

AcqKnowledge Software Guide

For Life Science Research Applications
Data Acquisition and Analysis with BIOPAC MP Systems



Reference Manual for
AcqKnowledge[®] Software & MP Hardware/Firmware
on Windows[®] XP, Windows[®] Vista, or Mac OS[®] X



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Preface to *AcqKnowledge* Software Guide

Welcome

Welcome to the *AcqKnowledge* Software Guide. The MP System is a complete data acquisition system that includes both hardware and software for the acquisition and analysis of life-science data. You can use the MP System for data acquisition, analysis, storage, and retrieval.

AcqKnowledge software not only makes data collection easier, but also allows you to perform analyses quickly and easily that are impossible on a chart recorder. You can edit data, cut and paste sections of data, perform mathematical and statistical transformations, and copy data to other applications (such as a drawing program or spreadsheet).

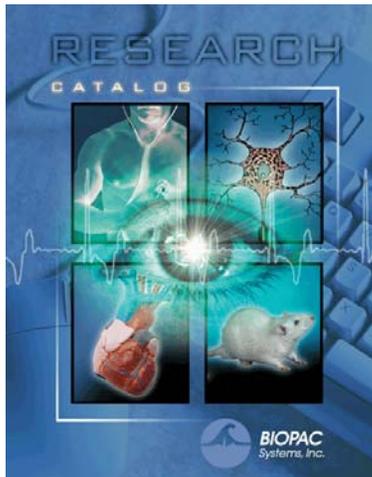
The MP System can operate on either a Macintosh® or a PC with Windows® (including notebooks). The MPWS system is designed to run on Macintosh® computers running Mac OS X or better. The MPWSW system is designed to operate with PC compatibles running Windows®.

Running in the Macintosh® or Windows® environment, *AcqKnowledge* uses the familiar point-and-click interface common to all Macintosh® and Windows® applications. Complex tasks such as digital filtering or fast Fourier transformations are now as easy as choosing a menu item or clicking your mouse.

This manual covers use of *AcqKnowledge* software with an MP System and details BIOPAC equipment available for a variety of applications. If the application you desire is not addressed, just visit the BIOPAC web site at <http://www.biopac.com> to download one of our many Application Notes, or call to request a hard copy.

See also:

- BIOPAC Installation Guide
Document shipped with the software CD and see also `Install_Guide.txt` on CD.
- BIOPAC Hardware Guide.pdf
(provides details on MP System modules, transducers, electrodes, etc., and setup and calibration)
- BIOPAC Research Catalog



What's new for Windows AcqKnowledge 3.9

BONUS!



AcqKnowledge 3.9 for Windows includes a courtesy copy of our new **Specialized Analysis** package under the Transform menu. See page 333 for details.

- **New Calculation Channels:**
 - Filter: Comb Band Stop (base frequency and its overharmonics)—page 75
 - Fourier Linear Combiners—page 88
 - Adaptive Filter—page 89
- **New Transformations:**
 - Digital Filters: Adaptive Filter—page 224
 - IIR Filter: Comb Band Stop—page 225
Filter out a fundamental frequency and its overharmonics (integer multiples of the base)
 - Fourier Linear Combiners (FLC)—page 228
 - Power Spectral Density—page 255
 - DWT Wavelet Transformation—page 261
- **Additional File Import/Export Options:**
 - Excel Spreadsheet Export—page 203
 - Raw File Import/Export—194
- Igor Pro Experiment—page 194/202
- Expression logic additions:—page 81
 - Source—Sample, Pi, True (1), False (0)
 - Function—and, equal, if (2-way), less, not, or, xor (exclusive), ceiling, floor, is infinity, conditional (3-way), not a number, floating point modulus, measurement
- Specialized Analysis—page 333
 - Heart Rate Variability
 - Gastric Wave (electrogastrogram)
- Automatic MP Firmware Update—page 131
- Paste/Copy Acquisition Settings—page 215

Note New features for AcqKnowledge 3.9 for Windows apply to the English language version of the software only. AcqKnowledge software also is available for the following languages: Chinese Simplified, Chinese Traditional, French, Italian, Japanese, Spanish, and Turkish. [Contact BIOPAC](#) to learn more about version 3.8.

What's new for AcqKnowledge 3.9 for Mac OS™ X

BONUS! AcqKnowledge 3.9 for Mac OS X includes a courtesy copy of our new Specialized Analysis package under the Transform menu. See [Specialized Analysis](#) details starting on page 333.

In AcqKnowledge 3.9.2

- Specialized Analysis Additions & Enhancements:
 - Respiration—page 382
 - Penh Analysis—page 384
 - Pulmonary Airflow—page 385
 - Compliance & Resistance—page 382
 - Neurophysiology: Amplitude/Half-Width Spike Discriminator to Locate Spikes—page 380
 - Heart Rate Variability: Locate R-waves Using Events—page 337
- Calculation Channel Additions & Enhancements
 - Metachannels: Use a single calculation channel to perform a chained computation—page 62
 - Filter: Comb Band Stop (base frequency and its overharmonics)—page 75
 - Rescale: adjust calibration values of analog channels—page 90; also in Automator—page 19
- Transformation Additions & Enhancements:
 - Delay: add time delays to signals—page 250
 - Filter: Comb Band Stop—page 225
 - Rescale: adjust calibration values of analog channels—page 250
- Spectrum Analyzer (real-time and post-acquisition FFT)—page 306
- Digital Filter Enhancements—page 75 (general explanation)
 - Cutoff frequency: Calculation channels FIR, IIR, Comb Band Stop Transformations FIR, IIR, Comb Band Stop, and Derivative Automator: Digital Filter-FIR/IIR, Comb Band Stop, and Derivative
 - # of coefficients: Transformations: FIR and Derivative Automator: Digital Filter-FIR and Derivative
- Clustering (K-means) Options
 - Export Clustering results to Excel Option —page 282
 - 3D Scatterplot Background Modification—page 282
- Measurements: Event Amplitude Maximum and Minimum—page 175
- Network data transfer: allow applications running on other computers attached to the same network to gain access to data from AcqKnowledge as it is being acquired—page 313
- Data Management Features
 - Data snapshot details—page 50
 - European Data Format (EDF) file import/export—pages 195/205
 - Batch Acquisitions Resume function—page 189
 - Selection Palette Options (Paste to Journal, Change Measurement Units)—page 304
 - Recently Used Transformations Submenu—page 219
 - 3D Dialog Positions—Tile, Stack, and Cascade
 - “Cancel” Button Added to Specialized Analysis Transformations

