computed, and the magnitude of the average FFT is set as the reference. Cyclic mean removal is applied to each period of artifact to compensate for baseline drift or signals with expected DC offset. A second pass is then made through the data. For each individual artifact, the FFT of that artifact is computed and the projection of that FFT onto the average FFT is removed. After projection removal, negative Fourier components are discarded and a time-domain signal is reconstructed using the inverse Fourier transform. This reconstructed, filtered signal is used to replace the MRI artifact in the original data.

Application of projection removal in the frequency domain has similar limitations to applying it in the time domain, that is, it assumes that the MRI interference is stationary (which is not necessarily the case). Variations in the MRI interference may cause this method to fail.

IMPORTANT Artifact Frequency Removal requires an MRI triggering signal or artifact onset events to locate artifact positions.

Artifact Projection Removal





Artifact Projection Removal attempts to remove the noise components from the artifacts within a signal. An ensemble average is made for each period of MRI artifact in a channel. Cyclic mean removal is applied to each period of artifact to compensate for baseline drift or signals with expected DC offset. As the artifacts are averaged together, the actual interference with the physiological signal caused by the MRI should become the dominant feature if a sufficient number of artifacts are present. A second pass is made through the artifacts to remove this average MRI artifact from each individual period.

The average artifact is removed using the Remove Projection transformation. This performs a vector projection of the signal onto the averaged artifact estimation and subtracts this projection. This is an improvement over straight subtraction of the average artifact as vector projection can compensate for changes to amplitude that may occur over time.

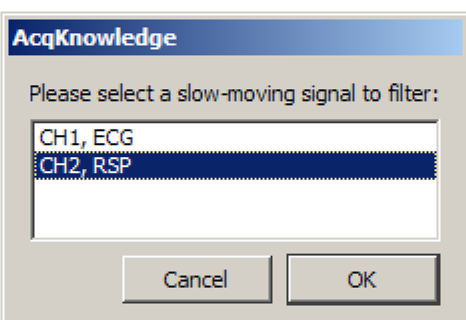
Artifact projection removal cannot compensate for MRI interference that varies in frequency due to changes in orientation of electrode leads within the MRI or other factors that may alter the MRI artifact.

Artifact projection removal is an adaptation of a denoising technique described in:

M. Samonas, M. Petrou and A. Ioannides, "Identification and Elimination of Cardiac Contribution in Single-Trial Magnetoencephalographic Signals," *IEEE Trans. Biomed. Eng.*, vol. 44, no. 5, pp. 386-393, 1997.

IMPORTANT Artifact Projection Removal requires an MRI triggering signal or artifact onset events to locate artifact positions.

Median Filter Artifact Removal

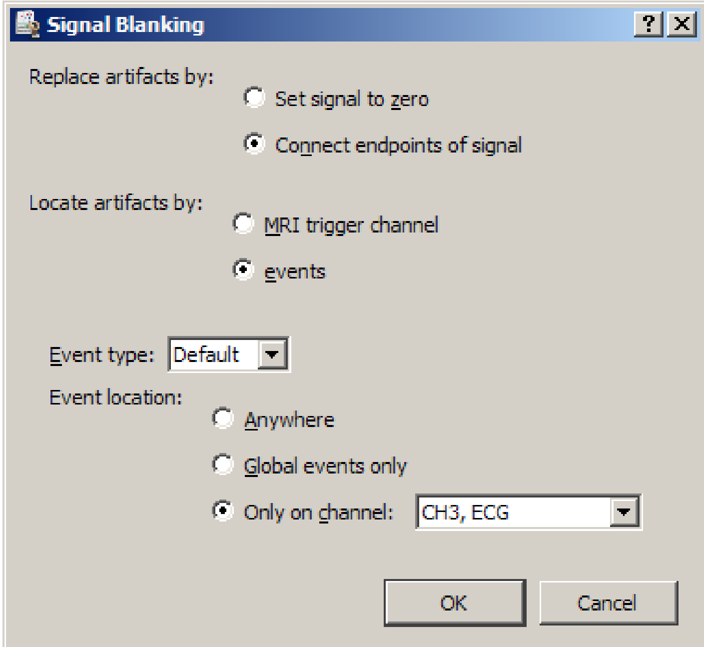


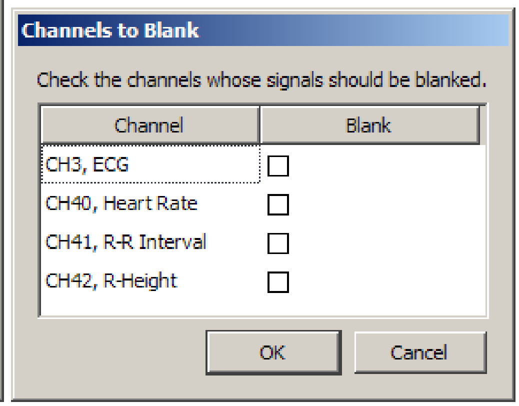
Median Filter Artifact Removal provides a basic artifact removal suitable for slow moving signals such as respiration, GSR, or temperature. It performs a windowed median transformation on the source channel with a window width of 1/10th of the acquisition sampling rate.

This median filtering approach is explained in the BIOPAC MRI application note AH223.

Median Filter Artifact Removal does not require an MRI triggering signal.

Signal Blanking





MRI artifact can grossly distort low level physiological signals, and this distortion can be several orders of magnitude larger than the signal of interest. A common practice for analyzing the physiological data is to discard the MRI artifacts and only examine the portions of the signal in between the MRI artifacts. One approach for this is outlined in BIOPAC MRI application note AH223.

Signal Blanking provides an alternate approach for discarding MRI artifacts from the signal. Using the MRI triggering signal or artifact event locations, this analysis option will locate the periods of MRI activity and "blank" the physiological signal during this period.

Two types of "blanking" can be performed:

- Set value to zero – The waveform is set to zero during each artifact.
  - For integrated measures, zeroing the signal may be preferable as it will have no effect on the running sum.
- Connect endpoints – For each artifact, a selection is made and the values within the interval are replaced with a line connecting the signal value before the MRI artifact to the signal value at the end of the interval.
  - For statistical measures or DC coupled signals, connect endpoint (linear interpolation within the interval) may be preferable to avoid causing the output to trend towards zero.

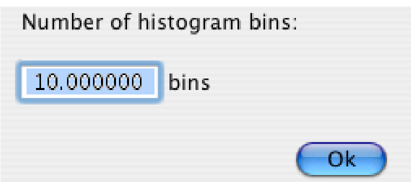
IMPORTANT Signal Blanking requires an MRI triggering signal or artifact onset events to locate artifact positions.

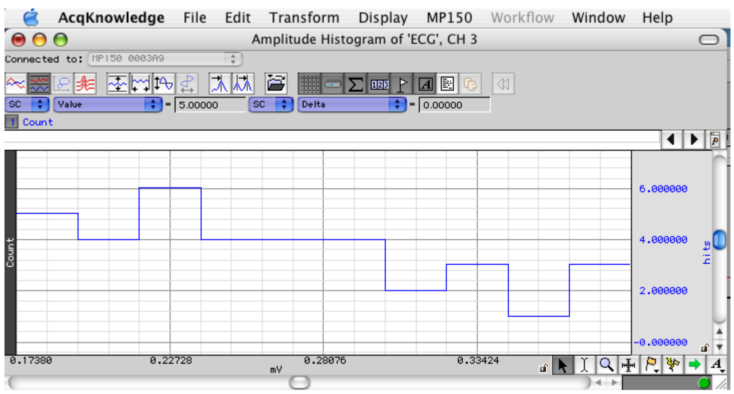
Neurophysiology

The Neurophysiology analysis package assists in the analysis of spikes within extracellular microelectrode recordings, such as those recorded using an MCE100C module. All of these analysis options require a continuous recorded single channel of microelectrode data.

- A *spike* is a deviation from the baseline caused by a neuron action potential. Frequently extracellular spikes will resemble exponentials. The point of maximum value of the spike will be used to locate neuron firing.
- A spike *episode* consists of a fixed time window around a spike that aims to capture the underlying neuron firing time. The episode consists both of the rise time (the time taken to reach maximum) and the relaxation period around the spike.

Amplitude Histograms



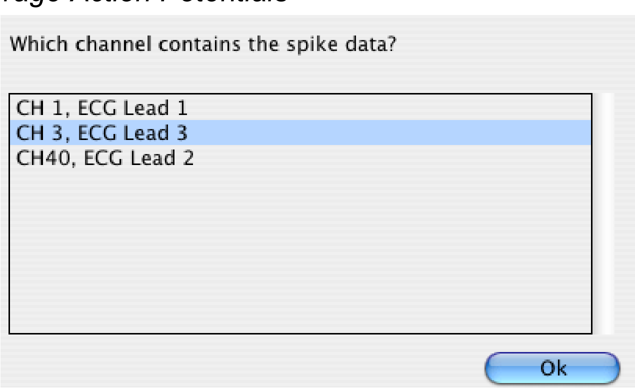


IMPORTANT To run this analysis option, the signal must first be transformed by the Classify Spike Episodes option or the Locate Spikes option. (See pages 467 and 468.)

Amplitude histograms show the population density of the maximum amplitude of neuron firing events. They may be used to interpret changes in neuron firing due to drug response or as rough indicators of the approximate number of classes of action potentials in a signal. Amplitude histograms can be generated on classified or unclassified signals.

- On classified signals, an overall amplitude histogram will be created for all of the spikes in addition to a single amplitude histogram per class (reflecting only the episodes of that class.
- On unclassified signals, a single amplitude histogram will be created from the maximum voltage within all of the spike episodes.

Average Action Potentials

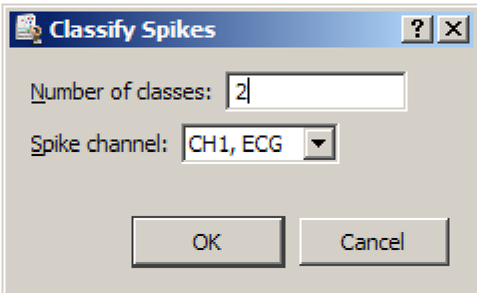


IMPORTANT To run this analysis option, the signal must first be transformed by the Classify Spike Episodes option or the Locate Spikes option. (See pages 467 and 468.)

After a classification has been completed for a spike signal, to assign spike episodes to different groups, users may wish to view the average shape of the waveforms of each class. Examining the shape of the different classes provides visual feedback as to the efficiency of the clustering, can allow for identification of certain classes as noise or artifacts, and helps to determine if the identified classes are indeed unique. Average Action Potentials can be generated on classified or unclassified signals.

- On classified signals, the resulting ensemble averages will have multiple channels.
  - The first channel will be the overall average of all of the spike episodes.
  - The remaining channels show the average of the members of each individual spike class.
- On unclassified signals, a graph will be produced with a single channel showing the average of all of the spike episodes.

Classify Spikes



IMPORTANT If cluster events from a previous spike classification are already defined on the recorded waveform, this option will erase them and replace them with the new classification of the potentials.

This analysis option will automatically classify action potentials in microelectrode data and divide them into different spike classes.

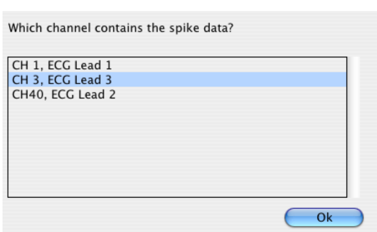
If the Locate Spike Episodes option wasn't used to find spikes before this option was selected, the Locate Spike Episodes option will be automatically performed prior to the clustering.

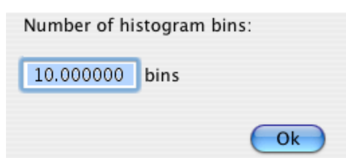
A single-feature k-means clustering classifier is used, and the entire data set is used for the clustering portion of the algorithm. The determining feature is the Sum criteria— that is, the sum of all of the data points within the waveform segment; this was one of the first features used in early action potential classifiers.

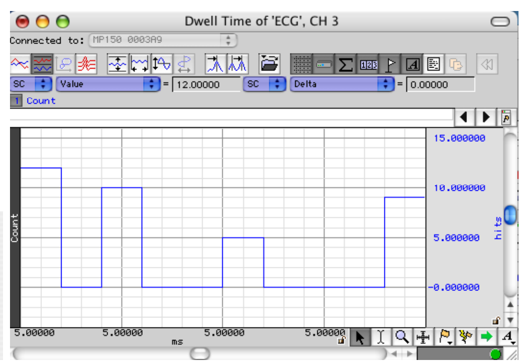
The clustering may not produce meaningful classes, so results should be examined for accuracy.

This style of classifier is for rudimentary spike analysis. For more advanced classification techniques, use the clustering algorithm in the Find Cycle detector. (See page 388.)

Dwell Time Histograms







IMPORTANT To run this analysis option, the signal must first be transformed by the Classify Spike Episodes option or the Locate Spikes option. (See pages 467 and 468.)

A dwell time histogram shows the population density of the duration of a neuron firing event. Dwell times can be approximated for an action potential by measuring the absolute value of the time interval between their maximum and minimum voltage levels reached during the firing of the neuron. After the minimum value in the firing recording has occurred, the neuron will be returning to its resting state, so the time difference is a good approximation for the firing duration. The dwell time histogram plots this time difference versus number of action potentials that have similar time differences. Examining varieties in dwell times can help to illustrate drug responses or to perform rudimentary classification of action potentials.

Dwell times will be defined as the time difference between the positions of the maximum signal value and minimum signal value within a spike episode. Since dwell time histograms can be used for classification purposes, they can be run on classified or unclassified microelectrode signals.

- On classified signals, an overall dwell time histogram will be constructed for all of the spikes in addition to a single histogram per class, showing times of only the spikes in that class.

- On unclassified signals, a single dwell time histogram will be created for all of the spikes. When run on a classified signal.

Find Overlapping Spike Episodes

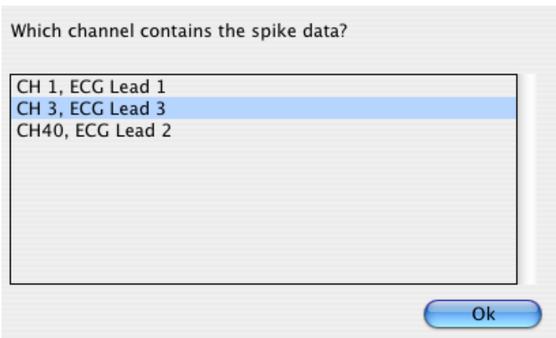
IMPORTANT To run this analysis option, the signal must first be transformed by the Classify Spike Episodes option or the Locate Spikes option. (See pages 467 and 468.)

In many extracellular recordings, it is frequent for there to be more than one neuron firing in response to the same stimulus. This can result in overlapping spike episodes when both neurons fire in close succession. Some types of analysis and spike classification are not able to produce meaningful results if too many overlapping episodes occur. “Find Overlapping Spike Episodes” can be used to locate overlapping episodes. After the spikes have been located in a signal, this option can be used to iterate only to those that are overlapping.

“Next Overlap” and “Cancel” buttons are available in the toolbar of the graph window to allow for iteration through the episodes.

Note This option is “view only.” Overlapping episodes are not affected by the analysis and will need to be manually removed manually to delete them from the file.

Generate Spike Trains



IMPORTANT To run this analysis option, the signal must first be transformed by the Classify Spike Episodes option or the Locate Spikes option. (See pages 467 and 468.)

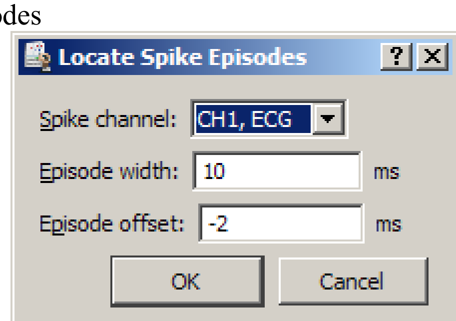
Spike trains are good visual indicators of when action potentials are firing and are good synchronization waves for further analysis and data reduction. A spike train is a channel in a graph whose value is 0 when there is no spike and 1 when there is a spike.

Spike train generation will operate only on signals whose action potentials have already been classified.

- A single spike train will be generated as a channel in the graph for each class of action potential in the signal. Be sure to choose “Graph Channels only” or “Text and Graph Channels” in the Neurophysiology Preferences. (See page 469.)
- If text output is enabled, the spike trains will be pasted as tables in the journal with one table per spike class.
- If spreadsheet output is enabled, the tables will be placed side by side so index 1 of the tables lines up for each action potential.

Locate Spike Episodes

Neurophysiology > Locate Spike Episodes



This option provides the basic spike detection for a microelectrode signal. Spike detection is performed using the following steps:

1. Obtain mean value of the entire signal.
2. Obtain standard deviation of the entire signal.

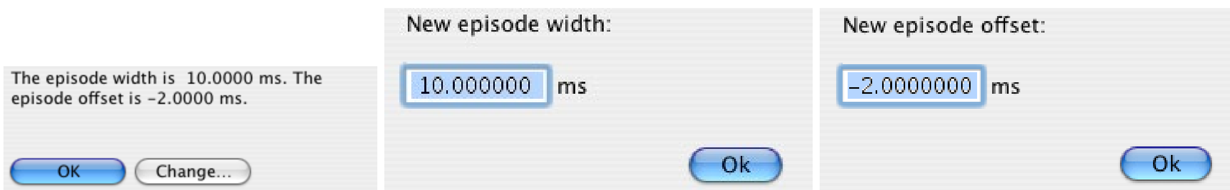
   OR: Obtain an Amplitude/Half Width Discriminator of the entire signal. See Neurophysiology Preferences for more information (page 469).
3. Detect spikes where the signal rises above a fixed threshold determined by adding a multiple of the standard deviation to the mean.
4. Position the episode around the threshold crossings according to the width and offset entered previously.

A "Spike Episode Begin" event will be placed at the start of each spike episode and will be located offset milliseconds away from the threshold crossing. A "Spike Episode End" event will be placed at the end of each episode.

- If text output is enabled, a table of the start time of each episode will be placed in the graph's journal.
- If spreadsheet output is enabled, a new spreadsheet will be created with the start time of each episode.

Spike episodes may also be located manually by using the Cycle Detector to define "spike episode begin" and "spike episode end" events in the graph.

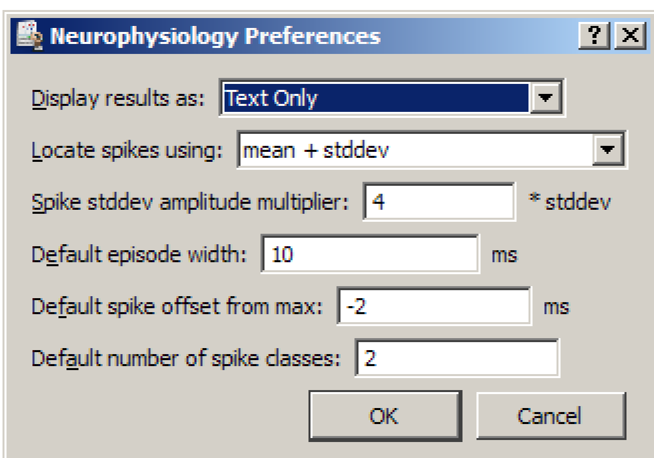
Set Episode Width and Offset



The first time spike detection is performed on a graph, the episode width and offset need to be entered. This width and offset is remembered and is used for all future spike detections in the graph performed by "Locate Spike Episodes" and other transformations. The width and offset that are entered are retained even if the file is saved and reopened.

Use this option to view or change the current width and offset.

Preferences



Preference	*Description*	*Default Setting*
Display results as:	Determines whether analysis results will be displayed as graph channels, textual tables in the journal, or Excel spreadsheets. Not all of the output types are applicable for each Neurophysiology analysis option.	Text output to journal only.

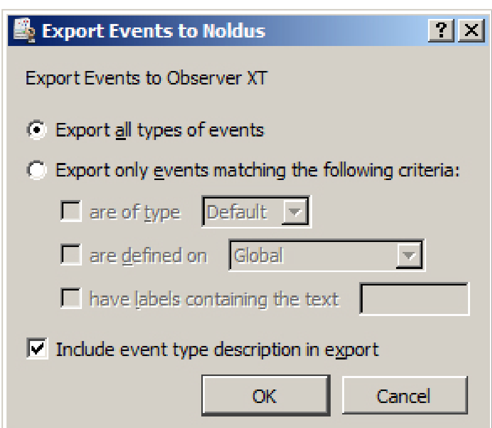
Preference	*Description*	*Default Setting*
Locate spikes using:	Choose how spikes are searched for in the signal. **Mean + Stddev**—uses fixed level peak detection with a level that is computed from the mean value plus a configurable number of standard deviations of the data. **Amplitude/Half-width Discriminator**—allows for basic isolation of spike shapes that have peak voltages within a configurable range and spike half-widths within a configurable range; uses the amplitude of the spike as well as the width of the spike to determine what constitutes a valid spike event. Half-width For a given spike, the discriminator searches from the maximum value of the spike to both the left and right of the maximum for the sample positions where the value has dropped below 50% of the maximum. The time interval between these sample positions is defined as the estimate of the half width. The acquisition sampling rate can be increased to improve accuracy of the spike half width estimates as neuron firing events involve high frequency components. Each time the discriminator is run, the user must input the amplitude low and high values as well as the minimum and maximum spike width. The discriminator searches for spikes in a signal x as follows: 1. Performs regular peak detection on x using a fixed threshold. This locates the local maxima occurring after each threshold crossing of the low amplitude area. This results in a sequence p of potential spike locations. 2. For each potential spike location p, computes the half-width time interval. $t_{half}(p) = t_{50r}(p) - t_{50l}(p)$ where t50r is the first time > p such that $x(t_{50r}) \leq 0.5\,x(p)$ t50l is the first time < p such that $x(t_{50l}) \leq 0.5\,x(p)$ Accepts the spike for each potential spike location p as a valid spike s if, where a is amplitude and t is time window: $a_{low} \leq x(p) \leq a_{high} \wedge t_{low} \leq t_{half}(p) \leq t_{high}$ For each valid spike location s, positions the spike episode start output at s+offset end output at s+offset+width The spike discriminator generates output only for spikes that fall within the bounds of the amplitude and offset windows. If a spike candidate falls outside the windows, no output is generated.	Mean + Stddev
Spike stddv amplitude multiplier:	Spikes are located in the signal by looking for locations where the signal deviates from its baseline by a certain number of standard deviations. This multiplier is set in this preference.	4 standard deviations

Preference	*Description*	*Default Setting*
Default Episode Width	The first time that any of the spike detection is run on a graph, the time width of each fixed width episode must be specified. This preference provides the default value that is seeded in the dialog. The episode width for an individual graph does not need to match this default.	10 ms
Default Episode Offset	Each fixed width episode is located around one of the spikes in the signal. The offset allows for the episode to begin before (or after) the spike threshold crossing so the leading edge of the spike can be captured. Negative numbers indicate episodes are to start before the spike threshold crossing, positive numbers indicate episodes that start after.	-2 ms
Default Number of Spike Classes	The Classify Spikes script requires the user to input the number of classes into which the spikes will be partitioned. This preference allows the default number to be modified. The number of classes that wind up being used does not need to match this default.	2

Noldus Format

Supports import and export of files in Noldus Observer format. Noldus is a popular Human Behavioral analysis software package and the Acq*Knowledge* Noldus feature allows behavioral markers to be imported from Noldus into Acq*Knowledge* and Acq*Knowledge* marker information to be exported into Noldus. The following options are available:

Export Events to Noldus XT



Acq*Knowledge* events can be exported to Noldus by “all types” or based upon selective criteria.

Import Markers from Noldus XT

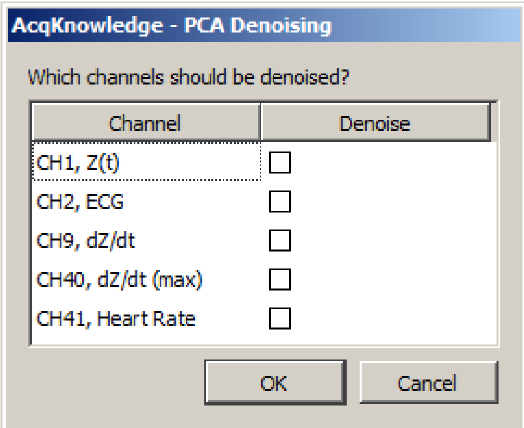
The Import markers feature will read the Noldus file data and define the events in the active Acq*Knowledge* graph. For each range of behavior, a pair of global markers will be added with labels correlating to the behavior type as well as the start of and end of the behavior.

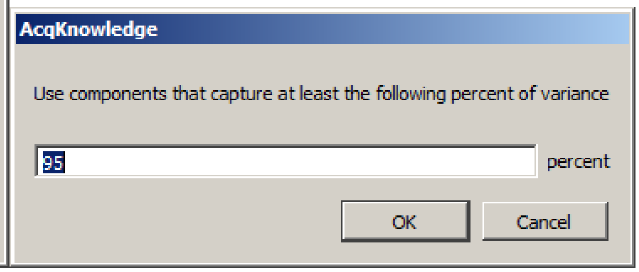
Import FaceReader Data

Launches a File Open dialog for importing data from tab-delimited FaceReader export files (*.txt format).

- Watch the Acq*Knowledge* Noldus Observer import and export video tutorial for a detailed demonstration of this feature.

Principal Component Denoising





Removes noise from certain types of signals. For principal component denoising to be effective, more than two signals should be used as sources and all source channels must have identical waveform sampling rates. PCA denoising is most effective on signals that are known to contain a high degree of similarity, such as multiple ECG leads or multiple EEG leads. PCA denoising should not be used on signals of different types or units as all of the principal components may be needed to fully capture the differences in the signals.

➲ To determine if PCA denoising will be effective on a particular set of data or to compute a appropriate variance percentage for denoising, examine the principal components directly with "Transform > Principal Component Analysis" before selecting this option.

Given a set of signals, a principal component analysis is performed. The strengths of the components are then analyzed, and the original signals are reconstructed from a subset of the principal components that capture a certain percentage of the total variance of the signals. This essentially eliminates one or more of the higher-order principal components. For certain types of signals, these principal components are the ones that model the noise inherent in the signals.

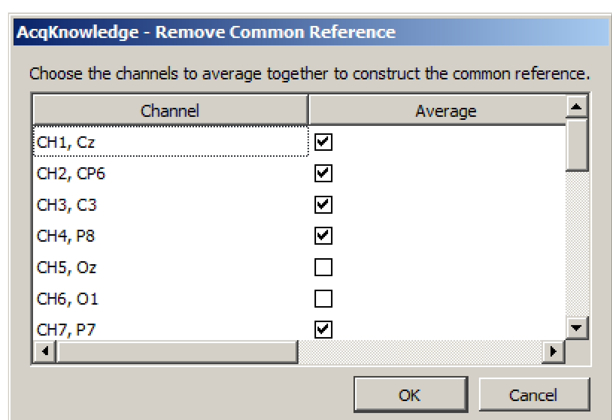
1. Check the "Denoise" column for the channels to be denoised.
2. Enter the overall percentage of the variance.
3. After the percentage is entered, the denoising process will begin.

Remove Common Reference Signal (for Mobita Hardware only)

Mobita hardware uses a common reference amplifier design with unipolar lead capture. With this type of amplifier design, there are common signals superimposed on all channels. When mixing unipolar and differential signals, the average of all of the unipolar signals must be subtracted from them in order to extract the unipolar signals. As this is a common operation for Mobita data processing a Specialized Analysis option has been created to make this process easier. (Note that this feature is only intended for use with Acq*Knowledge* data acquired with Mobita hardware.)

To remove the common reference signal, select the channels to be averaged and click OK. At each point, each signal will be replaced by its original value minus the average value of all selected channels.

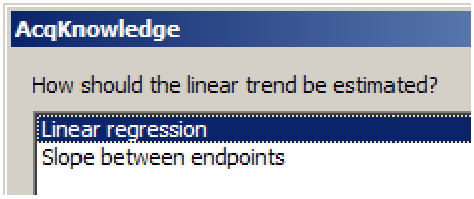
Note: This action cannot be undone, so is best performed on a copy of the original data, or the file should be saved under a different name after this action is performed.

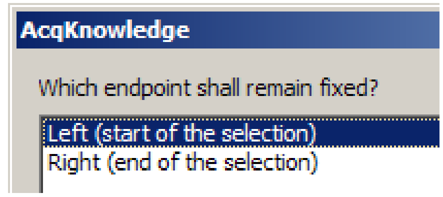


Remove Mean

Remove Mean allows for mean subtraction to be performed for the selected area (or entire wave if no data is selected). It will result in the mean value being the new zero value for the waveform.

Remove Trend





Remove Trend helps to remove baseline drift or other linear trends from data. This tool makes it easier to apply trend removal to only specific segments of a waveform. Given a selected segment of data, or an entire waveform, it computes the trend between the two endpoints (similar to the Slope measurement) and then removes this trend from the selected area such that the endpoints of the selection lie at the same voltage.

Linear Regression

Use linear regression to estimate the trend to be removed from the waveform.

Slope between endpoints

- **Left** keeps the starting point of the selection fixed at the same voltage. The software adjusts the data from left to right such that the right endpoint is aligned with the initial starting voltage.
- **Right** keeps the ending point of the selection fixed at the same voltage. The software adjusts the data from right to left such that the left endpoint is aligned with the initial ending voltage.

Respiration

***IMPORTANT*—Respiration analysis assumes a bidirectional airflow signal that records both inhale and exhale. Unidirectional respiration signals cannot be analyzed at this time.**

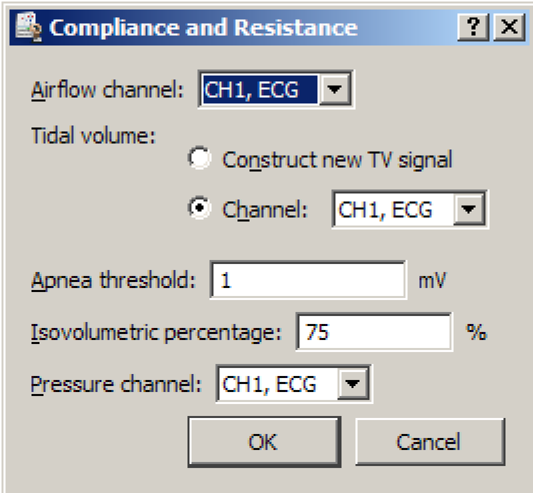
The respiration analysis package helps to analyze respiration- and airflow-related data. Other tools exist for respiration related analysis including Acq*Knowledge* transformations and the Respiratory Sinus Arrhythmia analysis in the Hemodynamics analysis package.

Compliance and Resistance

Compliance and Resistance analysis can be used to extract pulmonary resistance and pulmonary compliance in addition to basic airflow measures. This analysis requires an airflow signal and a pressure signal. The analysis will extract all of the measures of the Pulmonary Airflow analysis for the airflow signal. It also will locate apnea periods after exhalation using the same user-configurable threshold method as the Pulmonary Airflow analysis.

***IMPORTANT*— The flow signal must be recorded correctly for Compliance and Resistance analysis to work.** Compliance and Resistance analysis assumes positive flow indicates inhalation and negative flow indicates exhalation (the flow conventions of the recommended connections for a BIOPAC TSD107 pneumotach or a TSD117 airflow transducer).

- If the flow signal was recorded with exhalation positive instead of inhalation positive, multiply the flow signal by -1 to invert the signal.



Pulmonary resistance is computed using the isovolumetric method. On both sides of the tidal volume peak for a breath, the position where the volume reaches a user-specified percentage of the tidal volume is located. The pulmonary resistance is defined as the difference in pressure divided by the difference in flow at these two isovolumetric positions. Due to the discrete nature of sampled data, these points may not be exactly equal in volume. To improve the accuracy of the isovolumetric method, increase the sampling rate used to acquire data.

Dynamic pulmonary compliance is extracted on a breath-by-breath basis by dividing the tidal volume by the change in pressure between the exhale start and inhale start locations of the breath.

Individual breaths are defined as the period between consecutive Inhale Start events. Airflow units are assumed to be the standard liters/sec and pressure units mmHg. For each breath period, the analysis will define the following events:

- Inhale Start event on flow signal at start of inhale
- Exhale Start event on flow signal at start of exhale
- Apnea Start event on flow signal at beginning of apnea period (if present)
- Recovery events on volume signal at isovolumetric positions to left and right of tidal volume peak

If Inhale Start and Exhale Start events are already present on the flow signal at the start of analysis, those events will be used to define the breath periods. Apnea Start and Recovery events will always be regenerated by the analysis.

The analysis will extract the following measures from the data:

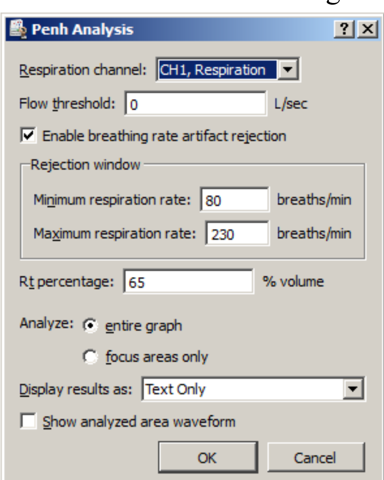
Name	***Abbrev.***	***Description***	***Units***
Cycle		Index of the breath in the data, beginning at 1.	
Time		Starting time of the inhale of the breath.	seconds
Peak Inspiratory Flow	PIF	Maximum absolute flow occurring during the inhale portion of the breath.	liters/sec
Peak Expiratory Flow	PEF	Maximum absolute flow occurring during the exhale portion of the breath.	liters/sec
Tidal volume	TV	Total volume of air inhaled during the breath.	liters
Minute volume	MV	Volume of air that would be inspired during a minute given the tidal volume and breathing rate of this breath. TV * BPM	liters/ minute
Breaths per minute	BPM	Breathing rate. $\frac{60}{TT}$	BPM

Name	*Abbrev.*	*Description*	*Units*
Inspiration time	IT	Time interval between the start of inhale and the start of exhale.	seconds
Exhalation time	ET	Time interval between the start of exhale and either: ● start of apnea (if apnea present) ● start of subsequent breath (if no apnea present)	seconds
Total breath time	TT	Time interval between the start of inhale and the start of inhale of the following breath. This is the sum of the inhalation time, exhalation time, and apnea time.	seconds
Apnea time	AT	Time after end of exhalation where the airflow signal remained within the apnea threshold defined at the start of the analysis.	seconds
Pulmonary resistance	RES	Change in pressure divided by change in flow at the isometric volume locations: $\frac{\Delta p}{\Delta f}$	mmHg/ (liters/ sec)
Pulmonary compliance	Cdyn	Tidal volume divided by the change in pressure between exhale and inhale locations in the breath: $\frac{TV}{\Delta p}$	liters/ mmHg

If text output is being generated, an additional row will be added containing the average values of the measures. Time and count are not output as waveforms in the graph since they can be found in the horizontal axis.

Penh Analysis

Penh Analysis script assumes standard recording methodology for a full body plethysmograph. Positive flow is treated as exhalation and negative flow is treated as inhalation.



Penh Analysis extracts measures from data recorded in a full body plethysmograph. It operates on a single channel of data recorded from an airflow transducer connected to the plethysmograph. The analysis takes a single parameter: the Rt percentage. This percentage is used to locate the plateau, or "pause," in the airflow signal. The pause begins at the time when the Rt percentage of the exhalation volume has been reached. The Rt percentage may be adjusted by the user and is set to a default of 65%. This analysis will place Inhale Start and Exhale Start events on the airflow signal. If these events are already present when the analysis starts, the user-defined inhale and exhale events will be used instead.

This allows for the analysis to be repeated after manual inspection and correction of inhale and exhale locations and allows for different methods to be used to define the breathing boundaries.

The following Penh Analysis options for enhancing data accuracy are also included:

Flow threshold – Using this setting allows breath detection to occur only when a subject's inspiratory flow exceeds a user-defined setting in units of liters per second. For example, if the threshold is set to 1.5 L/sec, the inspiratory flow must exceed 1.5 L/sec for each valid breath. If the setting is left at 0, all breath activity will be included in the output.

Breathing rate artifact rejection – Using this option will discard any respiration cycles that fall outside the boundaries of a user-defined minimum and maximum respiration rate. This is useful for eliminating unwanted signals resulting from small zero crossing spikes or other high frequency noise in the breath signal. This option is enabled by default and set to the average range of a mouse breathing rate.

Show analyzed area waveform – this option adds a new waveform to the graph indicating the time areas included in the analysis output. This analysis waveform can be useful for visually assessing the effectiveness of modifying the artifact rejection settings.

Penh analysis will place Recovery events on the airflow channel at the time positions where the corresponding percentage of the volume has been exhaled. The percentage used for the analysis is displayed in the label of the Recovery events.

For each exhalation period, the Penh Analysis will extract the following:

Name	***Abbrev.***	***Description***	***Units***
Cycle		Index of the exhalation cycle in the data, beginning at 1.	
Time		Starting time of the exhale for the cycle. This is the location of the Exhale Start event.	Seconds
Peak inspiratory flow	PIF	Maximum absolute airflow occurring in the inspiration cycle immediately preceding the exhalation cycle. This measure is recorded as an interval, so its value is always positive.	Airflow channel units
Peak expiratory flow	PEF	Maximum airflow during the exhalation cycle being examined.	Airflow channel units
Exhalation time	Te	Total time elapsed between the start of the exhalation cycle and the end. This is the time interval between the Exhale Start and following Inhale Start events.	Seconds
Relaxation time interval	Rt	Time required for the subject to exhale the specified percentage of the total exhaled air. This is the time interval between the Exhale Start and the subsequent Recovery event.	Seconds
Pause		Numerical factor describing the characteristics of the plateau at the end of the expiration cycle. Computed using the formula: $\frac{Te}{Rt} - 1$	

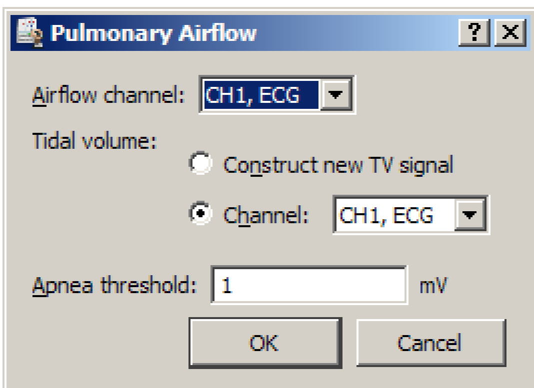
Name	*Abbrev.*	*Description*	*Units*
Enhanced pause	Penh	Pause scaled to be relative to the strength of the inhale and exhale. This helps take breathing variability into account. Computed using the following formula: $\frac{PEF}{PIF} * Pause$	

The Penh analysis excludes the following exhale cycles from the analysis:

- Exhale cycles that do not have a preceding inhale (may occur for partial cycles at the start of the data recording).
- Exhale cycles that do not have a corresponding recovery time (often occurs during apnea).
- Cycles that fall outside the boundaries of the selected flow threshold and artifact rejection parameters.

In addition, during periods of apnea, the analysis may produce invalid results, such as zero width recovery times. These results may be excluded from the analysis by either using waveform editing to remove apnea periods, discarding all events during apnea periods and rerunning the analysis, or deleting the corresponding rows from the Excel output.

Pulmonary Airflow



The Pulmonary Airflow analysis follows the flow conventions of the recommended BIOPAC connections for a TSD107 pneumotach or a TSD117 airflow transducer. Positive flow is assumed to indicate inhalation; negative flow is assumed to indicate exhalation.

The Pulmonary Airflow analysis extracts basic parameters from a calibrated airflow signal, such as would be recorded using a pneumotach or airflow transducer. In addition to inspiration and expiration, Pulmonary Airflow also can be used to examine apnea. Apnea is defined in this analysis as pauses in breathing that occur after an exhalation.

When performing the analysis, an airflow signal f is chosen. An apnea threshold a_f is also entered. Inhalation is defined to begin at the point where $f > a_f$. Exhalation is defined to begin at the point where $f < -a_f$. Apnea is defined to be the period between exhalation and inhalation where the flow lies within the apnea threshold: $f \in \left[-a_f, a_f\right]$. At least two consecutive samples must occur within the apnea threshold for a period of apnea to be defined. This allows for valid transitions from exhalation to inhalation to occur even if one of the samples in the transition happens to fall within the apnea threshold due to sampling.

The Pulmonary Airflow analysis will generate a tidal volume waveform if it is not present in the graph. It also will add Inspire Start and Expire Start events on the airflow signal if they are not present. New Apnea Start events will be defined each time the analysis is performed.

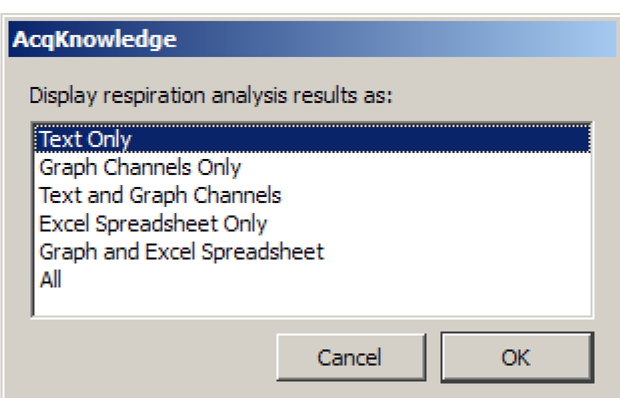
Individual breaths are defined as the period between consecutive Inhale Start events. Airflow units are assumed to be the standard liters/sec.

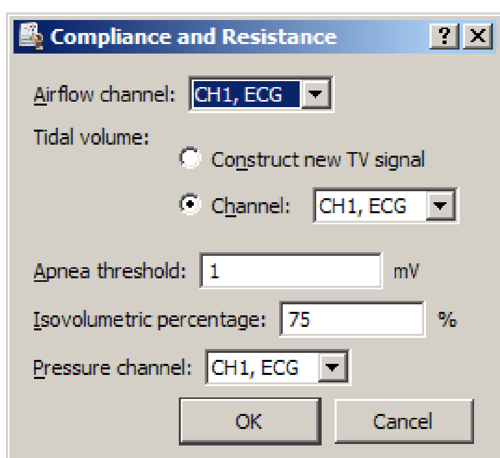
For each breath period, the analysis will extract the following:

Name	*Abbrev*	*Description*	*Units*
Cycle		Index of the breath in the data, beginning at 1.	
Time		Starting time of the inhale of the breath.	seconds
Peak Inspiratory Flow	PIF	Maximum absolute flow occurring during the inhale portion of the breath.	liters / sec
Peak Expiratory Flow	PEF	Maximum absolute flow occurring during the exhale portion of the breath.	liters / sec
Tidal volume	TV	Total volume of air inhaled during the breath.	liters
Minute volume	MV	Volume of air that would be inspired during a minute given the tidal volume and breathing rate of this breath. $TV * BPM$	liters / minute
Breaths per minute	BPM	Breathing rate for the breath. $\frac{60}{TT}$	BPM
Inspiration time	IT	Time interval between the start of inhale and the start of exhale in the breath.	seconds
Exhalation time	ET	Time interval between the start of exhale and either: ● start of apnea (if apnea present) ● start of subsequent breath (if no apnea present)	seconds
Total breath time	TT	Time interval between the start of inhale and the start of inhale of the following breath. This is the sum of the inhalation time, exhalation time, and apnea time.	seconds
Apnea time	AT	Time after end of exhalation where the airflow signal remained within the apnea threshold defined at the start of the analysis.	seconds

If text output is being generated, an additional row will be added containing the average values of the measures. Time and count are not output as waveforms in the graph as they can be found from the horizontal axis.

Preferences





Spectral Subtraction

Spectral subtraction is a denoising technique that operates on data projected into the frequency domain. It is frequently used in speech analysis denoising applications. Spectral subtraction examines a reference noise signal and performs a Fourier transform to get the noise frequency distribution. To denoise a signal, the Fourier transform of the signal is performed. The noise estimate frequency distribution is then subtracted from the source signal. The resulting processed spectrum with the noise frequencies removed is then reconstructed into a time domain signal using the inverse Fourier transform.

Spectral subtraction performs noise removal on the entire channel in a single Fourier transformation, which allows for denoising where the noise is stationary; there is no provision for sliding window spectral subtraction at this time.

The spectral subtraction is performed using a formula with two adjustable parameters. Given a frequency spectrum F_{noise} and a mixed signal F_{mix}, the denoised frequency spectrum is computed using the following formula:

$$F_{denoise} = \left[F_{mix}^{\gamma} - \alpha F_{noise}^{\gamma} \right]^{\frac{1}{\gamma}}$$

where

Alpha is the “scaling factor” and can be used to adjust the strength of the noise estimate.

Gamma (γ) is the “power factor” and can be used to vary how the noise is removed.

$\gamma = 1$ allows for pure subtraction

$\gamma = 2$ allows for Euclidean distance formulas

and so on

$F_{denoise}$ that is less than zero is discarded and replaced by zero to maintain a valid set of Fourier coefficients for the reconstruction.

When spectral subtraction is being used in practice, the noise signal may not always match the length of the signals to be denoised. To define the subtraction formula, the spectrum of the noise must have the same number of points as the spectrum to be denoised. If there is a length mismatch, the noise spectrum is resampled automatically to match the length of the spectrum to be denoised. Cubic spline interpolation is used during the resampling to provide a better estimate of the overall noise spectrum.

Stim-Response

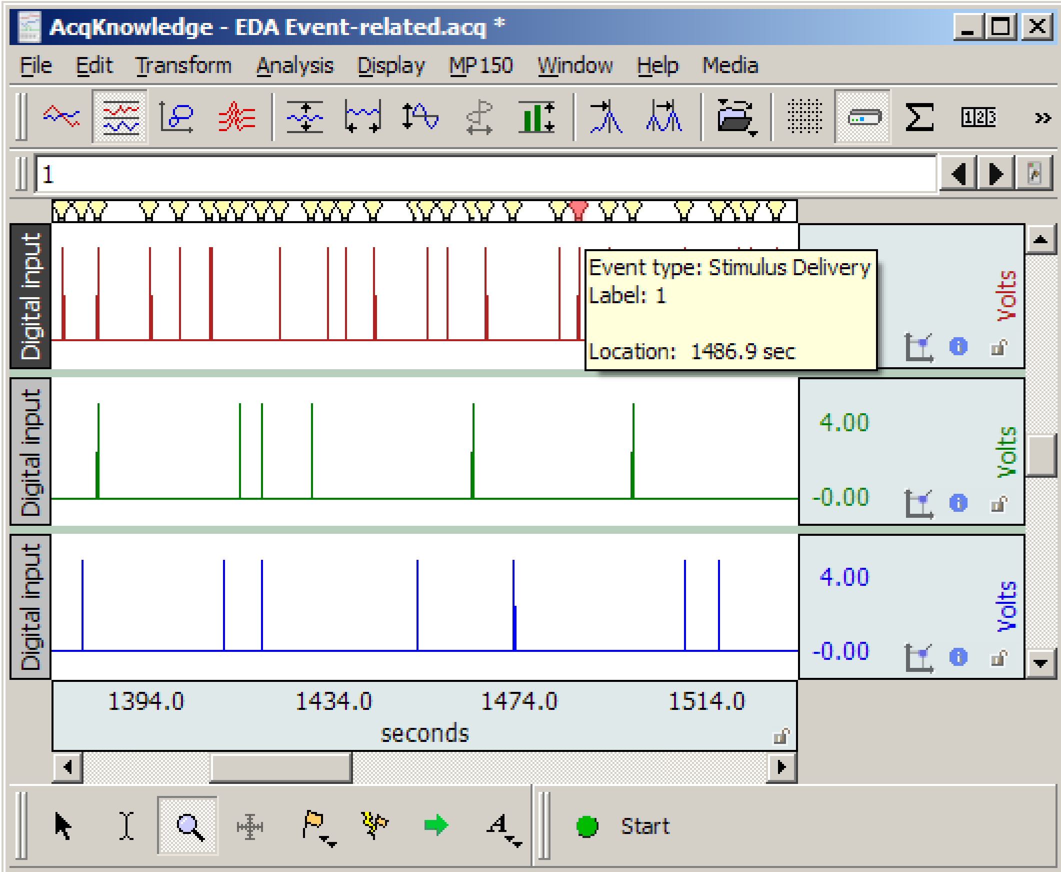
The Stim-Response analysis package can aid in analysis of stimulus-response studies. It allows for measurements to be extracted in tabular format for multiple stimulus classes. Stim-response configuration enhancements in

- Measurement configuration is preserved across launches of the application.
- Measurement presets may be accessed directly from the specialized analysis routine.
- Additional checking for invalid channels and measurement expressions that cannot be applied to the source data

The Event-related EDA Analysis routine uses the stimulus events to categorize specific and non-specific responses. Responses are matched to the appropriate stimulus events using a user defined time window. See the Electrodermal Activity EDA Event-related analysis section for further information.

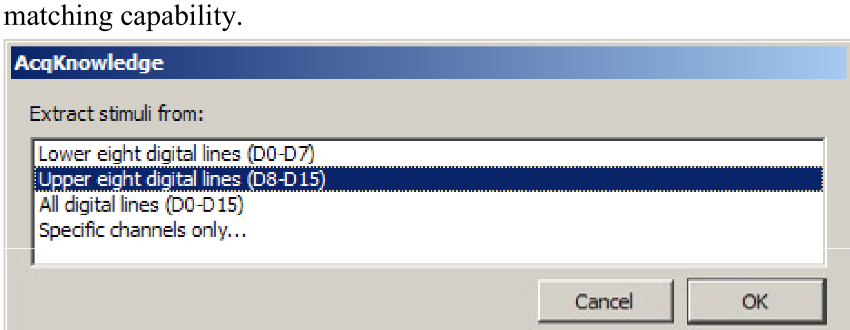
Digital Input to Stim Events

Digital Input to stim events identifies and labels stimulus events corresponding to any combination of digital inputs. A light bulb icon is placed in the global events bar, the event is labeled with the stimulus event type, and the mouse-over tag includes the event time. All event information is accessible and exportable from the Event Palette.

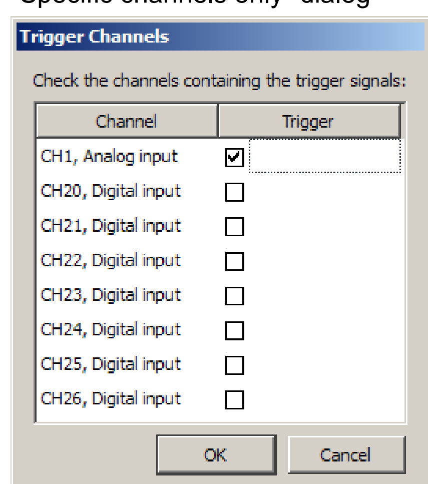


The Digital input to stim events function works with TTL trigger information coming from applications such as E-Prime®, SuperLab®, DirectRT®, MediaLab®, Inquisit®, and Presentation. It converts TTL data acquired on the digital channels of a hardware device into stimulus events. The system also works with analog and calculation channel signals coming from switch transducers. Unlike TTL signals, a voltage threshold level is used to determine the transition from low to high.

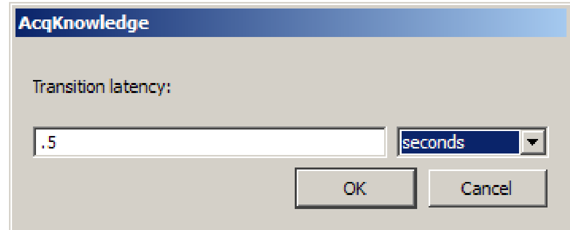
This analysis option converts TTL or switch data acquired on hardware into stimulus events. Stimulus delivery events are defined in the graph for each low to high transition of the digital data, the indications of stimulus delivery. The digital channels are interpreted as a binary number. Each stimulus event placed into the graph has the corresponding number included with its label. This allows further analysis to distinguish between different types of stimulus events by using the Cycle Detector’s label matching capability.



“Specific channels only” dialog

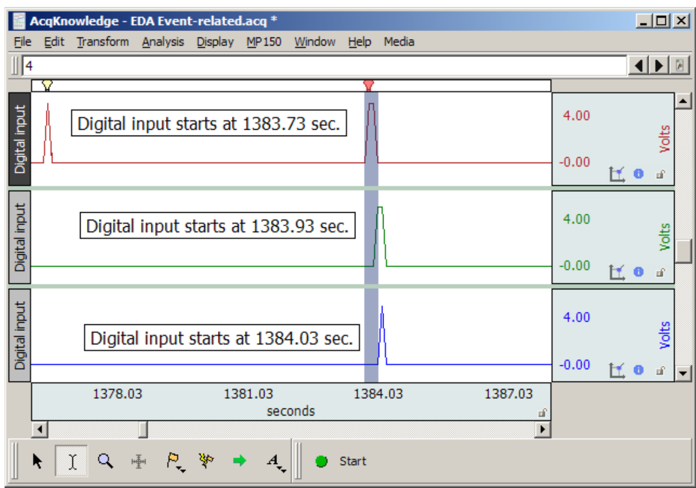


Digital line decoding can be two byte (using all 16 digital lines) or single byte (on either the low eight or high eight digital lines). Big endian bit and byte ordering are used, with digital line 0 representing the least significant bit.



When the stimulus labels are constructed, all numbers are zero-prefixed. All stimulus events will have the same number of base-10 digits with leading zeros, regardless of magnitude. This provides each stimulus event type with a unique label that can be used with the Cycle Detector (which uses substring matching).

Some systems that trigger digital lines such as parallel ports may not be able to do so instantaneously; they may require a time window before the transition from one state to another is fully complete. A "**transition latency**" time window can be given to the analysis, specified in microseconds, milliseconds, seconds, minutes, hours, or samples. If non zero, any transitions that are separated by less than this latency are treated as a single transition and only one stimulus event is inserted. The decoded value used for the transition is the maximum value observed during the transition latency window. In the following example graph, the three digital TTL inputs correspond to one event, as marked by the red icon in the global events bar. A transition latency of .5 seconds will consider all three as part of the same event since the transitions occur within .5 seconds of each other.



Watch the [Acq*Knowledge* Digital Input to Stim Events video tutorial] for a detailed demonstration of this feature.

Stim-Response Analysis

Stim-Response Analysis allows for extraction of measurements within fixed width intervals occurring at Stimulus Delivery events. Stimulus events must be present to perform this analysis. The Stimulus Delivery events may be defined either manually, with the Cycle Detector, or using the Digital Input to Stim Events analysis option. The information that can be extracted includes the majority of the measurements available from the graph window measurement toolbar, matching the Epoch Analysis options.

Unlike Epoch Analysis, the Stim-Response Analysis splits the analysis based upon the event labels. Stimulus Delivery events with different labels are interpreted as different stimulus types. Analysis results for each individual stimulus type are summarized in separate tables. Each independent text table has its own average of the measurements over that stimulus type.

Additional options are available for positioning the fixed width interval where measurements should be made:

- At each stimulus event – The measurement interval is aligned so the start of the measurement matches the time of the Stimulus Delivery event.
- At fixed interval offset before or after stimulus – The measurement interval begins a fixed amount of time either before (for pre-stim studies) or after the time of the Stimulus Delivery event. This allows measurements to be made at a time relative to each stimulus onset and may be useful for measurements focusing on a specific time range (e.g. P300).
- At matching response event – This option assumes that a second set of Response events have been defined for each stimulus either manually or using the Cycle Detector.
  Each Stimulus Delivery event is paired with the closest Response event occurring after it.

The fixed width measurement interval is aligned so the start of the measurement window is the time of this matching Response event.

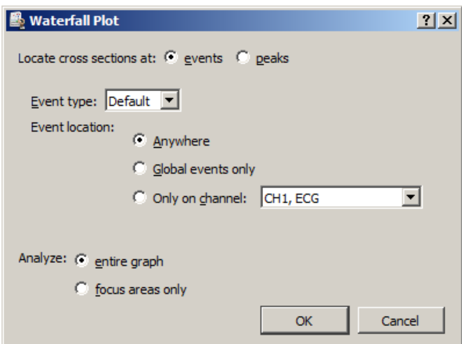
- To use the “at matching response event” window positioning option, Response events must be defined in the graph. Response events are in the “Stimulus/Response” event submenu. These events are *not* defined automatically.
  - Response events can be inserted manually into the graph using the Event tool.
  - Response events can be inserted using the event output of a data-driven Cycle Detector analysis.

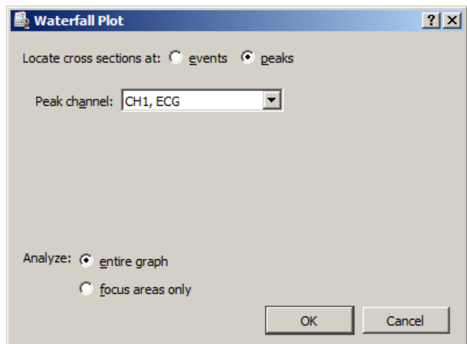
Note If EDA/SCR signals are being analyzed in response to stimulus delivery, also examine the “Event-related EDA Analysis” transformation located under Analysis > Electrodermal Activity.

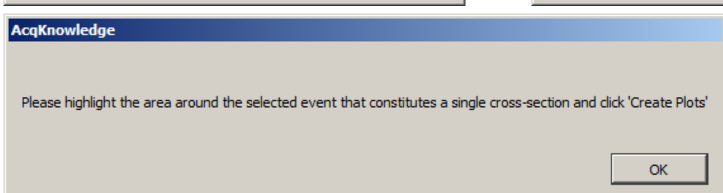
Watch the Acq*Knowledge* Stim-Response Analysis video tutorial for a detailed demonstration of this feature.

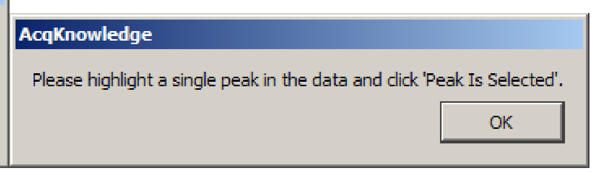
Waterfall Plot

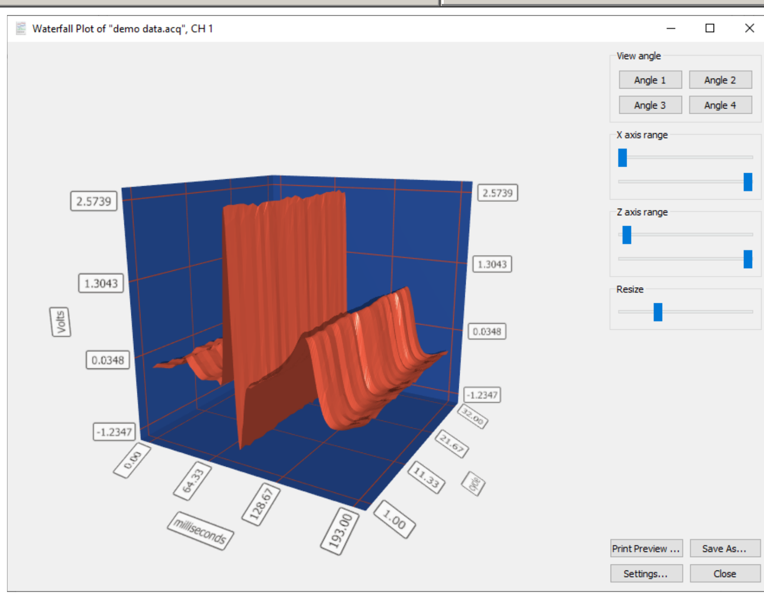
Assists in configuring the Peak Detector for 3D surface generation. 3D surfaces showing cycle-by-cycle graph data are commonly known as *waterfall plots*. Cycles are located in the graph using the same sequence of steps as the Ensemble Average transformation script, and cross sections for the plots can be selected on the basis of events or peaks (see figures below). Instead of generating an averaged graph, however, a number of 3D surfaces are rendered is a separate plot window. One surface is generated for each selected graph channel.





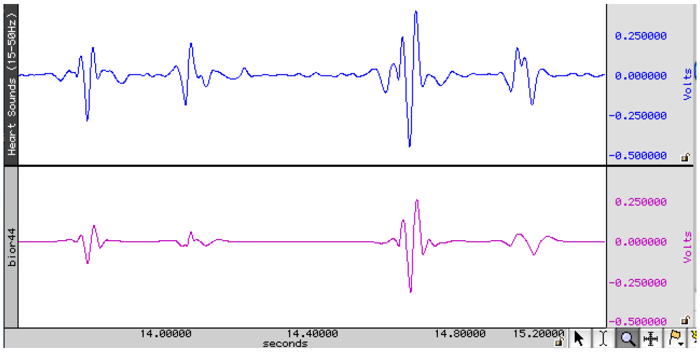






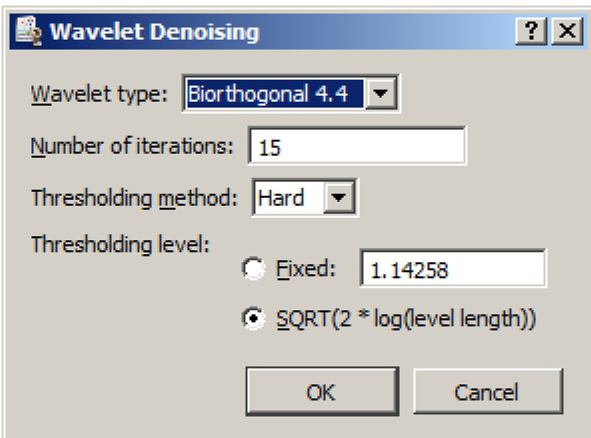
NOTE: Controls for viewing and manipulating the Waterfall Plot are identical to those used in the **Find Cycle 3D Surface View** described on page 383. Refer to that section for full descriptions of of the Waterfall Plot view angles, X, Y, and Z-axis range, plot resizing, and additional settings such as font size and color.

Wavelet Denoising



Sample output

Wavelet Denoising applied to heart sounds data may help clarify S_1 and S_2, as shown:



Wavelet Denoising uses the forward and reverse wavelet analysis operations to project source data into the wavelet domain, modify the wavelet coefficients (called "shrinking" the coefficients), and then reconstruct the data from the modified coefficients. Wavelet Denoising allows for noise to be removed from a signal while minimizing effects on portions of the signal that strongly adhere to a wavelet's shape.

To perform wavelet denoising:

1. Choose the wavelet type to use for the denoising (Biorthogonal 4.4, Symlet 4, Coiflet 6, or Daubechies 8).

   Certain signals may work best with different wavelet types.
2. Enter the number of iterations to use in the wavelet decomposition.

   Different numbers of iterations will have different effects on the results.
3. Choose which type of thresholding should be used to shrink the wavelet coefficients.
   - Hard thresholding replaces coefficients below the threshold with zero while leaving all other coefficients unmodified.
   - Soft thresholding zeroes out coefficients below the threshold and subtracts the threshold for coefficients that are above it.

   Soft thresholding may be useful for reducing edge effects, but hard thresholding will affect amplitudes less.
4. Choose the threshold level to use for shrinkage.
   - Fixed threshold for all levels. If a fixed threshold is selected, an additional window will appear into which the threshold can be entered.
   - Adaptive threshold level based on the number of coefficients in the DWT iteration (a VIS shrink procedure).

ECG Analysis Algorithm References

Acq*Knowledge* 4 software implements the open source ecgpuwave ECG boundary location software and the open source OSEA QRS detector and beat classification library for ECG analysis.

Automated ECG Waveform Boundary Location

➲ ecgpuwave ECG boundary location software

Acq*Knowledge* incorporates the ecgpuwave ECG boundary location software. Ecgpuwave is an implementation of a waveform boundary detection algorithm primarily developed by Pablo Laguna at the University of Zaragoza in Spain. This algorithm incorporates a variant of the Tompkins QRS detector, but contains additional rules that allow it to automatically extract the following characteristics of an ECG signal on a cycle by cycle basis: onset of P, P peak, end of P, onset of QRS, peak of QRS, end of QRS, onset of T, peak of T, and end of T.

NOTE: The algorithm was developed and tested primarily with data sampled at 1000 samples per second. The filters incorporated by the algorithm were designed for such data. If the algorithm is presented with data acquired at other sample rates, localization of ECG features or even entire cardiac cycles may not be optimal. Consider resampling data acquired at other rates to improve accuracy.

The algorithm is tuned to human ECGs through comparison with manual classification. Particularly, it seems to be within the standard deviation of human examiners for the onset and end of T waves, a particularly difficult feature to extract from an ECG complex. It also has the ability to take multiple ECG leads into account to reduce errors and misclassifications and appears to function for one to twelve lead ECGs. The algorithm is well documented in a number of papers. This algorithm development was sponsored by several government agencies including CICYT in Spain and the NIH.

The ecgpuwave tool is distributed from the PhysioNet NIH servers (http://www.physionet.org). This is a tool written in Fortran that will read WFDB formatted files. It will then output a series of annotations in WFDB format indicating the locations of the various ECG complexes within each cycle. It also depends on another tool, sortann (available from PhysioNet), to perform post-processing. This software reads and writes PhysioBank formatted files.

Acq*Knowledge* can automate the process of running ecgpuwave on source data and import its output back into Acq*Knowledge*. To run ecgpuwave on an ECG signal from within Acq*Knowledge*, select the ECG channel as the active channel and then choose “Analysis > Locate Human ECG Complex Boundaries”*. Acq*Knowledge* will execute ecgpuwave on that signal and read in its waveform boundary location output, placing events on the channel. This output will only be visible when events are shown.

Alternatively, save the file to PhysioBank format, run ecgpuwave manually from a Terminal, save the annotations to “atruth” and then reopen that PhysioBank file to see the ecgpuwave results. This is the same process that Acq*Knowledge* performs.

Ecgpuwave may be usefully applied to ECG data from non-human animals when the morphology of the animal ECG waveform is similar to that of human data. Two problems arise when attempting such an application. One is that mice, frequently used subjects, have ECG waveforms that typically lack a T wave.

The second is that the ecgpuwave algorithm incorporates artifact rejection based on heart rate. Small animals have much higher heart rates than humans, so the algorithm would reject such data as being purely artifactual. To deal with the first problem, "Locate Animal ECG Complex Boundaries..." by default does not output event marks for T-waves. A checkbox enables T-wave annotation for animals that do have ECGs with T waves.

For the second problem, an artificial sample rate is passed to the software so that the computed heart rate falls within human norms. An edit box allows the user to specify the average heart rate in the animal data. The default value is 600. The artificial sample rate is computed such that the average heart rate computed by that sample rate is 60 beats per minute. If data are acquired, for instance, at 2000 samples per second and the user specified the animal's average heart rate was 600 bpm, the ecgpuwave algorithm would be applied as though the data were acquired at 200 samples per second. Aside from that, the raw data are passed to the algorithm unmodified.

OSEA QRS Detector

➲ OSEA QRS detector and beat classification library

Since the release of software version 3.9, Acq*Knowledge* incorporates the open source OSEA QRS detector and beat classification library.

The OSEA library is a set of routines provided by EP Limited (http://www.eplimited.com). This C++ based software library provides robust QRS complex detection and rudimentary beat classification. This library is well documented and tested. The QRS detector uses a standard Tompkins-based filtering and derivative detection algorithm and has been in development since about 1985; the beat classifier development began in 1997. This algorithm development is sponsored by the NIH.

This algorithm is fairly robust against arrhythmias, baseline drifts, discontinuities, and other artifacts in the ECG signal. It achieves a 90% success rate on identifying QRS complexes on sample arrhythmia databases. The algorithm is tuned to human ECGs.

The QRS detector is optimized for 200 Hz sampled data. If the sampling rate is lower or higher, data will be internally resampled to 200 Hz before processing. The sampling rate difference may result in slightly different placement of beat events for different sampling rates.

QRS detection can be performed by selecting the desired channel of ECG data and choosing Transform > Specialized Analysis > Detect and classify beats. Acq*Knowledge* will execute the OSEA beat detector on the source data and output a sequence of events on that channel of ECG data. This output will only be visible if events are shown.

Source code for the QRS detector is released under an LGPL license and can be downloaded as a Zip file here.

Open Source Licensing

The ecgpuwave and OSEA algorithms are available as open source, which means that their source code is publicly available. The source code can only be used, however, under conditions of their licenses.

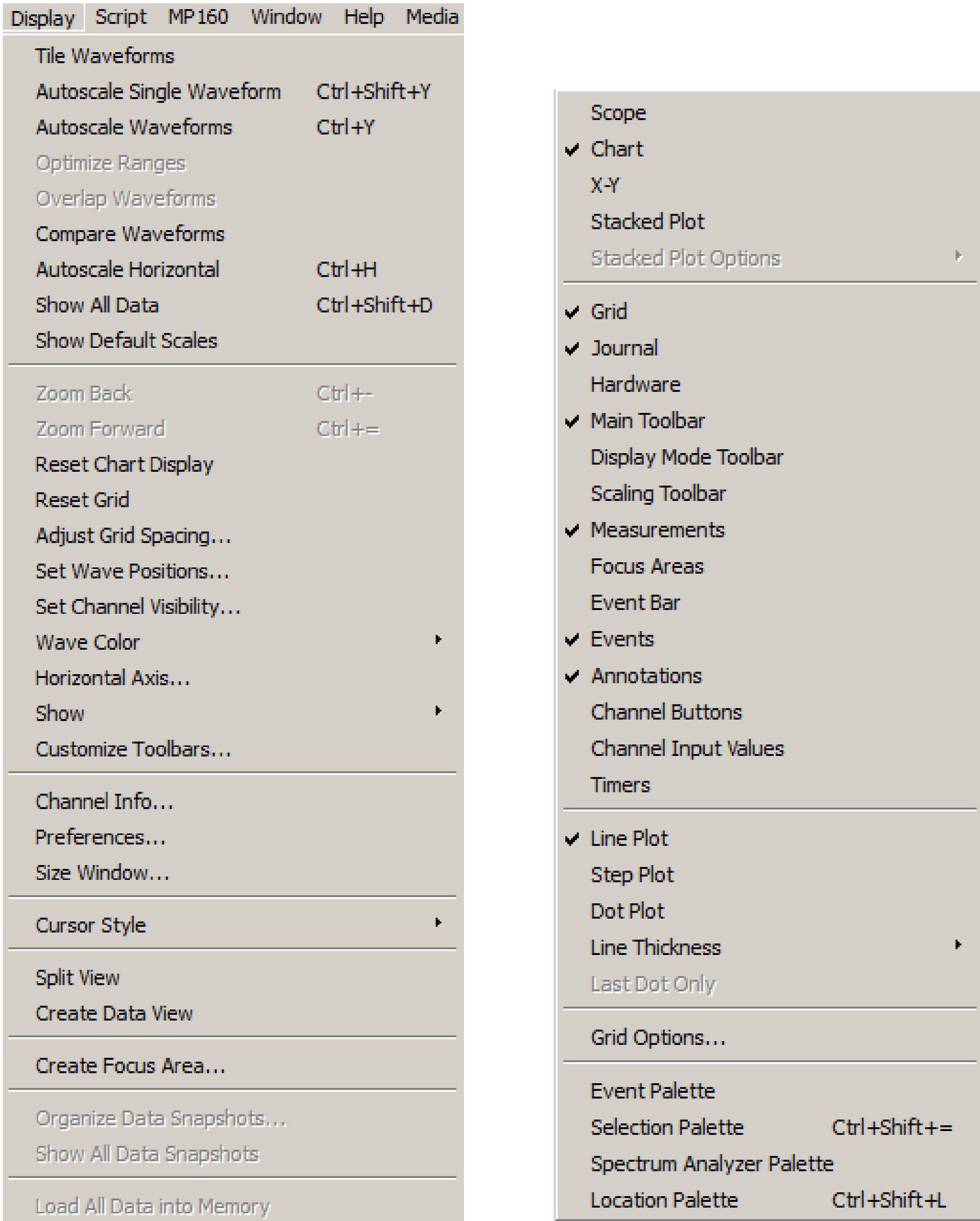
- ecgpuwave is under the GPL license
- OSEA is under the LGPL license

For the full text of both licenses, visit the Free Software Foundation (http://www.fsf.org).

Chapter 18 Display Menu Commands

Overview

The Display menu includes a number of features that control how the waveforms appear on the screen and how much data is displayed at a time.



Display menu and Show sub-menu

Although most of these options change the appearance of the data, they do not modify the data itself.

See the following shortcut options for Display menu commands:

- Toolbar shortcuts, page 60
- Context-sensitive shortcuts—page 73

Tile Waveforms

Tiling is an operation performed on all waveforms to visually separate them on the screen. Tile Waveforms adjusts the vertical offset to center waveforms in the display; if there are multiple waveforms displayed in chart mode, the waveforms will be centered in their "tracks." Tiling does not adjust the scale of the waveforms; it only affects the midpoints of the visible portion of the waveform. Tiling does not affect the vertical scale factor previously set for each channel (whereas Autoscale may affect the vertical scale factor as well as the offset).

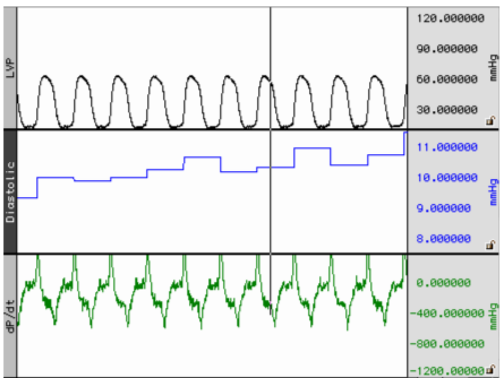
In Scope mode:

- Tiling staggers the midpoint of the channels to visually separate them on the screen while maintaining their scales.
- Waveforms are spaced evenly along the vertical axis of the screen, and each waveform is centered vertically in its division.

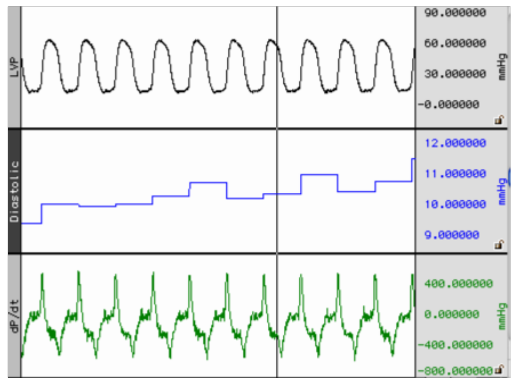
To apply tiling only to the selected waveform, hold down the CTRL key on Windows or the Option key on Mac OS before selecting Tile Waveforms.

When grids are locked, tiling will retain the appropriate heights and percentages.

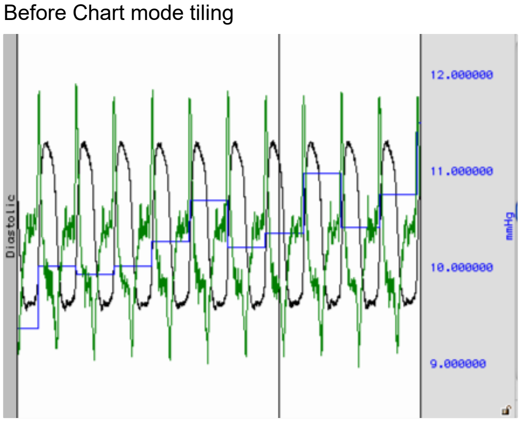
When grids are unlocked, the scale may be slightly larger in order to optimize the tick marks displayed on the vertical axis.



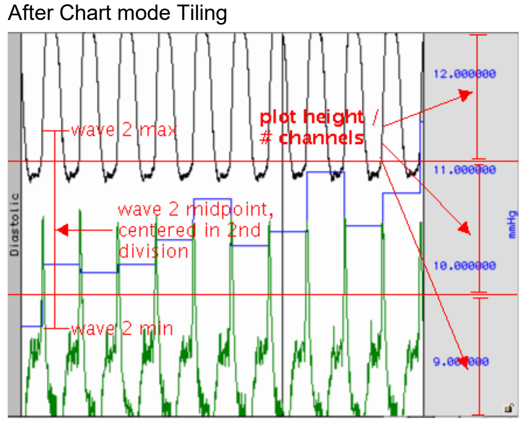
Before Chart mode tiling



After Chart mode Tiling



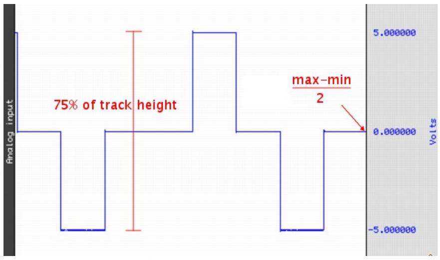
Before Scope mode tiling



After Scope mode Tiling (red lines for illustration only)

Note that the waveforms are centered relative to the horizontal divisions of the plotting area; the range and midpoint of the second waveform (blue square wave) are indicated in the figure above.

Autoscale Waveforms



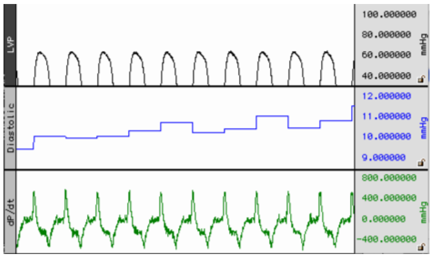
The primary use of Autoscale is to make all of the data of the channel within the current time range visible on the screen.

When Autoscale Waveforms is selected, Acq*Knowledge* determines what the “best fit” is for each displayed waveform. The percentages and midpoints are identical whether grids are locked or unlocked.

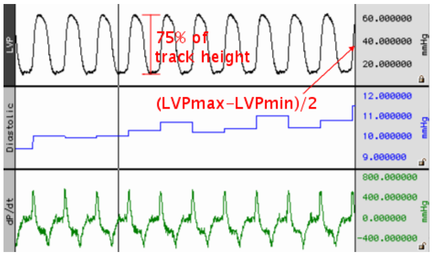
The software adjusts the vertical offset so that each channel is centered in the window (or within the channel track in chart mode) and adjusts the units per division on the vertical axis so that the waveform fills approximately two-thirds of the available area. In chart mode, the waveforms are autoscaled to fit their sections. In scope mode, the screen is evenly divided into horizontal “bands” and each waveform is scaled to fit the division without overlapping.

➲ The autoscaling algorithm for Chart mode and X/Y mode is:

1. Find maximum value of the channel in the time area, *max*.
2. Find minimum value of the channel in the time area, *min*.
3. If grids are locked, adjust scale such that *max-min* occupies 75% of the channel's track in Chart mode, or 75% of the entire plotting area X/Y mode.
4. Adjust the midpoint so (*max-min*)/2 is at the vertical center of the channel's track in Chart mode, or vertical center of the entire plotting area in Scope and X/Y modes.



Before autoscaling LVP channel



After autoscaling LVP (red lines for illustration only)

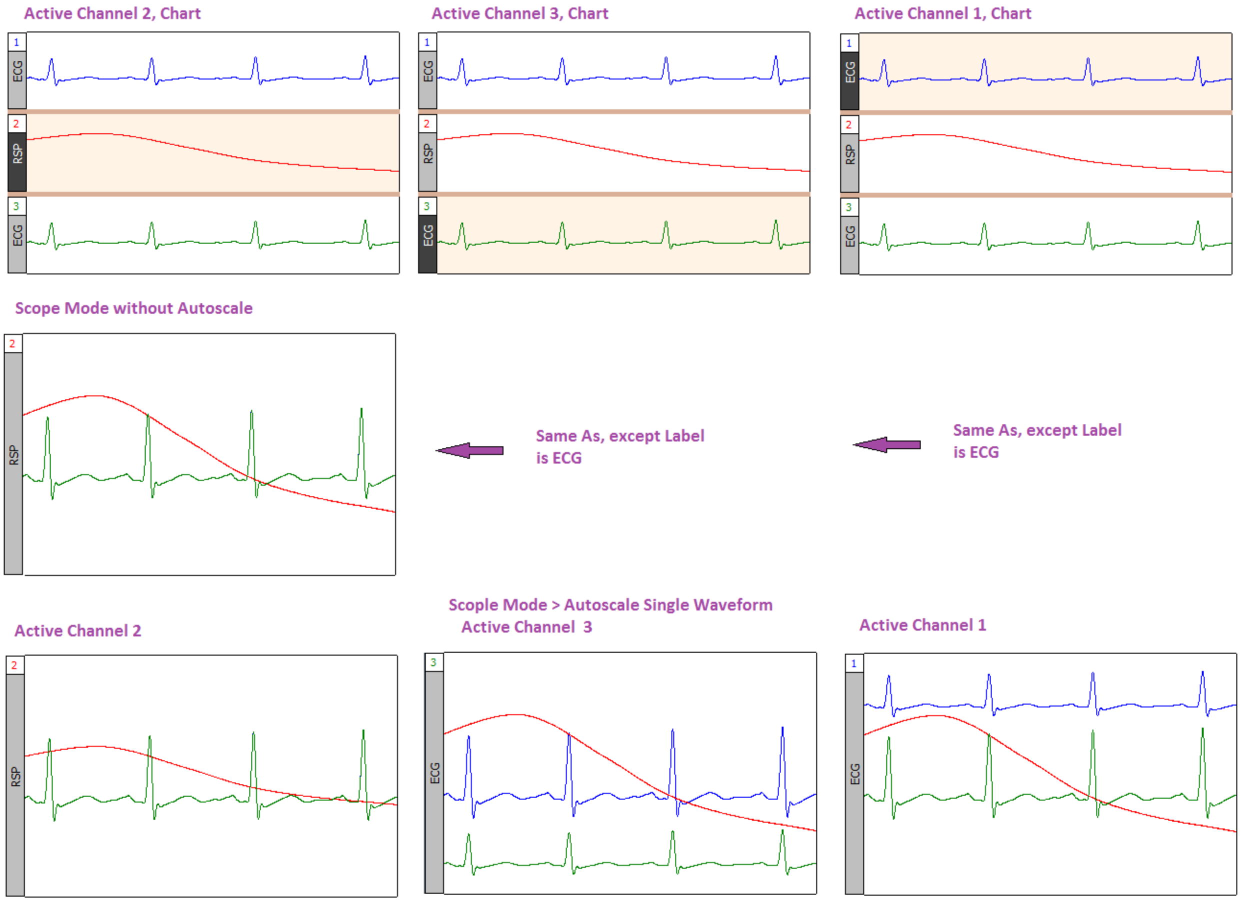
➲ The autoscaling algorithm for Scope mode is:

1. Divide the plot height into *m* equal sections of height *h* each.
2. Assign each visible channel to one of these plot sections.
3. If grids are locked, Scale the waveform such that the range between the max and min values will occupy 75% of *h*.
4. Place the midpoint between the max and min at the center of the waveform's section.

   In scope mode, the screen is evenly divided into horizontal “bands” and each waveform is scaled to fit the division without overlapping.

   Note: Autoscaling a single channel in Scope mode results in that channel occupying 1 / (num_visible_channels) of the overall waveform plotting area. It will be placed in the region of the graph that corresponds to its position in Chart mode.

   See following page for examples of autoscaling in Chart and Scope modes.



Autoscale Single Waveform

Use this option to perform the above autoscaling operations on a single selected channel rather than on the entire graph.

Optimize Ranges (MP36R Hardware only)

When Optimize Ranges is selected, the Vertical Scales will be automatically adjusted for all channels that have a Range Guide (green band) showing, such that the range limits are set to the upper and lower viewable limits of the Vertical Scales. This allows the total Range of each input channel to be displayed. This menu item is active when data is present AND at least one data channel has an active Range Guide.

This item is also selectable using the toolbar icon  or the right-click mouse shortcut. When selected with the icon or the right-click, this item only optimizes the Range Guide of the active channel. To optimize the ranges for all channels using this toolbar button, hold down the Ctrl or Alt key while clicking it.

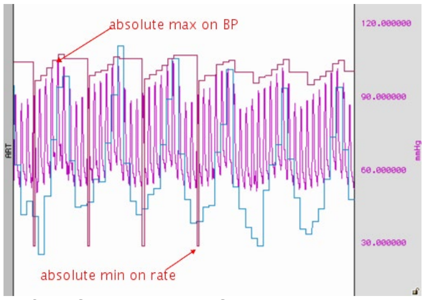
Note: The Range Guide is the green vertical band that appears in the Vertical Scale region for analog input channels only (not for duplicated, copied/pasted, or Calculation channels); see page 81.

Optimize Ranges and Range Guide are not available in MP160 or MP150 hardware.

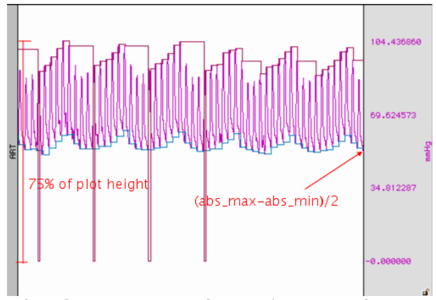
Overlap Waveforms

Overlapping waveforms places all of the waveforms at the same scale and midpoint so that the plotting location of a specific voltage on screen is at the same spot for every channel. Overlapping is useful for examining closely associated waveforms, such as the calculated diastolic, systolic and mean calculation channels “overlapped” with the raw blood pressure waveform from a continuous blood pressure signal.

In scope mode, when Overlap Waveforms is selected, the waveforms are “overlapped” into one screen. All of the currently displayed waveforms are arranged in the graph window with the same vertical scale and offset so all the displayed waveforms will fit on the graph; their magnitude reflects their size relative to the other waveforms. The overall chosen scale for all the displayed waveforms will be a function of the pk-pk value of the combined waves.



Before Overlapping in Scope mode

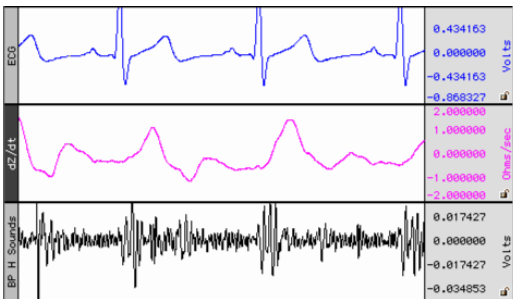


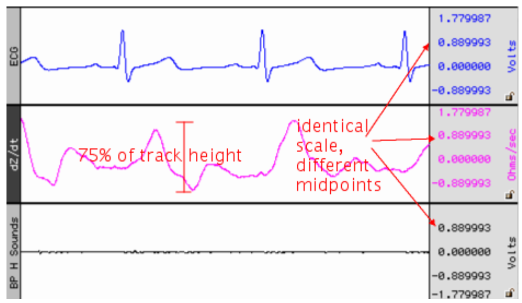
After Overlapping in Scope (red lines for illustration only)

Compare Waveforms

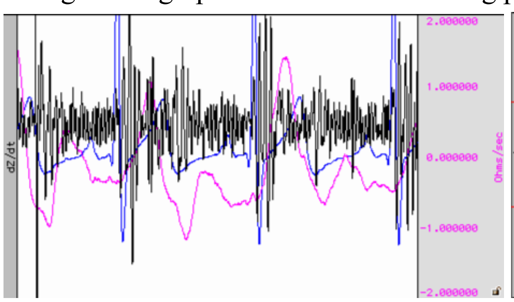
Compare Waveforms displays all of the channels with the same amplitude scale. Compare Waveforms automatically sets the vertical scale to be the same for all channels and adjusts each channel offset so that all displayed waves are centered in the display. The scale for all the displayed channels is determined by the channel with the largest pk-pk range in the display interval. Compare Waveforms is useful for gauging the relative amplitudes of a number of channels by placing them all on the same amplitude scale and discounting the effect of waveform offset (or baseline).

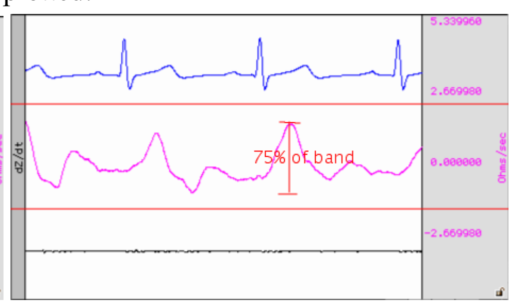
➲ In Chart mode, Compare Waveforms functions on each channel in its track.





➲ In Scope mode, the channel scaling is similar but disperses the channels through the plot area similar to tiling. For a graph with *m* channels being plotted:





Autoscale Horizontal

The Autoscale Horizontal command is a convenient way to display the entire data file (in terms of duration) on the screen. When this is selected, the display will be adjusted so that the duration of the entire waveform fits in the graph window. For long waveforms, this can take some time to redraw.

An Autoscale Horizontal function cannot be reversed with Edit > Undo. To revert to the previous display settings, use the Display > Zoom back command.

Show All Data

The Show All Data command enhances the view by autoscaling first horizontally, then applies an “autoscale all waveforms” operation. This enables all data vertical and horizontal data in the entire graph to be displayed for easy viewing.

Show Default Scales

This option will resets a graph’s vertical and horizontal scaling parameters to the default settings used when the graph was first opened.

Zoom Back / Forward

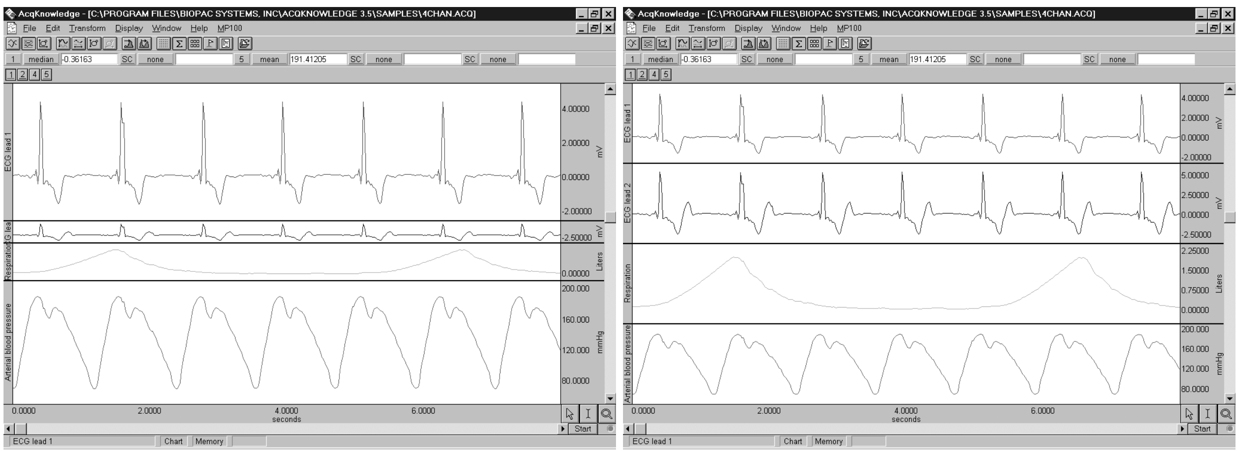
Zoom functions can affect the horizontal scale, the vertical scale, or both. Zoom restoration is functional for the Zoom tool, Autoscaling, and the Tile, Overlap, and Compare Waveform options. Zoom scales are stored until another zoom function is performed. Multiple levels of Zoom are supported.

- Zoom Back will restore settings one level at a time; This selection can be used to restore the original zoom scales. Essentially, Zoom back acts as an “undo” command for the zoom forward command and any other function that changes the amount of data displayed (either in terms of time or amplitude)
- Zoom Forward will redo a zoom function after it has been undone; repeat this selection to restore the latest zoom scales.

Zoom functions will work without limitation, until another Zoom is performed.

Reset Chart Display

The Reset Chart Display option redistributes the chart displays evenly after the boundaries have been changed so that each channel’s vertical size is the same. This function, which only works in *Chart Mode*, can be useful for expanding a display region for analysis and then returning to the original display.



Before Reset Chart Display …and after

Reset Grid

To return to the original grid, choose “Display > Reset Grid.” This will reconstruct the default, unlocked grid of four divisions per screen with solid light gray grid lines.

Adjust Grid Spacing

To modify the horizontal and/or vertical grid spacing, choose “Display > Adjust Grid Spacing.” This will generate a dialog for modifying the locked axes of the selected waveform. *See page 85 for details.*

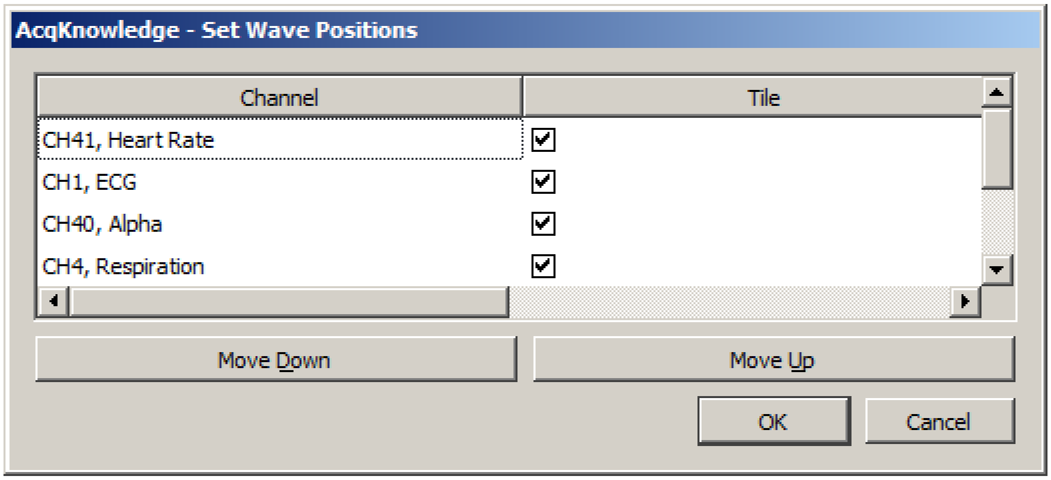
Set Wave Positions...

By default, channels are arranged on the screen based on their channel numbers, with the lower number channels being displayed at the top of the screen. The Set Wave Positions option allows waveforms to be placed in a user defined order.

- In chart mode this will result in vertical ordering of the individual waveforms.
- In scope mode this will result in vertical ordering of the individual waveforms after a tiling or autoscaling operation.

It’s also possible to set any waveform to ignore the autoscaling and tiling functions. This is useful for selectively applying autoscaling to certain graph channels of interest while omitting others.

The waveform positioning function is selected through the Set Wave Position in the Display menu. The following dialog will then appear, with a scrolling list of all stored channels:



If more channels are present than those displayed, scroll through the list by clicking on the vertical scroll bar at the right. The list will scroll when moving past the top or bottom and clicking and dragging the waveform positions.