Plus, from AcqKnowledge 3.9.1

- Manual Stimulator Control—page 109
- Specialized Analysis New Pkgs. & Enhancements—page 333
- Clustering (K-means)—page 279
- Template Options
 - Remove Projection Template—page 235
 - Normalized Correlation Coefficient—page 236
 - Adaptive Template Matching—page 236
- File Format Options
 - BSL File Import—page 190
 - Excel Spreadsheet Export—page 203
 - Spotlight Importer for Graph Files—19
 - WAV Files—Import, page 195; Export, page 204

Plus, from AcqKnowledge 3.9.0

- All the new features of AcqKnowledge 3.8—page 8
- New Calculation Channels:
 - Fourier Linear Combiners—page 88
 - Adaptive Filter—page 89
- New Transformations:
 - Digital Filters: Adaptive Filter—page 224
 - Fourier Linear Combiners (FLC)—page 228
 - Nonlinear Modeling—page 253
 - Autoregressive (AR) Modeling—page 254
 - Power Spectral Density—page 255
 - AR Time Frequency Analysis—page 256
 - DWT Wavelet Transformation—page 261
 - Principal Component Analysis—page 262
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- Additional File Import/Export Options:
 - Igor Pro Experiment—page 194/202
 - PhysioNet—page 194/202

- Text Annotations—page 144
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- Batch Files for Acquisition Automation—page 188
- Event Coding & Measurement Automation—page 164
- Cycle (Peak) Detector Interface—page 264
- Expression logic additions:—page 81
 - Source—Sample, Pi, True (1), False (0)
 - Function—and, equal, if (2-way), less, not, or, xor (exclusive), ceiling, floor, is infinity, conditional (3-way), not a number, floating point modulus, measurement
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- Flexible print range: visible area, selected area, or entire file—page 208
- “Friendly” grid scaling & Adaptive Scaling—140
- Journal Preferences, new options—page 312
- Multiple undo (adjustable)—page 210

Using this Manual

The *AcqKnowledge* Software Guide is divided into four parts:

Part A *Getting Started*

You should look through *Getting Started* whether you're new to computer-based data acquisition systems or an old hand at physiological monitoring. Use this section to acquaint yourself 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 MP 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 MP System and other information about the *AcqKnowledge* software.

See also:

BIOPAC Installation Guide

This guide was included with the software CD. It tells you how to install the hardware and software, and how to be up and running with the MP System in just a few minutes.

Hardware Guide

BIOPAC MP Hardware Guide.pdf gives practical examples of how the MP acquisition unit is used with different components for common types of data acquisition, and includes sample results and applications for widely used test procedures. Provides instructions for connecting external devices to the MP System (electrodes, transducers, amplifiers, etc.).

User Support System

User Support System files can be found on your hard drive in BIOPAC Systems, Inc/AcqKnowledge 3.x/User Support Systems in the Program Files or Applications folder.

-- AcqKnowledge Software Guide.pdf is the software support document

-- BIOPAC MP Hardware Guide.pdf is the hardware guide (with specifications)

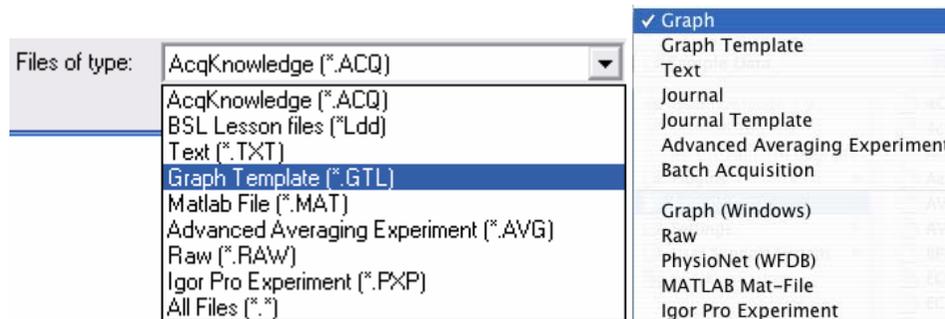
The User Support files can also be opened directly from the CD.

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

- If you don't currently have Adobe Acrobat Reader, you can download it for FREE at www.adobe.com under the Adobe Acrobat Reader site.

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 establish the channel setup and acquisition parameters required for a variety of applications.

- To open sample files, choose File>Open then Browse to the BIOPAC Samples folder.
- To open a graph template **Quick Start** file, choose File>Open then Browse to the BIOPAC Samples folder and change "Files of type" ("Enable" on Mac) to "Graph Template" and then select the desired file.



Where do I find help?

The Introductory sections are intended to provide you with enough information to get up and running with the MP System, and familiarize you with some basic *AcqKnowledge* functions. There are far more features than described in the first few pages, so here is a guide for how to continue using this manual.

➤ *Help menu*

You can get help from the online Help menu, which includes basic information about standard *AcqKnowledge* functions and links to the tutorial, software guide and hardware guide for online searchable Help while you are running *AcqKnowledge*, plus links to the BIOAPC web site.

➤ *Application Notes*

The BIOAPC web site at <http://www.biopac.com> has more than 50 available Application Notes. Download the Application Note you need, 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.

➤ *AcqKnowledge*

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 *AcqKnowledge* software.

➤ *Connecting input devices*

To find out how specific modules connect to the MP acquisition unit, turn to the *BIOAPC MP Hardware Guide* PDF file. This section describes how to connect signal-conditioning modules to the MP 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 MP System can handle such acquisitions—see the Appendices for information on how to optimize your setup for these types of acquisitions.

➤ *Troubleshooting*

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

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 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 MP System 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 you disconnect the BIOPAC Systems, Inc. instrumentation from the Subject.

Human Anatomy & Physiology Society Position Statement on Animal Use

Adopted July 28, 1995

It is the position of the Human Anatomy and Physiology Society that dissection and the manipulation of animal tissues and organs are essential elements in scientific investigation and introduce students to the excitement and challenge of their future careers.

The Human Anatomy and Physiology Society (HAPS) is a national organization of science educators dedicated to the task of providing instruction of the highest quality in human 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 animal body. Consistent with the origins and nature of scientific inquiry, HAPS endorses the use of animals as essential to the laboratory experiences in both human anatomy and human physiology.

Historically, the principal tool of investigation in anatomy has been dissection. A properly directed dissection experience 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. While anatomical models, interactive computer programs, and multimedia materials may enhance the dissection experience, they should not be considered as equivalent alternatives or substitutes for whole animal dissection.

HAPS supports the use of biological specimens for anatomical 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.

Physiology experiments involving 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, and analyze results. It is here that they learn to remain focused on the details of procedure and technique that may influence the outcome of the experiment and the responses of the animal. When faced with unexpected and even erroneous results, students develop and improve their critical thinking and problem solving skills.

Computer simulations and video programs are useful tools that help students acquire a basic understanding of physiologic principles. However, due to the inherent variability and unpredictable nature of biological responses, such programs fail to fully depict the uniqueness of living organisms and should not be viewed as equivalent alternatives or substitutes for live animal experiments. HAPS supports the use of biological specimens in physiology experiments 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.

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 contends that science educators should retain responsibility for making decisions regarding the educational uses of animals. Furthermore, it opposes any legislation that would erode the educator's role in decision making or restrict dissection and animal experimentation in biology.

Used with permission of: The Human Anatomy and Physiology Society (HAPS)
222 South Meramec, Suite 203, St. Louis, MO 63105
1-800-448-HAPS

Part A—Getting Started

Chapter 1 MP Systems Overview

Part A - Getting Started covers the basics of data acquisition and analysis with an MP System. All of the material in this section is covered in more detail in subsequent sections (see *Using this Manual, page 191*).

Overview

The MP System is a computer-based data acquisition system that performs many of the same functions as a chart recorder or other data viewing device, but is superior to such devices in that it transcends the physical limits commonly encountered (such as paper width or speed). Data collection generally involves taking 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 the hard disk). These signals can then be stored for future examination, much as a word processor stores a document or a statistics program saves a data file. Graphical and numerical representations of the data can also be produced for use with other programs.

There are two MP Systems available—MP150 or MP100—with the following distinctions:

Function	MP150	MP100
Aggregate Sample Rate		
Internal MP Buffer:	400kHz	70kHz
To Cpt. Memory or Disk:	300kHz	16kHz
Internal Buffer Size:	6M bytes	16k bytes
A/D Converter Signal/Noise Ratio:	86 dB typical	90 dB typical
D/A Resolution:	16 bits	12 bits
D/A Output rate:	Independent of A/D rate	Synchronous with A/D rate
Communication to Computer:	Ethernet (10 base T, UDP and DLC Type II)	USB

The MP System can be used on a Macintosh® or on a PC with Windows®. The system utilizes the same hardware, excepting the computer interface. The software has the same “look and feel” on both the Macintosh® and the PC.

- For the Mac®, the system is referred to as “MPWS”
- For PC with Windows®, the system is referred to as “MPWSW”

Your MP System consists of several major components, including hardware and software. The *AcqKnowledge* software included with your system allows you to edit your data and control the way it appears on the screen, 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 (such as FFT's and math functions);
- (d) Handle file management commands (saving, printing, and the like).

The heart of the MP System is the MP data acquisition unit, which takes incoming signals and converts them into digital signals that can be processed with your computer. The MP acquisition unit connects via:

- Ethernet for MP150 unit
- USB for MP100 unit

The system also includes a Universal Interface Module (UIM100C) for connecting external devices to the MP acquisition unit. Connect chart recorders, pre-amplified signals, and digital signals such as those from triggers or event counters/recorders. The UIM100C connects to the front of the MP acquisition unit via two cables (Analog and Digital). As a rule, both cables should be connected. The connectors for each of the two cables are different, so there is only one way the UIM100C can be connected to the MP acquisition unit.

A wall transformer is included with the MP System to convert AC mains power into DC power suitable for system operation and safety.

Unpacking

Visit the online support center at www.biopac.com

Please confirm that your MP System was delivered with one of each of the following items:

MPWSW for PC with Windows®	MPWS for the Macintosh®
MP System acquisition unit ➤ MP100 or MP150	MP System acquisition unit ➤ MP100 or MP150
Universal Interface Module (UIM100C)	Universal Interface Module (UIM100C)
MP100 only: 25-pin female to 25-pin female cable (0.6 meter)	MP100 only: 25-pin female to 25-pin female cable (0.6 meter)
MP150 only: 37-pin female to 37-pin female cable (0.6 meter)	MP150 only: 37-pin female to 37-pin female cable (0.6 meter)
DC wall adapter MP100: 12 VDC @ 1 Amp (120 or 240 V) MP150: 12 VDC @ 2 Amp (120 or 240 V)	DC wall adapter MP100: 12 VDC @ 1 Amp (120 or 240 V) MP150: 12VDC @ 2 Amp (120 or 240 V)
MP150: Ethernet card and two cables MP100: USB1W PC USB (2.0) adapter	MP150: Ethernet card and two cables MP100: USB1M Mac USB (2.0) adapter
<i>AcqKnowledge</i> software CD (v3.9) with License Agreement and Registration Card	<i>AcqKnowledge</i> software CD (v3.9) with License Agreement and Registration Card

When you have unpacked and are ready to install your MP System, refer to the “BIOPAC Install Guide” that was packaged with your software.