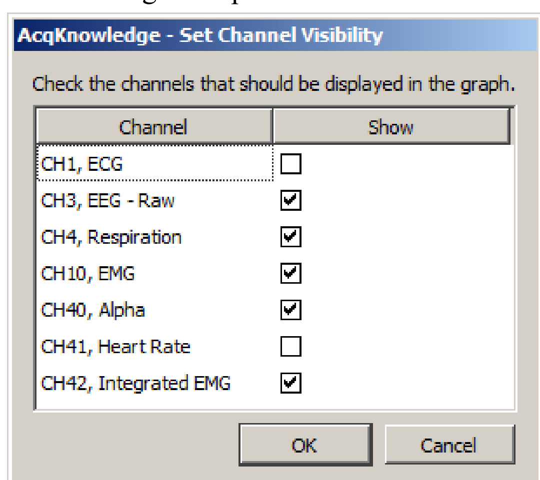
The "Tile" checkbox to the left of each channel enables tiling and autoscaling for each channel when checked. Click the checkbox to toggle the enable.

The on-screen position of the waveforms is the same as the ordering shown in the above dialog (from top to bottom). The waveforms can be repositioned by reordering the channel labels as they appear in this dialog. To change the order of any waveform, select the channel label (e.g., CH1, ECG) and then click the Move Down or Move Up button. Repeat this operation until the waveforms are in the desired order.

- Click OK to apply the selected order to the display screen.
- Click Cancel to revert all waveform positions to those set before the dialog was opened.

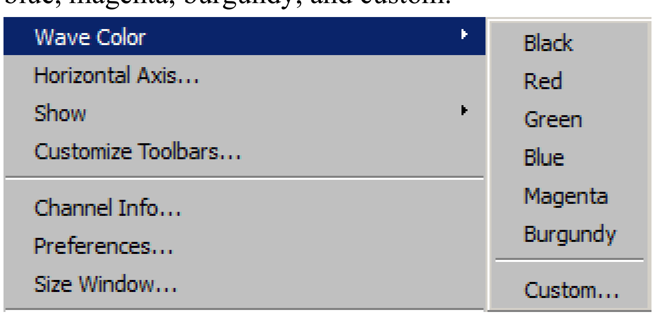
Set Channel Visibility

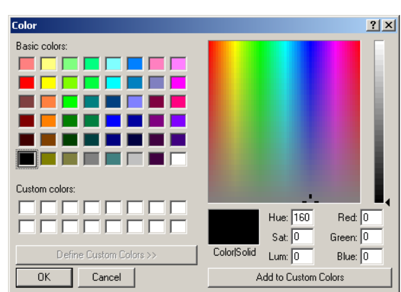
Set Channel Visibility offers an alternate means of showing and hiding channels. Simply check or uncheck the channel "Show" checkboxes to show or hide them. All channels can be shown or hidden simultaneously by holding down the Alt key while clicking the left mouse button. See also: Show/Hide Channels on page 95.



Wave Color

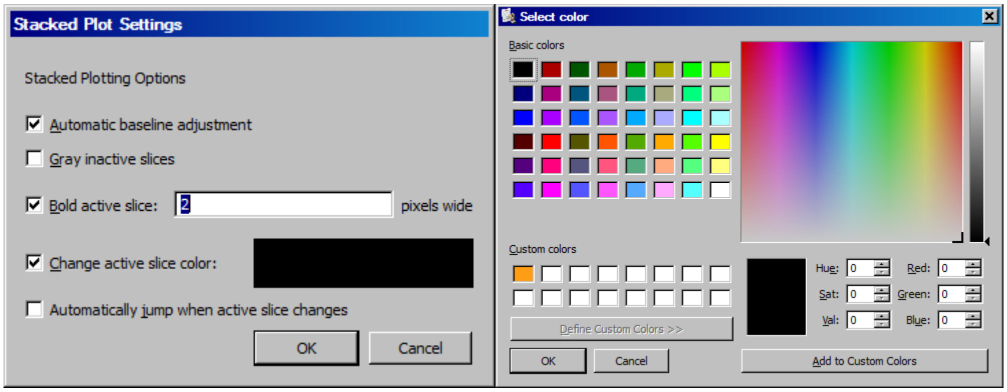
Select Display > Wave Color and then set the desired color of any waveform. In scope mode, the vertical scale, channel text, channel units and measurement popup menus take on the same color as the selected waveform. When adding new waveforms, Acq*Knowledge* assigns waveform colors in the following order: black, red, green, blue, magenta, burgundy, and custom.





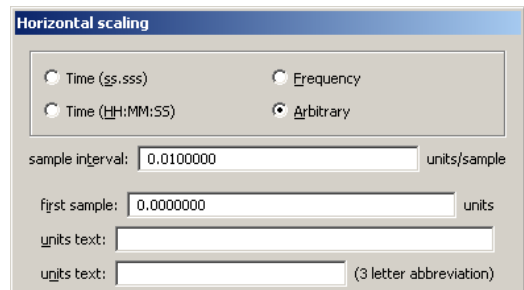
Or, click the right mouse button to bring up a menu, select Color, and then select the desired waveform color from the color palette menu.

Active Slice Color



To change thehe Active Slice Color in Stacked Plot mode (see page 38), use Display > Show > Active Slice and then select Drawing options.

Horizontal Axis

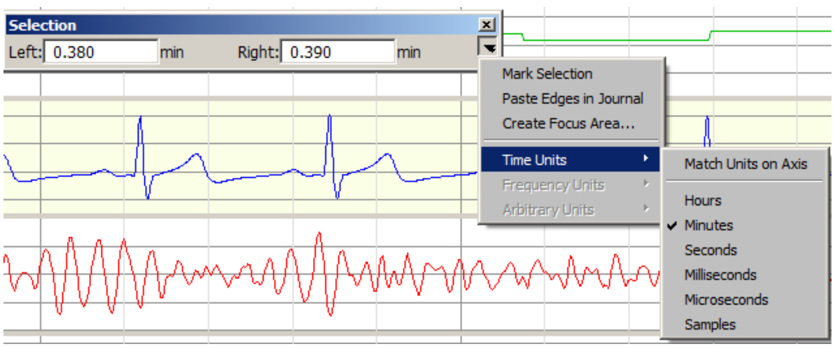


Horizontal Axis generates the Horizontal Scaling dialog. Set the axis in terms of time, frequency, or arbitrary units, and set the horizontal sample interval (the amount of time between two sample points) and the first sample (sample offset).

Time domain scaling has two options to store and display data:

- **(ss.sss)** —absolute seconds; the time scale for an event occurring 30 seconds into the record would be 30.00 seconds
- **(HH:MM:SS)** —hours:minutes:seconds; the time scale for the same event would be 00:00:30.

Set the Time Unit precision via Display > Show > Selection palette, then press Enter (return) to accept changes.



The **Frequency Units** option plots data from a Fourier analysis or other data with a frequency base (rather than a time base). This option is only available when frequency units are present in the graph. As with the time options, this feature is typically used for importing text files from other applications. For instance, when importing a text file with 1,000 sample points that covered a frequency range from 0 Hz to 100 Hz, set the interval to 1000 Hz/100 samples, or 0.1 Hz per sample in the box to the left of the interval text box. Similarly, if the frequency range was 20 Hz to 100 Hz, set the offset to 20 Hz. Arbitrary base units can also be attached to the data (rather than a time or frequency base When the horizontal axis corresponds to wavelength, and the data consists of 100 samples covering a range from 1 to 10 Angstroms, the interval should be 0.1 units per sample.

Arbitrary units are generally useful for changing the time base (or other horizontal scale) of data that has been imported into Acq*Knowledge* as a text file. For instance, to analyze data imported from a text file that contains 30 seconds of data that was collected at 100 samples per second (100 Hz), the first step would be to open the file (following the directions on page 289).

When arbitrary units are selected, two additional text boxes appear at the bottom of the dialog. The upper Units text box is used to provide a name for the horizontal scale units and the lower Units text box is used to provide an abbreviated label for the horizontal units.

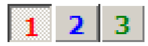
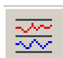
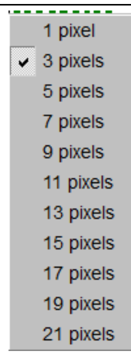
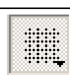
By default, Acq*Knowledge* assumes that the data was collected at 50 Hz, and would therefore plot the data so that a 60 second record was displayed that appeared to be collected at 50 samples per second. To change this to reflect the rate at which data was actually collected, change the sample interval box in the horizontal scaling dialog. When data are displayed on a 50 Hz time base, the sample interval will read 0.02 seconds per sample. This means that there is a 0.02-second "gap" between sample points in the record. To display data at 100 samples per second, change the interval to 0.01 seconds per sample.

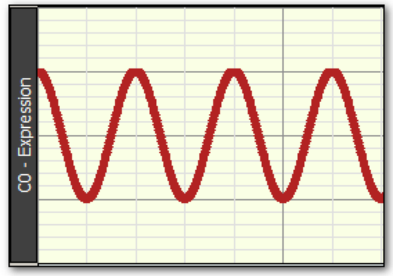
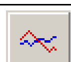
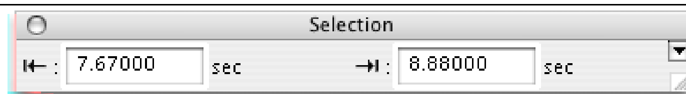
To determine the sample interval for other sampling intervals, divide 1 by the rate at which data was sampled (in terms of samples per second). Thus, a sampling rate of 0.5 Hz would translate into a sample interval of 2.00 seconds between samples, and data collected at 100,000 Hz (100 kHz) would have an interval between sample points of 0.00001000 seconds.

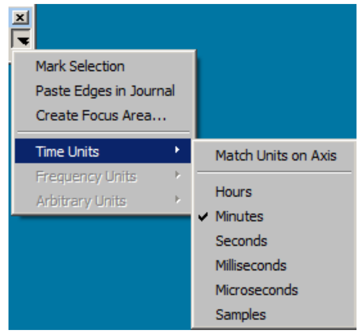
TIP: To confirm that Acq*Knowledge* is storing data in the same time base it was collected in, choose Channel Info from the Display menu. This will generate a dialog that describes (among other things) the sampling rate Acq*Knowledge* uses in analyzing the data. Once data has been saved as an Acq*Knowledge* file, X-axis base information is automatically saved along with the data. Acq*Knowledge* also saves X-axis in Frequency (FFT) or Arbitrary (Histogram).

Show

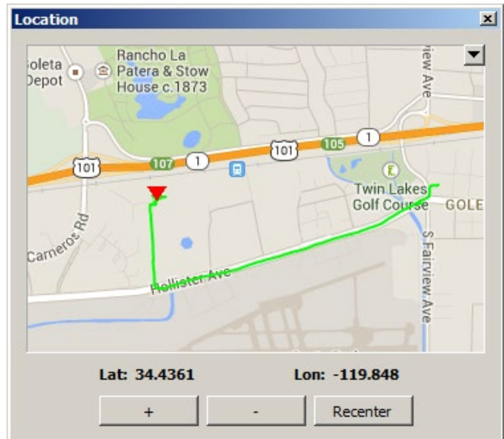
Selecting Display> Show generates a submenu controlling the data display options and other additional information appearing in the graph window. To enable an option, select it in the submenu. A checkmark appears next to the enabled menu items. The three display modes and the two plotting modes are mutually exclusive, but the remaining items can be enabled independently.

Show Option	Shortcut	Explanation
Annotations		Toggle show/hide of text annotations.
Channel Buttons		When the Channel Buttons option is selected, the channel boxes appear just above and below the graph area.  Channel Buttons with Channel 1 selected These buttons are useful for selecting channels and “hiding” channels by positioning the cursor over the channel box, holding the ALT key on the Windows or the Option key on the Mac, and clicking the mouse button.
Channel Input Values		When enabled, adds real-time display of channel amplitude values above the graph. (“Show textual value display” must be enabled in the Vertical Axis settings.)
Chart		Activates the Chart display mode (see page 36).
Display Mode Toolbar		Activates toolbar shortcuts for Chart, Scope, X/Y, Stacked Plot, Horizontal Split View and Data View.
Dot plot		Dot Plot allows viewing of data in a “dot” format. This is useful for demonstrating the concept of discrete digital sampling by dividing the waveform up into data points or “dots.”
Dot size		 Dot size is enabled after Dot Plot is selected. Dot size specifies how large each dot will be. Each dot is measured by the number of monitor pixels it occupies. Each “dot” corresponds to a sample point. (For example, data collected at 100 samples per second would display 100 dots per second.)
Events		Displays the event marker region at the top of the graph window. See page 248 for Events.
Event Bar		Enables Event Bar display on toolbar.
Event Palette		Displays the Event Palette (see page 251 for Event Palette details.)
Focus Areas		Enables Focus Area display. See page 96 for Focus Areas.
Focus Areas Bar		Enables Focus Area Bar display on toolbar.
Grid		Superimposes a Grid on the graph window (see page 51). To change grid precision, use the axis scaling dialog of the horizontal or vertical axis.
Grid Options		Activates the Grid Options dialog (see page 87)
Hardware		Show/Hide Hardware “Connected to:” dialog in the graph display; includes network access.
Journal		Activates the Journal (see page 53).
Last Dot Only		Plots only the most recently acquired data point. Only available in X/Y mode.

Show Option	Shortcut	Explanation
Line Plot	Right-click menu	Connects each sample point with a line to create the waveform. Waveforms that are displayed in line plot mode match a true analog plot (as closely as possible). This is the default display mode for most waveforms, except histogram plots, which are displayed in Step Plot mode (see 361). The line options can be changed by clicking the right mouse button, which will generate a menu displaying several commonly used features.
Line Thickness	Right-click menu	 Line thickness is enabled when Line or Step plot are enabled. Use to specify the plot thickness in pixels.  Sine wave set to thickness of 5 pixels
Main Toolbar		Controls visibility of Main Toolbar buttons (Grid, Show/Hide, Preferences and Customize Toolbar).
Measurements		Displays the measurement popup menus and windows above the graph window (see pages 50 and 98).
Scaling Toolbar		Controls visibility of Scaling Toolbar shortcut buttons (Autoscale Vertical, Autoscale Horizontal, Show All Data, Center Data Vertically, Center Data Horizontally).
Scope		Activates the scope display mode (see page 36).
Selection Palette		 Many tools within the Acq*Knowledge* environment are based around the selection. The selected range of data in the graph is used as the source for measurements, waveform editing, transformations, and other operations. The Selection Palette is a floating dialog that can be used to precisely enter the selection. • The Selection Palette can be used to adjust the selection at times when it is not possible to use the selection tool in the graph window, such as when transformation dialogs are being displayed for the graph. • The selection palette offers a way to change the selected area without having to cancel the transformation setup and lose any parameters typed in the dialog. To display the Selection Palette, choose Display > Show > Selection Palette. This dialog contains two edit fields that display the location of the left and right edges of the selection using the measurement units currently displayed in the horizontal axis. As the selection is changed, the new selection boundaries are shown. The Selection Palette also can be used to manually type in the edges of the selection. Double-click the edges and type in the new horizontal position of the edge of the selection. Press “Return” to adjust the selection to that time location and update measurements and the visible display on the screen. For graphs displayed in X/Y mode, the Selection Palette can be used to adjust the

		X-axis range of data plotted on the screen. Limiting the time range can be useful for generating X/Y plots for different intervals of the graph for comparison, such as examining PV loops from different time periods of a recorded signal. Click the small arrow in the top right of the selection palette for the following additional options:  • **Mark Selection**—Use this option to bracket a selected area with event markers. • **Paste edges in Journal**—This option pastes a line of text into the Journal that includes the left and right edge measurements of the selection. • **Create Focus Area**—This option turns data highlighted by the selection palette into a labeled Focus Area. • **Time units**—Use this submenu to change the time units used in the selection palette. The following time units are available: Match units on axis; Hours; Minutes; Seconds, Milliseconds, Microseconds and Samples. The Time units submenu will be dimmed unless the graph displays time/arbitrary measures). • **Frequency units**— Use this submenu to change the frequency units used in the selection palette. The following frequency units are available: Match horizontal axis, Kilohertz, Hertz, Millihertz and Samples. The frequency submenu will be dimmed unless the graph displays frequency-based measures. ***Note*** Changing time/frequency units in the selection palette can be helpful during zoom operations when the units displayed in the horizontal axis may not be the most convenient for inputting new selection boundaries. • **Arbitrary Units**—Use this submenu to change the arbitrary units used in the Selection Palette display (Units or Samples).
Spectrum Analyzer Palette		Provides a dynamic display of the frequency decomposition of data, in real time or post-acquisition. See page 501 for details.
Timers		Enables display of stopwatch and elapsed timer toolbar.
Location Palette		Acq*Knowledge* 5 supports import of GPS location data into Acq*Knowledge* graphs. This is useful for correlating a subject's geographic location with physiological data acquired during extended exercise studies where a subject might wear a long-range wireless device, such as BIOPAC's BioHarness loggers. The Location palette, like the Selection and Spectrum Analyzer palettes, is a floating dialog that can be dragged, resized or repositioned as desired. In order for the Location palette to be operational, the subject must first log data with a compatible GPS tracking device, such as the BIOPAC GPSTRACK. The resulting GPS data can be imported from the tracking device into the Acq*Knowledge* exercise study graph, which populates the Location palette in a navigable map format. The resulting map shows the physical location of the subject throughout the exercise. **After Import:**

- Browsing GPS graph data with the I-beam selection tool will relocate the red navigation arrow to the map location occupied by the subject at that exact point of the experiment.
- The map view is zoomable, and any of three different map servers can be selected in the preferences.



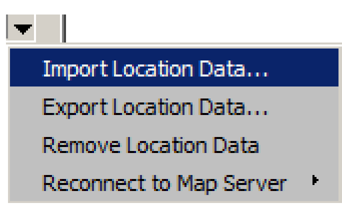
Location palette showing coordinates, zoom and recenter tools

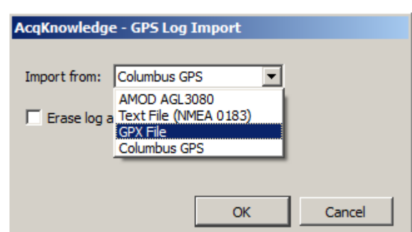
To log GPS data:

1. Attach the GPSTRACK device to the subject and turn on the power.
2. Run the experiment. (For example, subject walks, runs, or bicycles an assigned geographical route during an exercise study where data is being acquired into Acq*Knowledge* via a wireless logger.)
3. At the conclusion of the experiment, turn off the GPSTRACK and remove it from the subject.

To import GPS data into Acq*Knowledge*:

1. With the exercise study graph open in Acq*Knowledge*, launch the Location palette (Display > Show > Location Palette).
2. Connect the GPSTRACK to the computer's USB port.
3. Click the arrow in the upper right corner of the Location palette and choose "Import Location Data." The GPSTRACK used will appear in the "Import from:" menu.

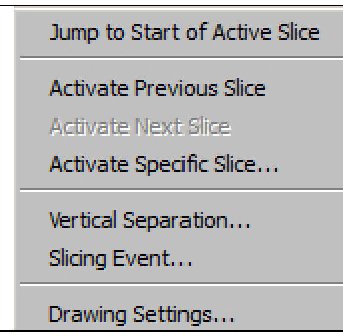
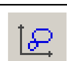




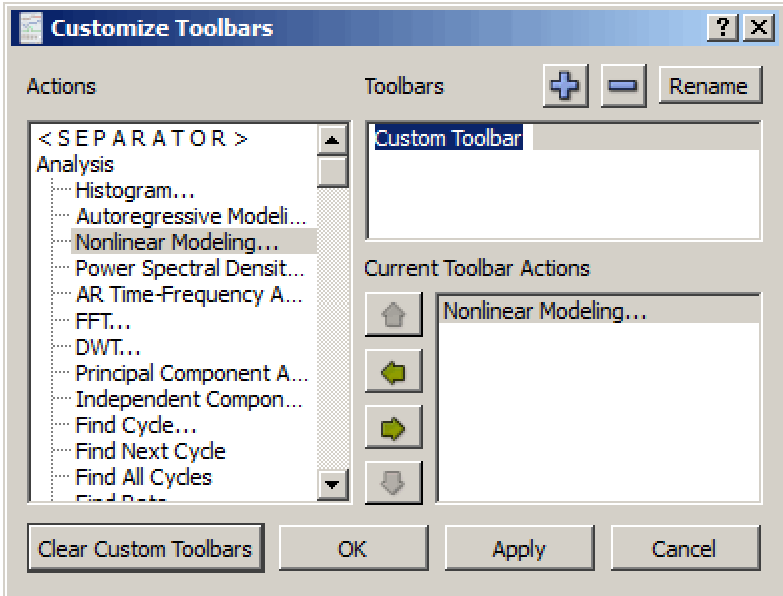
4. Click OK to import location data into the graph. The imported location data will be saved with the graph. Be sure to select the correct GPS device or file format. (AMCO AGL 3080, Columbus GPS, *txt or *.gpx format.)

Explanation of Options:

- **Import Location Data –** Use this option to import logged GPS data into Acq*Knowledge* graph.
- **Erase log after data is imported** – If selected, the log file on the GPS device will be deleted following import.
- **Export Location Data** – Use to export GPS data in graph to a text file format.
- **Remove Location Data** – Removes all location data from graph.

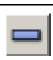
		• **Reconnect to Map Server** – Use to connect/reconnect to any of three supported map servers (Nokia Ovi Maps, Google Maps, Open Street Map) The default Map Server may also be selected in the **Location Preferences** (Display > Preferences > Location). **Limitations:** When using Edit > Merge to merge graph files from multiple hardware units: If only one graph file contains embedded GPS data, the GPS data will be copied into the merge output graph. If more than one graph has GPS data, no GPS information will be present in the merge output graph. Data snapshots will archive any GPS data present in the graph and retain it in the snapshot. When the snapshot is restored, the archived GPS data will be extracted into the newly created graph window, showing the data from the snapshot. GPS data in a graph file is read-only and cannot be modified directly within the software. To modify the GPS information, the data must first be exported, edited externally, and then re-imported.
Stacked Plot Options		Displays options that can help visually distinguish the active slice from other slices being drawn in Stacked Plot mode. See page 39 for details. 
Step plot		Displays waveforms in a “step” plot, meaning that the lines connecting sample points are drawn either vertically or horizontally. Step plot is most useful for displaying histograms and similar plots, but since it displays data much as it appears to a digital processor (like the MP and other hardware units), it can also be useful for examining the effects of various sampling rates. NOTE: Step plot is mutually exclusive of line plot.
Toolbar		Displays the toolbar (shortcut) icons across the top of the display (see page 60).
X/Y		Activates the X/Y display mode (see page 36).

Customize Toolbars



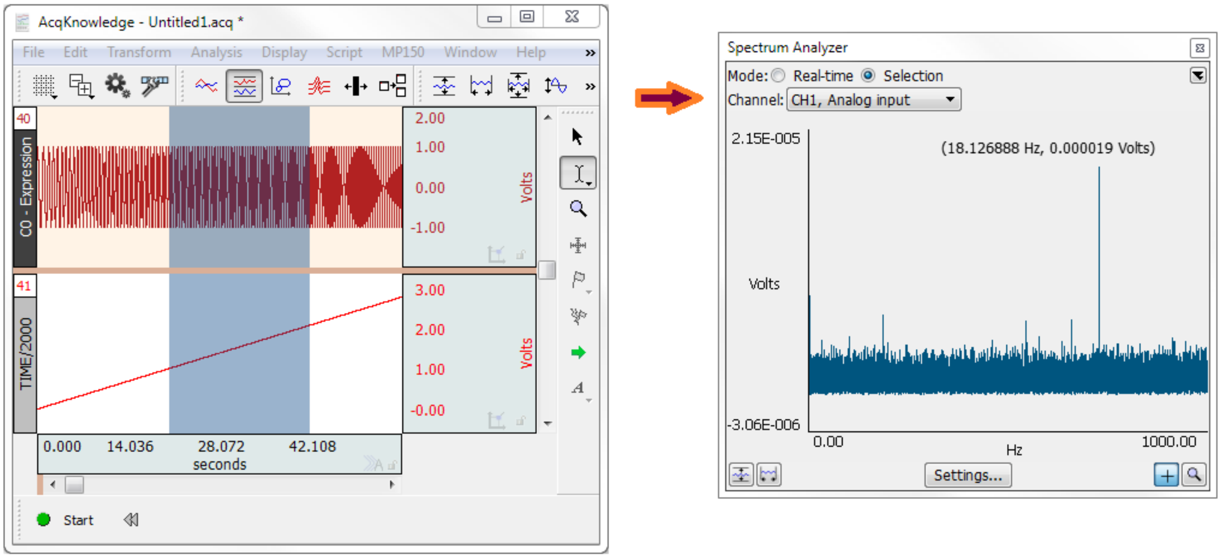
Use the Customize toolbar feature to create custom toolbars for easy access to post-processing Analysis, Transform, and Script actions. Toolbars are dockable and custom toolbar placeholders can be named independently of toolbar actions.

- **Actions** – Menu list of available Analysis, Transform, and Script functions
- **Toolbars** – List view of custom toolbar placeholders
- **Current Toolbar Actions** – List view of available actions from Analysis and Transform menu

Button	Function	Explanation
	Add toolbar button	Adds placeholder for new toolbar. (More than one toolbar action can be grouped under one placeholder).
	Remove toolbar button	Removes placeholder for toolbar.
Rename	Rename toolbar button	Allows existing custom toolbar name to be edited.
	Up arrow	Moves a toolbar action up the list.
	Left arrow	Removes a toolbar action from the list.
	Right arrow	Adds a toolbar action to the list.
	Down arrow	Moves a toolbar action down the list.
Clear Custom Toolbars	Clear button	Removes all toolbars from Toolbars and Current Toolbar actions list.
OK	OK button	Enforces addition or removal of toolbars from list or application toolbar region.
Apply	Apply button	Applies changes without closing Customize Toolbar window.
Cancel	Cancel button	Dismisses any toolbar changes without applying.

NOTE: If a Scripting license is present, the standard items of the script menu, as well as all user scripts in the menu will be available as buttons to be added into custom toolbars.

Spectrum Analyzer Palette Details



Spectrum Analyzer breaks time domain signals into their respective frequency components to provide a dynamic display of the frequency decomposition of data, in real time or post-acquisition. Spectra can be generated in real time based on the most recently acquired data or post-acquisition based on the selected area of a saved data file.

- Spectrum analyzers can be useful for locating and correcting noise sources in a system as well as other frequency domain analysis.
- The Spectrum Analyzer displays the FFT of a portion of data of a single channel.

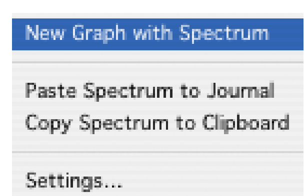
The spectrum analyzer applies to all graph windows displaying data in the time domain. Viewing the underlying time domain data at the same time as the spectral information also provides useful visual feedback with regards to signal quality. The palette allows for continuous availability of the spectrum analyzer across multiple graphs and for positioning alongside original data. The channel is always indicated by the popup menu within the spectrum analyzer itself. The graph whose data is analyzed will always be the topmost graph; this is the graph whose window is highest in the Z ordering.

Mode:

Real-time Analyzes the most recently acquired data in a graph. The analyzer generates full FFT output so, in linear units, it is the regular FFT multiplied by two. The analyzer extracts the spectrum based on a sliding window of samples at the tail end of the signal and periodically refreshes the spectrum plot during acquisition. The analyzer uses a fixed width window size. The first spectrum will be generated after the number of samples needed to fill the initial window has been acquired. If no data is being acquired, the analyzer will not display any frequency information and will appear to be off.

Selection Analyzes the highlighted section of the active channel of a saved graph (post-acquisition). Select the channel to be analyzed from the channel popup menu.

Palette popup  (upper right) Displays the spectrum analyzer palette popup menu for performing other operations on the spectrum including extracting the spectrum to a new graph window and copying spectrum data to the clipboard or journal. Options are dimmed if there is no spectrum available.



New … New Graph with Spectrum constructs a new graph window with the contents of the spectrum. This allows for more detailed examination of the spectrum than is possible with the tools in the spectrum analyzer palette.

Paste… Paste Spectrum to Journal makes a textual representation using the current Journal preferences and copies the text into the graph journal of the graph whose data is being analyzed. This will prompt to create a journal if none exists.

Copy… Copy Spectrum to Clipboard makes a textual representation using the current Journal preferences and copies the text to the Clipboard.

Settings… Displays the spectrum analyzer settings dialog. Equivalent to using the Settings button at the bottom of the palette; see Settings below for details.

Channel Indicates which channel of the hardware setup or graph is being analyzed. The "Channel" popup menu contents vary with the analyzer mode:

Real-time Channel popup menu lists active channels whose "Acquire" checkboxes are checked in Hardware > Set Up Channels. The channels will be listed as "{A,D,C}{0-16}, *chan_title*" where chan_title is replaced with the manually entered title in the channel setup window.

Selected The channel popup menu matches the channel menu of measurements in the topmost graph window. The menu starts with "SC, Selected Channel" which, when chosen, uses the data of the active channel of the graph. The remainder of the menu lists the channel numbers and labels of the channels within the topmost graph.

Plot display Plot of the spectrum of the corresponding data.

- Vertical axis units match the source channel (displays either "dbV" or linear)
- Horizontal axis displays frequency and is always displayed in "Hz."

If there is a valid data selection that can be used to compute a spectrum, the spectrum will be displayed in this area. If there is no valid data selection, no axes will be displayed and the plot will be replaced with the text "Not Available." The following conditions cause spectra to be unavailable:

- graphs that contain no data (either no channels or only empty channels)
- graph is being displayed in XY mode
- graph uses either frequency or arbitrary units for its horizontal axis

When operating in selected area mode, the following additional conditions also cause spectra to be unavailable:

- selection contains no data on the active waveform
- selection is a single-point selection (not enough data to compute FFT)

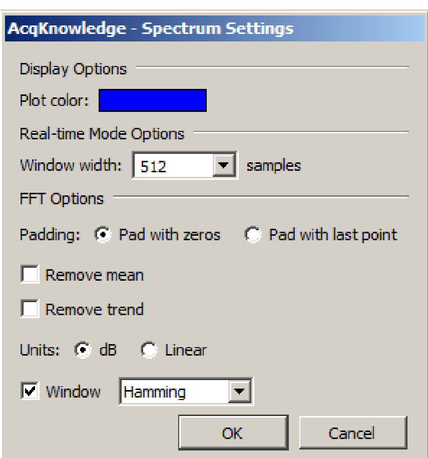
When operating in real-time mode, the following additional conditions also cause spectra to be unavailable:

- no data acquisition is in progress

Auto Vert Click to autoscale the spectrum to fit all amplitudes within the visible spectrum plotting area.

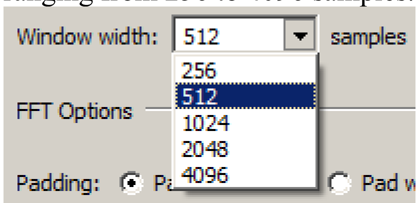
Auto Horiz Click to autoscale the spectrum to fit all frequencies within the visible spectrum plotting area.

Settings



Plot color Colorwell that changes the color used to draw the spectrum in the palette. Click to display a standard color picker.

Window Width specifies the window size used when performing analyses in real-time mode. The spectrum will always reflect the frequency characteristics of the most recently acquired data of the graph, using this window size as the number of sample points to use. This popup will list various powers of two, ranging from 256 to 4096 samples.



FFT Options

Padding—used whenever the number of input points is not an exact power of two. Data can be padded either with zero or with the amplitude of the last data point.

Remove mean—Subtracts the mean value of the data is prior to frequency analysis. This helps remove the zero frequency component caused by DC offset.

Remove trend—Connects the endpoints of the data with a line and removes this linear trend from the data prior to frequency analysis. This can help compensate for drifting baselines.

Units—control whether the data is displayed using a logarithmic scale or a linear scale.

Window—enables the standard Acq*Knowledge* FFT windowing options, to adjust the data to remove effects resulting from the discontinuities of data at the two edges. See page 367 for details about FFT.

Value Click the crosshair icon  to display the frequency and amplitude values of the spectrum when moved within the spectrum display. The mouse cursor will change to a crosshair when inside the spectrum plot. The frequency and amplitude values corresponding to the mouse position are displayed above the spectral plot. Hold the mouse button down to display the amplitude of the spectrum at the horizontal mouse position, along with a crosshair cursor highlighting the exact location shown on the spectrum. If the active spectrum is compressed (that is, if multiple samples exist for a particular horizontal position), the value extracted will be the maximum value displayed at that pixel position.

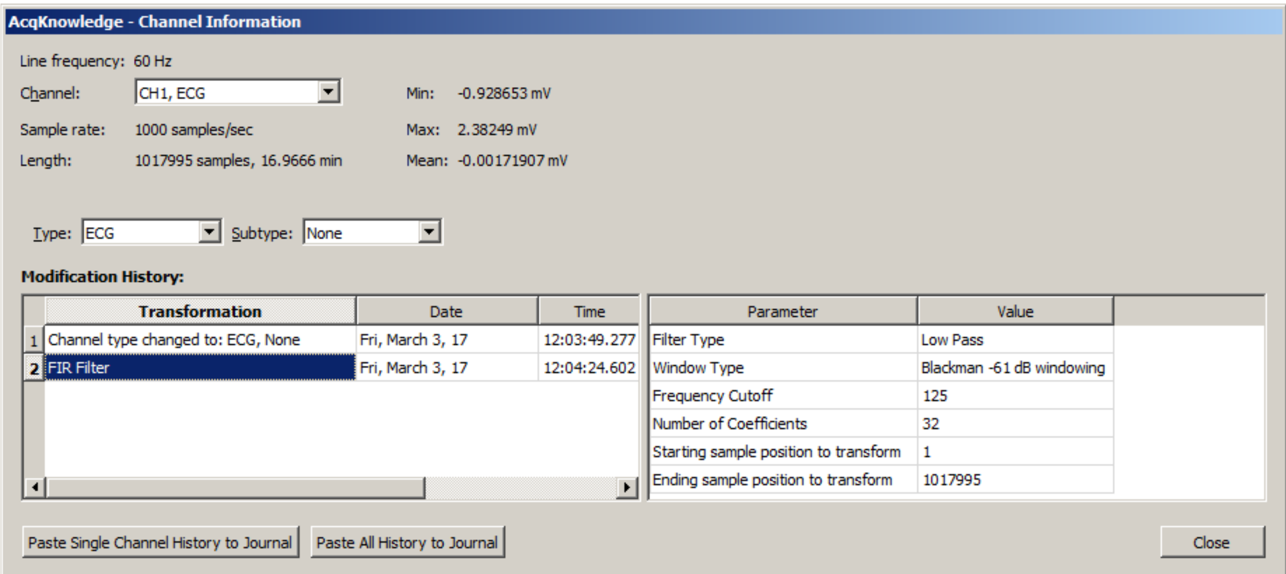
Zoom Click the magnifying glass  to perform zoom operations. Click and drag the mouse cursor (which will change to a magnifying glass) in the plot display to select the area to zoom in on. Alternately, click either of the axes of the spectrum palette to display a dialog used to enter display ranges manually. Enter the start and end points of the desired range for each axis. There are no grids in the spectrum analyzer palette, so the axis scaling dialogs of graphs are not applicable. Note: adaptive scaling will be disabled for the spectrum display when either the zoom tool or the axis endpoint entry dialogs are used.

TIP: To zoom out, hold the Alt key (PC) or Option key (Mac) while clicking mouse over zoomed area.

Channel Information

The Display > Channel Info…item generates an information dialog for the selected channel.

Channel Information may also be displayed by right-clicking in the channel and selecting “Channel Info…” from the contextual menu.



Line Freq: Files created with Acq*Knowledge* 4 and 5 include the line frequency (50 Hz or 60 Hz); files created in earlier versions will display “Unknown.”

Channel: Use this popup menu to select the desired channel for displaying information.

Type: Use this popup to set the primary signal type if it is not specified in the selected channel. Defining a signal type here will place an Analysis Shortcut button into the channel. For more information about Analysis Shortcuts see page

Subtype: Use this popup to set the secondary signal type in the selected channel. This can be a derivative of the primary signal.

Interval: The time between sample points, which is the reciprocal of the sampling rate. The sampling rate can be modified by using the resample function (described on page 355), by changing the interval horizontal scale (see page 493), or by pasting data collected at one sample rate into a graph containing data sampled at a different rate.

Length: Indicates the overall length of the channel in samples and in time. The waveform length is generally the same for all channels but there are exceptions:

- Downsampling a channel during acquisition
- Transform > Resample Waveform/Graph
- Edit operations – Cut, Copy, Paste, Clear

Min: Provides the minimum value for the waveform data.

Max: Provides the maximum value for the waveform data.

Mean: Provides the mean value for the waveform data.

The fields below the statistical information contain transformation histories, time/date stamps, parameters, and values for selected channels.

Modification History: Any change to the Type or Subtype will be logged and saved in this field. The date and time of the Type and Subtype are also recorded.

Parameter and Value If a transformation is applied to the data, the transformation type and its settings and values are also recorded in this field.

Paste Selected Channel to Journal	Pastes transformation modification history for selected channel to Journal.
Paste All Channels to Journal	Pastes transformation modification history for all channels to Journal.

Preferences...

To generate the **Preferences** dialog, select Display > Preferences on Windows or Acq*Knowledge* > Preferences on Mac. Use Preferences to control measurement options, how waveforms are displayed, and other Acq*Knowledge* features. Select an option in the list on the left of the Preferences dialog and then set the respective preferences displayed on the right.

See page…

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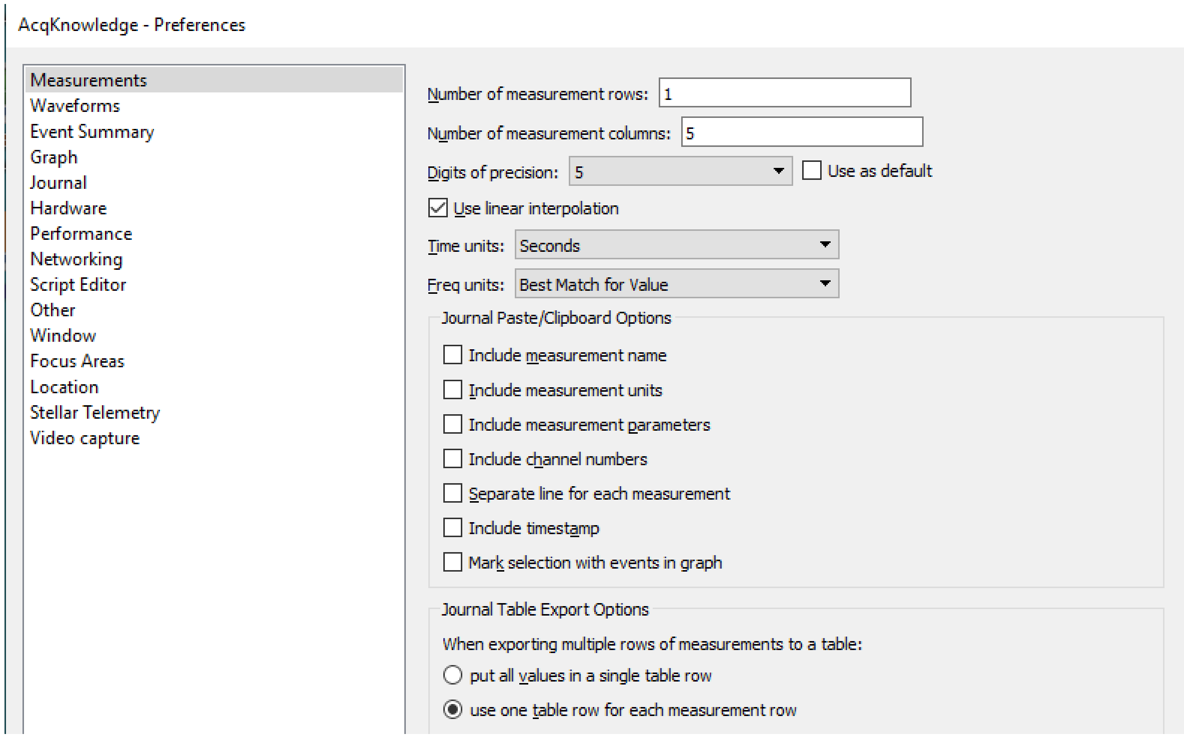
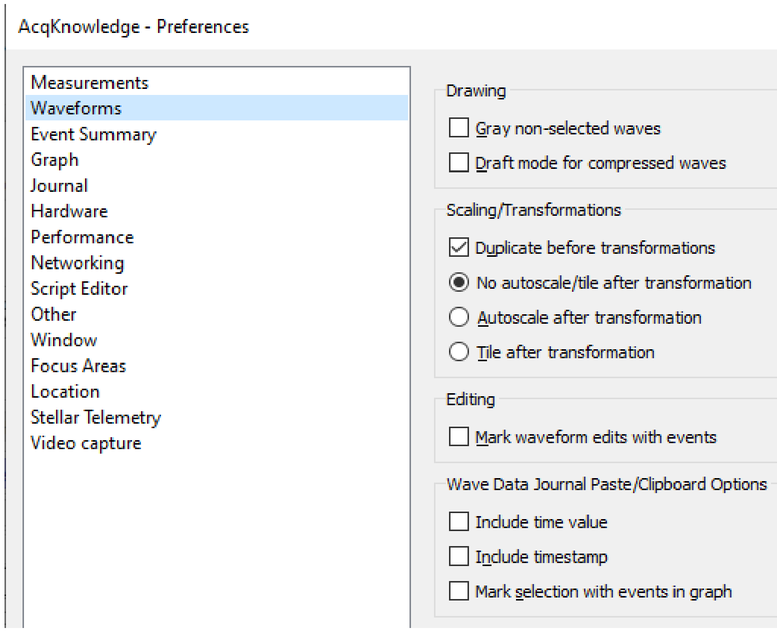


510



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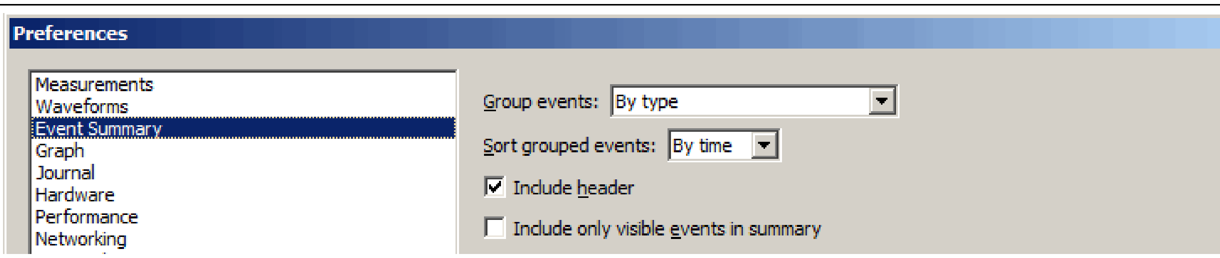
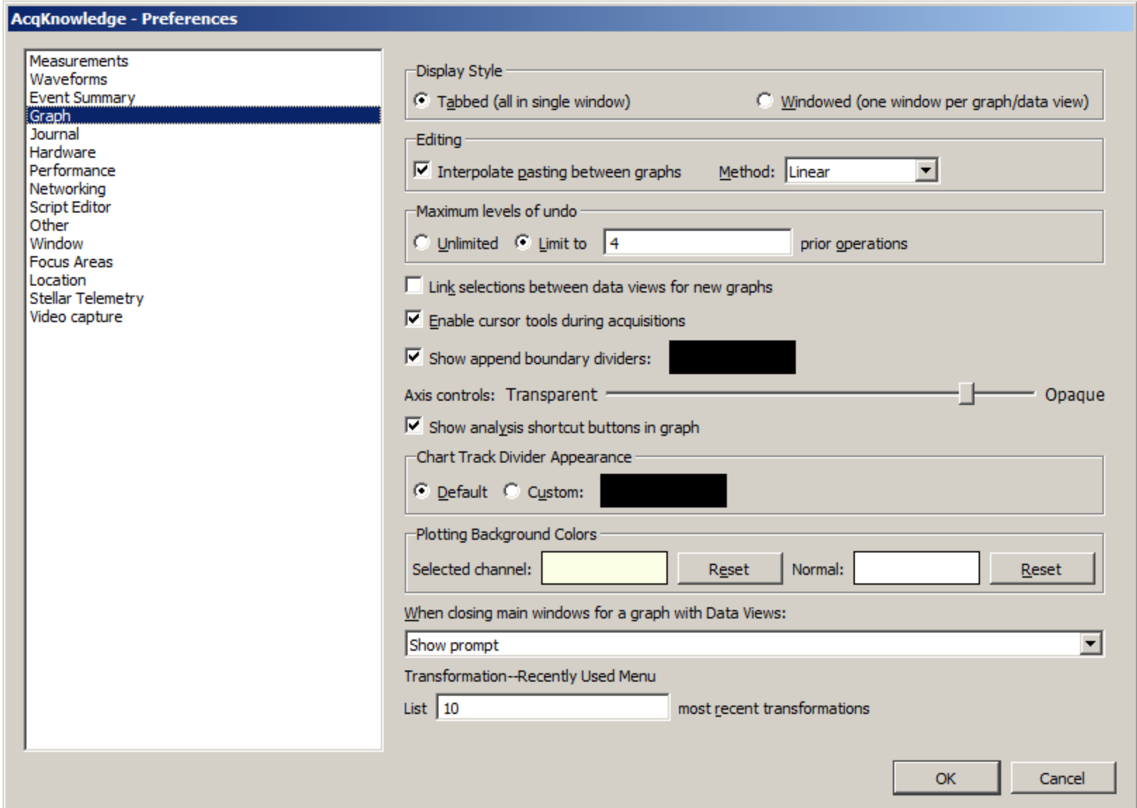
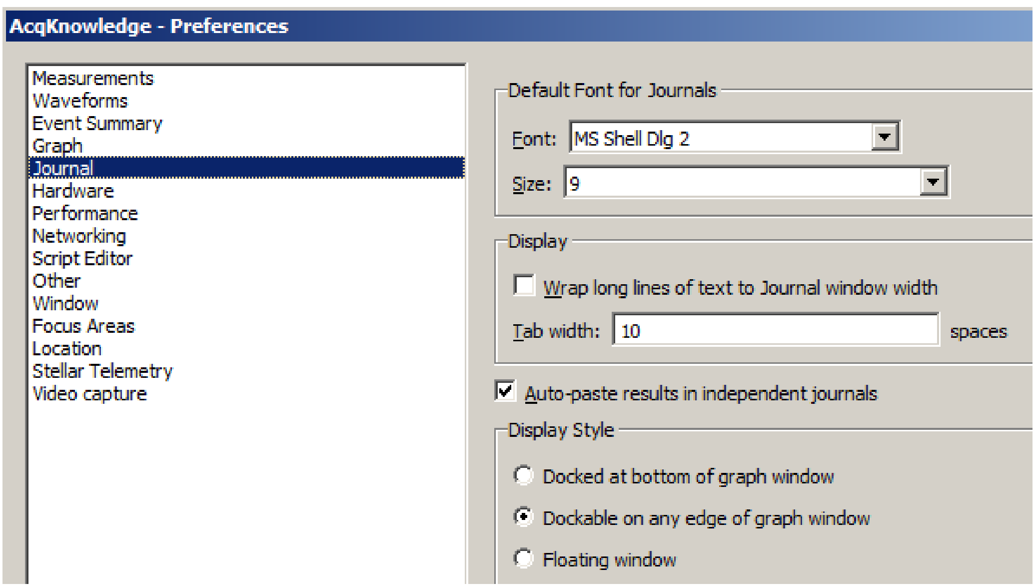


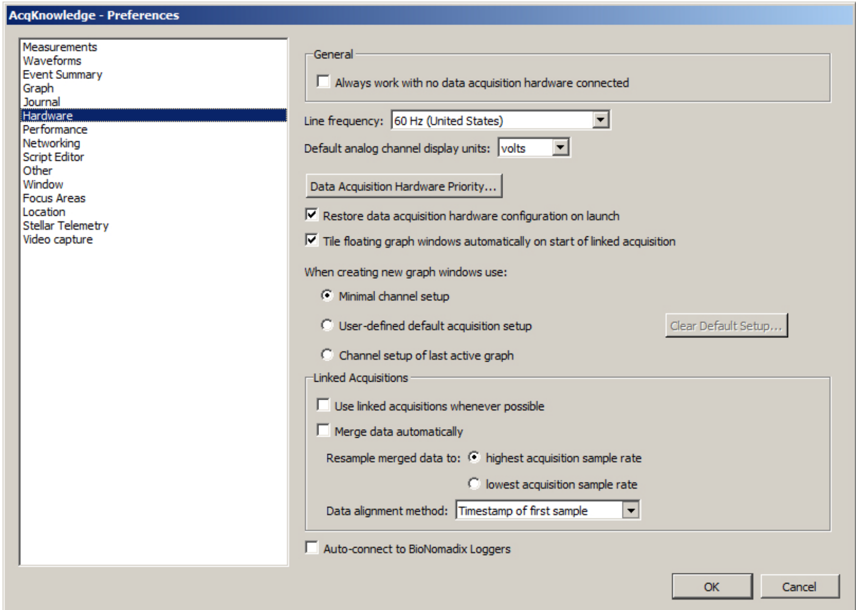
511


AcqKnowledge - Preferences
Measurements
Waveforms
Event Summary
Graph
Journal
Hardware
Performance
Networking
Script Editor
Other
Window
Focus Areas
Location
Stellar Telemetry
Video capture
Display Style
Tabbed (all in single window)
Windowed (one window per graph/data view)
Editing
Interpolate pasting between graphs
Method: Linear
Maximum levels of undo
Unlimited
Limit to 4 prior operations
Link selections between data views for new graphs
Enable cursor tools during acquisitions
Show append boundary dividers:
Axis controls: Transparent
Opaque
Show analysis shortcut buttons in graph
Chart Track Divider Appearance
Default
Custom:
Plotting Background Colors
Selected channel:
Reset
Normal:
Reset
When closing main windows for a graph with Data Views:
Show prompt
Transformation--Recently Used Menu
List 10 most recent transformations
OK
Cancel

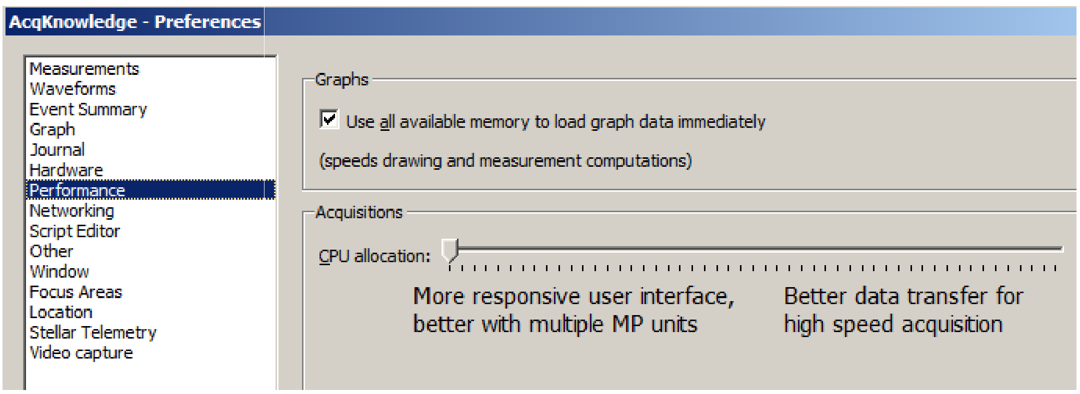
512


AcqKnowledge - Preferences
Measurements
Waveforms
Event Summary
Graph
Journal
Hardware
Performance
Networking
Script Editor
Other
Window
Focus Areas
Location
Stellar Telemetry
Video capture
Default Font for Journals
Font: MS Shell Dlg 2
Size: 9
Display
Wrap long lines of text to Journal window width
Tab width: 10 spaces
Auto-paste results in independent journals
Display Style
Docked at bottom of graph window
Dockable on any edge of graph window
Floating window

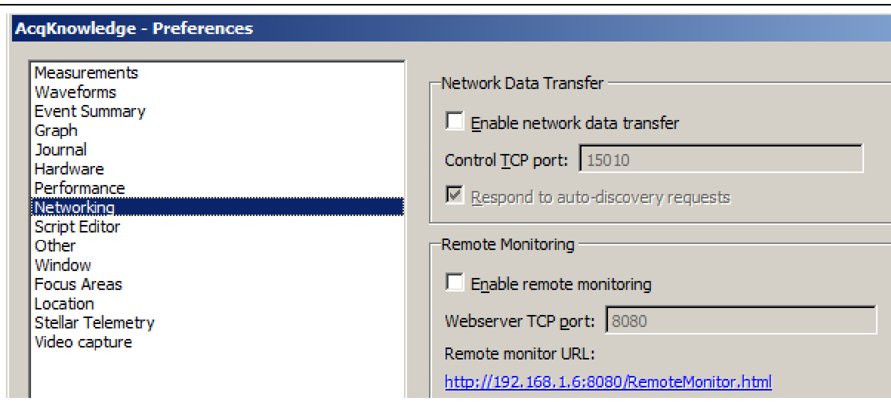
512



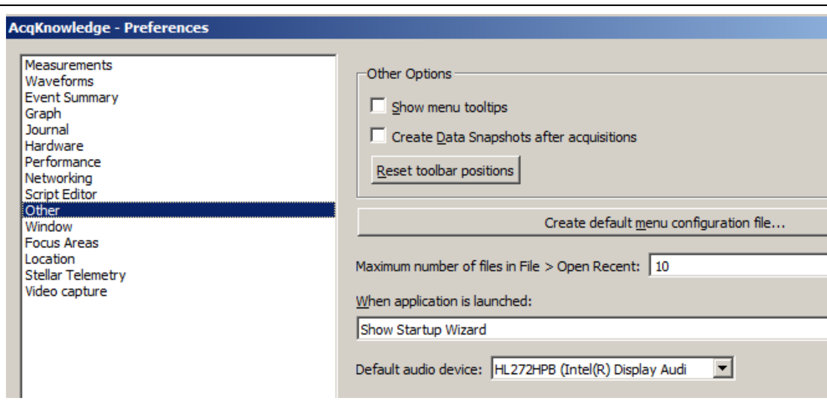
513



513



513



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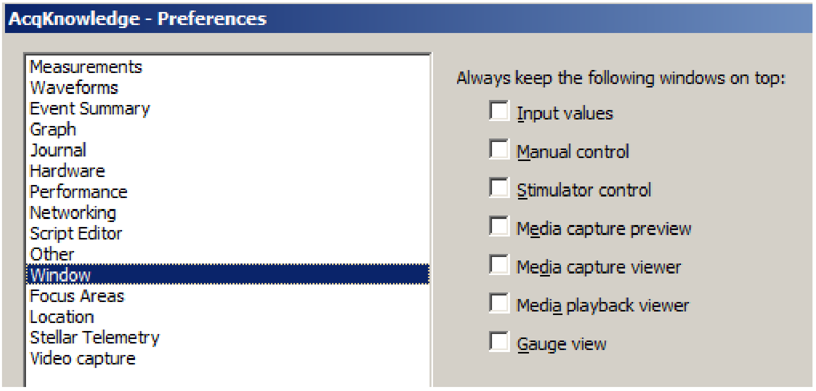
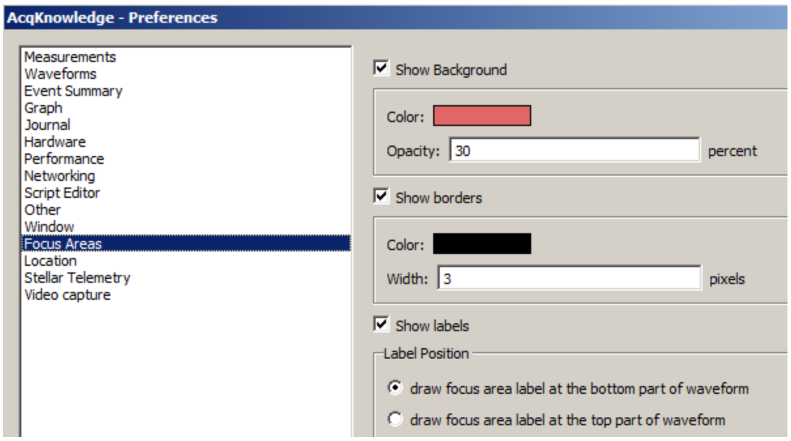
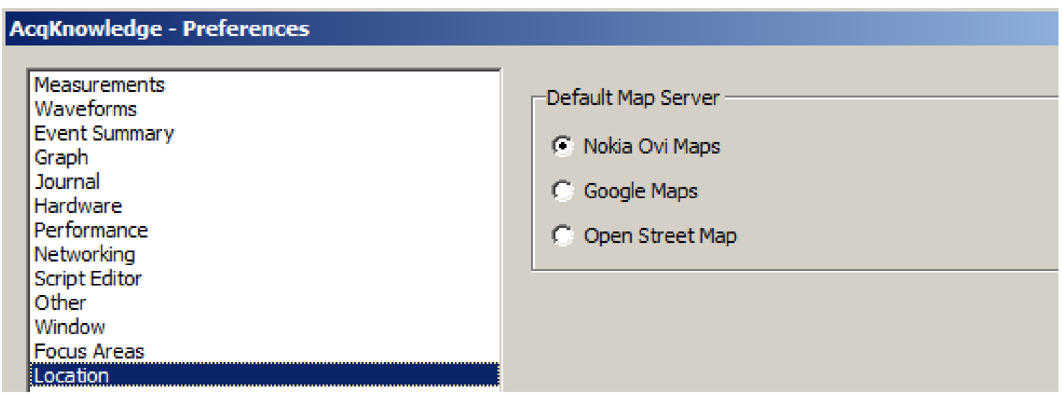


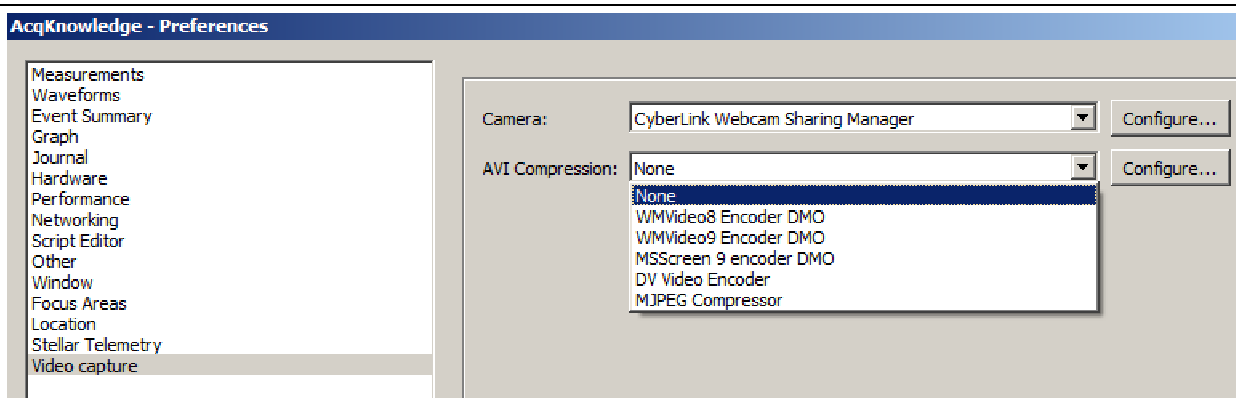
514



515



515



Measurements Preferences

- **Measurement rows**—determines how many measurement rows will be displayed in the graph window.
    - o Use Display > Show > Measurements to hide the measurements; see page 495 for details.
- **Measurement columns**—determines how many measurement columns will be displayed in the graph window.
- **Digits of precision**—controls the accuracy of digits displayed right of the decimal (1-8) for all measurement results. For example, with the precision set to 3, a measurement result might be 125.187.
- **Use as default**—applies the selected number of digits of precision as the global default for all graphs.
- **Use linear interpolation**—toggle to enable/disable measurement interpolation.
- **Time/Frequency units**—sets the measurement unit to use for time and frequency pop-up measurements. This locks the units for the measurement result display (i.e., if seconds is selected, a result of 70 seconds will display as "70 seconds" rather than "1.16667 minutes").
    - o Best match—Scales units to best match the interval for time and frequency based on the total file. For example, won't set a 3 hour file to display in msec.
- **Include for Journal/Clipboard options**
    - measurement name (i.e., BPM, Delta T, Freq, etc.) with the values.
    - measurement units (i.e., volts, mmHg, and so forth) after the numeric values.
    - measurement parameters used to compute the measurement function result, such as the location and operator used for Calculate measurements.
    - channel numbers at the top of each column of data.
    - timestamp—Automatically insert the time of day and the date when pasting measurements or wave data. This timestamp can be correlated with selection events to reconstruct the selected area.—useful for GLP auditing.
- **Use a separate line** for each measurement in the journal/clipboard
- **Mark selection with events in graph**—Automatically insert a pair of Global Selection Begin and Selection End events at the selection boundaries when pasting measurements or wave data. These events will be timestamped with the time of day and the date when the paste occurred. This timestamp can be matched to the result of "Include timestamp" to recreate selected areas for reconstructing measurement results or re-executing wave data exporting—useful for GLP auditing.
- **Journal Table Export Options** – Sets the options for how multiple measurement rows are displayed in a Journal table.
    - o <u>Put all values in a single table row</u> – Extends multiple measurement rows horizontally into one table row.
    - o <u>Use one table row for each measurement row</u> – Divides the measurements into multiple table rows in the same manner shown in the measurement toolbar.

Waveforms Preferences

In the center of the dialog are two options that control how waveforms are displayed on the screen.

- **Gray non-selected waves**—When enabled, the active wave will be drawn in a solid color and any non-selected waveforms will be drawn using lighter, dotted lines (or with lighter colored dots if dot plot is in use). This can help emphasize the selected waveform when viewing data in Scope mode.
- **Draft mode for compressed waves**—allows for some ("compressed") waveforms to be plotted in "draft" mode, which results in faster plotting time, although the display is not exact. A waveform is considered compressed when more than three sample points are plotted per pixel on the screen. For example, on a VGA display that is 640 pixels wide, a compressed waveform would be any type of waveform displaying more than 2000 samples (approximately) on the screen at any one time. Using the default horizontal scale (which plots eight seconds of data on the screen), any data sampled at more than 250 samples per second would be considered "compressed."
- **Scaling/Transformations**—the following options determine how data will appear on the screen after it has been transformed (e.g., filtered or mathematically operated on). Neither option affects how data appears on the horizontal axis, although both options change how data is presented along the amplitude (vertical) axis.

- **Duplicate before transformations** will create a new channel showing the data as it originally appeared before the transformation was applied. This will preserve the original view for comparison to the transformation.
- **No autoscale/tile after transformation** will disable automatic autoscaling or tiling after any transformation.
- **Autoscale after transformations** will automatically rescale all waveforms after a transformation to provide the "best fit" along the amplitude axis.
- **Tile after transformations** tiles all visible waveforms after any transformation, and is mutually exclusive of the autoscale command. Tiling visually separates the waveforms on the screen.

- **Mark waveform edits with events**—Insert an event at points where waveform edit commands have been applied.
- **Include time value**—copies the horizontal scale values along with the waveform data when data is copied to the clipboard. This means that horizontal scale information is retained when Acq*Knowledge* data is pasted into a spreadsheet or similar application.
- **Include timestamp**—Automatically insert the time of day and the date when pasting measurements or wave data. This timestamp can be correlated with selection events to reconstruct the selected area.—useful for GLP auditing.
- **Mark selection with events in graph**—Automatically inserts a pair of Global Selection Begin and Selection End events at the selection boundaries when pasting measurements or wave data. These events will be timestamped with the time of day and the date when the paste occurred. This timestamp can be matched to the result of "Include timestamp" to recreate selected areas for reconstructing measurement results or re-executing wave data exporting—useful for GLP auditing.

Event Summary Preferences

For the event summary that can be pasted to the journal, choose a method to group the events (i.e., type or channel), to sort the events (by time or label) and indicate whether to include all events or include only visible events in the summary. There is also an option to include a header row at the top of the summary.

Access Event (Marker) preferences under Display > Preferences > Event summary; see page 248 for details.

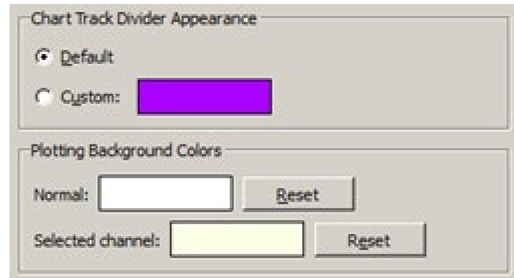
Graph Preferences

- **Display Style** can be set to **Windowed** or **Tabbed** view. Tabbed graphs can be navigated by clicking on the identifying tab at the top of the application window, or by clicking Ctrl+Tab. A tabbed graph may be moved to it's own window by right-clicking on the desired graph and choosing "Move Tab to New Window" (below right). The default setting for Acq*Knowledge* is tabbed view. When set to **Windowed**, multiple graphs appear as separate windows, which can be positioned as desired.

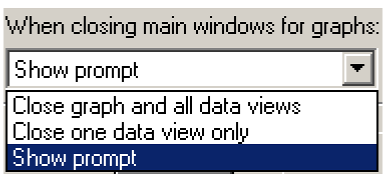
  - **Editing > Interpolate pastings** instructs Acq*Knowledge* to interpolate/extrapolate time base information when working with data sampled at two different rates. Acq*Knowledge* will interpolate data to fit the sample rate of the destination window. When doing this, data should be copied to a higher resolution window.

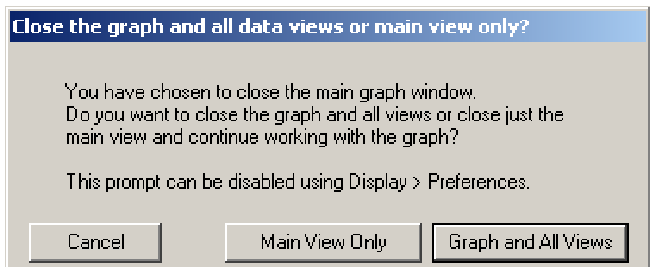
- **Maximum levels of undo**—Set the maximum number of undo operations. Unlimited may be memory-intensive, depending on the detail of each operation.
- **Link selections between data views for new graphs** – automatically synchronize selected areas of data views between graphs for a new graph.
- **Enable cursor tools during acquisition –** Allows access to cursor tools while recording is in progress.
- **Show append boundary dividers** – Controls visibility of append event boundary dividers.
- **Axis controls –** Controls visibility of set screen vertical axis controls.

- **Chart Track Divider Appearance** –Users may change the color used to draw the dividers between channels tracks The Preferences > Graph panel contains "Chart Track Divider Appearance" options.



- **Default** uses operating system specific dividers, which is a light color.
- **Custom** activates a colorwell for choosing a solid color to be specified for all dividers. The preference setting and color are shared by all open graphs and data views, as this is an application-level preference.
- **Plotting Background Colors** – Customizable background colors for active graph channels are also available.
- **Normal** activates a colorwell for choosing background color of the non-selected channels.
- **Selected** channel activates a colorwell for choosing background color of the selected channel.
- **When closing**… determines the degree of closing and what prompts, if any, for multiple data views.





- **Recently Used**—set the number of recently used Transform and Analysis options to list in the Transform > Recently used sub-menu; provides quick access to common options. Recently used items can also be launched using keystroke the combinations appearing in this menu.

Journal Preferences

The Journal Preferences dialog contains options controlling the format of data when it is pasted into the journal or clipboard.

- Change font type and size.
- Wrap Journal text—Wraps text to window size.
- Tabs: Specify the tab interval to make columns more readable when a high precision setting is set.

Auto-paste results—Toggle the checkbox to enable/disable the option to paste results to independent journals.
Display Style— Choose whether Journal window is fixed, dockable on any edge of graph, or independently floating.

Hardware Preferences

- **Always work with no data acquisition hardware connected** sets the default communication for no connection so the connection error is not displayed each time the software is launched.
- **Line frequency** is specified during software installation and can be changed here. (50 Hz for Europe, 60 Hz for the Americas.) Every time data is recorded, the line frequency setting is saved along with the data. If no line frequency data was saved, the line frequency setting for the installed/active version of Acq*Knowledge* will be used.
- **Default analog channel display units** – Use to set default channel units to volts or millivolts.
  - Volts – displays in Volt units, visible range +/-10V (MP160/150 default)
  - mV – displays in Millivolt units, visible range +/- 50 mV (MP36 default)
- **Data Acquisition Hardware Priority** launches a dialog allowing the default hardware device ordering to be set. This ordering is used to establish hardware communication when the application is first launched or if none of the previously-connected MP devices are available.
- **Restore data acquisition hardware configuration on launch** – when checked, communication with the last known hardware unit will be reestablished. When unchecked, the application will search for available new hardware units.
- **When creating new graph windows use** sets the default channel and hardware options for new graphs.

- Minimal channel setup – new graphs will use the application's factory default channel settings for the selected hardware.
- User-defined default channel setup – all new graphs are created with the user's default settings. To remove established default settings, click the "Clear Default Setup" button.
- Channel setup of last active graph – the settings of the most recently created active graph will be applied to all new graphs.

▪ **Use linked acquisitions whenever possible:** Use this option to automatically set up linked acquisitions if multiple hardware and multiple graphs are detected.

▪ **Merge data automatically:** Automatically merges data from multiple acquisitions into a single graph using the Resample and Data alignment options selected in the Preferences.

▪ **Resample merged data to:**

- highest acquisition sample rate—merged graph data is upsampled to the highest selected sample rate among the linked graphs.(Example, if one graph is being acquired at 500 s/s and the other 2000 s/s, the 500 s/s graph will be upsampled to 2000 s/s.)
- lowest acquisition rate—merged graph data is downsampled to the lowest selected sample rate among the linked graphs.(Example, if one graph is being acquired at 500 s/s and the other 2000 s/s, the 2000 s/s graph will be downsampled to 500 s/s.)

  If these preferences are not selected, linked acquisitions must be set up manually in the linked acquisitions dialog (MP menu > Set Up Linked Acquisitions).

▪ **Auto-connect to BioNomadix Loggers** will search for any BioNomadix Loggers that may be attached to the computer and attempt to connect to the unit.

Performance Preferences

▪ **Use all available memory** instructs Acq*Knowledge* to attempt to use all the available memory for loading data. Otherwise, a variable sized buffer is used to load portions of large data files. This option works best if there is enough free memory to load the entire data file.

▪ **CPU allocation** sets the priority for CPU (system resource) allocation. For a data focus, move right, for a function focus, move left.

- If buffer overloads occur, move indicator toward *Better data transfer for high speed acquisition*.
- To allow autoscale during acquisitions or jumping between hardware units, resizing displays, or working in other programs, move toward *More responsive*.

Networking Preferences

Enable networking to allow applications running on other computers attached to the same network to gain access to data from Acq*Knowledge* as it is being acquired. Data is sent to other applications over a network using TCP (recommended) or UDP connection during acquisitions.
All channel types may be exported (analog, digital, and calculation) channels. Acq*Knowledge* will continue to function normally while data transfer is in progress, displaying the new data in the graph window and performing any autoscrolling.

Respond to auto-discovery—Toggle the checkbox to enable/disable response during network data transfer.

The network data transfer feature is not intended for strict real-time delivery. It also does not provide direct control over the MP160/150 unit. Perform all hardware configurations manually using the Acq*Knowledge* interface.

Enable Remote Monitoring to allow acquisitions on the computer to be viewed remotely over a network through a client/browser interface. Acquisitions can be started and stopped remotely and graph data viewed while recording is in progress. This is handy if the Acq*Knowledge* computer recording the experiment is in one area and the researcher monitoring the experiment is in another.

For applications that require low latencies, high-data throughput, or direct hardware configuration and control, use BIOPAC Hardware API.

Other Preferences

▪ **Show menu tooltips** enables display of tooltips describing menu item functions. Tooltips appear when menu items are moused over.

- **Create Data Snapshots after acquisitions** toggles the snapshot (embedded archive) feature, which stores snapshots of original acquired data along with the graph file for easy comparison of results to original waveforms or to intermediate stages of analysis; see page 54 for details.

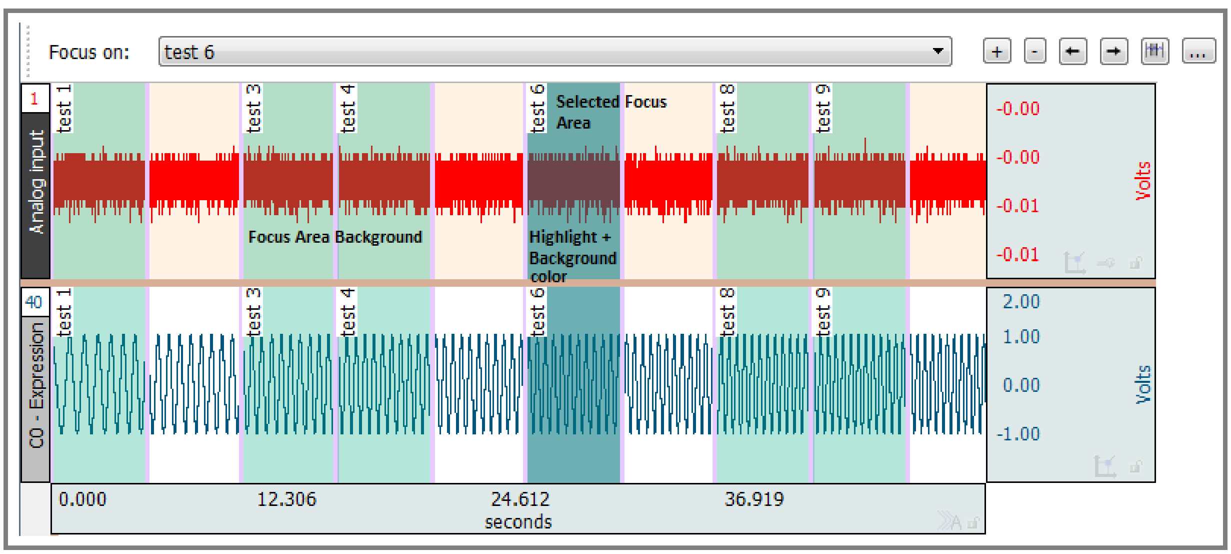
  IMPORTANT: Archive functions do not create a new file—they are not backup functions.
  Original data is copied and pasted to the end of the original file.
  This feature cannot be used to recover lost or damaged original data.

  When this Preference is enabled, a date-stamped archive of the data in the graph will be created each time the acquisition is stopped. In Append mode, the entire graph is backed up with each Append, old data as well as the newly acquired data.evt_.
- **Reset toolbar positions**—Resets location of toolbars to default setting.
- **Create configuration file**— Create default menu configuration file to customize menu display. See page 695 for customization details.
- **Maximum number of files in File > Open Recent**—Sets the number of files that will appear in the 'File > Open Recent' list.
- **When application is launched:**—Chooses between display of Startup Wizard or a new empty graph following application launch.
- **Default audio device**—Use this option to select the default audio device to be used by the application.

Window Preferences

- **Always keep the following windows on top:** — Sets options for keeping any of the following windows active above the main application window: Input Values, Manual Control, Stimulator Control, Media Capture Preview, Media Capture Viewer, Media Playback Viewer, Gauge View.

Focus Areas Preferences



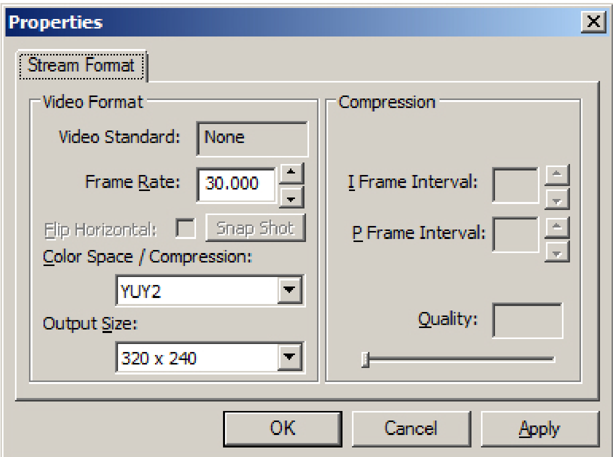
- **Show background**—Sets option for main graph visibility in the background of the selected focus area.
- **Color (background)**—Sets background color of focus areas. Click color square to change color of focus area background. (This option not active if "Show background" is unchecked.)
- **Opacity**—Sets transparency level of background. (0 is transparent, 100 fully opaque.)
- **Show borders**—When checked, borders will appear on both sides of the focus area.
- **Color (borders)**—Click to change the color of focus area borders.
- **Width**—Controls width of focus area borders.
- **Show Labels**—Controls visibility of Focus Area labels. Labels can be shown or hidden.
- **Label Position**—Controls where the Focus Area labels will appear in the graph. Options are at the top part of the waveform or the bottom part of the waveform.

Location Preferences

- **Default Map Server –** selects the map server used to display GPS tracking data in the Location Palette. The available map servers are Nokia Ovi, Google Maps or Open Map.

Video Capture Preferences

Video preferences are available in Acq*Knowledge* 5.0.3 and higher, and offer configuration/setup options for video cameras and AVI compression for using the Linked Media feature (see page 521). Click the Camera "Configure" button to launch the following dialog for setting new defaults for frame rate, compression, quality, output size and more.



Frame Rate: Use this control to select the number of frames-per-second of the video capture. For output sizes 160 x 120 to 1280 x 720, generally frame rates ranging from 5 to 30 fps are supported. Output sizes 1280 x 960 and larger are limited to 5 fps. (For certain cameras, up to 60 fps frame rate is supported.)

Color Space/Compression: Use this control to set the encoding to RGB24 or YUY2 format.

RGB24 and YUY2 are two different "colorspaces" for representing colors.

In RGB colorspace there are three components, one for the amount of Red, one for the amount of Green and one for the amount of Blue.

In YUV colorspace, one component represents lightness (luma) and two other components represent color (chroma).

Output Size: Use this option to select the output size of the video display in pixels. For a larger display, choose a larger size output.
Compression: Video compression is performed through a video codec that works on one or more compression algorithms. Usually video compression is accomplished by removing repetitive images, sounds and/or scenes from a video. For example, a video may have the same background, image, or sound played several times or the data displayed/attached with video file is not that important. Video compression will remove all such data to reduce the video file size.

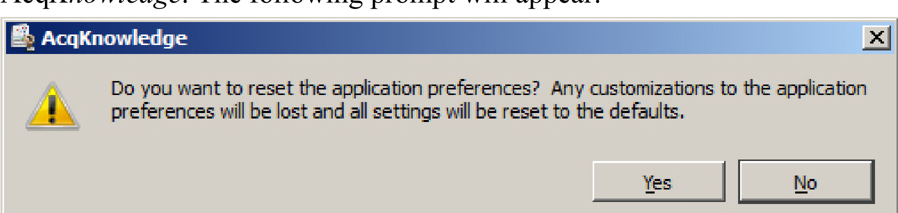
Once a video is compressed, its original format is changed into a different format (depending on the codec used). The video player must support that video format or be integrated with the compressing codec to play the video file.

Depending upon the camera type used, this options in this property may not be available in the Video Preferences.

About Video Formats: Output video formats supported by the Acq*Knowledge* Media feature are Audio Video Interleaved (*.avi) and Windows Media Video (*.wmv). AVI is a higher quality format more suitable for editing, but creates very large files. WMV is lower quality but offers the advantage of saving file space.

Resetting All Preferences to Factory Default

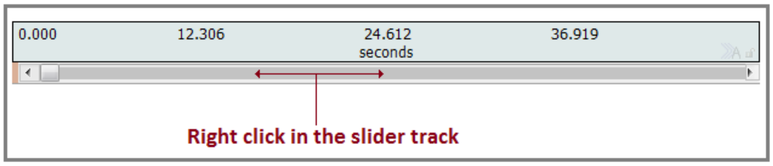
All preferences can be reset to the default factory configuration by holding down the Shift key while launching Acq*Knowledge*. The following prompt will appear:

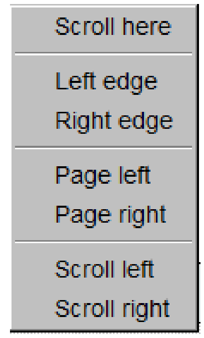


<u>It is important to note that accepting this option will reset ALL application defaults to the factory configuration.</u>

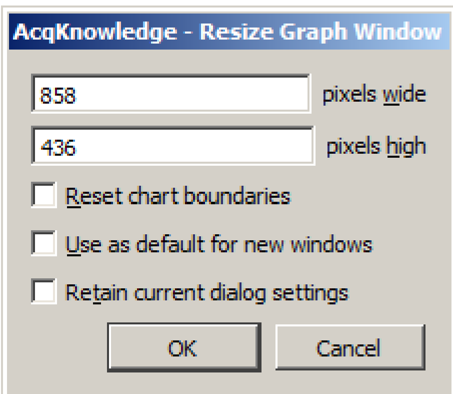
Scroll options

The Scroll options help navigate through large data files. Right-click below the horizontal scroll track to generate the contextual menu with scroll options.





Size window...



The Size Window function is useful for setting exact dimensions for the size of the graph window. Use this to create consistently sized windows for pasting into documents. The two text box fields are used to enter interior screen width and height, both of which are scaled in terms of pixels.

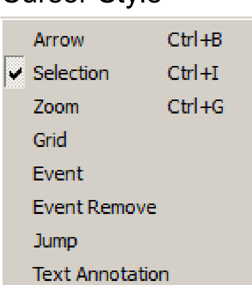
Each operating system may add additional dimensions as necessary to put in window adornments depending on the appearance configuration preference of the user (e.g. extra space for title bar of the window, any additional space put around the edges of the window frame, etc.).

When the <u>R</u>eset chart boundaries box is checked, the boundaries between the waveforms will be reset so that each channel "track" is the same size.

When Use as default for new windows is checked, the user-modified dimensions are applied as the default graph window size.

When "Retain current dialog settings" is checked, the dimensions used when the dialog was previously dismissed are applied to all subsequent graphs.

Cursor Style



This option allows the active cursor tool to be adjusted via the Display menu.

Create Data View

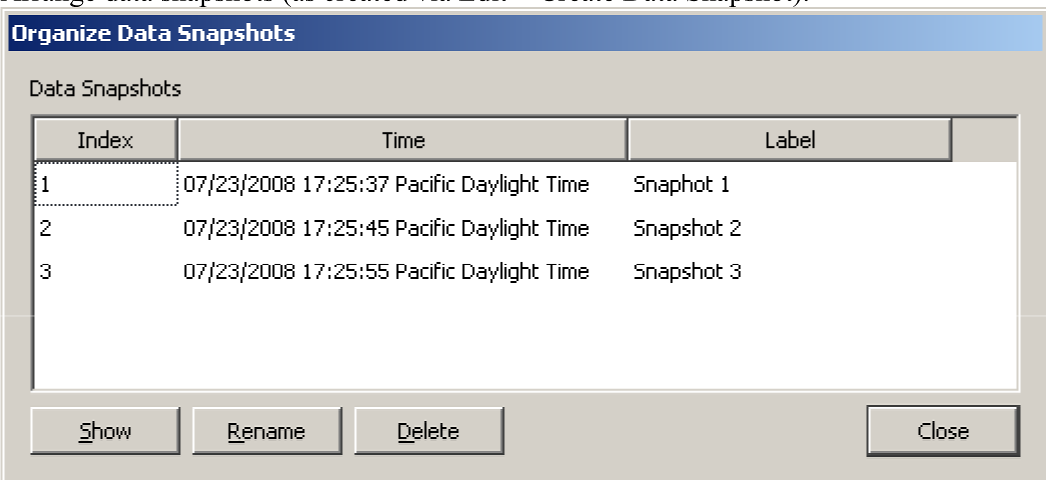
Creates a new Data View for the active (frontmost) graph and names the new window "Data View of 'Filename'" For Data View details, see page 43.

Create Focus Area

This option becomes available only when an area of data is selected, and brings up a Focus Area naming dialog. For full details on using the Focus Area feature, see page 96.

Organize Data Snapshots

Arrange data snapshots (as created via Edit > Create Data Snapshot).



Show All Data Snapshots

1 Manual Archive: description and time

2 Original file

3 Auto-Archive: time only

To view the embedded snapshot(s)/archive(s) associated with a graph file, choose Display > Show Original Data/All Data Snapshots. This will open a new graph window for each archive/snapshot associated with the graph. The time portion of the Filename for each graph is from the computer clock (saved with semi-colons because a file with colons in the filename cannot be saved). The "Snapshot from…" graph will open with no Start button.

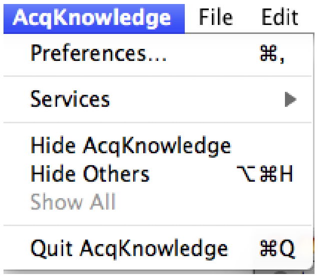
Each embedded archive is essentially a "snapshot" of the original acquired data that is stored with the graph file so the archive can be viewed at a later time to compare results to original waveforms or intermediate stages of analysis. Append events are not preserved in the snapshot/embedded archive file. For details on creating snapshots/embedded archives, see page 54.

Load All Data Into Memory

Use with large files to improve plotting performance, measurement response, etc. Memory can hold up to two gigabytes of data.

Chapter 19 Program & OS Menus

Acq*Knowledge* menu



Mac OS only—System generated menu. Use for Quit and Preferences. (Quit can also be found in the File menu.)

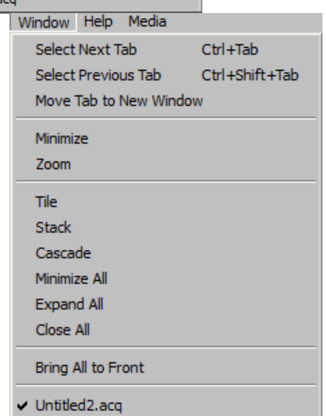
Window menu

The Window menu is a standard OS function. See Windows or Macintosh OS Guide for details.

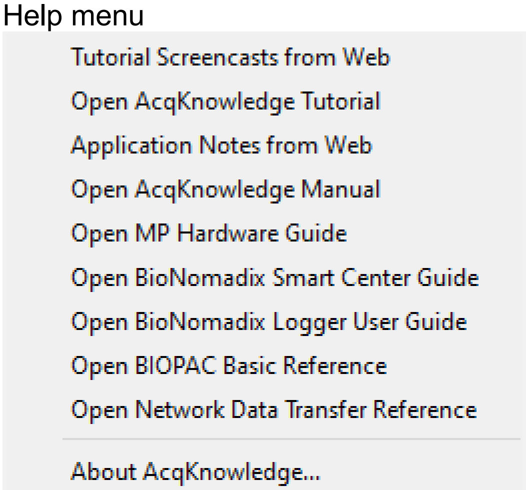
Bring All to Front

If other programs are running, this command will bring all Acq*Knowledge* windows to the front (on top of all other application windows); this command does not change the windows size or position.

Additional options become available when the Tabbed graph display preference is selected. (Right figure)



Help menu



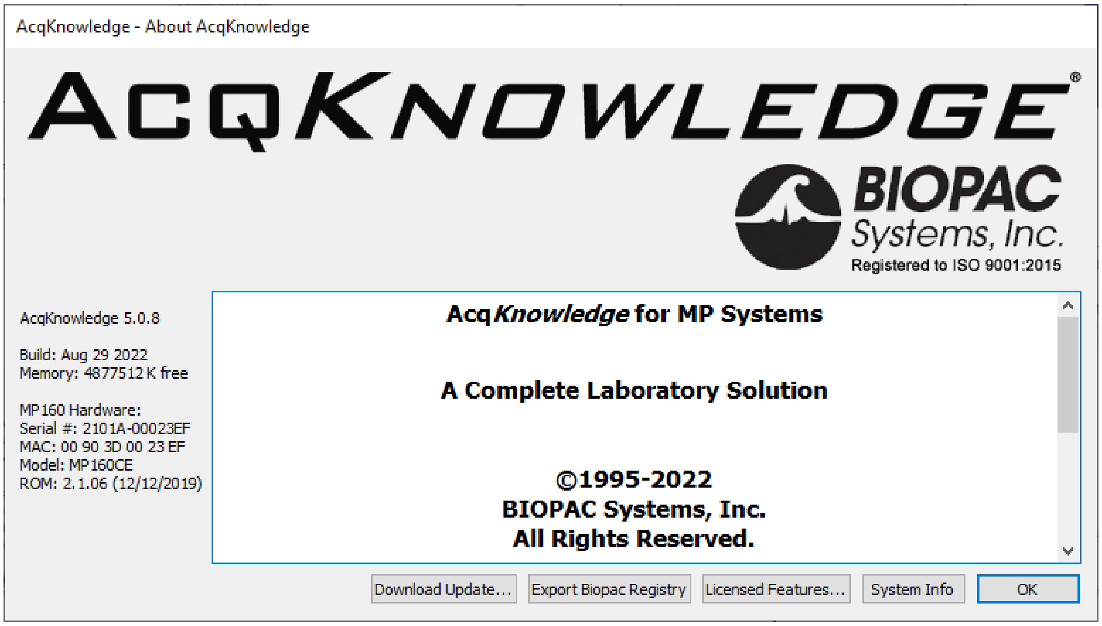
Use the User Support System pdf files for online help with the software.

Selecting “” from the Help menu generates a dialog that providing information about the Acq*Knowledge* software being used and system parameters, which can be useful when contacting Technical Support.

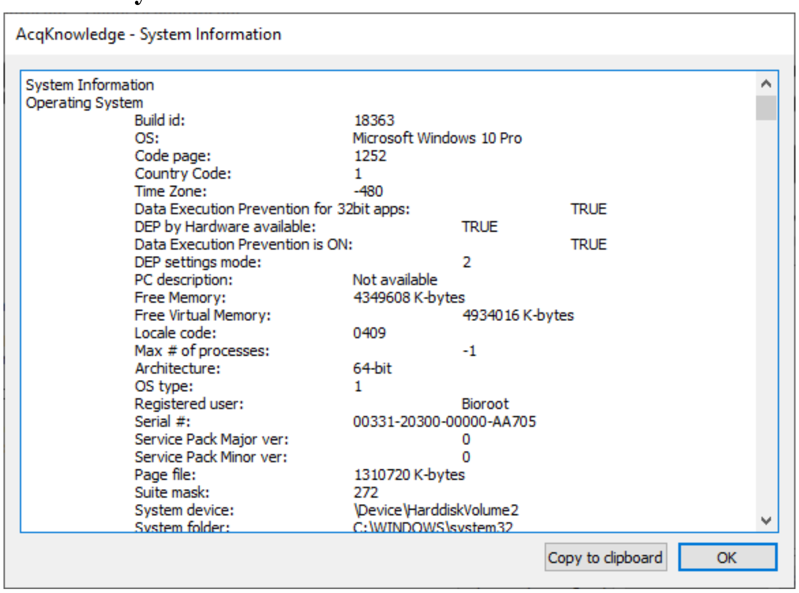
Note: For information about the MP160/150 data acquisition unit and firmware, click MP160/150 menu >MP160/150 Info.

About Acq*Knowledge*

“About Acq*Knowledge*” provides access to the following information.

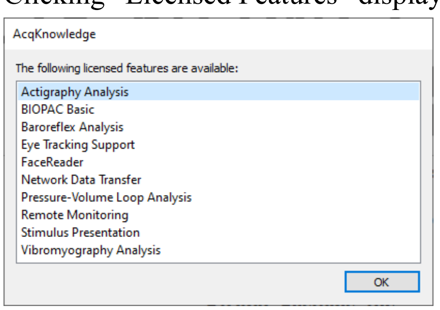


Click the **System Info** button for more detailed information.



The **Copy to clipboard** button makes it easy to paste system info into an email for Technical Support.

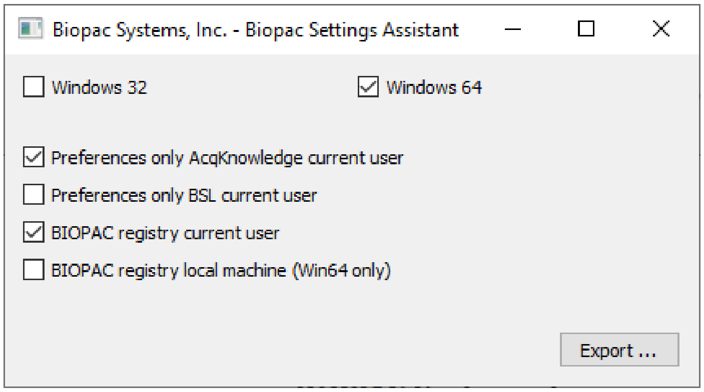
Clicking “Licensed Features” displays information about any installed licensed features.



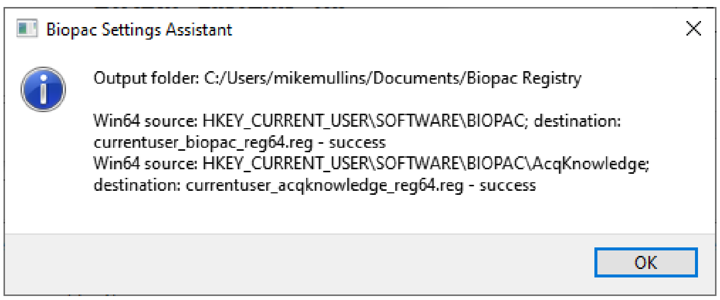
Export Biopac Registry (Acq*Knowledge* 5.0.6 and higher) provides a tool that creates a snapshot of system registry entries used by Biopac products (Acq*Knowledge* and Biopac Student Lab)

To use:

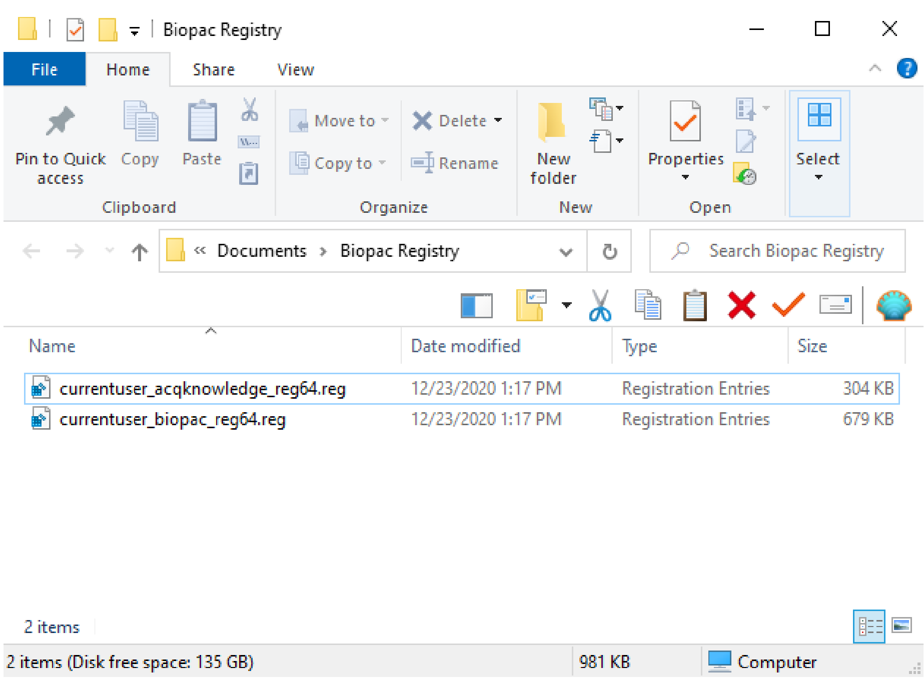
1. Click **Export Biopac Registry** to start the utility.
2. Tick the checkboxes to export the desired registry keys.