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 you plan to acquire data for more than a few hours and/or are sampling at more than 1,000 samples per second, see the [Disk Space](#) note.

Windows	For AcqKnowledge 3.9.0	
OS	Requires Windows XP	
Port	Requires Ethernet (UDP) for MP150 or USB for MP100 To use an MP150 with UDP communication on a network with a non-Windows DHCP server, you must use firmware 1.1.12 or greater for the MP 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 X, and other DHCP-aware devices.	
Hard Disk	Requires 128 MB to store the software and online manuals; additional 1 GByte recommended for data storage	
RAM	128 MB recommended	
Processor	CPU with at least 128 MHz clock speed recommended; math coprocessor for 80386-based machines	
Macintosh	For AcqKnowledge 3.9	
OS	Requires Mac OS X 10.3 or higher	see Mac on Intel and Mac OS 10.4 Tiger Notes
Port	Requires Ethernet (DLC) for MP150 or USB for MP100	
Hard Disk	Requires 128 MB to store the software and online manuals; additional 1 GByte recommended for data storage	
RAM	128 MB recommended	
Processor	PowerPC G3 (or higher); minimum recommended processor is a 500Mhz G4	

MP150 DLC Limitations

UDP is the default communication for MP150 units, but DLC communication will also work. Use Preferences to establish the communication type. An administrator password is required in order to access the Ethernet network under Mac OS X. Without an administrator password, AcqKnowledge 3.9 can only be used in the “No Hardware” mode for data analysis.

- The only setup that requires DLC Communication is multiple MP150s performing online averaging simultaneously with independent external triggers.

Disk Space

With any program, you will need disk space to store your data files. Although BIOPAC saves files in a format as compact as possible, some users may generate data files of several dozens of megabytes. To acquire data for long periods (more than a few hours) and/or sample at relatively fast rates (more than 1,000 samples per second), you should have as much available disk space as possible (or have access to a removable storage device). See your BIOPAC Software Guide for hints on working with large files.

Mac on Intel Compatibility

AcqKnowledge has been updated to a Universal Binary. This allows it to run natively on both PowerPC and Intel-based Macintosh computers. AcqKnowledge also integrates directly with operating system features when running on Mac on Intel-based computers, such as Automator and Spotlight.

Some features are not yet available for Mac on Intel-based computers due to the lack of third-party support. These features include:

- MP100 support (requires Intel-compatible Keyspan drivers).
- MATLAB File Exchange (requires Mac on Intel support from MATLAB and The MathWorks).
 - If MATLAB File Exchange is required, the application can be run in emulation mode by checking the “Open with Rosetta” checkbox in the Get Info inspector of the Finder.

Contact BIOPAC Systems for more details on when these features may become available.

Mac OS X 10.4 “Tiger”

Spotlight Importer for Graph Files

“Tiger” includes a feature named Spotlight. Spotlight is a new way to search for data on your computer. *AcqKnowledge* includes a Spotlight Importer that allows Spotlight to extract and search information from *AcqKnowledge* graph files including:

- Graph title
- Duration of the recorded data in the graph
- Text included in the Journal
- Labels of data channels in the graph

For example, if you record the names of your subjects in a graph's Journal, Spotlight will now be able to locate the graph file based upon that name extracted from the Journal. If you keep enough information in the channel labels and journal of your graph file, graphs can now be located and grouped using the Spotlight search features in ways not possible without Mac OS X 10.4.

The Spotlight importer only supports files generated by Mac *AcqKnowledge* 3.7.0 or higher.

- Older Mac *AcqKnowledge* or any Windows *AcqKnowledge* files must be resaved to disk using a compatible Mac *AcqKnowledge* file format.

Automator Integration and Scripting Support

This feature is available only when *AcqKnowledge* is running on Mac OS X 10.4 “Tiger”.

Mac OS X 10.4 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 *AcqKnowledge* 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 *AcqKnowledge* environment using the new “Workflow” menu. The Workflow menu allows you to create workflows that can be specific to your user account or shared by all *AcqKnowledge* 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 *AcqKnowledge* is launched. By simply selecting the name of the workflow from the Workflow menu, *AcqKnowledge* 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 *AcqKnowledge* environment (e.g. used as Folder Actions) should begin with a “Launch Application” action to start *AcqKnowledge* followed by an “Open Graphs” or a “Get Active Graphs” action.

Mac *AcqKnowledge* 3.9.2 and later

Digital filter options have been as follows:

Cutoff freq: digital filter-FIR, digital filter-IIR, comb band stop, and derivative

- 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: digital filter-FIR and derivative

- 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.

Rescale: To apply textual changes to a channel's units, apply the "Replace Active Channel Units" action.

Delay

For more information about Automator and help constructing workflows, see the Apple website at: <http://www.apple.com/macosx/features/automator/>

MP System Features

In conjunction with your computer, the MP System is a complete system for acquiring almost any form of continuous data, whether digital or analog. The MP System can perform a range of recording tasks, from high-speed acquisitions to long duration acquisitions. Generally speaking, for physiological applications, the MP System is limited only by the speed of your computer and the available memory or disk space. Features of the MP System include:

Easy to use	The MP System offers the same convenient and easy-to-use features which Macintosh® and Windows® users are accustomed to. Since the MP System software runs under these environments, you can run other applications while you are collecting data. In terms of hardware setup the MP System uses simple plug-in connectors and standard interface cables. <i>You don't need a degree in electronics to set up your system!</i>
Flexible	The MP System 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 MP150s). You control the length of acquisition, the rate at which data is collected, how data is stored, and more...all with a few clicks of the mouse button. Whether you're measuring alpha waves or collecting zoological data, the MP System can meet your needs.
Menu flexibility	You can easily customize menu displays to show only the functions you are using, thereby reducing the risk of error or confusion in your lab. This function is extremely powerful for laboratories working to GLP guidelines. It is also useful for teaching applications where instructors can hide unnecessary menu items. <i>See Appendix D—Customizing Menu Functionality.</i>
High Speed Sampling	Sample rates up to 400 KHz aggregate (MP150), 70 KHz aggregate (MP100)
Arbitrary Sample Rates	Apply different sample rates between channels or operate the STM100C stimulator at a different rate than the acquisition sample rate
View & Control Multiple MP150s	View and control multiple MP150 units over a local area network (LAN).
Calculation Channel Presets	Customize your recording for specific measurements.
Template files	AcqKnowledge <i>“Quick Start”</i> 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 the MP System provides an extensive array of measurements and transformations you can apply to collected data, sometimes you need to perform computations <i>while</i> data is being collected. The online Calculation functions allow you to calculate new channels based on incoming signals. This feature allows you to compute BPM, for instance, based on raw ECG data.
Online filtering	Many times, it is preferable to filter data as it is being collected, rather than having to wait until after the fact, so now you can apply filters to incoming data and view the results in real time. That means online monitoring of data filtered to suit your needs.
Online measurements	The MP System can instantly compute over a dozen 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	You can validate measurements with the <code>ValidateMeasurements.acq</code> sample file that was included with the software. The measurement definitions (page 151) include measurement formulas and “ <i>Sample data file</i> ” explanations.
Preview your data	Similar to chart recorders, the MP System allows you to change both the vertical scale and the horizontal scale. You can change the amplitude scale or the time scale to any value you wish, or you can have the MP System automatically scale them for you.
Replace (or augment) a chart recorder	Whether you want to replace a chart recorder or simply supplement an existing setup, the MP System is fully compatible with most major recording devices. What’s more, the MP System is compatible with most popular input devices, so you can continue using the same transducers, electrodes and sensors.
Simplified editing	It used to be that once your data was collected, the only way to edit it was with scissors and adhesive tape. Now you can delete unimportant sections of your data with a keystroke. You can “paste” together sections from different waves, or simply edit out noise spikes from individual waves.
Append mode	For some applications, data only needs to be recorded during some portions of a long experiment. <i>AcqKnowledge</i> has an “Append” mode that lets you pause the acquisition for as long as you wish, and resume the acquisition as many times as needed. In this mode, you can start and stop a recording as you would with a chart recorder. Appending data saves on storage space and processing time for transformations.
Digital filtering	All data contains measurement error and noise. Now you can reduce or eliminate that error by using the digital filters and smoothing transformations included in the MP System. You can smooth data across any number of samples, or filter out noise from any frequency or bandwidth you wish.
Digital Output	You can control external devices when an input or calculation channel meets trigger conditions you specify. Use the Control channels to output a pulse when the signal on an analog channel falls above or below a given threshold.
X/Y plotting	You can view and acquire data in the form of an X/Y plot, with one channel on the horizontal axis and another on the vertical axis. This allows you to explore relationships between different channels and opens up a whole range of applications, from chaos plots to respiration analysis to vectorcardiograms.
Histogram function	You can easily examine the variability and the measures of central tendency of any waveform data with the histogram function. Set the plotting options to suit or let the software determine the “best fit” for graphing your data.
Math functions	In many cases, simply collecting raw data is not enough. <i>AcqKnowledge</i> has 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). You can even chain multiple functions together to form complex equations.
Annotation	<i>AcqKnowledge</i> has a Journal you can use to append comments concerning your input data, either online or after the fact. This is especially useful for noting the characteristics of an acquisition (what was involved, what manipulations took place, and the like) for future reference. <i>See also:</i> Text annotation, page 144

Triggering	If you need to measure response times or start data collection only after some event has occurred, the MP System allows you to trigger an acquisition in a number of different ways. You can trigger on the level of a signal, or with an external synchronizing trigger.
Event marker	Many times, especially during a long acquisition or in a laboratory setting, it is useful to make a note of when specific events occurred so that these events (such as when a manipulation occurred) can be recorded and any changes in the data can be noted. The marker function allows you to insert symbols in the record and add text for each marker. These can be added either while data is being collected or after the fact. Marker functionality can be automated for sequential application or customized for Function keys.
File compatibility	You can save your data in a number of different formats. Save data to a word processor program like Microsoft Word [®] , spreadsheet software like Microsoft Excel [®] , a drawing program. You can output your data in either text or graphical form, and AcqKnowledge can even read-in raw data from a text file. Open (import) or save as (export) MATLAB [™] and Igor Pro Experiments, or raw (binary) data for low level exchange.
Pattern recognition	Using an advanced pattern search/recognition algorithm, the MP System can automatically find a specific pattern within waveforms. This is useful for finding abnormal waveforms (such as irregular ECG waves) within a data file.
Peak detection	AcqKnowledge has a built-in algorithm to find either positive or negative peaks from any size data file. You can even search for all the peaks with one command and automatically log statistics like peak time and area to the journal.
Printing	The MP System provides a range of printing options, and allows you to fit your data on one page or many. You can print several graphs per page, even if you only have one-channel recordings. Since the MP System runs on the Macintosh or under Windows, no special printer drivers are required.
Report generation	AcqKnowledge has 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, markers, etc.). Use the Playback mode to simulate acquisition for presentations.
User Support	Whether you have a question about compatibility with your existing equipment or you need to develop a specialized measurement device, BIOPAC's Applications Department can address the problem.