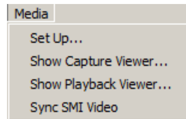
3. Click **Export**.
4. Navigate to the desired destination folder and click **Select Folder** in the subsequent dialog.
5. Click OK in the Settings Assistant confirmation dialog.



6. The target location of the exported registry keys will open in Windows Explorer.



Chapter 20 Media Menu



Also applicable to multi-camera systems and CAM-HFR-A high-speed camera. For Media Menu setup for CAM-HFR-A, see page 526.

Media functionality allows users to capture and playback video and/or audio with a USB web cam or firewire DV device and synchronize it with physiological information from an hardware device. The key functionality is a strong link between the video and data cursor when graphs are being used in post-acquisition mode; changing the selection in the graph window will automatically jump the video to the time corresponding to the cursor position. The reverse tie is also in place where scrolling the video will move the data cursor to the corresponding data point in the graph.

For synchronized playback of media player with Acq*Knowledge* cursor in data view, BIOPAC recommends that the users sample the hardware unit at least as fast as the video frame rate 30 Hz. In this case, any measurement errors are limited to the basic frame rate error window (1/30 sec). For exact match of Video and Data samples, BIOPAC recommends frame rate 25 fps and acquisition rate 25 samples/second (or its derivatives).

Set Up Establish Sources, Output and Media parameters. Set device type for audio and or/video. Use refresh after connecting a new device to make it a selectable option. Browse using standard file open/save functionality to specify media files. If desired, set a Delay between file segments.

Show Capture Viewer Use for video signal directly from a video camera; this option is disabled (grayed) in the record mode when both the Capture video and Capture audio options in the Media Setup dialog are off.

Show Playback Viewer Use to play back media from the disk (stored media files); this option is disabled (grayed) if there is no media assigned to the file.

Sync SMI Video This feature is used specifically for synchronizing video exported from SMI BeGaze eye tracking software. The SMI video is synced by using timestamp information extracted from the exported BeGaze data file. For more information about SMI Begaze Import/Export, see page 296.

Video Playback and Capture preview include a right-mouse contextual menu item “Grab bitmap” which, when selected, generates a Save As dialog to save the current displayed frame as a *.bmp image.

Media Notes

- Media capture performance is improved under Windows 8 and 7 OS. If the selected webcam drops frames because of poor performance/low quality, the degree of synchronization will be compromised. Testing indicated the Microsoft Lifecam NX-3000 gave reliable performance with no dropped frames.
- Several Acq*Knowledge* files can point (link) to the one media file.
- Acq*Knowledge* files can link to media files created by other programs. If the media file is shorter or longer than the Acq*Knowledge* files, just align the two files at the start.
- Acq*Knowledge* files alignment precision with the media file is user-controlled through the use of a delay function that allows a forward or backward time shift.
- Acq*Knowledge* files store the location (path) of the media file. This path is editable, so the Acq*Knowledge* file can link to other media files too.
- Media functionality does not support the *Autosave file* acquisition mode.
- Using the “Reset” function on appended acquisitions does not delete any previously recorded Media segments.
- Output video formats supported by the AcqKnowledge Media feature are Audio Video Interleaved (*.avi) and Windows Media Video (*.wmv). AVI is a higher quality format more suitable for editing, but creates very large files. WMV is lower quality but offers the advantage of saving file space.

Synchronization Tip

To optimize synchronized playback of the media and the physiological record, use the OUT103 LED to determine the delay between the media and the data. The LED must be in view of the video camera and the LED channel must be recorded.

MP160 Media synchronization - Windows only

Option 1: MP160 and AMI100D or HLT100C setup using an Analog Output

a. Connect the OUT103's 3.5 mm phone plug from the LED to one of the arms of the included Y-cable.

b. Connect the included CBL100 to the other arm of the Y-cable.

c. Connect the stem of the Y-cable to a CBL122 connected to one of the two Analog Output connections on the front face of the AMI100D or HLT100C.

d. Connect the other end of the CBL100 to a CBL122 connected to an otherwise unused Analog Channel also on the front face of the AMI100D or HLT100C.

e. Use "MP160 > Set Up Channels..." (in Acq*Knowledge*, choose "Channels" in the left pane after choosing "MP160 > Set Up Data Acquisition...") and acquire and plot the analog channel to which the CBL100 is connected.

f. Use "MP160 > Set Up Stimulator..." (in Acq*Knowledge*, choose "Stimulator" in the left pane after choosing "MP160 > Set Up Data Acquisition...") to send 5-volt pulses through the Analog Output.

MP150 Media synchronization - Windows only

Option 1: MP150 and UIM100C setup using an Analog Output

g. Connect the OUT103's 3.5 mm phone plug from the LED to one of the arms of the included Y-cable.

h. Connect the included CBL100 to the other arm of the Y-cable.

i. Connect the stem of the Y-cable to one of the two Analog Output connections near the bottom of the front face of the UIM100C.

j. Connect the other end of the CBL100 to an otherwise unused Analog Channel also on the front face of the UIM100C.

k. Use "MP160/150 > Set Up Channels..." (in Acq*Knowledge*, choose "Channels" in the left pane after choosing "MP160/150 > Set Up Data Acquisition...") and acquire and plot the analog channel to which the CBL100 is connected.

l. Use "MP160/150 > Set Up Stimulator..." (in Acq*Knowledge*, choose "Stimulator" in the left pane after choosing "MP160/150 > Set Up Data Acquisition...") to send 5 volt pulses through the Analog Output.

MP36R setup - *additional items required*

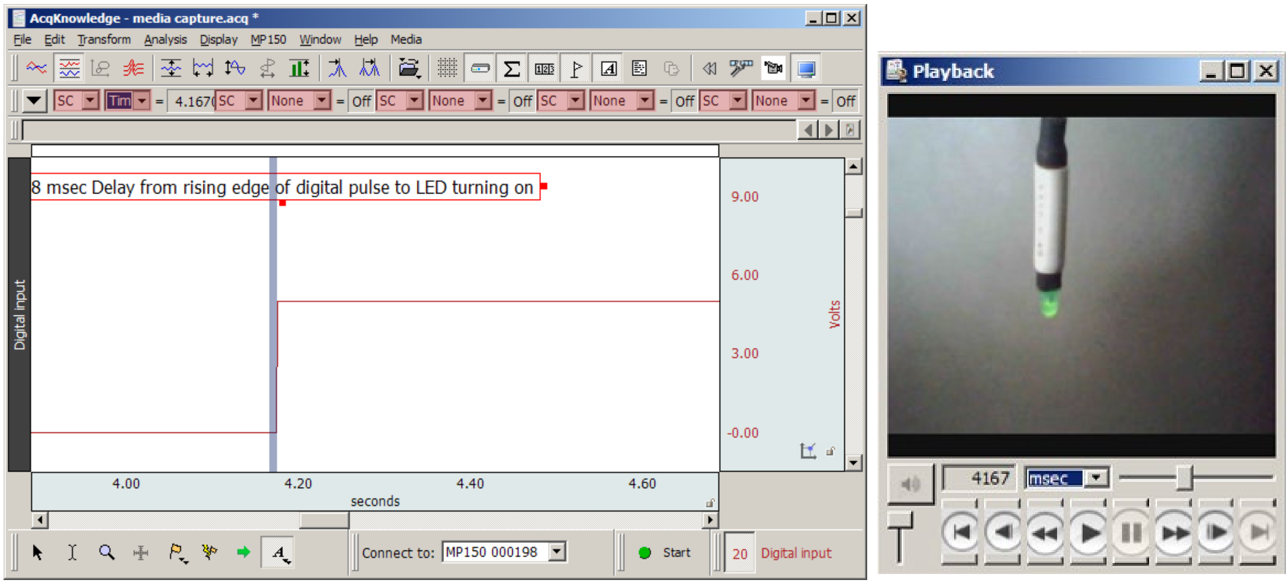
a. Connect an OUT3 (BNC adapter) to the 'Analog Out' port on the rear of the MP36R.

b. Connect a BSLCBL6 (interface cable: BNC to 3.5 mm) to the OUT3.

c. Connect the OUT103 3.5 mm plug to the BSLCBL6 3.5 mm socket.

d. Set MP36 > Output Control 'Low Voltage Stim' option
- set Pulse width to 100 msec
- set Pulse level to 5 Volts
- set Reference Channel to any digital channel
- click the 'ON' button to output a digital pulse

- Once the LED has illuminated and the square wave in the file is visible, the channel can be hidden.
- After the recording is complete, use the I-beam selection tool to measure the offset between the LED illumination and the leading edge of the digital impulse. Use a Delta T measurement to determine the delay information; Delay may be positive or negative based on camera performance. Delay should be entered in the Linked Media row for each segment—see page 524.

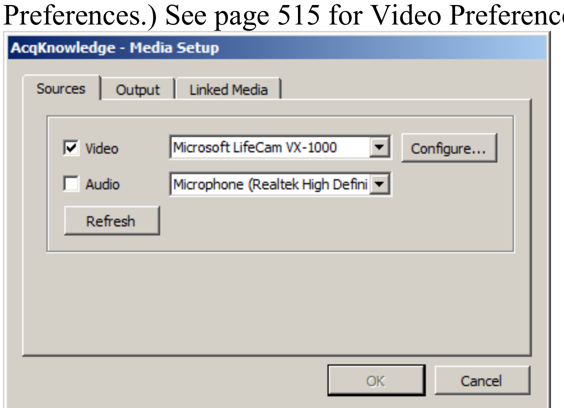


Media > Set Up

Source

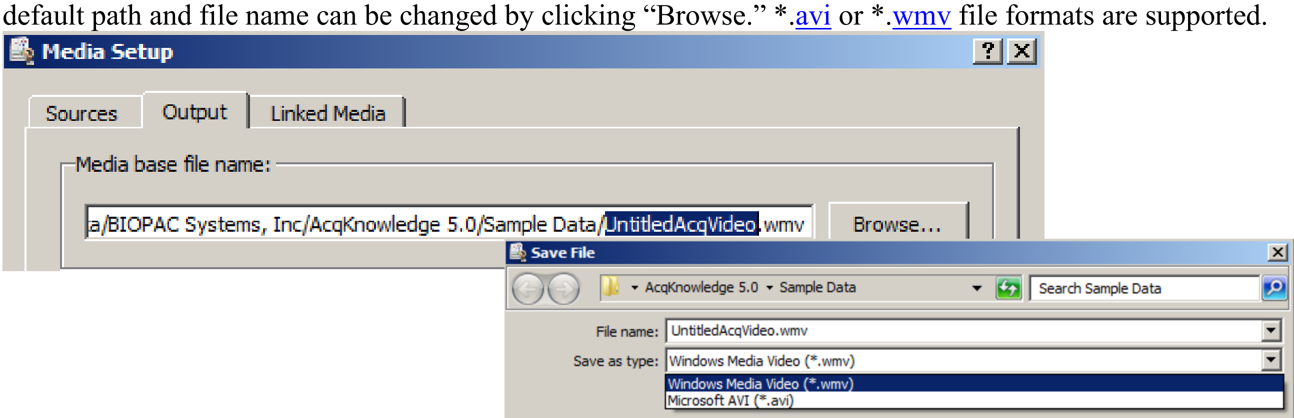
Use this dialog to select media source and select audio and video to record. Click Refresh to update the list if a video or audio device is connected after the dialog was opened. When video/audio for capture is selected, an output file must also be selected. Input file name and click OK; this will close the Media Setup dialog and automatically open the media window if the Capture option is ON.

All video camera, audio (microphone) input parameters can be set up by user with the UI provided by camera manufacturer, or use the "Configure" button for direct access to camera properties, such as exposure, saturation, contrast, white balance, etc. Additional parameters can also be set in the **Video Preferences** pane (Display > Preferences.) See page 515 for Video Preferences details.



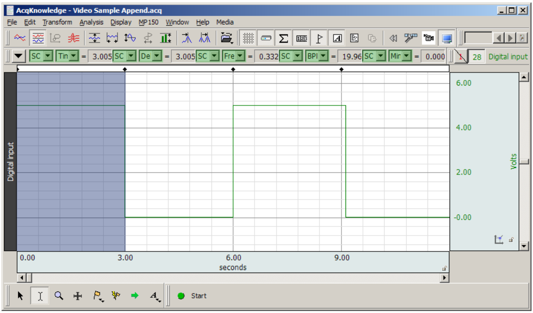
Output

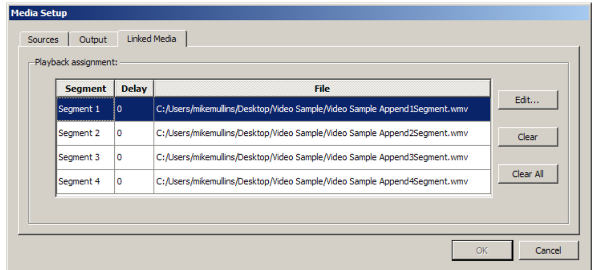
Video/audio capture Output assigns a media file to a default filepath in the Acq*Knowledge* program folder. The default path and file name can be changed by clicking "Browse." *.avi or *.wmv file formats are supported.



Linked Media

IMPORTANT An Acq*Knowledge* data file must be opened before linking to a media clip.



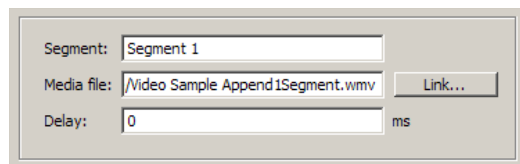


If media was captured with the data file, the Linked Media dialog will display a row for each appended segment in the Acq*Knowledge* data file and will list the file location of the corresponding media for each segment. The samples above show four Acq*Knowledge* data segments and four linked media Files.

Click anywhere in the row (or choose the Edit button) to set a delay to synchronize the media file with the physiological data. Delay range: Min= 1 millisecond, Max = segment duration.

- See Synchronization Tip on page 522.

If media was not captured with the data file, click the appropriate row and click "Link" to browse to the desired media file from that segment.



Delay—Each segment can have a distinct delay. Click in the Delay cell or click Edit to generate the dialog for Delay entry.

"+" Delay places start of video file after graph start

"-" Delay places start of video file before graph start

The best possible synchronization can't be better than the video frame rate (usually 1/30 of a second).

Media > Capture

Use Set Up to assign a Source and Output to enable the Capture menu option. There are no Preview window controls and the size reflects default video camera resolution.

Playback Preview

As the media file is manually scrolled or automatically played, the Acq*Knowledge* cursor keeps moving to reflect the corresponding location in the Acq*Knowledge* graph. If the Acq*Knowledge* cursor is moved, the media file is automatically scrolled to keep time sync with the data file.
Media files linked to appended data segments are loaded in sequential order. After playback of the first media segment, the cursor will automatically advance to a still-frame view marking the beginning of the next segment. The Play button must be pressed in order to play back subsequent segments.

Audio Mute button and level slider

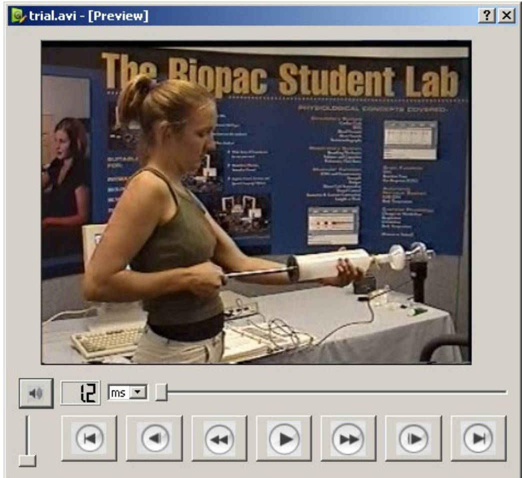
Video Digital indicator (time in milliseconds or frame number for the segment clip) and Horizontal slider (progress bar) to navigate the media file. The start point can be set from either the media clip or the data file. For precise selection, hold the shift key and use the forward or backward arrow keys on the media player or the keyboard to move single video frame (mostly 1/30 seconds) or data point.

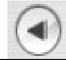
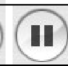
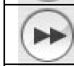
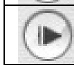
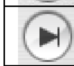
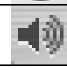
Use the scroll bar to navigate to different frames. Synchronization should be maintained with data in the graph window. This should result in a single sample selection cursor shown at the time closest to the displayed video frame.

The media window displays the text "No media assigned" in Playback Preview when the media window is visible but there is no video/audio file assignment for given data segment.

During the capture or playback of audio only, the media window will be displayed with a static musical note image as shown at right.

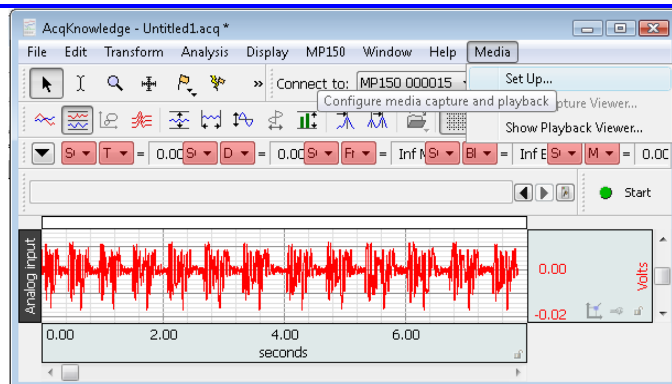
The Playback viewer uses standard media player controls.



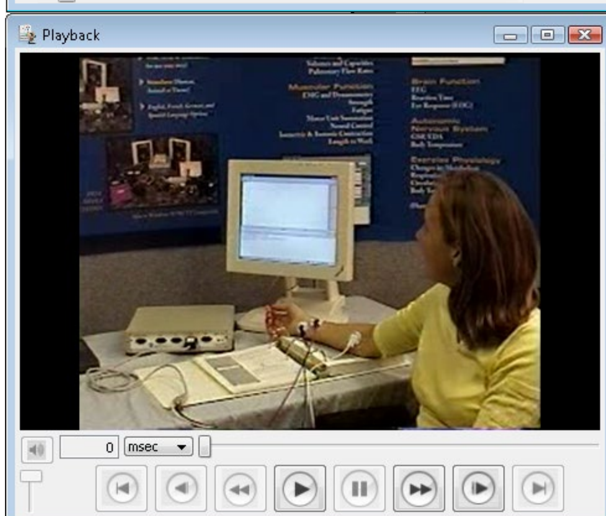
	Go to previous segment / go to beginning of segment
	Step backward a frame/sample
	Fast backward / reverse rewind
 	Play/ pause
	Fast forward
	Step forward a frame/sample
	Go to following segment
	Mute sound

Media Playback Example

1. Launch Acq*Knowledge*.
2. Open a saved acquisition file.

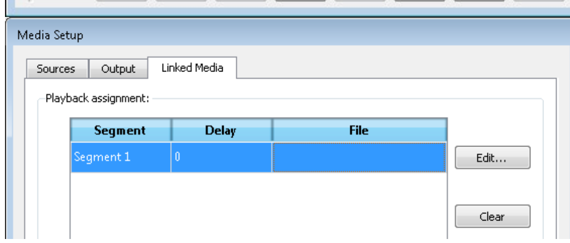


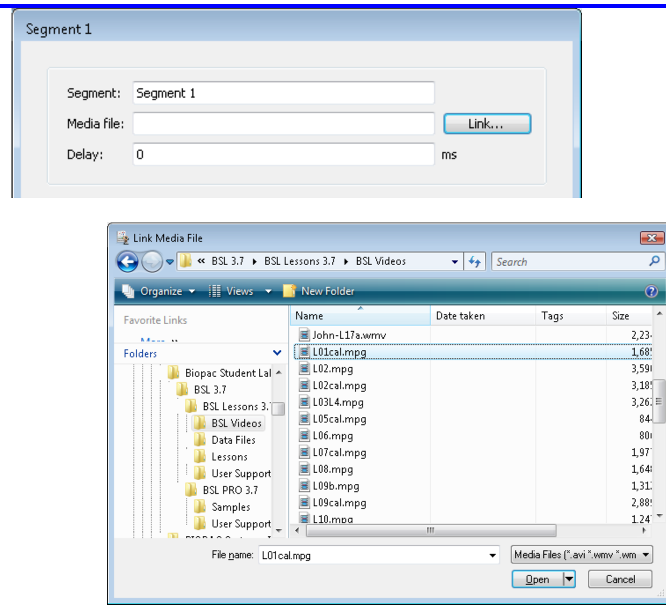
3. Select Media > Show Playback Viewer.
4. Experiment with the following options:
   - Select I-beam cursor on graph and push "Play" button on the player.
   - Change selection with I-beam on graph and see the video.



IF media is not assigned, locate the video clip for the appropriate segment:

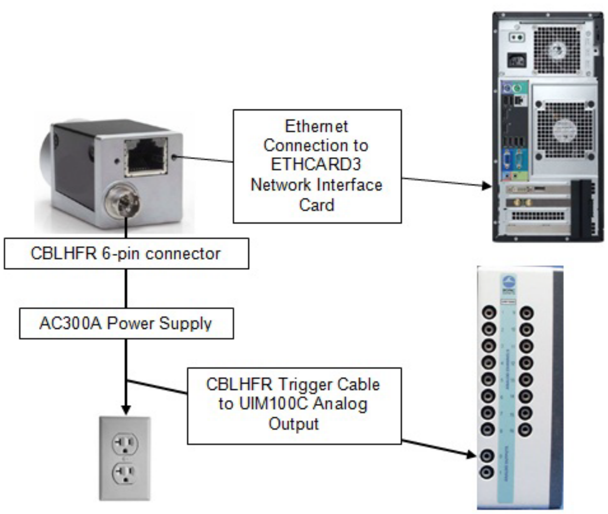
a.) Select Media > Set Up
b.) Select the "Linked Media" tab
c.) Select Segment 1 and click "Edit.
d.) Click "Link" and select a saved media file.

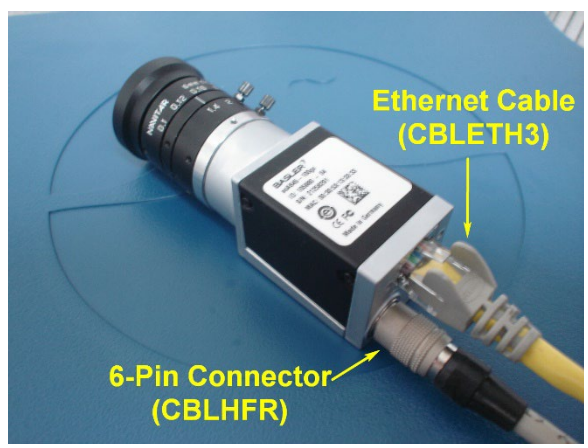




Media Capture Setup with CAM-HFR-A High Speed Camera

The CAM-HFR-A is a high-speed camera capable of capturing more precise video at rates up to 100 frames-per-second. Acq*Knowledge* versions 4.3.1 and higher support use of this camera. The Media setup procedure differs from that of a standard USB camera, with the Acq*Knowledge* Stimulator providing a “sync pulse” between the MP160/150 and the camera. Therefore, no manual synchronization procedure is required. The following pages describe hardware and software setup for the CAM-HFR-A.



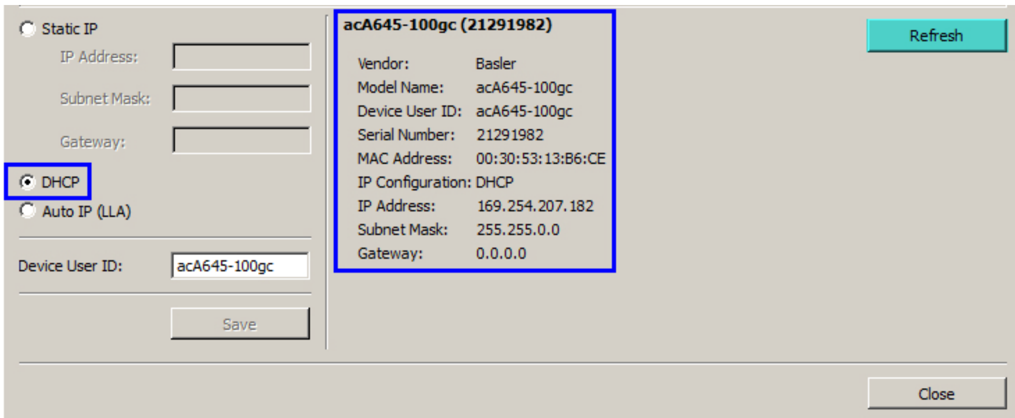


A. Connect Camera Hardware:

<u>Before beginning:</u>

<u>Make sure the camera drivers and the provided ETHCARD3 Network Interface Card are installed on computer.</u>

1. Connect the CBLHFR 6-pin-connector to the camera input.
2. Connect the female end of the CBLHFR connector to the AC300A power supply adapter cable.
3. MP160: Connect the CBLHFR Trigger Cable to a CBL122 RJ11 adapter and plug into an AMI100D or HLT100C Analog Output. For MP150, connect the CBLHFR Trigger Cable to the UIM100C Analog Output.
4. Plug the AC300A power supply cord into wall socket.
5. Connect the Ethernet cable between the camera's Ethernet port and the ETHCARD3 network interface card supplied with the system. Attach the 6 mm lens to camera (included as LENS-CAM-A).
6. Launch the pylon IP Configuration Tool from the Desktop shortcut to verify camera/network connection. If successful, the camera's network settings will appear in the IP configuration window as shown below. (Make sure the IP configuration is set to DHCP.)



NOTE: If the camera's network settings don't appear in the pylon IP Tool Configuration window, click the "Refresh" button and highlight the camera device from the list at the top of the Configuration Tool.

If the camera's network settings still don't appear or appear in the pylon IP Configuration Tool window as "unreachable," reset the IP configuration to Static IP.

B. Set Up Camera Configuration in AcqKnowledge Software:

<table>
<tr>
<td>

1. Launch Acq*Knowledge* and select Media > Set Up. The Basler camera should appear as selected in the "Video" list.
2. Check the "Video" option (and "Audio" if sound is to be recorded).

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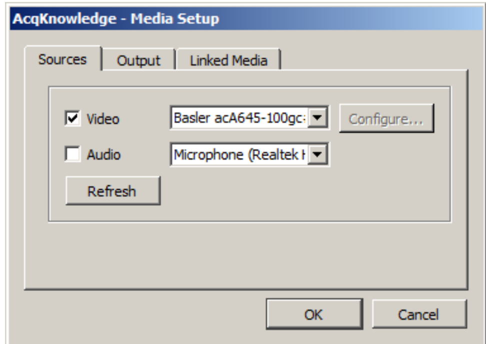

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3. Click the "Output" tab. A default path is assigned automatically, or click "Browse" and choose a new filename, path and/or format** (***.wmv** or ***.avi**) for the new media file.
4. Click "Save."

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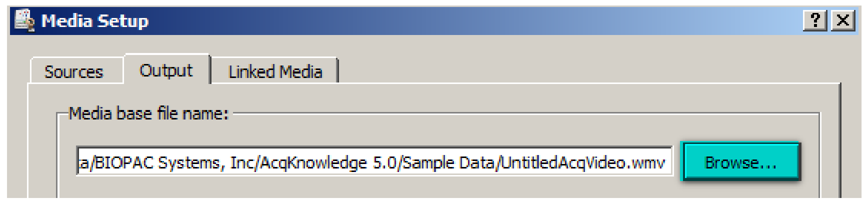

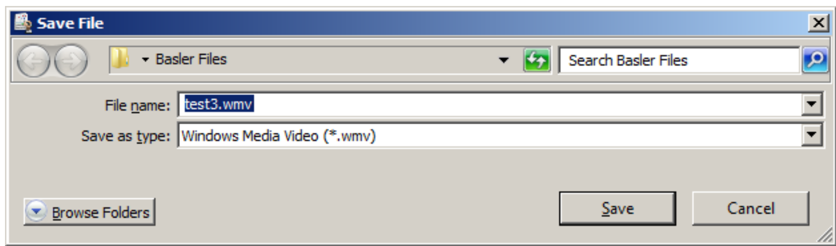

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5. Click "OK" to bring up the Video Capture Viewer. This is useful for determining proper camera positioning, lighting, etc.
6. To access the "Video" properties (Exposure or Gain controls), go to Media > Set Up and click the "Configure" button.

NOTE: The "Configure" button is not active until the Media > Set Up dialog is dismissed with "OK" and reopened.

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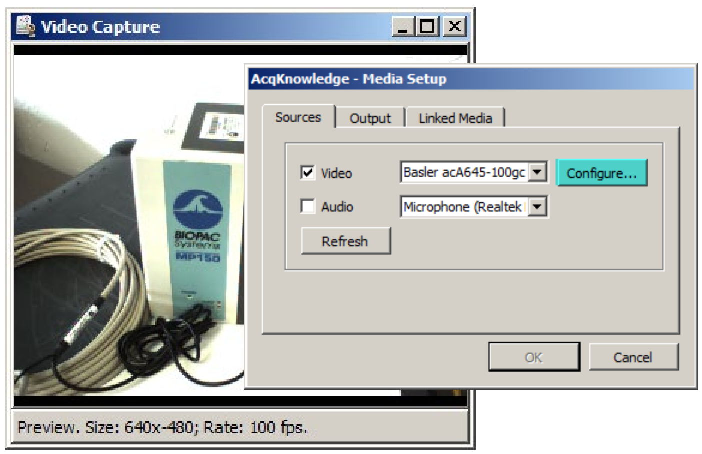

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7. Click the "HW Trigger" tab to:
   - Use the MP160/150 Stimulator to trigger and synchronize the camera recording with Acq*Knowledge* data collection.
   - Set the camera frame rate (25, 50, or 100 fps).

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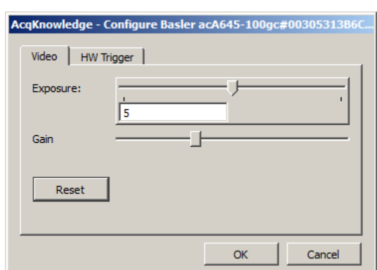

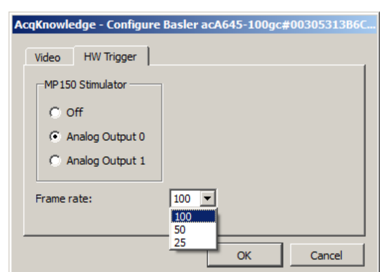

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**Dropped frames while recording in *.avi format are an indication that the computer may lack sufficient resources to support this larger-scale format. If this occurs, it's advisable to use *.wmv format instead.

NOTE: The CAM-HFR-A can link with only one graph at a time. A previous graph must be closed prior to connecting to a second graph, or a conflict error message will result.

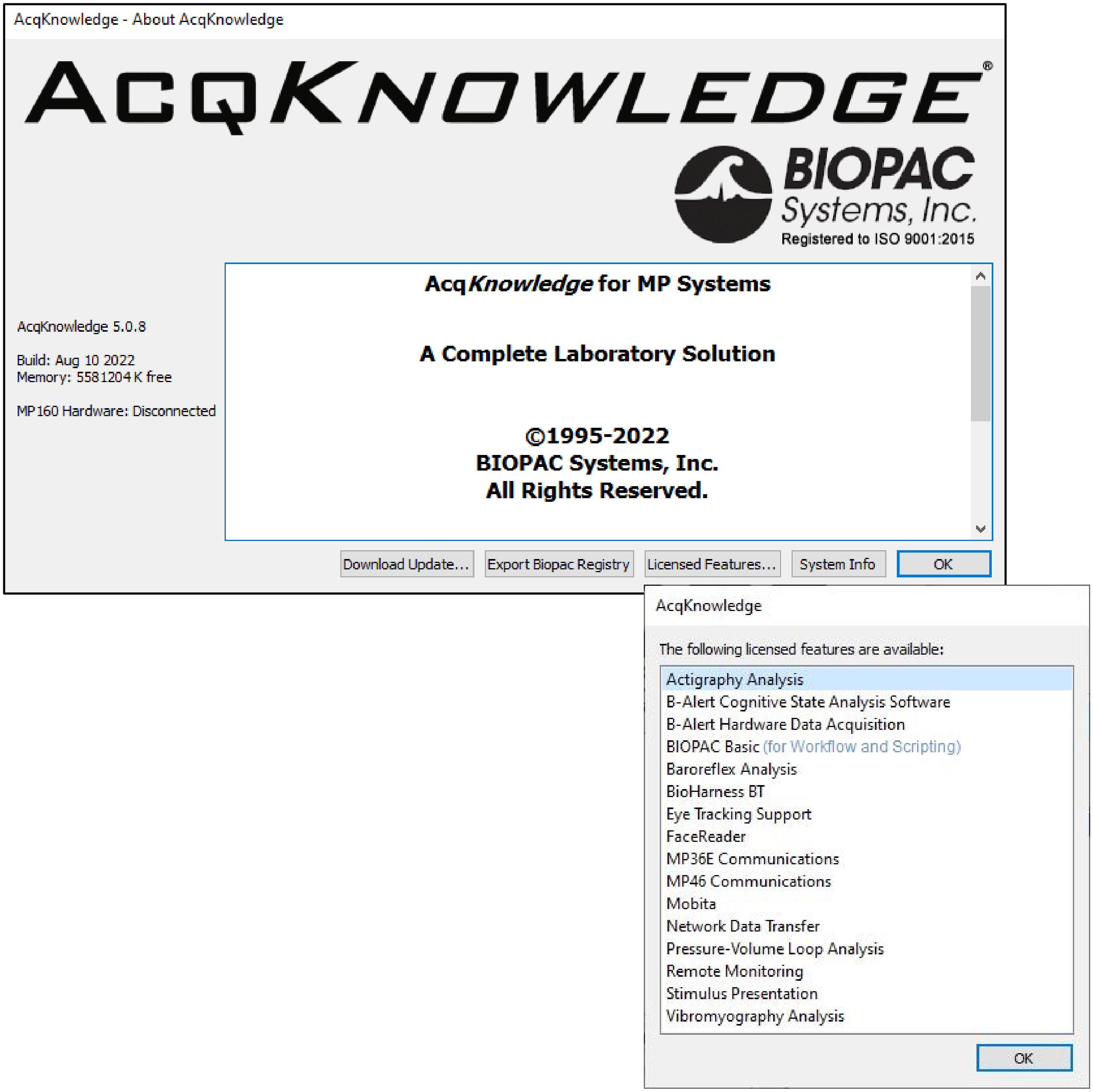
For camera specifications, see the CAM-HFR-A Product Sheet or the BIOPAC Hardware Guide.

Watch the Acq*Knowledge* CAM-HFR-A video tutorial for a detailed demonstration of this feature.

Part D — Licensed Functionalities

Acq*Knowledge* Licensed Functionalities consist of powerful optional features not included in the standard Acq*Knowledge* installation. These features become available with the purchase of an enhanced licensing level, and can be purchased individually or in a bundle at any time and added to an existing installation.

Access to the licensed features is enabled by a USB License Key provided by BIOPAC, and the USB key must be connected for the licenses to be active. With the license key connected, information about the available licenses can be found by going to Help > About and clicking the "Licensed Features" button.



Important: Starting with Acq*Knowledge* 5.0.6, a current version of Acq*Knowledge* is required to add or upgrade licensed features.

The following chapters offer an overview of the various licensed features available from BIOPAC.

Chapter 21 Licensed Functionality: Workflow

Workflow functionality is available through an optional license available with Acq*Knowledge* 5. The license must be authorized to access Workflow functionality, which runs on and automatically includes BIOPAC Scripting. To add a Workflow license to an existing MP System, please contact BIOPAC.

Using Workflow to Create Automated Analysis

Acq*Knowledge* Workflow is a licensed feature that allows users to create automated analysis routines or macros without any prior scripting knowledge. Workflow uses a simple and intuitive drag-and-drop interface to string together a series of Actions. This feature requires Acq*Knowledg*e 5.0.8 or later.

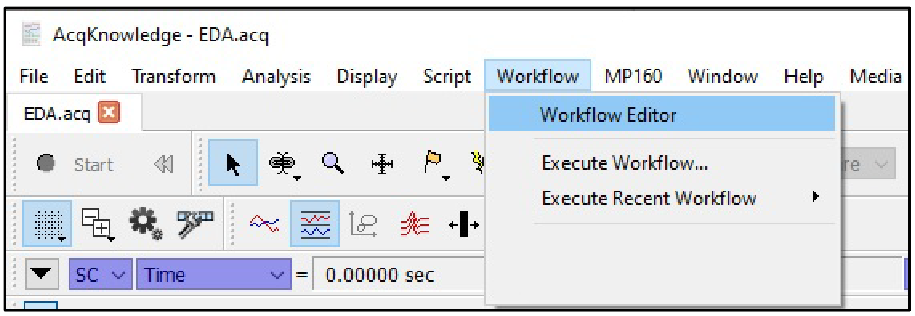
The Workflow license for Acq*Knowledge*

- enables the Workflow menu with drag-and-drop interface

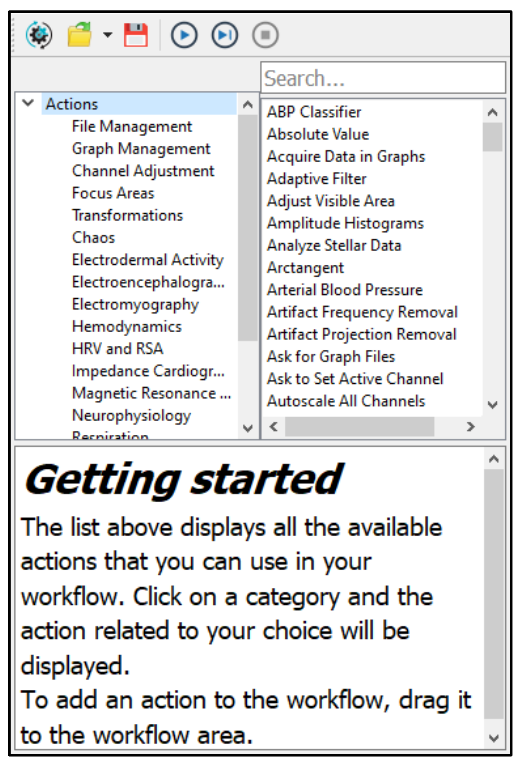
Workflow runs on and automatically includes BIOPAC Scripting (see Chapter 22: Scripting), which enables the Workflow menu, links the BIOPAC Basic Reference under Help, adds Preferences for Scripting, and adds the "Run Macro" Calculation channel Preset.

Getting Started with Workflow

1. To create a new Workflow, choose the menu item Workflow > Workflow Editor from the menu bar in any graph file. Note that the **Transform** and **Analysis** tabs are greyed out and unavailable when in Workflow Editor.

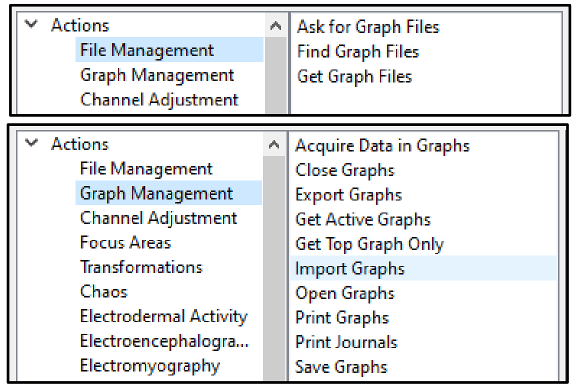


2. Three windows will be displayed on the left side of the screen. The upper left window lists Actions Categories under the heading **Actions**. Clicking the **Actions** heading will display a comprehensive list of possible Actions that can be performed in the window to the immediate right (beneath the **Search** window). Clicking a category filters the Actions in that category, and only those filtered Actions appear in the right window. Actions can also be located by entering key words into the **Search** window.
The information window in the bottom left side of the Editor screen displays a description of what each Action does. If no specific Action is selected, it will display the "Getting started" dialog. This dialog provides basic instructions on how to select Actions and add them to your Workflow.



3. Six control icons are located on the tool bar above the Action windows. The Actions these icon buttons control are (from left to right) **New Workflow**, **Open Workflow**, **Save Workflow**, **Run Workflow**, **Run Workflow Step by Step**, and **Stop Workflow**.

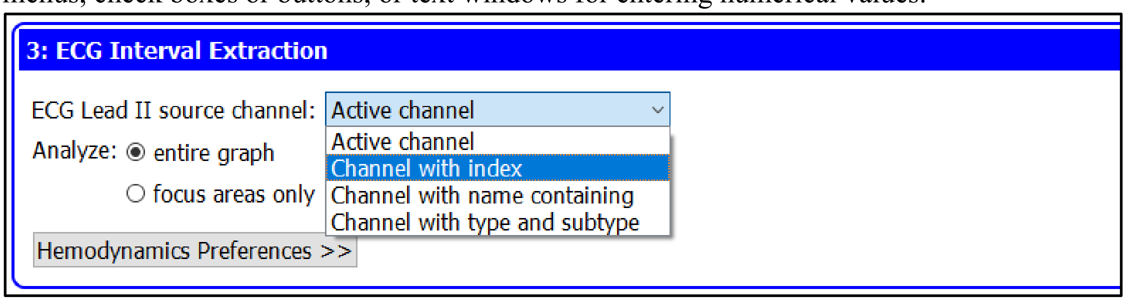
Creating a New Workflow by Adding Graphs



1. Workflows operate on graph windows selected via the **Graph Management** Actions category. Graph windows may be opened either through the user interface (e.g., via “File > Open…”) or via **File Management** Actions.
2. Select a graph or graphs via Actions in the **Graph Management** category. If no such Actions are selected, the Workflow will not perform any useful function. Drag and drop the Action into the **Workflow** window.

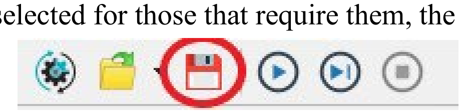
Selecting and Adding Actions to Workflow

1. Once one or more graphs have been added to the Workflow, additional Actions can be added by simply dragging and dropping them into the **Workflow** window.
2. Once an Action has been dropped into the Workflow window, it will be displayed as a numbered step in the Workflow. After an Action has been added to the Workflow, it cannot be dragged to a new position. If a user wishes to change the order of Actions or remove the Action from the Workflow, click the “x” in the upper right corner of the Action in the Workflow window to delete the Action. Actions can then be readded to the Workflow in the desired location or a new Action can also be added to any position in the Workflow order.
3. Many Actions have options and variables for the user to select and/or define, which are displayed once the Action has been dropped into the Workflow window. These user-defined options may be shown as pull-down menus, check boxes or buttons, or text windows for entering numerical values.

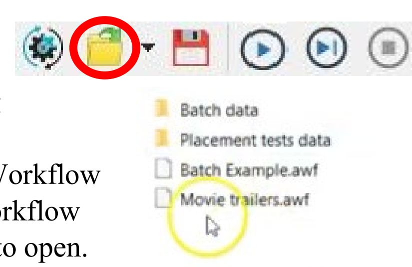


As an example, the above image shows the **ECG Interval Extraction** Action with options shown in both pulldown menus and buttons, as well as a **Hemodynamics Preferences** tab (closed), which when opened allows the user to select an additional range of options.

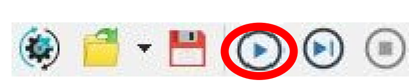
4. Once Actions have been added to a Workflow and options have been selected for those that require them, the completed Workflow can be saved by clicking the **Save** icon and naming the Workflow file, which will be saved with the .awf file extension.

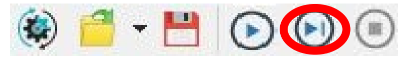


Running a Workflow in Acq*Knowledge*



1. Once a Workflow has been saved it can be run in conjunction with an Acq*Knowledge* .acq file. Begin by opening the associated .acq file (in Acq*Knowledge* 5.0.8 or later) with which you would like to run an existing Workflow.
2. With the Acq*Knowledge* file open, select the Workflow tab and open the Workflow Editor. With Workflow Editor open, select the Open File icon from the Workflow toolbar and navigate to the Acq*Knowledge* Workflow file (.awf) you wish to open.
3. Once the Workflow is open, the list of Actions will be displayed in the Workflow window.
4. Make sure the Workflow contains the Actions to select the correct graph or graphs from the Graph Management category (see Creating a New Workflow by Adding Graphs).
5. To execute the Workflow, simply click the **Run Workflow** icon from the toolbar.



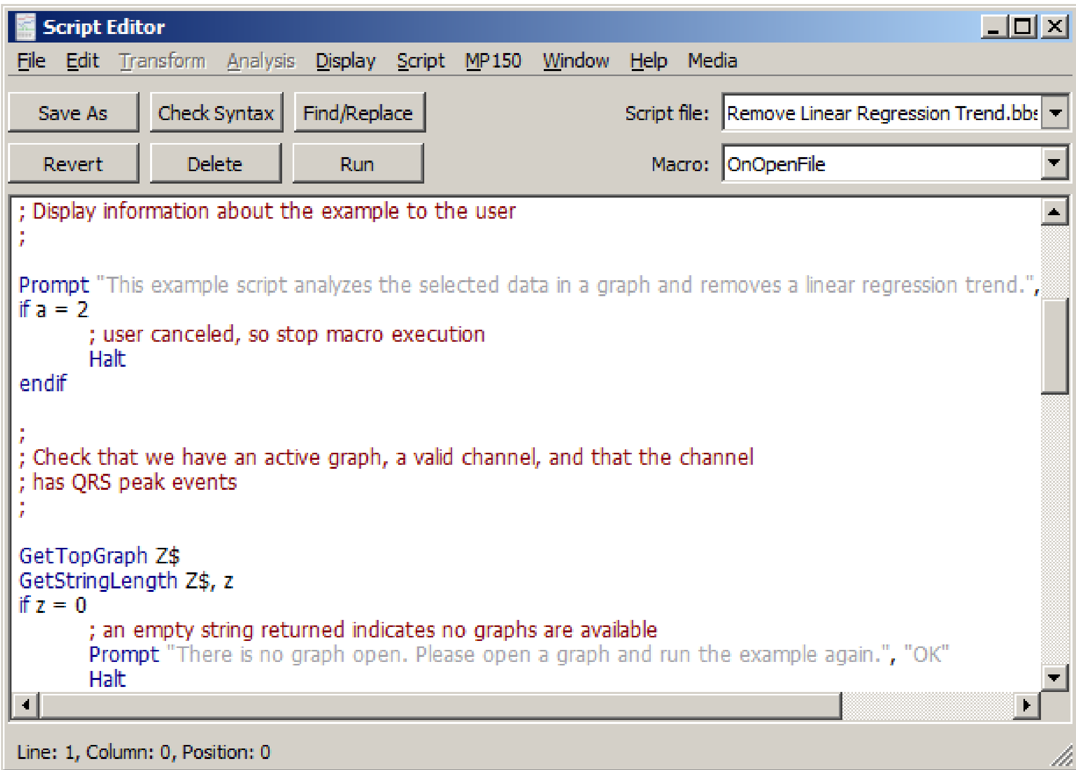


6. Optionally, users can run the Workflow so that it pauses after each step. To do this, click the **Run Workflow Step by Step** icon and continue clicking it to progress the Workflow through each Action. Click the **Stop Workflow** if you need to halt the Workflow's progress mid-run.
7. The Workflow will stop automatically once all Actions have been completed.

Chapter 22 Licensed Functionality: Scripting

Scripting functionality is available through an optional license available with Acq*Knowledge* 5. The Scripting license must be authorized to access Script functionality for executing, authoring, and debugging BIOPAC Basic scripts. To add a Scripting license to an existing MP System, please contact BIOPAC.

BIOPAC Basic Scripting is a scripting language development option for Acq*Knowledge* that allows for viewing of runtime variables, creating new script files and editing existing script files, triggering of individual script functions for testing and single step functionalities. Only users that have licensed the BIOPAC Basic feature may run user-generated scripts; if the feature is not available only digitally signed BIOPAC scripts may be executed. Scripting is available in any hardware supported in Acq*Knowledge* but configuration commands may not be available for non-MP hardware.

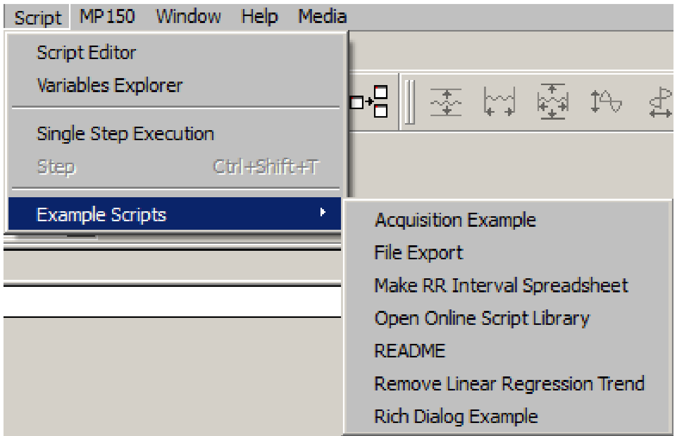


The Scripting license allows the following:

- enables Script menu
- enables Workflow menu for automation (see Chapter 21: Workflow)
- adds the Calculation channel Preset “Run Macro”
- links the **BIOPAC Basic Reference** under Help
- adds Preferences for Scripting

Script Editor Controls	**Functionality**
Save As	Saves changes applied to a script
Check Syntax	Click to check the current macro for errors.
Find/Replace	Opens a find and replace dialog for quickly editing text within the current macro.
Revert	Click to discard any changes to the current macro.
Delete	Click to remove currently displayed macro function from the script. This operation cannot be undone.
Run	Click to run the currently displayed macro. If single step mode is active, only the first line will be executed.
Script File:	Use to open an existing script or create a new one.
Macro:	Use to create or select the macro or callback to be applied. For more information, se the Biopac Basic Reference under the Script Editor or Acq*Knowledge* Help menu.

Scripting Menu



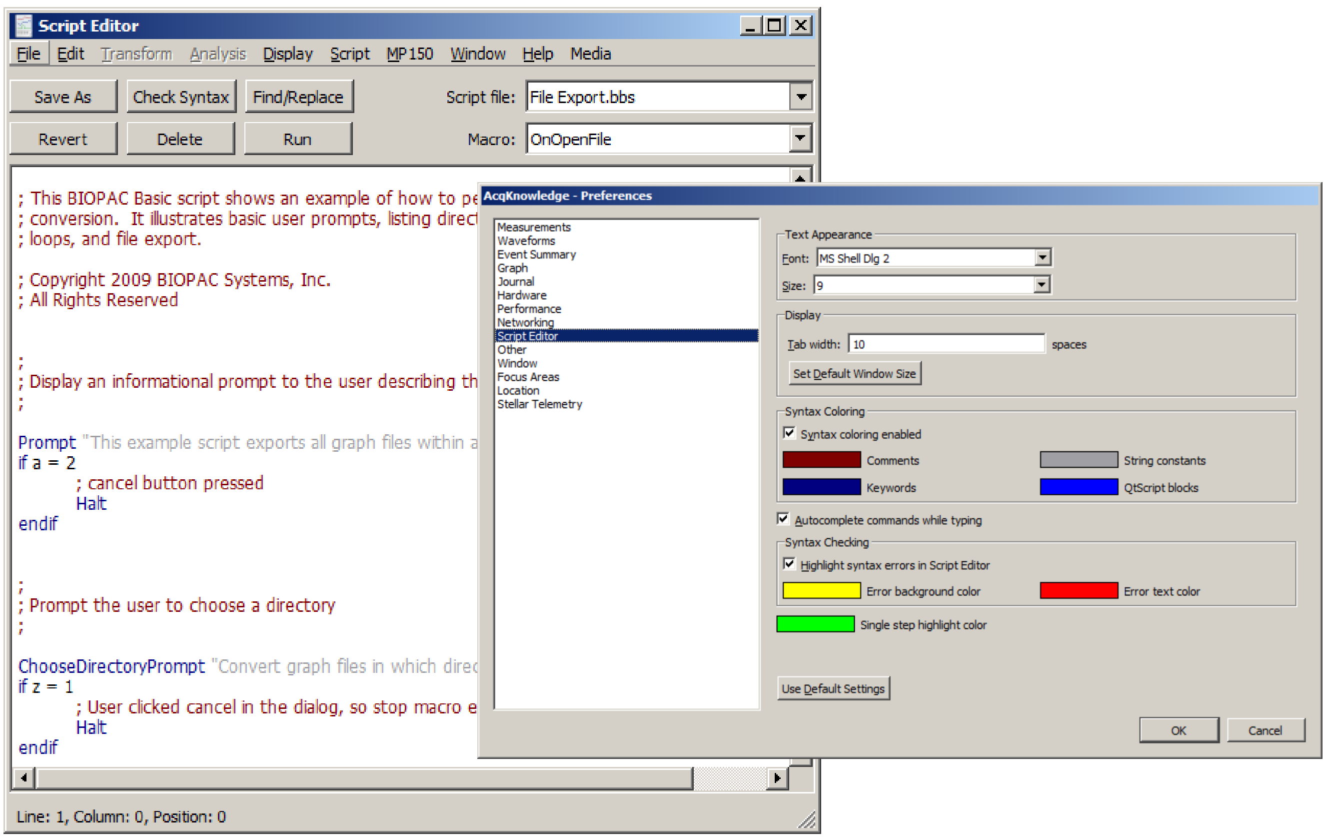
Script Editor

The Script Editor is the window used for creating and editing scripts. The window appears blank by default unless an existing script file (*.bbs) is selected or a new script is created.

To create a new script in the Editor, select **New Script File** from the "Script file:" menu.

To open any of the existing Acq*Knowledge* Specialized Analysis scripts, choose **Open Analysis Script** from the "Script file:" menu and select the desired script file.

Script Editor formatting is controlled in the Script Editor Preferences (Display > Preferences > Script Editor).

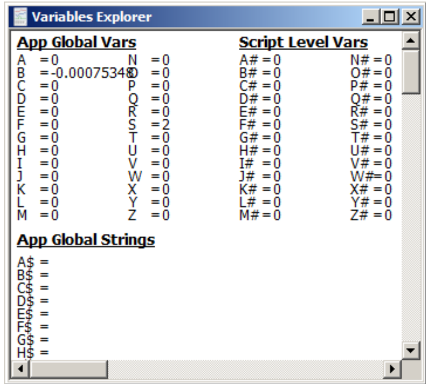


The size of the Script Editor window can be customized by using the "Set Default Window Size" preference option. (Acq*Knowledge* 5.0.1 and higher). To resize to a new default setting:

1. Open the Script Editor window (Script > Script Editor)
2. Resize the window to the desired size by clicking and dragging the corner.
3. in Display > Preferences > Script Editor, click "Set Default Window Size" and click OK.

Default settings can be restored with the "Use Default Settings" button.

Variables Explorer



Variables Explorer Window

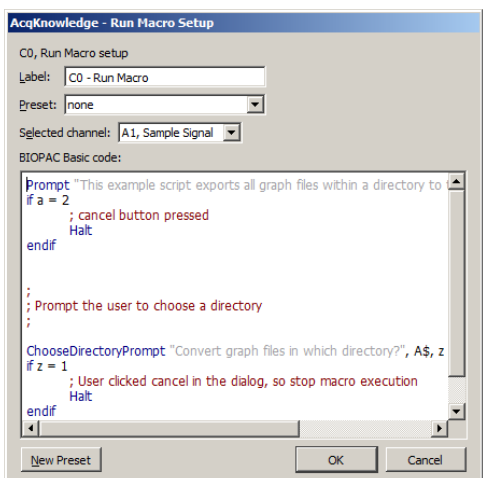
The **Variables Explorer** window (Script > Variables Explorer) shows the contents of the scripting language variables.

Single Step Execution mode (Script > Single Step execution) halts execution after each individual line of a macro, which allows for stepping through macros line by line for debugging and development purposes.

Example Scripts

Several BIOPAC example scripts and macros are available in this menu. When a script file is selected, the scripting language for the selected script is displayed in the Script Editor.

Run Macro Calculation Channel



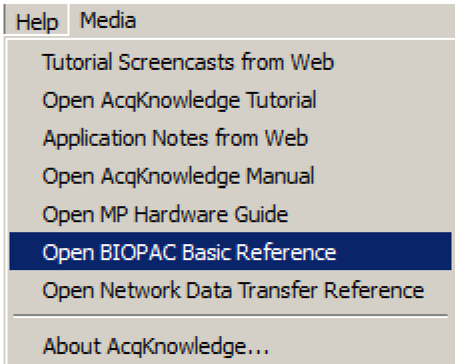
Run Macro Calculation Channel Setup Dialog

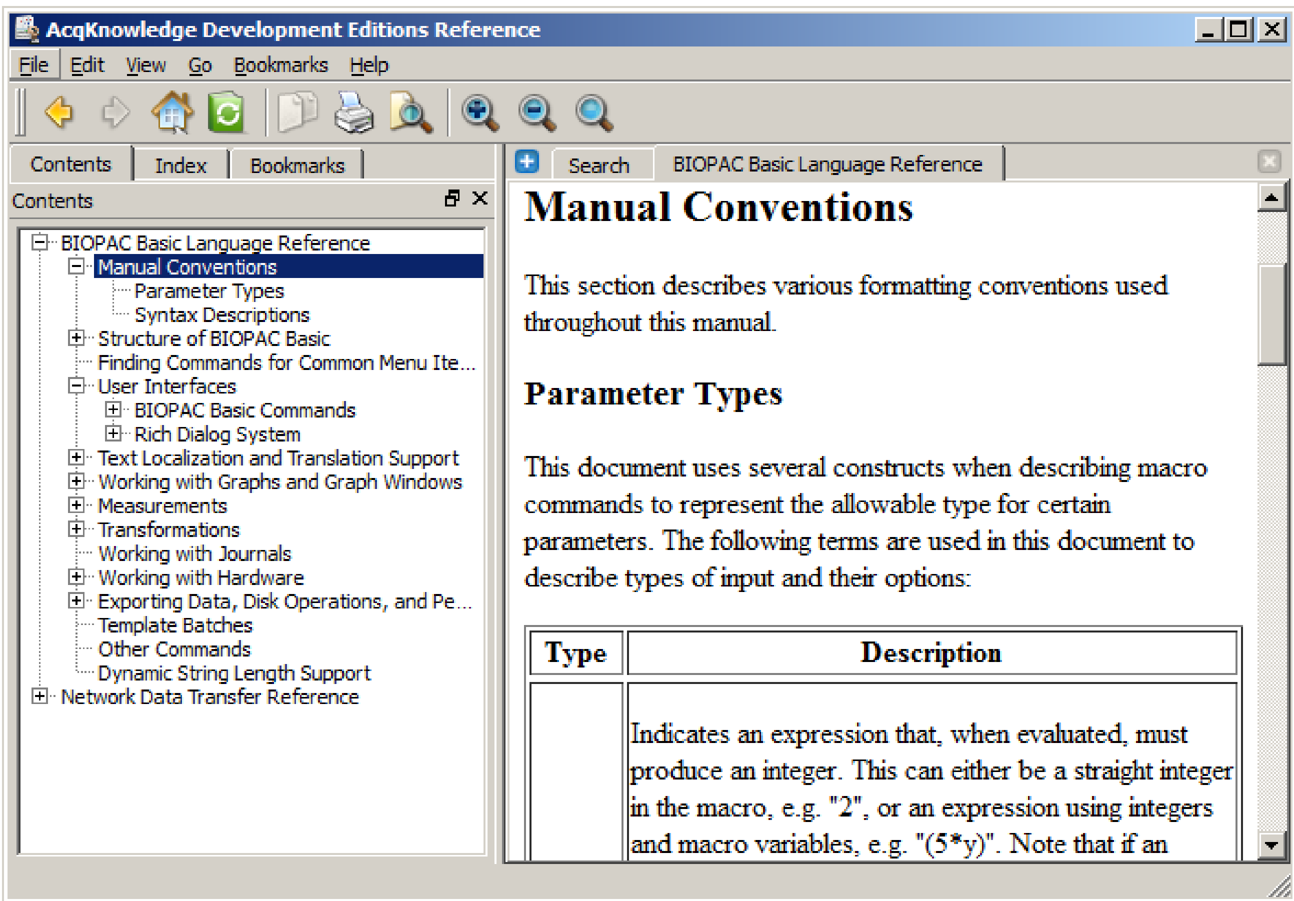
The "**Run Macro**" Calculation Channel Preset enables automatic post-processing at the end of acquisition.

Note

- Inserting an extra End in the middle of the macro creates a second macro upon saving. The second macro starts immediately after the inserted End.
- Run Macro calculation channels created with a licensed version will run if opened in a copy of Acq*Knowledge* without a Scripting license, but the macro cannot be edited.

To view the full online BIOPAC Basic Reference Scripting Manual, see the Acq*Knowledge* Help menu.





More Scripting References

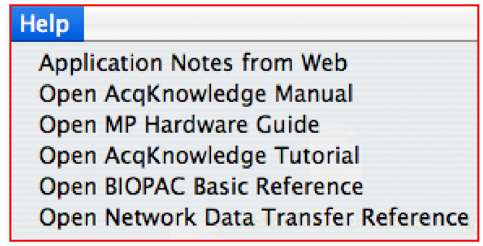
For more information about creating user-defined scripts for automated analysis routines, see the Tutorial Video.

Preconfigured scripts for automated routines may also be downloaded from BIOPAC here.

Chapter 23 Licensed Functionality: Network Data Transfer

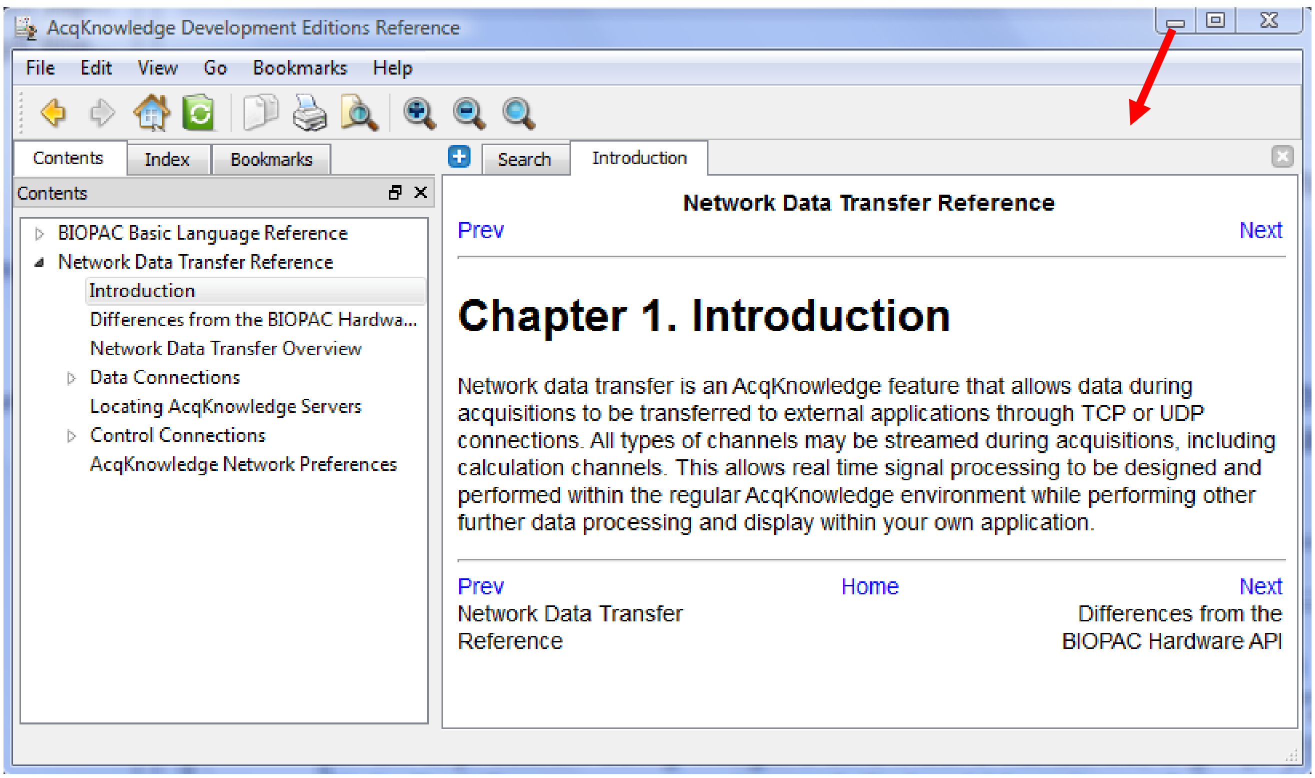
Network Data Transfer (NDT) functionality is available through an optional license available with Acq*Knowledge* 5. The license must be authorized to access NDT functionality. To add an NDT license to an existing MP System, please contact BIOPAC.

Network Data Transfer (NDT) is a real-time data transfer system that allows access to the data being acquired into a graph by Acq*Knowledge* for use in an external application; the Acq*Knowledge* process and the custom application may run on the same computer.
Make TCP or UDP connections to external applications and stream binary data during acquisitions. Network Data Transfer is supported in MP160 or MP150 hardware only.

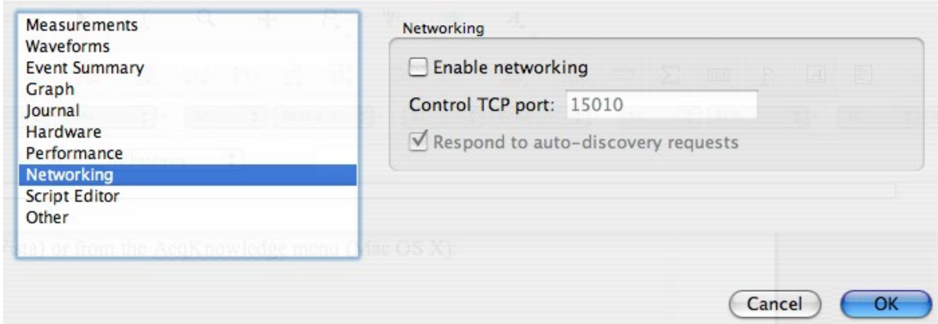


The NDT license

- allows Network Data Transfer functionality
- links the **Network Data Transfer Reference** under Help
- includes network data transfer Preferences



Most of the settings for the network data transfer functionality are set by clients through control connections. Several settings for the Acq*Knowledge* server may be set directly in the Acq*Knowledge* preferences. Versions of Acq*Knowledge* that include network data transfer functionality have an additional "Network" group of settings underneath their Preferences. These Preferences are accessed from the Display menu (Windows 8, 7/Vista) or from the Acq*Knowledge* menu (Mac OS):



NDT is a basic method for allowing third party applications to tap into the data stream being generated by both the MP unit and Acq*Knowledge* during data acquisitions. NDT provides

- networking facilities that allow for integration into a distributed application environment
- basic control facilities to allow external applications to query and control the Acq*Knowledge* application state.

The NDT system is split into two separate types of connections: data connections and the control connection.

A. Data connections deliver data from Acq*Knowledge* to external applications during acquisitions.

B. Control connections are made from external applications to Acq*Knowledge* to query application state and adjust data connections.

The *server* refers to the Acq*Knowledge* process and the computer on which it is running. The *client* refers to the custom application that is to receive data from Acq*Knowledge* and the computer on which it is running.

All connections should be made using standard network protocols, either TCP or UDP. Single system image architectures should make connections using the loopback interface. It is assumed that network implementations have appropriate IP networks in place with routing between machines that can be identified either by IP address or by hostname. Firewalls must be properly configured to allow network communications between the client and server. Appropriate network configuration is the user's responsibility.

Data Connections

Data connections are used to deliver data from the Acq*Knowledge* server to the client application. Data connections stream both data acquired from an MP unit and computed data from Acq*Knowledge* calculation channels. Data connections are available in a variety of formats and can be configured to meet the needs of the client application and bandwidth requirements.

Data connections are created only at the start of acquisitions. It is not possible to "attach" to data acquisitions that are already in progress.

XML-RPC calls for retrieving data are also described in this section. These connections are not persistent and not established from server to client, but rather a request made from client to server. The recommended mode of operation is regular TCP or UDP operation.

Variable Sampling Rates

Acq*Knowledge* uses variable sampling rates that allow different channels of data to be acquired at different sample rates. This allows fast moving signals (such as EMG) to be acquired at high sampling rates while simultaneously recording slow moving signals (such as respiration) at lower sampling rates. The primary use of variable sampling rate is to optimize storage requirements by minimizing space spent retaining slow moving data.

In addition to the storage optimizations, variable sampling rates are also used to optimize data connections. Channels that are sampled at lower rates require less network bandwidth to transfer from client to server. If channels of data cannot be disabled and overall bandwidth is limited, variable sampling rate can be used to lower the bandwidth required to move data between the server and the client.

The use of variable sampling rates requires the client to be aware of downsampled channels and handle data accordingly. Variable sampling rate may also affect the interpretation of the incoming data connection stream, as indicated below.

Transfer Types

Clients may choose between two different transfer types:

- **single connection** uses one data connection between the server and the client to deliver all data
- **multiple connection** uses multiple data connections delivering data simultaneously

Single Connection

The single connection transfer type uses a solitary connection between the server and the client to deliver data. When multiple channels of data are being delivered, all data is sent over the single connection in an interleaved format.

The interleaved format mingles the data of all channels in order. For example, an interleaved representation of two samples from three channels of data would be: C1 C2 C3 C1 C2 C3. This is equivalent to two sample frames where a *frame* contains the data at a particular sample location for all of the channels, in this case "C1 C2 C3." Frames are delivered sequentially over the data connection.

The single connection transfer type allows for all data to be processed from a single location and uses only one network connection resource. Single connection transfer has drawbacks including the need for the client to demux the data stream as well as account for variable sampling rates.

Variable Sample Rate Considerations

When variable sampling rate is being used, the single connection transfer type has the characteristic where not all frames have the same size. If a frame occurs at a sample position where a channel is not being sampled, that channel will not be included in the frame.

All downsampling within the Acq*Knowledge* variable sampling rate environment occurs at integer divisions of the base sampling rate. Only frames with indexes (zero-based) that are evenly divisible by the downsampling divider will contain data for that channel.

It is the responsibility of the client to compute and retain the frame index and to properly check channel dividers against the frame index to determine which channels are represented in that frame.

Frame 0 always contains a data point from every channel.

For example, consider a three channel acquisition. Channels 1 and 3 have a downsampling divider of 1, that is, they are being acquired at full speed. Channel 2 has a downsampling divider of 2, that is, channel 2 is being acquired at half speed. The first five frames of data in the single connection transfer type will appear as follows:

C1 C2 C3 | C1 C3 | C1 C2 C3 | C1 C3 | C1 C2 C3

Note how frames 1 and 3 are shorter as they occur at positions where channel two is not defined.

If variable sampling rate is being used, clients are required to perform proper frame indexing in order to demux the interleaved data stream. If clients cannot handle variable sampling rate correctly and are using the single stream transfer type, clients should check all of the downsampling dividers using the control connection to Acq*Knowledge* and warn the user if the configuration cannot be supported with that client.

Multiple Connection

The multiple connection transfer type uses a single connection from server to client for each channel of data that is being delivered. Using multiple connections offers the benefit of avoiding the client having the need to demux all of the data from each sample. If the client is operating in a high-load environment, the elimination of the demuxing may be useful in reducing processor overhead. It also allows client code to be simpler if variable sampling rate is being used.

The primary disadvantages of using the multiple connection transfer type are the usage of more network ports and the client assuming responsibility for synchronization of data across multiple channels. The data immediately available on one network connection may not be guaranteed to be the identical sample index of data being received for another channel. The client must keep track of sample index on an individual channel basis to properly synchronize data across multiple channels.

Variable Sampling Rate Considerations

Using variable sampling rate in a multiple connection transfer type is significantly easier. Each individual channel's connection delivers data at that channel's sampling rate. On a given connection, all samples have an identical length.

Clients still must be aware of variable sampling rates. The sampling rate of information on a downsampled channel connection is different than the sampling rate of information on an upsampled channel connection. If the client is performing any time domain measurements or other computations involving the sample interval, the difference in inter-sample-interval must still be taken into account.

XML-RPC

The XML-RPC transfer type allows clients to explicitly request data from the server. Instead of data being automatically pushed to clients, the client must post an XML-RPC function call to the server. This allows the client to query the server for the most recently acquired data sample value for a particular channel. Clients that do not require continual data streams or interact with only slow moving data may wish to use this method communication method. This method returns values only; no information about sample indexes or lengths is returned.

XML-RPC has significant overhead for both client and server, so this transport method cannot handle more than a few requests per second. If faster response time is required, the client should implement either the single connection or multiple connection streaming methods.

XML-RPC is not a true data connection as it does not involve the server constructing a streaming connection to the client.

Transport Protocol

Data connections offer a choice of using either TCP or UDP as the transport protocol for delivering data to the client. Choice of protocol depends on application requirements. When a client is receiving data, it is assumed that all data connections are using the same transport protocol.

TCP/IP

TCP is the preferred transport protocol. As TCP guarantees reliable, ordered delivery, all data is simply transferred from the server to the client without any additional information. Data is streamed continuously as it becomes available. TCP is recommended for all clients that require a guarantee of receiving all information. It is also recommended for any configuration using up to two computers. The port number used for data connections is specified by the client using the control connection prior to the start of acquisition. Once a client passes along port information, the client should begin listening for connections on that port.

When using TCP data connections, the start of acquisition is signaled to clients by the establishment of a connection on an appropriate port to the client. The end of an acquisition is signaled by the termination of the connection.

UDP

UDP is a connectionless protocol that does not guarantee either delivery or properly ordered reception of packets by clients. Data connection is allowed to be switched to UDP delivery mode. The primary benefit of using UDP datagrams is that a single data stream can be multicast to a number of computers. Multicasting is not offered implicitly by the Acq*Knowledge* data connection protocol but can be achieved implicitly by requesting a data connection be bound to a broadcast address.

UDP delivery used fixed size datagrams. The default size is 512 bytes. Clients can modify this size to any fixed number of bytes prior to the start of acquisitions. The UDP packet size is stored in the template and is different for each graph. UDP clients that require a specific packet size should set that packet size prior to the start of each acquisition.

Each datagram will contain the following:

Field	***Data Type***	***Offset***	***Description***
Starting sample index	unsigned long (four bytes, network order)	0 byte	This indicates the starting sample position of the first sample of data contained in the packet. This number is always monotonically increasing and can be used to reassemble datagrams that are received out of order. This field is always stored in network order. Usage of htonl()/ntohl() should convert from network order into host endian.
Length of data section in bytes	unsigned long (four bytes, network order)	4 bytes	Total number of bytes in the data section. Data is sent by Acq*Knowledge* as it is available, so not all data packets will contain the same amount of data. This field is always stored in network order. Usage of htonl()/ntohl() should convert from network order into host endian.
Data section	(type and endian specified by client)	8 bytes	Data section containing the binary data that was acquired. The data is converted into the appropriate data as configured by the client.

All of the data delivery is performed as data is available from the MP unit. The actual size of the data section in packets that get delivered to the client is dependent on the speed of data acquisition and other activity on the host computer. If variable sampling rates are being used, frames will not be split up. All of the data for the final frame is contained in the UDP packet. If a frame will not fit in the amount of space in a packet, it is sent in the next packet.

There are no provisions for clients to request retransmissions of packets from the server. Clients should be aware that data may not be delivered when using UDP and should be prepared to examine sample indexes at the beginning of each packet and handle missing data accordingly (padding, warning user, etc.).

The port on which datagrams is delivered is specified by the client prior to the beginning of acquisition on the control connection. Once the client specifies its port, it should begin listening for datagrams delivered to that port. The start of acquisition is signaled by the first datagram that is sent to that port. The sample index of the first datagram corresponds to the first hardware sample of data acquired by Acq*Knowledge*. If the graph is initially empty, the index is zero.

Unlike TCP connections which get explicitly disconnected at the end of acquisitions, there is no direct messaging for UDP delivery indicating the end of acquisitions. Datagrams will not be sent to the client after the end of acquisition. Clients requiring explicit termination notification should either use TCP or implement a timeout mechanism combined with an XML-RPC getAcquisitionInProgress call on the control connection to locate the end of acquisitions.

XML-RPC

The XML-RPC "get most recent data sample" call will use standard XML-RPC connection semantics involving the client making an HTTP POST request to the server and interpreting the response as appropriate. Handling of XML-RPC can be performed by a library in the client's appropriate implementation language.

Real-time Delivery Guarantees

No delivery time guarantees exist for any data connection. Data is delivered to the client as it becomes available. The overall latency of the system from physical sample time to data delivery is dependent on a number of factors including network load, Acq*Knowledge* overhead (which is variable due to calculation channel processing time,

user interface activity, thread scheduling, and other operations), system load, and other factors. The actual sampled data itself is guaranteed to be accurate; the sample time of a signal acquired into the hardware unit is always accurate.
It is only the time between the physical time corresponding to a sample and its delivery to the client application that is variable.

Clients that require strict real time guarantees or more predictable latencies should investigate using the hardware API on their local machine.

Data Formats

It is assumed that the data transfer feature is used in a mixed host environment, potentially with clients running in environments that have restricted data types. The sampled information delivered by a data connection is allowed to be controlled to appear in a variety of different formats for the client:

- 64 bit floating point – This format will always be available for all channels and may be delivered in either big endian byte order or little endian byte order. This is equivalent to a C style double data type.
- 32 bit floating point – This format will always be available for all channels and may be delivered in either big endian byte order or little endian byte order. This data type is not native to Acq*Knowledge*, so the precision of received data may differ from data as recorded by Acq*Knowledge*. This is equivalent to a C style float data type.
- Signed 16 bit integer – This format is available only for analog data channels. It may be delivered in either big endian byte order or little endian byte order. This is equivalent to a C style short data type. Clients receiving data in 16 bit integer format should use the control connection to determine appropriate floating point scaling factors that need to be applied to the data to convert into actual units.

Data formats should be specified by the client prior to the start of acquisition. If left unspecified, the default data format depends on channel type:

Channel Type	Default Data Type
Analog	16 bit signed integer, little endian
Digital	16 bit signed integer, little endian
Calculation	64 bit floating point, little endian

XML-RPC get most recent sample requests will always return the double type of XML-RPC (in ASCII notation).

Default Data Connection Settings

If the client does not modify any data connection settings, the following is used:

- Single connection transfer type
- TCP/IP transport protocol
- Port 15020 for single connection
- For multiple connections, each channel type (16 channels per type) is set as follows: analog channels [15020-15035], digital channels [15040-15055], calculation channels [15060-15075].
- Default data formats for each channel type as indicated in the “Data Formats” section

Note that no channels are enabled for delivery by default. Both data connection delivery and get most recent sample tracking are disabled. Clients will still need to enable channels in order to receive data.

Locating Acq*Knowledge* Servers

It is possible that clients and servers may be located on networks with dynamic IP addresses or other features that make establishing the connection between machines difficult. In this case, a simple UDP broadcast mechanism can be used to locate known servers.

Acq*Knowledge* will listen for incoming UDP packets on port 15012. If the UDP packet contains the sequence of ASCII characters "AcqP Client" and only that sequence, it will send a broadcast packet containing "AcqP Server Port:" followed by the port number on which the server is listening for control connections. The port number is expressed in base 10 ASCII notation.

It is possible to configure Acq*Knowledge* to not acknowledge discovery requests for security purposes.

Control Connections

Clients connect to an Acq*Knowledge* server using control connections. A control connection allows the client process to control how data is going to be delivered to it, query settings, modify settings, and perform other basic operations without requiring graphical interaction with the Acq*Knowledge* environment.

On the start of an acquisition, all data connections are established to the client that most recently established a control connection unless the client has modified the destination by using the changeDataConnectionHostname command.

It is possible to configure Acq*Knowledge* to not respond to any control connections for security purposes.

The majority of all control connections use XML-RPC. The XML-RPC specification can be located at http://www.xmlrpc.com/spec. XML-RPC consists of an HTTP POST request being assembled by the client along with data content expressed in the XML-RPC notation. The remote procedure call will then return with an appropriate response to the caller. By design, XML-RPC is client and platform agnostic.

XML-RPC implementations exist for a number of languages. If there is no implementation in the client's language, hardcoded requests can be embedded or a small helper application or shared library can assist in providing the control connection interface.

The URI that should be used when connecting to the server is the recommended "/RPC2" for XML-RPC. For example, a URL for localhost control connections would be "http://localhost/RPC2."

TCP Port

Only one control connection may be opened by a client to a server at a time. The server will listen on port 15010 by default. As this port may conflict with other network services or may need to be modified for firewall accessibility, Acq*Knowledge* will allow the server port to be modified by the user in the Display > Preferences panel. Clients should be aware that control connection port numbers are not fixed and should either allow users to change the port number from the client or use the dynamic discovery mechanism for locating Acq*Knowledge* servers.

Control Procedure Calls

Control procedure calls are remote procedure calls with a set method name and response. All method names and strings are case sensitive. The available control calls are roughly split up into querying acquisition parameters, configuring data delivery, and limited calls for modifying acquisition parameters and affecting application state.

Channel Index Parameter Structures

Some procedure calls take a *channel index structure* as a parameter. This is an XML-RPC structure that consists of the channel type and index. The channel type is a string member named "type" that is one of the following strings: analog, digital, calc. The channel index is an integer member named "index" and contains a zero-based index indicating the channel. For example, the following channel index parameter structure can be used to refer to calc channel 2 (recall, in Acq*Knowledge* calc channels are indexed from zero):

```
<struct>
        <member>
```

```
            <name>type</name>
            <value><string>calc</string></value>
        </member>
        <member>
            <name>index</name>
            <value><int>2</int></value>
        </member>
</struct>
```

Querying Acquisition Parameters

The calls for querying acquisition parameters are intended to allow clients to request information required for them to fill out appropriate parameters and to verify that previous control requests have been properly applied. The following control calls are recognized:

getMPUnitType

Method name: acq.getMPUnitType
Parameters: None
Return value: int

Retrieves the type of MP unit to which the server is connected. This may be zero (indicating no unit is connected, e.g. “No Hardware” mode), 160/150 (for MP160/150), or 36 (for MP36R).

The client can use this value to decide between appropriate templates to download or other channel settings.

getEnabledChannels

Method name: acq.getEnabledChannels
Parameters: string
Return value: array populated with int

Retrieves the channels that are available for acquisition and data delivery over a data connection to the client. The type of channels that are to be returned are specified in the string parameter. The string parameter may be one of the following: analog, digital, calc. The type must be lowercase. “analog” returns information about analog channels, “digital” digital channels, “calc” calculation channels.

The enabled channels are returned as an array of channel indexes, zero-based. These are the indexes that can be validly used in calls for configuring data connection parameters.

getChannelScaling

Method name: acq.getChannelScaling
Parameters: channel index parameter structure
Return value: struct containing scaling

For channels that can be delivered in short integer format, the channel scaling provides the scale factor and offset used to convert the short into physical units using the formula: sample*scale+offset. The scaling is returned as a structure containing two double-valued members: “scale” contains the multiplication factor, “offset” contains the offset factor.

Channels that cannot be delivered as short integers cannot be scaled. If this method is called with an invalid type of channel, a fault response is returned.

getSamplingRate

Method name: acq.getSamplingRate
Parameters: None
Return value: double

Returns the current sampling rate expressed in Hz. This is the rate at which data is sampled for a channel whose downsampling divider is 1.

getDownsamplingDivider

Method name: acq.getDownsamplingDivider
Parameters: channel index parameter structure
Return value: int

Retrieves the downsampling divider for a particular channel. A channel is sampled at the base sampling rate divided by this factor. This factor is also used to determine which frames contain samples for this channel.

Data Connection Configuration Commands

While it is possible to configure data connection parameters using Acq*Knowledge*, frequently clients may need to alter data connection configurations based upon dynamic information regarding the machine on which they are running (e.g. port collisions with other services, unexpected endian changes, etc.). The following commands may be used to configure how data is delivered to the application.

getDataConnectionMethod

Method name: acq.getDataConnectionMethod
Parameters: none
Return value: string

Returns the method currently being used for data connections between the server and client. The string value is either: single, multiple. “single” corresponds to a single data connection being made between the server and the client with all data interleaved over that connection. “multiple” corresponds to opening an individual connection to the client for each channel.

changeDataConnectionMethod

Method name: acq.changeDataConnectionMethod
Parameters: string
Return value: 0 on success, or fault code

Changes the method used to deliver data to the client. The parameter is a string that is one of the following: single, multiple. “single” opens up a single data connection and sends data in an interleaved fashion. “multiple” opens up an individual data connection for each channel.

getDataConnectionHostname

Method name: acq.getDataConnectionHostname
Parameters: none
Return value: string

Returns the currently set hostname for data connections. When data connections are established on the start of acquisition, the IP address associated with this hostname is sent the data. Hostnames must properly resolve in order for data connections to be made; DNS configuration is outside of the scope of the network data transfer feature.

If this hostname is empty, data connections is made to the most recently connected client application. This is the default setting.

Hostnames are unique on a graph by graph basis and are saved in templates and graph files. Clients redirecting data to another machine should check and set the data connection hostname as appropriate prior to the start of acquisition.

changeDataConnectionHostname

Method name: acq.changeDataConnectionHostname
Parameters: string

Return value: 0 on success, fault on error

Changes the destination machine for data connections, the recipient of the network delivered data. If the parameter is an empty string, data connections will automatically be made to the most recently connected client. The empty setting is the default.

If non-numeric hostnames are specified as parameters, they must be resolvable. If a hostname cannot be resolved, a fault is returned. Proper DNS configuration of the server is beyond the scope of the network data transfer feature.

getTransportType

Method name: acq.getTransportType
Parameters: None
Return value: string

Retrieves the transport type that is being used to deliver data from the server to the client. The transport type is a string that is one of the following: tcp, udp. Note that the XML-RPC data delivery method may be used in addition to this transport type if channels are enabled.

changeTransportType

Method name: acq.changeTransportType
Parameters: string
Return value: 0 if successful, else fault code

Change the transport type that is used to deliver data from the server to the client. The transport type is a string that has one of the following values: tcp, udp. XML-RPC last value data delivery may be used in addition to this type provided channels are enabled properly.

getUDPPacketSize

Method name: acq.getUDPPacketSize
Parameters: None
Return value: int

Returns the current size in bytes of UDP packets that is delivered to clients. Datagrams are always this fixed byte length although each individual datagram may contain varying amounts of data.

setUDPPacketSize

Method name: acq.setUDPPacketSize
Parameters: int
Return value: 0 on success, fault on error

Changes the size in bytes of UDP packets that are delivered to clients. Each individual datagram will always be this fixed length although the amount of data sent in specific packets may vary.

getUDPBroadcastEnabled

Method name: acq.getUDPBroadcastEnabled
Parameters: None
Return value: boolean

Determine if UDP packets are sent only to the client or are broadcast to the broadcast IP of the network. Broadcasting is supported only when the transport type is UDP.

changeUDPBroadcastEnabled

Method name: acq.changeUDPBroadcastEnabled
Parameters: Boolean
Return value: 0 if successful, fault code on error

Modify whether UDP packets are sent only to the client or are broadcast to the broadcast IP of the network. Broadcasting is supported only when the transport type is UDP.

getSingleConnectionModePort

Method name: acq.getSingleConnectionModePort
Parameters: None
Return value: integer

Returns the port number on which the server will connect to the client to deliver data. This port is used only when the connection mode is set to “single” which interleaves all data over a single connection.

changeSingleConnectionModePort

Method name: acq.changeSingleConnectionModePort
Parameters: integer
Return value: 0 on success, else fault code

Modifies the port on which the server connects to the client to deliver data. This port is used only when the connection mode is set to “single” which interleaves all data over a single connection.

getDataDeliveryEnabled

Method name: acq.getDataDeliveryEnabled
Parameters: channel index parameter structure
Return value: boolean

Query whether a channel is enabled for data delivery. Channels must be enabled for data delivery in order for their data to be delivered to the client. Not all channels that are being acquired are required to be delivered to data delivery.

changeDataDeliveryEnabled

Method name: acq.changeDataDeliveryEnabled
Parameters: channel index parameter structure, Boolean
Return value: 0 for success, else fault code

Change whether or not data delivery is enabled for a particular channel. Data delivery can only be changed prior to the start of an acquisition. Changes to data delivery enabling are only applied on the next start of acquisition.

getMostRecentSampleValueDeliveryEnabled

Method name: acq.getMostRecentSampleDeliveryValueEnabled
Parameters: channel index parameter structure
Return value: Boolean

Query whether a channel is enabled for most recent data sample requests. If a client wishes to use the XML-RPC calls to fetch the most recent value of data acquired of a channel, the channel must be enabled for this functionality prior to the start of acquisition.

changeMostRecentSampleValueDeliveryEnabled

Method name: acq.changeMostRecentSampleDeliveryValueEnabled
Parameters: channel index parameter structure, Boolean
Return value: 0 for success, else fault code

Change whether or not a channel is enabled for most recent data sample requests. When a channel is enabled, XML-RPC calls can be used during an acquisition to return the most recent sample of data acquired (or computed) for the channel. Any changes to the enabled state of a channel is applied on the start of the next acquisition. If a client wishes to use XML-RPC calls to read the value of a channel, that channel must be enabled prior to the start of the acquisition.

getDataConnectionPort

Method name: acq.getDataConnectionPort
Parameters: channel index parameter structure
Return value: int

Retrieves the port on which the server will deliver the data for the channel specified in the parameters to the client. Per-channel data connections are only used if the data connection method is set to "Multiple."

changeDataConnectionPort

Method name: acq.changeDataConnectionPort
Parameters: channel index parameter structure, integer
Return value: 0 for success, else fault code

Changes the port on which the individual connection is made by the server to the client to deliver the data for the channel specified in the parameters. This style of connection is used only if the data connection method is set to "Multiple."

getDataType

Method name: acq.getDataType
Parameters: channel index parameter structure
Return value: structure

Returns the data type that is being used in the binary data streams for the channel's data. The return value is a structure with a type and endian member. The type member, named "type", is a string and contains one of the following values: short, double, float. These strings correspond to their matching C-style data types. The endian member, named "endian", is a string and contains one of the following values: little, big. "little" corresponds to little endian byte order, big endian bit order. "big" corresponds to big endian byte order, big endian bit order.

changeDataType

Method name: acq.changeDataType
Parameters: channel index parameter structure, type structure
Return value: 0 on success, or fault code

Changes the data type that is used for binary data streams of the channel's data. The type structure is a struct containing two members. The "type" member is one of the following strings: double, float, short. Each string corresponds to the matching C-style data type. The "endian" member is one of the following strings: little, big. Each corresponds to the matching byte endian. Bit order within a byte will always be big-endian.

Not all channels may be able to support all data types. If the channel cannot be transmitted in the requested data type, a fault code is returned.

setDataConnectionTimeoutSec

Method Name: acq.setDataConnectionTimeoutSec
Parameters: integer of new timeout in seconds
Return value: 0 on success, or fault code

Changes the timeout in seconds after which the data connections is closed when acquisitions complete. Clients may need to set this keep-alive timeout in order to receive the trailing data at the end of acquisitions. The default value is "0" seconds which terminates all data delivery connections immediately when the final sample of data is acquired.

Reading Data During Acquisition

Normally data is delivered to clients during acquisitions using data connections. Data connections are either TCP or UDP connections established from the server to the client over which the server streams the incoming data. In some languages and environments however, it may not be possible to handle continuous data streams. The following XML-RPC commands are offered to assist these types of clients. Due to the large overhead of processing connections and XML-RPC requests, this data transfer type is not recommended and TCP/UDP should be used wherever possible.

getMostRecentSampleValue

Method name: acq.getMostRecentSampleValue
Parameters: channel index structure
Return value: double, or fault code

This procedure allows clients to read the most recent data value of a specific channel during acquisitions. In order for this call to be successful, a data acquisition must be in progress and the channel must be enabled for most recent sample value data delivery. Issue a changeMostRecentSampleValueDeliveryEnabled call prior to acquisition to allow this procedure to be used.

getMostRecentSampleValueArray

Method name: acq.getMostRecentSampleValueArray
Parameters: none
Return value: array of structures with channel info and values, or fault code

This procedure allows clients to retrieve the most recent data values of all channels during acquisitions in a single call. If clients are interested in the values of multiple channels, using this method is more efficient than performing consecutive getMostRecentSampleValue calls (which require an individual POST request per call).

Only channels that are enabled for most recent sample value data delivery is returned. Issue a changeMostRecentSampleValueDeliveryEnabled call for each desired channel prior to acquisition in order for this to return the value for a channel.

The return value is an array of structures, one per channel. Each structure contains two members. The “channel” member will contain a channel index structure with members set to appropriate type and index information for the channel. The “value” member is a double that contains the most recent sample value of the channel specified in the “channel” member.

This procedure cannot be called unless there is an acquisition in progress and there is at least one channel enabled for most recent sample value delivery.

Other Control Connection Commands

Control connections will also allow for the following additional commands to be used by clients:

loadTemplate

Method name: acq.loadTemplate
Parameters: base64 encoded binary Acq*Knowledge* graph template
Return value: 0 on success, or fault code

Attempts to open the passed template within the Acq*Knowledge* environment. The parameter is a base 64 encoded Acq*Knowledge* “gtl” graph template file. Only templates in PC Acq*Knowledge* 3.7.1 or Mac Acq*Knowledge* graph templates are allowed to be used with this command. The parameter must include the entire contents of the template file.

The parameter in the XML-RPC call should be a base64 parameter with the raw binary contents of a graph template file. When this parameter is decoded, it should correctly provide the contents of a template file on disk.

This function will return 0 on success, otherwise a fault code if the template could not be loaded. Once a template is loaded, the hardware settings contained within that template is used for subsequent data acquisitions. Templates for ACQ 3.9.2 and higher will retain any data connection settings that have been specified by clients. After loading a template, clients should re-send any configuration information for ports and data connection methods if they do not match the new settings from the template.

If the template data is corrupted or is incompatible with Acq*Knowledge*, user interaction may be required on the server computer to dismiss any error messages when attempting to load the template. If user interaction is required on errors, this call may not return until the user interaction has completed. Clients who are using XML-RPC bindings that offer timeout services may wish to use them with this function.

getAcquisitionInProgress

Method name: acq.getAcquisitionInProgress
Parameters: none
Return value: Boolean

Query whether data acquisition is currently in progress or not. A value of true is returned if data acquisition is occurring in any open Acq*Knowledge* graph window.

toggleAcquisition

Method name: acq.toggleAcquisition
Parameters: none
Return value: 0 on success, else fault code

Toggles data acquisition in the frontmost graph. If data acquisition is in progress, it is halted. If none is in progress, data acquisition is started in the graph.