Application Features

See Appendix G for basic descriptions of these Application Features.

Use your MP System with AcqKnowledge software for a wide array of applications, such as:

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

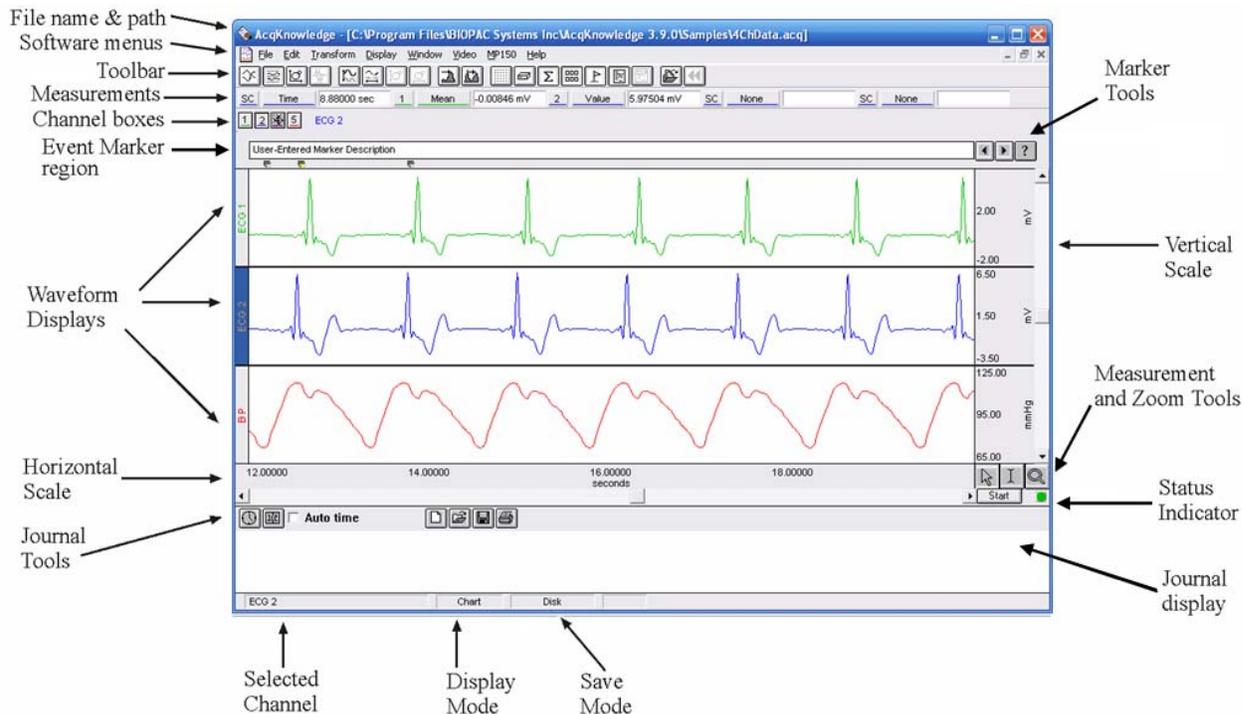
MP System Application Notes

BIOPAC has prepared a wide variety of application notes as a useful source of information concerning certain operations and procedures. The notes are static pages that provide detailed technical information about either a product or application. A partial list of Application Notes follows. You can view or print application notes directly from the Support section of the BIOPAC website www.biopac.com.

APP NOTE	Application
#AH101	Transducer Calibration and Signal Re-Scaling
#AH102	Biopotential Amplifier Testing w/ CBLCAL
#AH103	Remote Monitoring System (TEL100C)
#AS105	Auditory Brainstem Response (ABR) Testing
#AS105b	ABR Testing for Jewett Sequence
#AS108	Data Reduction of Large Files
#AS109	3-, 6-, and 12-Lead ECG
#AH110	Amplifier Baseline (Offset) Adjustment
#AS111	Nerve Conduction Velocity
#AH114	TSD107A* Pneumotach Transducer
#AH114b	TSD107B* Pneumotach Transducer
#AS115	Hemodynamic Measurements—Part I
#AS116	Hemodynamic Measurements—Part II
#AS117	Pulse Transit Time and Velocity Calculation
#AS118	EMG Signal Analysis
#AS119	EMG Power Spectrum Analysis
#AS120	X/Y Loop Area Analysis
#AS121	Waveform Data Reduction
#AS122	Power Spectrum Analysis
#AH125	Pulse Oximeter Module Operation
#AH127	Precision Force Transducers
#AH128	Active Electrode Specifications and Usage
#AS129	Heart Rate Variability
#AH130	Blood Pressure Measurement
#AS131	Averaging Mode
#AH132	TSD105A Variable Force Transducer
#AH135	TSD117 Pneumotach Transducer
#AH136	BAT100 Instructions
#AH140	Angular Measurements with Goniometers
#AH141	Tri-Axial Accelerometer Calibration
#AS142	AcqKnowledge Rate Detector Algorithm
#AS143	Importing AcqKnowledge Data Into Excel
#AH144	Hand Dynamometer Calibration
#AH145	TSD101B Respiratory Effort Transducer
#AS148	Automated ECG Analysis
#AH149	O2100C Module
#AH150	O2100C Module—Sample application
#AH151	CO2100C Module
#AH152	CO2100C Module—Sample Application
#AH153	Physiological Sounds Microphone
#AH154	HLT100C High Level Transducer
#AS158	Analysis of Inspired and Expired Lung Volume
#AH159	TSD116 Series Hand Switch and Foot Switch
#AH160	Gas Analysis Module Response Time
#AS161	Automated Tissue Bath Analysis
#AH162	Stimulation Features
#AS168	Analysis of Intraventricular Pressure Wave Data (LVP Analysis)
#AS169	Speech Motor Control
#AH170	LDF100A Laser Doppler Flow Module
#AH175	Using the STMISOC Stimulus Isolator
#AS177	ECG Analysis using the Offline Averaging Mode
#AS183	VO ₂ Measurement
#AH186	Psychological Assessment using the TSD115
#AH187	Electrodermal Response (EDR) using the GSR100 or TEL100
#AH190	Using the MCE100C Micro-electrode Amplifier
#AS191	Cardiac Output Measurement using the EBI100C and AcqKnowledge