Note that this function invocation may block if physical user interaction is required to start the acquisition in the graph, such as dismissing an overwrite warning, warnings on incompatibilities between different MP unit types, specifying a save location for acquisition to disk, etc. If the implementation of the XML-RPC binding used by the client supports timeout capabilities, it is highly recommended to enable timeouts for this function.

setOutputChannel

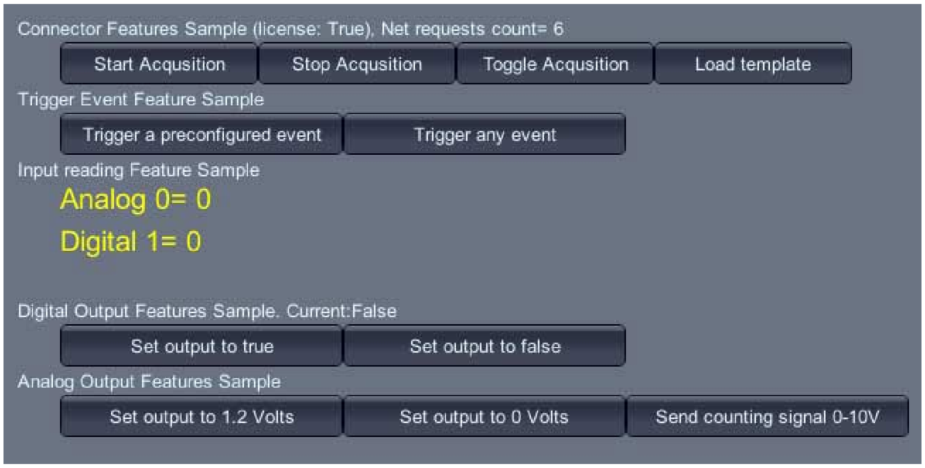
Method name: acq.setOutputChannel
Parameters: channel index structure, float output value
Return value: 0 on success, else fault code

Changes the voltage on the specified output channel of the MP device. For analog outputs, the value should be in the range (-10, 10) for the voltage level. For digital outputs, a value of 0 will turn the specified line off, a non-zero value will turn it on. The latency of when the output line is changed is variable and non-guaranteed. Additionally, the output channel may be modified by other areas of the software including control channels, manual user intervention, configured stimulators, etc.

The valid output channels are dependent on the type of MP device that is connected.

- MP160/150 units allow analog 0, 1 and all digital output channels
- MP36R units allow no analogs and digital 0-8.

*Unity Interface for Acq*Knowledge (requires Network Data Transfer License)



Unity® Interface for Acq*Knowledge*® allows for easy connection of Unity3D projects with Acq*Knowledge* software.

- Create a virtual environment using industry-standard Unity
- Connect and configure projects with Acq*Knowledge* in real time
- Control Acquisition from Unity to Custom Markers, Digital, and Analog I/O
- Deploy to your devices. Immerse your users and capture biofeedback for analysis

This Unity3D package allows Unity developers to access the Acq*Knowledge* network API (Network Data Transfer) v5.0 from Unity scripts without having to deal with the details of network communication, threading, and data access.

The Unity Interface for Acq*Knowledge* is compatible with recent versions of Windows and macOS.

Chapter 24 Licensed Functionality: Vibromyography

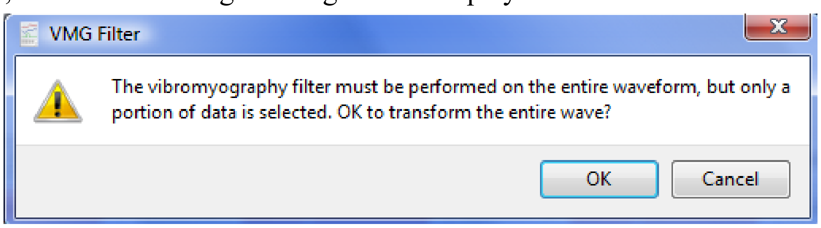
VMG functionality is available through an optional license available with Acq*Knowledge* 5. The VMG license must be authorized to access VMG functionality. To add a VMG license to an existing MP System, please contact BIOPAC.

The vibromyography transducer (TSD250) uses an accelerometer to measure surface vibration during activity which is directly correlated to muscle activity; this allows for muscle force and balance to be assessed without using surface electrodes or needle probes. The VMG license allows access to software processing algorithms that are incorporated into Acq*Knowledge* to perform data reduction for analysis of data collected from a VMG system.

The VMG license:

- adds “Vibromyography” Calculation channel Preset with required scaling and calibration
- adds “Vibromyography Filter” option under the Analysis menu
- includes Quick*Start* Q45 Vibromyography (.gtl format)—the journal of the file introduces VMG and the hardware settings use Module Setup to add a “VMG Transducer” to analog channel 1 and analog channel 2 of an AMI100D or HLT100C module. Two calculation channels are set to the “Vibromyography” preset using analog channel 1 and analog channel 2 as the respective source channels.

The VMG analysis reduces the channel sampling rate by a factor of 32. In the AcqKnowledge software, all data in an individual waveform share the same acquisition sample rate and each channel may have a lower sample within certain parameters, see (link for variable rate sampling). It is not possible to mix sampling rates within a channel. This analysis is preformed for the entire channel or appended segment (see VMG and append on page 46x). Traditionally, if there is only a single point selected, then the entire data channel is transformed. If only a portion of the wave is selected, then the following warning will be displayed:



When OK is clicked, analysis will be performed on the entire waveform. The selected area will be maintained but the waveform regions outside the selected area will still be transformed. This matches the “Transform entire wave” checkbox operation of other transformations. Cancel exits without modifying the data.

Sampling Rate Restrictions

The Vibromyography Filter is designed to process data acquired at 2 kHz sampling rate only. If the correct sampling rate is not used (via Hardware menu > Set Up Data Acquisition > Length/Rate), results may be unpredictable.

Transducer Setup

The TSD250 VMG transducer is a MEMS accelerometer transducer used for recording vibromyography signals from major muscle groups.

- MP160/150: Activating the VMG license adds the “VMG Transducer” option to the MP160/150 module setup; it is an AMI100D or HLT100C high level transducer.
- MP36R Support—the MP36R system may be useful for VMG analysis as four channels allows for comparison of muscle balance between two muscle groups. No analog channel preset exists for the VMG transducers, but a Vibromyography preset exists for the calculation channel. See page 554.

Post-Analysis Selection Adjustment

After the analysis completes, the waveform sampling rate of the selected waveform will be reduced by a factor of 32. As this reduction occurs, the selected area or cursor will adjust to the nearest sample point in the processed VMG channel.

Data Modification History Name

This operation will be displayed in data modification logs (Display > Channel Info) as "VMG Analysis." It will not have any parameters.

VMG Calculation Channel Preset

The Vibromyography calculation channel preset uses the VMG channel as its source channel. The calculation channel preset automatically applies a downsampling divider of 32 based on the acquisition sampling rate.

- The Vibromyography preset automatically adjusts the channel sampling rate by a factor of 32. After setting up the Vibromyography calculation channel, adjusting the channel sampling rate for the VMG source channel will not change the sampling rate of the Vibromyography calculation channel. The channel sampling rate can be manually adjusted.

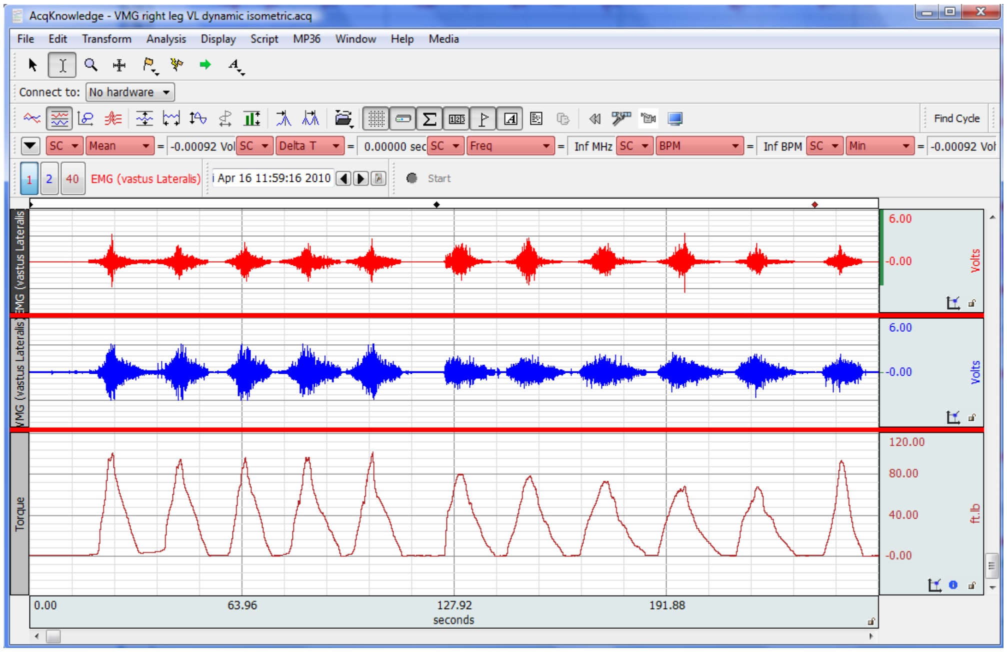
At the end of an acquisition, the Vibromyography preset automatically performs the following steps:

1. Checks for the Vibromyography license. If the license is not found, then the appropriate prompt is displayed.
2. Checks if acquisition is running in append mode. If this is the case then additional parameters are checked and the user will be prompted as needed.
3. Perform Vibromyography Analysis filtering.
4. Adjust selection to highlight only the most recently acquired data segment. If not in append mode, all data will be selected.
5. Copy the processed data to the clipboard.
6. Select the destination calculation channel.
7. Paste processed data from clipboard over the zero valued data for the appended segment (or entire channel if not in append mode).
8. Remove the duplicated channel created earlier.

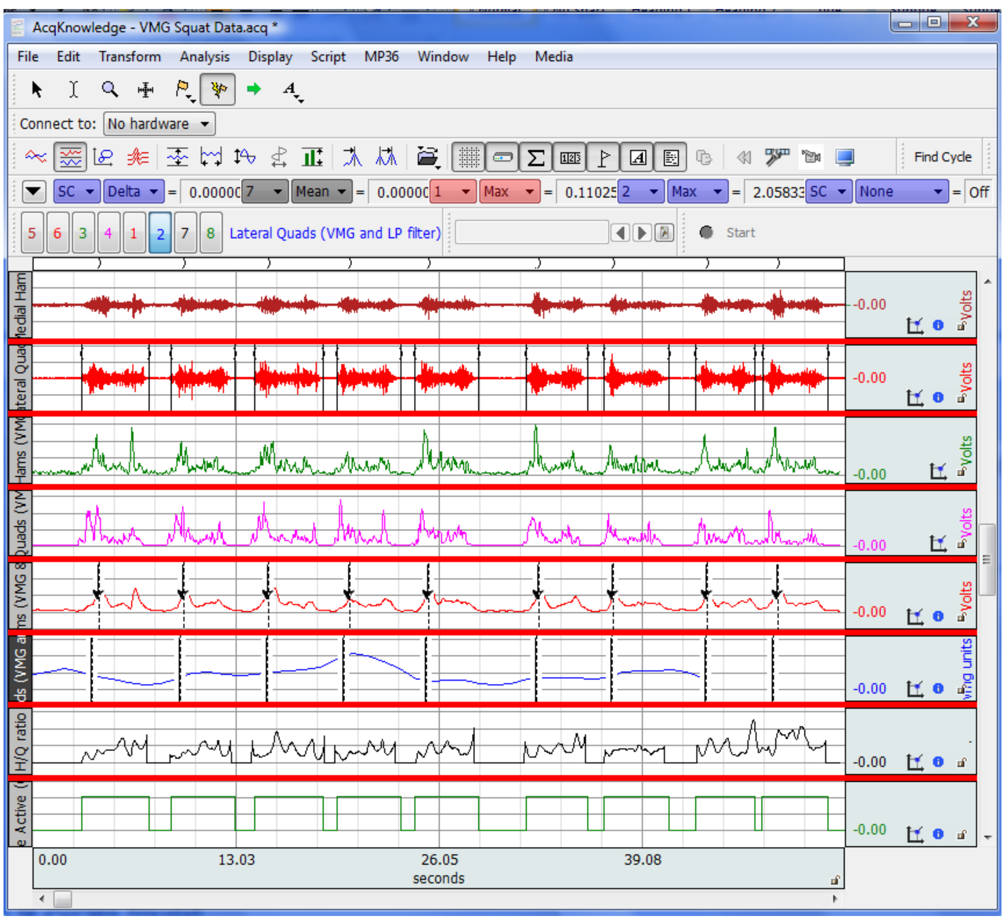
VMG Sample Data Files

Two sample data files illustrating basic VMG data and analysis results are included:

- **VMG right leg VL dynamic isometric.acq**



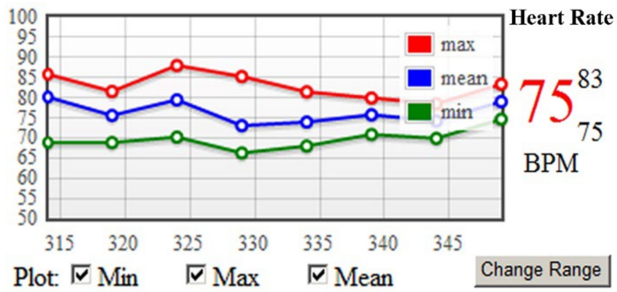
- **VMG Squat Data.acq**



Watch the [Acq*Knowledge* Vibromyography video tutorial] for a detailed demonstration of this feature.

Chapter 25 Licensed Functionality: Remote Monitoring

Remote Monitoring functionality is available through an optional license available with Acq*Knowledge* 5. The license must be authorized to access Remote Monitoring functionality. To add a license to an existing MP System, please contact BIOPAC.



Remote Monitor

Track the welfare of the subject with alarms to warn when signals fall out of range. The system will work on any device that has access to the same IP based network as the MP160/150, or wireless devices such as the B-Alert or BioNomadix that communicate over their own frequency.

Simplified user interface to view subject data on another computer or mobile device – 'bedside monitor' display.

Acq*Knowledge* MP devices are generally tethered to specific computers where data acquisition is performed. In some laboratories, this computer may not be in the same location as the researcher performing the experiment. In MRI situations, for example, the data acquisition computer may be in the MRI control room but the researcher may be in a separate area. Acq*Knowledge* Remote Monitoring offers researchers the capability of checking on critical parameters from an alternate location.

Remote Monitoring is a client/server application capable of locating and connecting to computers running Acq*Knowledge* on the same network. It consists of a simple browser interface, from which acquisitions can be started, stopped and remote data viewed during and post-acquisition. Remote Monitoring is supported in MP160/150 hardware only.

About Remote Monitoring

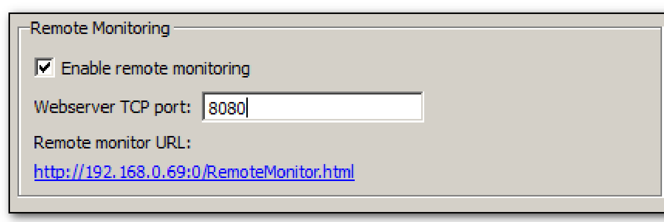
- Remote Monitoring is licensed functionality and must be activated by BIOPAC.
- Remote Monitoring is for viewing of data only. Transformation and specialized analysis of graph data is not supported within the Remote Monitoring interface.

The Remote Monitoring web interface consists of three primary pages:

- A list of open graph windows
- Configuration settings for an individual graph
- The data monitoring page.

Remote Monitoring in Acq*Knowledge* Networking Preferences

Remote Monitoring is enabled by default in Acq*Knowledge* Networking Preferences (Display > Preferences > Networking > Remote Monitoring). The **Enable remote monitoring** checkbox option activates the local machine on the network, making it visible to other local network machines also running Acq*Knowledge* Remote Monitoring.



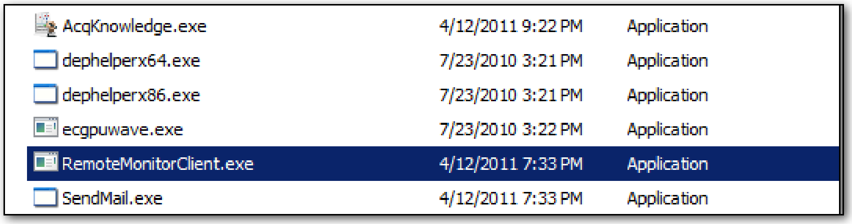
The **Webserver TCP port** is the numerical port on which Acq*Knowledge* listens for remote requests. (This port is set to 8080 by default.) The **Remote monitor URL** is a clickable link that opens Remote Monitoring in the local machine's default web browser. **This view will display acquisitions running on the local machine only**. (This is actually an easy way to become familiar with Remote Monitoring). To view acquisitions running on machines in other network locations, the stand-alone **Remote Monitoring Client** application must be used. For further details, see the Remote Monitoring Client section on the following page.

NOTE If a Remote Monitoring preference or port setting is changed, the new preference will not be applied until the subsequent Acq*Knowledge* application launch.

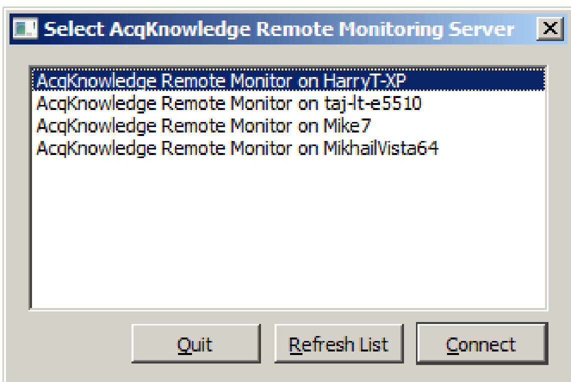
Remote Monitoring Client

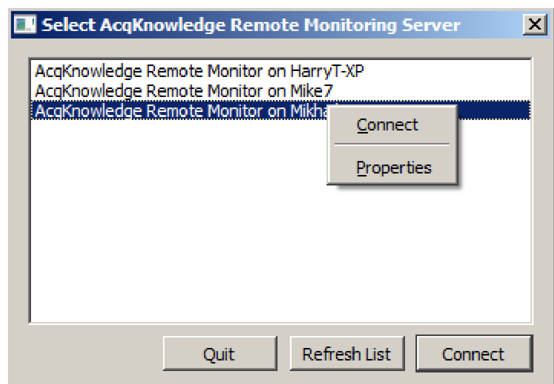
The Remote Monitoring Client is a stand-alone application residing in the Acq*Knowledge* program folder. This application facilitates the remote connection to other computers running Acq*Knowledge* acquisitions on the local network. Acq*Knowledge* does not need to be running on the local machine in order to use the Remote Monitoring Client to observe remote acquisitions in progress. To launch the Client, browse to the following directory:

Main Drive:\Program Files\BIOPAC Systems, Inc\Acq*Knowledge* 5\RemoteMonitorClient.exe



Double-click on the **RemoteMonitorClient.exe** to launch the application. After launching, the first presented item is the **Remote Monitoring Server** list. This is a list of other Acq*Knowledge* computers on the network that have Remote Monitoring enabled.





Quit Exits Remote Monitoring Client

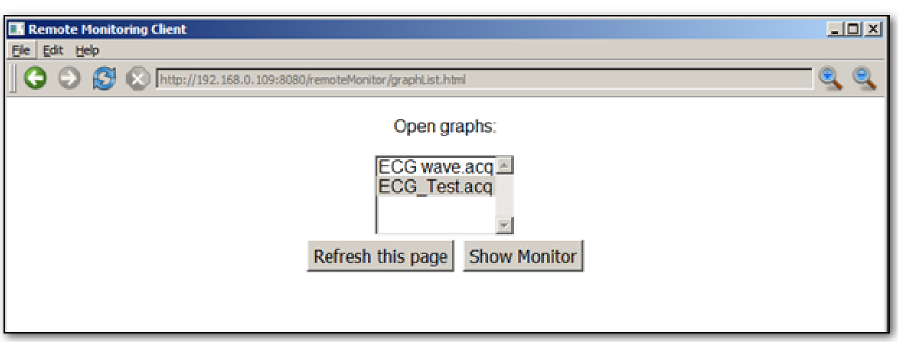
Refresh List Updates list of available Acq*Knowledge* Remote Monitor computers on network

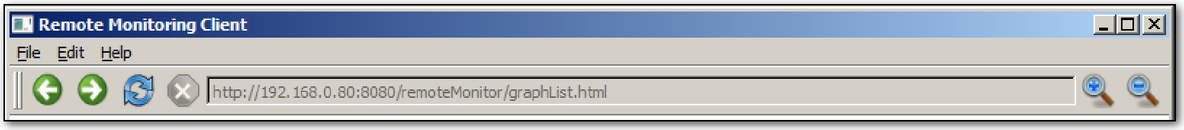
Connect Connects to the computer selected in list

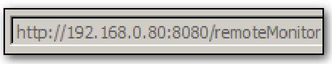
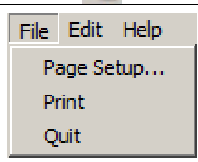
The above-right figure shows a right-click contextual menu available within the Remote Monitoring Server List, which allows an alternate means of connecting to a selected computer. The Properties option displays the Acq*Knowledge* application status, along with network and hardware information about the selected computer.

Remote Monitoring Client Browser

Selecting a computer from the list launches the Remote Monitor Client browser interface. The navigation buttons operate in the same manner as most Internet browser controls. See the following page for details on the Remote Client browser buttons.

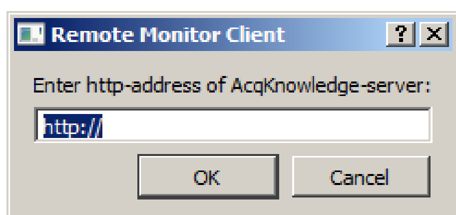




Icon	Button Function	Explanation
	Back	Moves browser back one page
	Forward	Advances browser ahead one page
	Refresh	Reloads the current page
	Stop	Stops loading of current page
	Address bar	Displays I.P. address of currently-connected computer
	Zoom in	Master control for enlarging size of browser content
	Zoom out	Master control for decreasing size of browser content
	File, Edit, Help menus	**File** contains Page Setup and Print controls for Remote Monitoring chart displays. Quit exits the Remote Monitor. **Edit** contains a Copy option. (Copy function not supported in Windows version) **Help** displays "About" information for the current version of Remote Monitoring Client*

NOTE for Windows only:

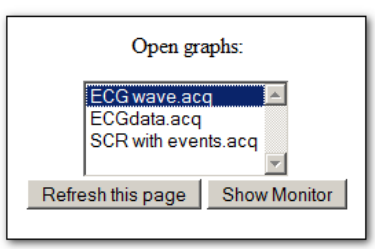
In order for the Remote Monitor Client to properly display the server list of additional Acq*Knowledge* computers on the network, Bonjour Service for Acq*Knowledge* must be installed. (The option of installing Bonjour Service is presented during the licensed Acq*Knowledge* application installation). If Bonjour is not installed, the following dialog will be presented upon launch of the Remote Monitoring Client:



The I.P. address of the desired computer can be entered into the http-address field. If the address is valid, clicking OK will connect the Remote Monitoring Client to this computer. An acceptable entry should include the server IP address and UDP port number. (Example; http://192.168.1.76:8080)

Open Graphs Page

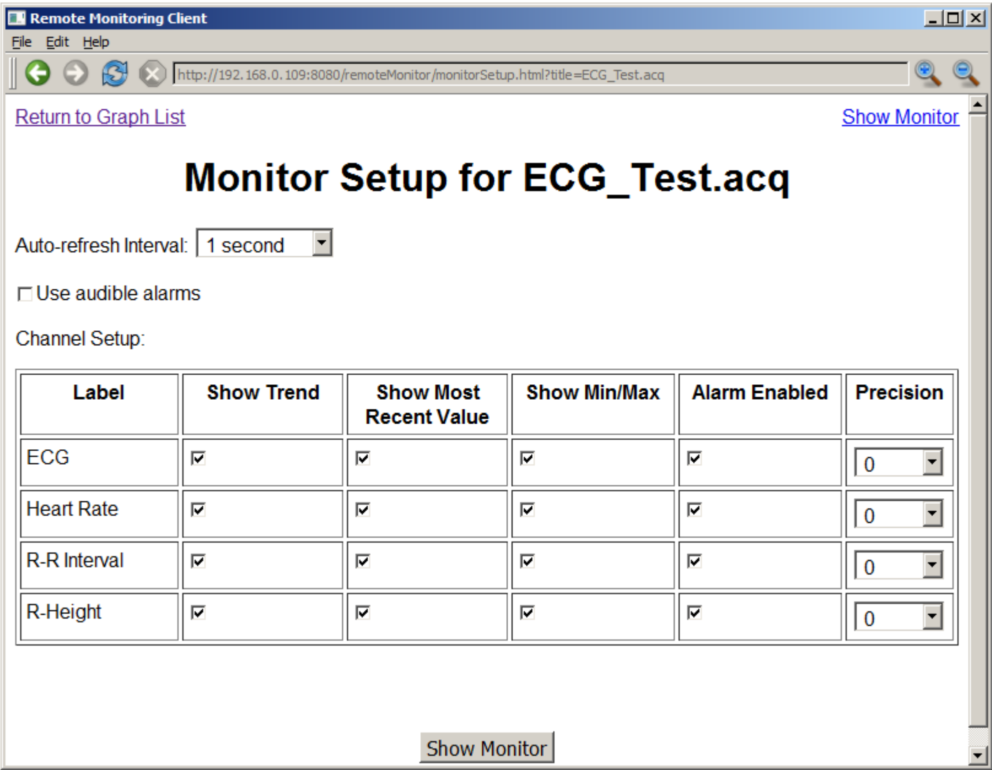
When the Remote Monitoring Client browser is launched, a scrollable list of all graph windows currently open on the selected remote machine is presented. Only one graph may be selected at a time.



Refresh this page	Reloads the page and refreshes the list of available graphs.
Show Monitor	Advances the browser view to the selected file’s setup page.

Configuration Settings Page

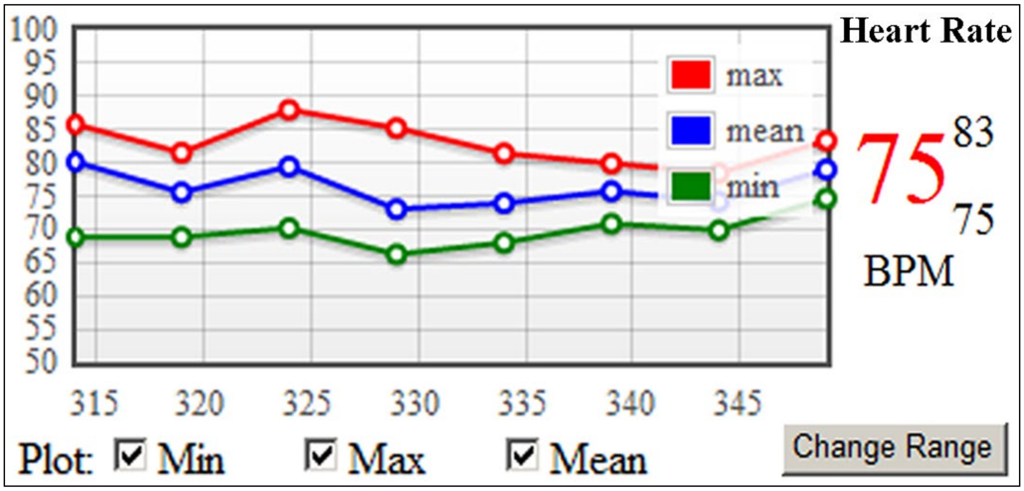
After selecting a graph and clicking **Show Monitor**, the following Monitor Setup page is displayed. This page contains configurable options for data display and other viewable parameters in the Remote Monitor graph. Note that all available options are set individually per channel.



Control	Description
Return to Graph List	Returns browser to list of currently-open graphs. Serves the same function as the browser’s ‘back’ button.
Show Monitor	Saves the selected setup and advances the view to the data monitoring page. (‘Show Monitor’ button at bottom of screen duplicates this link’s function)
Auto-refresh interval	Chooses the interval at which the monitored data is being refreshed over the network. The increments range from 1-sec. to 5 minutes.
Use audible alarms	When enabled, an alarm will sound if the Remote Monitoring graph data display exceeds its maximum or minimum visible ranges. The audio sound is a one-second beep followed by one second of silence. This audio playback is supported only on HTML5 compliant browsers.
Label	Displays assigned label of the Acq*Knowledge* data channel
Show Trend	Displays a graphical plot of the currently monitored data.
Show Most Recent Value	If checked, the most recent value of the channel data is displayed in a large font. If unchecked, textual display of this value is omitted.
Show Min/Max	Displays minimum and maximum value of currently monitored data.
Alarm Enabled	If the channel value exceeds the current trend display range, the alarm changes the color of the textual display to red and optionally plays audio.
Precision	Sets number of decimal places following channel display values.

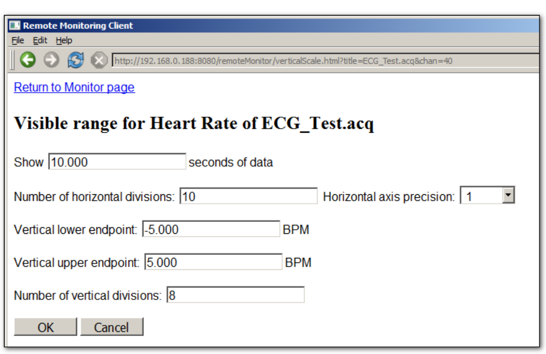
Data Monitoring Page

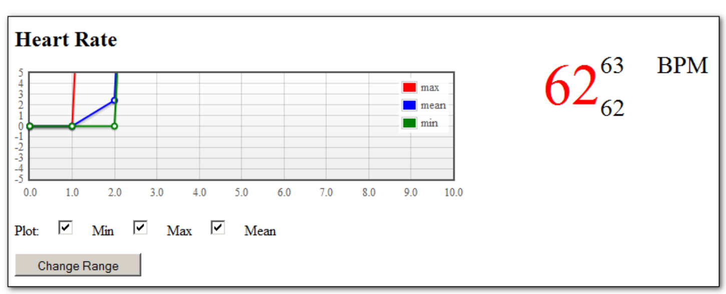
After the desired channel setup parameters are selected, choosing **'Show Monitor'** will advance the view to the data monitoring page.



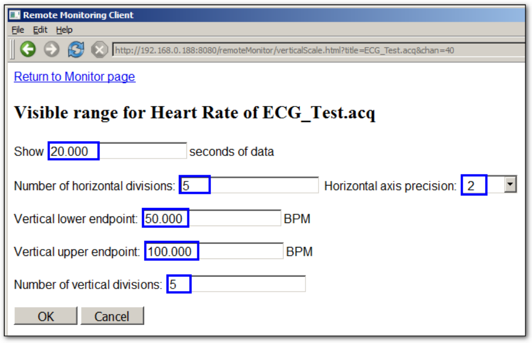
If an Acq*Knowledge* acquisition is already in progress and data being plotted, the screen will appear similarly to above, with the graph plot tracing at intervals determined by the Monitor setup auto-refresh rate. If the acquisition has not been started prior to launching Remote Monitoring; the **Start** button will be displayed in this screen. (Remote acquisitions can be easily started or stopped from within this data monitoring page).

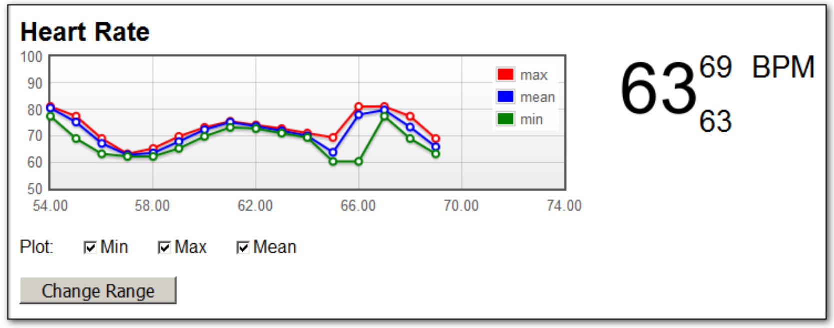
Control	Description
Return to Graph List	Displays scrollable list of all currently-open graphs.
"-" and "+"	Controls for decreasing and increasing size of the input values display font.
Reset	Resets size of input values font display to default setting.
Show Monitor Settings	Returns to the "Monitor Setup" page for adjusting refresh rate, display options, and other monitoring parameters.
Start/Stop	Toggles between starting/stopping acquisition in Remote Monitoring graph.
Refresh Now	Updates data and controls on Monitoring page.
Stop Alarms	Halts any audio alarms that may be playing. Active only if Audio Alarm option is enabled.
Plot	Controls visual display of Min, Max and Mean values display of current graph
Change Range	Allows adjustment of visible ranges of the chart, similar to the vertical and horizontal scale dialogs found in the Acq*Knowledge* application. This is useful for viewing data that may otherwise appear out of range of the default scaling. Change Range only affects the data display in the Remote Monitoring window, not in the actual Acq*Knowledge* graph data. (See below for Change Range example and further details).





Default Visible range. (Note BPM data from this graph is 'out of range' in the above chart)





Visible range is modified via 'Change Range' to include entire data set. Horizontal time scale and vertical divisions were also modified.

Controls in Visible Range (Change Range) dialog

Control	Description
Return to Monitor page	Clickable link for paging back to the Monitoring screen.
Show seconds of data	Determines visible horizontal time scale in chart display.
Number of horizontal divisions	Sets the number of horizontal divisions in chart.
Horizontal axis precision	Sets number of decimal places following horizontal time values.
Vertical lower endpoint	Determines low end of vertical graph scale.
Vertical upper endpoint	Determines high end of vertical graph scale.
Number of divisions	Sets the number of vertical divisions in chart.

NOTE: **Remote Monitoring** plots are only updated in the data monitoring window while an acquisition is in progress. Once a Remote Monitoring acquisition is stopped, the graph will remain visible only as long as the browser page is displayed. After navigating away from the page, the plot will not be retained or reconstructed. To save a Remote Monitoring plot for future reference, printing a hard copy or printing to a PDF file is recommended.

*For Remote Monitoring technical support, contact BIOPAC Systems, Inc at (805) 685-0066 or support@biopac.com

Chapter 26 Licensed Functionality: B-Alert

B-Alert functionality is available through optional licenses* available with Acq*Knowledge* 4.4.x. (B-Alert wireless headset hardware is also necessary).

* B-Alert Headset integration: must be authorized to access basic B-Alert functionality.

* Cognitive States Analysis: must be authorized to access this enhanced functionality.

To add licenses please contact BIOPAC.

The B-Alert Hardware Data Acquisition X10 license adds:

- Basic wireless recording of up to nine channels of raw or decontaminated EEG data

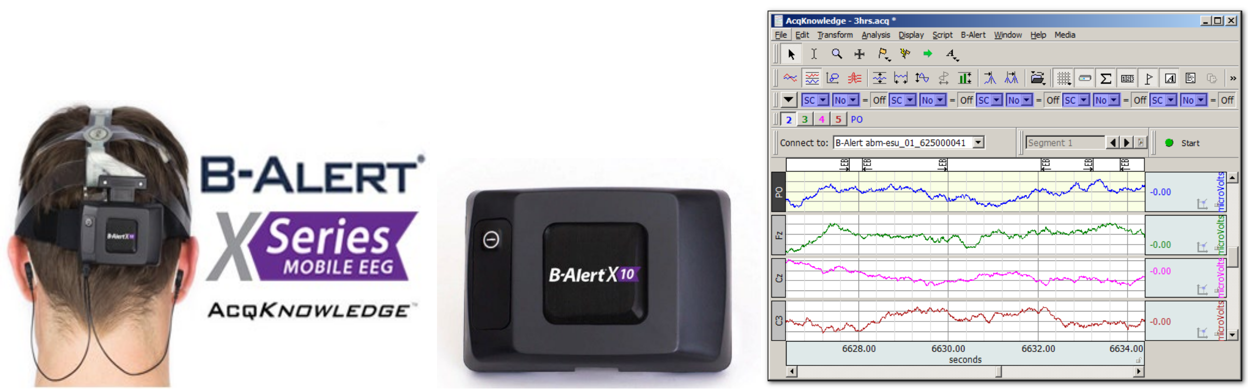
The B-Alert Hardware Data Acquisition X24 license adds:

- Basic wireless recording of up to 24 channels of raw or decontaminated EEG data

The Cognitive States Analysis Software license adds:

- Functionality described above, plus the ability to create individual baseline recordings for each subject
- Additional analysis software and specialized calculation channels

Data Acquisition and Analysis with B-Alert™



B-Alert™ X10/X24 are Bluetooth wireless systems and sensor headsets integrated with Acq*Knowledge* software to record up to 9/24 channels of monopolar EEG, plus one optional channel of ECG data. **B-Alert** data can be acquired simultaneously with BIOPAC MP160/150 Hardware, if additional graphs are used.

IMPORTANT NOTE: In Acq*Knowledge* for B-Alert:

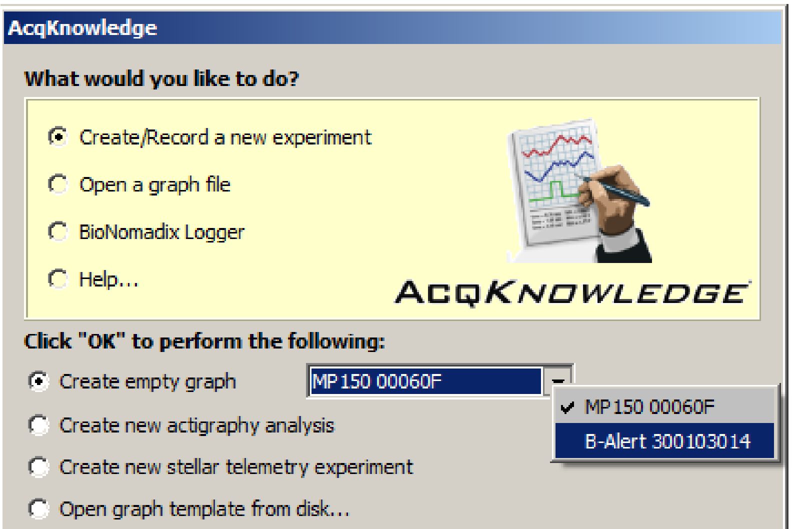
- **B-Alert** is licensed functionality and must be activated by BIOPAC
- Analog channels can be toggled on/off but not modified
- Digital channels are not supported
- **B-Alert**-specific calculation channels are available when the optional Cognitive States Analysis software license is applied (Acq*Knowledge* calculation channels C8 and higher can be used if configured manually)
- Data acquired with **B-Alert** is outputted in standard BIOPAC *.acq format
- The older-style (silver) B-Alert headsets are not supported in Acq*Knowledge* 5.0.5 for B-Alert

B-Alert™ users should refer to the **B-Alert X10/X24 User Manual** for complete hardware setup instructions. This guide, and other B-Alert material can be found on the BIOPAC Manuals Support page.

Acq*Knowledge* software is used to view, record, and analyze data acquired with the B-Alert unit.

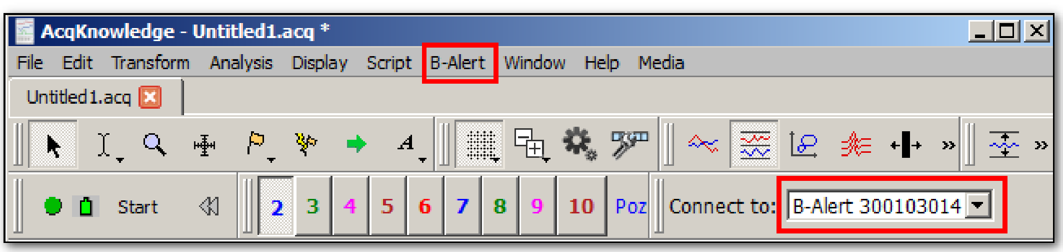
To launch software with B-Alert hardware:

1. Connect the **B-Alert** dongle to a USB port and turn the X10 headset unit's power switch ON.
2. Choose **B-Alert** device from the Acq*Knowledge* Startup Wizard Hardware menu or from the **'Connect to > Add New Device'** menu in the application window. (See figures below.)
3. Use the **B-Alert** menu options for acquisition and channel settings.

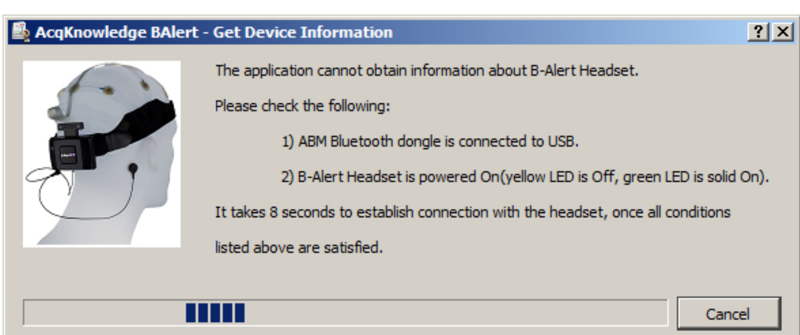


OR:

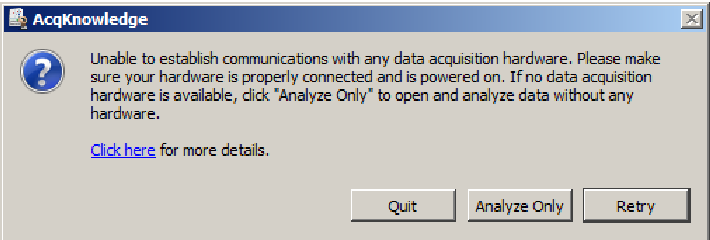
When Acq*Knowledge* launches in B-Alert mode, the MP menu will be replaced by the B-Alert menu and the B-Alert device ID will appear in the Acq*Knowledge* graph "Connect to" menu.



If the B-Alert headset cannot be located or is disconnected, the following dialog will appear:



Click ‘Cancel’ in the B-Alert Headset Warning dialog and re-check the headset connections. If the connections are not found, Acq*Knowledge* software can be started in analysis mode. This operates identically to MP “no hardware” mode, for which data can be analyzed and transformed but not recorded.



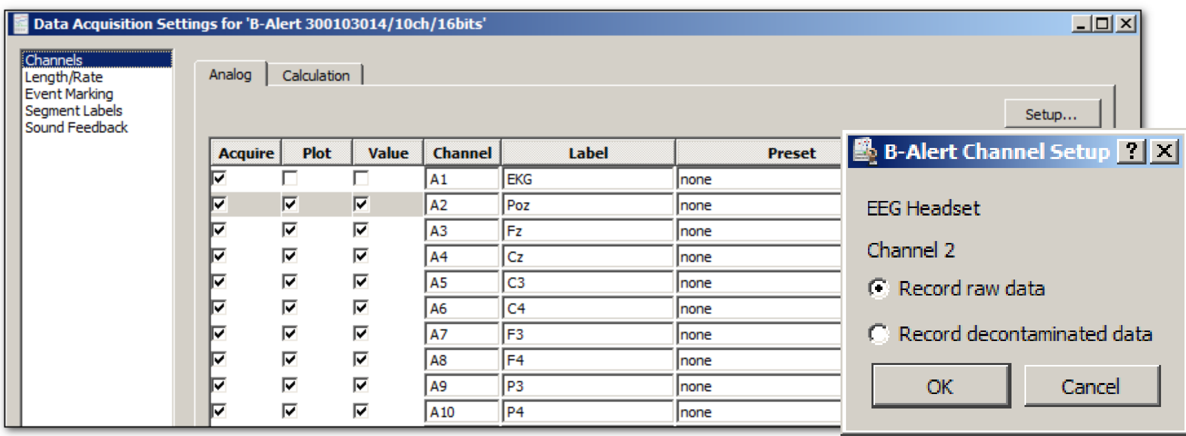
Acquisition Setup

Standard recording modes found in MP hardware (except for Averaging) are supported in B-Alert but the acquisition sample rate is limited to a maximum of 256 samples per second. Dependent upon licensing level, there are two additional checkbox options in the B-Alert Set Up Data Acquisition > Length Rate dialog:

- **Record EEG artifacts as events:** When checked, recorded EEG artifacts are translated into visible events (eye blinks, EMG interference, etc.). When unchecked, artifacts are discarded and only data is acquired.
- **Use B-Alert Definition File:** When checked, enables use of a subject’s baseline Definition File. This option is only available if the Cognitive States Analysis license is applied. See page 569 for a detailed explanation of Definition File setup in Acq*Knowledge*.

Channel Setup

Nine analog input channels of monopolar EEG data are enabled by default in B-Alert, along with one optional ECG (EKG) channel. Channels are configurable as desired. In the standard B-Alert setup, calculation channels C8 – C15 remain available for additional online transformation/filtering of data (for C0-C7, see page 572). (Digital channels, stimulation or triggering are not supported in B-Alert hardware.)

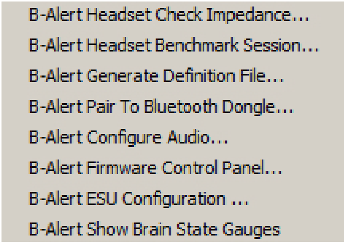


Under the standard **B-Alert** license, the Input channel setup contains options for recording raw or decontaminated EEG data. These parameters are set individually per channel. It is possible to record raw data on one channel and decontaminated data on another.

- **Record raw data**: records unfiltered data. Any further filtering must be applied through calculation channels or transformations. (Default setting)
- **Record decontaminated data**: filtered data will be recorded for the channel. This setting applies algorithms to minimize artifact resulting from eye blinking or other small involuntary movements.

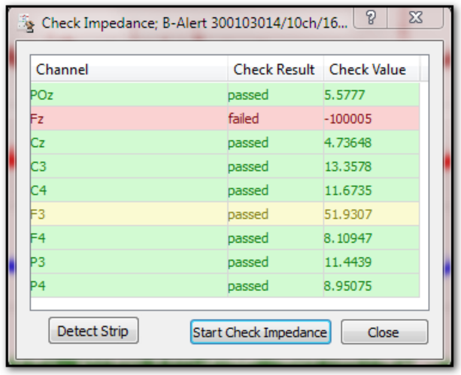
The optional **B-Alert** Cognitive States Analysis license offers additional functionality, such as creation of a baseline “Definition” file (based upon a subject’s responses to some simple cognitive tests), and access to pre-configured calculation channel setups.

B-Alert-specific Hardware Menu Options



B-Alert Headset Check Impedance

This item is found in the B-Alert menu, (which replaces the MP menu in B-Alert hardware configuration) and is used to initiate an impedance check to verify the headset's electrode contact quality. Results and resistance values are displayed in the dialog when the check is complete. If any of the channels show red or fail the impedance check (as shown on Channel Fz on the right), verify that electrodes are firmly attached and making good contact, and then rerun the check.



B-Alert Headset Benchmark Session

Requires Cognitive States Analysis license

Use to set up an "Alertness Memory Profile" (AMP) Baseline recording of a subject's EEG definition file. The baseline (Benchmark) recording consists of a three-choice psychomotor vigilance task (3CVT) and eyes open/eyes closed.

Subject: Field for 4-digit identifier unique to subject being recorded.

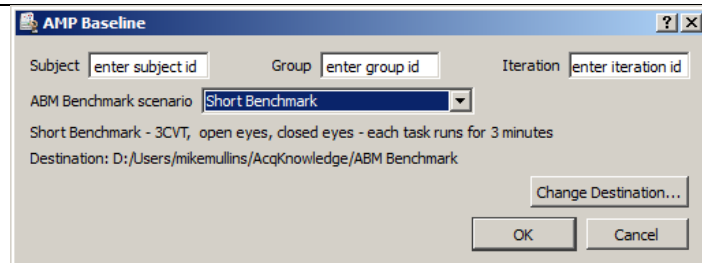
Group: Field for single-digit identifier used to distinguish the subject's group number.

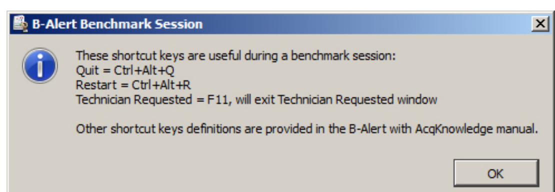
Iteration: Field for single digit identifier identifying the session, if additional Baseline sessions are recorded for a subject.

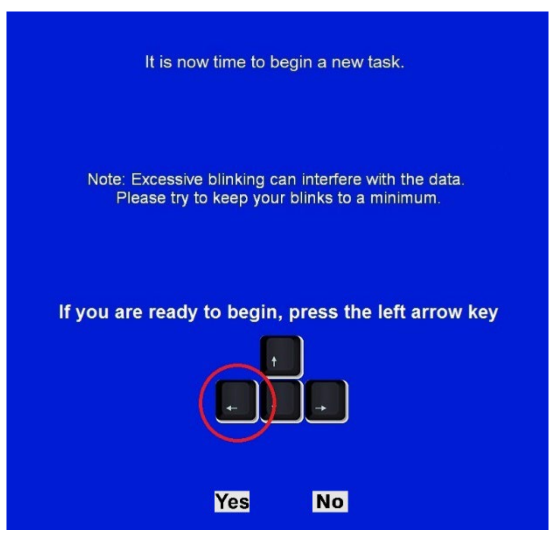
ABM Benchmark scenario: Choose the type and length of the baseline recording. The following recording lengths are supported:

- Short Benchmark – 3CVT (three-choice Psychomotor Vigilance Task, 3 minutes per task)
- Medium Benchmark – VPVT (Visual Psychomotor Visual Task, 5 minutes per task)
- Long Benchmark – APVT (Auditory Psychomotor Vigilance Task, 20 minutes per task)

After setting up the required fields, click OK to launch the baseline recording user interface, which will resemble the example to the right. A series of onscreen step-by-step instructions will follow.







For more details about the Benchmark recording user interface and additional software controls, refer to the Benchmark section of the **B-Alert** Software Manual.

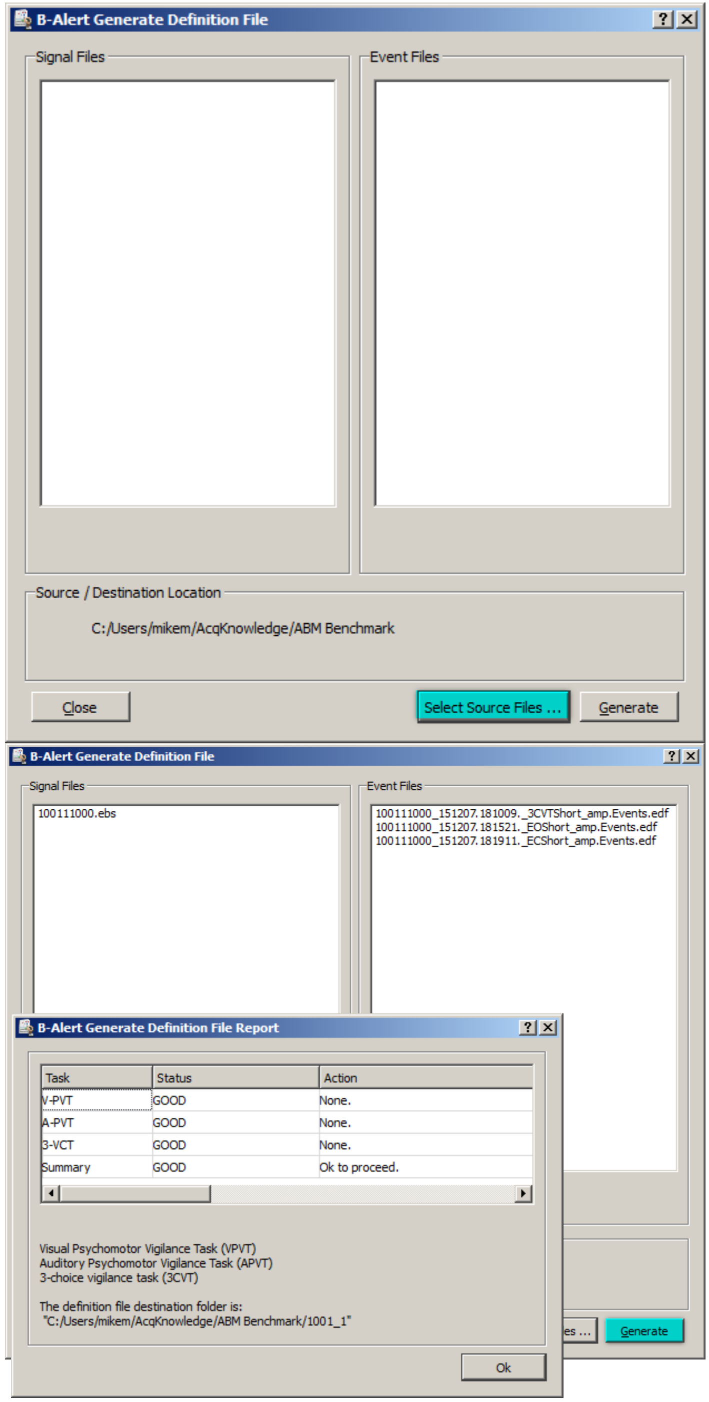
B-Alert Generate Definition File

Requires Cognitive States Analysis license

Use this option to generate or recreate a definition file from a previous Headset Benchmark session.

After completing a Benchmark session (see previous page), a definition (.def) file is automatically generated and saved to the subject folder. This *.def file is used to generate the Benchmark Report file. If the *.def file needs to be recreated, the "B-Alert Generate Definition File" option can be used. **Note:** The previous Benchmark Signal *.edf and all baseline Events *.edf files must be located within the same folder, and have the same 9-digit number for a definition file to generate properly. Follow the steps below to create a definition file:

1. Choose “B-Alert > B-Alert Generate Definition File.”
2. Click “**Select Source Files…**”.
3. Navigate to the desired folder containing the Benchmark session *.ebs “Signal” file.
4. Select the *.ebs “Signal” file and click “Open.”
5. Select the “Event” (*.edf) files (a minimum of three must be selected) and click “Open.”
6. Click “**Generate**” to create the new definition file and report and save them to the Benchmark destination folder. Once created, the individualized .def file can be reused across sessions (for Cognitive State and/or Workload Metric classifications) for a given individual.
7. See page 569 for further details about using and assigning a definition file.



B-Alert Pair to Bluetooth Dongle (or ESU)

Use this option to pair the B-Alert to the Bluetooth Dongle or optional ESU (External Synchronization Unit). B-Alert headsets are shipped paired to either a B-Alert Dongle or an ESU. If the pairing is lost or it becomes necessary to change to a different Bluetooth unit, the devices can be re-synced using this option.

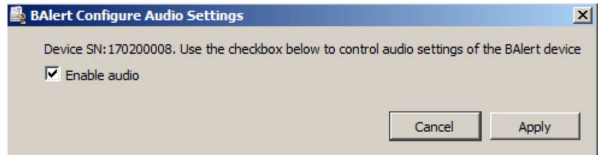
1. Connect the B-Alert headset to USB and power on if necessary.
2. In Acq*Knowledge*, choose “**B-Alert > Pair to Bluetooth Dongle**” and follow the onscreen prompts.
3. Connect the B-Alert Dongle or ESU to a USB port.
4. Once pairing is complete, disconnect the B-Alert headset from USB and restart it.

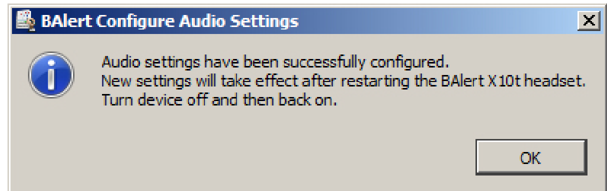
LEDs on the paired devices will be solid when connected.

B-Alert Configure Audio

Use this option to activate or deactivate the B-Alert voice prompts. When activated, these audio prompts report the B-Alert device's power and connection status. The audio option is enabled by default but can be turned off by unchecking the "Enable audio" box and clicking "Apply."

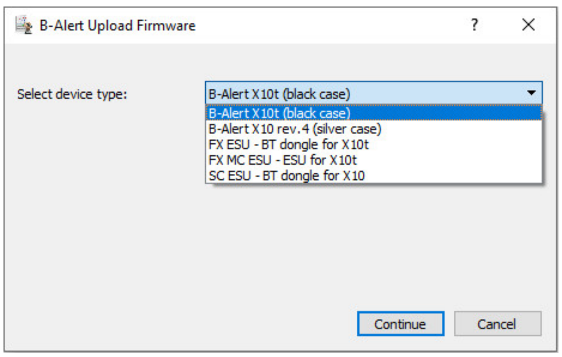
Power-cycle the B-Alert unit to apply the new setting.





B-Alert Firmware Control Panel

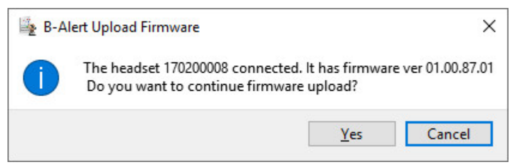
This option enables updated firmware to be downloaded to the B-Alert dongle, ESU, and headset.

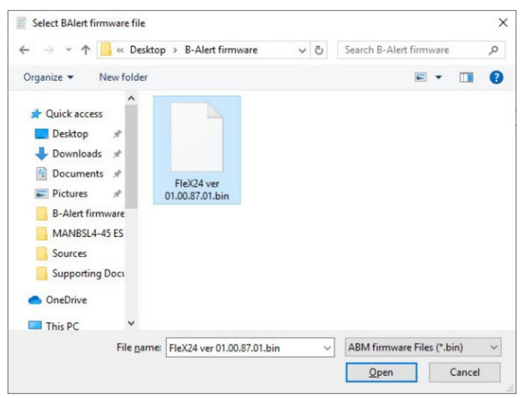


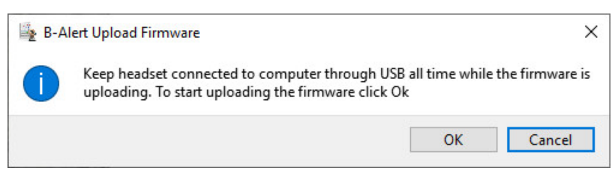
To update firmware, contact BIOPAC Support to obtain access to the current firmware file and save the file to a known directory.

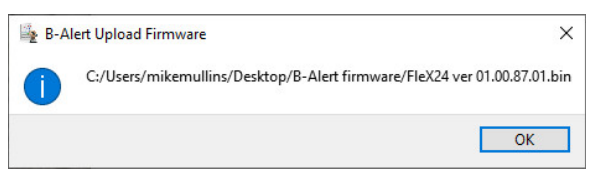
Make sure the B-Alert hardware is connected, select the Firmware Control Panel menu item, choose the appropriate dongle, ESU, or headset.

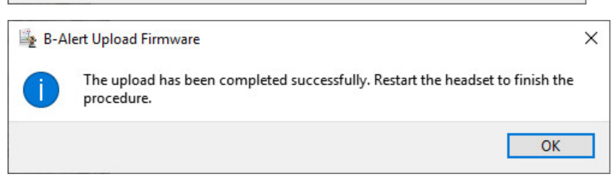
Click "Continue" and follow prompts to complete the firmware upgrade.











B-Alert ESU Configuration

The B-Alert ESU unit is a multi-channel external synchronization unit that serves as a communication interface between the B-Alert unit and the computer. It allows for synchronization of data between the B-Alert hardware and other third-party data acquisition devices.

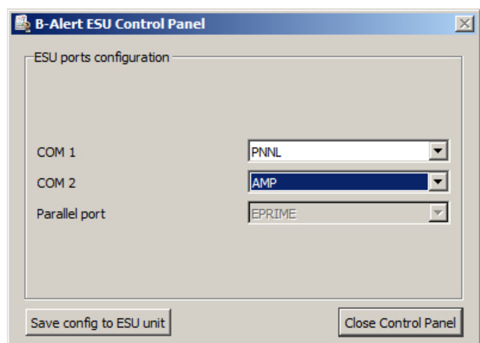
The ESU is helpful if the user is synchronizing with stimulus presentation systems and doesn't have a MP160. If a MP160 system is being used at the same time, it's recommended to use the STP100C to interface with the stimulus presentation system, and the CBLX10 to sync the B-ALERT X10 to the MP160. https://www.biopac.com/product/b-alert-x10-to-uim100c-analog-out/.

For more information about the B-Alert ESU unit, see the B-Alert with Acq*Knowledge* Quick Guide or the B-Alert Software Manual.

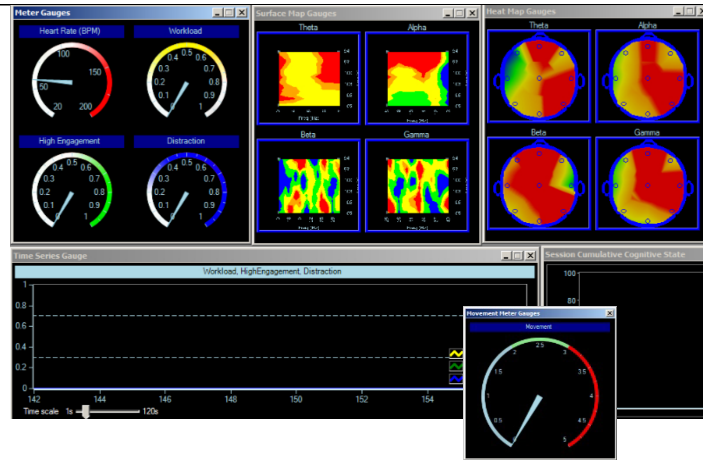
NOTE: Before configuring the ESU settings, the ESU must be paired with the B-Alert unit via a Bluetooth connection. The pairing procedure for ESU is the same as for "B-Alert Pair to Bluetooth dongle" described on the previous page.

To Configure the ESU in Acq*Knowledge*:

1. Go to Display > Preferences > Hardware and verify that B-Alert is the top item in the "Data Acquisition Hardware Priority" list.
2. Connect the B-Alert headset to USB and power on if necessary.
3. In Acq*Knowledge*, choose "**B-Alert > Pair to Bluetooth Dongle**" and follow the prompts.
4. Plug the ESU unit into a computer USB port. **IMPORTANT:** Make sure the B-Alert Bluetooth dongle is disconnected. (Multiple Bluetooth connections are not supported.)
5. Once pairing is complete, disconnect the B-Alert headset from USB and restart it.
6. In Acq*Knowledge:* choose B-Alert > B-Alert ESU Configuration.
7. In the ESU Control Panel, use the pop-up menus to configure ESU third-party data (two serial COM ports and one parallel port) as desired (see below).

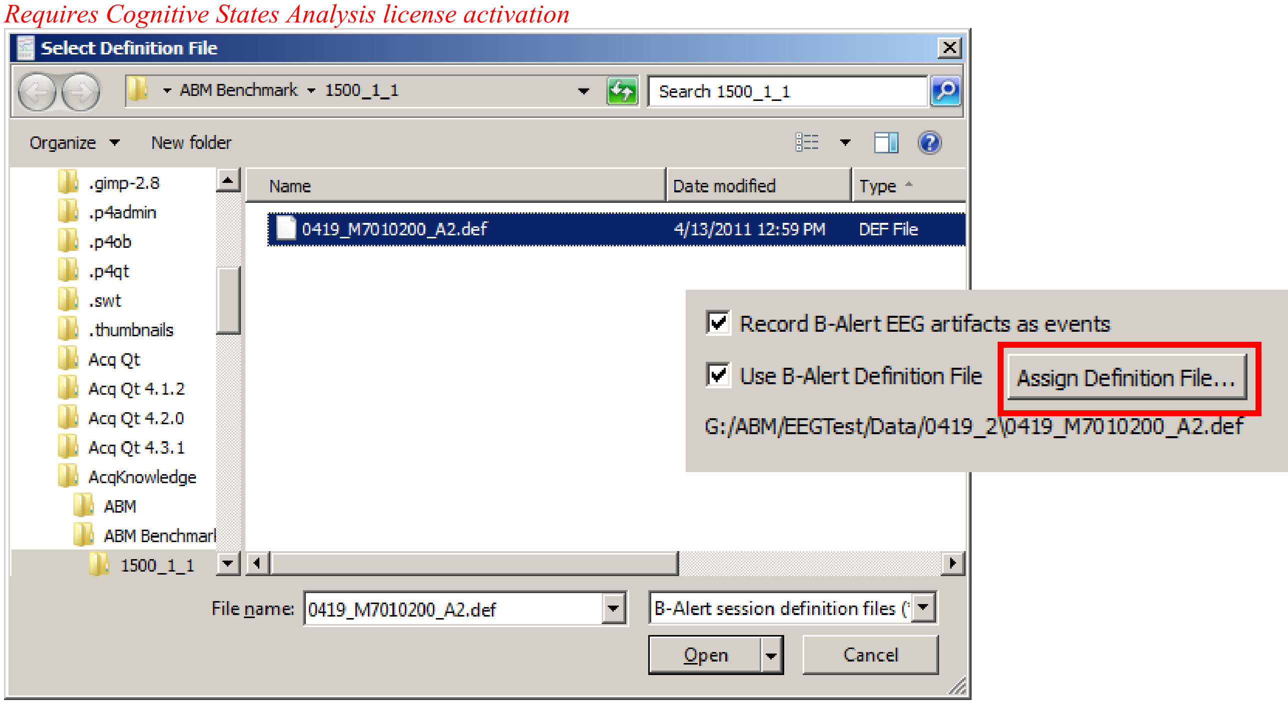


8. Click "Save config to ESU unit" to save the settings.
9. Wait until the "saved configuration" confirmation dialog appears. Restart the ESU by unplugging it and then re-plugging into the computer's USB port.

B-Alert Show Brain State Gauges	
Requires Cognitive States Analysis license activation Displays real-time views of B-Alert headset data as it is being acquired. Information includes Meter Gauges (*Top Left*) with Engagement, Workload and Drowsiness (along with Heart Rate) Time Series (*Bottom)* Movement Meter Gauge (*Bottom right*) Heat maps (*Top Right*) display EEG power spectral densities (PSD) in both spatial and temporal maps for the traditional Hz bands (Beta, Alpha, Theta, Gamma).	

Assign Definition File

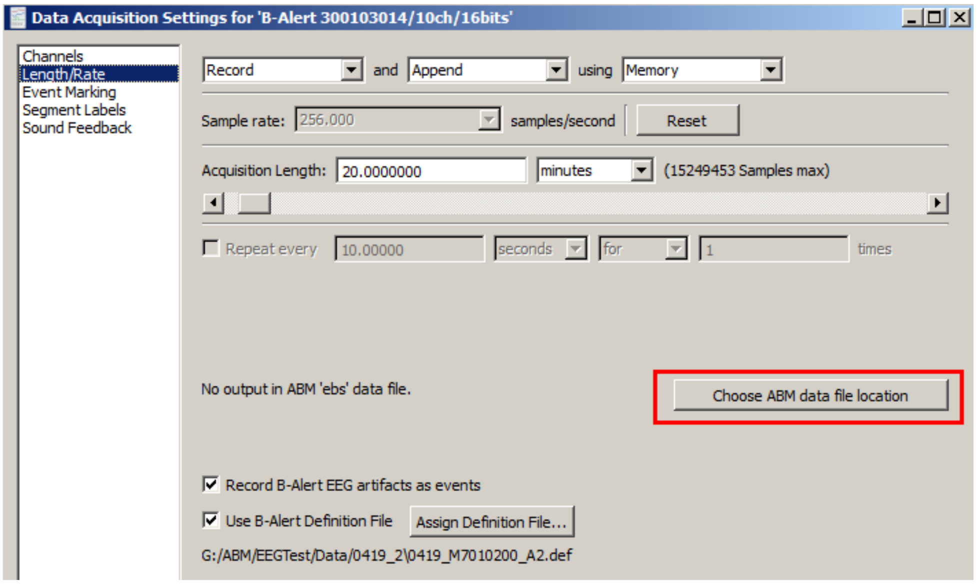
Requires Cognitive States Analysis license activation



The Definition File is created when the subject undergoes an initial baseline EEG recording while responding to some simple onscreen tests, or can be recreated from an existing Benchmark session via the "B-Alert Generate Definition File" menu item. (The Definition File setup is configured in the B-Alert Headset Amp Baseline dialog, referred to on the previous pages). The file is saved to the directory containing the subject's B-Alert profile folder. Once created, a subject's Definition File will always be referenced for subsequent recordings and analysis.

Output to ABM File Format

Acquisition setup options are available for controlling data output to a separate B-Alert ABM file format, which contains an “*.ebs” extension. Outputting to *.ebs format can be useful for preventing raw EEG data from being overwritten while recording in decontamination mode. (Acq*Knowledge* does not save the original raw EEG data within the default *.acq file format if the decontamination option is applied.) To set the filepath for saving ABM files, open B-Alert > Set Up Data Acquisition > Length Rate, and click “Choose ABM data file location.” A file chooser dialog will appear for setting the desired path.

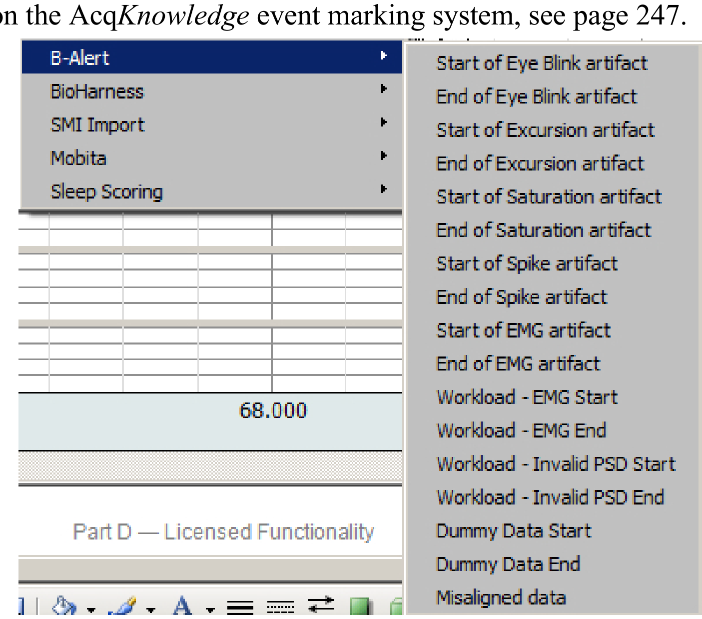


If no user-defined ABM data file location is selected, the ABM files will be saved by default to C:\Users\username\AcqKnowledge\ABM.

Other B-Alert Setup Options are:

- **Record B-Alert EEG artifacts as events:**

  When this option is selected, artifacts appearing in the B-Alert data (i.e., eye blinks) will be assigned event markers as these artifacts are detected during the recording. B-Alert events can also be manually assigned to recorded data while in progress or in post-acquisition analysis by using the Event tool . For more details on the Acq*Knowledge* event marking system, see page 247.



Event types supported for B-Alert recordings

- **Use B-Alert Definition File:**

  When this option is selected, the Benchmark definition file will be used for the recording (requires Cognitive States licensing level).

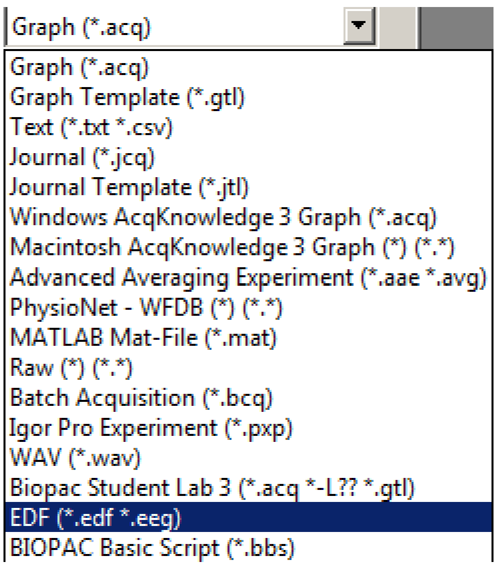
- **Assign Definition File:**

  Use this option to navigate to and select a different definition file for the recording.

Opening the ABM Data File

The outputted ABM *.ebs format data file can be opened in Acq*Knowledge* by choosing File > Open, browsing to the file location and selecting "EDF" format from the file type list. For a complete list of outputted ABM data see the Data Output table on page 573.

NOTE: Even though the file extension in the output dialog appears as "*.ebs", the file will open in Acq*Knowledge* by choosing "EDF" format.



Linked Acquisitions in B-Alert

Linked acquisitions are supported in B-Alert. In a Linked Acquisition session, different hardware device types can acquire data simultaneously into individual graphs. B-Alert acquisitions can be synchronized with and triggered by an MP160/150 unit and the multiple data recordings merged into one graph at the end of the session. For example, the user has access to the raw EEG and calculated state data. The ABM data will appear in one graph window and the other signals from the MP160 will appear in a second graph window. The graph windows can be automatically merged into one new graph if that option is selected when using Linked acquisition mode. Linked acquisition mode simultaneously starts and stops both devices.

NOTE: In order to use "master synch device" mode to link signals between B-Alert and MP160/150 hardware, a CBLX10 cable is necessary. See the MP Hardware Guide for more CBLX10 details.

To connect the CBLX10 for an MP160/150/B-Alert linked acquisition:

1. Plug the black connector into an Analog Output on the UIM100C* module connected to the MP unit.

   *If using the AMI100D or HLT100C module with the MP160 hardware, connect the black connector to a CBL122 adapter cable (3.5 mm jack to RJ11 connector).

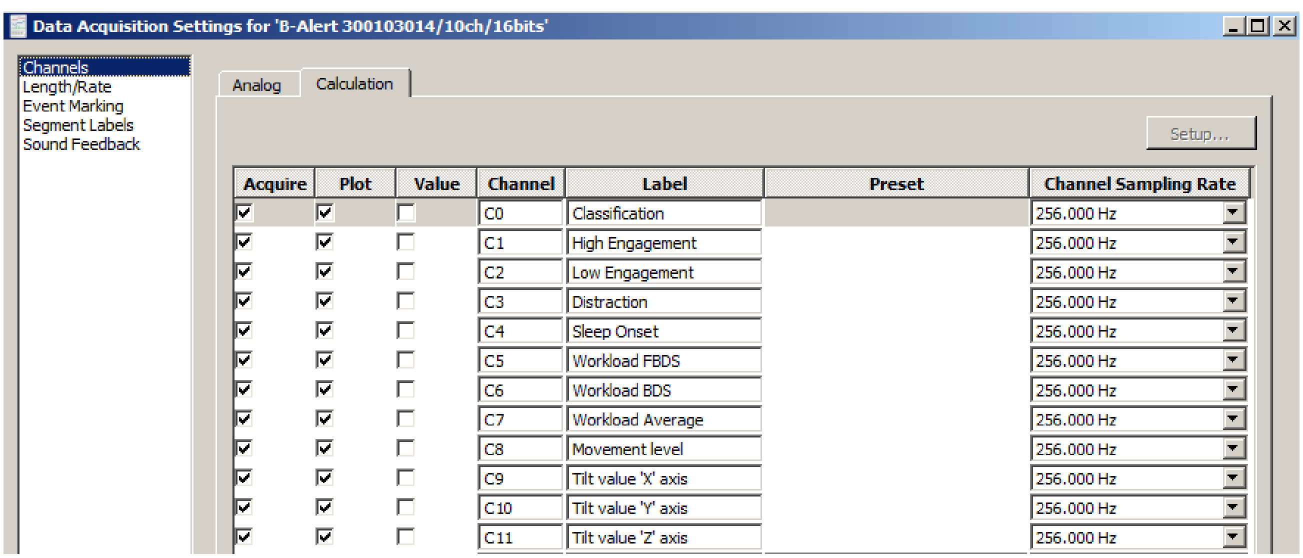
2. Plug the blue connector into the 2-pin (ECG) input on the top of the B-Alert unit.
3. In Acq*Knowledge*, choose "MP160/150 > Set Up Data Acquisition > Set Up Linked Acquisitions" and select "Use the master synchronization" as the synchronization method to pair and synchronize data obtained during linked MP160/150 and B-Alert X10 acquisitions. This is the only configuration where the "Master Sync Device" radio button is active.

IMPORTANT: About 10-12 seconds after starting a linked MP160/150/B-Alert X10/X24 acquisition, and verifying that both independent signals are being plotted correctly in Acq*Knowledge*, disconnect the CBLX10 from the B-Alert headset to avoid introducing extraneous noise into the B-Alert signal.

For further details on setting up Linked Acquisitions, see page 267 or watch the Tutorial video.

Cognitive Analysis Calculation Channels

Pre-configured calculation channels C0 – C11 become available when a subject's B-Alert Definition File is active. These signals are mapped from the Definition File and extract cognitive workload, high/low engagement, distraction, drowsiness, movement, and tilt angle data. The channel setups and presets are not editable but can be enabled or disabled as desired.



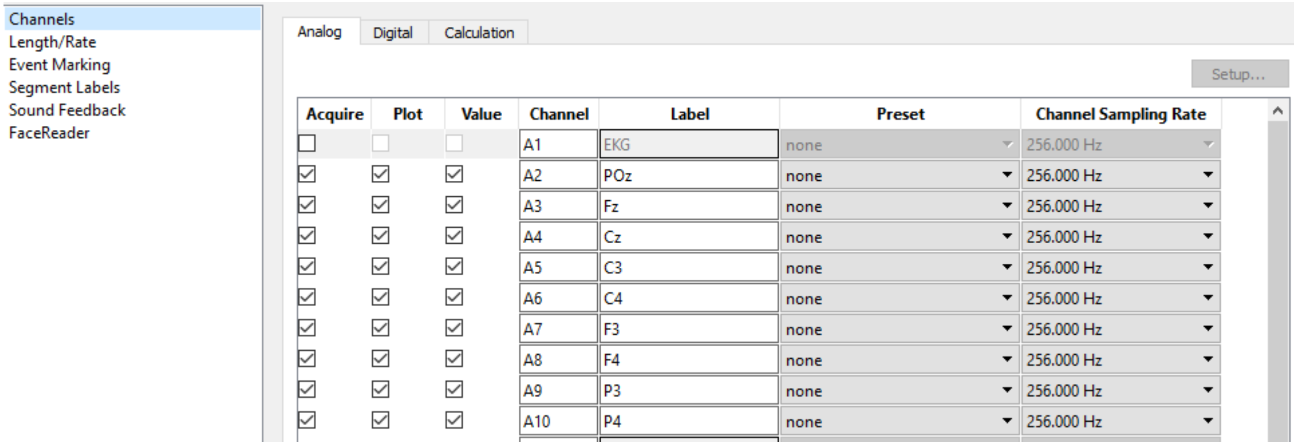
For specific information on additional B-Alert GUI software controls, see the **B-Alert** Software Manual.

Data Output

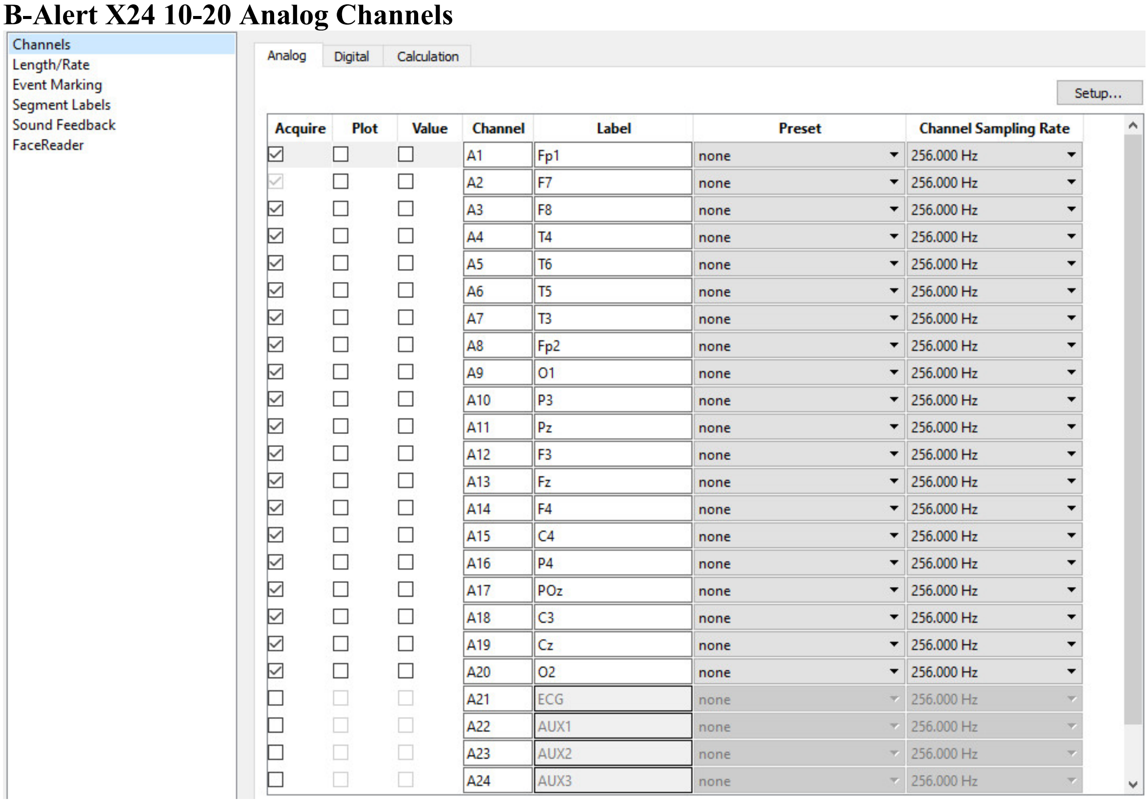
The following data is collected during a B-Alert experiment and merged into a standard Acq*Knowledge* *.acq file:

Real-Time Output file name	Description
Data file	
.edf	European data format containing nine raw and nine decontaminated EEG channels, raw ECG channel, plus derived heart rate, head movement value and head movement level
_Impedance.csv	Lists the values obtained for each channel each time impedance was measured
Automatically Generated during Acquisition – for all EEG Channels	
_Ref_Raw.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands labeled by channel (no edge-effect window)
_Ref_Class.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands labeled by channel (with Kaiser window)
Automatically Generated during Acquisition – Derived Signals	
_HR_beat.csv	Presentation of heart rate based on beat-to-beat interval
_HR_epoch.csv	Beat-to-beat heart rate interpolated to sec-by sec value
Optionally Generated with B-alert Cognitive State Classifications	
_Classification.csv	Probabilities for sleep, distraction, low and high engagement, cognitive state from DFA with greatest probability, probability of high workload based on forward and backward digit span (FBDS), backward digit span (BDS), and average of FBDS and BDS
_Diff_Raw.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands for differential channels: FzPO,CzPO,FzC3,C3C4, and F3Cz (no edge-effect window)
_Diff_Class.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands for 5 differential channels FzPOz, CzPO, FzC3, C3C4, F3Cz (with Kaiser window)
_Zscore_class.csv	Updates and applies mean and standard deviation with each new second to provide z-scores for B-Alert cognitive states (sleep onset, distraction, low and high engagement, three workload measures)
_Zscore_psd.csv	Updates and applies mean and standard deviation with each new second to provide z-scores for PSD for all channels requested in initialization process

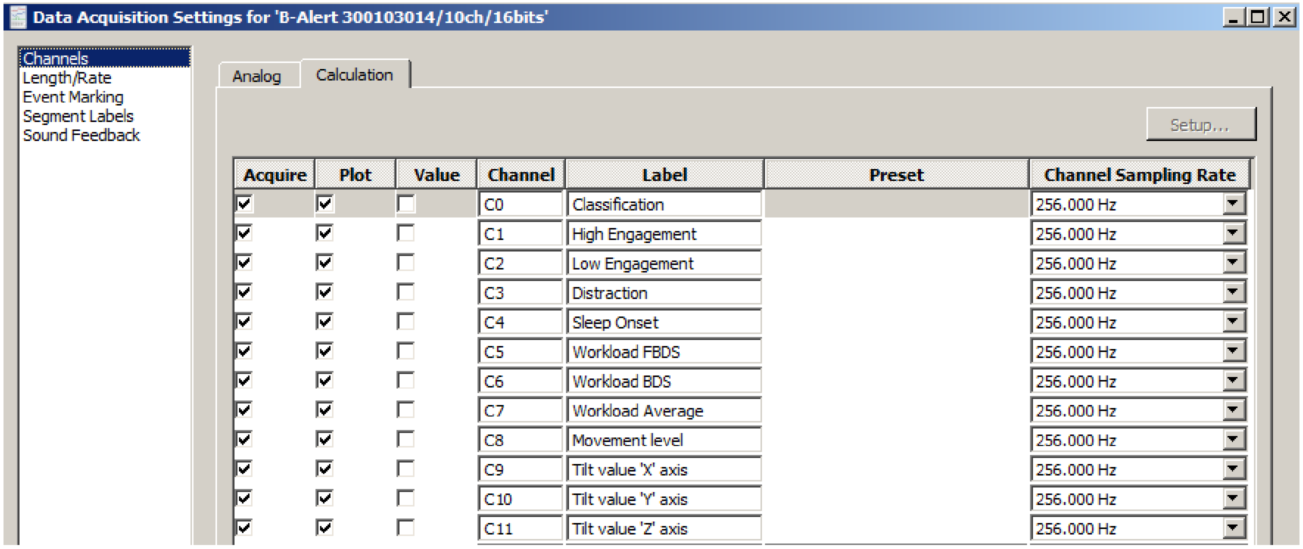
B-Alert X10 Analog Channels



B-Alert X24 10-20 Analog Channels



B-Alert Cognitive States Calculation Channels (X10 and X24 10-20)



Chapter 27 Licensed Functionality: PV Loop Analysis

PV (Pressure-Volume) Loop Analysis is available through an optional license available with Acq*Knowledge* 5. The license must be authorized to access this Analysis tool. To add a license to an existing MP System, please contact BIOPAC.

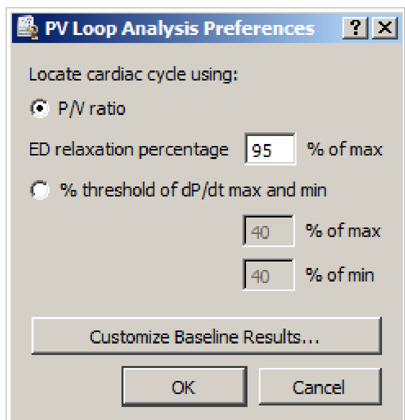
Pressure-volume loops (a.k.a. PV Loops) measure blood pressure and flow from a catheterized system. This analysis tool extracts various measures of heart function, including contractility, elasticity and ventricular characteristics. Sophisticated algorithms in this advanced analysis feature help circumvent the laborious visual process of identifying loop ranges while allowing the inclusion or exclusion of individual loops in the analysis output. Extracted measurements can be saved to an Excel spreadsheet, and selectable XY data views clearly show a wide range of outputted data. A pressure-volume loop graph template containing the necessary analog/calculation channels, data views and custom toolbars is included with the feature. (Q46-Pressure Volume Loop.gtl) PV Loop Analysis is supported in MP160/150 hardware only.

Loop Location

The two primary time locations for an individual PV loop range from the end systole (ES) point where the aortic valve closes, and the end diastole (ED) point where the mitral valve closes. On a PV loop XY plot, the end systole point is located at the top left corner of the loop and the end diastole is at the bottom right corner of the loop. An individual loop is defined as the extent from one end diastole to next end diastole, the equivalent of one heartbeat.

PV Loop Analysis Preferences

PV Loop Analysis Preferences are accessed via the Analysis > PV Loop menu and offer two methods for locating cardiac cycles.

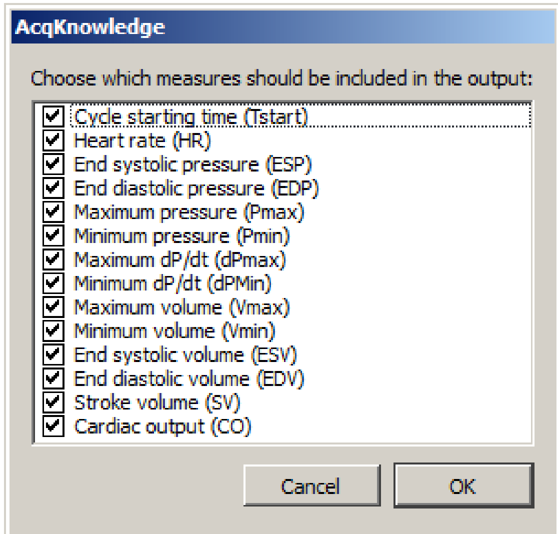


PV Loop Analysis Preferences dialog

PV Loop Analysis Preference Controls	Description
P/V ratio	When selected, ES and ED are located by analyzing the ratio of pressure over volume.
ED relaxation percentage	Percentage that P/V ratio must fall from ES in order to locate ED.
% threshold of dP/dt max and min	When selected, ES and ED are located using the pressure signal derivative only.
% of max	Defines percentage of the positive pressure derivative local maximum for ED.
% of min	Defines percentage of the negative pressure derivative local minimum for ES.
Customize Baseline Results	Displays a checkbox dialog for selecting measures to be included or excluded from baseline analysis. (See next page for complete list of available measures)

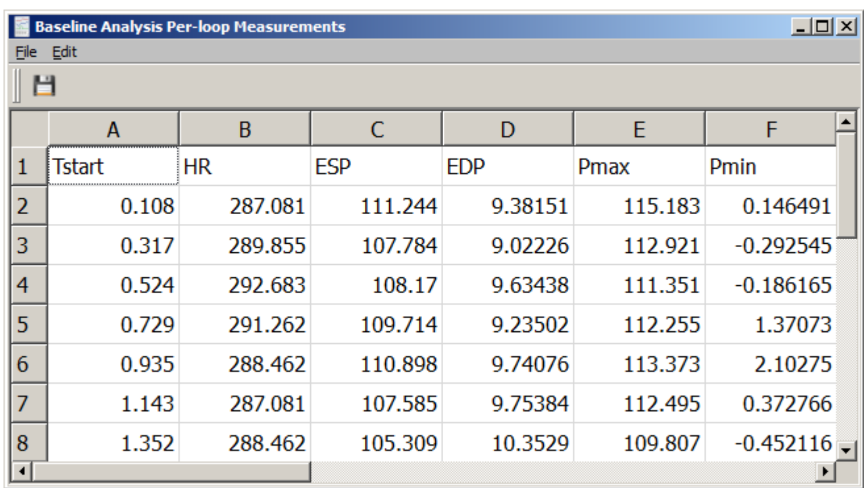
Baseline Analysis

Baseline analysis extracts basic single-loop measures over selected data ranges. These measures are used to assess proper positioning of the catheter for calibration and for assessing various changes during the experiment. Baseline analysis is accessed via Analysis > Pressure-Volume Loop > Baseline Analysis, or via the "Analyze Baseline" button on the PV Loop graph template. Measures to be extracted or excluded are accessed in the Preferences > Customize Baseline Results menu.



Available Baseline Analysis measures

The figure below shows a partial view of single-loop Baseline Analysis measures. The Save icon on the top left is used to save the measures to an external Excel file.



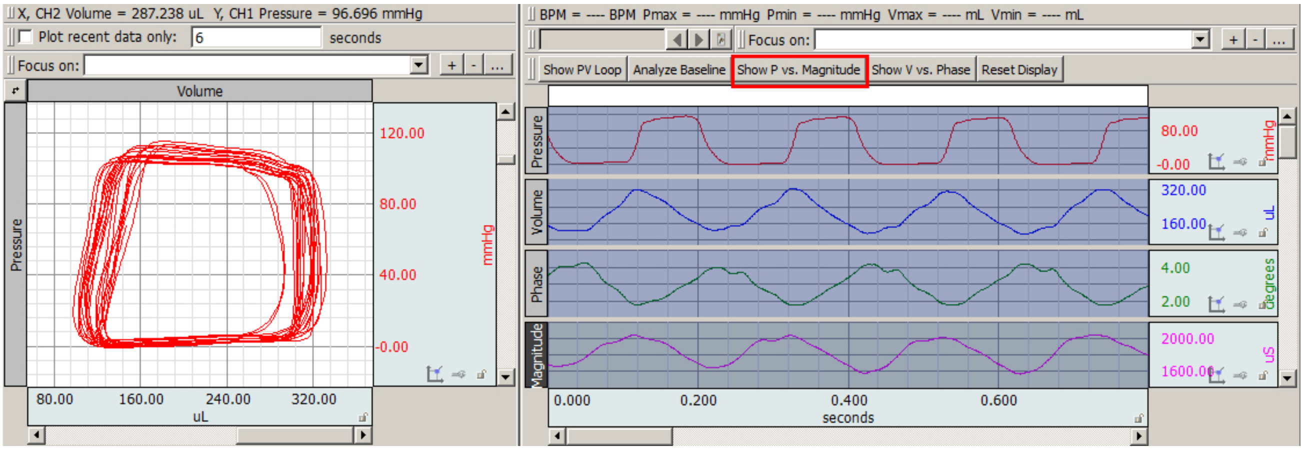
	A	B	C	D	E	F
1	Tstart	HR	ESP	EDP	Pmax	Pmin
2	0.108	287.081	111.244	9.38151	115.183	0.146491
3	0.317	289.855	107.784	9.02226	112.921	-0.292545
4	0.524	292.683	108.17	9.63438	111.351	-0.186165
5	0.729	291.262	109.714	9.23502	112.255	1.37073
6	0.935	288.462	110.898	9.74076	113.373	2.10275
7	1.143	287.081	107.585	9.75384	112.495	0.372766
8	1.352	288.462	105.309	10.3529	109.807	-0.452116

Locate ES and ED Boundaries

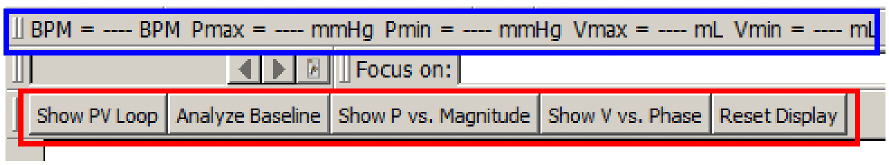
This option is accessed via "Analysis > Pressure-Volume Loop > Locate ES and ED Boundaries." It locates the ending systole and ending diastole boundaries in a selected area and inserts events into the graph marking their location.

Realtime Display

Realtime display during PV Loop acquisitions involves setting up multiple views, toolbars and calculation channels specifically tailored for PV Loop analysis. For convenience, a Pressure Volume Loop Quickstart graph template is included with Acq*Knowledge* software. This template is configured for MP160/150 hardware and contains all above-mentioned setups, as well as two additional toolbars for realtime and post-processing data display.



PV Loop Quickstart showing graph data and Pressure vs. Magnitude XY data view



The above figure shows the additional toolbars present in the PV Loop Quickstart template, with toolbar functions explained below.

- Recent Values toolbar (outlined in blue)

The Recent values toolbar extracts the following measurements in real time from the cardiac calculation channels 42-46. (Values are displayed during acquisition.)