Chapter 2 AcqKnowledge Overview

Overview



The MP System software is called *AcqKnowledge* and 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 of the acquisition parameters can be found under the MP menu. The other menu commands pertain to analysis functions such as viewing, editing, and transforming data.

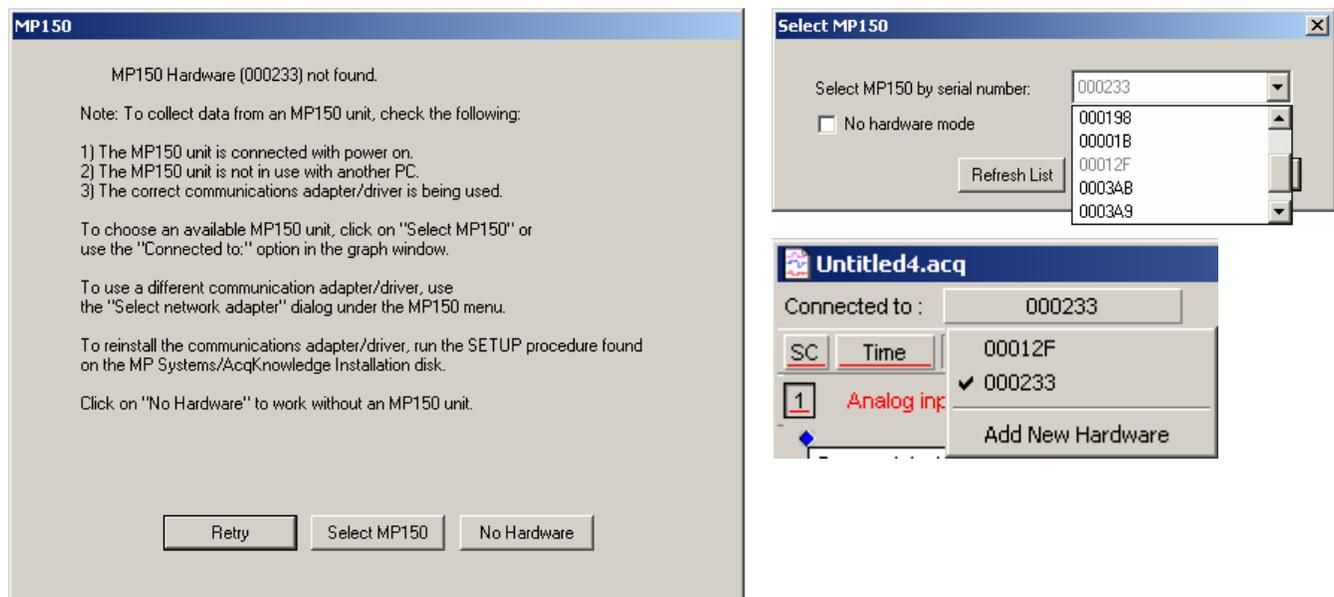
Note: Some very minor differences exist between the Macintosh and the PC-compatible screen displays and keystroke/mouse functionality. These differences are noted throughout this section.

Menu	Functionality	See Page
MP150 or MP100	Set up Channels, Set up Acquisition, Set up Triggering, Set up Stimulator, Show Input Values, Manual Control, Auto Plot, Scroll, Warn on Overwrite, Organize Presets. Select Network Adapter, MP150 Serial Number, About MP150	53
File	New, Open, Close, Save/Save As, Print, Printer Setup, Exit	187
Edit	Undo, Cut, Copy, Paste, Clear/Clear All, Select All, Insert Waveform, Duplicate Waveform, Remove Waveform, Clipboard (copy measurement, copy wave data, copy graph), Journal (paste measurements, paste wave data)	209
Transform	Digital Filters, Math Functions, Template Functions, Integral, Derivative, Integrate, Smoothing, Difference, Histogram, Resample, Equation Generator (Expression), Waveform Math, FFT, Find Peak, Find Rate	217
Display	Tile Waveforms, Autoscale Waveform, Overlap Waveforms, Compare Waveforms, Autoscale Horizontal, Zoom, Reset, Set Wave position, Wave color, Horizontal Axis, Show, Statistics, Preferences, Size Window, Set Font	294
Window	Controls the position of windows on the monitor	317
Help	Provides online support files (PDFformat and web links).	317

Launching the AcqKnowledge software

The first step is to launch the software by double-clicking on the *AcqKnowledge* icon. You may receive a message regarding the hardware.

PC users:

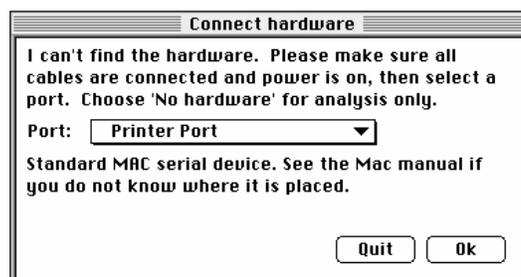


If you receive the above warning when you launch *AcqKnowledge*, there are two possibilities: You have not properly connected everything and/or you have not powered up the MP System.