Heart Rate (BPM)

Maximum Pressure (mmHg)

Minimum Pressure (mmHg)

Maximum Volume (mL)

Minimum Volume (mL)

- Custom Button toolbar (outlined in red)

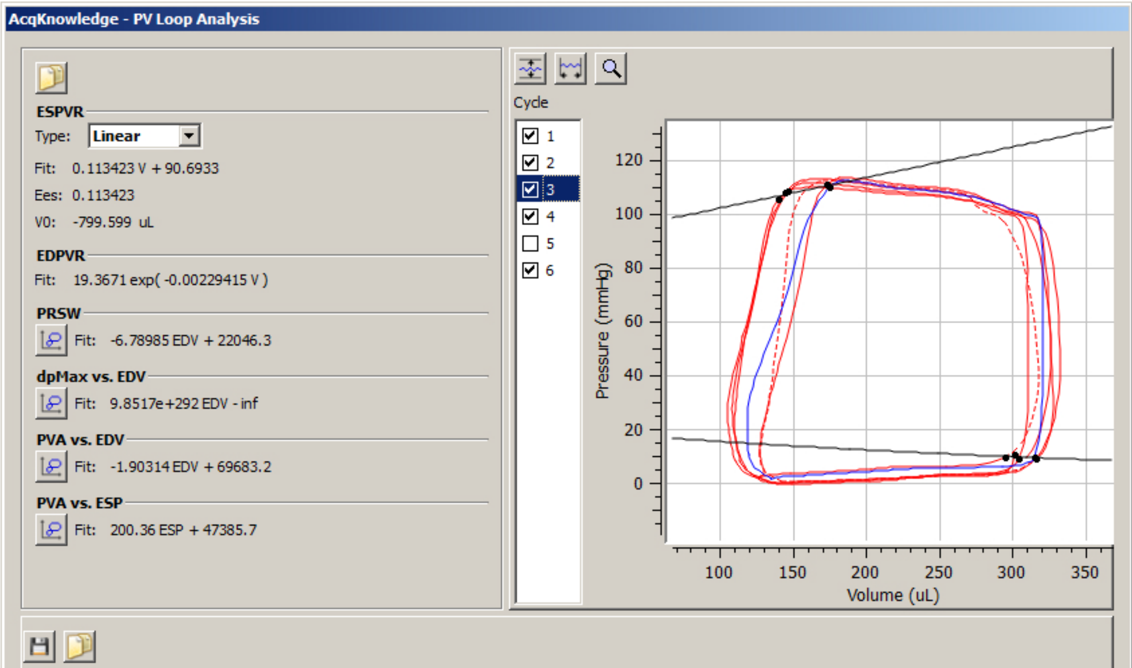
This toolbar provides quick access to the following functions during recording and in post-processing

Show PV Loop	Displays the Pressure Volume Loop in XY view. Plot shows most recent 6 seconds of pressure (X) vs. volume (Y). Useful for viewing experimental effects or determining catheter positioning.
Analyze Baseline	Performs baseline analysis on selected graph data. (A shortcut to choosing Analysis > Pressure Volume Loop > Baseline Analysis.)
Show P vs. Magnitude	Displays the Pressure vs. Magnitude data in XY view. Plot shows most recent 6 seconds of pressure (X) vs. Magnitude (Y). Useful when positioning the catheter.
Show V vs. Phase	Displays the Volume vs. Phase data in XY view. Plot shows most recent 6 seconds of pressure (X) vs. phase (Y). Useful for viewing oscillating muscle contributions in the signal.
Reset Display	Sets the display back to the default view.

Full PV Loop Analysis

After all pressure volume data has been acquired, it may be analyzed in detail using the full static analysis tool. This is accessed via Analysis > Pressure-Volume Loop > PV Loop Analysis. This tool enables the examination of all loops within the selected area of the graph. PV Loop Analysis is a manual process where outliers are defined both visually and through determining how different sets of loops affect defined parameters. When activated, if End Diastolic and End Systolic events are already present in the selected data, they will be used to define the loop boundaries. If none are present, new events will be defined using the desired location method and preferences.

The full PV Loop dialog appears as follows:



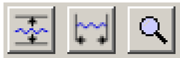
	Active	Tstart	HR	ESP	EDP	Pmax	Pmin	dPmax	dPmin	Vmax	Vmin
1	Yes	0.317	289.855	107.784	9.02226	112.921	-0.292545	****	****	326.693	108.455
2	Yes	0.524	292.683	108.17	9.63438	111.351	-0.186165	****	****	314.86	105.527
3	Yes	0.729	291.262	109.714	9.23502	112.255	1.37073	****	****	321.097	118.908
4	Yes	0.935	288.462	110.898	9.74076	113.373	2.10275	****	****	327.791	126.328
5	No	1.143	287.081	107.585	9.75384	112.495	0.372766	****	****	317.775	127.464
6	Yes	1.352	288.462	105.309	10.3529	109.807	-0.452116	****	****	332.512	110.061

The PV Loop Analysis dialog is divided into three basic panes.

- **Loop display** (right pane)
- **Multiple loop measures** (left pane)
- **Per loop measures** (bottom pane)

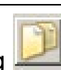
The loop display shows an XY plot of volume vs. pressure. Individual loops are drawn using the waveform plot color of the pressure channel. Overlaid in black on top of the loops are two best fit curves for end systolic pressure volume relationship (ESPVR) and end diastolic pressure volume relationship (EDPVR). Use the checkboxes under 'Cycle' to include or exclude individual loops in the plot analysis. Excluded loops will appear as dotted lines and the actively selected loop will be outlined in blue. Excluded loops will also be grayed out in the per loop measure display (bottom pane).

The loop display can be rescaled by clicking on the XY graph's vertical and horizontal axis in the same manner as in any graph, and then modifying the scaling parameters.

Use the controls  in the upper left of the loop display region to autoscale vertically, horizontally, and zoom data.

Multiple loop measures

Once a set of loops has been identified, various models are constructed showing ideal boundaries of pressure and volume extents for varying cardiac cycles. Additional relationships between per-loop measures are also extracted to help assess overall cardiac condition. Multiple loop measures include the following relationships and controls:

ESPVR (End Systolic Pressure Volume Relationship)	Theoretical maximum pressure for any given volume.
Type	Use to select the equation upon which to base the PV loop curve fit: Linear or quadratic.
Ees	Index of overall myocardial contractility.
V0	Theoretical volume of loop at zero pressure.
EDPVR (End Diastolic Pressure Volume Relationship)	Passive filling properties of ventricle, reciprocal of ventricular stiffness.
PRSW (Preloadable recruitable stroke work)	Pressing  displays a plot showing linear regression between stroke work and diastolic volume between loops.
dpMax vs. EDV	Pressing  displays a plot showing maximum change in pressure vs. end diastolic volume.
PVA vs. EDV	Pressing  displays a plot showing pressure volume area vs. end diastolic volume.
PVA vs. ESP	Pressing  displays a plot showing pressure volume area vs. end systolic pressure.
Other controls	Pressing  copies the loop-specific measures to the clipboard. Pressing  saves the loop-specific measures to an Excel file.

Per loop measures

	Active	Tstart	HR	ESP	EDP	Pmax	Pmin	dPmax	dPmin	Vmax	Vmin
1	Yes	0.317	289.855	107.784	9.02226	112.921	-0.292545	****	****	326.693	108.455
2	Yes	0.524	292.683	108.17	9.63438	111.351	-0.186165	****	****	314.86	105.527
3	Yes	0.729	291.262	109.714	9.23502	112.255	1.37073	****	****	321.097	118.908
4	Yes	0.935	288.462	110.898	9.74076	113.373	2.10275	****	****	327.791	126.328
5	No	1.143	287.081	107.585	9.75384	112.495	0.372766	****	****	317.775	127.464
6	Yes	1.352	288.462	105.309	10.3529	109.807	-0.452116	****	****	332.512	110.061

The bottom pane of the analysis window contains a table display of individual loop analysis results. Each loop occupies one row. Comparative measures are automatically updated upon any changes to included loops.

Each per loop measure is recorded in its own table column. The following hemodynamic measures are reported:

Measure	***Abbrev.***	***Formula***	***Units***	***Description***
Heart rate	HR	$\dfrac{60}{(t_{ED} - t_{start})}$	BPM	Provides the heart rate.
End systolic pressure	ESP	$P(t_{ES})$	mmHg	Blood pressure at end of systole.
End diastolic pressure	EDP	$P(t_{ED})$	mmHg	Blood pressure at end of diastole.
Maximum pressure	Pmax	$maxP(t), t \in (t_{start}, t_{ED}]$	mmHg	Maximum pressure within the loop, left endpoint exclusive right endpoint inclusive.
Minimum pressure	Pmin	$minP(t), t \in (t_{start}, t_{ED}]$	mmHg	Minimum pressure within the loop, left endpoint exclusive right endpoint inclusive.
Maximum dP/dt	dPmax	$max\dot{P}(t), t \in (t_{start}, t_{ED}]$	mmHg / sec	Maximum change in pressure within the loop, left endpoint exclusive right endpoint inclusive.
Minimum dP/dt	dPmin	$min\dot{P}(t), t \in (t_{start}, t_{ED}]$	mmHg/sec	Minimum change in pressure within the loop, left endpoint exclusive right endpoint inclusive.
Maximum volume	Vmax	$maxV(t), t \in (t_{start}, t_{ED}]$	ml	Maximum volume within the loop, left endpoint exclusive right endpoint inclusive.
Minimum volume	Vmin	$minV(t), t \in (t_{start}, t_{ED}]$	ml	Minimum volume within the loop, left

Measure	***Abbrev.***	***Formula***	***Units***	***Description***
				endpoint exclusive right endpoint inclusive.
End systolic volume	ESV	$V(t_{ES})$	ml	Volume at ES.
End diastolic volume	EDV	$V(t_{ED})$	ml	Volume at ED.
Stroke volume	SV	$V(t_{ED}) - V(t_{ES})$	ml	Volume of blood ejected.
Cardiac output	CO	$SV * HR = \frac{60[V(t_{ED}) - V(t_{ES})]}{(t_{ED} - t_{start})}$	ml / minute	Amount of blood pumped per unit time.
Ejection fraction	EF	$100\frac{SV}{EDV}$	(none)	Percent of the end diastolic volume ejected during each contraction.
Maximum power	MaxPwr	$max(P(t)\dot{V}(t)), t \in (t_{start}, t_{ED}]$	$\frac{mmHg * ml}{s}$	Maximum cardiac power within the loop, left endpoint exclusive right endpoint inclusive. With appropriate factors may be converted into Watts.
Parallel power	PlPwr	$\frac{MaxPwr}{V(t_{ED})^2}$	$\frac{mmHg}{ml * s}$	
Stroke work	SW	$\sum_{t=t_{start}}^{t=t_{ED}-\delta} \frac{(P(t+\delta) - P(t))(V(t+\delta) + V(t))}{2}$ where $\delta = intersampleinterval$	mmHg * ml	Work performed by the ventricle to eject the stroke volume. Equivalent to the area of the PV loop.
Arterial elastance	Ea	$\frac{ESP}{SV}$	mmHg / ml	Measure of arterial load for measuring coupling between heart and arterial system.

Relaxation Constant

The relaxation constant, or **tau**, is a measure of the shape of pressure decay during ventricular relaxation. The relaxation period is defined as the time of minimum change in pressure until the time when the pressure signal has dropped under the EDP of the previous loop (or to ED if no previous loop is located). Multiple methods are used to extract tau:

Method	***Description***	***Units***
Tau Weiss	Tau parameter in best fit of pressure data to: $$P_0\mathrm{e}^{\frac{-t}{\tau}}$$ where P_0 is the value of the LVP signal at the time of dP/dt minimum and *t* is the time coordinate shifted such that *t* is 0 at the time of dP/dt minimum.	(unitless)
Tau Logistic	Tau parameter in best fit of pressure data to the zero asymtote logistic: $$\frac{F_A}{1+e^{t/\tau}}$$ where *t* is the time coordinate shifted such that *t* is 0 at the time of dP/dt minimum. Let us fix the initial endpoint such that $F_A = 2P_0$. The logistic fit is computed by the best linear fit to the equation $cT = Y$ where $T = t$ and $Y = \ln(\frac{2P_0}{P(t)} - 1)$, such that $\tau = \frac{1}{c}$.	(unitless)
Tau Glanz	The Raff-Glanz relaxation constant method is described in http://circres.ahajournals.org/content/48/6/813.full.pdf. This extends the Weiss method by allowing a non-zero asymptote to be incorporated into the relaxation model such that the formula is: $$P_0e^{\frac{-t}{\tau}} + P_B$$ To solve for the constant, the slope *a* of the best fit linear regression of the series of points $[P(t), \dot{P}(t)], t \in relaxationperiod$ resulting in $\tau = -\frac{1}{a}$.	(unitless)
Tau Mirsky	Time interval between dP/dt minimum and when *P* drops below a threshold of $\frac{P(t_{ES})}{2}$.	ms

Comparative Measures

After multiple loop measures are extracted, the following additional measures may be extracted for each loop to examine its relationship to the volume-relationship analyses of a set of loops and expected theoretical baselines. These measures are based upon various multiple loop measures and should be recomputed any time they are changed due to modifications to the set of loops included in the analysis: (See following page.)

Measure	**Abbrev.**	**Description**	**Units**
Pressure volume area	PVA	Provides a measure of the total mechanical energy produced by a ventricular contraction. From the set of loops the ESPVR model provides the theoretical baseline volume at zero pressure $V0$. The PVA for a loop is then determined from the following formula: $$\frac{P(t_{ES})[V(t_{ES})-V0]}{2}-\frac{P(t_{ED})[V(t_{ED})-V0]}{4}+SW$$ where SW is the stroke work for the loop.	mmHg * ml
Potential energy	PE	Provides a measure of the elastic potential energy built during the systole and stored in the ventricular wall at the onset of relaxation. From the set of loops the ESPVR model provides the theoretical baseline volume at zero pressure *V0*. The PE for a loop is then determined from the following formula: $$PVA-SW$$ That is the total mechanical energy minus the actual work used to eject the stroke volume.	mmHg * ml
Efficiency	Eff	Provides the fraction of the total mechanical energy used to eject the stroke volume: $$\frac{SW}{PVA}$$	(unitless)
Maximum time varying elastance	Emax	The normalized time varying elastance for an individual loop is adjusted from the theoretical baseline volume at zero pressure *V0* and is given by the Suga and Sagawa formula: $$E(t)=\frac{P(t)}{V(t)-V0}$$ For a given loop, the maximum value of E(t) will occur when pressure is highest and volume is lowest, or at the time of ES: $$E_{max}=\frac{P(t_{ES})}{V(t_{ES})-V0}$$ This is also the slope of the line connecting V0 with ESP within the XY loop plot[1].	mmHg / ml

See the AcqKnowledge PV Loop Analysis video tutorial for a detailed demonstration of this feature.

Chapter 28 Licensed Functionality: Baroreflex Analysis

Baroreflex Sensitivity Analysis (BRS) functionality is available through an optional license available with Acq*Knowledge* 5. The license must be authorized to access BRS functionality. To add a BRS license to an existing MP System, please contact BIOPAC.

Baroreflex analysis measures the relationship between blood pressure and heart rate and is derived from measures of blood pressure and ECG. The body regulates blood pressure to ensure proper blood flow to organs underneath different conditions, e.g. supine to standing. Baroreflex sensitivity is a measure of how quickly the blood pressure system compensates for changes in conditions, such as would be observed in increasing or decreasing exercise. Variations in baroreflex sensitivity are useful as a comparative measure between subjects and for assessing various external impacts.

The Baroreflex licensed functionality adds two additional measures to the Specialized Analysis > Hemodynamics menu.

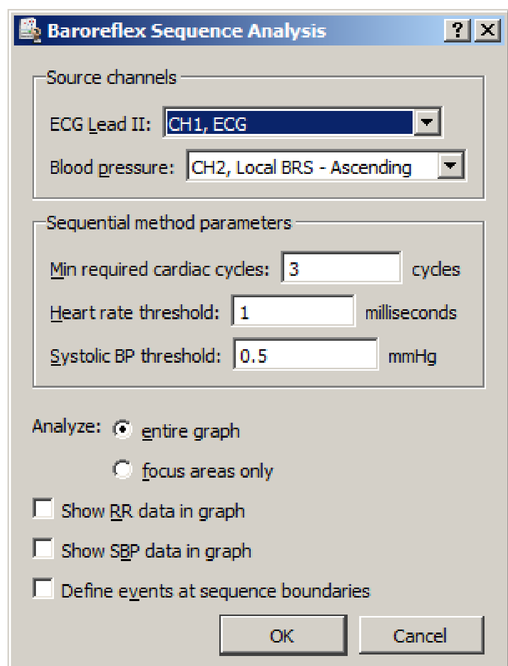
Baroreflex Sequence Analysis

Baroreflex Sequence analysis method produces measures of Baroreflex sensitivity (BRS) by automatically locating time periods to analyze. Analysis results can be outputted to a graph channel and/or spreadsheet. The output format is selected in the Hemodynamics global preferences.

The Graph channel output consists of two channels:

- "Local BRS – Ascending" with values set to the BRS estimate slope during the time periods of all ascending Heart Rate and Systolic Blood Pressure sequences.
- "Local BRS – Descending" will have its values set to the BRS estimate slope during all time periods of descending Heart Rate and Systolic Blood Pressure sequences.

Sequence Analysis Setup Dialog



Choosing the Baroreflex Sequence Analysis option produces a dialog with the following controls:

Source channels:

- **ECG Lead II** – Selects the ECG channel for detecting heart rate
- **Blood Pressure** – Selects pressure channel for extracting systolic pressure

Sequential method parameters:

- **Min required cardiac cycles –** Minimum number of increasing or decreasing cardiac cycles required to initiate a sequence analysis operation
- **Heart rate threshold –** Minimum heart rate change required to initiate a cardiac analysis operation
- **Systolic BP threshold –** Minimum systolic blood pressure change required to initiate a BP analysis operation

Analyze:

- **entire graph – T**he entire graph is analyzed for Baroreflex measures
- **focus areas only –** Only defined focus areas are analyzed for Baroreflex measures
- **Show RR data in the graph** – Outputs the RR interval as a graph channel
- **Show SBP data in the graph** – Outputs the systolic blood pressure data as a graph channel
- **Define events at sequence boundaries** – Outputs events at the beginning and end of sequence

Note When "focus areas only" is selected, the entire graph is still scored for QRS events and systolic BP events, but only defined focus area data is included in the analysis output.

Baroreflex Sequence Analysis description references can be found on page 588.

Baroreflex Slope Analysis

The **Baroreflex Slope** analysis method uses linear regression to determine a measure of Baroreflex sensitivity (BRS). The analysis output area displays the current BRS estimate and the slope of the best linear regression fit to all of the cardiac cycles included in the analysis.

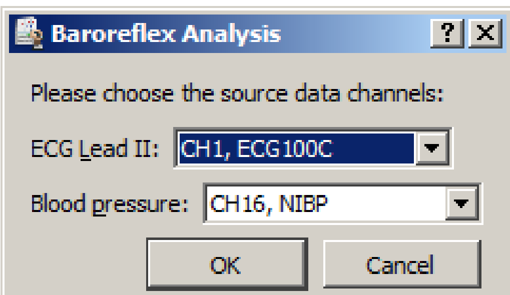
First, a source time interval is defined in the cardiac recording, generally located around regions of induced change in blood pressure. The pairs of heart rate and systolic pressure within this time interval are extracted. A linear regression of these coordinates is computed, with pressure as the x coordinate and heart rate interval as the y interval. BRS is defined as the slope of the best fit linear regression, in units of ms/mmHg.

The slope method is useful when correlating with studies using this method, performing validations, or when areas to be measured are very well known. This method can only be used on an area of selected data. If attempted on unselected data, a dialog will appear prompting for data selection with the I-beam tool or a defined focus area.

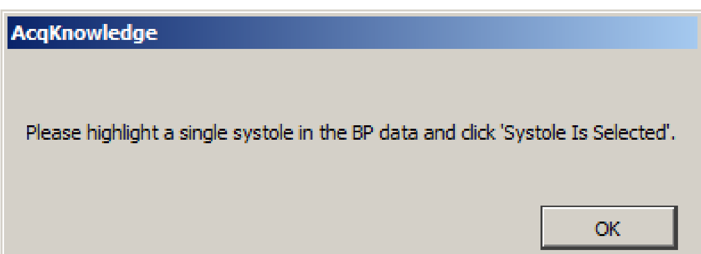
Baroreflex Slope Analysis description references can be found on page 588.

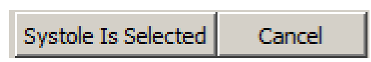
Slope Analysis Setup Dialog

Choosing the Baroreflex Slope Analysis option produces the following dialogs:

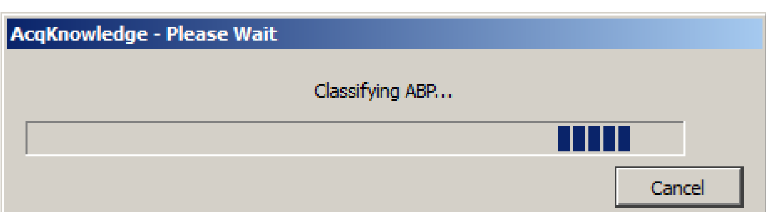


In the initial dialog, the ECG and blood pressure channels are selected (above).





The subsequent dialogs prompt for the highlighting and selection of a systole in the BP data (above).



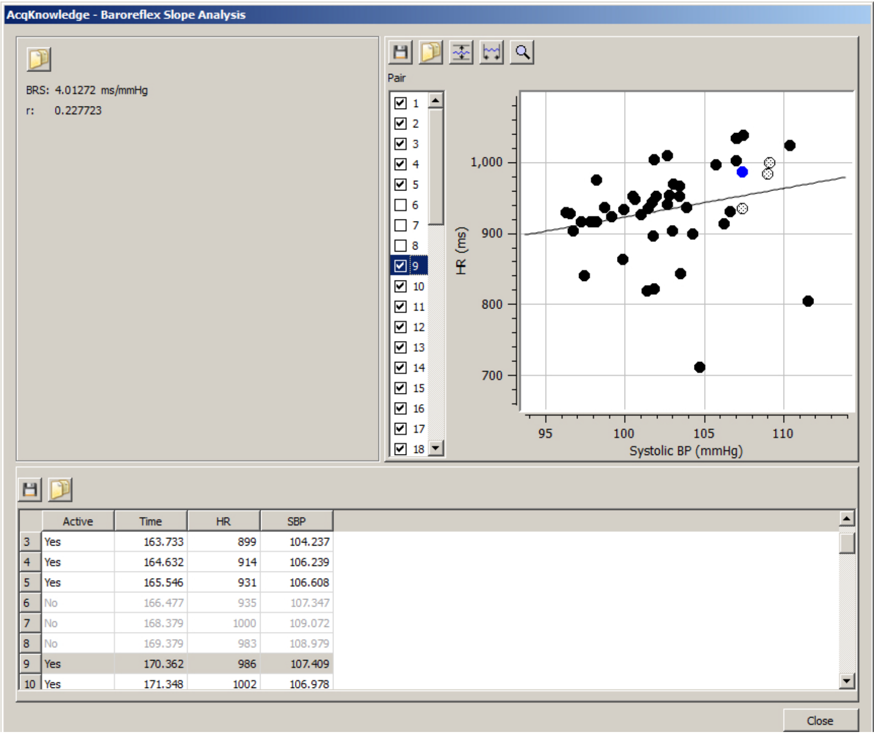
Following systole selection, the arterial blood pressure events are scored. This can take some time, depending on the width of the selected area (above).

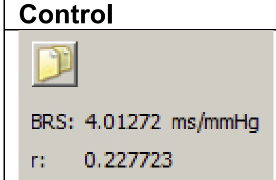
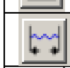
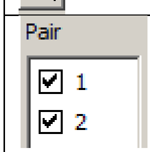
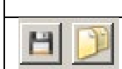
An interactive plot (see next page) will appear, and displays the best present linear curve fit and the cardiac cycles as points on an XY plot of systolic blood pressure versus heart rate.

Include or exclude points from analysis by checking or unchecking the numbered cardiac cycle boxes, or by clicking on individual points while holding down the ALT key. When individual points are excluded or included, the best linear fit will be automatically recalculated. The cardiac cycle table at the bottom of the analysis window provides a tabular spreadsheet view, and includes:

- Active (checked) or hidden (unchecked)
- Time on horizontal scale that cardiac cycle occurred

- Heart Rate (HR) in milliseconds
- Systolic Blood Pressure (SBP) in mmHg



Control	Description
	The analysis output area in the upper left corner displays the current BRS estimate, the slope of the best linear regression fit to all cardiac cycles included in the analysis. Underneath it the present r value, goodness of fit, is displayed. These values are updated dynamically if plot data is modified. The “Copy” button in this area copies the text to the clipboard.
	Copies the plot to a *.jpeg file.
	Copies the plot data to the clipboard.
	Autoscales the plot vertically.
	Autoscales the plot horizontally.
	Toggles between selection and zoom mode in the plot.
	The “Pair” checkboxes allow for dynamic interaction with the individual heart rate (HR) and systolic blood pressure (SBP) points (also referred to as pairs). This is useful for visual identification and the exclusion of outliers. • Check/uncheck a box to show or hide a point, or click a point while holding down the ALT key. Active points appear like this: • Hidden points appear like this: • Click on a point to highlight it. The highlighted point will also be selected in the cardiac cycle table in the lower part of the screen. Highlighted points appear like this:
	Click the left icon above the cardiac cycle table data to save table data to an Excel spreadsheet; click the right icon to save it to the clipboard.

Baroreflex Sequence Method Description

The **Baroreflex Sequence** method is described in the following papers:

Kuusela, Tom; "On the Analysis of Baroreflex Sensitivity," 2010.

Reyes del Paso, Gustavo A; "A program to assess baroreceptor cardiac reflex function," "Behaviour Research Methods, Instruments & Computers," 1994, 26 (1), 62-64.

The sequence method first applies criteria to the heart rate and systolic pressure signals to locate time ranges for analysis. Given a minimum number of samples *n*, a minimum rate of change in heart rate RR_{thresh}, and a minimum rate of change in systolic blood pressure P_{thresh}, the sequence of RR and pressure intervals is examined for time ranges of rising and falling signals.

As indicated in section 2.5 of the Reyes del Paso paper, the pressure value at index *u* will actually be paired with the heart rate value at index *u*+1. This one index delay is estimated to provide a better estimation of BRS.

A rising time interval is defined as a time range where at least *n* consecutive data points $i \in \{j, k\}$exhibit $RR(i + 2) - RR(i + 1) > RR_{thresh}$and $P(i + 1) - P(i) > P_{thresh}$, that is the heart rate and pressure signals are increasing by at least their thresholds in between consecutive data points. These intervals must be at least *n* samples but will be extended until the first sample where the signals either decrease or the increase is underneath the appropriate thresholds.

A falling time interval is defined as a time range where at least *n* consecutive data points $i \in \{j, k\}$exhibit $RR(i + 2) - RR(i + 1) < -RR_{thresh}$and $P(i + 1) - P(i) < -P_{thresh}$, that is the heart rate and pressure signals are decreasing by at least their thresholds in between consecutive data points. These intervals must be at least *n* samples but will be extended until the first sample where the signals either increase or the decrease is less than the appropriate thresholds.

For each of these defined periods, the baroreflex sensitivity is computed using the slope method. That is, the best linear fit for each individual sequence with pressure as the x coordinate and heart rate as the y coordinate will be computed. As with the range identification, the source data used for this regression analysis will be the pressure at index *u* paired with the heart rate at index *u*+1. The slope of this best fit line is the local BRS, expressed in units of ms/mmHg.

The default values of the thresholds and count are defined in section 4 of the Kuusela paper as follows: $n = 3$, $RR_{thresh} = 1ms$, $P_{thresh} = 0.5mmHg$.

Because of the delay applied to the heart rate signal from the systolic pressure, the slope method may not be directly used to validate local BRS measures from the sequential method.

Baroreflex Slope Method Description

The **Baroreflex Slope** method is described in the following papers:

Kuusela, Tom; "On the Analysis of Baroreflex Sensitivity", 2010.

Patakas, D., Louridas, G. et. Al; "Reduced baroreceptor sensitivity in patients with chronic obstructive pulmonary disease", Thorax 1982; 37:292-295.

Chapter 29 Licensed Functionality: Actigraphy

Actigraphy Analysis functionality is available through an optional license available with Acq*Knowledge* 5. The license must be authorized to access Actigraphy tools. To add an Actigraphy license to an existing MP System, please contact BIOPAC.

Actigraphy is the long-term study of accelerometer data correlated to subject activity. One of the primary uses of actigraphy is to conduct sleep studies in which subjects are relatively motionless for extended periods. With this Acq*Knowledge* licensed feature, long-term data recordings acquired with accelerometers and BIOPAC's wireless BioNomadix or BioHarness systems can be employed to empirically detect periods of waking and sleep. Using Actigraphy, researchers have the ability to noninvasively measure a subject's activity level and analyze the resulting data to assess sleep disorders and other sleep related criteria. These types of studies usually span at least one day and often encompass several weeks of data.

The purpose of the Acq*Knowledge* Actigraphy analysis tool is to import and process accelerometer data from graph data files and perform further data reduction into meaningful sleep metrics. A new file format (actigraphy analysis file or *.act) allows multiple recordings to be stored and analyzed for individual subjects across multiple time periods.

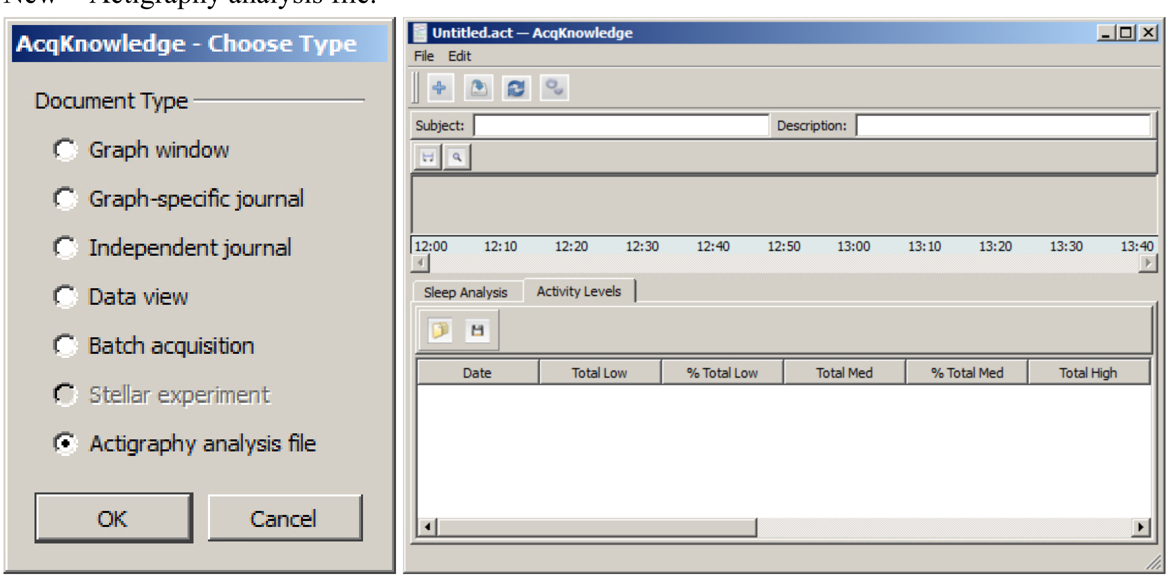
Actigraphy User Interface

A separate user interface and file format is employed for saved actigraphy analysis files within Acq*Knowledge*. The actigraphy analysis (*.act) file retains the following information and settings:

- Subject name and description
- One or more activity records. Each activity record contains the calendar date starting time and activity count data (1-minute epochs)
- Time used to separate days (default is 12:00 PM)
- Sleep onset interval detection setting
- Low activity level threshold
- High activity level threshold
- Previous analysis results for each day containing activity records (primary sleep onset, end, sleep deprived measures, and activity level analysis)
- Number of visible activity level count plots
- Index of last visible tab of analysis results in the window (sleep vs. activity)

Creating Actigraphy Files

To create a new actigraphy analysis file, select "Create new actigraphy analysis" in the Startup Wizard, or choose "File > New > Actigraphy analysis file."



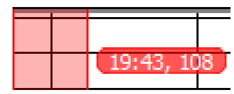
This creates a blank actigraphy analysis window similar to the example above.

Importing Raw Accelerometer Data

Acq*Knowledge* records raw accelerometer data which must be imported and processed into activity counts for use in actigraphy analysis.

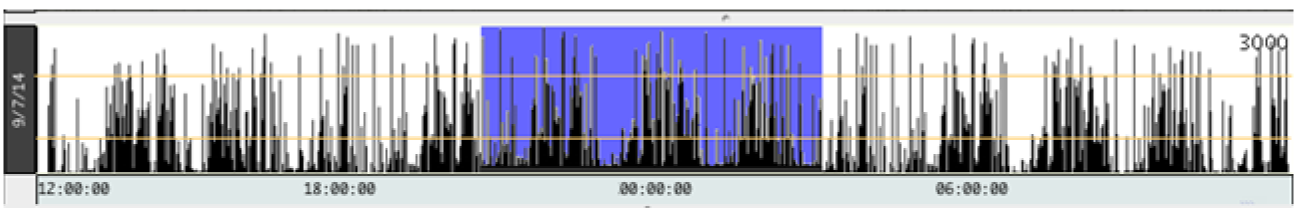
To import data from an external accelerometer sleep study file, click the  toolbar button in the Actigraphy Analysis window, navigate to the raw data file's location and choose "Open." Once the data is imported, it (along with the extracted sleep and activity level measures) can be saved as an actigraphy analysis (*.act) file.

After accelerometer data is imported into the main Actigraphy window, (or after an existing actigraphy analysis file opened) the raw data appears in graph format in the upper "activity count plot" area of the window, with all data correlating to a navigable and scalable horizontal time scale. The default scaling is for a 24 hour period, but data can be zoomed by clicking and dragging over any portion of the activity plot data.

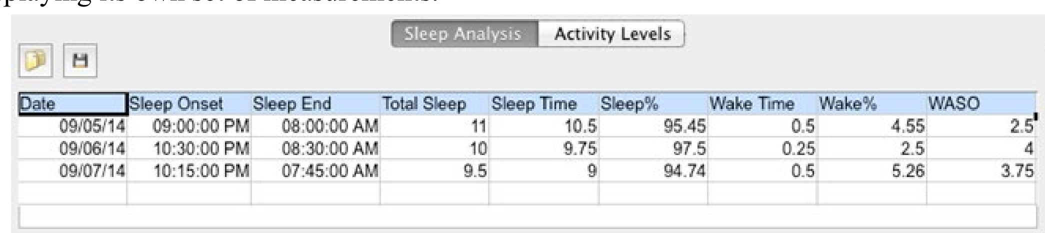


During zoom, the rescaled clock time is displayed in red at the right border of the zoomed area. (Right)

The activity count plot area displays activity data for the subject. Its overall vertical area is split up into a variable number of plots, controllable within the Analysis Settings (see page 592). Each plot represents 24 hours of activity data. The leftmost plotted position is the starting time where time periods are to be split. The vertical label for the plot is set to the calendar date at that starting time position and the horizontal axis shows time of day in a 24 hour time format. Every time the window is first opened, data is horizontally scaled to show all 24 hours. Data plotting is vertically autoscaled so the bottom of each individual plot is zero and the top of each plot area is the maximum activity count within the entire data set.



Following data import, multiple measures are extracted and displayed in column format in the lower pane of the Actigraphy window. This pane is divided into two tabbed categories, *Sleep Analysis* and *Activity Levels*, with each category displaying its own set of measurements.



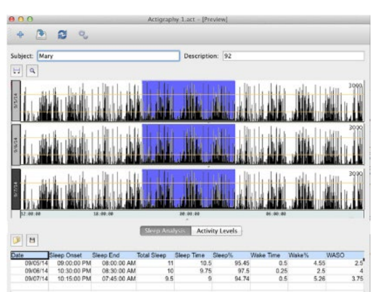
Date	Sleep Onset	Sleep End	Total Sleep	Sleep Time	Sleep%	Wake Time	Wake%	WASO
09/05/14	09:00:00 PM	08:00:00 AM	11	10.5	95.45	0.5	4.55	2.5
09/06/14	10:30:00 PM	08:30:00 AM	10	9.75	97.5	0.25	2.5	4
09/07/14	10:15:00 PM	07:45:00 AM	9.5	9	94.74	0.5	5.26	3.75

All extracted measures can be exported to a text (*.txt) or Excel spreadsheet format.

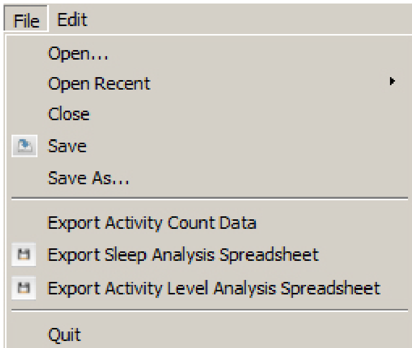
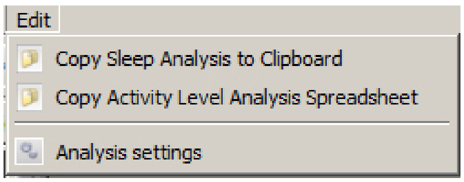
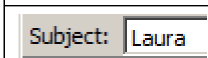
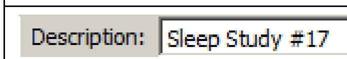
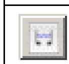
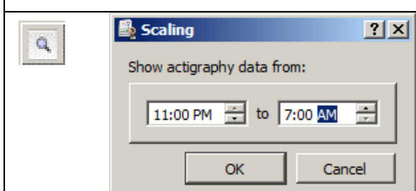
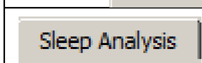
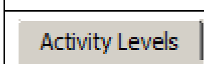
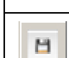
Opening an Existing Actigraphy File

To open an existing actigraphy analysis file, choose File > Open in the analysis window, navigate to the *.act file location and click "Open."

Below: Actigraphy Analysis window populated with accelerometer sleep data (Max OS version).

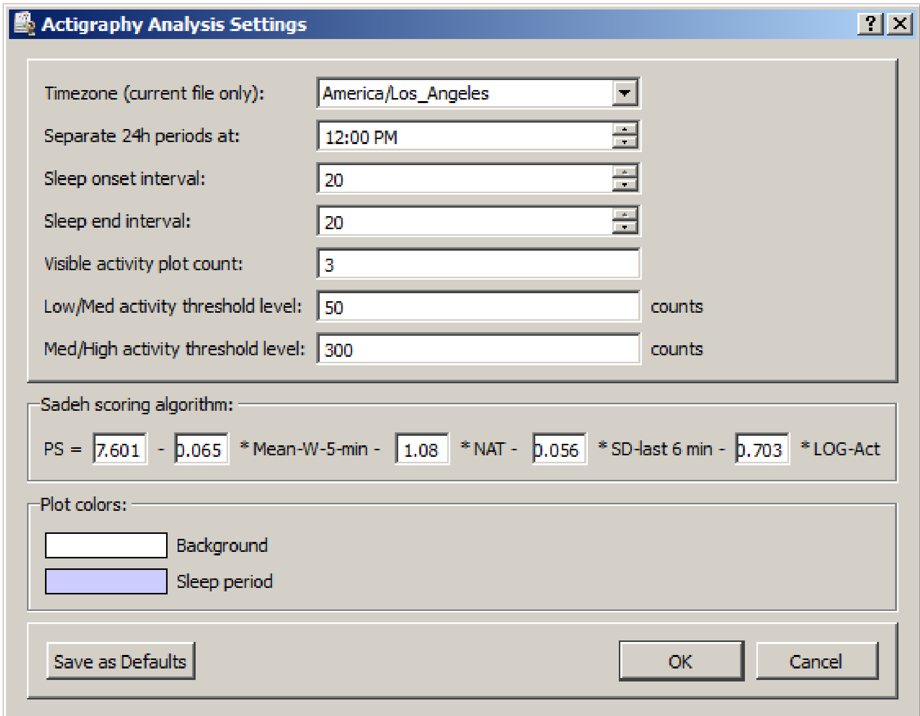


The following table explains the various menus, options and controls in the Actigraphy Analysis window:

Item	Description
	**File** > Open – displays File Open dialog for navigating to existing *.act (actigraphy) files. Open Recent – displays most recently opened *.act files. Export Activity Count Data – saves all raw accelerometer data to a text format. Export Sleep Analysis Spreadsheet – saves all sleep derived measures to a spreadsheet format. Export Activity Level Analysis Spreadsheet – saves all Activity Level Analysis measures to spreadsheet format.
	**Edit** > Copy Sleep Analysis to Clipboard – Exports sleep derived measures to clipboard. Copy Activity Level Analysis Spreadsheet – Exports activity level analysis information to clipboard. Analysis settings – opens the Actigraphy Analysis Settings setup dialog. See details on page 592.
	**Add/Import** – use to navigate to and import external accelerometer data file into the Actigraphy Analysis “activity plot” window.
	**Save** – saves any changes to the imported data file and Actigraphy window settings.
	**Reanalyze** – manually reanalyzes data to locate primary sleep periods and repopulates the derived measure table.
	**Settings** – opens the Actigraphy Analysis Settings setup dialog. See details on page 592.
	Field for entering text identifying Subject.
	Field for entering text describing pertinent study information.
	**Autoscale** – horizontally autoscales the activity plot data back to the original 24 hour period.
	**Scaling** – time scaling button. Opens setup dialog for adjusting the time range of the Actigraphy window’s plotting area.
	Tab for displaying sleep derived measures extracted from the data file under analysis. For a list of specific sleep derived measures, see page 594.
	Tab for displaying activity level measures extracted from data file under analysis. For a list of specific activity level measures, see page 594.
	**Copy text** – copies sleep derived measures to clipboard. (Performs same function as Edit > Copy Sleep Analysis to Clipboard).
	**Export spreadsheet** – exports sleep derived measures to a spreadsheet. (Performs same function as File > Export Sleep Analysis Spreadsheet).

Actigraphy Analysis Settings

As stated in the previous section, choosing "Edit > Analysis settings" (or clicking the  toolbar button) generates the Analysis settings setup dialog. This is where important parameters are selected and applied to the Actigraphy Analysis file.



The following table describes the various parameters available in this dialog.

Actigraphy Analysis Settings Controls

Item	Description
Time Zone (current file only):	Indicates the time zone in which the time data is being analyzed. This varies on a file-by-file basis and is set to the computer's time zone when the file is first created.
Separate 24h periods at:	Provides the cutoff where data is split into new 24 hour blocks for analysis. Only one primary sleep period is allowed per block, so this should be set to a time when the subject is expected to be awake. Default setting is 12:00 PM.
Sleep onset interval:	Selects the time interval for detecting onset of sleep. 10, 15, or 20 minute intervals are available. Default value is 20 minutes.
Sleep end interval:	Selects the time interval for detecting end of sleep. 10, 15, or 20 minute intervals are available. Default value is 20 minutes.
Visible activity count plot:	Selects the number of 24 hour activity plots to display in the actigraphy analysis window. Default value is 3.
Low/Med activity threshold level:	Threshold level used for separating the low and medium activity bands. Default value is 50.
Med/High activity threshold level:	Threshold level used for separating the medium and high activity bands. Default value is 300.
Sadeh scoring algorithm:	See below for separate explanation of this algorithm and associated settings.
Plot colors:	Clicking either option generates a colorwell for modifying the background or sleep period plot colors.
Save as defaults:	Saves any modified settings as a new default for subsequent Actigraphy analyses.

Sadeh Scoring Algorithm for Wake/Sleep Classification

After the activity count has been extracted from the accelerometer data, each data epoch is classified as either a **sleep** or a **wake** interval based upon a formula cited in a widely-acclaimed sleep study publication, "**Activity-Based Sleep-Wake Identification: An Empirical Test of Methodological Issues (1994)**" by Avi Sadeh, Katherine A. Sharkey and Mary A. Carskadon.

Sadeh (1994) proposed one of the classic formulas referenced in multiple papers. Given the activity count **sequence *A***, this heuristic defines the "probability of sleep".

The following table contains derived measures with formulas as described in Table 1 of Sadeh (P. 202):

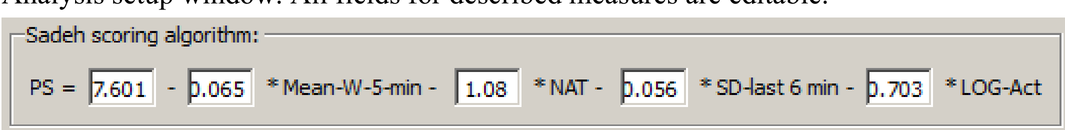
Measure	Description	Abbreviation	Formula(s)
Mean-W-5-min	Windowed mean of overall activity count in the present interval and the 5 minutes prior to and after the present interval.	M	$M(i) = \frac{\sum_{k=i-5}^{k=i+5} A(k)}{11}$
SD-last 6 min	Standard deviation of a 6 minute activity window including the present interval.	S	$\bar{A}(i) = \frac{\sum_{k=i-5}^{k=i} A(k)}{6}$ $S(i) = \sqrt{\frac{\sum_{k=i-5}^{k=i} (A(k) - \bar{A}(i))^2}{5}}$
NAT	Number of intervals within an 11 minute window centered on the current interval having activity counts within this example range [50, 100).	N	$T(i) = \begin{cases} 1 iff 50 \le A(i) < 100 \\ 0 iff A(i) < 50 \lor A(i) \ge 100 \end{cases}$ $N(i) = \sum_{k=i-10}^{k=i+10} T(k)$
LOG-Act	Natural logarithm of the current activity count plus 1.	L	$L(i) = 1 + \ln A(i)$

Given these source parameters, the probability of sleep ***PS*** is defined on page 202 of Sadeh (1994) as:

$$PS(i) = 7.601 - 0.065M(i) - 1.08N(i) - 0.056S(i) - 0.703L(i)$$

If PS is negative, the minute at **interval *i*** is classified as a waking interval. If PS is zero or positive the interval is classified as a sleep interval.

The default scoring algorithm can be modified if desired in the Sadeh scoring algorithm portion of the Actigraphy Analysis setup window. All fields for described measures are editable.



Sleep Derived Measures (Sleep Analysis)

After the primary sleep period has been located, it will be further subdivided into “bouts.” A “bout” is a contiguous section of data that has been classified as either wake or sleep.

Once the primary sleep period has been located in the data file, the following measures are extracted:

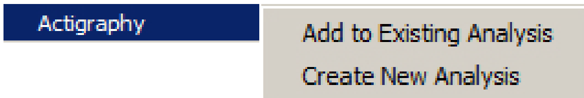
Measure	Description
Date	This is the calendar date for the start of the primary sleep period. For most normal sleep periods the ending time will be assumed to be the next day; the date is for the start of the sleep cycle.
Sleep Onset	Starting time of the primary sleep period.
Sleep End	Ending time of the primary sleep period.
Total Sleep	Total duration of primary sleep interval.
Sleep Time	Number of minutes in the primary sleep interval classified as sleep.
% Sleep	Total percentage of the sleep period that was spent in the sleeping state.
Wake Time	Number of minutes within the primary sleep interval classified as waking.
% Wake	Total percentage of the sleep period that was spent in the waking state.
WASO (Wake After Sleep Onset)	Number of minutes after the initial sleep onset period to the first epoch classified as waking.
Sleep Bouts	Total number of sleep bouts within the primary sleep period.
Mean Sleep Bout Len	Average length of a sleep bout in minutes.
Wake Bouts	Total number of wake bouts within the primary sleep period.
Mean Wake Bout Len	Average length of each wake bout within the primary sleep period.

Activity Level Measures

The following measures are extracted from Activity Level Analysis.

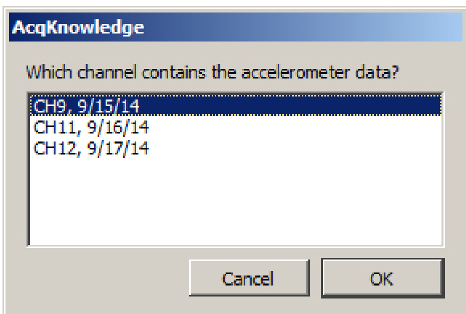
Measure	Description
Date	Calendar date and starting time of the period being analyzed.
Total Low	Total low activity time for the entire period in minutes.
% Total Low	Percentage of the entire period spent in the low activity state.
Total Med	Total medium activity time for the entire period in minutes.
% Total Med	Percentage of the entire period spent in the medium activity state.
Total High	Total high activity time for the entire period in minutes.
% Total High	Percentage of the entire period spent in the high activity state.
awakeLow	Time spent in a low activity state when subject was not sleeping.
awakeLowPercent	Percentage of time subject was in a low activity state when not sleeping.
awakeMedium	Minutes in the medium activity state while subject was not sleeping.
awakeMedPercent	Percentage of time subject was in a medium activity state when not sleeping.
awakeHigh	Minutes in the high activity state while subject was not sleeping.
awakeHighPercent	Percentage of time subject was in a high activity state when not sleeping.

Actigraphy Specialized Analysis

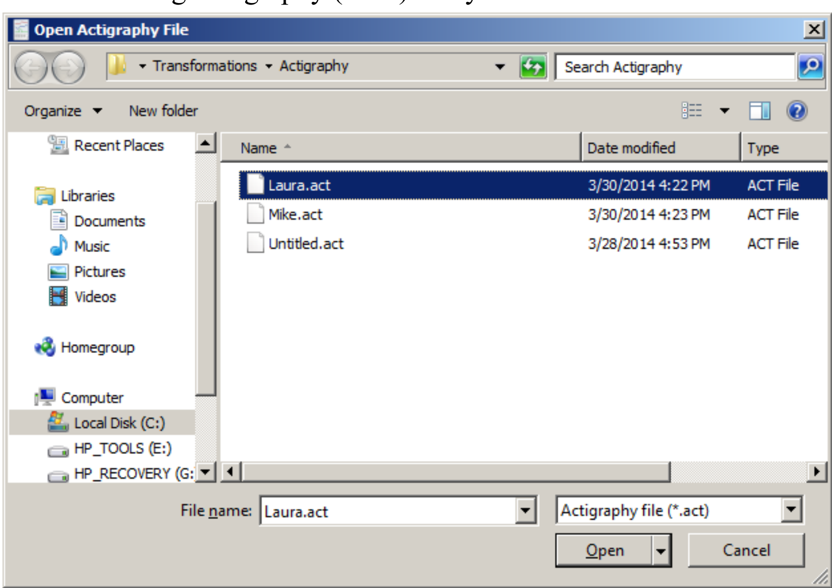


The Specialized Analysis menu contains options for performing Actigraphy import and analysis on any currently-open Acq*Knowledge* data files. These options are defined as follows:

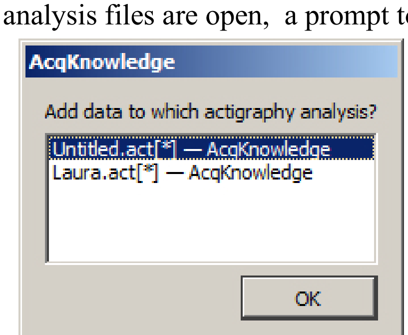
- **Add to Existing Analysis** – allows a channel of data in the graph to be added to a pre-existing actigraphy analysis. This operation may be used often after importing or recording the next set of data from a subject. To add to an existing analysis:
  1. Open the graph containing the accelerometer data to be added to the existing Actigraphy analysis file.
  2. Choose Specialized Analysis > Add to Existing Analysis.
  3. If the graph contains multiple channels, select the channel containing the accelerometer data to be added and click OK.



  4. Choose the existing Actigraphy (*.act) analysis file to add the new data to and click "Open."



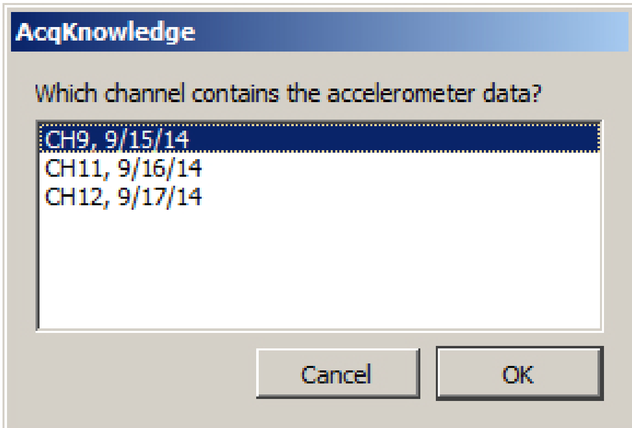
Note If multiple Actigraphy analysis files are open, a prompt to select the desired file will appear:



- **Create New Analysis** – Imports and performs Actigraphy analysis on the currently-open Acq*Knowledge*

graph.
To create a new Actigraphy analysis from the currently open file:

1. Choose Specialized Analysis > Create New Analysis.
2. If the graph contains multiple channels, a prompt will appear to select the desired channel for import.

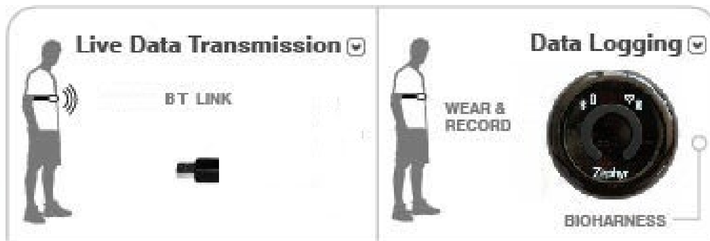


3. In the Actigraphy analysis window, choose File > Save as to save the new Actigraphy (*.act) analysis.

Chapter 30 BioHarness Bluetooth

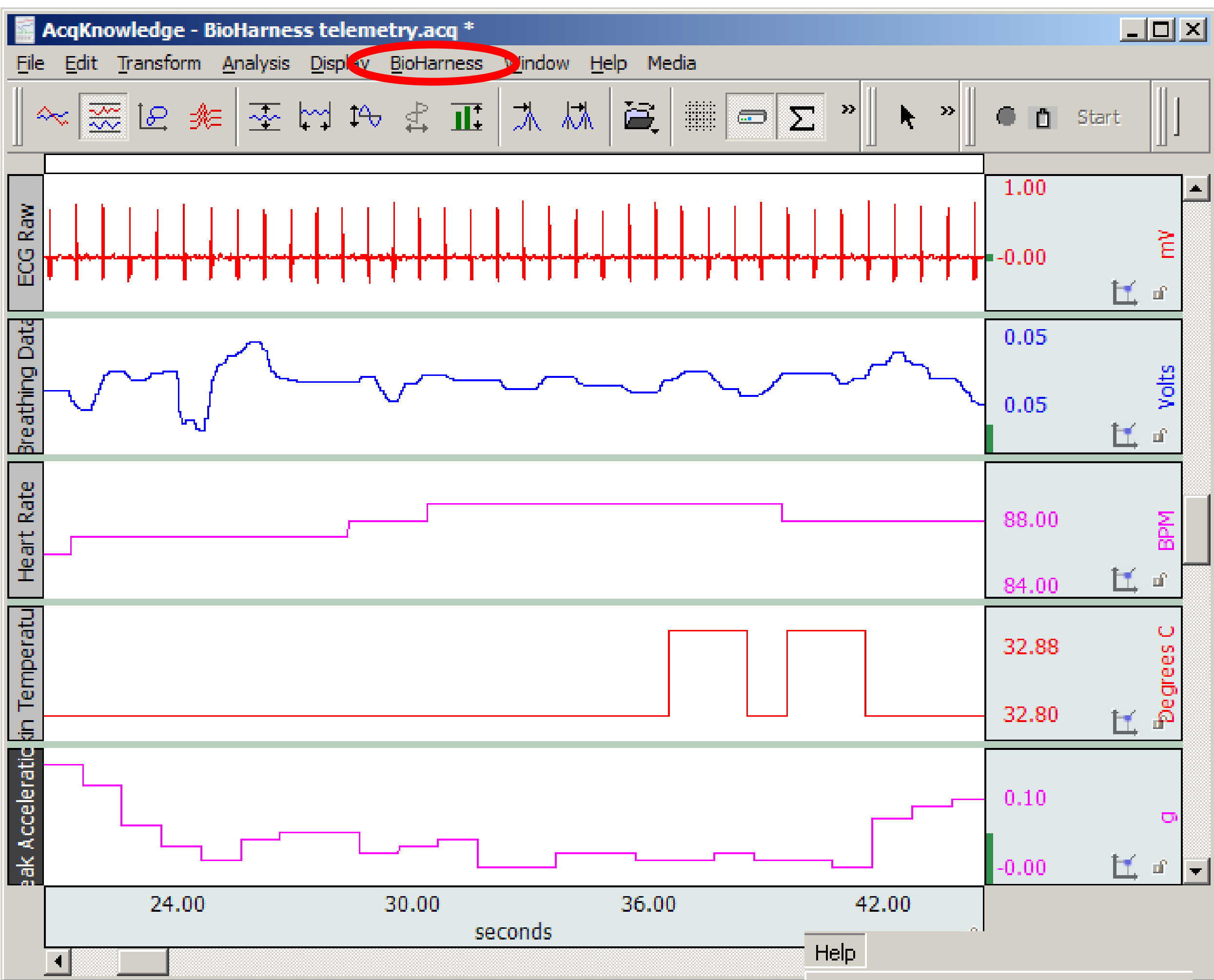
A specially licensed version of Acq*Knowledge* is included and required when used with BioHarness.

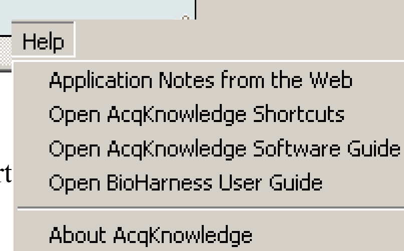
Data Acquisition and Analysis with BIOPAC BioHarness™



IMPORTANT NOTE: In Acq*Knowledge* for BioHarness

- **BioHarness** menu replaces the **MP** menu
- Analog channels can be turned on/off but not changed
- Other functionality remains the same

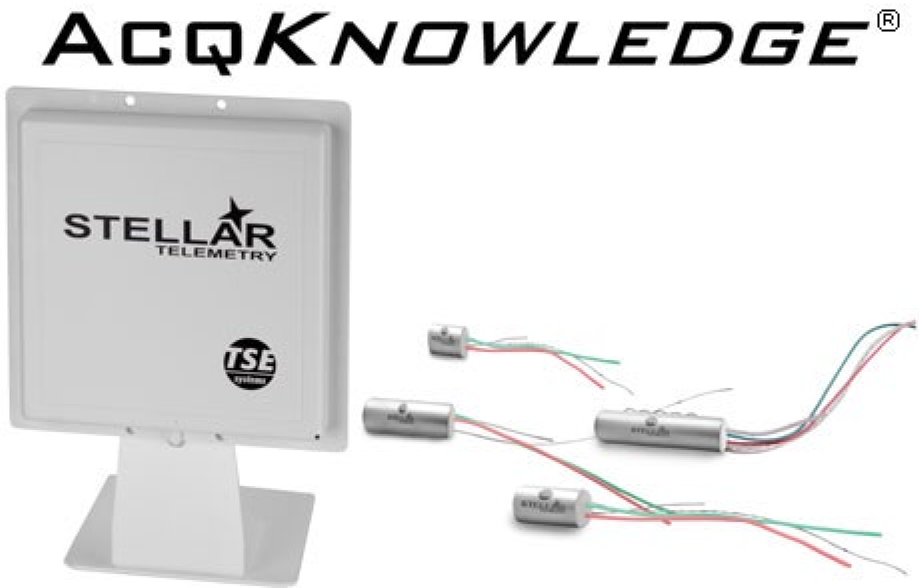




BioHarness™ users should see the **BioHarness User Guide** available under the Help menu and installed to the User Support folder in the program folder.

Chapter 31 Stellar Telemetry

Stellar Telemetry Control interface for existing Stellar Small Animal Telemetry System & Implants is available through optional licensing available with Acq*Knowledge* 5. The license(s) must be authorized to access functionality for the specified number of implants. Please contact BIOPAC to discuss licensing options.



Stellar Telemetry System

The Stellar Telemetry System wirelessly acquires physiological data from single or multiple animal subjects. The system consists of a small implantable recording device with an antenna and USB base station for communicating with the implanted units. There are two types of recording device, memory-type implants that can log or transmit live and continuous or real-time implants that have no memory and thus can only transmit live data. Acq*Knowledge* software is used to configure Stellar experiments and analyze blood pressure, ECG, temperature, and accelerometer data to be transmitted live or imported from logging sessions. Specific data recording parameters, such as the desired signal type, recording schedule, duration/repetition interval, and selection of animal subjects are set up beforehand in Acq*Knowledge*. For memory implants, data may only be displayed after import. Acq*Knowledge* has specialized analysis routines that may be run on data acquired in real-time or imported from logs. Stellar Telemetry is a licensed feature of Acq*Knowledge* programmed onto the USB License Key. The number of *animal units* (allowable animal subjects controlled per experiment) is determined by the specific quantity of animal units purchased in the software license.

This chapter describes how Acq*Knowledge* software is used with the Stellar Telemetry System. For Access Point hardware driver installation and troubleshooting, see the Access Point Configuration Guide.

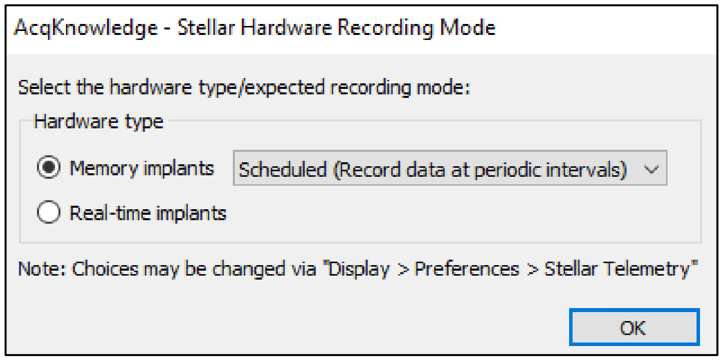
Before beginning: *It is important to note* that the Stellar Telemetry System may lose communication with the Access Point if the computer is allowed to go to sleep, resulting in a loss of data. To prevent this from occurring, disable the computer's sleep mode prior to conducting a Stellar experiment. To disable, go to "Control Panel" > "Power Options" and set the "Change when the computer sleeps" option to "Never." Similarly, Windows updates may cause the host computer to reboot, which may also result in lost data, so it is important to configure the system not to automatically install updates during acquisition. For scheduled sessions and memory implants, an automatic update should not interfere with logging but may make it more difficult to retrieve logged data. Furthermore, if a new recording schedule is started, logs will be erased even if they were not previously downloaded.

In addition to there being two types of implants, there are two basic types of receiver. Older receivers connect to the host computer using a single USB cable and can communicate only with memory-type implants. Universal receivers have two USB cables and can be used to communicate with either memory or real-time implants. When communicating with memory implants, the USB connection labeled “ULC” is not necessary and so only one USB cable should be used.

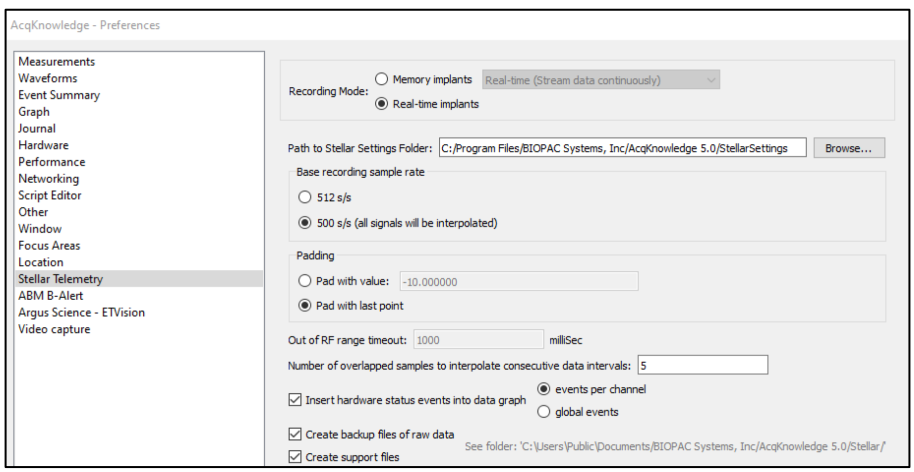
Stellar Preferences

With Acq*Knowledge* 5.0.8.1 and later, opening the Stellar Preferences pane offers options for setting the Recording Mode to **Memory implants** or **Real-time implants**. In previous releases, users could choose between Scheduled and Real-time modes for just memory implants. Those options are still available as dropdown menu items when the **Memory implants** radio button is selected.

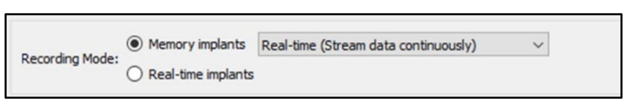
1. When launching Acq*Knowledge* for the first time, users will be prompted to select which type of hardware is being used and if using Memory implants, which type of memory implants.



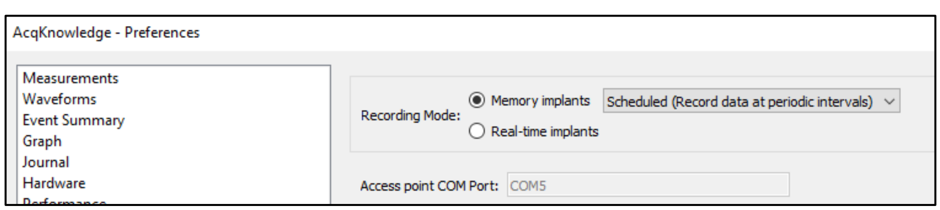
2. Stellar preferences (Real-time implants recording mode selected)



3. Memory implants with **Real-time mode** selected



4. Memory Implants with **Scheduled mode** selected



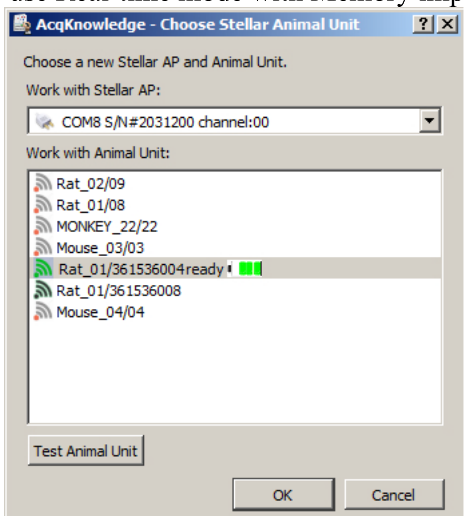
These mode options are only available for memory implants. The remaining options available will depend on which hardware/recording mode option is selected. Real-time mode does not have any additional options. If **Scheduled (Record data at periodic intervals)** is selected, a box for **Access point COM Port** will be shown displaying the com port for communication with the access point.

When the Real-time implants recording mode is selected (see example 1 above), several options become available. The **Path to Stellar folder** window displays where the software will look for information about the implants (setting files are provided by Stellar, not BIOPAC). With **Base recording sample rate** set to 512 s/s software will as much as possible preserve the data as acquired by the hardware. When set to 500 s/s interpolation will be used to resample all signals. This resampling produces rounder values for intersample intervals. **Padding** allows the user to set what data values Acq*Knowledge* will insert if the signals are lost. **Out of RF range timeout** indicates when padding will begin when no data are received. User can also set the number of overlapped samples to interpolate consecutive data intervals. Each interval is one (1) second. The number of overlapping samples is determined by taking N samples from the end of the previous one-second data period and N samples from the next one-second period. Acq*Knowledge* uses Barycentric Rational Interpolation to interpolate data. Check boxes also allow the user to insert hardware status events into data graph, create a backup file of raw data, and create support files.

Stellar preferences can always be changed or set up later in Acq*Knowledge*. If the Recording Mode is changed in Stellar Preferences, the modified setting will be applied the next time Acq*Knowledge* is launched.

Stellar Real-time Mode for memory implants

When Stellar Preferences are set to use Real-time mode with Memory implants, the following dialog appears:



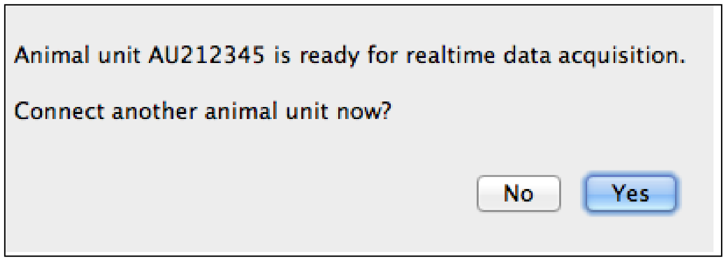
The following controls are available in Realtime mode setup:

Work with Stellar AP:	Lists all recognized access points and COM ports.
Work with Animal Unit:	Lists animal unit configuration files in the Stellar directory compatible with the selected access points.
Test Animal Unit	Conducts a test of Animal Unit to verify proper connection to the Access Point.

Access points should be configured prior to using Stellar units. Please refer to the Stellar Access Point Configuration document for this information.

- Animal units previously connected for Realtime data acquisition will not appear in the Animal unit list.
- Only one animal unit may be selected from the list at a time.

After selecting an animal unit from the list, the following prompt will be displayed:



As many animal units can be connected as are allowed by the Stellar license. Animal units are provided along with the Stellar license.

Configuration files for animal units must be stored within the Stellar configuration directory.

Data acquisitions for Realtime mode can be configured in Acq*Knowledge* by selecting Animal Unit > Set Up Data Acquisition, similar to using Acq*Knowledge* with other supported hardware.

Note that Stellar Animal Unit data acquisition settings are limited to the following items:

- Channels
- Length/Rate
- Event Marking
- Animal Unit Info

12 analog and 16 calculation channels are available for Stellar animal units. Digital channels are not supported.

As previously stated, Real-time data acquisition enables recording of Stellar data from memory implants directly into Acq*Knowledge* using the standard controls found in Acq*Knowledge* graphs. (Start/Stop button, standard toolbars, measurements, menus, etc.)

To set up and use Stellar in **Scheduled** mode, please proceed to the next section.

Stellar Experiment Interface in Acq*Knowledge*

The following section refers to the Stellar “Scheduled” mode preference setting. In Scheduled mode, experiments are set up in advance and the logged data downloaded into an Acq*Knowledge* graph when recording is complete.

Stellar experiments are configured in Acq*Knowledge* in a dedicated experiment setup window. Launch the experiment setup by selecting “New Stellar Experiment” or by choosing File > New > and selecting “Stellar Experiment” in the “Choose type” option dialog.

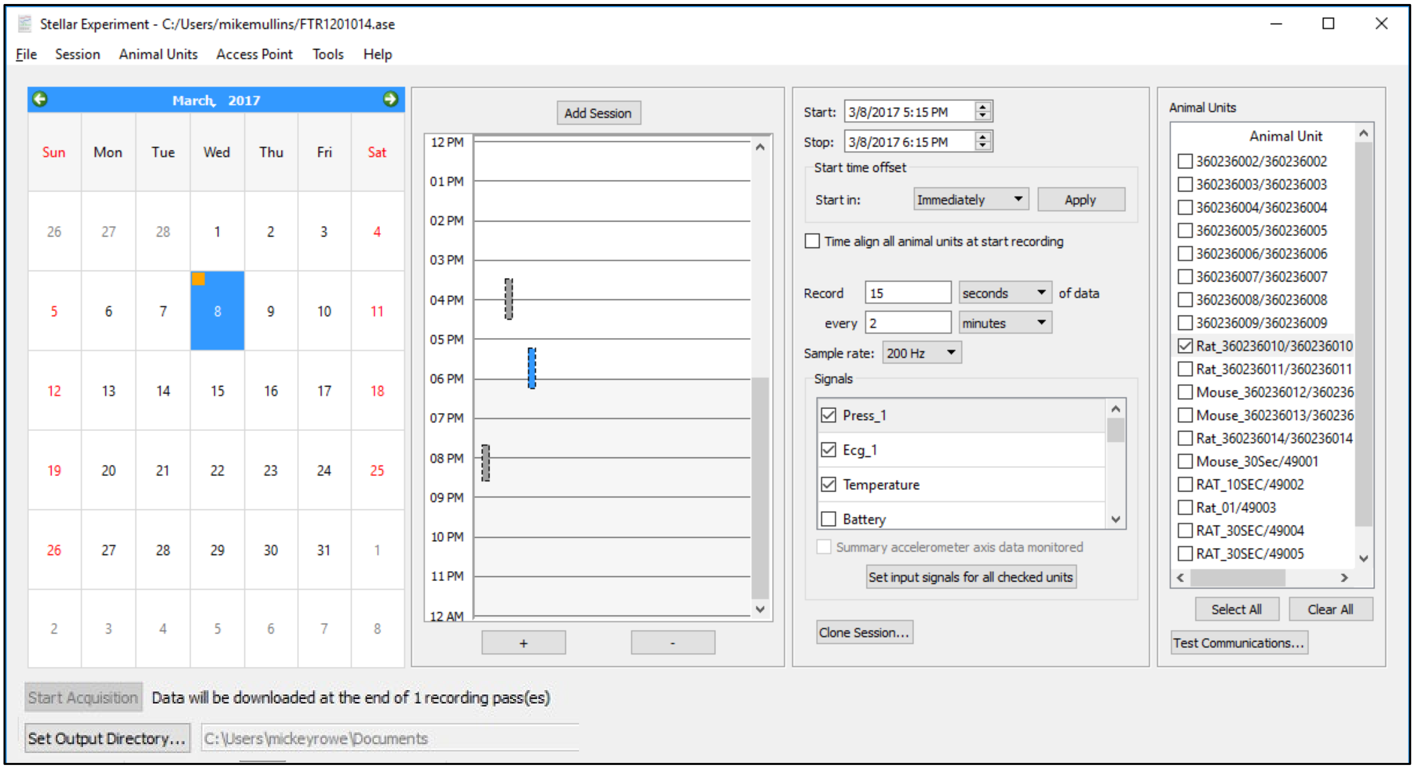
Key Terms:

Throughout this section the following terms will be used in reference to setting up a Stellar experiment:

Experiment: A session or set of sessions.

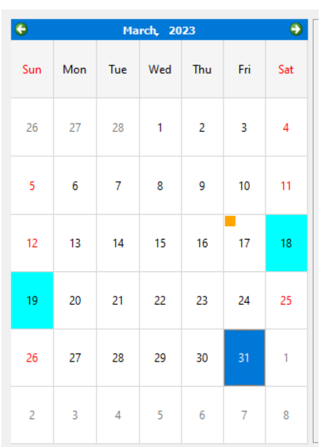
Session: A group of scheduled recording passes.

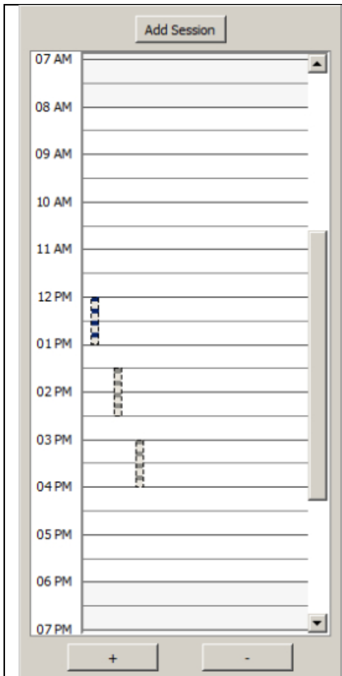
Recording pass: An acquisition of data including one or more signals from one or more animal units.



Stellar Experiment Setup Window

Description of the Stellar Experiment Window Controls

<table>
<tr><th>CONTROL</th><th>DESCRIPTION</th></tr>
<tr><td>Visual Calendar view
</td><td>This is the calendar view in the left pane. The interactive calendar indicates date/time of scheduled logging sessions. The beginning of scheduled sessions are highlighted with orange squares. If a session spans multiple days, additional days are shaded cyan. Dark blue indicates a day that is selected for scheduling. Double-clicking a date allows the user to define a new session. If a session has already occurred, double-clicking the date launches and displays AcqKnowledge graph files containing data acquired during that date's session. The month display can be advanced or regressed by using the arrows to the right and left of the current month display or by clicking on the month and selecting from the list (right).
</td></tr>
<tr><td>Graphical Day view</td><td>Scrollable 24-hour representation of the selected calendar day. Vertical bars represent scheduled session intervals, with one “session bar” per scheduled session. Double-clicking an empty time slot creates a new 60-minute session comprising four recording passes (see ‘Session Details Controls’ for information about editing the recording passes). Single-click an existing session bar to select and highlight it. While a session is running, the active session bar becomes shaded in black, indicating elapsed time of the session in progress. The session start/end time can be adjusted to the nearest 15-minute interval by dragging the edge of a selected bar upward or downward. For more precise scheduling, adjust the start/end time using the navigation arrows in the Start and Stop fields, to the right of the Day View.
Graphical Day View Buttons:</td></tr>
</table>

<table>
<tr>
<td></td>
<td>
Use the “Add Session” button to quickly add a session to the schedule. (This performs the same function as double clicking on a date in the Visual Calendar as described above.)

Graphical Day View Contextual Menu:

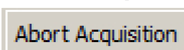
Graphical Day View supports the following contextual menu items. To display the contextual menu, right-click a session bar in the Day View.

- **Delete:** Removes the selected session
- **Clone**: Shortcut to the “Clone Session” setup dialog (see below)
- **Delete cloned sessions:** Removes cloned sessions.

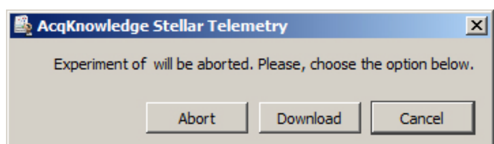
Zoom Controls:

Use the “+” and “-“ buttons to zoom in or out on the graphical day view grid for optimal viewing of scheduled sessions.
</td>
</tr>
<tr>
<td>
Start Acquisition

Abort Acquisition


</td>
<td>
Stellar data logging will begin with the next scheduled session. Scheduled sessions do not start automatically. They must first be initiated using the “Start Acquisition” button.

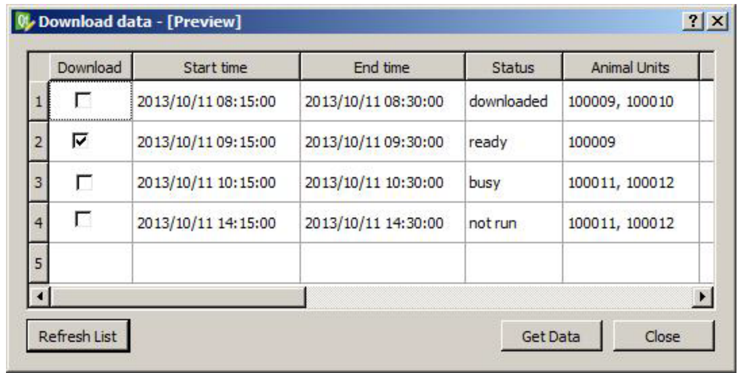
During an active logging session, an “Abort Acquisition” button becomes available, which enables the session to be ended prematurely if necessary. The session can then be aborted (cancelled) or the available data downloaded (see below).



</td>
</tr>
</table>

Download Data button

Allows sessions to be downloaded manually at any time. This button is only visible while a session is in progress.



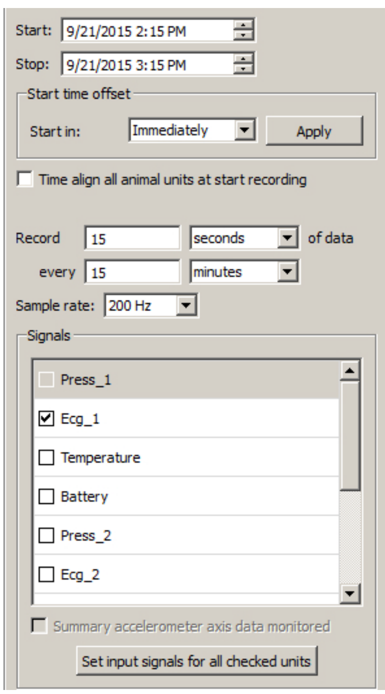
The manual download window consists of the following elements and controls:

Session List: This list displays all available sessions, status, scheduled start and stop times and animal units. The "Download" checkbox selects a session for manual download.

Refresh List: Updates status of listed sessions.

Get Data: Activates downloading process of selected sessions.

Session Details Controls



Sets specific scheduling parameters for the session.

Start: Displays and adjusts the start time of the scheduled session.

Stop: Displays and adjusts the stop time of the scheduled session.

Start time offset – Start in: Allows the session to be automatically scheduled to start two minutes (or more) from the present time. Clicking Apply schedules the selected time offset.

Time align all animal units: All animal unit sesions will start at the same time. The start time based on the "Start" value plus the sum of the RF wake-up times for all animal units in the session. The wake-up time for a given animal unit is determined by the second-to-last digit of its serial number as follows: 5 = 1 seconds, 6 = 5 seconds, 7 = 10 seconds, 8 = 20 seconds, 9 = 30 seconds.

Record – of data: Sets the duration of the data recording.

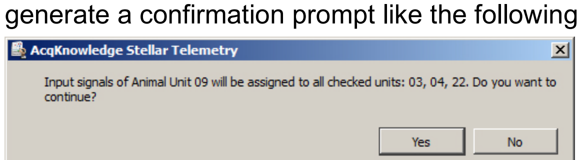
every: Sets the repetition interval of scheduled recordings.

Sample rate: Sets the data acquisition rate in samples per second (Hz). Available sample rates are 100, 200, 500 or 1000 Hz, the default being 200 Hz.

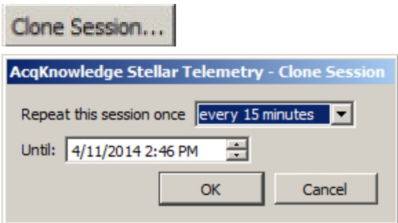
Signals: Selects the physiological signals to acquire during the session, with option to show or hide the continuous battery voltage level. Available signals are Blood Pressure (2), ECG (2), Temperature and Accelerometer (X, Y, & Z axes).

Summary accelerometer axis data monitored: Checking this option combines the three axes accelerometer data into a single integrated accelerometer signal.

Set input signals for all checked units: Use this option to apply the same input channels to all selected animal units. Signals not supported by a particular animal unit will be ignored. Using this option will generate a confirmation prompt like the following:



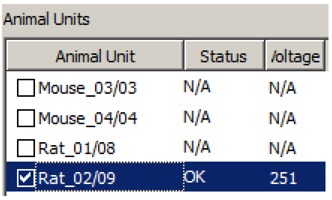
Clone Session button



Configure multiple instances of a given session without manually repeating the session setup. This is useful when an experiment extends over many weeks or months and the sessions need to be frequently repeated.

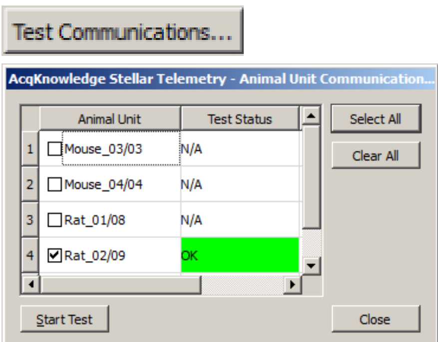
Selecting “Clone Session” launches the following setup dialog, allowing selection of session repetition intervals and duration.

Animal Units



An “Animal Unit” refers to a specific Stellar transmitter implanted in an animal subject. This option controls which available animal units are to be included in the session. The displayed information includes unit serial number, animal ID, and last known status. Specific Access Point and Animal Unit signal strengths are also indicated under the **AP RSSI** and **AU RSSI** columns (not depicted). Ranges of 0-10 indicate poor signal strength, 10-15 fair, 15-20 good, and +20 excellent.

Test Communications button



“Pings” the animal units and provides feedback on the communication status. “OK” indicates a successful communication. “Error” indicates a failed communication with an animal unit. Specific Access Point and Animal Unit signal strengths are also indicated under the **AP RSSI** and **AU RSSI** columns (not depicted). Ranges of 0-10 indicate poor signal strength, 10-15 fair, 15-20 good, and +20 excellent.

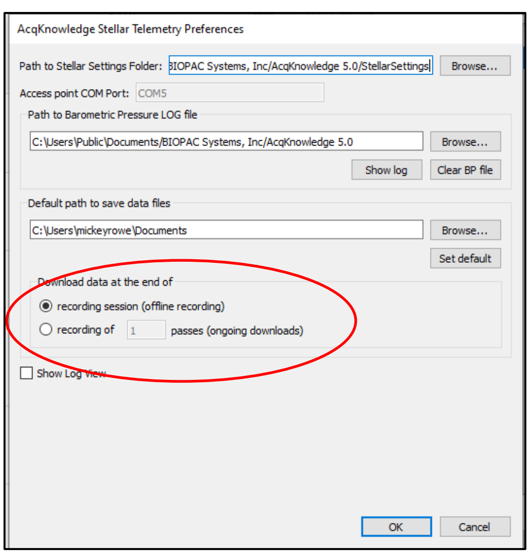
Possible causes of communication failure:

- Animal unit may be out of radio range of the access point.
- Animal unit may be in use for a recording by another access point.
- Animal unit may be frozen and require a magnetic reset.
- Animal Unit battery may be dead (in which case the unit must be replaced).

Automatically download data at end of

- recording session (offline recording)

- recording of x passes (ongoing downloads)



These **Preferences** are managed under the **Tools** menu (see below).

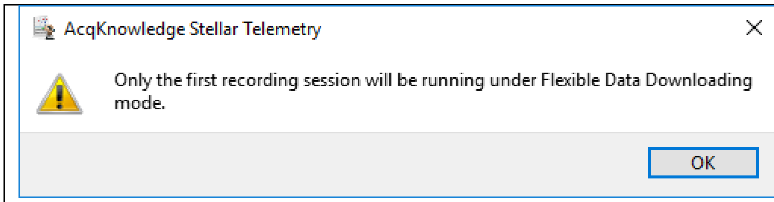
If “recording session (offline recording)” is selected: After the final session is completed, all data is automatically downloaded from active animal units to the output directory. The recording passes will occur as scheduled for each session in the experiment.

NOTE: If this option is chosen, the experiment must contain only one session. If more than one session is included in the experiment, only the session with the earliest start time will occur. Other sessions will be ignored.

If “recording of x passes (ongoing downloads)” is selected: The data will automatically be downloaded into the *.acq graph following completion of the number of recording passes entered in the “passes (flexible schedule) field. The remaining passes will be downloaded at the end of the full session.

NOTE: Using this option may break the scheduled timing because new data cannot be acquired by an implant while older data are being downloaded from that implant.

If more than one recording session is requested in the flexible schedule field, the following dialog will be displayed once following application launch:

<table>
<tr><td colspan="2">

During a flexible schedule download, a Flexible Data Downloading Control Panel window is displayed during the recording and download process. See page 614 for an overview of this window.</td></tr>
<tr><td>Set Output Directory button</td><td>Chooses directory where AcqKnowledge graphs containing downloaded data will be stored. If undefined, the default path is the user's Documents directory.</td></tr>
</table>

Further Information about Flexible Data Download

- Flexible Data Download allows users to access portions of data while a recording experiment is in progress. (For example, a recording session is scheduled for a 24 hour duration, but the user would like to download portions of data without waiting until the end of experiment.)
- The recording session may include multiple animal units and various input signals per unit.
- All signals from all animal units will be combined into a single graph file – one graph channel per signal.
- Data from multiple recording passes are added to the graph file as appended segments with appropriate labels and timestamps. The downloading process does not interfere with the session in progress.
- If there is a conflict between multiple animal units while downloading, Acq*Knowledge* will queue the data and attempt the download later.
- Transformations/Analysis operations not affecting the channel length are allowed.
- Due to hardware limitations, Acq*Knowledge* downloads data from one animal unit at a time. (This will temporarily cause a target graph file to display channels of different lengths.)
- All channel lengths in the *.acq file will be of the same duration after Acq*Knowledge* downloads all data from all animal units at the completion of the experiment.

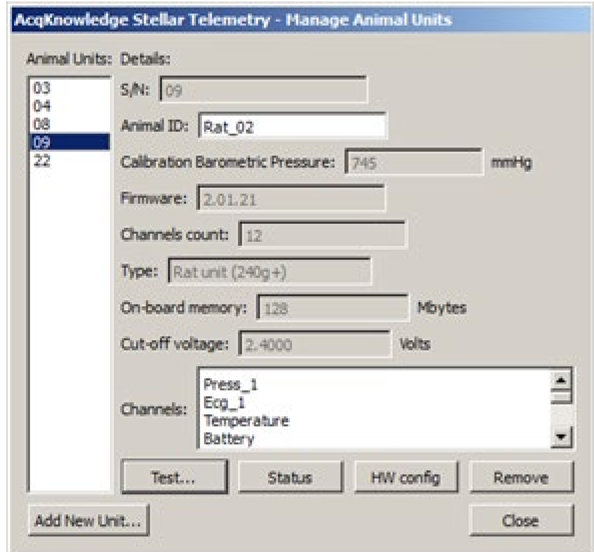
Flexible Data Download Limitations

Flexible Data Downloading may not be available at times due to:

- A single communication channel may be in use by another animal unit
- Large data downloads can be a long process and may delay the next recording pass
- Due to hardware limitations, Acq*Knowledge* downloads data from only one unit at a time.

Stellar-specific Setup Window Menus

File Menu	
> New Experiment	Creates a new experiment window.
> Open Experiment...	Displays a “File > Open” dialog for opening a Stellar experiment file from disk.
> Open Experiment for downloading	Opens a Stellar experiment file from disk (*.ase format) and activates manual data downloading based on the settings stored with experiment file.
> Save Experiment	Saves any changes to the current experiment.
> Save Experiment As	Displays a “Save As” dialog allowing the experiment to be saved to a new file on disk.
> Close	Closes the current experiment window, prompting to save any changes to the experiment.
> Quit	Exits Acq*Knowledge*.
Session Menu	
> New Session	Adds a new session to an experiment on the date selected in the Calendar view.
> Clone...	Displays dialog for cloning the selected session. (Performs same function as “Clone Session” button.)
> Delete	Deletes a selected session after a confirmation prompt. Disabled if no session is selected.
> Delete cloned sessions	Deletes a selected cloned session after a confirmation prompt. Disabled if no cloned session is selected.
> Start Acquisition	Reschedules a selected session to start immediately. Dimmed if an acquisition in progress or no session is selected.
Animal Units Menu	
> Add New Animal Units...	The Stellar license includes the purchased animal unit configuration files. To add an animal unit: 1. Choose “Add New Animal Units.” 2. Navigate to the file location and select the file(s) with a *.set extension. 3. Click “Open.”
> Test Communications...	Performs the same function as the “Test Communications” button in the setup window.
> Manage Animal Units...	Use to select or modify the animal unit configuration.



Animal Units: Lists available animal units

Details > S/N: Displays serial number of currently selected unit.

Animal ID: Editable field for displaying additional information about animal unit, name, etc.

Calibration Barometric Pressure: Indicates barometric pressure at the time the animal unit was calibrated.

Firmware: Displays animal unit firmware version.

Channels count: Displays unit's available input channels.

Type: Displays animal unit information.

On-board memory: Displays installed memory of animal unit.

Cut-off voltage: Displays lowest battery voltage allowable to run data acquisition.

Channels: Displays list of animal unit input channels.

Test…: Performs short (2-sec) test acquisition of the selected unit

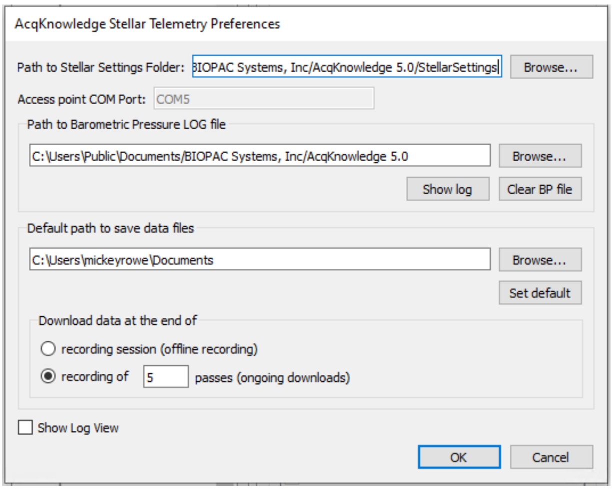
Status: Displays status information of the selected animal unit. This option is only available between recordings. Status results are not returned during an active recording.

HW config: Displays hardware configuration of selected unit. This option is only available between recordings.

Remove: Removes selected animal unit from the list.

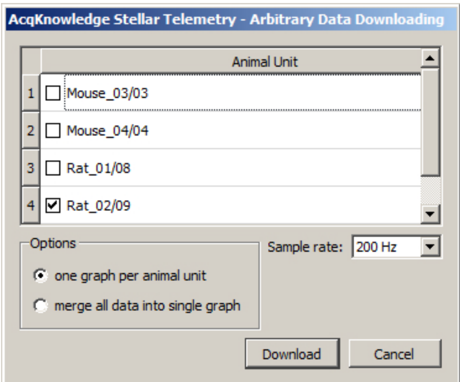
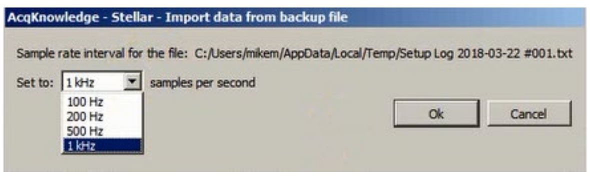
Add New Unit: Performs same function as "Add New Animal Units" in the Animal Units menu.

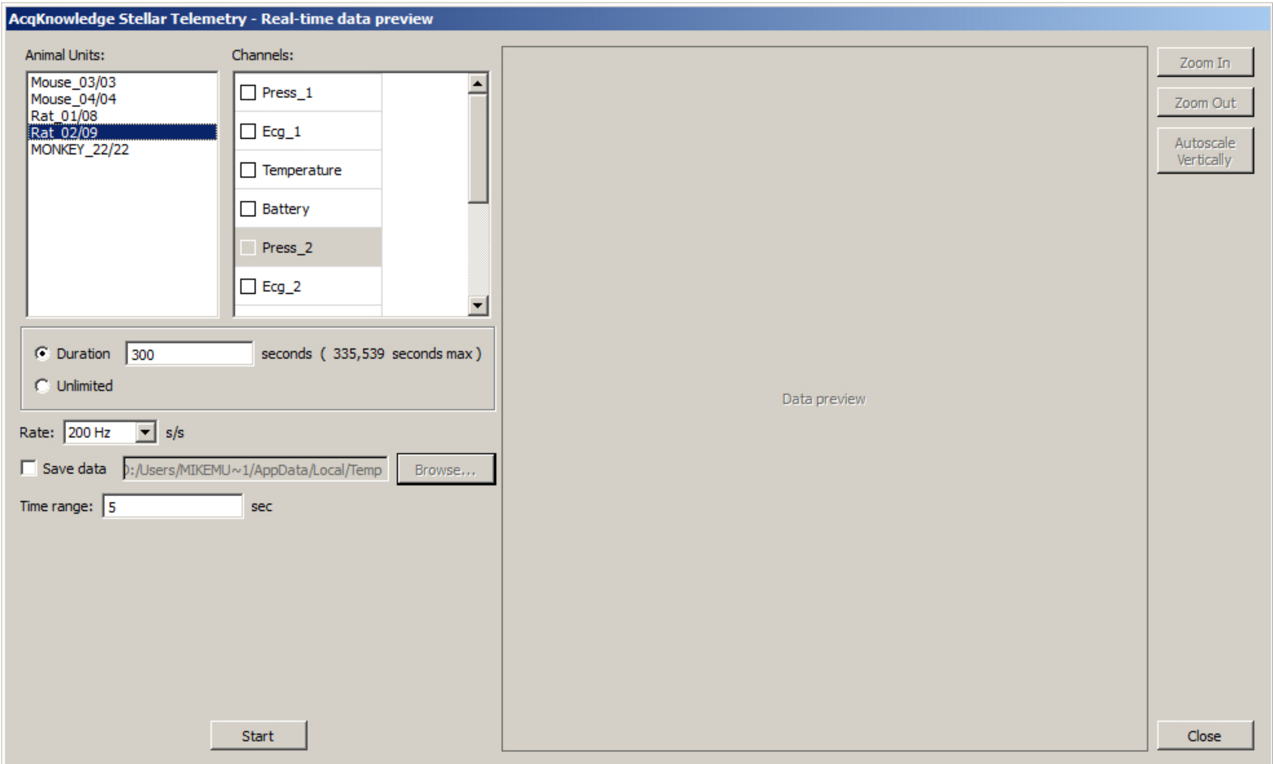
Access Point Menu	
> Get Info...	Displays current access point information, including serial number, communication status, and current barometric pressure.
> Change Access Point...	**NOTE:** This functionality is not currently supported. Only one access point may be used with the software at a time.

Tools Menu	
> Stellar Preferences  	Set the following important parameters in the Stellar Preferences dialog: **Path to Stellar Setting Folder** – Displays the path location of Stellar access point and animal units setup files. **Access point COM port** – Identifies COM port unit is set to. **Browse** – Selects the path to location of Stellar access point and animal units setup files. **Path to Barometric Pressure Log file** – Displays the path location of the "Stellar_BaroPressure.log" file. Browse – Selects the path to location of the "Stellar_BaroPressure.log" file. **Show Log** – Displays the Barometric Pressure LOG file in a pop-up window with two columns: Date/Time and BP Value. The LOG information can be sorted by clicking the header. **Clear BP file** – Used to delete the Barometric Pressure LOG file. **Default path to save data files** – Displays the default location of Stellar data files. **Browse** – Opens a browse window for setting an alternate data file path. **Set default** – Resets the filepath to the original default file path. (User's Documents folder) **Download data at the end of** – User can choose either "recording session (offline recording)" or "recording of x passes (ongoing downloads." If "**recording session**" is selected, all data automatically downloads from active animal units to the output directory after the final session is completed. The recording passes will occur as scheduled for each session in the experiment. If this option is chosen, the experiment must contain only one session. If "**recording of x passes**" is selected: The data will automatically be downloaded into the *.acq graph following completion of the number of recording passes entered in the "passes (flexible schedule) field. The remaining passes will be downloaded at the end of the full session. NOTE: This option may break scheduled timing. **Show Log View** – Displays the Journal log view by default for new experiments to show real-time experiment information. (This may also be controlled via the Options menu in the Scheduler window.)
> Show/Hide Log (Journal)	When "Show" is selected, real-time experiment status information is displayed at the bottom of the Scheduler window.

	This field resembles the Acq*Knowledge* Journal but is not user editable. (See below example.)

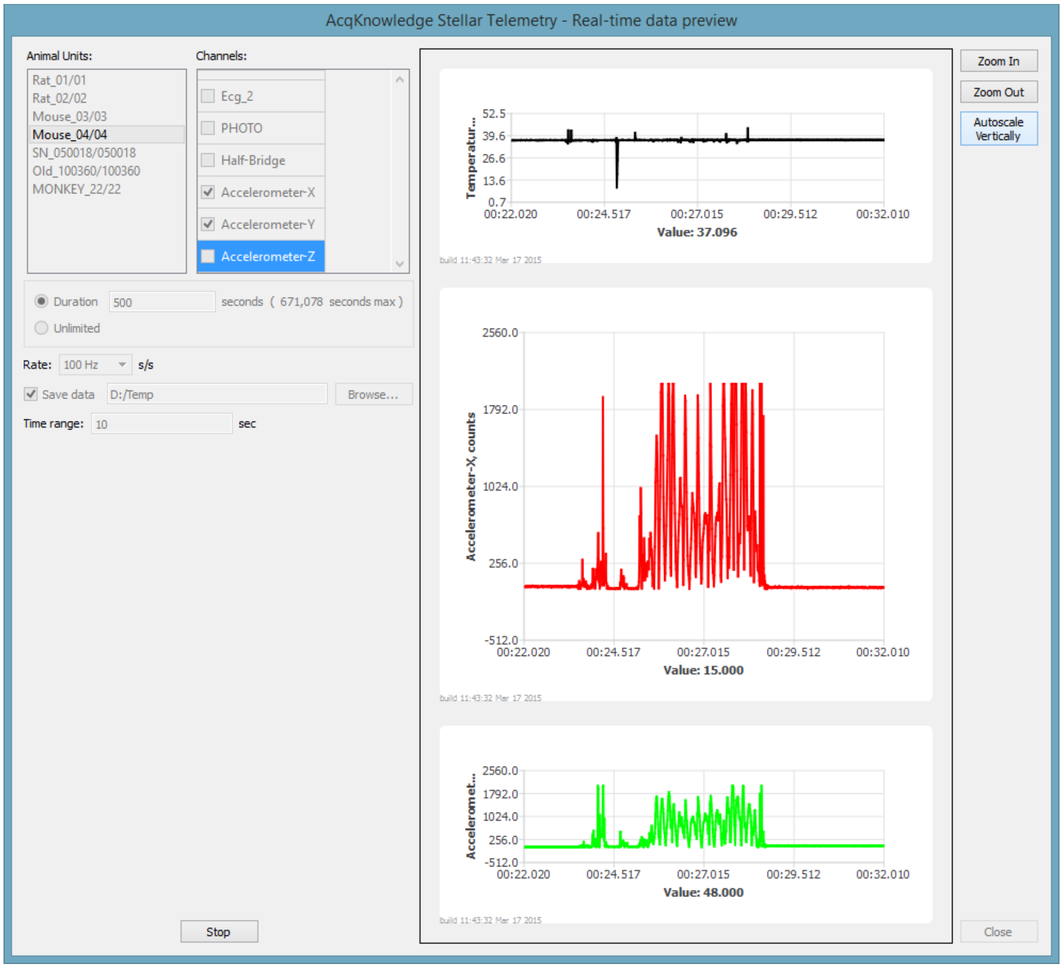
```
2014/04/09 14:35:01 ==================================
2014/04/09 14:35:01 STARTING. Session with start time 2014/04/09 14:35:00, end time 2014/04/09 14:36:00:
2014/04/09 14:35:01 STARTING. On AU = 000020. AP = FTR1201014. Rate = 200, Blocks = 3. BP = 1, T = 0, ECG = 0, Battery = 0. Interval: 00:15:00
2014/04/09 14:35:10 STARTED. Session with start time 2014/04/09 14:35:00, end time 2014/04/09 14:36:00. Animal units: 000020.
2014/04/09 14:35:10 WAITING. Session to complete at 2014/04/09 14:36:00
2014/04/09 14:36:09 GET DATA. On AU = 000020. AP = FTR1201014. Rate = 200, Blocks = 3. BP = 1, T = 0, ECG = 0, Battery = 0. Max Samples: 3072
2014/04/09 14:36:14 COMPLETED. Session with start time 2014/04/09 14:35:00, end time 2014/04/09 14:36:00. Animal Units: 000020.
2014/04/09 14:36:14 ==================================
2014/04/09 14:36:15 SAVED. Session with start time 2014/04/09 14:35:00 and end time 2014/04/09 14:36:00 saved to file 'D:\Users\mikemullins\Documents
2014/04/09 14:36:15 COMPLETED. Stellar experiment completed successfully.
```

> Print Log	Opens a dialog for printing contents (or a selection) of the log and for setting the desired print parameters.
> Copy Settings to Clipboard	Copies experiment settings to clipboard in text format.
> Import data from animal units  	Downloads data from selected animal units into an Acq*Knowledge* graph. 2. Select the animal units for data import via the Animal Unit checkboxes. 3. Select the option to create separate Acq*Knowledge* graphs for each selected animal unit or to merge all animal units into the same graph. 4. Choose the sample rate at which the animal data unit was acquired. This information is critical for accurate display of the imported data. 5. Click “Download.”
> Import data from backup file  	To protect the animal unit data, Acq*Knowledge* creates a raw data backup file every time data is downloaded from the selected animal unit(s). Backup files are located at pre-defined folder titled “C:\Users\Public\Documents\BIOPAC Systems, Inc\AcqKnowledge 5.0\Stellar .” Backup file names and their subfolder names include the recording session start date and time (e.g., “Session_2023_09_18_16_40_00”). Use this menu item to select backup file(s) and import the data into Acq*Knowledge*. The import options allow one of four user-defined sample rates to be chosen for the imported data. Supported sample rates are: 100 Hz, 200 Hz, 500 Hz, and 1 kHz.
> Real time data preview	This option allows for the previewing of plotted data prior to initiating the actual experiment and is helpful for configuring the real time data recording and plotting. Parameters such as Animal Unit, input signals, sample rate, and duration can be modified and the result plotted in real time after clicking the “Start” button. Data preview graphs can be autoscaled vertically while in progress for enhanced data display. See the following page for a full explanation of the Real time data preview options.



Real time data preview setup options

Animal Units	Displays the animal units available for preview. Only one animal unit at a time may be selected.
Channels	Displays the channels available for preview. Multiple channels may be selected.
Duration	Sets the length of preview in seconds.
Unlimited	Choosing this option allows the preview to run until manually stopped.
Rate	Use this option to select the sample rate for the data display. Sample rates of 100, 200, 500 and 1000 s/s are supported.
Save data	Use this option to choose a path to save the preview data to a *.txt file format. This option is available when the duration is set to seconds. It is not supported for unlimited data previews.
Time range	Use this option to set a horizontal scale range for the data preview display. (Horizontal autoscaling is not supported in the preview graph.)
Start	Toggles between Start/Stop of data preview. When clicking Start/Stop it may take a few seconds for the application to respond before starting or stopping the preview. When this occurs, a “Please wait” dialog will appear. Avoid repeated mouse clicking within the application window during this time or AcqKnowledge may become temporarily unresponsive.

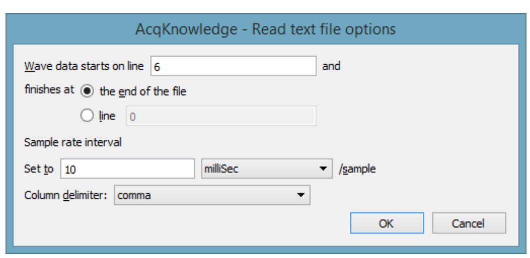


Real time data preview in progress after clicking "Start"

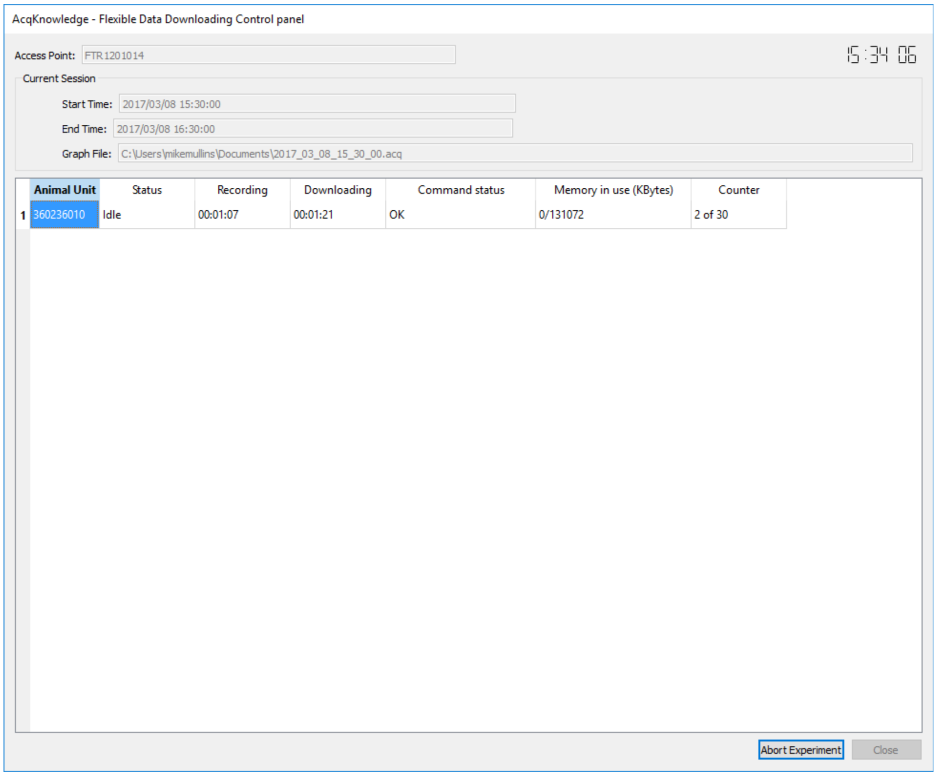
Animal units and Channels selected for Real time data preview are displayed as in a moving graphical format while the preview is in progress. The preview signals can be autoscaled vertically but not horizontally, so it is important to set the horizontal display in the "Time range" field prior to clicking "Start." Enhance the preview vertical display using the "Zoom In" or "Zoom Out" buttons. (2x zoom is supported.)

Real time data previews set to duration of seconds can be saved in *.txt file format to a user-defined location. These saved files can be reopened in Acq*Knowledge* using the following steps:

1. File > Open and choose "*.txt, *.csv" as the files of type.
2. Navigate to the saved preview *.txt file and open using the following import settings:



Flexible Data Download Control Panel



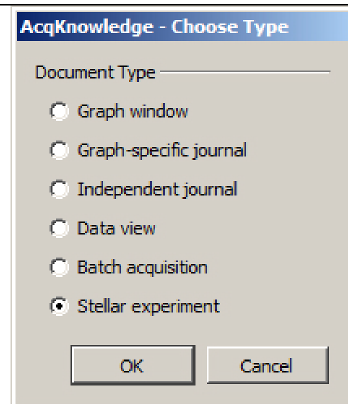
When the flexible schedule download option is selected, the above control panel is displayed while the recordings and downloads are in progress. In addition to Access Point, Start/End Time, Graph Filepath and clock time (upper right), the following parameters are displayed:

Animal Unit	Displays the number of animal unit(s) used in the recording and downloading process.
Status	Displays whether animal unit is recording or in idle status for downloading.
Recording	If animal unit is in Recording state, this shows elapsed time of recording. If animal unit is in Downloading state, this shows estimated time until next recording pass.
Downloading	If animal unit is in Downloading state, this shows elapsed time of download. If animal unit is in Recording state, this shows estimated time to next download.
Command Status	Shows status of last command sent to animal unit. OK – command successfully executed. Error – command failed. Busy – command could not be sent because communication channel is busy.
Memory in use (Kbytes)	Displays estimated memory usage of animal unit.
Counter	Displays number of completed and requested recording passes for the current recording session.
Abort Experiment	Cancels all activity and ends experiment.
Close	Closes control panel window. Dimmed while recording session is in progress.

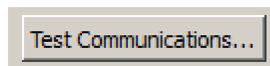
Running a Scheduled Stellar Experiment with memory implants

The example below is a guide to scheduling and conducting a Stellar experiment. These steps assume that the Stellar hardware is set up correctly, and successful hardware connection between the Access Point and the Animal Unit has been established. For hardware setup instructions, see the “Access Point Configuration and Troubleshooting Guide.” While these instructions describe the additional of a single session, **multiple session may be added**.

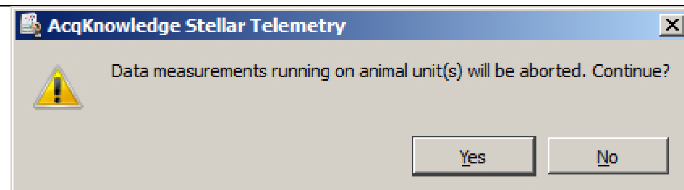
1. In Acq*Knowledge*, launch a new experiment. (File > New > Stellar Experiment). This will launch the Calendar window. A “Create new stellar telemetry experiment” option is also available in the Acq*Knowledge* Startup window.



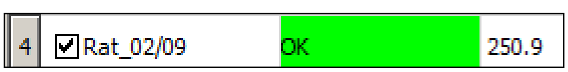
2. **Prior to session setup**, it is important to test the Animal Unit communications status.
3. Click “Test Communications.”

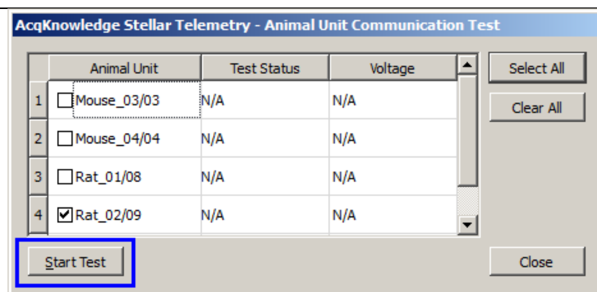


4. Click “Yes” to the resulting dialog to continue.

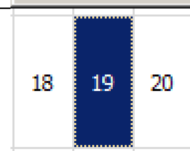


5. Enable the check boxes corresponding to the Animal Units to be used during the session and click “Start Test.”
   - A successful connection is confirmed by a Test Status of “OK.”

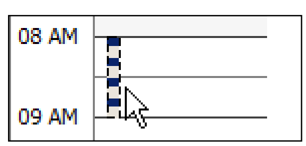


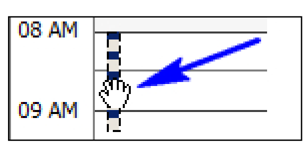


6. The Calendar will default to the current date. If the session is to be scheduled for a future date, click on the desired date to highlight.

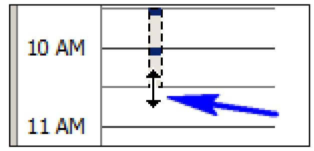


7. Choose a time for the experiment to start by double-clicking in the Graphical Day View region or by clicking the “Add Session” button. This highlights a one-hour time period with a series of squares called a “session bar.” Each black and white square represents a 15-minute time block.
   a. Hold left mouse button down to drag the highlighted session bar to a different location on the time scale. The bar can be dragged up or down in



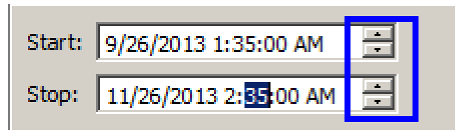


15-minute increments or greater.

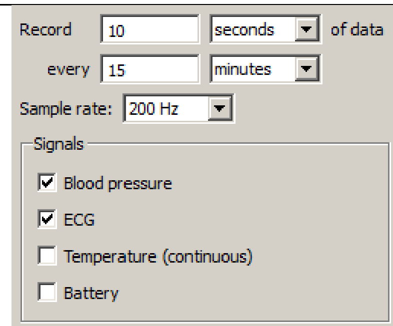


b. Position the left mouse button over the session bar border and drag the arrow cursor up or down to adjust the session length. 15-minute increments or greater are supported.

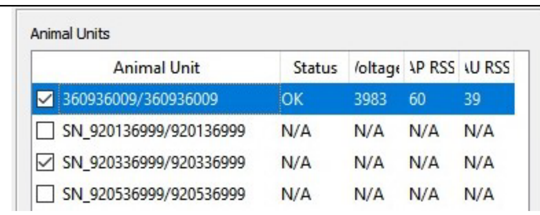
c. Conversely, the session length can be more precisely modified by using the spinners in the "Start/Stop" fields.



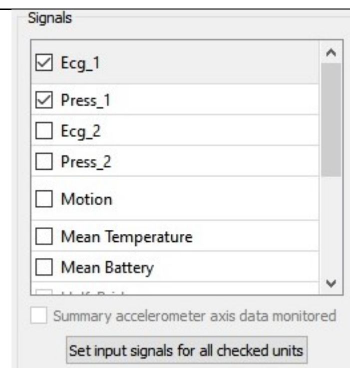
8. Select the recording length, repetition, sample rate, and the signal types to be acquired.



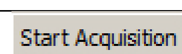
9. Select Animal Units to be included in the session by checking the corresponding boxes.



10. For each Animal Unit included, select the signals to be acquired. To select a signal, click the Animal Unit's SN ID to highlight it and then select the signal from the list in the Signals menu on the left. If all animal units will use the same set of signals, click the "Set input signals for all checked units" button after selecing the signals for one unit.



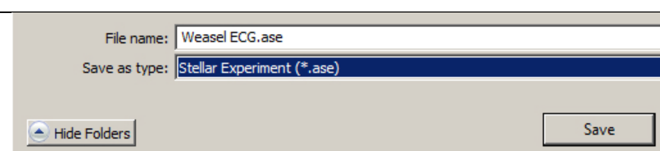
11. Once the recording parameters and Animal Units are selected for the session, click "Start Acquisition."

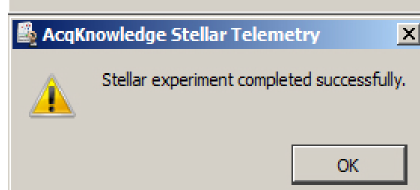


12. Choose a file name for the experiment.

a. The session will start at the scheduled time and will be downloaded and displayed in an Acq*Knowledge* graph according to your preference settings.

NOTE: If Stellar preferences are set to download data on a flexible schedule, the experiment must contain only one session. If more than one session is included, only the session with the earliest start time will occur. Other sessions will be ignored.

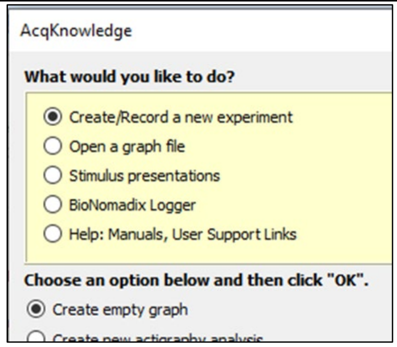




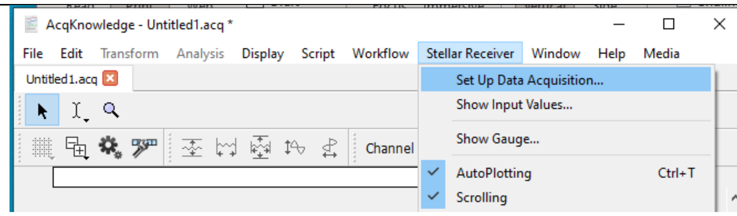
Acquiring Data with Real-time Implants

With Acq*Knowledge* 5.0.8.1 and later, users can acquire data from multiple animal units in real time using Stellar's real-time implants and Universal Receiver.

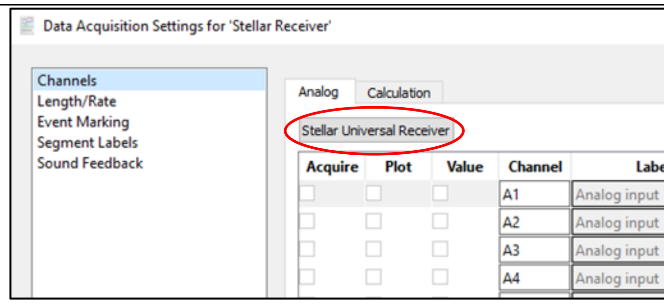
1. Launch Acq*Knowledge* and select "**Create/Record a new experiment**" from the "What would you like to do?" menu and "**Create empty graph**" from the options menu. Click **OK**.



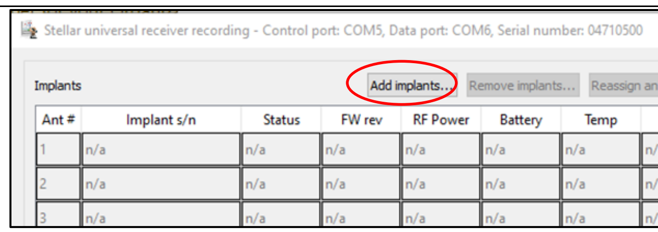
2. Click the "Stellar Receiver" menu item and choose "Set Up Data Acquisition" from the pull-down menu.



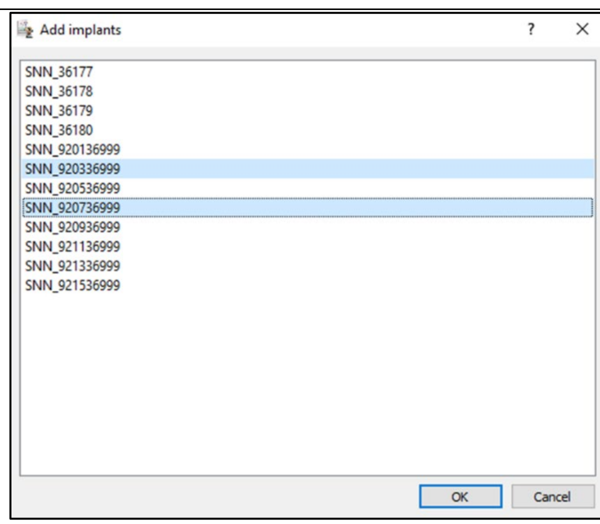
3. The first step is to select and initialize implants/transmitters from which data will be acquired. Highlight "Channels" and click the **Stellar Universal Receiver** button.



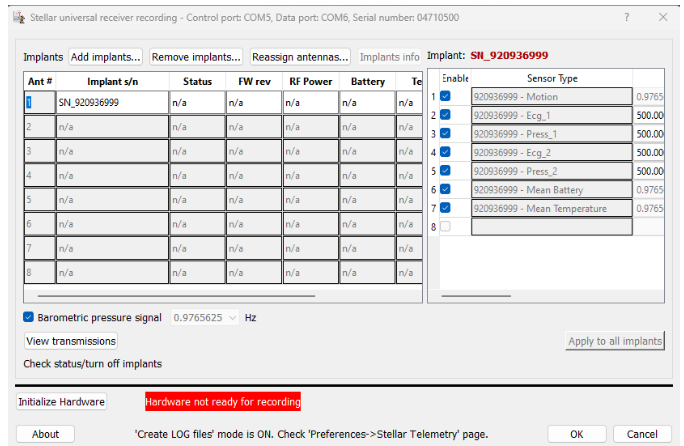
4. Click the **Add Implants** button.



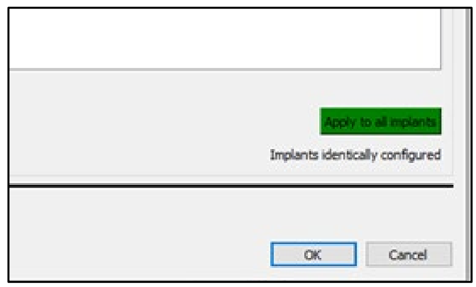
5. This will open a list of available implant units. Select the units to record from and click **OK**.



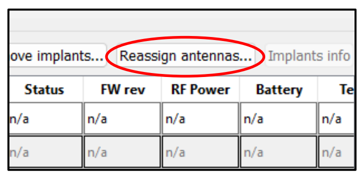
6. Select/de-select signals to be acquired via “Enable” checkboxes. Note that selecting an implant on the left determines which implant you are selecting signals for on the right.

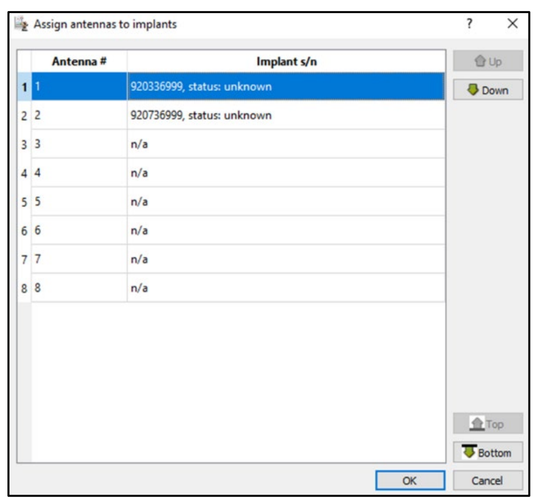


7. To acquire the same set of signals for all animal units, click **Apply to all implants** in the lower right corner. Click this *after* selecting all desired signals unless it is intended that additional signals be acquired for the currently selected animal unit only.

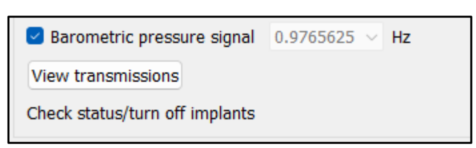


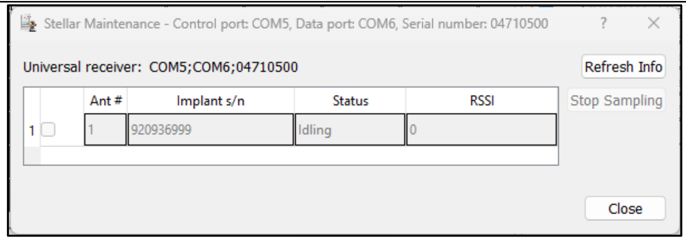
8. Antennas used for each implant may be switched by clicking the **Reassign antennas**… button. To do this, highlight an implant by clicking in Implant s/n column and move it using the **Up**, **Down**, **Top** and **Bottom** buttons on the right to reassign it to a new antenna.



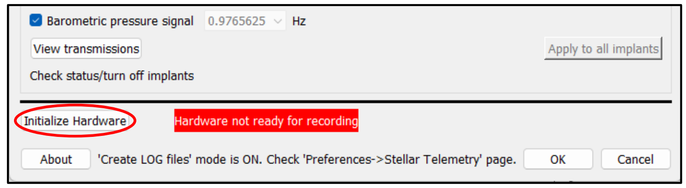


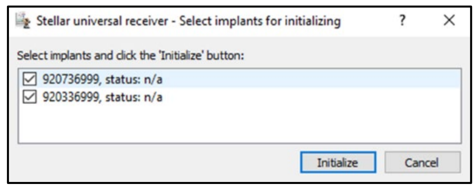
9. Optionally, click the **View transmissions** button to see which implants are transmitting signals to the Universal Receiver.

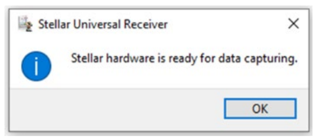




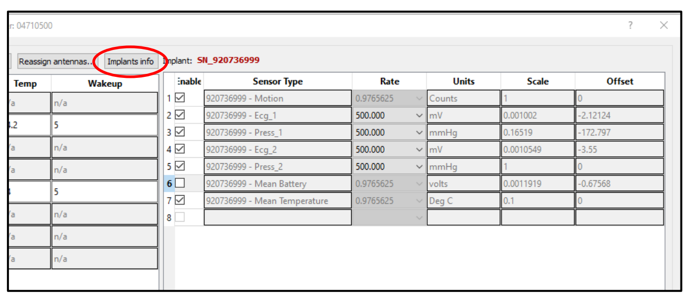
10. To prepare the implants to send requested signals, click the **Initialize Hardware** button near the bottom left of the Universal Receiver window. This will open window labelled "Select implants for initializing." Use the checkboxes to select the corresponding implant/transmitter and click **Initialize**.
 This will open an information dialog box that will list the actions the software is taking and the status/results of these steps. A progress bar at the bottom of the dialog box will show overall progress of the initialization process. Once the initialization process is completed, another dialog box will open stating that the hardware is ready for data capture. Click **OK** and **Close** to proceed.





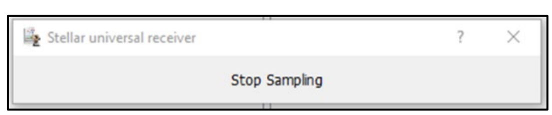


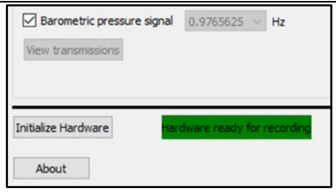
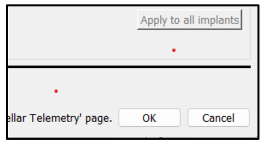
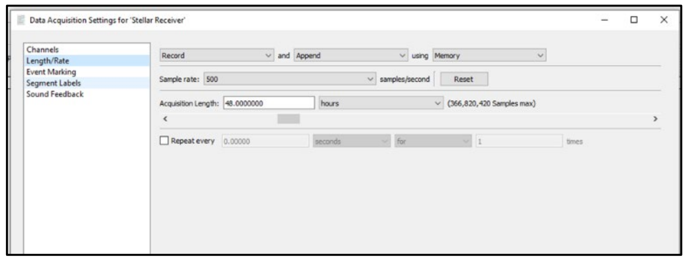
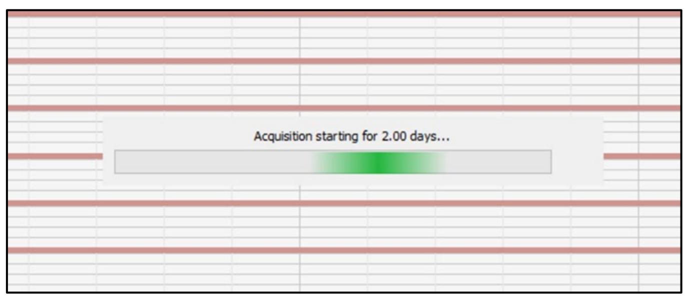
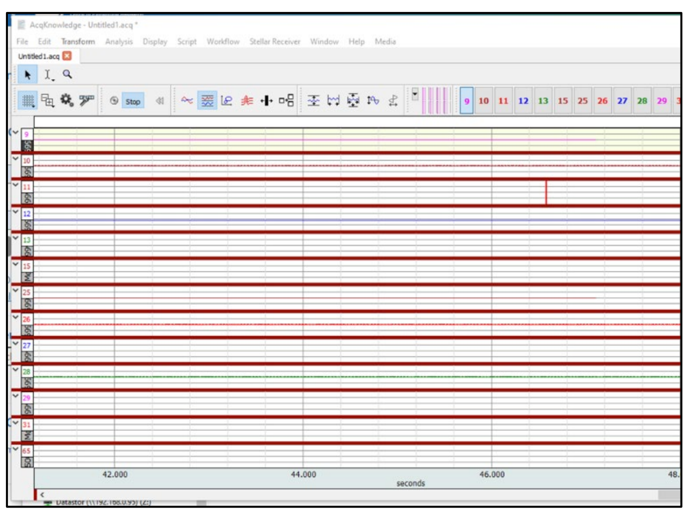
11. Optionally, click the **Implants Info** button to update the table at the left for each initialized implant.



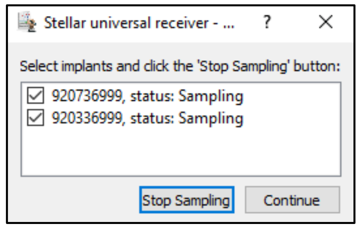
12. Clicking the **About** button displays information about the software used to communicate with the Stellar Universal Receiver.

13. Antennas can be reassigned; however, sampling must be stopped. Sampling will stop when the user selects **Reassign Antennas** and clicks **OK**. The follow message will display.

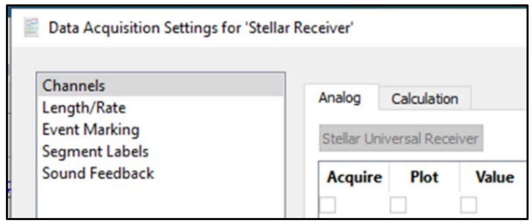


Once sampling has stopped, the implants are no longer acquiring data. To restart the process, click **Initialize Hardware** again. Note: Initializing hardware will disable the **View Transmissions** button.	
14. Click **OK** to close the Stellar receiver setup window.	
15. Now that the implants have been selected and initialized, other functions can be carried out. **Length/Rate**, **Event Marking**, **Segment Labels**, and **Sound Feedback** function as they do for MP devices. Once these settings have been selected for data acquisition, click **Close** to exit the Settings window. Note: The default acquisition length for Stellar real-time implants is two days.	
16. Click **Start** to begin acquisition. There will be a brief delay as the software communicates with the transmitter and receiver before data acquisition begins.	
17. Channel numbers displayed reflect the antennas/signals selected. For example: Channels 1-8 would display signals from Antenna 1, 9-16 for Antenna 2, etc.	

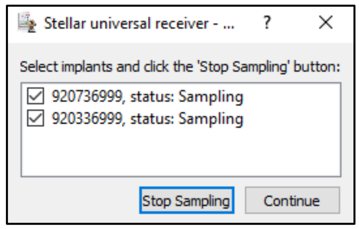
18. Clicking the **Stop** button stops recording and opens the "Stop Sampling" menu box. *At this point the implants are still sending data.* To stop an implant from sampling data, select the implant's corresponding check box and click **Stop Sampling**.



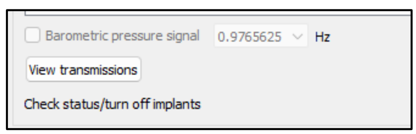
19. If user presses **Continue**, units continue to send, and cannot be re-configured as the Stellar Universal Receiver button is disabled.

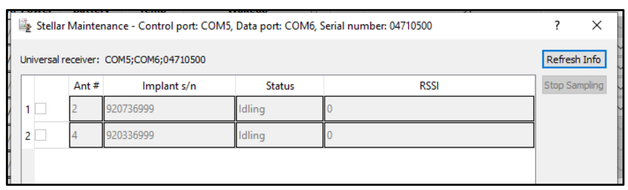


20. If the graph window is closed, all units will stop sampling.

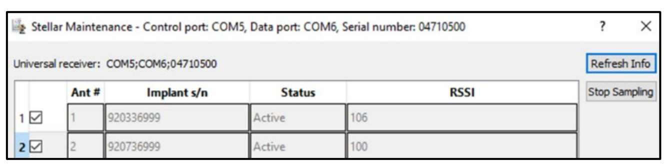


21. Opening another graph window will enable Stellar setup. The **View transmissions** button will now be enabled, and all units will be shown to be idling.





22. If implants are transmitting data without Acq*Knowledge* prompting them to do so, their status will show as "active." They may be checked and stopped via the **Stop sampling** button.



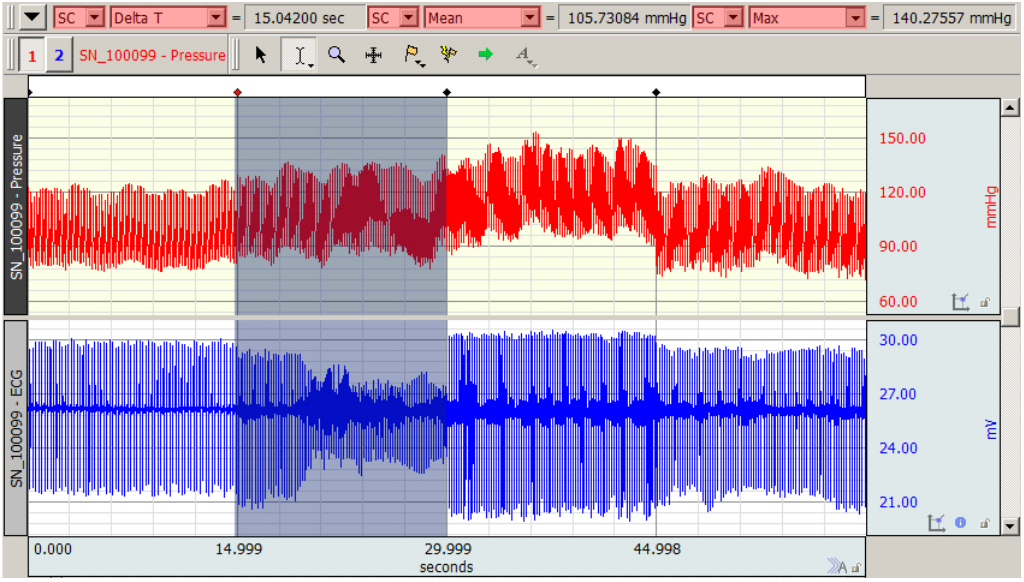
23. If hardware has not been initialized, data cannot be acquired. Under that condition, this dialog box will appear after the **Start** button is pressed.

Import and Display of Stellar Data in Acq*Knowledge*

Following completion of a scheduled experiment, the logged Stellar data is downloaded to an Acq*Knowledge* graph for review and analysis. Stellar-optimized analysis tools enable selective viewing and spreadsheet output of recorded data for all selected animal units.

- Physiological signals extracted from the Stellar experiment are imported into an Acq*Knowledge* graph and displayed as separate channels.

- Repeated recordings (for example, 15 seconds every 15 minutes for the duration of the session), are displayed as appended segments.



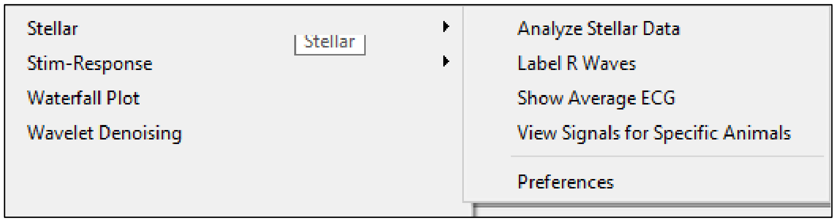
Saving Graphs and Settings from Stellar Experiments

It is important to note that Stellar experiment data files and Stellar experiment settings are stored separately. Graphs containing data imported from Stellar experiments are in standard Acq*Knowledge* *.acq or *.gtl format, and like all Acq*Knowledge* graphs, are opened and saved via the main application window “File” menu. Conversely, Stellar experiment settings and parameters are saved and opened via a separate File menu in the Scheduler window. (See Stellar-specific Scheduler menus on pages 601-605.) Stellar experiments are saved in *.ase (Acq*Knowledge* Stellar Experiment) format and contain the following settings:

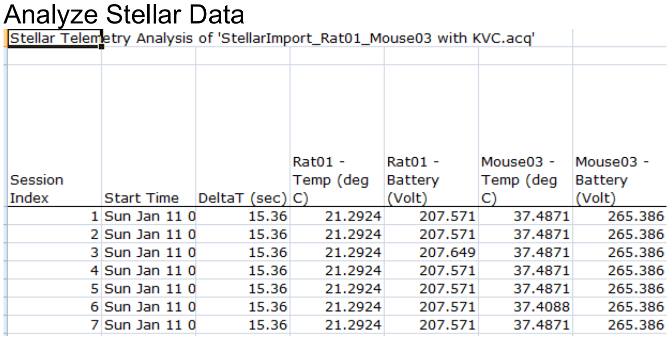
- Access Point ID
- Output directory
- List of Animal Units with their last known status
- List of Animal Unit IDs included in each session
- Start Date/Time for each session
- End Date/Time for each session
- Single Record duration for each session: value and time units
- Interval between recordings for each session: value and time units
- Sample rate in Hz for each session
- Input signals for the recording session: (Blood Pressure, ECG, Temperature, Accelerometer, Battery voltage)

Stellar Analysis in Acq*Knowledge*

After the logged Stellar session is downloaded into an Acq*Knowledge* graph, or an acquisition has been completed with real-time implants, data can be extracted and examined using the Stellar specialized analysis tools. Access these tools by using the Analysis > Stellar menu option in the main graph window.

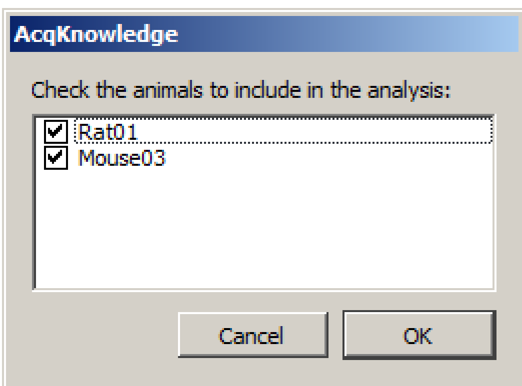


Analyze Stellar Data



Stellar Telemetry Analysis of 'StellarImport_Rat01_Mouse03 with KVC.acq'

Session Index	Start Time	DeltaT (sec)	Rat01 - Temp (deg C)	Rat01 - Battery (Volt)	Mouse03 - Temp (deg C)	Mouse03 - Battery (Volt)
1	Sun Jan 11 0	15.36	21.2924	207.571	37.4871	265.386
2	Sun Jan 11 0	15.36	21.2924	207.571	37.4871	265.386
3	Sun Jan 11 0	15.36	21.2924	207.649	37.4871	265.386
4	Sun Jan 11 0	15.36	21.2924	207.571	37.4871	265.386
5	Sun Jan 11 0	15.36	21.2924	207.571	37.4871	265.386
6	Sun Jan 11 0	15.36	21.2924	207.571	37.4088	265.386
7	Sun Jan 11 0	15.36	21.2924	207.571	37.4871	265.386



Creates a spreadsheet output of combined data from selected animal units included in the session. All measurements are selectable in the Stellar Analysis preferences and include the following:

- Delta T (duration of each recording interval)
- Mean Systolic Pressure
- Mean Diastolic Pressure
- Mean Mean Pressure
- Standard Deviation Systolic Pressure
- Standard Deviation Diastolic Pressure
- Mean Pulse Pressure (systolic pressure minus diastolic pressure)
- Standard Deviation Pulse Pressure
- Mean Heart Rate from Pressure
- Mean Heart Rate from ECG
- Standard Deviation Heart Rate from ECG
- Standard Deviation Heart Rate from BP
- Mean P-P from ECG
- Standard Deviation P-P from ECG
- Mean Temperature
- Battery
- Barometric Pressure (mmHg)
- Activity Sum (measures overall activity during the entire recording segment by summing all activity count data)

Note that outputted measurements are dependent upon the signal types selected in the setup window.

If the session includes multiple animal units, the rows extend outward to accommodate all subjects and displays measurement data for each.

5.0.8.1 Fixes to resolve data acquisition errors:

- **Analyze Stellar Data** script now performs checks to detect missing data
- Upon finding evidence of missing data, script fills in zeros for those segments

<table>
<tr>
<td></td>
<td>

Script alerts about the detection and requests verification that the insertions were made correctly
If user opts to verify, they need to re-run the same analysis after they are satisfied the insertions are correct
On the second run, the software will find no evidence of missing segments and so will proceed through the analysis

</td>
</tr>
<tr>
<td>Analyse Stellar Data (applied to data acquired from Real-Time Implants)</td>
<td>

Analyze Stellar Data script attempts to determine if data were acquired with new (real-time) implants
When data is acquired with new implants, the script provides options for breaking the file into separate pieces for analysis – see Epoch Analysis for steps, noting the following differences:

Unlike Epoch Analysis, the user cannot choose an output type. All results are output to to a spreadsheet file. A new column called “focus area” will be added to the spreadsheet if the user selects the “focus areas only” option.
Under the Events option for “Locate event at,” users can select a new option for epoch, “between events.”

Interval width has been disabled for this choice; interval is defined as time from one event to the next.
When the user chooses this option in conjunction with “focus areas only,” an epoch is added to the analysis only if both event marks (start and end) are within a given focus area.

No option exists for selecting output statistics. Extracted stats are determined by “Analysis > Stellar > Preferences.”

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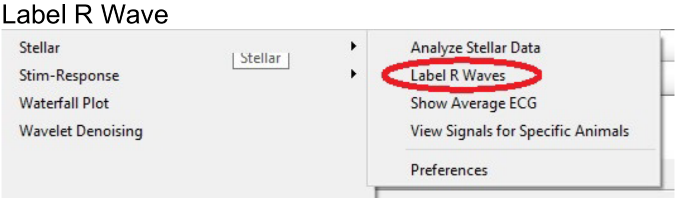
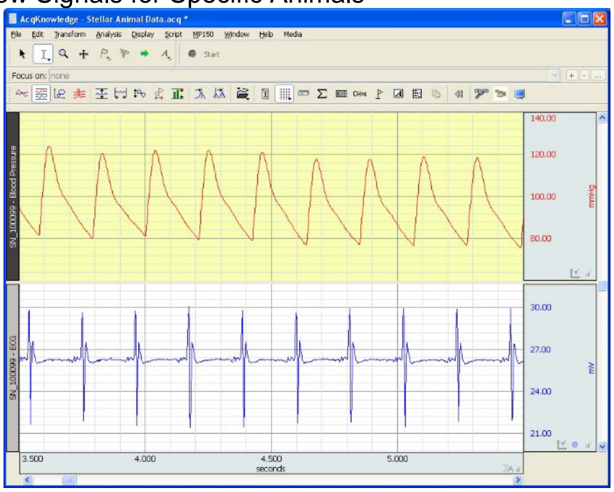
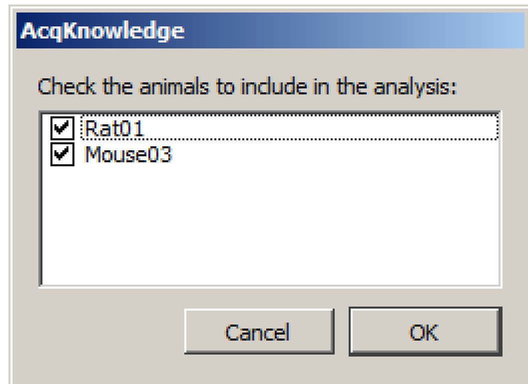
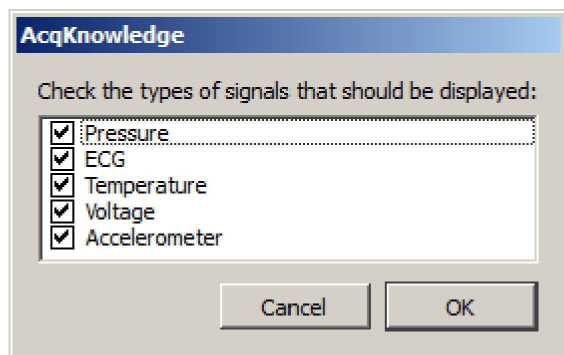
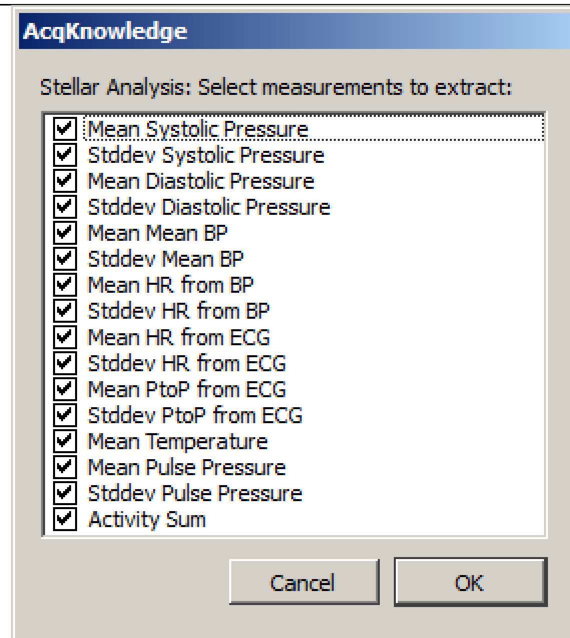
</tr>
<tr>
<td>Label R Wave


</td>
<td>This feature allows event marking of QRS peaks. Selecting this option launches a script that carries out the following actions:

Places event marks at locations identified in the Analyze Stellar Data script prior to computing mean heart rates.
Allows user to select implants prior to analysis
Identifies R-wave peak events already present and gives the option to delete before adding more

</td>
</tr>
</table>

	• No action is taken when ECG signals are not detected
Show average ECG	This option averages the ECG signal and provides the average ECG waveform for the entire acquisition period. When selected. Acq*Knowledge* performs an ensemble average ECG complex for each recording session and then overlaps them to obtain the average.
View Signals for Specific Animals 	The following parameters can be adjusted using the "View Signals" controls:  The above option selects the animal units to be included in the graph. Unchecking an animal unit hides the graph channel containing the deselected unit.  Show or hide the various signal type channels acquired during the session for a better view of a particular signal.
Preferences > Stellar Analysis: Select measurements to extract	Use this option to select or deselect the measurements to be included in the analysis.

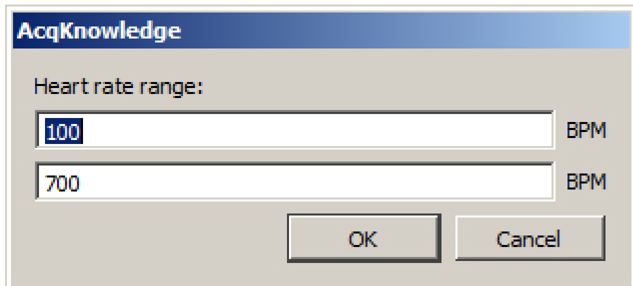

AcqKnowledge
Stellar Analysis: Select measurements to extract:
Mean Systolic Pressure
Stddev Systolic Pressure
Mean Diastolic Pressure
Stddev Diastolic Pressure
Mean Mean BP
Stddev Mean BP
Mean HR from BP
Stddev HR from BP
Mean HR from ECG
Stddev HR from ECG
Mean PtoP from ECG
Stddev PtoP from ECG
Mean Temperature
Mean Pulse Pressure
Stddev Pulse Pressure
Activity Sum
Cancel
OK

Preferences > Heart Rate Range

Use this preference to enhance the accuracy of heart rate ranges extracted during analysis. This option (based upon the Acq*Knowledge* Find Rate windowing algorithm,) can help improve results by reducing the standard deviation of BPM values falling outside of the defined range. These results appear as selected measurements in the “Analyze Stellar Data” spreadsheet output.

In general, adjusting the maximum BPM to a lower value helps prevent excessive motion artifact from adversely affecting the heart rate results.

This preference is also useful for tuning the heart rate “window” for a specific subject type and experimental condition, or in cases where the 700 BPM default maximum heart rate may not be applicable.



To set the Heart Rate Range preference for an experiment:

1. Analysis > Stellar > Preferences
2. Dismiss the initial “Select measurements” dialog.
3. Enter the desired minimum BPM value into the top field.
4. Enter the desired maximum BPM value into the bottom field.
5. Click OK to apply the settings.

The example below shows how mean heart rate and standard deviation results can be enhanced by lowering the maximum heart rate range from a default value of 700 BPM (left) to 300 BPM (right).

56023 - Mean HR from ECG (BPM) (CH1)	56023 - Stddev HR from ECG (BPM) (CH1)
166.019608	81.2977369
127.442673	16.3411845
119.07607	9.05015577
108.028482	11.5076062
109.886304	10.9902428
154.557763	94.8174003
144.951621	11.7752942
133.544329	44.2635671
153.638255	85.0186415
129.97489	53.84373
108.859904	11.8379417
104.863876	12.7436838

56023 - Mean HR from ECG (BPM) (CH1)	56023 - Stddev HR from ECG (BPM) (CH1)
153.180505	14.8308058
127.442673	16.3411845
119.07607	9.05015577
108.028482	11.5076062
109.886304	10.9902428
135.221167	35.2295007
144.951621	11.7752942
129.486757	5.78133416
136.676308	20.2107231
123.006982	9.58501232
108.859904	11.8379417
104.863876	12.7436838

For more information about the Acq*Knowledge* Find Rate feature and windowing setup, see page 396.

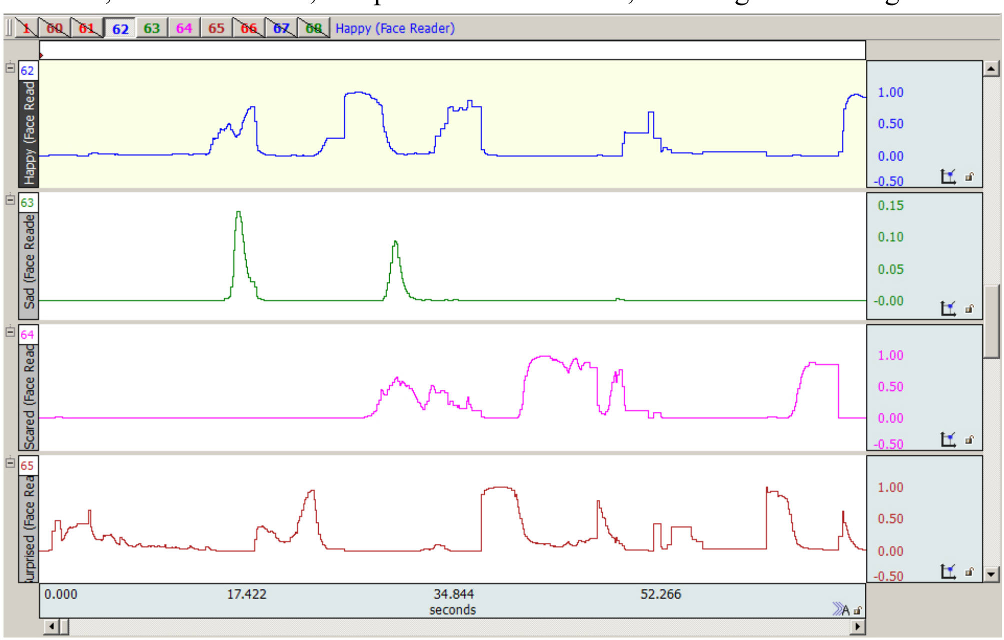
Chapter 32 FaceReader

FaceReader™ with Acq*Knowledge* is available through optional licensing in Acq*Knowledge* 5. FaceReader runs on Windows only and current releases are supported on Windows 10. Contact BIOPAC for licensing details.

FaceReader™ is the premier professional software for automatic analysis of facial expressions. FaceReader emotion reading software locks onto a subject's face and analyzes facial movements to classify the subject's response. The software was "trained" with more than 10,000 manually annotated images. Easily integrate with physiological parameters from an MP160 or MP150 Research System or eye tracking data. Start Acq*Knowledge* to begin recording, and FaceReader data is automatically synchronized and recorded in the same graph file. Monitor data in the FaceReader display for real-time feedback. Classifications include:

- Happy
- Sad
- Scared
- Disgusted
- Surprised
- Angry
- Contempt
- Neutral

Add Action Units to measure three common affective attitudes: boredom, interest, confusion. FaceReader also provides gaze direction, head orientation, and person characteristics, such as gender and age.



Seamless Integration – easily integrate and synchronize physiological data or eye tracking through Acq*Knowledge.*

Complete Facial Expression Analysis – accurate modeling of the face by describing over 500 key points delivers objectivity in observations.

Useful for a Variety of Applications – psychology, educational research, consumer behavior research, usability studies, and neuromarketing research.

How Does FaceReader Work?

FaceReader software uses the computer's (or external) camera, a still photo, or a video image to detect and analyze a subject's emotional state by utilizing the facial action coding system (FACS) first developed in the 1960s by Swedish anatomist Carl-Herman Hjortsjö and later expanded by Dr. Paul Ekman. The FACS algorithm is capable of interpreting the tiniest of facial movements, rendering an accurate and nuanced interpretation of a subject's emotional responses. This automated state scoring has become popular in advertising and neuromarketing for assessing subject feedback to videos and other stimuli, and is also often used as another measure during self-assessment studies.

The FaceReader licensed feature allows response classifications to be selectively recorded as channels in an Acq*Knowledge* graph, and includes the following functionalities:

- Receive emotional state data from FaceReader in real-time*
- Store emotional state data in Acq*Knowledge* graph files
- Incorporate emotional state data with other physiological signals and data analysis

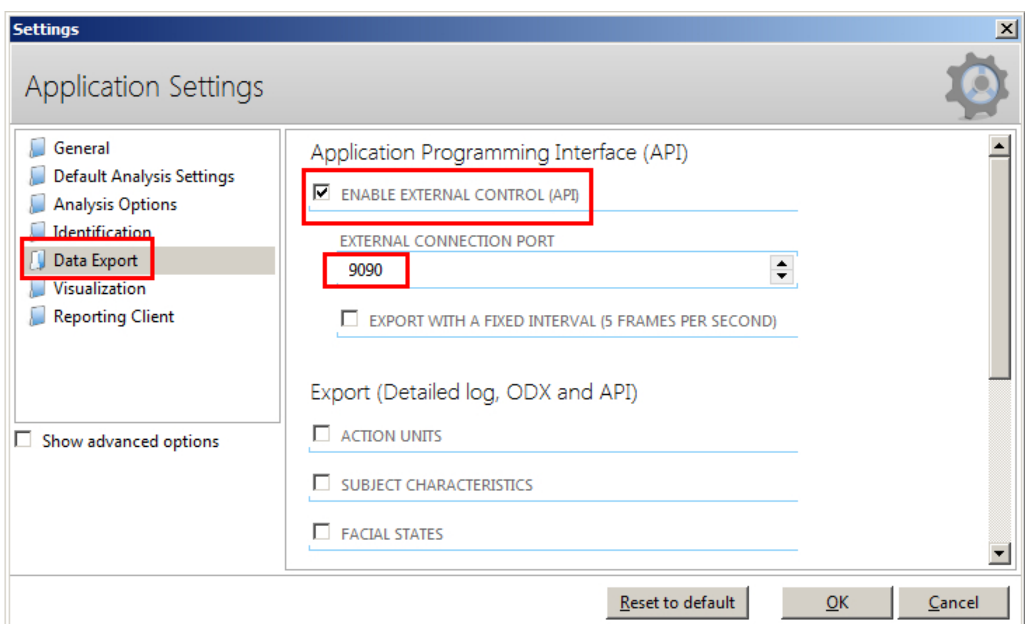
*Due to initial latency, the first second of FaceReader classification data and video may not be fully synchronized. To synchronize video recorded by FaceReader with data recorded in Acq*Knowledge*, an LED connected to the MP should be used to visually mark the first video frame corresponding to the start of data acquisition. For more information see the video synchronization section of the Media Chapter on page 522.

Acq*Knowledge* FaceReader options become visible when the optional FaceReader license has been activated. Additionally, FaceReader software must be installed on the Acq*Knowledge* computer, or on a networked computer or server. See the FaceReader Software Reference Manual for installation and configuration instructions (i.e., FaceReader software and camera setup.)

Using FaceReader with Acq*Knowledge*

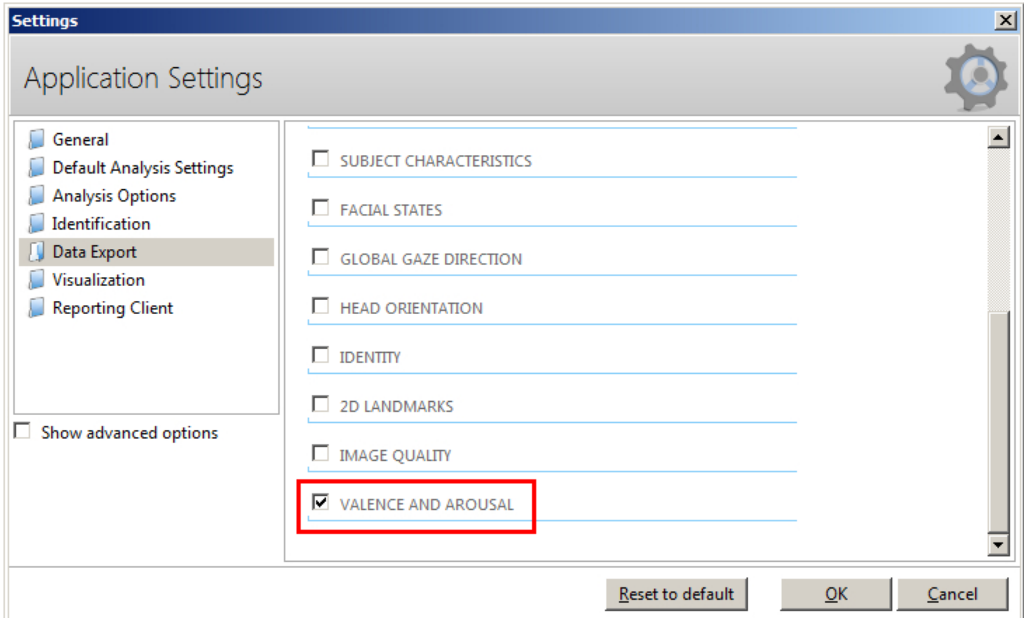
To configure FaceReader for use in Acq*Knowledge*:

1. Launch the FaceReader software and create a new project.
2. Choose "File >Settings."
3. Select "Data Export" and check the "Enable External Control (API)" option.
4. Note the External Connection Port number. The default setting of 9090 shouldn't need to be changed unless there is a conflict with another application:



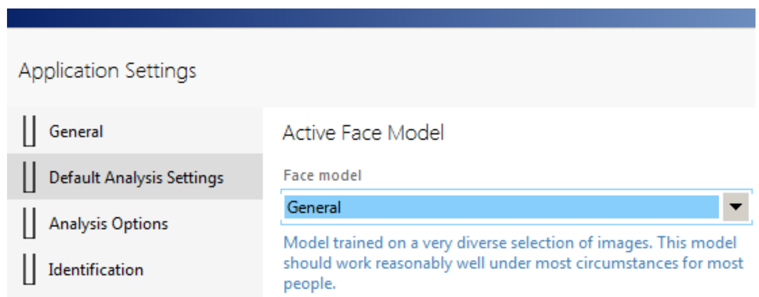
Enabling data connection in the FaceReader software settings

5. To record overall valence and activity signals, scroll down the Application Settings screen and check the “Valence and Arousal” option (see below figure). For more information on valence and arousal signals, see page 632.



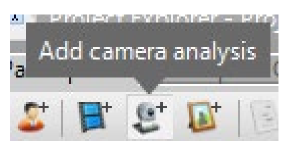
6. Click OK to exit the Application Settings screen.

Important: If using FaceReader for the first time: In Application Settings, choose “Default Analysis Settings” and set the “Active Face Model” selection to “**General**.” (If accidentally set to “Baby,” subsequent adult data may not be properly classified.)

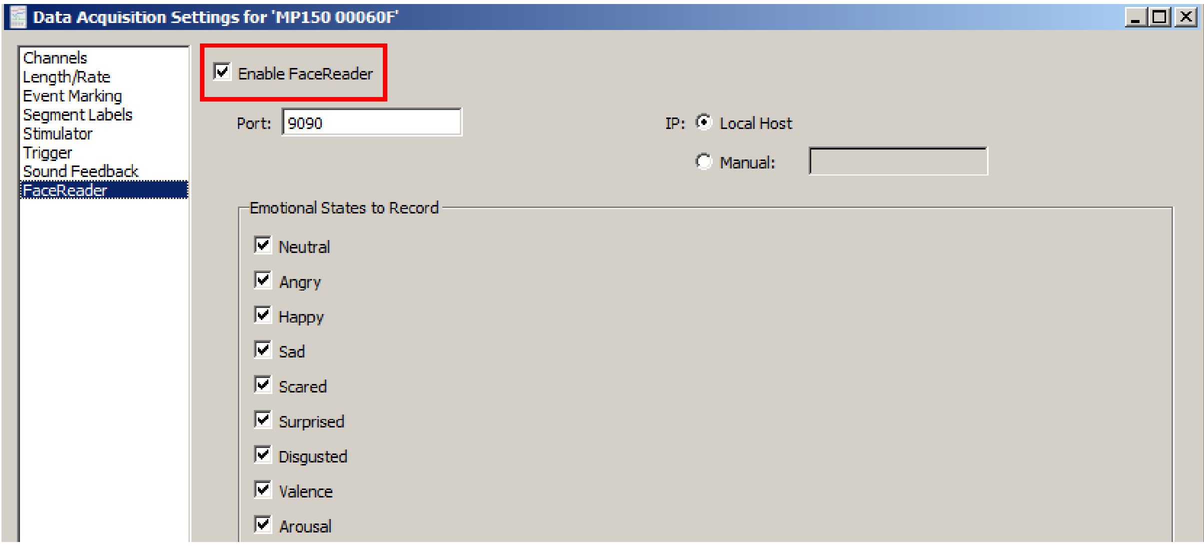


Creating a FaceReader Project and Recording in Acq*Knowledge*

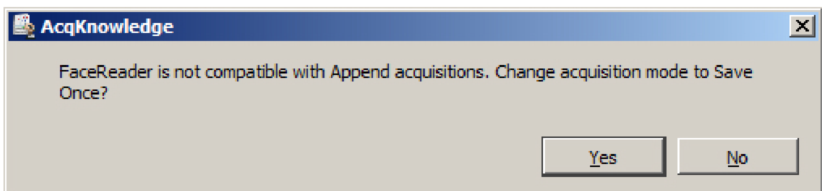
1. After performing the above configuration steps 1-5, launch the FaceReader software and choose “Create New Project.”
2. Add a participant to the project.
3. Add a camera analysis (Camera toolbar icon in FaceReader software UI) and note the camera preview for positioning the subject.



4. Launch or return to Acq*Knowledge*. (If necessary, create a new graph.)
5. Choose MP160/150 > Set Up Data Acquisition > FaceReader. (This option is only visible if a FaceReader license is present.)



6. Check the “Enable FaceReader” checkbox.
   NOTE: Appended acquisitions are not supported in FaceReader. If the “Length/Rate” record mode is set to Append, the following prompt will appear:

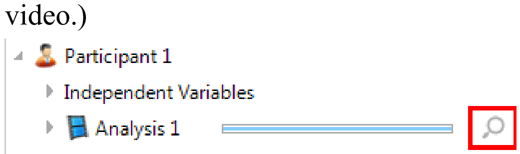
   - If the FaceReader software is installed on the local Acq*Knowledge* computer, select “Local Host” as the “IP” setting and use the default Port number of “9090.”
   - If the FaceReader software is installed on another networked computer, choose the “Manual” option and enter the I.P. address of the FaceReader computer. (The I.P. address can be found by choosing Start > Run “cmd” and using the “ipconfig” command.)
7. Select the desired “Emotional States to Record” signals. **NOTE:** All emotional states can be selected or deselected at once by pressing the Alt/Option key and clicking a selection.
8. Exit the Channels > FaceReader setup screen and click the Acq*Knowledge* “Start” button. (At least one Acq*Knowledge* Analog channel must be enabled in order for the recording to start.)
9. The selected Emotional State data will be recorded into a new set of channels alongside other Acq*Knowledge* data.
10. Click “Stop” to halt Acq*Knowledge* FaceReader recording.

TIP: In the Acq*Knowledge* FaceReader tab, click the “Save as Graph Template” button to permanently save the Port setting and selected Emotional States for future sessions.

Creating Acq*Knowledge* Graphs from a Saved FaceReader Analysis

Existing saved FaceReader analyses can be extracted into an Acq*Knowledge* graph, even if the analysis was not originally performed using Acq*Knowledge*. To do this:

1. In FaceReader, open an existing project.
2. Open the Analysis for the project (click the magnifying glass icon to display the saved video.)



3. Launch Acq*Knowledge* and make sure FaceReader is enabled in the application (See Steps 5-6 above).
4. Click "Start" in Acq*Knowledge*. The recorded FaceReader analysis will be displayed in Acq*Knowledge* graph channels.

FaceReader Signals

FaceReader records various emotional states and displays the analysis in real-time. As previously explained, this analysis extracted as graph channels in Acq*Knowledge* software. FaceReader implements a neural network trained on the following facial expressions:

- Neutral
- Angry
- Happy
- Sad
- Scared
- Surprised
- Disgusted

These recorded expressions are used to extract the subject's dominant emotional state during the response period, otherwise known as "valence."

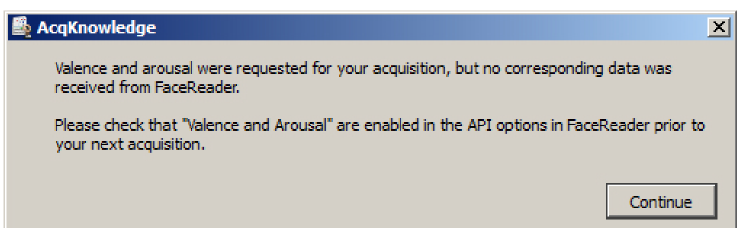
Valence and Arousal

Valence and Arousal are two additional high level signals derived by FaceReader. Valence is used as an indicator of a subject's overall emotional state based on sum of positive emotions minus the sum of negative emotions, and ranges in value from 1 to -1. (The most positive emotional state being 1, the most negative -1.)

Arousal is used as an indicator of whether a subject is active or inactive and is based on average activity of the various facial action units within the last 60 seconds. A value of 0 corresponds with an inactive subject and a value of 1 with an active subject.

The seven emotional states, plus the derived valence and arousal signals provide useful high-level information about a subject. FaceReader also provides tools for extracting other lower level facial information, including state of standard FACS action units, general gaze direction, head orientation, eyes open/closed indicators and other parameters. These high-level signals are relevant for psychophysiology.

If "Valence" and "Arousal" Emotional States are selected in the Acq*Knowledge* FaceReader tab but have not first been configured for output in the FaceReader software, the following dialog will appear.

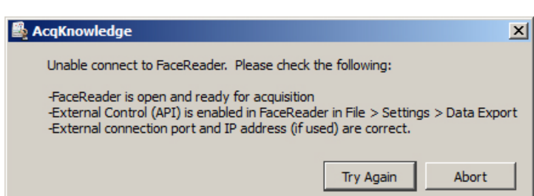


If this occurs:

1. Return to the FaceReader software, choose "File >Settings."
2. Scroll to the bottom of the Application Settings screen and check the "Valence and Arousal" box.
3. Click OK to exit the FaceReader Application Settings screen.
4. Return to Acq*Knowledge* and rerun the FaceReader recording to verify that valence and arousal data are present.

Connection Issues

If, after clicking "Start" Acq*Knowledge* fails to establish a connection with FaceReader, the following dialog will appear:



If FaceReader and Acq*Knowledge* are installed on the same computer:

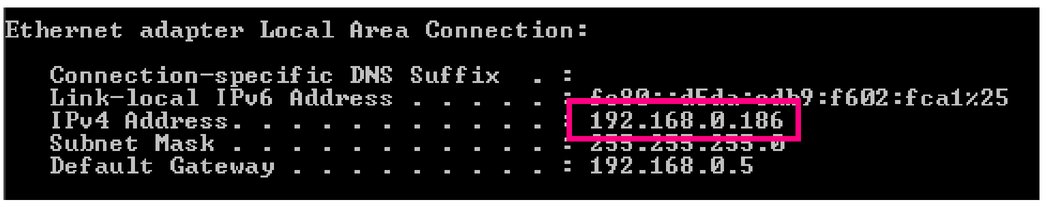
Check the IP port setting for both applications as shown on pages 629 and 630. The port settings should match. (The default is 9090.) This port number may need to be changed if there is a conflict with another application.

If FaceReader is installed on a different computer on the network:

Make sure the I.P. address of the FaceReader computer is correctly entered in the Acq*Knowledge* FaceReader tab's **Manual** field. Auto-location of the I.P. address is not supported, so this value must be entered manually.

To determine the I.P. adress of the FaceReader computer:

1. On the FaceReader computer, choose Start > Run.
2. Type "cmd" to bring up a command window.
3. Type "ipconfig" and press the Enter key.
4. Note the I.P. address.
5. Return to the Acq*Knowledge* computer.
6. Enter the I.P. address in the Acq*Knowledge* FaceReader tab's **Manual** field and click OK.



Camera Connection Issues

For certain types of USB cameras, the camera connection may become lost following a FaceReader analysis session. If this occurs, unplug and reconnect the camera before continuing with a subsequent analysis. It is recommended that an integrated camera be used if possible and set as the default camera.

For further instruction and technical details about Noldus FaceReader software, see the FaceReader Software Reference Manual.

For more information about the Acq*Knowledge* FaceReader Licensed Feature, visit www.biopac.com.

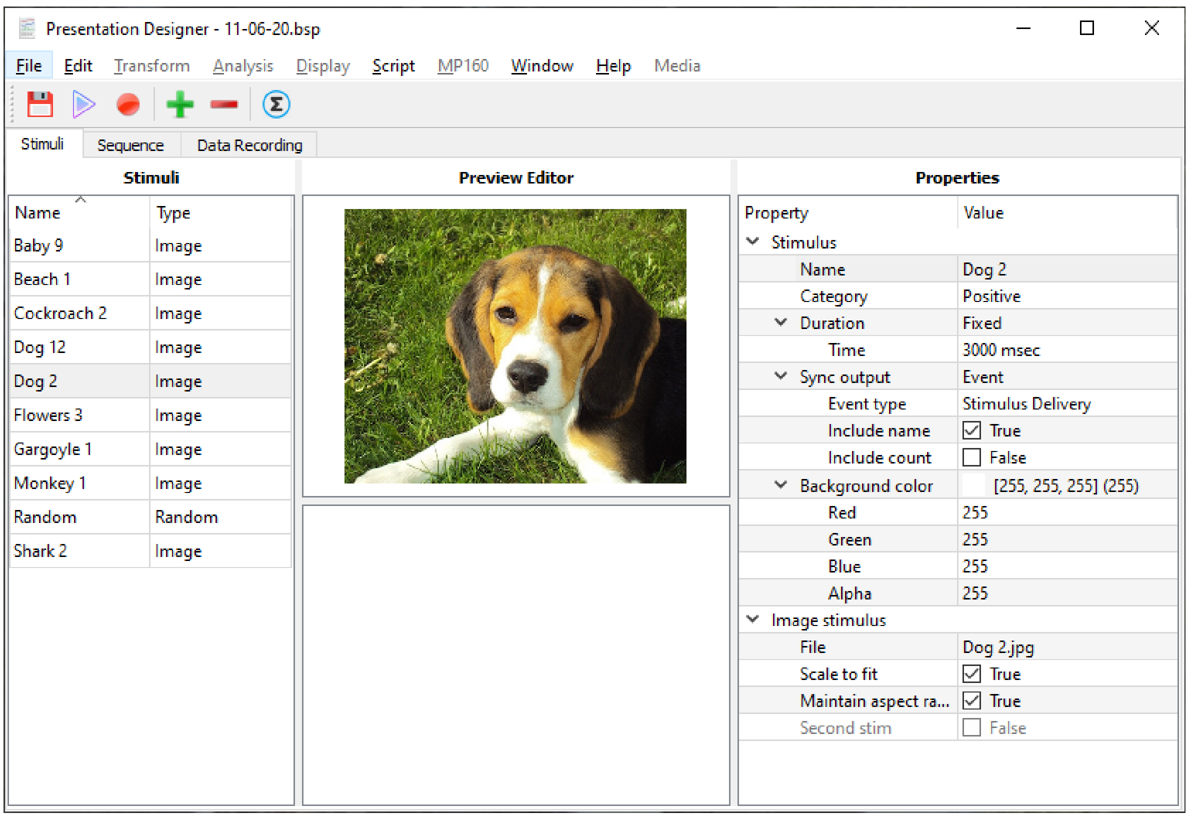
Chapter 33 Stimulus Presentation with Eye Tracking and FaceReader Support

Stimulus Presentation with Acq*Knowledge* is available through optional licensing in Acq*Knowledge* 5.0.6. Stimulus Presentation is supported on Windows 10 only. Contact BIOPAC for licensing details.

Acq*Knowledge* Stimulus Presentation is a licensed feature that enables users to create stimulus programs from within the Acq*Knowledge* application, thereby bypassing the need for third-party stimulus presentation software. The Acq*Knowledge* Stimulus Presentation program simplifies the setup and running of stimulus protocols, while integrating presentations with available Eye Tracking and FaceReader acquisitions, in addition to the full range of physiological signals supported by Acq*Knowledge* and the MP160 System.

With this feature, the user can create simple presentations using the following stimulus types:

- Text
- Images
- Video
- PDF

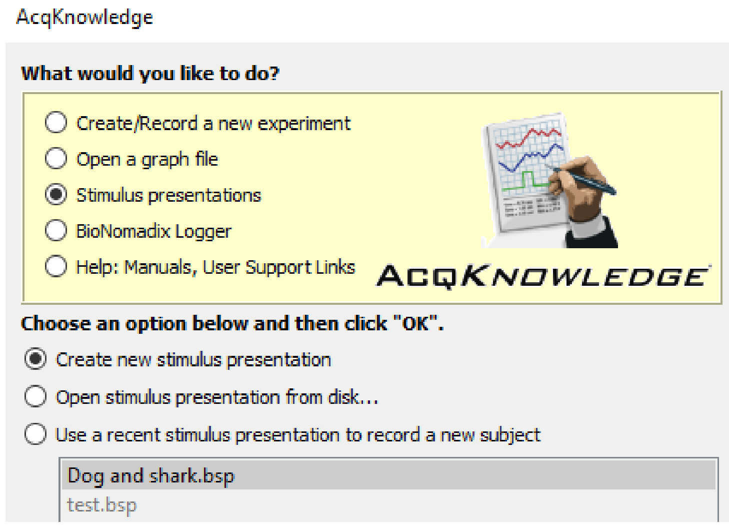


A *presentation* is a sequential list of stimuli presented on a computer monitor to a subject in a fixed or random order.

An overview of the various Acq*Knowledge* Stimulus Presentation features are explained on the following pages.

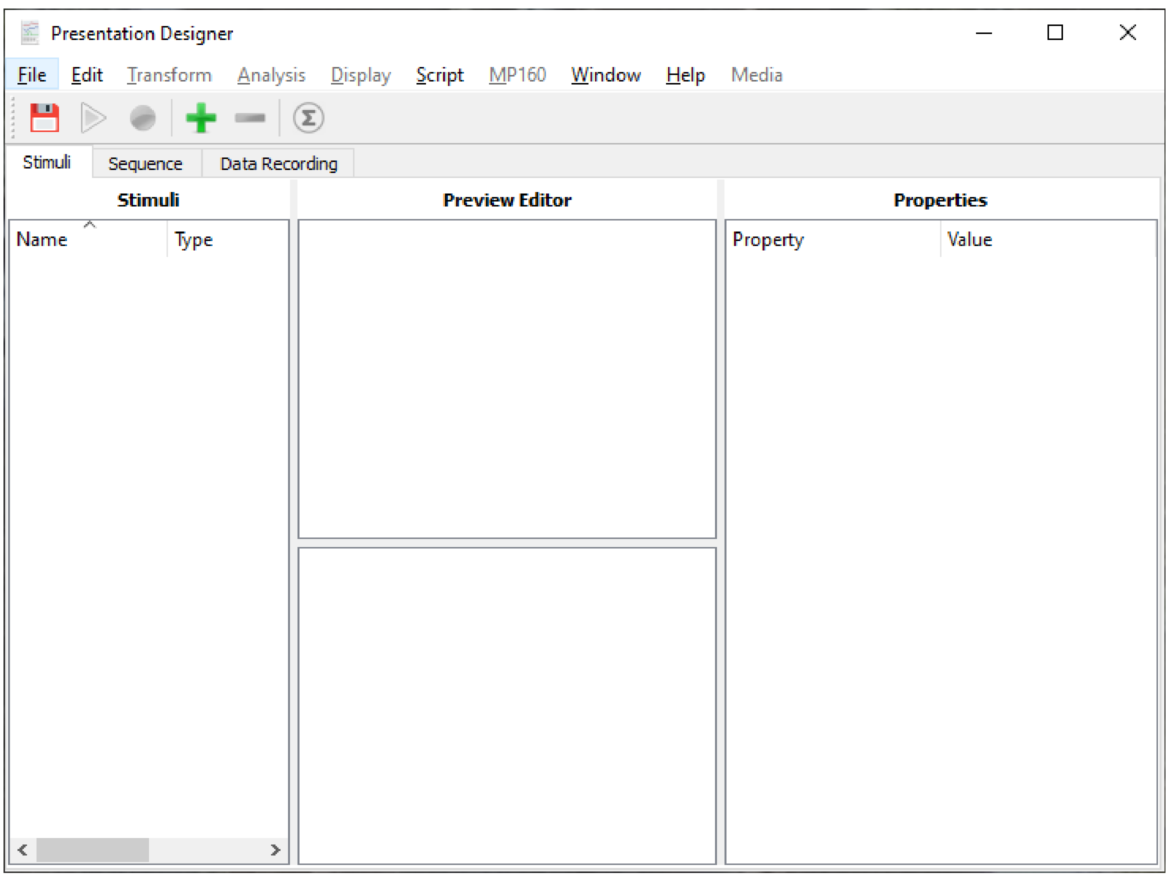
Presentation Designer

The Presentation Designer is the interface used for setting up the stimulus presentation experiment. To open the Presentation Designer in Acq*Knowledge*, choose the "Stimulus presentations" startup option.



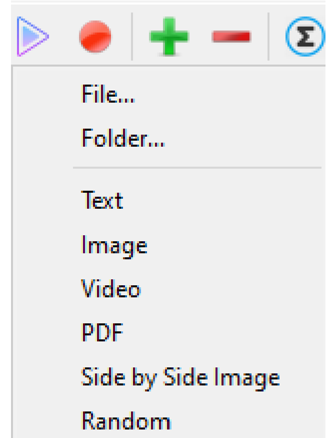
The available options allow creation of a new presentation, opening an existing saved presentation, or choosing a recent saved presentation from the provided list. (Saved presentations use a unique *.bsp file extension and incorporate all Acq*Knowledge* graph settings.)

After choosing "Create new stimulus presentation," the following screen will appear with the "Stimuli" tab selected.



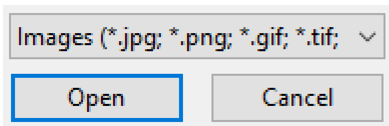
The Presentation Designer window

Creating a new presentation



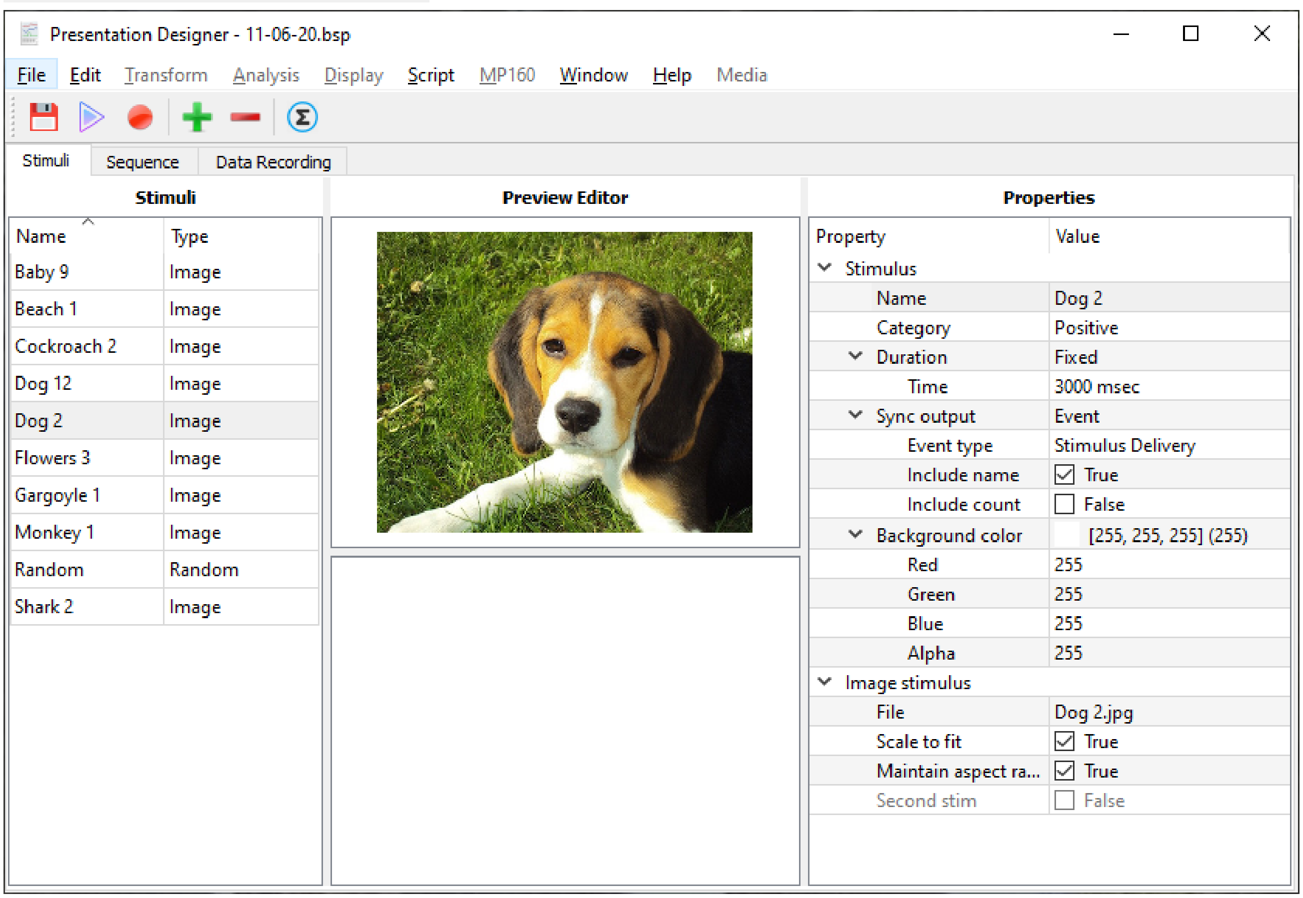
The Presentation Designer window contains the following three tabs: “Stimuli”, “Sequence” and “Data Recording”. The three tabs of this window are used to build up a library of items (“Stimuli”), arrange those items into the order they should be presented to the subject (“Sequence”), and to configure the collection of data to be obtained from the subject during the presentation (“Data Recording”). To create a new presentation, the “Stimuli” tab must be selected in the designer. Click the “Add” button on the toolbar . This action presents options for selecting supported stimulus types, such as images, videos, or text.

“File…” opens a file chooser for selecting single or multiple supported stimulus file types from any directory. The chooser has a filter dropdown menu allowing the user to select the type of files to add.



Users may select multiple items by using the Ctrl key while clicking additional files. Similarly, the Shift key allows the selection to extend over a range of consecutive files in the chooser. After Clicking “Open,” the content of the selected file(s) will appear in the Stimuli list.

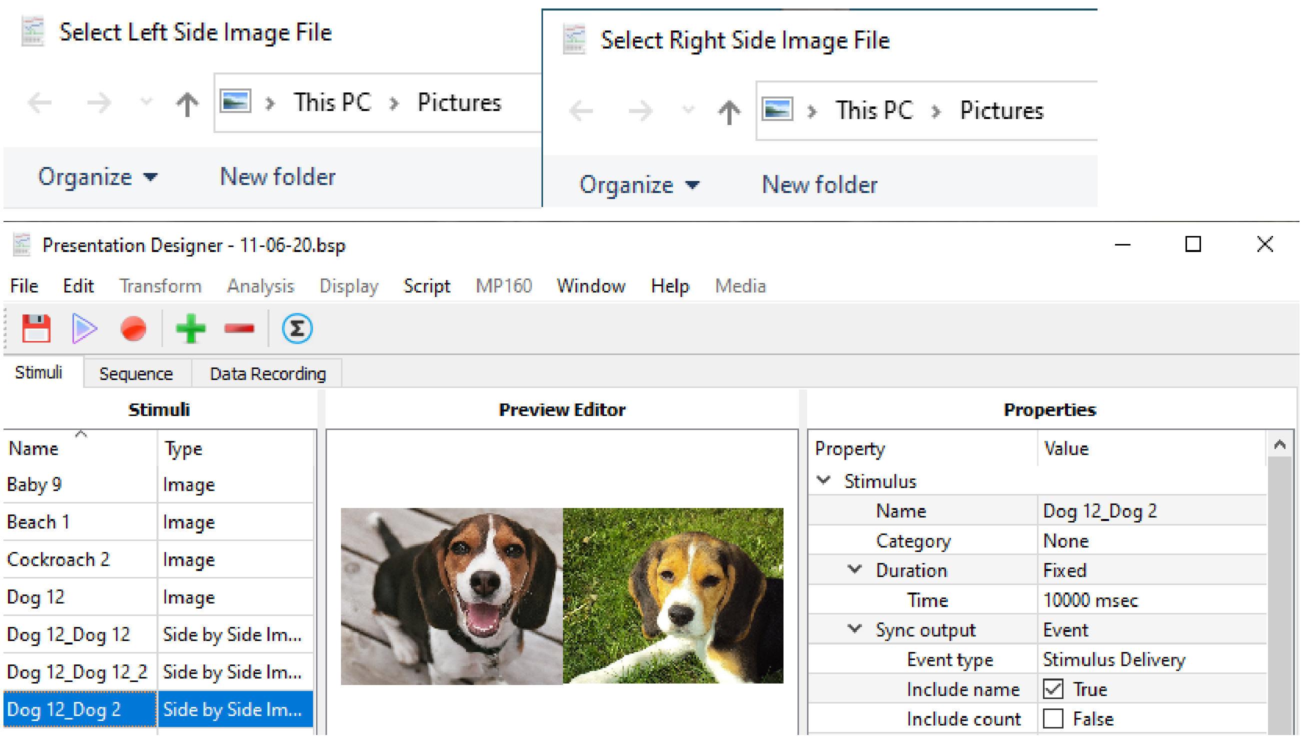
“Folder…” opens a chooser for selecting a folder containing files that may be included in the presentation. When a folder is selected, the contents of all supported file types are imported into the presentation’s library.



"Text" adds to the library a slide containing a simple editable text message. A text slide will present that text in a uniform color against a uniform background. Location on screen, font, font size, colors, etc. can be configured (see discussion of Properties below).

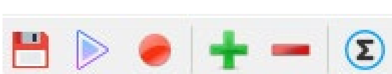
"Image", **"Video"**, **"PDF"** add the contents of selected files of the appropriate type. These choices are equivalent to the "File…" choice except that the file filter option cannot be changed to allow addition of the other types of selection. These choices are shortcuts allowing the user to add elements from files without the step of specifying stimulus type.

"Side by Side Image" places two images next to each other in the presentation. The File Chooser dialog will open twice, first allowing the user to select the image that will appear on the left and then the image on the right.

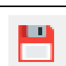
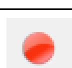


"Random" creates an item that may be used where the experimenter wants to display an item randomly chosen from the library of stimuli created with the other stimulus addition options. Learn more in the section below titled "Adding a Random Stimulus to the Presentation".

The Stimulus Presentation Toolbar (available under Stimuli tab only)

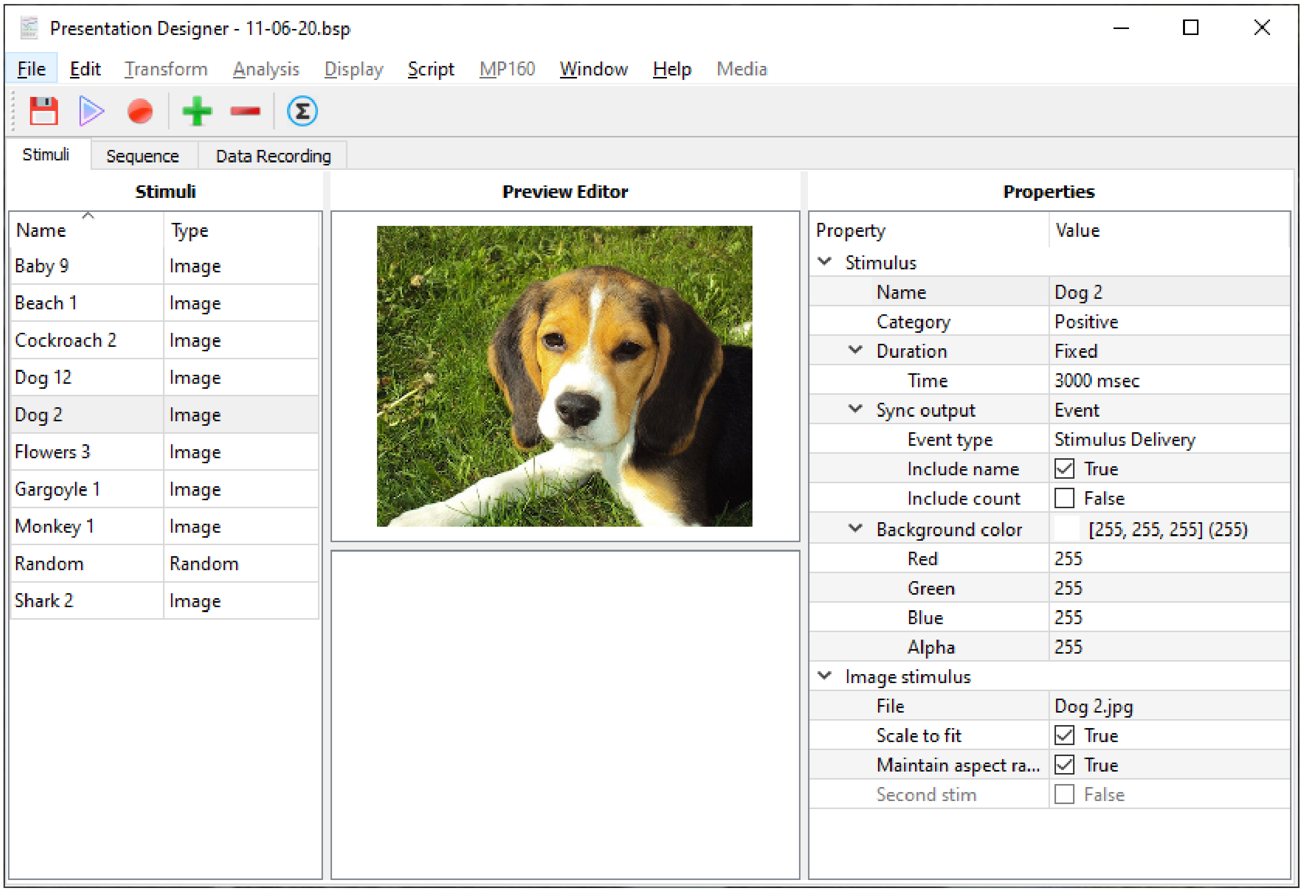


The Stimulus Presentation Toolbar in the upper left of the Presentation Designer window includes the following options:

Button	Icon	Action
Save		Saves the Stimulus Presentation as a BIOPAC Stimulus Presentation (*.bsp) file. This file can be saved to any location and re-opened for subseqent use.
Dry Run		Initiates a visual run through the Stimulus Presentation Sequence without recording data.
Record		Creates a new graph window associated with the presentation and opens the Visual Experiment View window which includes an option to Start Recording.

Add		Add elements to the Stimulus Presentation file's library(see previous section). Note: Stimuli are **not** necessarily presented in the order they are added to the Stimulus Presentation. Use the "Sequence" tab to specify order.
Delete		Deletes the selected stimulus from the presentation.
Summary		Displays an onscreen summary of the Stimulus Presentation elements.

Stimulus Presentation Details



The **Stimuli** pane displays the stimulus names and types in list format.

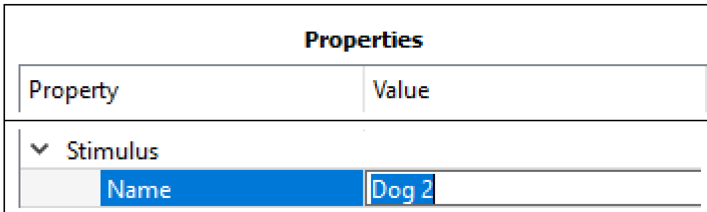
The **Preview Editor** shows the currently selected stimulus as it will appear to the participant.

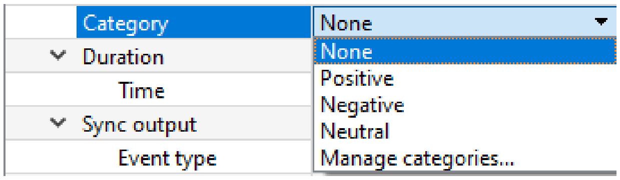
The **Properties** pane consists of two sets of elements:

- **"Property"** lists the editable parameters of the selected stimulus.
- **"Value"** indicates the current setting for each property and methods for the user to change those settings for the current selection. Note: it is possible to select more than one stimulus at a time and some properties may be edited for several stimuli simultaneously.

Setting the Values of Stimulus Properties

Each image stimulus can be modified using the following options:

	Click into the "Value" field to edit name of the stimulus as displayed in the library and data recordings.

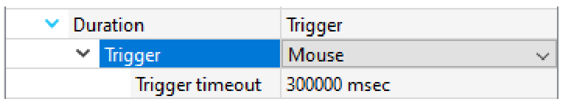


Assign the stimulus to a category. Click "Manage categories…" to create a new category.

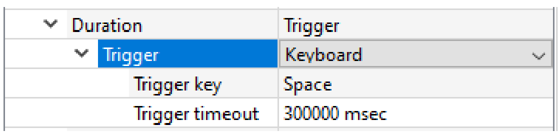
Categories are important when adding random stimuli. Please refer to the "Adding a Random Stimulus to the Presentation" section for more information.

Fixed Duration

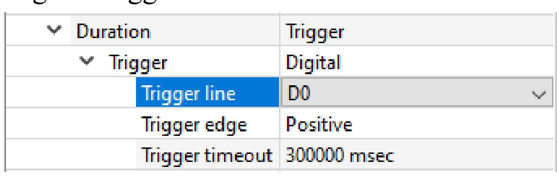
Mouse Trigger



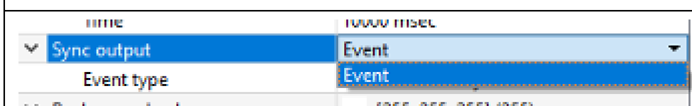
Keyboard Trigger



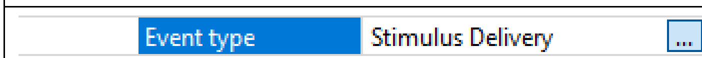
Digital Trigger



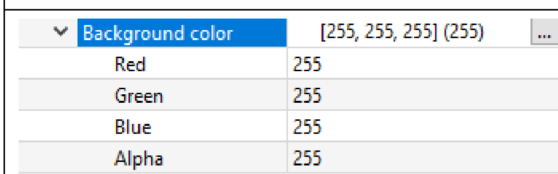
Use this field to set the desired duration the stimulus will be displayed to the participant. The duration can be set to either fixed or triggered. Setting the Duration to 'Trigger' will allow the user or an external device to truncate the length of time the stimulus is displayed. Adjust 'Time' for 'Fixed' or 'Trigger timeout' for 'Trigger' to establish the stimulus duration. In the latter case, this value indicates the duration the stimulus will remain if no trigger is received. In both cases the field is directly editable or can be adjusted with the arrow buttons. When Trigger is selected, a pulldown will appear allowing the user to choose the trigger method—keybord, mouse, or digital. The Keyboard trigger further allows the user to select what key will act as trigger. If Digital is selected, a pair of pulldowns appear, allowing the user to select the digital trigger line (D0-D15) and trigger edge (positive for flipping the channel from low to high or negative for high to low).



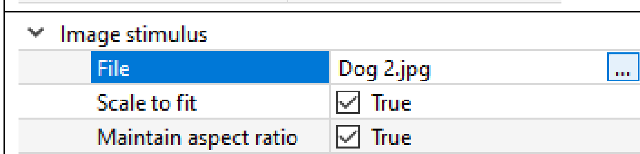
The Sync Output specifies the output type generated when the onscreen stimulus is presented. When set to Event (presently the only option), a global event will be defined when the stimulus is presented.



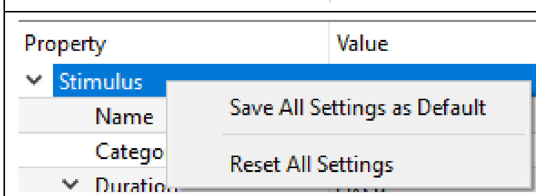
Click the button to choose the event type to be inserted into the Acq*Knowledge* graph when the stimulus appears.



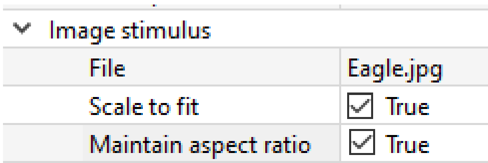
The background color can be customized by entering numerical values, or by clicking the "…" button to open a color picker. (Background will only be visible for images that do not fill the monitor.)



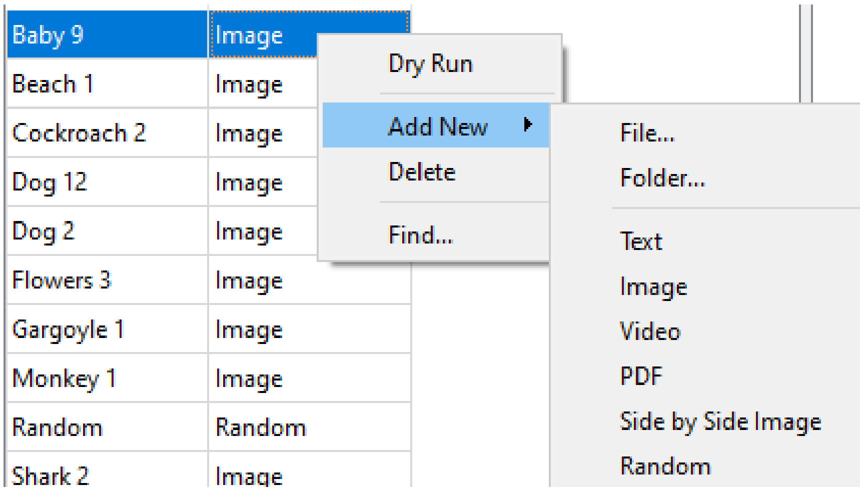
Click the "…" button to the right of "File" to navigate to the directory containing the selected stimulus or use it to select a different image file.



Right-click any property to save modified settings as the new default or choose "Reset all settings" to revert to the original default. This option is global for all properties.

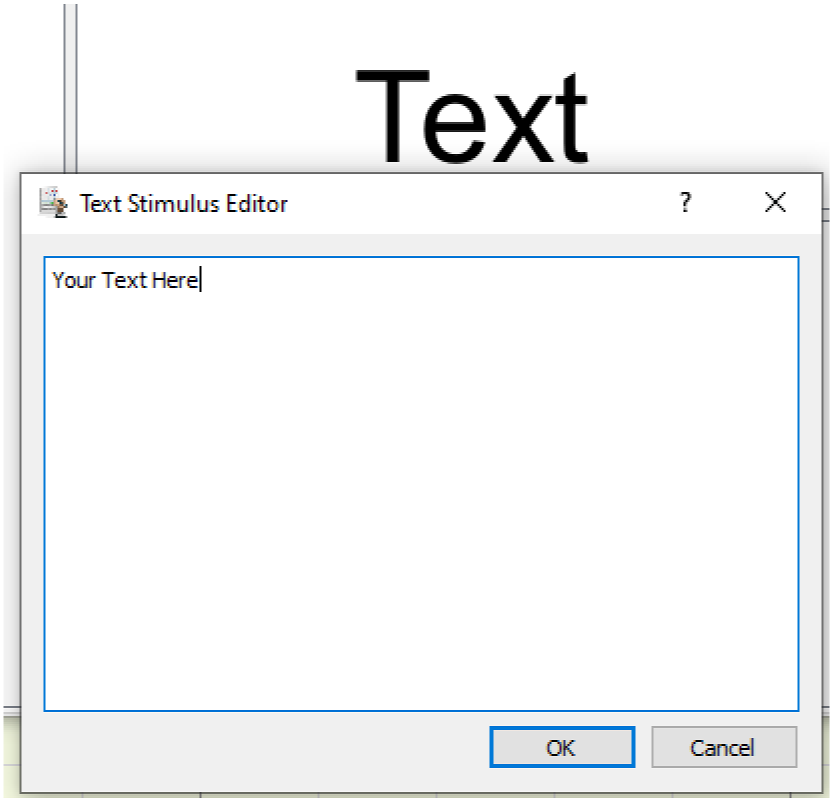
	If the image is larger or smaller than the stimulus display monitor, checking “Scale to fit” will adjust the size of the image during presentation. Checking “Maintain aspect ratio” preserves the relative height and width of the image, potentially leaving some areas of the monitor to contain a solid background color.

Tip Right-click any stimulus selected in the stimuli list to open a contextual menu for options as shown in the image below. Use the “Find” feature to quickly locate any stimulus in the list. This is useful for protocols requiring a large number of stimuli presentation.



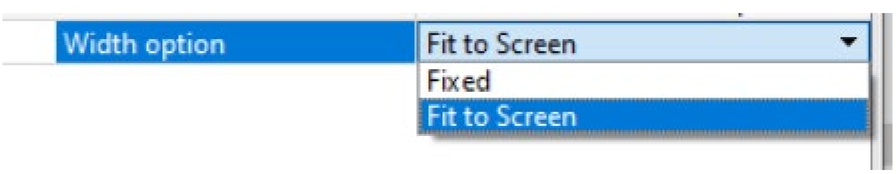
Properties available for video stimuli are similar to those of images. Note that the “Duration” property of video stimuli defaults to the length of the video in the file. Setting the duration shorter will truncate the end of the video. Setting the duration longer than the video adds a blank background (color determined by the “Background color” video property) into the presentation at the end of the video.

Unlike other stimulus types, “Text” stimuli are not imported from independent files. Double-clicking the text in the Preview window opens a Text Stimulus Editor box into which text may be typed:



Position of the text on the screen, font size, font type, etc. properties may be modified in the Properties pane for Text stimuli. Note: the "Alpha" Value of Background Color and Text Color Properties specifies transparency level from 0 (fully transparent) to 255 (fully opaque) allowing text and background colors to blend. Whenever a Value is changed, the Preview window is immediately modified, making it easy to determine the effects of each change.

PDF stimuli allow the width to be stipulated, or scaled to fit the width of the monitor. PDF stimuli cannot be scaled to fit vertically; aspect ratio of original file is maintained at all times. If the width is such that the vertical extent of the file is larger than the monitor, the user may scroll the pdf during the presentation.



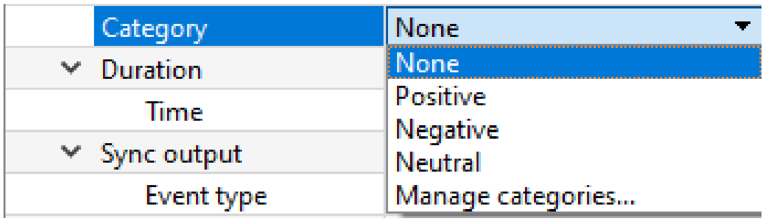
Note: For experiments including eye tracking, PDF stimuli should be restricted to files that can fit within the stimulus display monitor without scrolling. While the current release supports the ability to scroll during stimulus presentation, it does not support the proper analysis of eye tracking data if the user scrolls.

Random items have only two Properties, the Name and the Category. When a Random item is added to the sequence (see next section), the item displayed to the subject will be randomly selected from any items that match the Category selected for that Random element. Stimuli may be assigned to the Category "None", so "None" should be treated as a Category Value. The "Any" Category for a Random stimulus is a wild card. With that Value selected for a Random stimulus, the entire library of stimuli in the presentation is the pool from which the stimulus is drawn during the experiment.

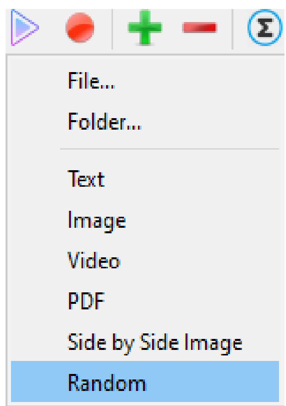
Adding a Random Stimulus to the Presentation

In addition to presenting specific stimuli in a fixed order, there is the option to introduce a randomization element to the Library. To add a random stimulus:

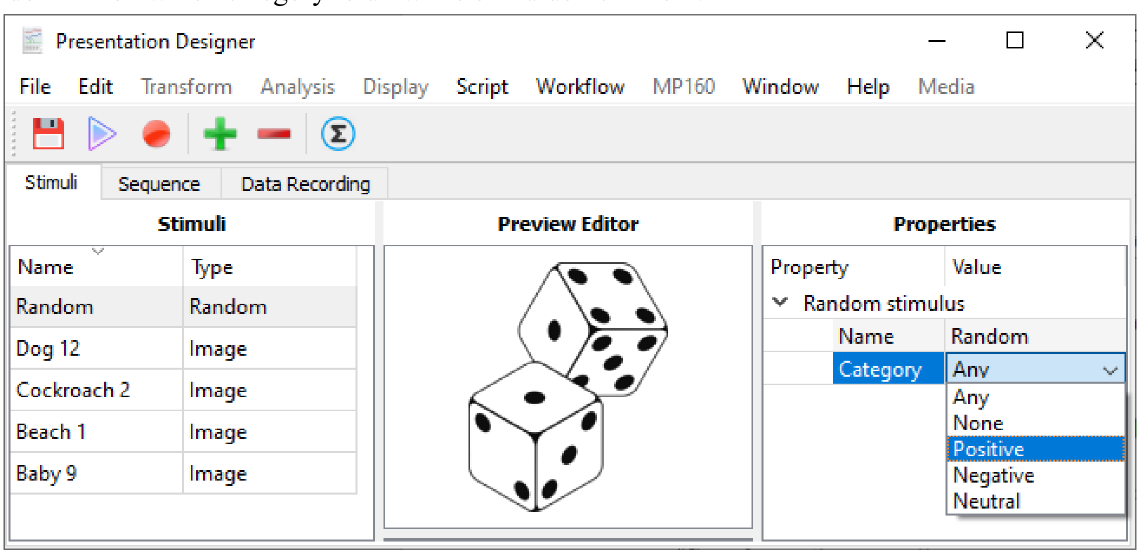
1. Under the Stimuli tab, populate the Library with other types of stimulus items (images, text, video, etc.)
2. Assign each stimulus element to a Category (Positive, Negative, Neutral, or custom) in the Stimuli Properties.



3. With the Stimuli tab selected in the Presentation Designer, click the  toolbar button and choose the “Random” option.

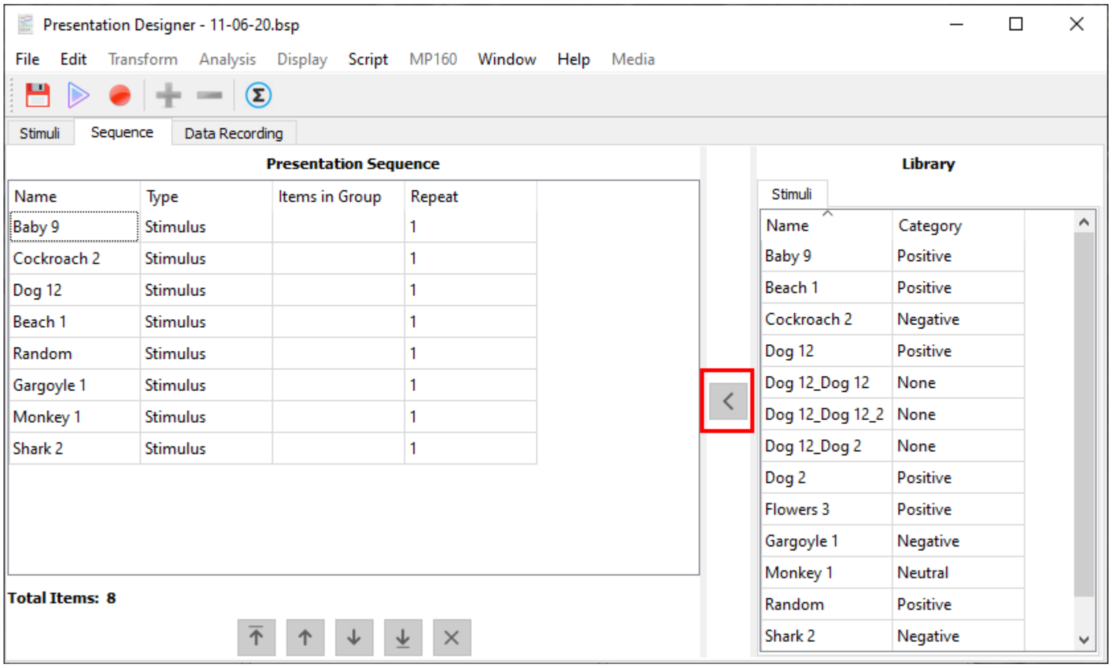


4. Under the Properties of the newly added random stimulus, assign a Category. This tells the randomization which category to draw the stimulus item from.

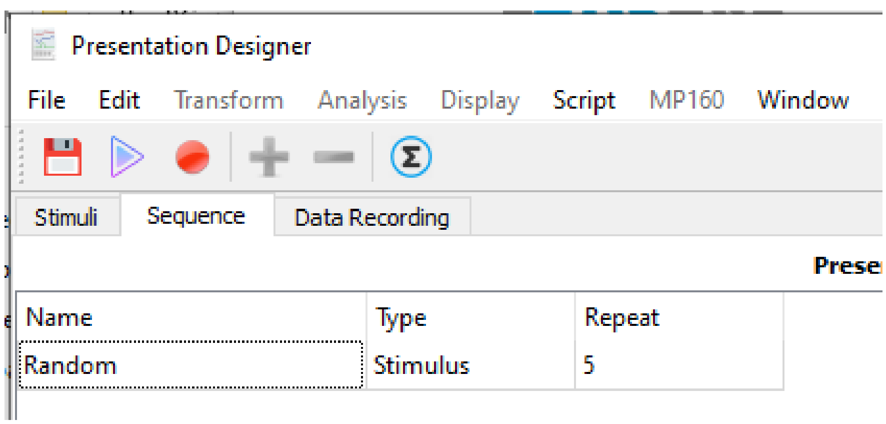


For example, if “Positive” is selected, the Random stimulus will be selected only from the stimuli that have been previously assigned to the Category “Positive”. Multiple “Random” items may be added to the Library with a different Category for each entry.

5. Next, switch to the “Sequence” tab. Use the left arrow button to add the Random stimulus (or any other elements) over to the Presentation Sequence. Individual stimuli in the Library can be added multiple times to have them be shown multiple times during the presentation.

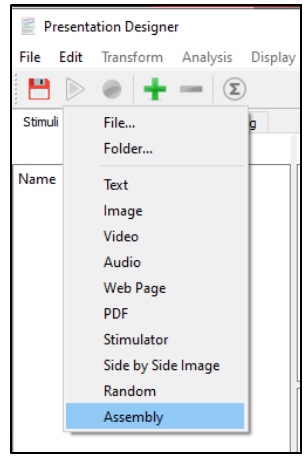


6. .



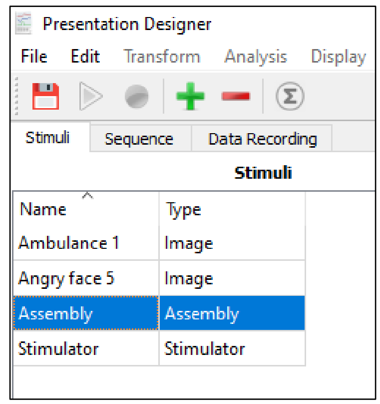
Note: Stimuli are drawn randomly with replacement, so a given stimulus item may appear more than once if multiple random draws are selected either by increasing the “Repeat” value (as in image above) or by moving the same Random stimulus from the Library into the sequence multiple times.

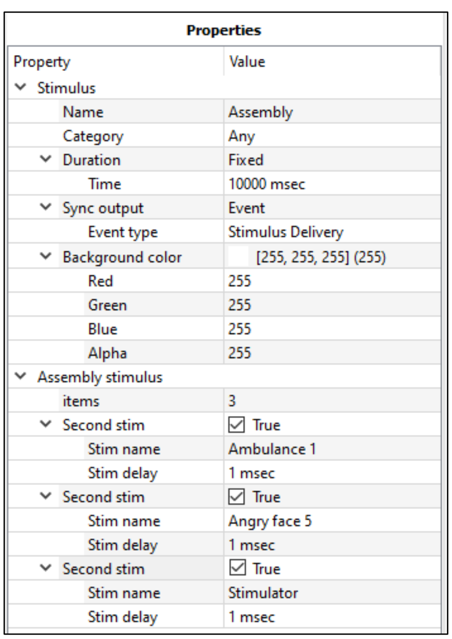
Creating and Adding an Assembly to a Presentation



Assembly allows users to combine stimuli so that they can be presented as a single object with overlapping elements rather than being arranged sequentially. These elements include images, sound files, and stimulators (e.g., scent delivery control).

1. Assembly can be accessed by opening a new or existing stimulus presentation. While in Presentation Designer, click the button to bring up a list of possible stimuli that includes Assembly.
2. Each assembly has a set of user-defined properties that can be set in the Properties window (see below).
3. Begin by adding the stimuli that will be combined in the assembly, for example, two images and a stimulator.
4. Add Assembly as one of the Stimuli.
5. Clicking on Assembly from the Stimuli list opens the Assembly properties in the Properties window.
6. The user can now combine stimuli from the Stimuli list in the Assembly properties window by setting the number of stimuli and assigning stimuli to the assembly. See the **Controls** list below for complete descriptions of all the settings for Assembly properties.





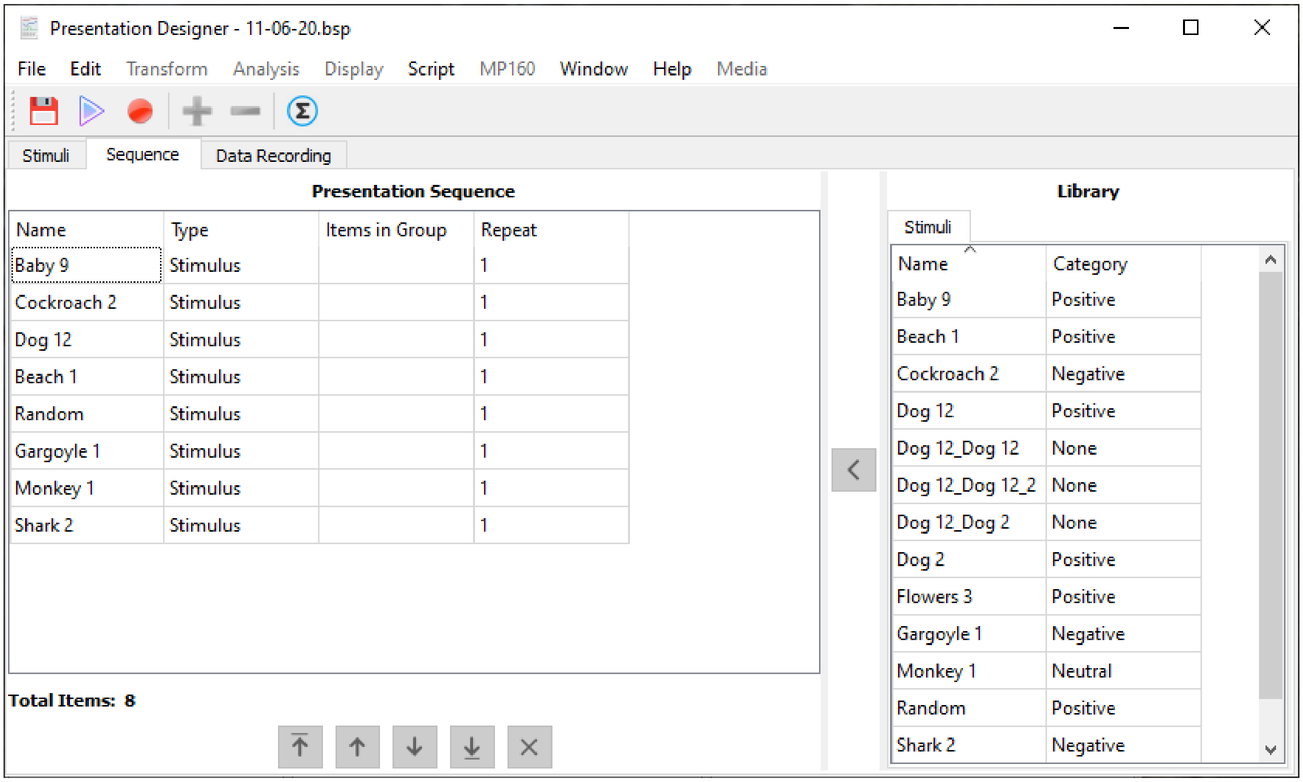
Control	Description
Name	This field allows the user to rename the assembly.
Category	This pulldown lets the user apply the following categories to the assembly: Any, None, Positive, Negative, Neutral, or Manage. Manage allows the creation of a custom category. Assembly items may be presented as part of a Random sequence. See "Adding a Random Stimulus to the Presentation" for more information.
Duration	Pulldown sets fixed or triggered duration. Selecting "Trigger" sets a new duration: "Trigger timeout." See "Setting the Values for Stimulus Properties" for additional information.
Time	(Fixed Duration) Sets the amount of time for the duration of the assembly. Every object has a default duration of 10 seconds. The duration of the assembly must be longer than longest stim delay of all objects contained in Assembly (see **Stim delay** below).
Sync Output	This pulldown specifies the type of event mark to be inserted into the graph window to indicate the time at which the Assembly began

Background Color	These controls set the background color values. for red, green, blue, and alpha. If an image does not fill the screen or a sound or stimulator object is presented without an overlapping image, the background color will be visible to the subject.
Assembly stimulus	
Items	Sets the number of stimulus items to be included in the assembly.
Second Stim	Check box (True) to add stim.
Stim Name	Pulldown selects stim to add to Assembly.
Stim Delay	Sets delay time for stim. Delays cannot be negative.

Implementation Notes for Assembly

1. Various properties of Assemblies and of the items they contain interrelate as the presentation is played. For this reason, it is imperative when designing a stimulus presentation that the presentation be tested to ensure that desired behavior is achieved.
2. Though images can be formatted to contain a Second Stim (audio or stimulator), it is not recommended that users include images formatted in this way as duration conflicts may cause errors. To combine an image with an audio or stimulator object, best practice would be to combine the objects in an Assembly rather than use the Second stim property of images.
3. Assembly objects and the items they contain all have Duration properties associated with them. Assemblies should be carefully designed such that the duration of the Assembly equals the sum of the durations of items it combines. Note that the Duration property of images is ignored when the images are part of an Assembly. In the trivial case of an Assembly containing a single image, the image will appear to the subject after the Stim delay period has elapsed but will then remain on screen until the Assembly ends (or it is replaced by another image in cases where an Assembly contains multiple images). Images are not blended.
4. Audio objects may overlap. In such instances the objects will blend, i.e., the subject may be presented with multiple sounds played simultaneously. Audio objects may still be truncated, however, if the stim delay plus duration add to an amount larger than the duration of the Assembly itself.
5. Note that the duration property of items added to an Assembly is ignored even if the Duration of an item is set to “Trigger.” The Assembly itself has a duration property which can be set to Trigger. If so, the entire Assembly ends when the trigger is received.

The Sequence Tab

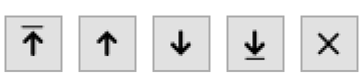


Once stimuli have been added and assigned properties, they can be organized into a desired order under the **Sequence** tab.

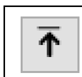
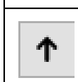
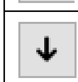
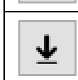
Under this tab, the **Library** pane on the right displays all stimuli available in the presentation file (i.e., all items added using controls under the **Stimuli** tab). To add a stimulus to the **Presentation Sequence**, select that stimulus in the Library and use the  button to copy it into the **Presentation Sequence** list. Multiple stimuli may also be selected by using the Ctrl key (add individual files) or Shift key (select a range of files). When multiple items are moved into the sequence together, their relative sequencing in the presentation is the same as their relative sequence in the library.

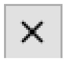
The **Repeat** field in the presentation sequence is editable and used to present a stimulus multiple times as desired before moving on to the next stimulus in the sequence.

Sequencing Buttons

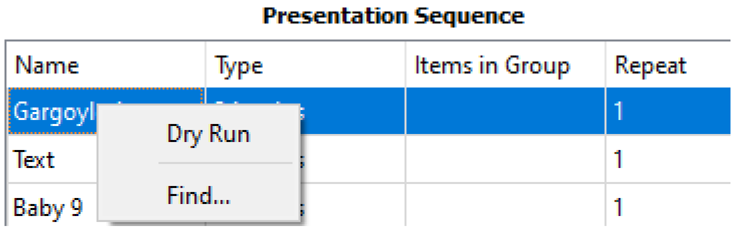


The buttons at the bottom of the screen are used for moving stimulus items within the Stimulus Presentation sequence list and hence their order in the presentation. To move an item, click to select it in the list and click the appropriate button. Multiple items can be selected in the list but only if the selection encompasses all consecutive items (Shift and Ctrl keys are equivalent in this context; both select a range of stimuli).

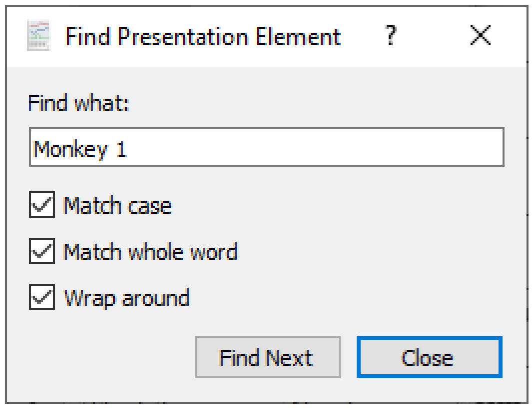
	Move selected item(s) to the beginning of the Presentation Sequence.
	Moves selected item(s) up one space in the Presentation Sequence.
	Moves selected item(s) down one space in the Presentation Sequence.
	Move selected item(s) to the end of the Presentation Sequence.

	Deletes an item from the Presentation Sequence. **NOTE:** This action deletes from the Presentation Sequence only. It does *not* delete the item from the Library.

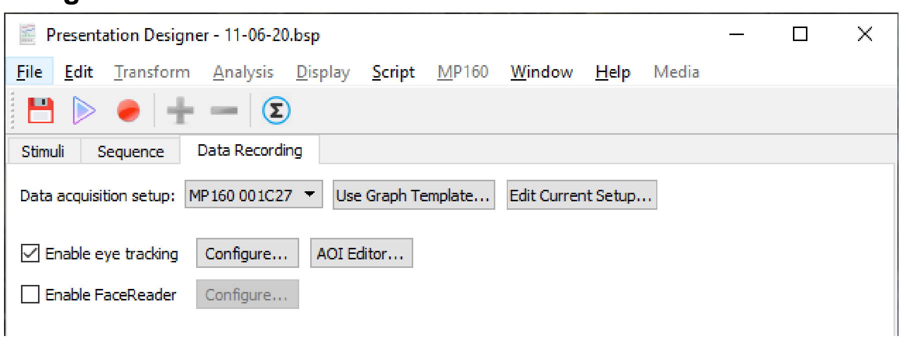
Tip Right click an item in the Presentation Sequence list to open a shortcut pop-up menu to perform a Dry Run (presentation run-through without recording data) or quickly find any item that may be out of view in the list.



To use **Find**, type the name of the desired element in the list and click **Find Next**.



The Data Recording Tab



The **Data Recording** tab contains options for selecting the MP hardware, loading the hardware configuration from a saved graph template, or editing the current hardware configuration.

Data acquisition setup: The pop-up menu immediately to the right of "Data acquisition setup:" provides access to main hardware settings for selecting the connected MP hardware.

Use Graph Template: This option opens a dialog for selecting an existing saved graph template to use with the Stimulus Presentation. Note that the settings may be modified via the "Edit Current Setup…" button after the template file is loaded. Such changes affect the settings associated with the current stimulus presentation file but do not affect the graph template file on disk.

Edit Current Setup: Opens the Data Acquisition Settings dialog used for modifying the Acq*Knowledge* recording and channel settings.

IMPORTANT If the length of the Stimulus Presentation exceeds the set length of the data acquistion, the Stimulus Presentation length will override the set Data Acquisition length. (For example, if the Data Acquisition length is set to 60 seconds but the Stimulus Presentation Sequence takes 75 seconds to complete, the acquisition length will be 75 seconds plus a little extra time at the beginning as data acquisition commences before the first stimulus appears.)

Enable eyetracking (available only with Eye Tracking License)

This option is available only when an EyeTech Eye Tracking Bar is connected.

Note If a supported Eye Tracking Bar is connected to the computer with a license key that includes the eye tracking integration license but “Enable eye tracking” is disabled, save the Stimulus Presentation file, close it, open an empty graph window, add the eye track bar through “MP160 > Manage Hardware Connections…”, and re-open the Stimulus Presentation file.

If not recording additional signals aside from eye tracking, the MP160 hardware must still be connected and one Analog channel or Digital channel must be enabled in the graph. This is because the Eye Tech hardware works with the MP160 to interface with the Acq*Knowledge* graph. The “empty” MP160 Analog or Digital channel can be hidden from view by checking “Acquire” but leaving “Plot” unchecked in the Channel view of MP160 Data Acquisition Setup dialog box.

Note A single .bsp file can be used in separate Acq*Knowledge* graphs, and subsequently separate saved .acq files. Each .acq file saved after recording with the same .bsp file (for example, when running the same experiment on multiple subjects) will be associated with that .bsp file. This association will prevent users from changing a .bsp file after it has been used for recording data.

Eye Tracking Options in the Presentation Designer

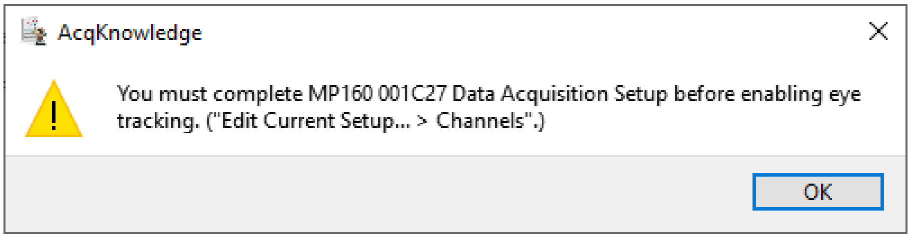
- **Configure:** Opens a wizard for selecting the eye tracking signals to be recorded and for setting the fixation algorithms. For more information about eye tracking options, see the following section.
- **AOI Editor:** Opens a setup dialog for configuring Areas of Interest (AOIs) for the presentation used with the eye tracking experiment. For more information about eye tracking AOIs, see the following section on page 653.

Enable FaceReader: Opens a dialog for setting software options for FaceReader facial expression data. This option is available only when a FaceReader license is installed. See Chapter 32 for information about FaceReader.

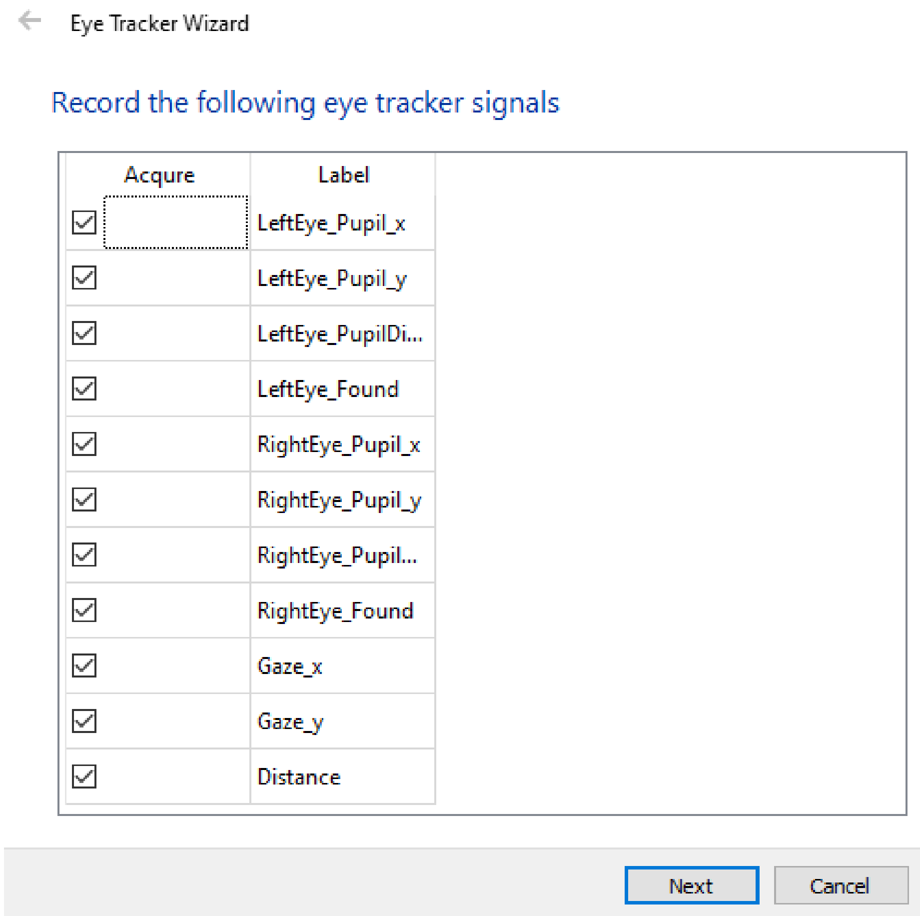
Eye Tracking Configuration Options – Eye Tracker Wizard

The Eye Tracker Wizard in the Data Recording tab is used to configure the eye tracking signals via the following steps.

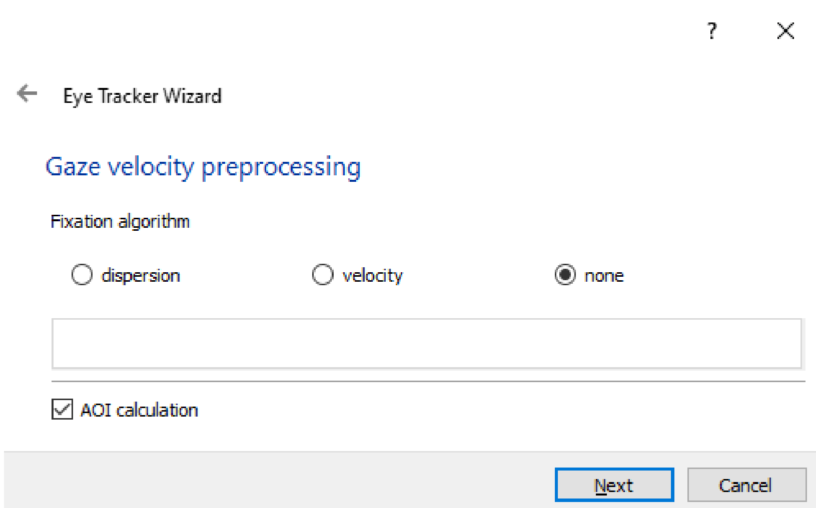
1. Make certain the Eye Tracking hardware is connected to a USB port.
2. Make certain the MP160 hardware is connected and powered on.
3. Make certain at least one MP160 Analog or Digital channel has the “Acquire” box checked. If not, the following warning will appear when attempting to enable eye tracking:

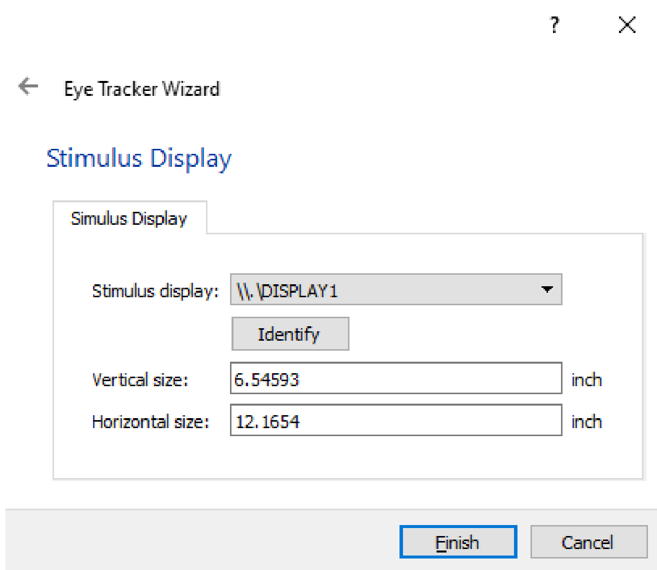
   To complete the MP160 setup, click the “Edit Current Setup” button on the upper right of the Presentation Designer’s Data Recording screen and add a new module (“View by Modules > Add New Module”) or enable an Analog channel (choose “View by Channels” and check any box in the “Acquire” column) or Digital channel (select the “Digital” tab and check any box in the “Acquire” column).
4. Check the “Enable eye tracking” checkbox.
5. Click “Configure” to open the Eye Tracker Wizard.
6. Select the tracker signals to be recorded. By default, Gaze_x and Gaze_y are selected as these are the most important variables for tracking eye positions. Their values indicate the location of the subject’s gaze with respect to the stimulus display monitor at every data point during acquisition. Units are expressed as percentages from the left edge to the right edge of the monitor (Gaze_x) and from the top to the bottom of the monitor (Gaze_y).



7. Click "Next."

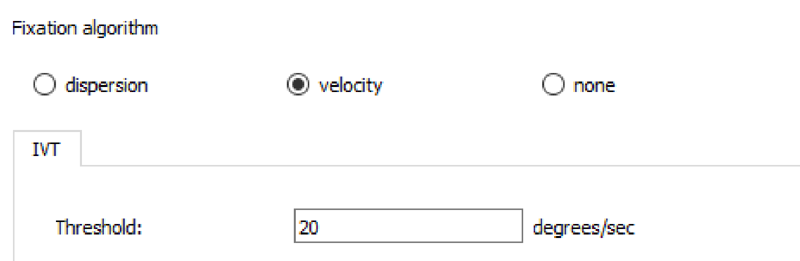


8. Select the Fixation Algorithm (See below for descriptions of Fixation Algorithm choices).
9. Click "Next".
10. If desired, click "Identify" to verify the stimulus display (the monitor on which stimuli will be presented). See table below for details of the information provided in this dialog box.
11. Click "Finish" to exit the Eye Tracker Wizard



Stimulus display	Selects the monitor used to display the stimulus presentation. This would be the monitor the participant is using, not the monitor the researcher is using.
Identify button	Identifies the stimulus display selected.
Vertical size	Vertical screen size of the detected monitor display.
Horizontal size	Horizontal screen size of the detected monitor display.

Fixation Algorithms



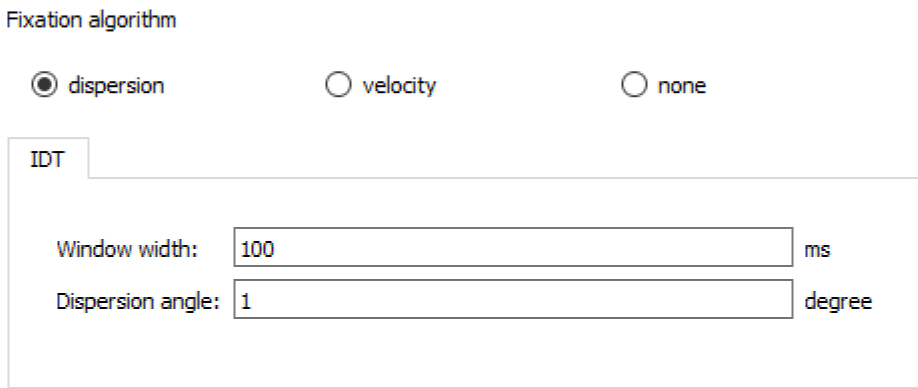
Fixations are periods when a participant's eyes are held relatively steadily on a particular location in space.

Fixation algorithms, routines for assessing whether the eyes are fixed, are available for Dispersion and Velocity.

Note Algorithms for both sets of computations are described in https://doi.org/10.1145/355017.355028 Salvucci, D.D., and Goldberg, J.H. (2000). "Identifying Fixations and Saccades in Eye-Tracking Protocols", *Proceedings of the 2000 Symposium on Eye Tracking Research and Applications*, 71-78.

Dispersion

The dispersion algorithm identifies fixations by locating periods where the gaze position remains within a specified visual angle for a fixed duration of time. Dispersion algorithms are useful for eye trackers with sample rates too low to extract useful velocity information. While robust, dispersion algorithms are unable to precisely identify the starting and ending time of a fixation within a time window. The dispersion algorithm can only determine that the time window contained a fixation and its probable center location.



Dispersion Parameters	Description
Window width:	Selects the time window width for applying the dispersion algorithm in milliseconds. The default value is 100 ms.
Dispersion angle:	Sets the dispersion angle in degrees the gaze must remain within to be considered a fixation. The default value is 1 degree.

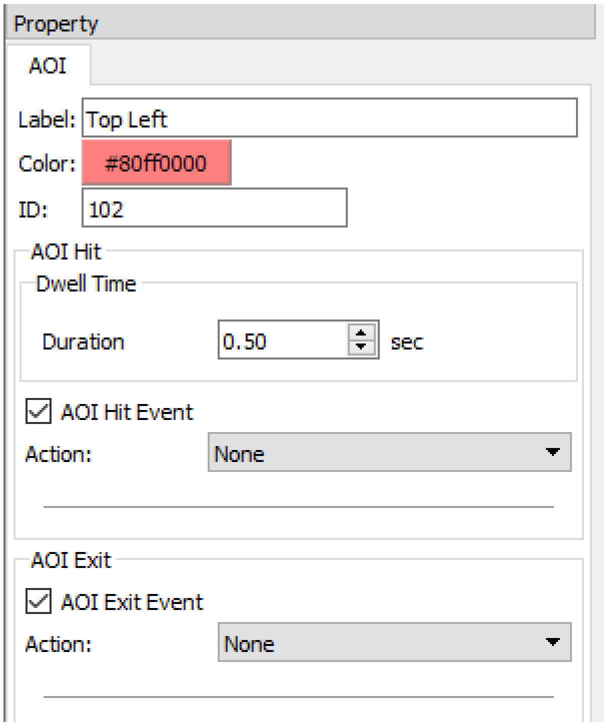
Velocity

Velocity algorithms identify fixations as periods where eye motion does not exceed a specific threshold. More often these algorithms are designed to detect saccades, smooth pursuit, and other motions along with fixations. A higher sampling rate eye tracker is required to accurately use a velocity based algorithm given the timing resolution necessary to accurately detect rapid changes in gaze angle. With superior temporal resolution, velocity algorithms are able to better identify fixation onsets, offsets, and duration and are also useful for categorizing other types of eye motions.

Velocity Parameters	Description
Velocity threshold:	Threshold in degrees per second that separates saccades from other eye movements. Default value is 20 degrees/sec.

Area of Interest (AOI) Editor

The Area of Interest (AOI) Editor is used for defining specific areas within a stimulus where the participant's gaze might be expected to fall and to measure how long the gaze was held within that AOI. Event marks may be automatically inserted when an AOI Hit or Exit occurs.

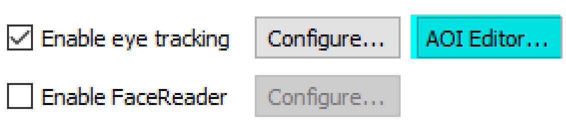


If "AOI Hit Event" is checked, an AOI entry event mark will be inserted into the graph when a subject's gaze moves into the bounds enclosed by the AOI and rmains within that AOI for the specified Dwell Time. If "AOI Exit Event" is checked, an event mark will be inserted when the gaze moves from inside the AOI to the outside (if the gaze had remained within the AOI long enough to be registered as a Hit).

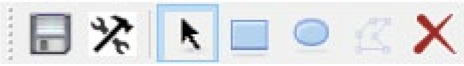
Multiple AOIs can be created for any given stimulus, **but please note:** although AOIs can technically overlap, overlapping is not recommended because not all AOI events will be recorded. Maintain space between AOIs!

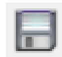
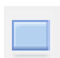
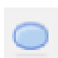
AOI Hit and Exit events may also be used to initiate the following actions; Next stimulus, Beep, Start stimulator, Stop stimulator, or Set digital output.

To open the AOI Editor, click the "AOI Editor…" button.

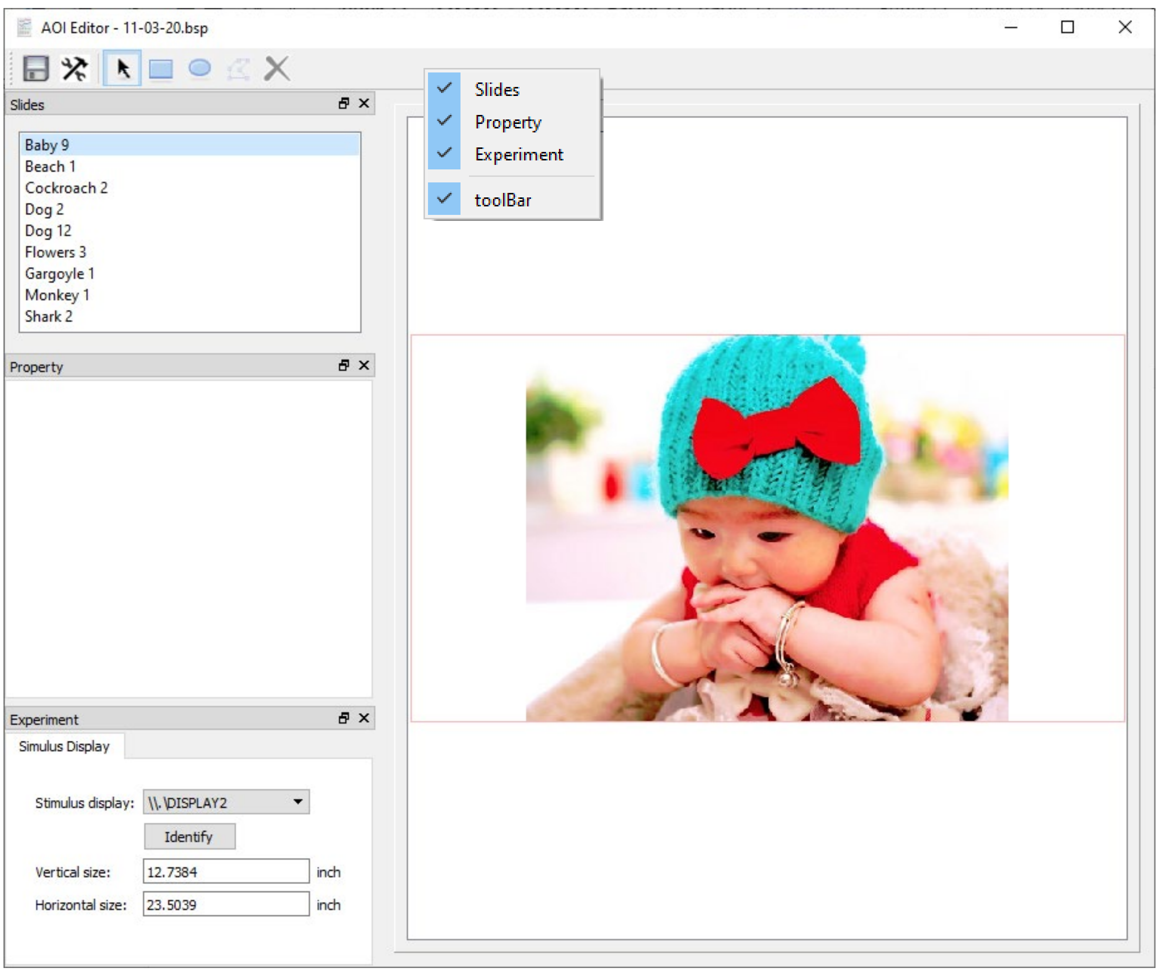


The AOI Editor Toolbar



	Save button. Saves the AOI edits for the experiment.
	Slides button. Shows or hides the list of slides (stimuli) in the AOI Editor.
	Selection tool. Use to select an AOI to resize, reposition, or edit the events or actions associated with AOI Hit and AOI Exit.
	Rectangle tool. Use this to create a square or rectangular area.
	Ellipse tool. Use this to create an elliptical area.
	Line or multipath tool. Use this to create a polygonal area.
	Delete tool. Use this to delete an AOI from the slide. An AOI must be created for this control to become active.

The AOI Editor Screen



Tip To show or hide the main toolbar, Slides, Property, or Experiment windows, right click in the gray toolbar area, and check/uncheck the desired item. (See above figure.)

After opening the AOI Editor, note the “Slides” pane in the upper left of the screen. This is where stimuli to be used in the Stimulus Presentation are listed and can be selected for defining the AOIs. The “Slides,” “Property,” and “Experiment” panes can also be detached from the window for a floating display if desired.

Property: This is the area where the properties for a defined AOI will appear by default.

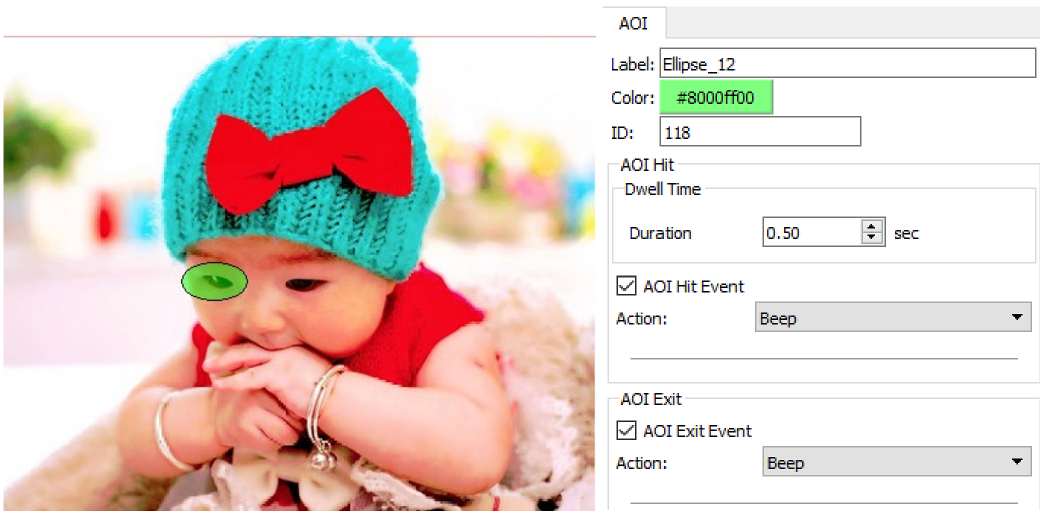
Experiment: Provides assignment of and information about the monitor that will be used for stimulus presentation.

Stimulus Display: The monitor where the presentation will be shown to the participant. This is normally a dedicated display in addition to the one the experimenter is using. The “Identify” button flashes a green screen on the monitor selected in the “Stimulus display” menu.

Vertical/Horizontal Size: The physical dimensions of the monitor selected for stimulus display (information only; not editable).

Defining Areas of Interest (AOIs)

1. Double-click a slide in the Slides list to display it in the viewing pane.
2. Click the Rectangle, Ellipse, or Multipath toolbar button.
3. Hold the mouse button down and draw a shape around the portion of the slide to encompass the desired area of interest. Below, an ellipse has been drawn over the infant’s right eye.



4. A colored shape appears over the defined area, and the AOI Properties dialog appears. This includes configurable options for the AOI.

Properties for the AOI include the following:

Label: The default title will include the shape of the selected AOI along with a sequence number. However, this field is editable and the selected title will appear in the Acq*Knowledge* graph and statistical reports.

Color: The color is editable by clicking the colored box, which opens a standard color picker.

ID: A sequential ID number assigned to the AOI. This value is also user-definable.

AOI Hit Dwell Time: This is the duration a participant’s gaze must remain within an AOI before a Hit event is created. The default is 0.5 seconds, but this can be set to any value greater than or equal to zero.

AOI Hit Event: Check this box to generate an AOI Hit Event to be inserted into the Acq*Knowledge* graph events bar. This event occurs when the participant’s gaze is detected within the AOI for the specified Dwell Time.

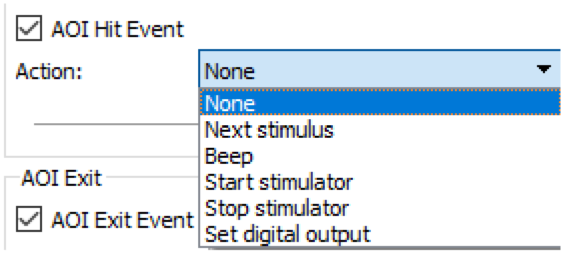
Action: Defines the action to take place when an AOI Hit Event is created. See below for more details about these actions.

AOI Exit/Exit Event: Check this box to generate an AOI Exit Event to be inserted into the Acq*Knowledge* graph events bar. This event occurs when the participant's gaze moves outside the AOI.

Action: Defines the action to take place when an AOI Exit Event is created. See below for more details about these actions.

Assigning Actions to AOI Hit and Exit events

The following actions can be assigned to AOI Hit and Exit events:

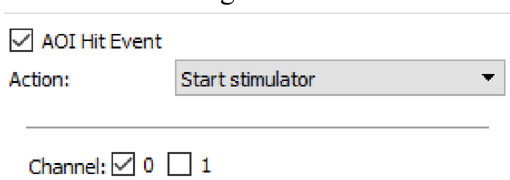


None When "None" is selected, no action is taken when AOI Hit or Exit events are detected.

Next stimulus Choosing "Next stimulus" will advance the presentation to the next item in the presentation sequence when AOI Hit or Exit events are detected.

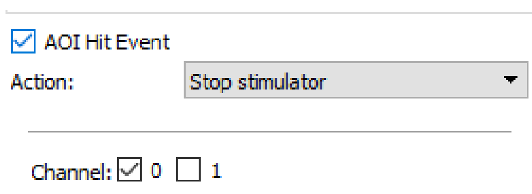
Beep When "Beep" is selected, an audible beep will be heard when AOI Hit or Exit events are detected. **NOTE**: The beep is generated by the computer system sound scheme. Make sure the computer sounds are enabled or the beep will not be audible.

Start stimulator When "Start stimulator" is selected, a stimulator driven by one of the MP160's analog outputs will start when AOI Hit or Exit events are detected. The stimulator must be set up in Acq*Knowledge* and connected to the appropriate Analog Output port on the AMI100D or STM100C with 'Source' switch set to Out 0 or Out 1 as appropriate. Enable "0" or "1" to select the Analog Out channel for this action.

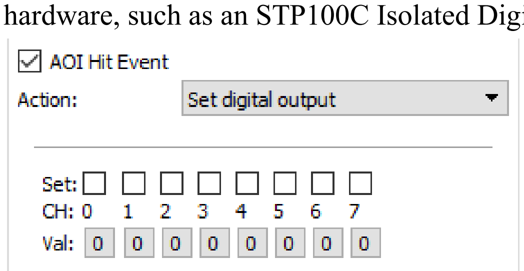


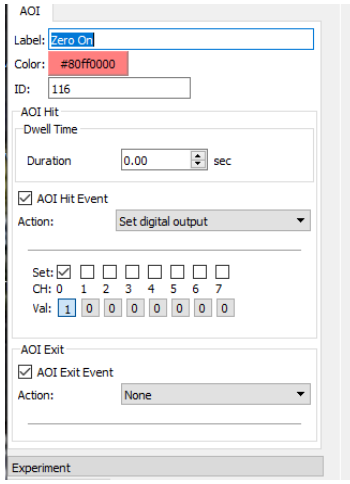
Tip The stimulator should be configured to start with the On/Off button. This can be configured by selecting "Use manual stimulator control" under the "Timing" section. Please refer to Chapter 9 for more information.

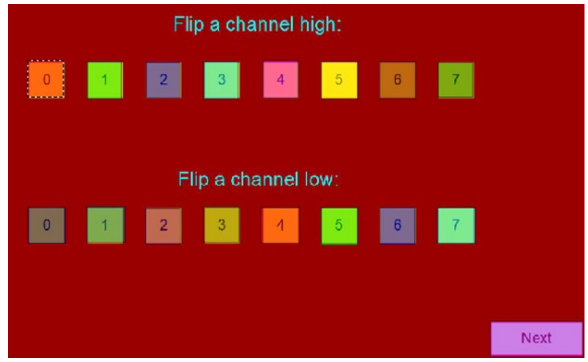
Stop stimulator When "Stop stimulator" is selected, the AcqKnowledge Stimulator will stop output when AOI Hit or Exit events are detected. Enable "0" or "1" to select the Analog Out channel for this action



Set digital output When "Set digital output" is selected, the digital channels can be toggled on and off when AOI Hit or Exit events are detected. This can be used to control external hardware, such as an STP100C Isolated Digital Interface.





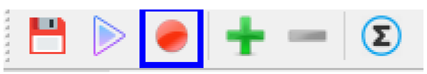


Calibration and Recording

Before recording eye tracking data, the Eye Tracker hardware must be calibrated for the experiment participant. It is recommended that the experimenter configure the presentation and observe data collection on a separate monitor from the one used for presenting stimuli to the subject.

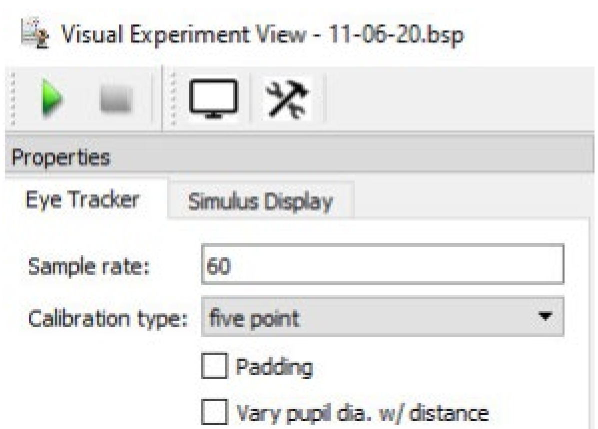
Before beginning, make sure the Eye Tracker is connected to a USB port and the participant is seated comfortably in front of the presentation monitor.

To begin Calibration setup in preparation for recording, click the red button in the Presentation Designer toolbar.



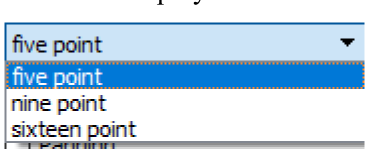
This action opens the Experiment View window, with the Eye Tracker Calibration tab enabled. A new Acq*Knowledge* graph window is also opened, unless a saved graph template was selected and opened prior to calibration.

Eye Tracker tab



Sample rate: This is the rate at which the processor is digitizing the images of the participant's eyes. This value is not editable and is determined by the connected EyeTech hardware's capability.

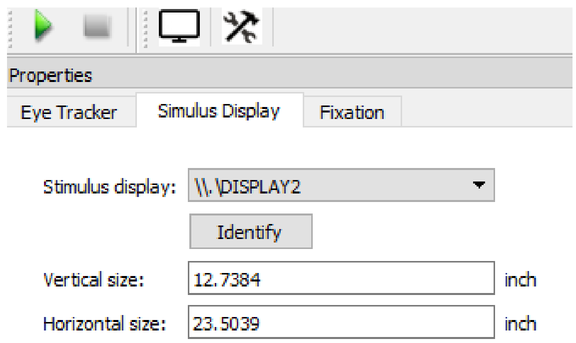
Calibration type: This menu selects the number of visual calibration points to be presented to the participant in the Stimulus Display. The options are five point, nine point, or sixteen point. The default setting is five point. (The calibration cross will be presented at five different areas of the Stimulus Display screen: the center and four corners.)



Padding When the subject blinks or the tracking hardware otherwise loses the ability to identify the gaze direction, the eye position values will hold at the last known location when this box is checked. When it is not checked, gaze position values will be zero when tracking is lost.

Vary pupil dia. w/distance The eye tracker system infers the subject's distance from the monitor and can report this distance as well as the pupil diameter as optional data channels. When this box is checked, the subject's distance from the monitor is used to "correct" the pupil size if the subject moves closer to or farther from the monitor. This may improve the accuracy of pupil diameter recordings if such data are collected.

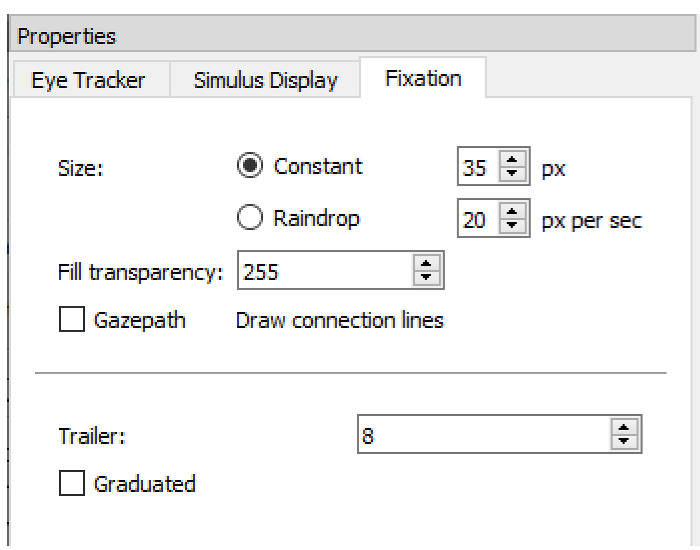
Stimulus Display tab



The Stimulus Display tab contains options for choosing the monitor to be used for the stimulus presentation. This will also be the monitor used to perform Eye Tracker calibration. The controls here are the same as presented in the last dialog box of the eye tracking setup wizard.

Stimulus display:	Choose the stimulus display from the detected monitors available in the pop-up menu.
Identify:	Projects a green background onto the selected stimulus display for approximately two seconds to verify which monitor is selected for the stimulus display and Eye Tracker calibration
Vertical size:	Indicates the viewable vertical area of the selected stimulus display.
Horizontal size:	Indicates the viewable horizontal area of the selected stimulus display.

Fixation tab



The Fixation tab becomes available after the green Start button  is clicked but only if either the dispersion or velocity fixation algorithm options has been selected in the Eye Tracker Setup Wizard.

These parameters affect how the gazepath and fixations are displayed to the experimenter (the gazepath is not displayed on the monitor displaying stimuli to the subject).

Size:

Constant: Fixations are displayed as solid dots and the size remains constant across fixations. Dot size may be adjusted; "px" specifies the diameter of the dot in pixels.

Raindrop: In Raindrop mode, the size of the fixation dot is proportional to the fixation duration. The fixation size can be modified using the "px per sec" control. This control sets the relationship between fixation duration and dot size.

Fill transparency: Adjusts the opacity of the fixation dot. Range is from zero (invisible) to 255 (fully opaque).

Gazepath: Enables the gazepath to be displayed as a connecting line between fixations.

Trailer: If "Graduated" is checked, this setting how quickly the fixations/gazepath fade. When a new fixation occurs, the dot representing it has the opacity specified by the fill transparency. If user checks "Graduated", fixations/gazepath fade with time and then disappear. Allowable values for trailer raange from zero (fixations/gaze instantly fade) to 99 (fixations/gaze barely fade at all).

Graduated: Choosing this setting will display the gazepath and fixation to become more transparent as time progresses.

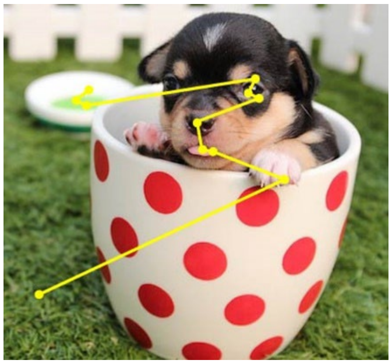
Fixation Only (Constant)

The fixation only drawing method searches through the fixation time interval and draws an overlay on the stimulus image of all fixations detected within the time interval, all at 100% opacity. In the image example, fixations are drawn in yellow. In the application, the fixations are green.

Graduated Fixation (Raindrop)

In addition to their location in the stimulus, each fixation also has an associated onset time. The graduated fixation display uses transparency of the fixation overlay to convey where in the fixation time interval it occurs. A fixation occurring at the precise end of the time interval will be drawn with 100% opacity. That is, it obscures the stimulus image underneath it. A fixation occurring at the precise beginning of the time interval will be drawn with the user specified opacity, allowing the underlying stimulus image to be partially visible beneath the fixation indicator. Fixations that are "clustered" close in time will be drawn with a similar opacity. In the example at left, fixations are overlaid in a graduated fashion from 65% opacity at the earliest time of the interval. The variations in opacity indicate both that the earliest fixation was on the lower left in the grass with the final on the blurred bowl in the background with a fixation "pace" over the entire fixation interval that is fairly consistent across the interval.

Gazepath

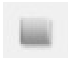
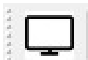


The gazepath display is similar to the fixation only display. All fixations within the fixation time interval are drawn as circles with lines drawn between the center of each fixation, the path starting from the center of the earliest fixation within the time period and ending at the last fixation within the time period. Fixations and lines are all drawn at 100% opacity. In the image example, the gazepath is in yellow (gazepaths are green in the actual display).

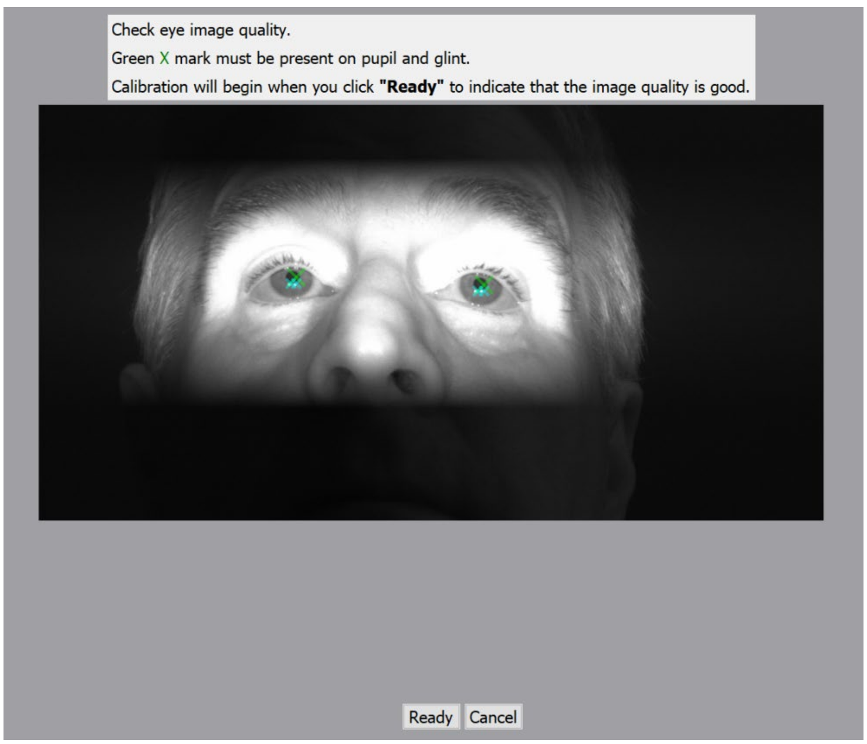
Graduated Gazepath

The graduated gazepath display is an extension of the graduated fixation display with connecting lines drawn in the overlay between the center of each fixation. For each pair of fixations, the connecting path line is drawn at the opacity of the earliest fixation time. This allows the intensity of the gazepath itself to reflect the time and speed at which the subject changed their point of interest during the fixation time interval.

Visual Experiment View Toolbar

	Start button to begin calibration.
	Stop button to abort calibration.
	Shows the selected stimulus display in full screen with the following instruction: Eye Tracker stimulus display full screen. Close display: Alt-F4, switch back: Alt-TAB.
	Toggles the Properties window view on/off.

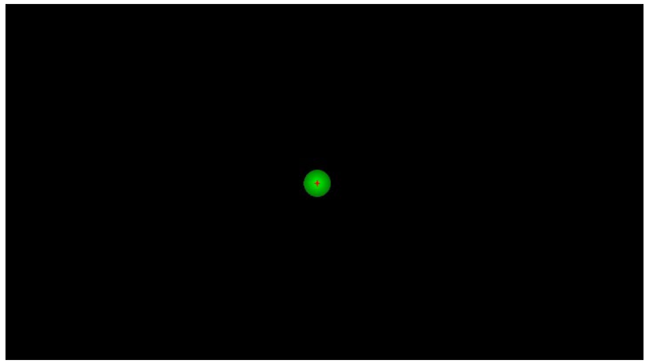
To begin the Calibration sequence, click the green Start  button on the toolbar.
Have the subject follow the onscreen instructions. Click “Ready” when the subject is prepared to look at the fixation points or “Cancel” to abort the experiment.



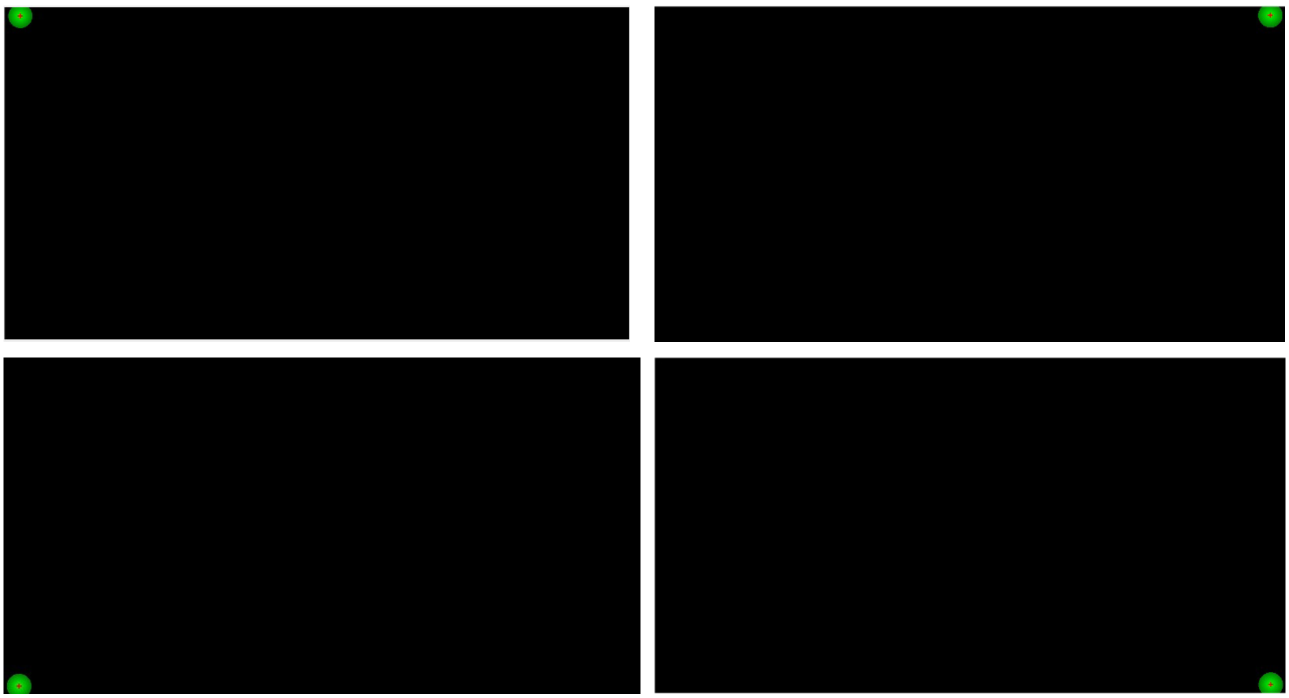
Special Notes

- Eyeglasses, excessive light, reflections, drooping lids, excessive blinking can affect the quality of the calibration. Make sure the green X marks are clearly visible over the pupils.
- Infrared and fluorescent lights can also affect the quality of the eye tracking signal and result in poor calibration results.
- Eye Track bar works best when the subject’s eyes are within a finite volume in a three dimensonal space in front of the monitor. Subject’s eyes should be about 0.75 meters away from the monitor. Positioning the subject nearer or further away can have a dramatic effect on the hardware’s ability to correctly compute gaze angle. Green LEDs on the Eye Track bar indicate when each of the two pupils are captured. When the subject is positioned well, the LEDs should turn off only when the subject blinks.

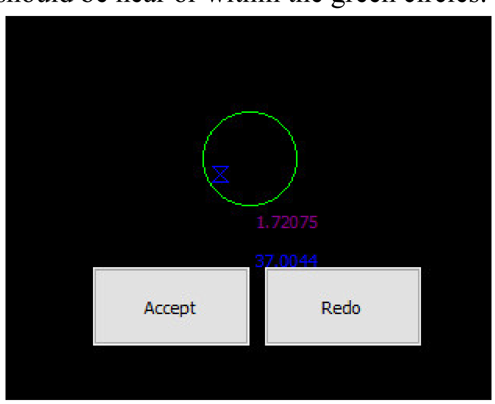
After clicking "Ready," the calibration screen will appear.



Have the subject look at each fixation point (the green circle) as soon as it appears and continue fixating on that point until it disappears. The images above and below indicate all points used when "five point" calibration is selected.



At the end of calibration, the X's should be near or within the green circles. If not, click "Redo."

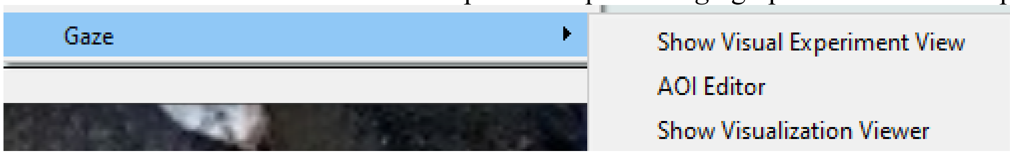


Accepting the calibration result will start the experiment (a three second onscreen countdown will cue the participant.)

At the conclusion of the presentation, the Acq*Knowledge* acquisition will stop. The Eye Tracking data will will appear in the graph along with any other physiological data that was acquired.

Eye Tracking Data Analysis

Select MP160 menu > Gaze in the completed Acq*Knowledge* graph to access these options:

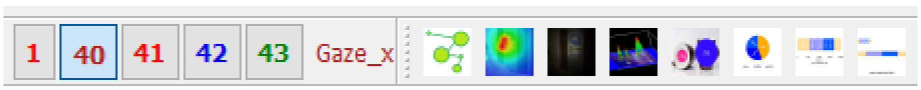


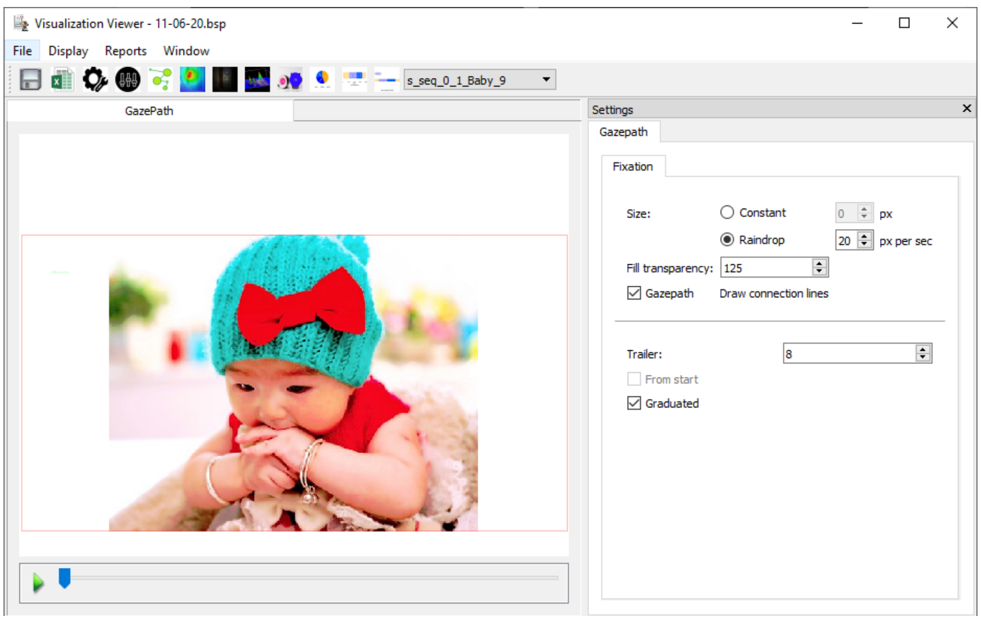
Note: The following Edit menu items are disabled in Stimulus Presentation Acq*Knowledge* graphs because executing them could interfere with proper alignment of eye tracking and other data:

Cut	Clear	Insert Waveform	Remove Last Appended Segment
Paste	Clear All	Remove Waveform	

Visualization Viewer

With the Acq*Knowledge* graph open, choose MP160 > Gaze > Show Visualization Viewer. The Visualization Viewer can also be accessed by selecting the data (or a portion of data) with the I-beam cursor and selecting one of the Visualization toolbar buttons for gazepath, heat map, luminance map, attention map, AOI KPI, pie chart, scarf plot, or string plot; these buttons appear after the graph window has been closed and re-opened.





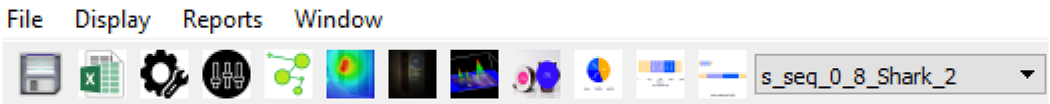
The Visualization Viewer allows the Gazepath Fixation settings to be modified for better viewing during analysis and includes a video-style scrollbar that synchronizes the stimulus and AOI display with the Eye Tracking graph data.

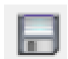
Other tools available in the Visualization Viewer:

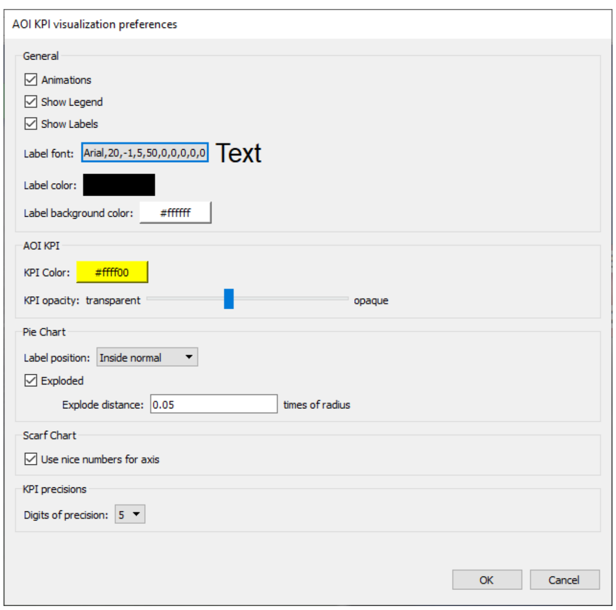
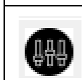
- Attention Maps
  - Heat map
  - Luminance map
  - 3D surface map
- Area of Interest (AOI) Reports
  - Pie Chart – recording Key Performance Indicators (KPIs) for Areas of Interest
  - Scarf Plot
  - String Plot

- Combining eye tracking metrics with physiological data: for instance mean heart rate and total time on the AOI/time of first hit in one single Excel report

Visualization Viewer Toolbar



<table>
<tr><td></td><td>Saves the selected AOI map or chart as a *.jpg file.</td></tr>
<tr><td></td><td>Opens the statistical report setup dialog for generating a spreadsheet output of the AOI summary, dwelling sequence, and/or fixations sequence.


The report can be output as:
Create a temporary file—generates a spreadsheet file that is viewable but not saved.
Ask for spreadsheet filename and location—opens a save dialog box for selecting a location for saving the report spreadsheet.
Open spreadsheet with report(s)—report spreadsheet opens automatically when this option is checked.</td></tr>
<tr><td></td><td>Opens the AOI Visualization Preferences setup dialog for setting appearance, colors, label position of the AOI KPIs.

</td></tr>
<tr><td></td><td>Opens the Visualization Parameters setup screen or Settings pane depending on which window is on top.</td></tr>
</table>

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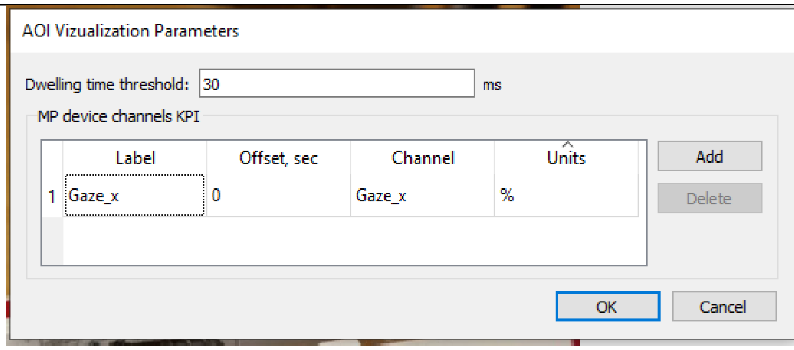
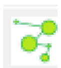
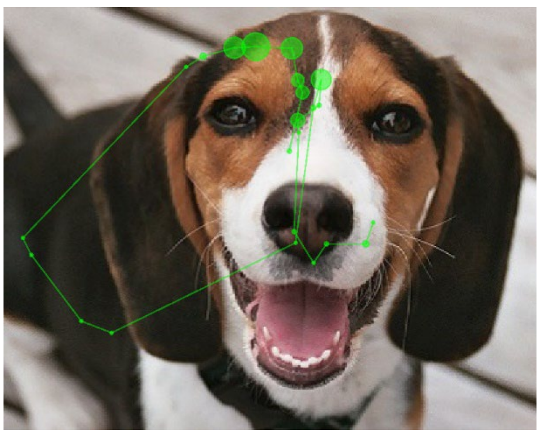
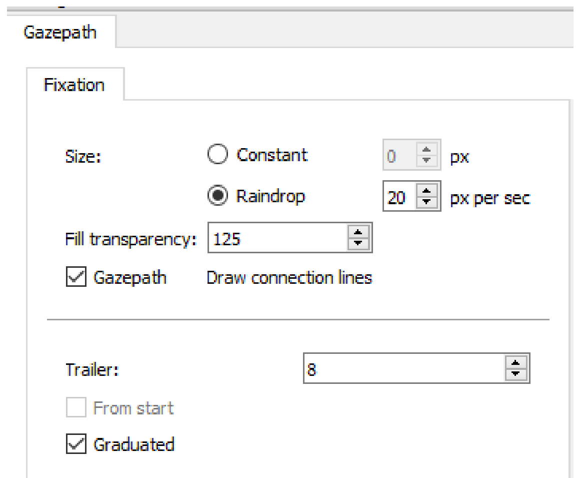
<tr>
<td></td>
<td>


Above is the KPI parameter input window. Add/Delete buttons allow new KPIs to be added or old ones to be removed from analysis. KPIs can be derived from any channels in the graph window. Offset is for variables, such as skin conductance level, that exhibit delayed responses. A positive offset for a KPI shifts the window toward later times. For instance, if a subject's gaze was within an AOI from t = 1 until t = 3 seconds and the Offset for a given KPI was 1 second, reports of the KPI would indicate its level from t = 2 until t = 4 seconds for the given AOI.
</td>
</tr>
<tr>
<td></td>
<td>
Opens the Gazepath overlay recorded during the presentation. Gazepath Settings on right.





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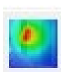
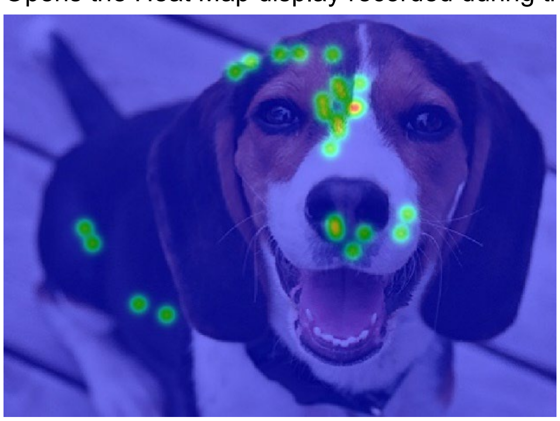
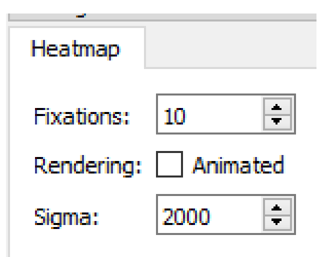
<td></td>
<td>
Opens the Heat Map display recorded during the presentation. Heatmap Settings on right.





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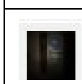
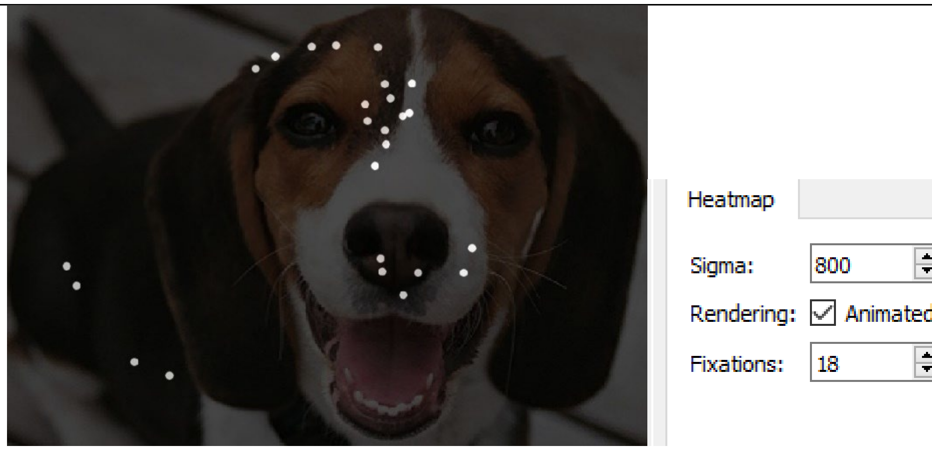
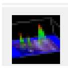
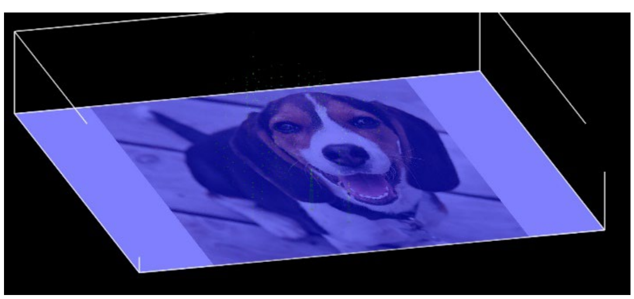
<td></td>
<td>Opens the Luminance Map display recorded during the presentation. Luminance Map Settings on right.</td>
</tr>
</table>

	
	Opens the Attention Map display recorded during the presentation. Attention Map Settings at right. 
	Opens the AOI KPIs recorded during the presentation.

<table>
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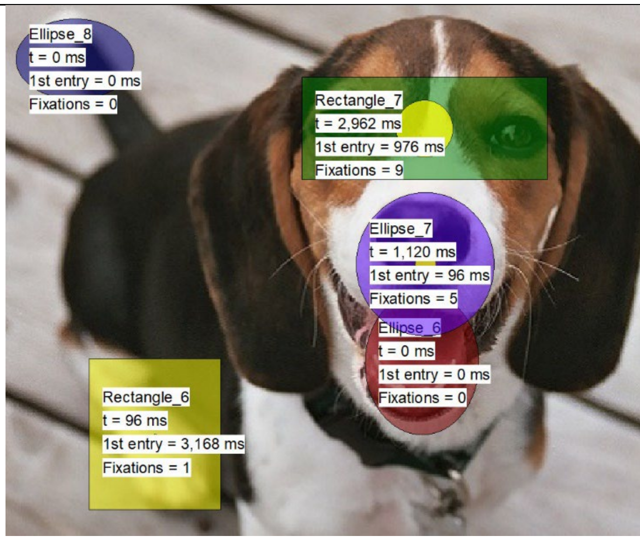
<td></td>
<td>
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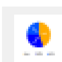
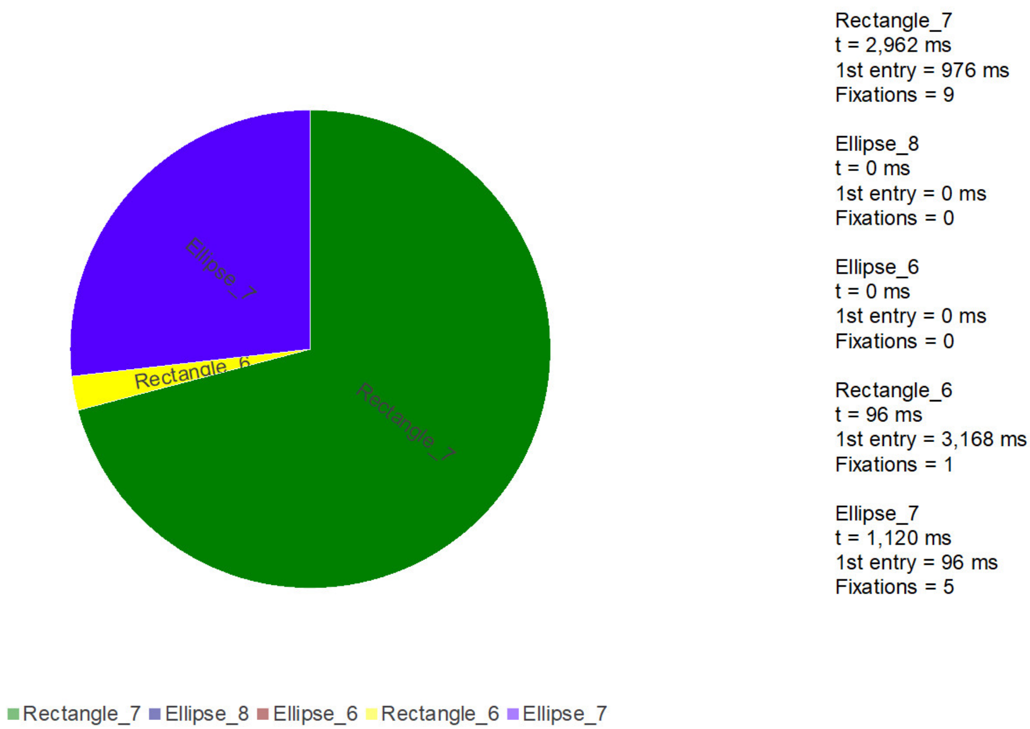
<td></td>
<td>Displays Pie Chart of AOIs recorded during the presentation. Mouse over an individual section of the pie chart to display statistics for the KPI represented by that sector.

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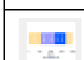
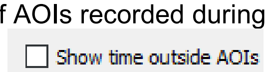
<td></td>
<td>Displays Scarf Plot of AOIs recorded during the presentation. Areas outside of AOIs can also be included by checking 
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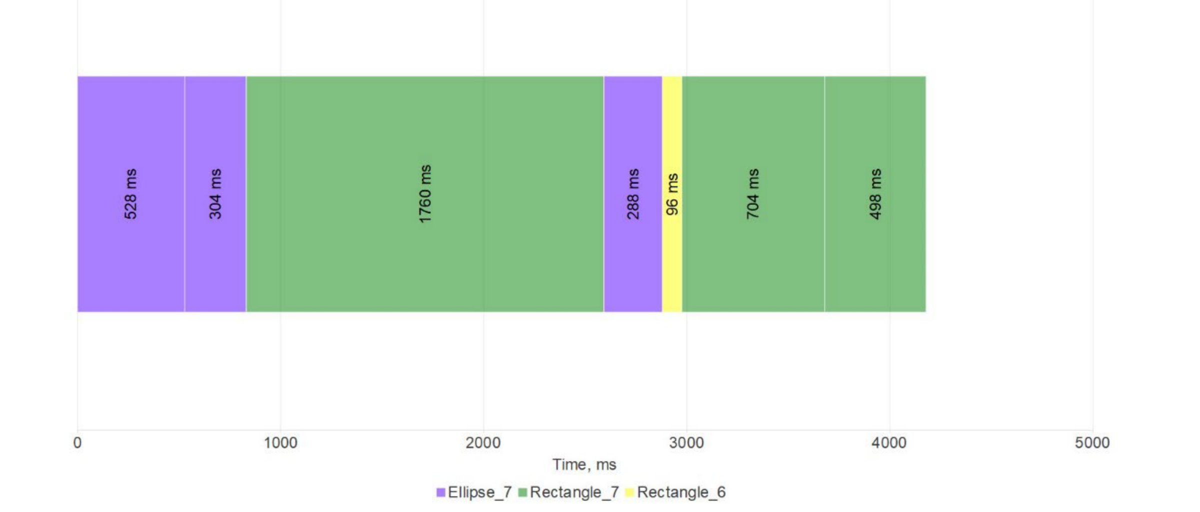
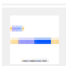
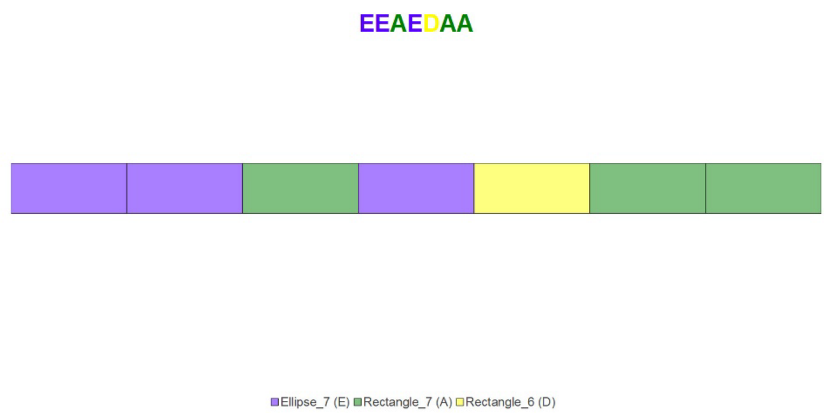
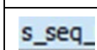
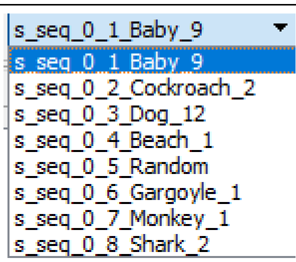
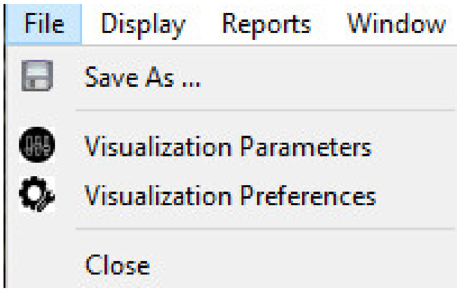
<tr><td></td><td></td></tr>
<tr><td></td><td>Displays String Plot of AOIs recorded during the presentation.
</td></tr>
<tr><td></td><td> Stimuli Sequence—use the pop-up menu on the toolbar to select stimuli for individual display in any of the Visualization Viewer options.</td></tr>
</table>

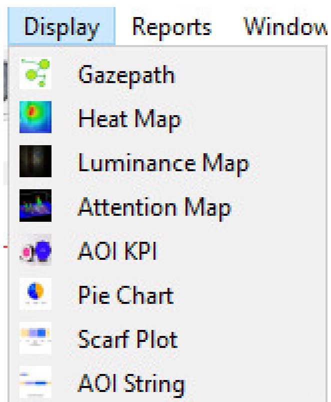
Where appropriate, the “Animated” checkbox determines whether fixations are updated as the gazepath video is played or fixations for entire slide are drawn all at once. If animated, the number of fixations shown may be edited. The “Sigma” parameter for Heat Map, Luminance Map, and Attention Map affect how quickly the representation of a fixation fades with distance from the center. Larger values produce larger representations of fixations of a given duration.

File Menu



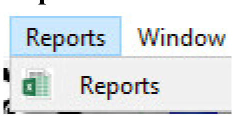
The Visualization Viewer File Menu provides an alternate method for saving the selected overlay view as a *.jpg file and for accessing the Visualization Parameters and Preferences.

Display Menu



The Display Menu provides an alternate method for accessing the Gazepath, various overlays, and charts.

Reports Menu



The Reports Menu provides an alternate control for generating statistical reports. Selecting this will display the following popup window:

After running reports, a notification will show that the statistical reporting has been completed, and an excel sheet is created with the selected types of reports.

At the top of any report is a timestamp indicating when the report was created, the filenames and locations of the stimulus presentation (.bsp) file and data (.acq) file along with statistics about the data acquisition. The rest of the spreadsheet will contain any or all of AOI Summary, AOI dwelling sequence, and Fixations sequence depending on which of the Reports type checkboxes are checked when the report is created.

AOI Summary

This report is a high-level overview about each image in the presentation and associated AOIs within those images.

The following labels appear in the AOI Summary report:

Stim Image	The Name of the stimulus element
Start Time/End Time	The time markers for how long the image was displayed to the subject. Measured in milliseconds from the start of recording.
All AOIs dwell time, ms	Sum of the total dwell time on all AOIs in the image. Measured in milliseconds. Gaze dwells within an AOI from the time the gaze enters until it leaves the AOI. This statistic is independent of fixations. Gaze can dwell within AOI without ever fixating any location within it.
AOI ID/Label	Corresponding numerical and descriptive identifiers of the AOI within the image.
Dwell time, ms	Time subject was recorded looking within an AOI. Measured in milliseconds.
# of entries	Number of times a subject looked at the specific AOI within the image.
Time to first entry, ms	Amount of time after the image was displayed before the subject gazes at the AOI. Measured in milliseconds.
Min/Max/Mean Dwell time, ms	The shortest amount of time, longest amount of time, and average duration of all dwell times for the AOI. These numbers will all be the same if there is only one entry into a specific AOI. Measured in milliseconds.
# of fixations	Number of fixations within an AOI. Note as above that dwelling time and fixation are independent except that it is impossible to have a fixation within an AOI if there is no dwell within AOI. A dwell without fixation is possible as is multiple fixations within a single dwell. The latter occurs if the subject fixes their gaze, makes a saccade, and fixes their gaze again all without the gaze leaving the confines of the AOI.
Time to first fixations, ms	Amount of time after the image was displayed before the subject fixated on a point within the AOI. Measured in milliseconds.
Total fixations time, ms	Sum of the fixation times within an AOI
STD	Standard deviation of time in milliseconds between dwell times. This value will be 0 for all events with 1 entry.

AOI dwelling sequence

The generated report displays detailed information on dwell time and events within Areas of Interest for images in a presentation.

The following labels appear in the AOI dwelling sequence report:

Stim Image	The image displayed with Areas of Interest
Start Time/End Time	The time markers for how long the image was displayed to the subject. Measured in milliseconds from the start of the data recording.
All AOIs dwell time, ms	Sum of the total dwell time for all AOIs in the image. Measured in milliseconds. Note: all areas not encompassed by an AOI are Background. This statistic is the sum of all non-Background dwellings.

AOI ID/Label	Corresponding numerical and descriptive identifiers of the AOI within the image. Space not enclosed within an AOI is listed as “Background” with an AOI ID of -1.
Dwell time, ms	Time subject was recorded looking at an AOI. Measured in milliseconds.

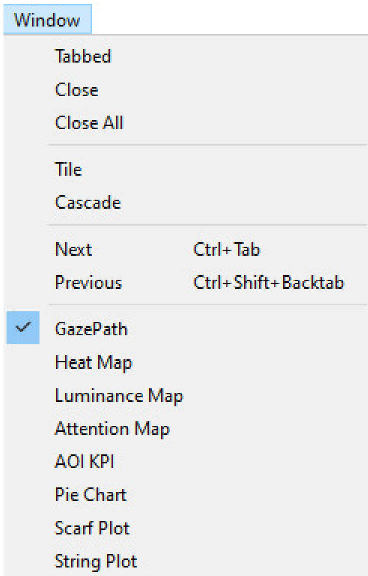
Fixations sequence

The report will display a list of all fixations in each image, with columns indicating if the fixations were within an AOI or not. Space not enclosed within an AOI is listed as “Background” with an AOI ID of -1.

The following labels appear in the Fixations sequence report:

Stim Image	The image displayed with Areas of Interest
Start Time/End Time	The time markers for how long the image was displayed to the subject
Fixation Time, ms	Time that the subject fixed their gaze at a particularlocation. Time is measured in milliseconds. Note that this is recorded differently from a Hit Event as the time is from the start of fixation. Also note that Fixation Times are expressed with respect to the start of recording.
Fixation X/Y coord	X and Y coordinates of fixation centers. Units are stimulus monitor pixels indicating distance from the left edge (X) and top (Y) of the monitor.
Fixation Duration, ms	Length of time the subject is recorded fixated around a single point
AOI ID/Label	Corresponding numerical and descriptive identifiers of the AOI within the image.

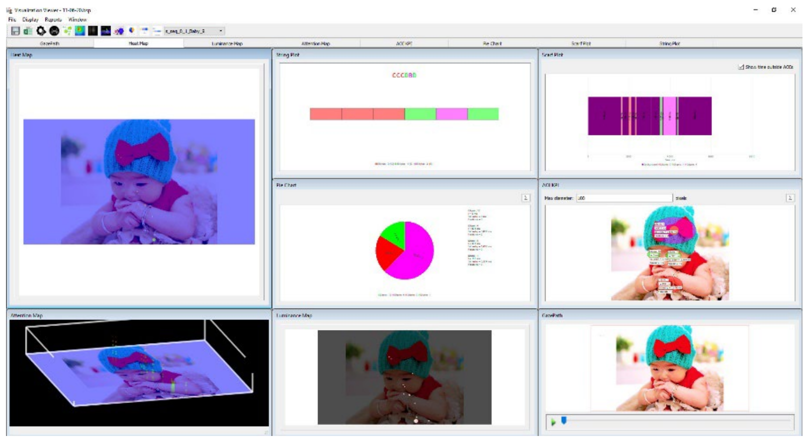
Window Menu

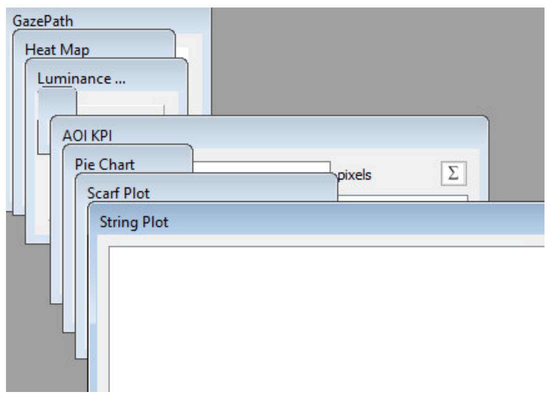


The Window Menu provides options for changing the display of the visible Visualization Viewer options.

Deselecting "Tabbed" allows the various map overlays to be displayed as individual resizable windows.

Map overlays can be tiled or cascaded for viewing more than one at a time. Tiled and cascaded examples of maps and charts are shown below.





Chapter 34 ET Vision Eye Tracking

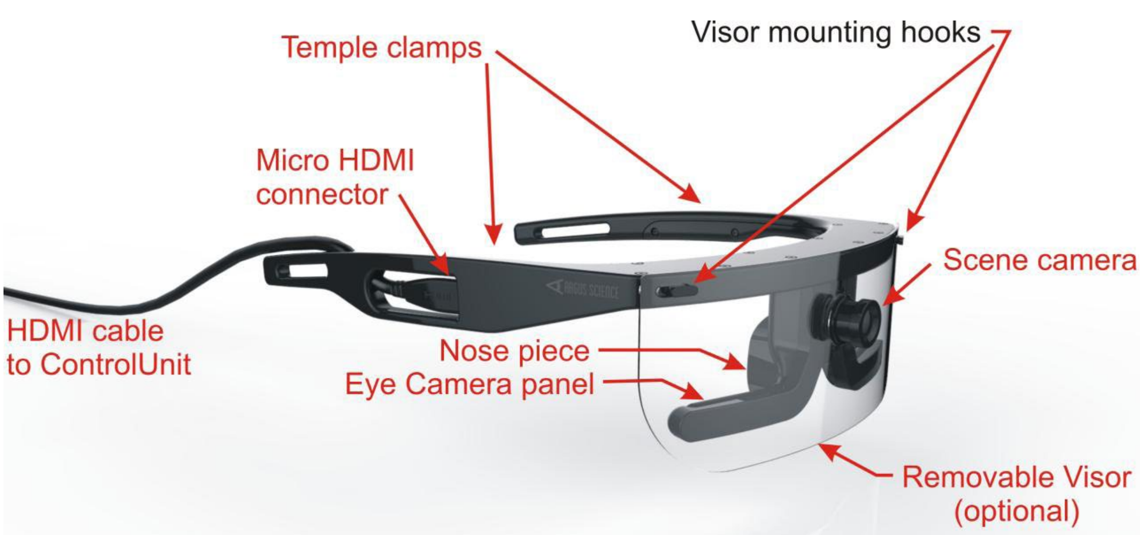
This licensed feature enables Acq*Knowledge* users to integrate ETVision eye tracking data and associated video into Acq*Knowledge* in real time. The ETVision System consists of Argus Science Eye Tracking Eyeglasses and ETVision software and the Eye Tracking data is ported into Acq*Knowledge* via a TCP connection. Up to 52 channels of eye tracking data are supported.

NOTE: To achieve the expected performance, ETVision must run on a PC (usually a laptop) with the following minimum specifications:

- CPU: Intel i7-8750H
- OS: Win10 Pro 64-bit
- Memory: 8 GB DDR4 RAM
- Wireless: 802.11ac
- Graphics: Nvidea GeForce GTX1060 – 6GB GDDR5 Memory
- Features: 10/100/1000 LAN, 2X USB3, SD Card Reader, Audio (Mic & Speaker)

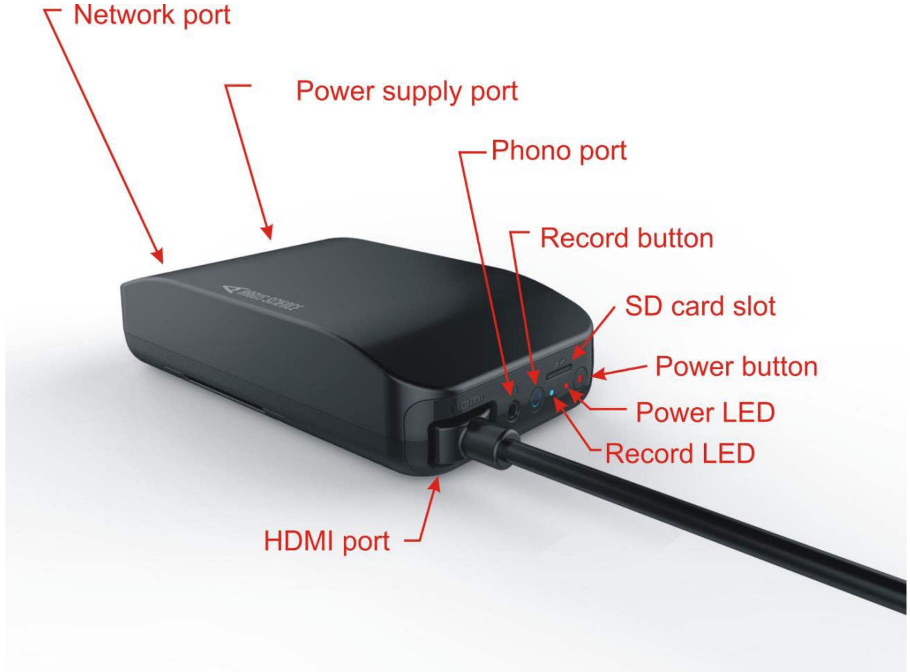
ETVision Eyeglasses and Controller

The lightweight Argus Science Eye Tracking eyeglasses (wearable optics) can be worn over presecription glasses and contain miniature rear facing "eye cameras" (to show the participant's eyes in the monitor display) and a forward facing "scene camera" that views the scene in front of the participant. A built-in microphone is also included.



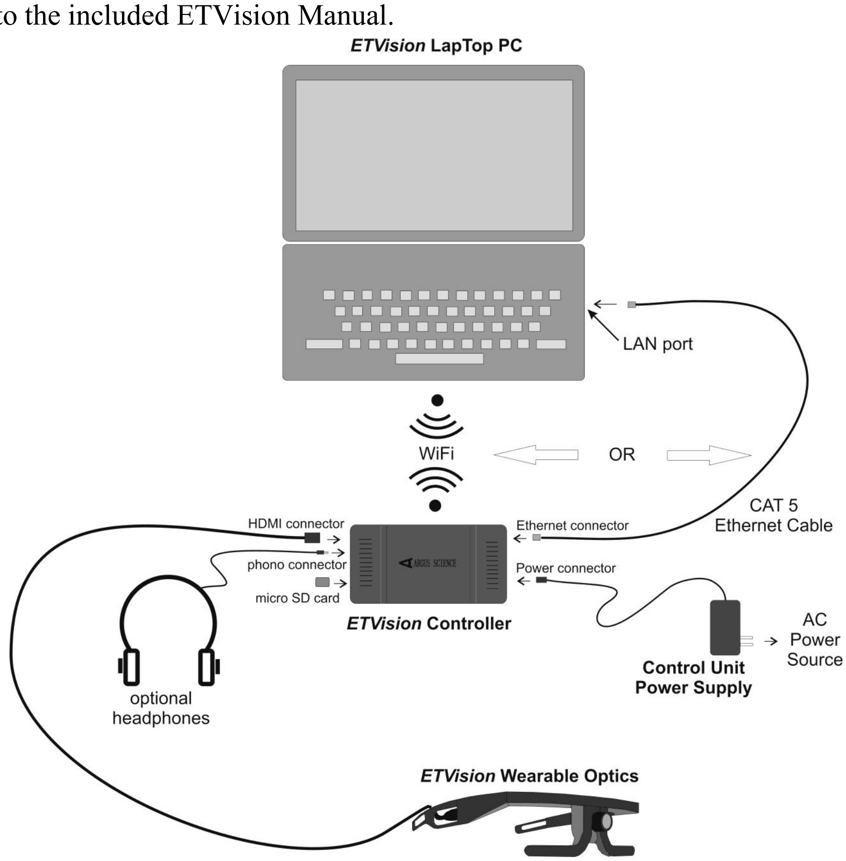
ETVision Eye Tracking Glasses

ETVision Controller

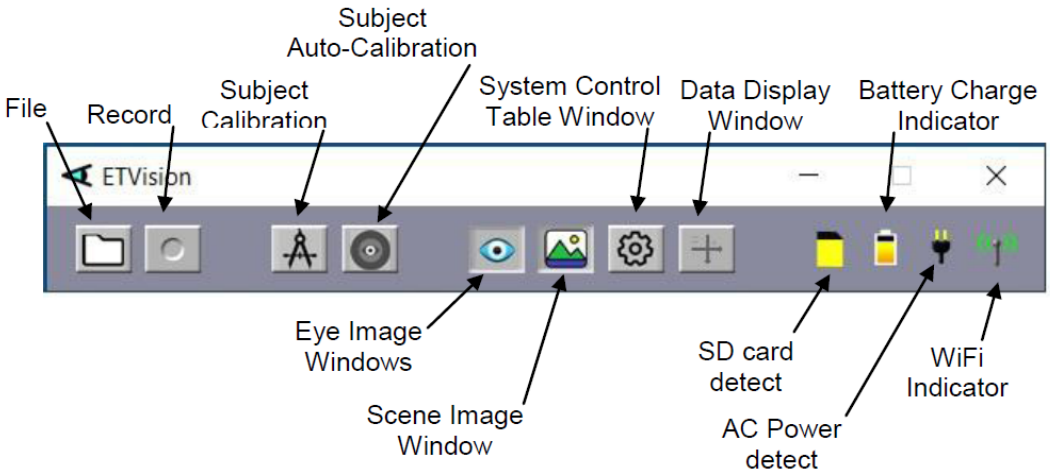


The ETVision Controller connects to the Eyeglasses via a HDMI cable. The controller is connected to the computer using the LAN port and standard LAN cable. Alternately, the controller can record video and audio data directly to an included micro SD card, which can be copied to the computer later. This allows for complete autonomy for participants to acquire eye tracking and scene data while taking a walk, driving, or engaging in other activities outside the lab.

A basic connection diagam is included below. For detailed Eyeglasses/Controller connection and calibration information, refer to the included ETVision Manual.



ETVision Software



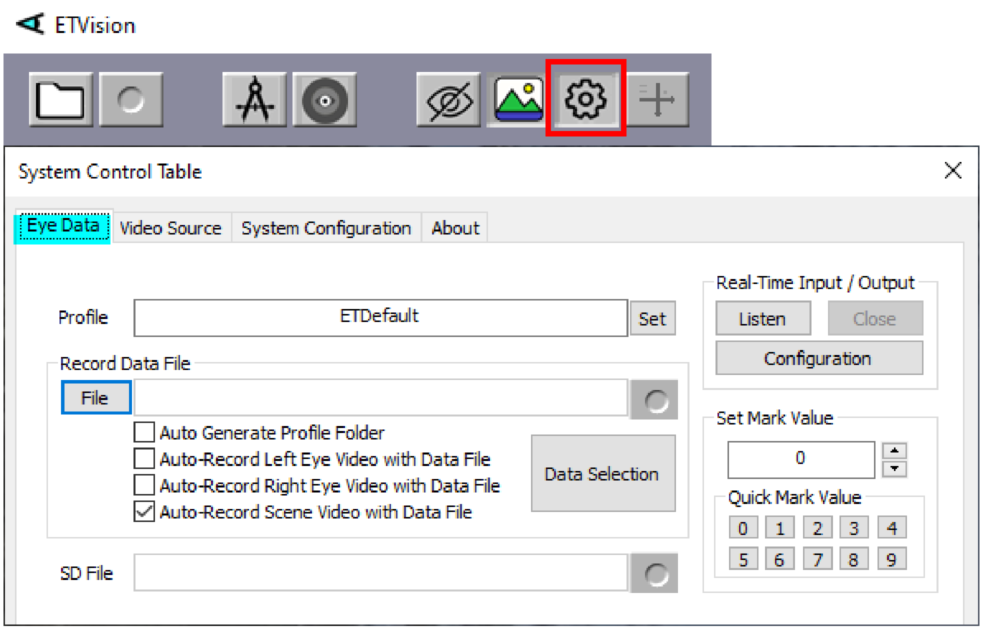
ETVision Software Toolbar with ETVision Eyeglasses connected

Eye Tracking Recording and Playback Basics

NOTE: In order to preserve timestamp accuracy when using ETVision with Acq*Knowledge* software, open the ETVision software before launching and configuring Acq*Knowledge*.

After ETVision Eyeglasses connection and calibration (refer to the ETVision Manual), use the following steps to set up for a basic recording. For full recording details, refer to the ETVision Manual.

Click the **System Control Table** toolbar button. Make sure the **Eye Data** tab is selected.



If recording an Eye Tracking data file to disk:

1. Click the File button, or click the toolbar icon and choose a directory for saving the data file (outputted as an *.eyd file or *.csv file). This action will change the File button to a Close button and will illuminate the **Record** button, as shown below:

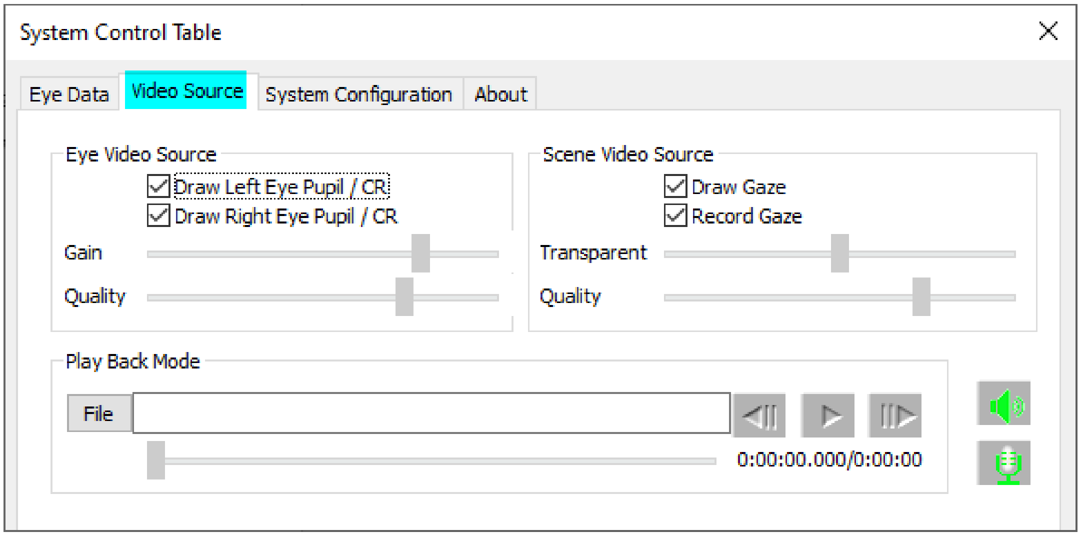
2. Clicking the red button (or the red button on the ETVision Toolbar) will start the Eye Tracking recording.

To record to Micro SD Card, see the instructions on page 41 of the ETVision Manual.

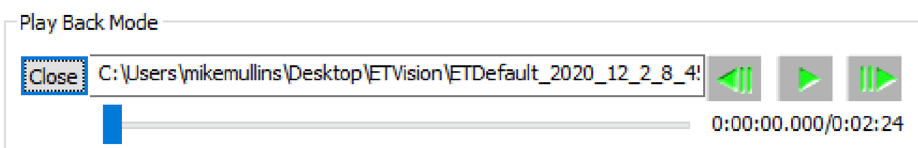
To Playback an existing Eye Tracking file:

The “Play Back Mode” controls are used to play and process video from *.emv type files recorded on SD card by the *ETVision* Controller. It’s recommended to copy *.emv files onto the hard drive before opening them for Play Back.

1. Click the Video Source tab in the System Control table window.



2. Click the File button and navigate to the directory where the *.emv file is saved. The File button will toggle to a Close button and the playback controls will illuminate.

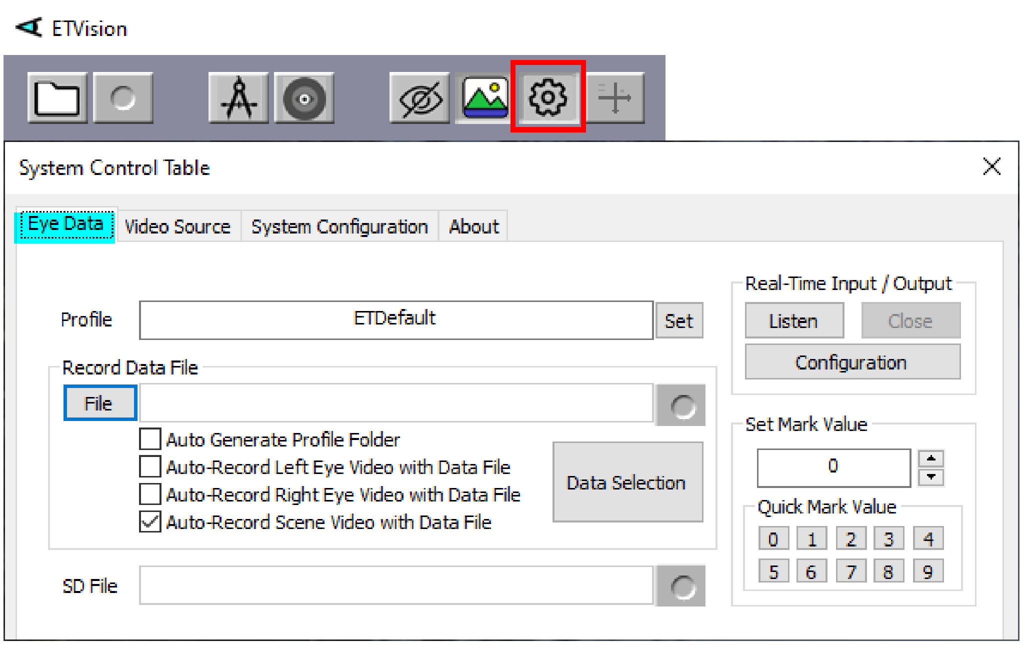


3. Click the center green button to play back the video.

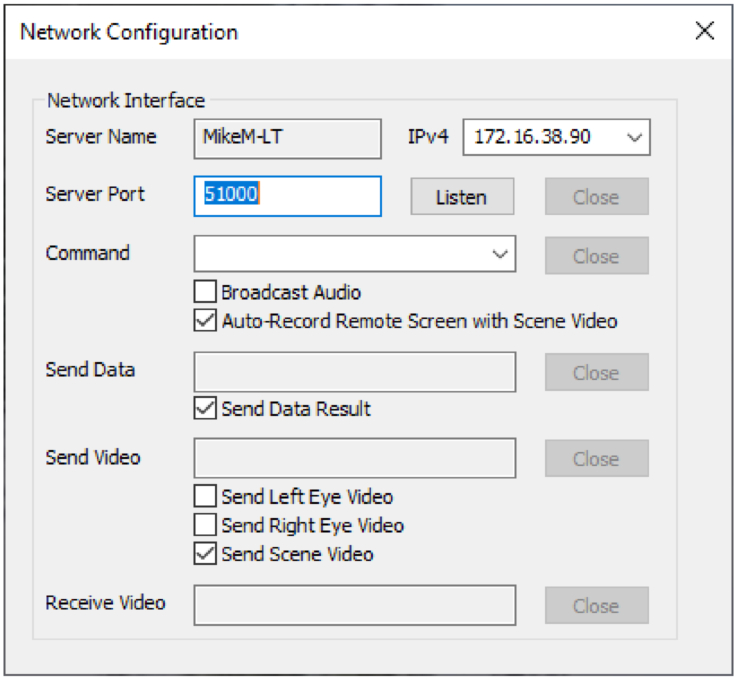
See the ETVision Manual for full details on Play Back operation.

Setup for Transferring Live or Pre-recorded Eye Tracking Data into Acq*Knowledge* for Capture:

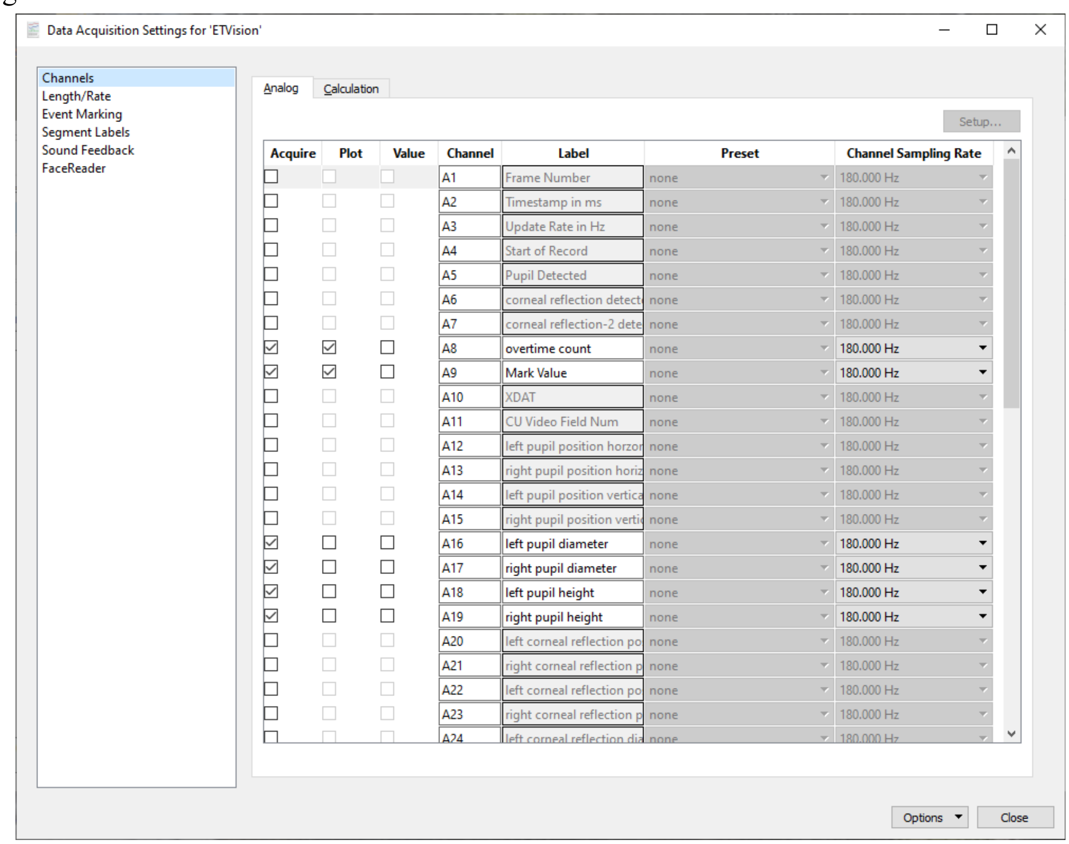
1. Launch **ETVision** and click the System Control Table toolbar button. Make sure the **Eye Data** tab is selected.



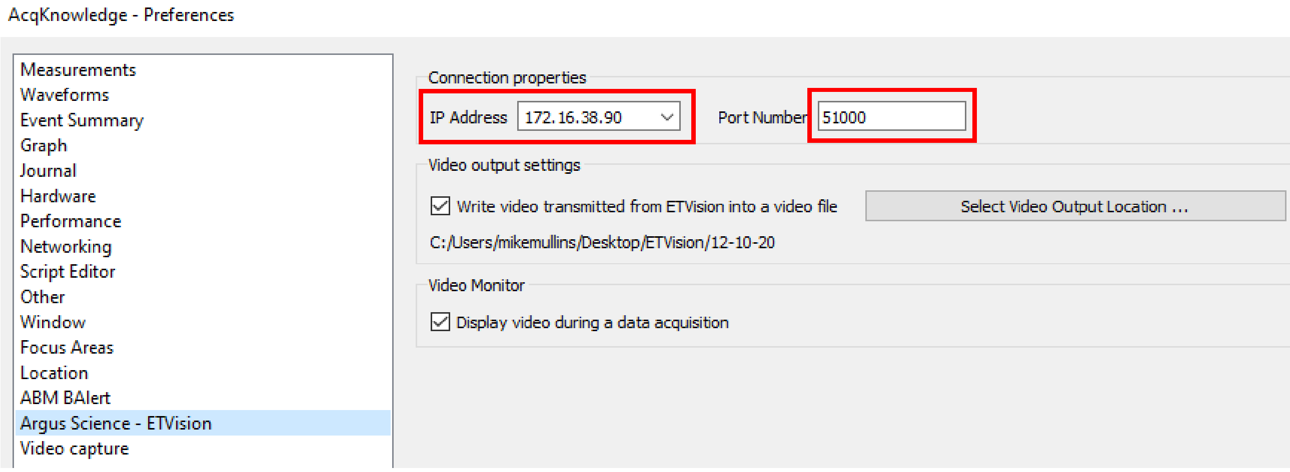
2. Click **Configuration** to open the **Network Configuration** dialog.



3. Click **Listen**. The ETVision software is now configured to transmit eye tracking and video data to the Acq*Knowledge* application. Make a note of the IPv4 address. The same address will need to be selected in the Acq*Knowledge* > **Argus Science ETVision** Preferences.
   - The **Send Video** options are used to select the ETVision video stream to display in Acq*Knowledge* over the network.
4. Launch **Acq*Knowledge*** and select the desired ETVision channels to record in “Data Acquisition Settings > Analog Channels.”



5. Choose Display > Preferences (or click the Preferences toolbar icon in Acq*Knowledge*) and select the **Argus Science – ETVIsion** setup preference.



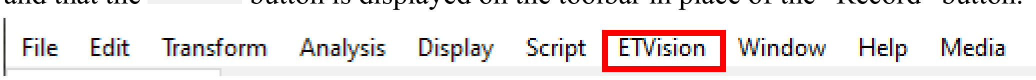
6. Under "Connection Properties," make sure the IP Address and Port Number in Acq*Knowledge* match the addresses in the ETVision software Network Configuration.
   - A video file of the ETVision video can be saved in Acq*Knowledge* by checking the "Write video transmitted from ETVision into a video file" box and selecting an output location. If this option is selected, the Acq*Knowledge* Media Playback window will automatically open after stopping a data acquisition. This video is attached to the most recent segment of the acquisition. The various Media Playback controls can be used to browse through the graph data, the same as in any other linked Media file. (See the Acq*Knowledge* Media Chapter for more details on Media Capture and Playback.)
   - The video captured during the ETVision Eye Tracking recording or from a previously captured ETVision *.emv file can be displayed in the Acq*Knowledge* Media Capture window by selecting "Display video during a data acquisition."

Starting a Eye Tracking Recording with ETVision and Acquiring Data into an Acq*Knowledge* Graph

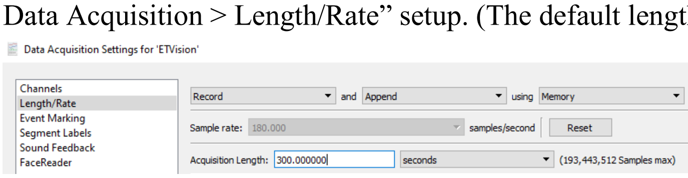
This example assumes that the ETVision Eyeglasses have been calibrated per the manufacturer's instuctions and that previously-shown steps to set up ETVision and Acq*Knowledge* software have been performed. (For full details about ETVision Eyeglasses and software, see the ETVision Manual.)

1. Click the ETVision red **Record** button under the ETVision System Control Table > Eye Data tab, or click the red **Record** button on the ETVision toolbar.

2. In Acq*Knowledge*, make sure that "ETVision" is showing in the Acq*Knowledge* menu bar (not MP160), and that the Capture button is displayed on the toolbar in place of the "Record" button.

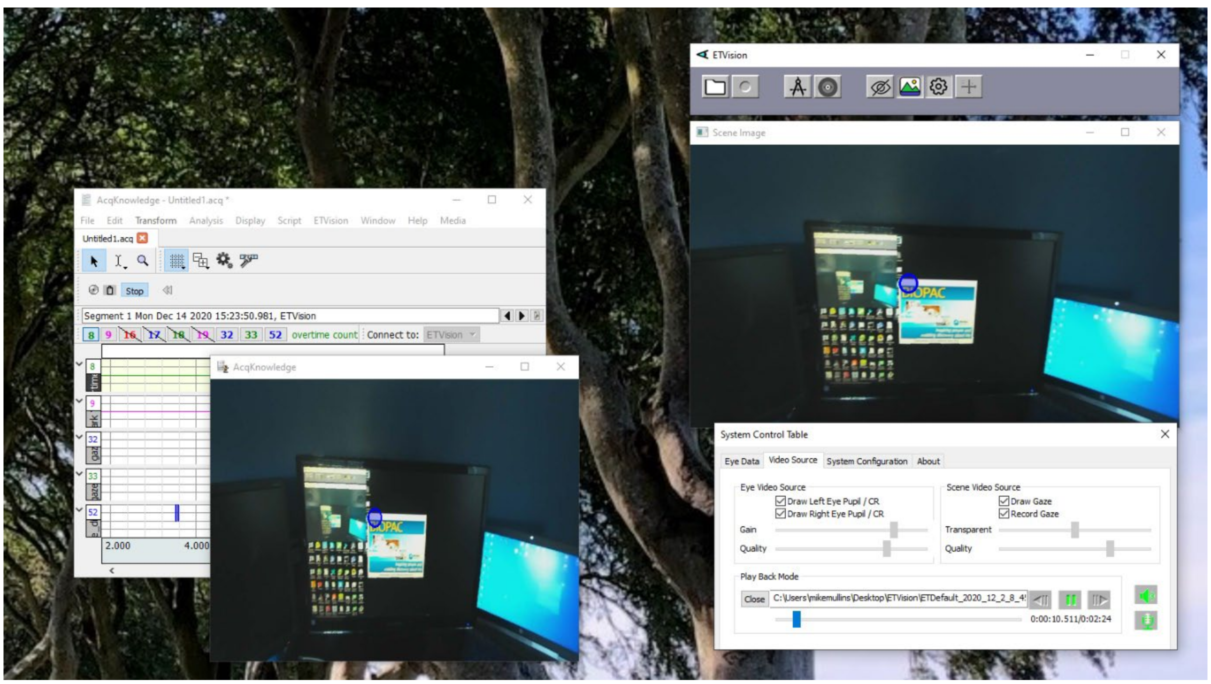


3. In the Acq*Knowledge* window, click the Capture button to begin acquiring eye tracking data into the Acq*Knowledge* graph.
4. Click "Stop" when finished capturing data, or set a duration for the capture in the AcqKnowledge "Set Up Data Acquisition > Length/Rate" setup. (The default length is 1800 seconds or 30 minutes.)



Special Notes:

- Note that when importing live or recorded eye tracking data from ETVision, the usual Acq*Knowledge* "Record" button is replaced by a Capture button. This is because ETVision is performing the actual eye tracking recording and Acq*Knowledge* is "capturing" the recording and converting it into EEG data into an *.acq graph.
- Like Recording length, the Capture length can be set as desired in the Data Acquisition Settings > Length Rate
- When actively acquiring, or "capturing," the "Capture" button toggles to a "Stop" button.
- The user may stop the Acq*Knowledge* data capture at any time independent of ETVision. In other words, ETVision can still be recording or playing back an eye tracking experiment and clicking "Stop" in Acq*Knowledge* will not affect the operation of ETVision.
- Pressing "Stop" and then "Capture" again in Acq*Knowledge* will insert an append marker and add an appended data segment to the graph.
- Depending on computer resources and graphics power, the playback may be slower than in real time. This has no effect on the quality of the data being transferred from ETVision to Acq*Knowledge*.
- The ETVision Eye Tracking Glasses interface with ETVision software only. They do not connect directly to the Acq*Knowledge* application.

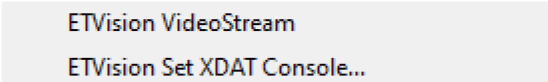


Eye Tracking data and video being captured and displayed in AcqKnowledge (left) from ETVision (right). ETVision Playback mode shown in above example.

ETVision Eyeglasses video recorded by ETVision software can also be imported into Acq*Knowledge* as eye tracking data. Acq*Knowledge* can also display and save a separate copy of the ETVision video as a Media file in *.wmv or *.avi format.

To capture ETVision video into Acq*Knowledge*, select the System Control Table > Video Source tab in ETVision and use **Play Back Mode** to select and play the video. (Refer to **To Playback an existing Eye Tracking file** on page 676.

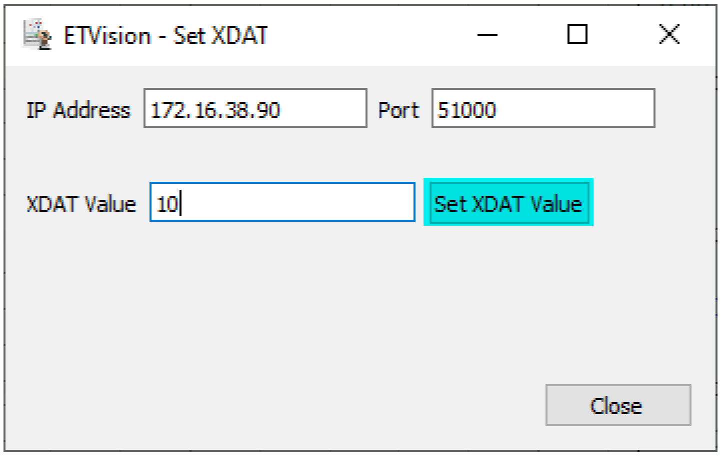
Other Acq*Knowledge* ETVision Menu Items



Two ETVision-specific menu items are located in the AcqKnowledge ETVision menu:

ETVision Video Stream: This is the window used to display ETVision video during an acquisition.

ETVision Set XDAT Console: XDAT values are external data values that can optionally be sent by an external device via LAN connection. The console is used to send a specified value to the optional XDAT channel in the Acq*Knowledge* graph. It is most often used for marking events. For example, the XDAT channel might be used by an external device to mark the onset of a particular stimulus, etc.



Eye Tracking Data Item List

For full details on the types of eye tracking data supported by ETVision that can be imported into Acq*Knowledge*, see pages 57-58 of the ETVision Manual.

Importing saved eye tracking data

For information about importing eye tracking data previously recorded, please see Chapter 13.

Chapter 35 SDS200-SYS Scent Delivery System

The SDS200-SYS uses digital channels in Acq*Knowledge* to control fans that deliver scent to research participant(s). Fans deliver scent in pulses of air with several factors determining the timing, length, and concentration of scent delivered. These include the distance odorant travels from the scent module to the participant via scent tube and the duration of the pulse. The nature of the MP device's digital channels is that they are either on or off. To allow these channels to control both the magnitude and duration of odorant exposure to a subject, the software produces patterns by timing the activation of a digital channel. Although the digital channels are always either on or off, the fans they control have inertia, i.e., the fan blades do not instantaneously spin at full speed when the digital channel switches on nor do they immediately stop when the channel is off. Since short pulses will not allow the fan to reach full velocity, longer pulses produce higher concentrations of odorant molecules, as well as longer durations over which the odorants are pushed toward the subject (Fig. 1).

A train of short pulses may be used to produce a persistent low concentration of odorant in the air pushed toward the subject (Fig. 2). A train of pulses may allow the fan to spin at a nearly constant non-maximal rate. The duration of individual pulses and the time between pulses can be manipulated to generate a range of fan speeds.

The next section defines terms that are used in configuring pulse trains to control scent delivery.

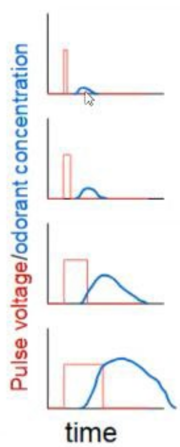


Fig. 1

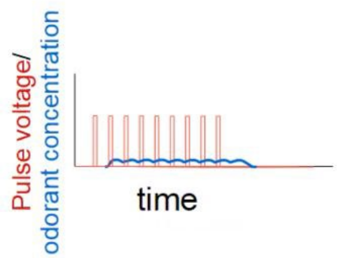
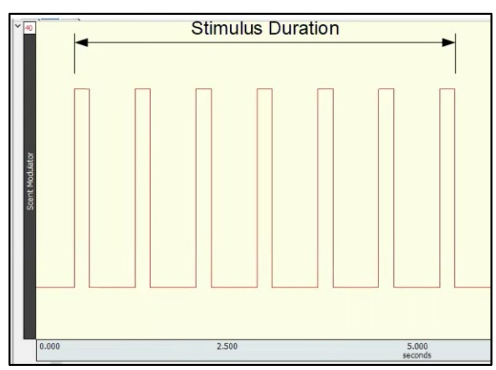


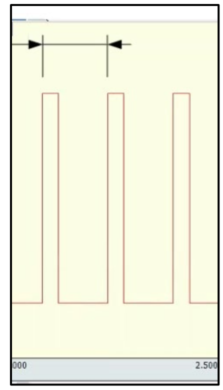
Fig. 2

Key Terms

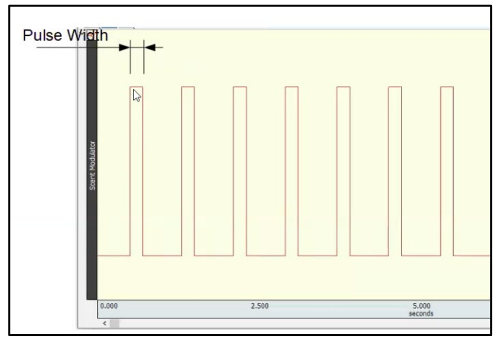
Duration: The period over which pulses are produced.



Pulse Interval: The time from the start of one pulse until the start of the next pulse.



Duty Cycle: Duty cycle equals the pulse width divided by pulse interval and is expressed in percent.

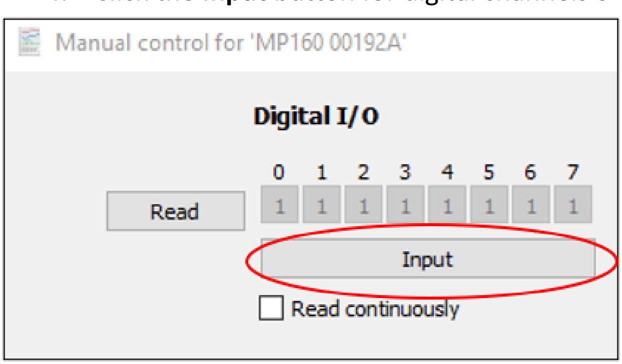


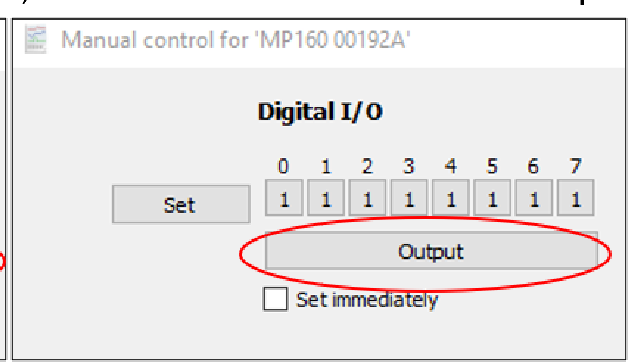
Pulse Train: A series of pulses over the duration of scent presentation.

Note: Digital Channel Settings when Powering Up MP160

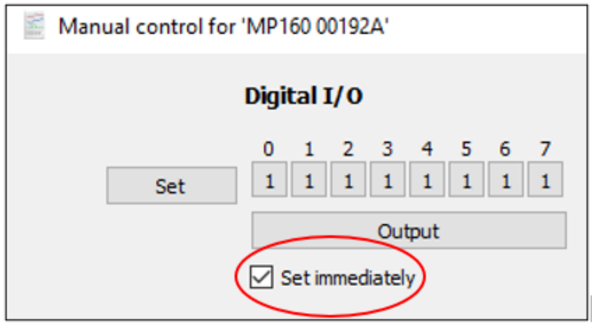
When the MP160 is powered up, digital channels will be set to a "high" state by default. If the scent delivery system is connected, it will cause the fans to switch on at full power. We recommend that users ensure that digital channels are set to "low" before connecting the scent delivery system. This can be done by taking the following steps:

1. Start with the SDS200 disabled or disable its links to the MP160. This can be done by disconnecting cables to the OUT8. If an STP100C or STP100D is used instead, disconnect the BNC cables or disconnect STP100C/STP100D module from the MP device. Users can also disconnect the power supplied to the SDS200 module. This prevents the fans from being turned on via the MP160's digital channels.
2. Power on the MP160 and launch Acq*Knowledge*.
3. Create an empty graph window and choose "MP160 > Show Manual Control..."
4. Click the **Input** button for digital channels 0-7, which will cause the button to be labeled **Output**.

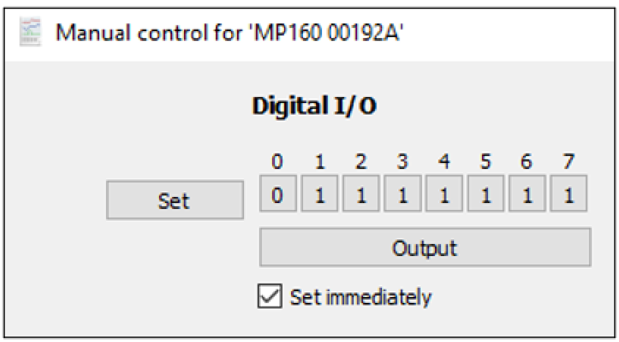


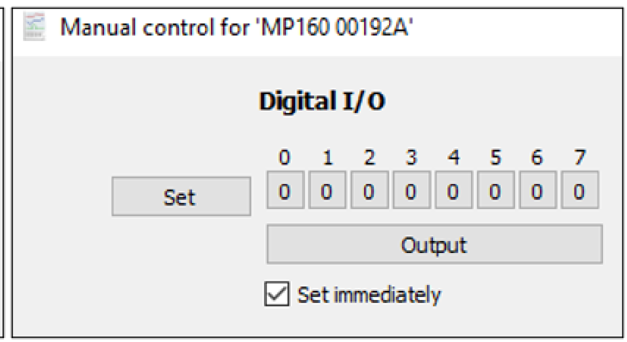


5. Check the box "Set immediately." Now, when the buttons are clicked to change the state of digital channels, they instantly take effect.



6. Click the button associated with each individual channel to set it low. In the first example below the button for channel 0 has been set to low (0). In the second image, all eight channels are set to low.



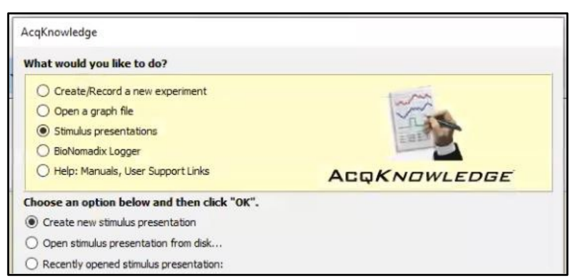


7. The OUT8 or STP100C/STP100D can now be connected to control the SDS modules.

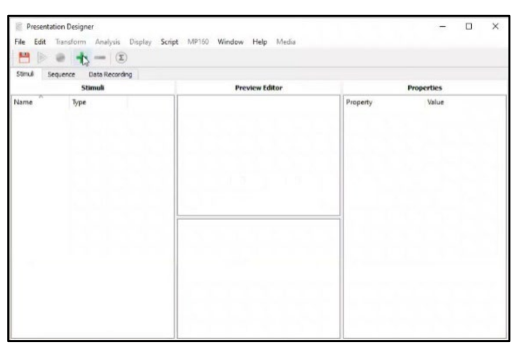
Creating a New Stimulus Presentation in Acq*Knowledge*

1. Set up the SDS200-SYS hardware according to instructions in the SDS200-SYS specification sheet.

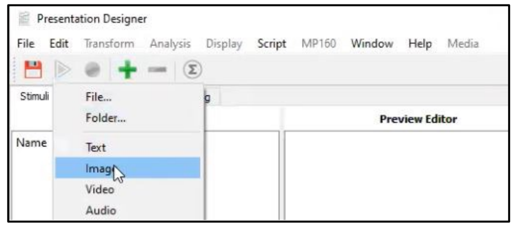
2. Open Acq*Knowledge* and when prompted by the dialog "What would you like to do?" select "Stimulus presentations" and "Create a new stimulus presentation." Click OK.



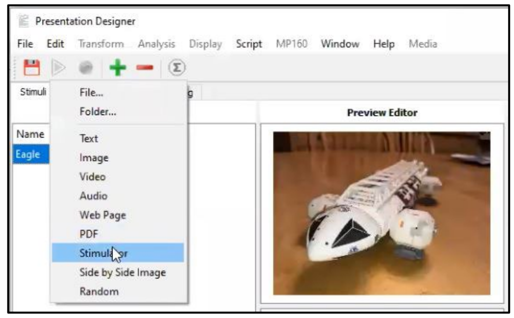
3. This will open the Presentation Designer. Click on the + sign to begin adding stimuli.



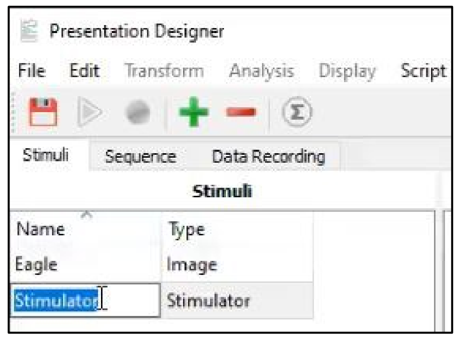
4. From the dropdown menu, select the first type of stimulus. In this case we are selecting an image that will later be paired with a scent stimulus. This will allow the user to select an image file from their computer's hard drive.



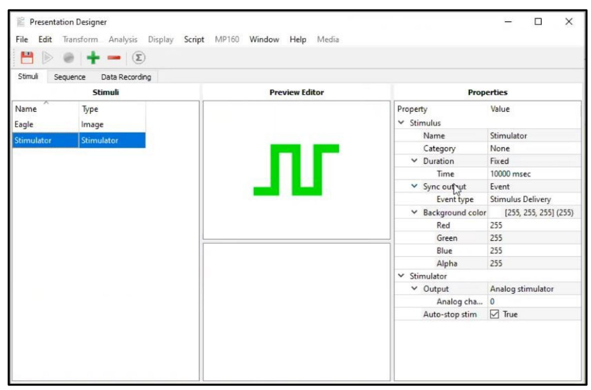
5. From the same dropdown menu, choose "Stimulator" as the second stimulus. This will be the SDS200.



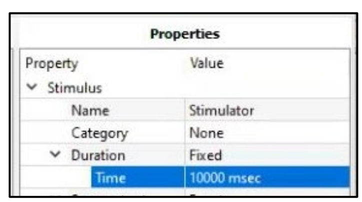
6. Users have the option of renaming the stimulus by clicking the name column and entering a new name. For example, the stimulus can be renamed to reflect the scent being used (e.g., rose, popcorn, gunpowder).



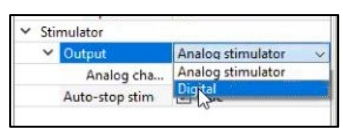
7. With the "Stimulator" object selected in the Stimuli window, the user can now set the Properties for stimulus presentation.



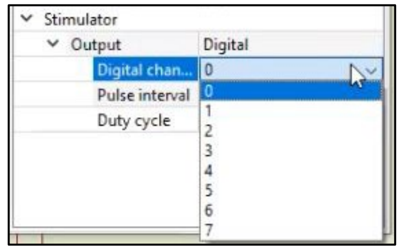
8. In the Properties window, set the Duration of the stimulus pulses by clicking Time and entering the duration in the Value field. Units are in milliseconds.



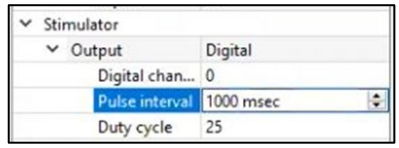
9. Next, set stimulator Output to Digital in the pulldown menu.



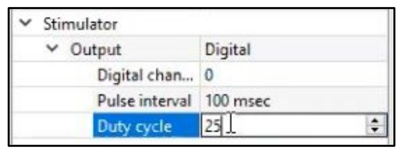
10. Select the digital output channel from the pulldown menu. The channel should correspond with name given the channel in step 6 (assuming the channel was renamed)—the channel on the OUT8 connected to the SDS200 scent module. Note: *Only one digital channel may be associated with a given image or video.*



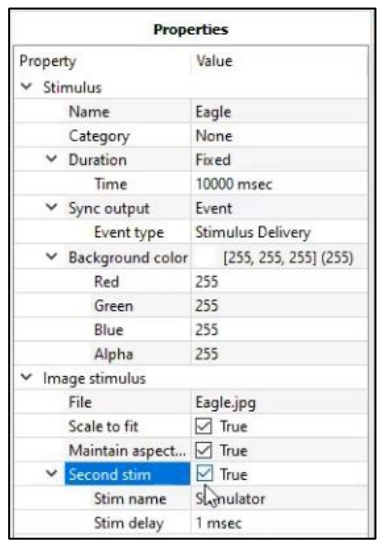
11. Click Pulse Interval and enter the period from the beginning of one pulse to the beginning of the next pulse (see above description). Note: *Control of digital channel timing is not precise. Ideally, both pulse width and time from end of one pulse to start of the next should more than 200 milliseconds.*



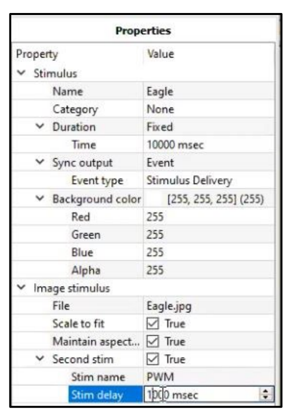
12. Click Duty Cycle and enter the value as a percentage for each cycle.



13. The final step is to link stimuli together. In this case the user wants to trigger the scent when the image file is presented. To do this, check the 'Second stim' checkbox to enable the pairing of a stimulator object with the image.



14. Enter a time in milliseconds in the "Stim delay" dialog box. This will determine the amount of time between when the first stimulus is presented to the participant and when the SDS200 module is triggered to begin the pulse train. Keep in mind that there will be an additional time delay for the scent to travel from the module to the participant. For this reason, the delay may be set to a negative value, allowing the fan to turn on before the image is presented. This allows the presentation of scent and image to be simultaneous.



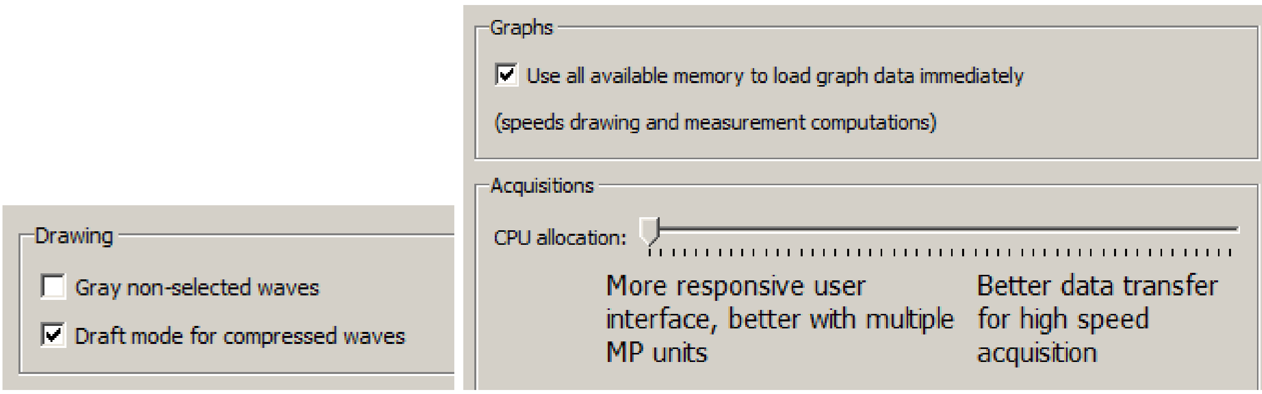
Part E — Appendices

Appendix A - Frequently Asked Questions

Q: I have a large data file and it seems to take a long time to redraw the screen. Is there anything I can do to speed it up?

A: Yes. There are several remedies for this.

(1) The simplest solution is to check the Draft mode for compressed waves and Use all available memory boxes in the Preferences dialog (shown below). Checking these two boxes will cause Acq*Knowledge* to plot data faster (at the expense of some precision) and use as much available memory as possible.



(2) The time interval per division can be reduced, which causes less data to be displayed on the screen at one time, and should reduce plot time.

(3) If a high-resolution video card is installed (one capable of displaying millions of colors), it may be helpful to reduce the resolution to speed up plotting time.

(4) Load all data into memory; see page 517 for details.

Q: Can I use other software with the MP System (MP160, MP150 or MP36R)? Can I use Acq*Knowledge to control other data acquisition hardware?*

A: No. The MP System was designed to work with the Acq*Knowledge* software. However, the software can read in previously acquired text files generated by Acq*Knowledge* or any other software.

Q: I have a device that outputs an RS-232/RS-422 signal. Can I connect this to the digital I/O lines?

A: No. These types of digital output devices have their own communication protocols and are more complex than the digital pulses that the MP System (MP160, MP150 or MP36R) can accept as inputs.

Q: I imported a text file and the time scale is wrong. What happened?

A: When a text file is imported, Acq*Knowledge* assumes (by default) that the data was sampled at 100 Hz or 100 samples per second. This is arbitrary, and there are two ways to adjust this. Both methods involve Calculating the interval between sample points. To calculate the sampling interval, the rate at which the data was originally sampled must be known. The sampling interval is calculated by dividing one by the sampling rate. The sampling interval can be adjusted to the appropriate value via the File > Open dialog before the data is read in, or if the data is already present, change the time scale in the Display > Horizontal scale dialog.

For instance, if 20 minutes of data was originally collected at 2Hz and is read into Acq*Knowledge* as a text file, the software will interpret this as data collected at 100 samples per second. To set the time scale to accurately reflect the data, change the sampling interval from 0.01 to 0.5 seconds per sample.

To change this setting before data is read in, click the Options button in the File > Open dialog and change the value in the Sampling Interval dialog. To change the time scale after data has been read in, adjust the units per division in the Display > Horizontal axis dialog. If the data are time-domain data, the seconds/sample interval can be adjusted at the bottom of the dialog. This value defines the interval between sample points, and can be changed to fit the rate at which the data was originally acquired.

Q: I just filtered a waveform and now my data file is huge. Why is that?

A: When Acq*Knowledge* performs any type of transformation on a waveform (e.g. digital filtering, waveform math), it converts the entire waveform from integer format (two bytes per sample) to floating-point format (eight bytes per sample). Since each sample point in the waveform now takes up four times as much space, the file should be approximately four times as large. Acq*Knowledge* still saves the file as compactly as possible, and since some of the information stored describes the time base, the file size will not increase by exactly a factor of four.

Q: My MP data acquisition unit seems to be connected, but I can't acquire data. What should I do?

A: This can be caused by one of several conditions:

(a) Check to make sure that the MP data acquisition unit is ON and, if so, that all the connections to the MP data acquisition unit were made properly. When the MP data acquisition unit is powered up, a light on the front panel of the MP data acquisition unit will illuminate. If the power light will not illuminate, check to make sure the proper power supply is connected. The power supply that comes with the MP data acquisition unit is rated at 12 VDC @ 1 Amp, and using other power supplies may result in damage to the MP data acquisition unit.

(b) If the proper power supply is connected but the power light still does not illuminate, disconnect the power supply and check the fuse in the back of the MP data acquisition unit. The fuse is a standard 2.0 Amp fast blow fuse, and can be changed by unscrewing the fuse cap and replacing the fuse.

(c) If the power light does illuminate, the next step is to see if the busy light (next to the power light on the front panel of the MP data acquisition unit) illuminates when the MP data acquisition unit is powered up. When the MP data acquisition unit is powered up, the busy light should illuminate for three or four seconds and then extinguish.

NOTE: The busy light is normally off (except at startup), but it will remain on while data is being acquired and will illuminate for the duration of each trial when data is being acquired in averaging mode. If the busy light does not illuminate when the system is powered up or does not turn off after a few seconds, contact BIOPAC at one of the locations listed in Appendix A.

Q: I set up the channels but I only seem to be acquiring noise. What's wrong?

A: A number of phenomena can cause this. Check to make sure that the settings in the Set Up Channels dialog correspond to the channel switch settings on the amplifier modules and/or direct analog connections to the AMI100D/HLT100C or UIM100C. When a direct analog input is set to the same channel as an amplifier, the resulting data will appear quite noisy or erratic. Check to see that no two amplifiers are set to the same channel.

Another possible cause is that the gain settings on the amplifiers are too low and should be increased. It also may be helpful to select Autoscale waveforms from the Display menu. This will automatically adjust the waveforms to provide the "best fit" in terms of scaling the data to fit in the available window space.

It is also possible that the electrodes/transducers themselves are the source of the noise. Proper electrode adhesion techniques involve abrading the skin and securing the electrode in place to reduce movement artifact.

Q: What is the storage and operation accuracy of Acq*Knowledge*?

Acq*Knowledge* performs all internal calculations to the accuracy defined by the IEEE format for double precision floating point numbers and stores the results of those calculations in double precision floating point format. This format assigns 8 bytes to all numbers involved in calculations or resulting from calculations. The 8 bytes (64 bits) are assigned as 52 bits to mantissa, 1 bit to sign, and 11 bits to exponent. The effective decimal accuracy for calculation operation or storage will be defined as [2 to the 52] power or approximately 4.5 E15. Accordingly, the effective decimal accuracy will be between 15 and 16 digits.

Appendix B - Filter characteristics

Filter types

Acq*Knowledge* employs two types of digital filters:

(a) Finite Impulse Response (FIR) perform filtering calculations online (during an acquisition) or post-processing (after an acquisition).

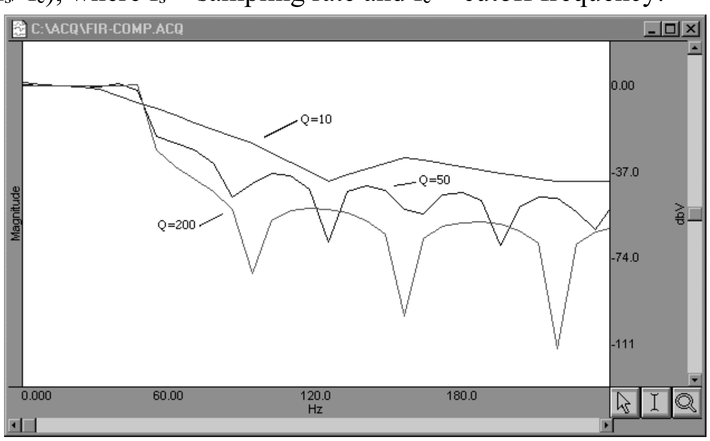
(b) Infinite Impulse Response (IIR) perform filtering calculations online (during an acquisition) or post-processing (after an acquisition).

Although the similarities between the two types of filters outweigh the differences, some important distinctions remain.

1. IIR filters tend to be less accurate than FIR filters. Specifically, IIR filters tend to cause phase distortion or "ringing." When the phase of a waveform is distorted, some data points on a waveform are shifted (either forward or backward in time) more than others. This can result in the intervals between events (such as the Q-R interval or the inter-beat interval in an ECG waveform) being slightly lengthened or shortened compared to the original signal. In practice, however, the effect of this distortion is usually minimal since the frequencies which are most distorted are also attenuated the most. By contrast, FIR filters are phase linear, which means that the interval between any two sample points in the filtered waveform will be exactly equal to the distance between the corresponding sample points in the original waveform.
2. IIR filters have a variable Q setting that defines the filter response pattern, but FIR filters do not have a Q component. The optimal Q of an IIR filter is 0.707, with lower values resulting in a flatter response and higher values resulting in a more peaked response. The default Q for all IIR filters is 0.707 (except for Band pass filters where Q defaults to 5), which is appropriate for nearly all filter applications.

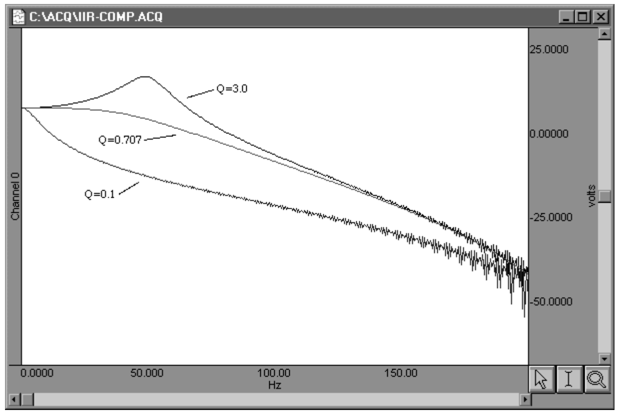
In the examples on the following page, the filter responses of several different types of filters are compared. All of the filters are 50 HZ low pass filters operating on the same data.

The first graph shows how the number of filter coefficients in FIR filters (Q) affects the filter's frequency response. Note that as the number of coefficients (Q) increases, the filter becomes more accurate. A good rule of thumb is to set $Q \geq 2(f_s / f_c)$, where f_s = sampling rate and f_c = cutoff frequency.



FIR filter performance as a function of number of coefficients (Q)

The next graph shows how the pole or zero locations of the filter, as related to filter "peaking" (specified by Q), affect the frequency response of the filter. The "Q" in this case is not to be confused with the Q from the FIR filter. Note how increasing "Q" in the IIR filter case affects filter "peaking."



FIR filter performance as a function of changes in pole or zero locations

Coincidentally, the FIR (Q = 10) and IIR (Q = 0.707) filters have very similar responses in this case.

Technically, the coefficient setting for FIR filters determine the number of multiplies performed by the filtering algorithm. In practical terms, it determines how "steep" the frequency response of the filter is. Filters with a large number of coefficients have a steep roll-off, whereas the frequency response of filters with a smaller number of coefficients is not as steep.

Window Functions

Window functions are used for two purposes in Acq*Knowledge*. Windows are applied to the impulse response in the (FIR) digital filtering functions, and can optionally be applied as part of the FFT function. In either case, a window refers to a computation that spans a fixed number of adjacent data points.

Typically, window functions are used to eliminate discontinuities that may result at the edges of the fixed span of points of the digital filter function (FIR filters) or the data points of the FFT.

Digital filtering. When a window is used in digital filtering, the impulse response of the filter (rather than the data itself) is modified. When the impulse response smoothly approaches zero at both the beginning and end of the data, this works relatively well. When the impulse response is not so well behaved, edge effect occurs. Edge effects can be minimized by windowing, or forcing the edges of the impulse response to smoothly approach zero. The exact process depends on the window selected (see below).

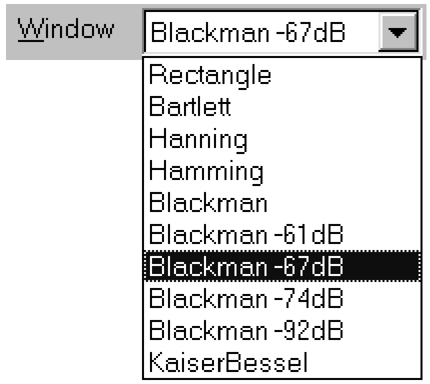
Another way to minimize edge effect with a FIR filter is to increase the number of coefficients used to transform the data.

FFT. The FFT function also windows data, although the nature of the windowing function is somewhat different in the sense that the window operates on the data. One of the assumptions of the FFT is that the input data is an infinitely repeating signal with the endpoint wrapping around. In practice, the endpoints are almost never exactly equal. This can be checked by choosing the Delta measurement item from the measurement popup menus, which returns the amplitude difference between the first selected point and the last. To the extent that the endpoints differ, the FFT output will produce high frequency components as an artifact of the transformation.

- Acq*Knowledge* displays only the positive coefficients of an FFT. In this FFT presentation, there is an implicit negative frequency component for each positive frequency component, so if looking at amplitude levels in a linear FFT, it's necessary to multiply by two (negative frequency can only be created with positive frequencies in the real world).

By windowing the data, the effects of this phenomenon are greatly diminished. When data are windowed, a window is moved across the data, much as the smoothing function moves across the data. Whereas the smoothing function simply takes the average of a specified number of points, each type of window weights the data somewhat differently.

The Window pull down menu offers the following options:



Bartlett implements triangular windowing and Rectangle does not window the data. The "shape" of the other windows is defined by the following formula, where $n = \overset{N-1}{\underset{0}{n}}$ and A, B, C and D are constants:

$$A - B\cos\frac{2\pi n}{N} + C\cos\frac{2\pi 2n}{N} + D\cos\frac{2\pi 3n}{N}$$

The table below details the different parameter values for each type of window.

	Parameter Values			
Type of Window	A	B	C	D
Bartlett	n/a	n/a	n/a	n/a
Blackman	0.42000	0.50000	0.08000	0.00000
Blackman -61	0.44959	0.49364	0.05677	0.00000
Blackman -67	0.42323	0.49755	0.07922	0.00000
Blackman -74	0.40217	0.49703	0.09392	0.00183
Blackman -92	0.35875	0.48809	0.14128	0.01168
Hanning	0.50000	0.50000	0.00000	0.00000
Hamming	0.54000	0.46000	0.00000	0.00000
Kaiser-Bessel	0.40243	0.49804	0.09831	0.00183
Rectangle *Windows/PC only*	n/a	n/a	n/a	n/a

Appendix C - Hints for Working with Large Files

It is not uncommon for users to generate large data files (on the order of several gigabytes) through some combination of (a) high-speed acquisitions, (b) long acquisitions, and (c) multi-channel acquisitions. Users frequently encounter system limitations (such as storage space limitations) and find the files are difficult and slow in loading to memory.

File size is limited by the restraints of the operating system and the available memory space on a hard drive or disk (depending to which the file is saved). Software for Windows and MacOS may have different limitations due to system restrictions.

The software provided with the MP System (MP160, MP150 or MP36R) stores the data in as compact a format as possible. Each sample takes up roughly two bytes of storage space. When a waveform (or a section of a waveform) is transformed (i.e., filtered or integrated) each data point takes up roughly eight bytes of storage space. As a result, file size can change drastically after transforming one or more waves.

WINDOWS OS

Current release: Acq*Knowledge* 5.0.5 – 64 bit - Acq*Knowledge* 5.0.2 and higher 64-bit offers major improvements in terms of file size and memory limitation.

All released versions have the same single limit applied to channel(s) length in **SAMPLES**.

Channel length is limited by 2 GigaSamples = **2,147,483,648 samples**

Any **EDIT** functions (copy/paste, resampling, merging, duplicate channel, remove waveform, cut selected data area) cannot exceed this 2 GigaSamples limit

File functions

Acq*Knowledge* 5.0.2 and higher can read/save **data files of virtually unlimited size in bytes**. The only limitation is free hard disk space.

Acq*Knowledge* 5.0.2 and higher cannot avoid 2 GigaSamples limit per channel, but can handle 100+ calculation/transformation channels (8 bytes per sample).

Example: Acq*Knowledge* 5.0.2 and higher was tested with data files as large as 45 Gbytes – 4 analog channels + 4 calculation channels, length approximately 1.1 GigaSamples

Memory functions

Acq*Knowledge* 5.0.2 and higher utilizes two features – 64-bit addressing and Virtual memory supported by Windows – and to allow handling of data files in instances when size is limited by Physical RAM and Virtual Memory settings of Windows OS.

Acq*Knowledge* 5.0.2 and higher can **allocate ALL physical RAM on the computer** to load data into the memory for transformations, and also can **utilize virtual memory on the computer**.

Use of virtual memory for transformations or "load all data into memory" is very helpful. However, the user should expect transformation delays because using virtual memory means using the hard drive as a memory substitute.

MS Windows settings that control the size of virtual memory are explained here:

https://www.geeksinphoenix.com/blog/post/2016/05/10/how-to-manage-windows-10-virtual-memory.aspx

Example: Computer has 16 GB of RAM and the virtual memory configuration for PAGE FILE is set to Initial size:

= 24 GB and Max size = 48 GB. Under this setting, Acq 5.0.2 can load into the memory a data file of about 16 GB

+ 48 GB = 64 GB (minus memory allocated by OS Windows and other processes)

MAC OS

- Acq*Knowledge* 3.9.0 and above files (including merged files) are not limited
- Acq*Knowledge* 3.8.2 and below files (including merged files) cannot exceed 2 GB

Use the following equation to calculate the memory required for acquisition

Memory required (bytes) = [(8**C** + 2**A**) x **S** x **T**] + 1 MB*

C = Number of calculation channels

A = Number of analog channels

S = Sample rate (samples/second)

T = Recording time (acquisition length)

* 1 MB = memory required to store file information

Journals, events, and other information are variable and will also require more disk space. Once analog channels are filtered or otherwise transformed, the required amount of storage will increase to 8 bytes per sample, identical to calculation channels.

The following tips can be helpful in getting the most out of the MP System (MP160, MP150 or MP36R) when working with large data files.

- Remove waveforms

  Since each waveform adds to the total size of the file, try removing (or copying to another file) some of the waveforms from a multi-channel file. This is especially true when performing transformations.

- Sample slowly

  Theoretical and methodological concerns will, to a large extent, dictate sampling rate. However, if it's possible to reduce the sampling rate, choose to do so. Or, use Transform > Resample (page 355) to resample data after collecting it.

- Set preferences

  Check the "Use all available memory" and the "Draft mode for compressed waves" options under the Preferences menu item. This should decrease the time it takes to redraw waveforms and allow the software to access all available memory for storage.

- Store to disk

  Although slightly slower than storing to memory, much larger data files can also be stored to disk. Loss of power to either the computer or the MP unit can result in data loss. To avoid potential data loss, connect both the computer and MP power supply to an uninterruptible power supply.

- Use the Append mode

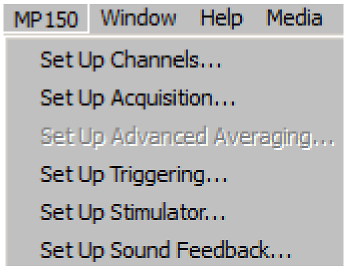
  The Append mode allows the acquisition to be paused for arbitrary periods. This can be helpful when recording only a few key events that will occur randomly over a long period of time, since it will reduce unnecessary data.

- Compress Files

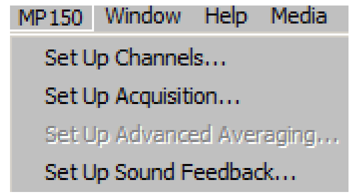
  Use the File > Save As > Compressed option to store or transfer data

Appendix D - Customizing Menu Functionality

Acq*Knowledge* now includes a powerful customization feature that allows menu options to be displayed selectively. For a specific procedure, it may be helpful to limit the menu options to list only the functions necessary for the experiment, thereby reducing the chance for confusion or error. For example, it may be helpful to remove the “Set Up Triggering” and “Set Up Stimulator” options from the MP160/150 menu, as shown below:



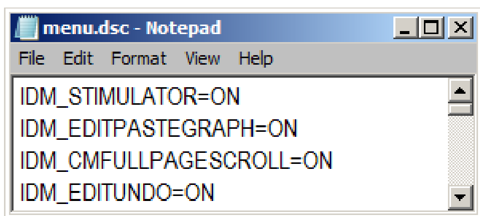
Default MP menu



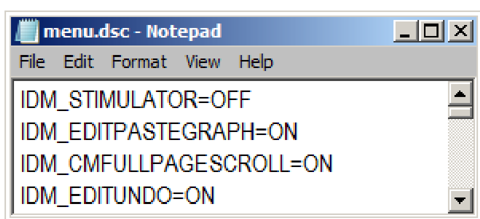
Customized MP menu

Follow the simple procedure below to customize the menu display.

1. With the Acq*Knowledge* application closed, navigate to the menu.dsc file: DRIVE:\ProgramData\BIOPAC Systems, Inc\Acq*Knowledge* 5\menu.dsc
2. Open the menu.dsc file in Notepad.



3. Find the menu and item to be changed (scroll through list as necessary) and type “OFF” to disable the menu display. In the example below, the IDM_STIMULATOR option has been changed to OFF.
   - Note that ON/OFF is case-sensitive and must be typed in ALL CAPS.
   - Deleting a file listing instead of typing OFF will not remove the feature; it will default to ON unless OFF is entered.



4. Save the changes to the menu.dsc file and close it.
5. Restart Acq*Knowledge*.
6. Check the menu listing.

> To reactivate a menu item set to OFF, just repeat the above procedure and type “ON” for the desired menu item.
>
> To revert a customized menu.dsc to the factory default, choose Display > Preferences > Other and select “Create default menu configuration file.” After choosing “Yes’ in the subsequent dialog, the application must be closed and relaunched in order for the change to take effect.

Note: Application menu customization has a corresponding effect on contextual menu display. If a contextual menu item does not have a corresponding application menu item, the menu customization file identifier will begin with “IDM_CM.”

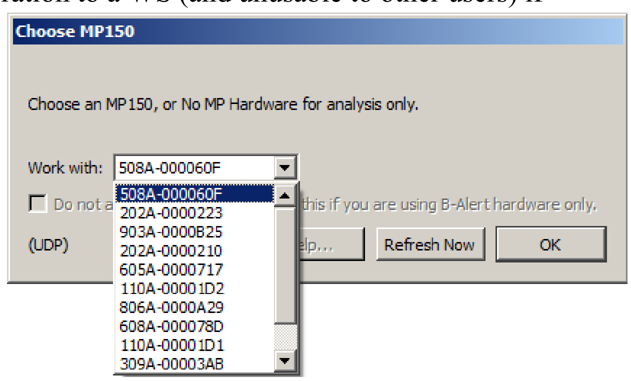
Appendix E—Locking/Unlocking the MP160/150 for Network Operations

The MP160/150 is primarily designed to work in Local Area Networks (LAN). In a LAN, each MP unit may be accessed from any workstation (PC or Mac) running an Ethernet version of Acq*Knowledge* software. Theoretically, two or more workstations (WS) could be connected to one MP160/150 at the same time, but the MP160/150 cannot perform independent acquisitions simultaneously, so in such cases one or all connected WS would receive corrupted/invalid data and/or crash.

To prevent this, Acq*Knowledge* uses new "lock/unlock" technology that establishes communication between an MP160/150 and one —and only one— dedicated WS in the Network.

Acq*Knowledge* locks an MP160/150 as soon as it connects to it, which tells the MP160/150 to only respond to commands from that particular computer and the communication method (serial or Ethernet). The lock has a timeout which is reset every time the MP160/150 unit receives a command from the computer that locked it. To locate MP160/150s in the local network, Acq*Knowledge* sends a broadcast packet to the local area network that asks all the MP160/150s in the network to respond. All the MP160/150s—whether locked or unlocked—will respond to this prompt. This means that the "Select MP160/150" menu may allow a user to select an MP160/150 that is locked. In such cases, Acq*Knowledge* will fail to connect (to a locked MP160/150 unit), as expected. To resolve this issue, unlock or power cycle the unit.

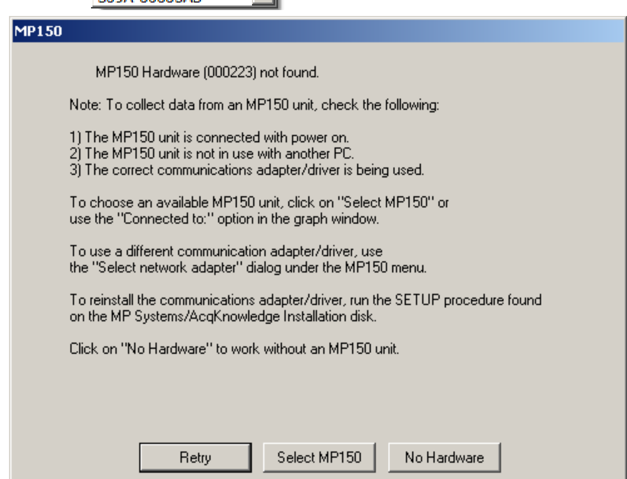
Locked An MP160 or MP150 becomes "locked" in operation to a WS (and unusable to other users) if



a) An MP160/150 unit is selected from "Choose MP160/150." The dialog lists all MP160/150 units that are powered ON and sitting on the same local area network. Unfortunately, this dialog cannot provide the locked/unlocked status of each MP160/150 in the LAN. Refer to the BUSY and ACTIVITY lights on the MP160/150 to determine the status—if the MP160/150 shows no connection but its lights indicate data traffic or acquisition, the MP160/150 is probably connected to another WS.

b) When Acq*Knowledge* is launched. Acq*Knowledge* will "remember" and try to connect the last MP160/150 used by a WS; if the last used MP160/150 is not available, the user must pick an available MP160/150 unit from the "Select MP160/150" dialog.

c) With the advent of any new communications or the start of any type of acquisition to the MP160/150 unit. When a WS communicates with an "unlocked" MP160/150 unit, Acq*Knowledge* sends a "lock" command.



When an MP160 or MP150 is locked, its serial number is listed in the Select MP160/150 dialog but any attempt to select a locked MP160150 will generate a Hardware Not Found prompt (shown above).

Unlocked An MP160/150 automatically "unlocks" and becomes available to other users

a) When the user exits Acq*Knowledge*.

b) The user selects another MP160/150 in the Select MP160/150 dialog.

c) The user selects the "No Hardware" option in the Select MP160/150 dialog.

Other, less common conditions that may unlock the MP160/150 include

d) The MP160/150 is powered OFF and then ON.

e) The MP160/150 does not receive commands/data from the WS or Acq*Knowledge* for about 5 minutes. This time-out can occur when

- An Acq*Knowledge* dialog (About, Calculation setup, etc.) is open for a long time.
- Acq*Knowledge* or the WS crashes for any reason.
- The connected WS was turned off without exiting Acq*Knowledge*.

If the MP160/150 becomes unlocked due to a time-out, two scenarios are possible:

1) The MP160/150 is locked—If another user has locked the MP160/150, the No Hardware Prompt will be displayed. Check the MP160/150 lights to determine its status.

2) The MP160/150 is unlocked—The WS will "lock" the MP160/150 as soon as communication or acquisition is initiated. Until then, the MP160/150 remains unlocked and available to others.

No Hardware When a user selects the "No Hardware" option, the menu of available MP160/150 units is grayed out and becomes unselectable. If a user attempts to connect to a locked MP160/150, an error message will be generated to advise that the MP160/150 unit is locked to a different computer.

Cannot lock

If the "cannot lock" prompt appears, check that no other user on the network is using the MP160/150, power-cycle the MP160/150, check the current firmware version (About MP160/150), and, if necessary, update the firmware using MP160/150Tools (see next Appendix).

MP160 or MP150 Firmware Upgrade

MP160/150 firmware is upgraded automatically. Unless a firmware warning is displayed at application launch, the MP160/150 already has the latest firmware revision and no further action is necessary. If a firmware warning is displayed, or if existing firmware needs to be rolled back to an earlier version, contact BIOPAC technical support.

Check the firmware version via the MP160/150 > MP160/150 Info menu item in Acq*Knowledge*.

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Open source software for Specialized Analysis:

- PCRE

  Regular expression support is provided by the PCRE library package, which is open source software, written by Philip Hazel, and copyright by the University of Cambridge, England. ftp://ftp.csx.cam.ac.uk/pub/software/programming/pcre/

- The Apache Software License, Version 1.1

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