- To use *AcqKnowledge* without an MP acquisition unit, press the “No Hardware” button.

When *AcqKnowledge* is first launched, the user must pick an available MP150 unit from the Select MP150 Serial number dialog. The dialog lists all MP150 units that are powered ON and sitting on the same local area network. If you are using more than one MP150 unit or working across a network, you will need to lock/unlock an MP150 to acquire data (see Appendix E on page 328 for details). The selected MP unit will listed in the upper left of the graph display as “Connected to:” if the  Show/Hide Hardware toolbar icon is enabled.

Macintosh USB users:



You may receive a message similar to the preceding prompt. Use the pull-down menu to select a connection port, or choose the No Hardware option. Options are generated based on your system configuration (printer port, modem port, USB port, etc.). If hardware is not detected, check all connections and power sources. Unplug the USB adapter, wait a few minutes, then replug the adapter or try a different USB port.

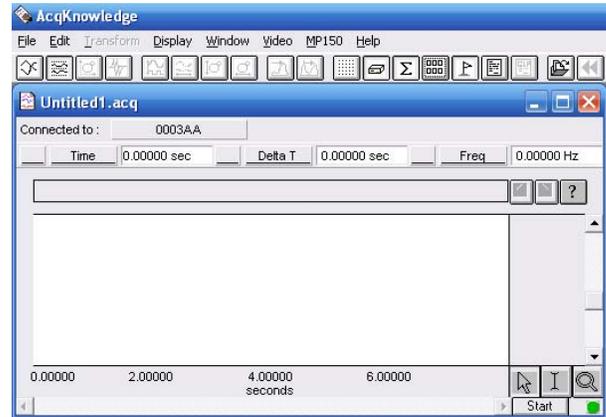
Assuming everything is properly connected and there are no conflicts, *AcqKnowledge* will open as follows:

- PC MPWSW System: an empty *AcqKnowledge* graph window will be generated.

A “window” is the term used for the area on your computer’s screen where data is displayed and/or manipulated. The graph window on the screen is designed to provide you with a powerful yet easy-to-use interface for working with data.

At this point, you can use this window, create a new window, or open an existing window.

- To create a new graph window, access the File menu and select New. It’s a good idea to create a new graph window for each acquisition.



Journal

AcqKnowledge includes an “electronic notepad” or journal, which allows you to record notes and data associated with a graph file. You can use the journal at the same time you are acquiring data. Every graph file has a graph-specific journal file permanently linked to it. (Mac OS X users can also generate independent journals for data view or protocols, see page 48). To display the graph-specific journal,

- select the journal icon  from the toolbar
- Display > Show > Journal on Windows
- File > New > Graph-specific Journal on Mac OS X.

The journal will appear at the bottom of the graph window. Once a journal is open, you can enter text, data, or both.

- To enter text, just click the cursor in the journal area and begin typing. *AcqKnowledge* will automatically “wrap” the text to fit the screen width. This is especially useful for noting the date and time of a recording, what was involved, and so forth. You may also paste measurements and waveform data into the journal.
- To paste measurements into an open journal, select the desired area or point and choose Paste measurements from the Edit>Journal menu. This will paste all visible measurement window data into the journal.
- To paste waveform data into the journal, select the desired area and choose Paste Wave Data from the Edit>Journal menu. This will insert a text file of your waveform into the journal, where points and trends can be analyzed.

The graph-specific journal is saved with the graph file, but can be saved as a separate file via File > Save Journal Text As.

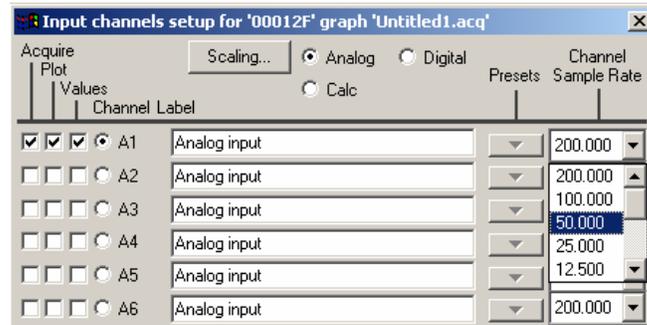
Acquisition

Once you have connected your system setup and input devices, try a sample acquisition. The most basic and commonly used options are under the MP menu. For any acquisition, you will need to specify:

- How many channels there are and which channels contain data (Set up Channels).
- At what rate the MP will acquire the data (Sampling rate).
- How long the acquisition will last (Acquisition length).

Setting up channels

To tell the MP System how many channels will be acquired (or collected), select Set up Channels from the MP menu. This will generate the Input Channels dialog.

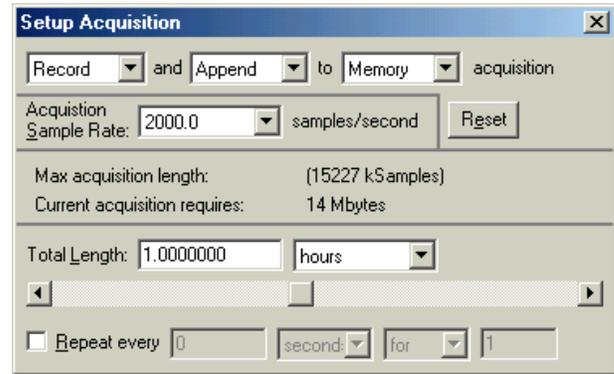


- Acquire** When the Acquire box is checked for a given channel that means data will be collected on that channel.
- Plot** Determines if data will be plotted in real-time during the acquisition. If the plot box is unchecked, data will still be recorded for that channel, but the waveforms can only be plotted after the acquisition is over.
- Values** Enables you to bring up a window that will display (numerically and/or graphically) the values for each channel in real time. These values are displayed in a separate window from the main graph window. The default is to collect one channel of data on channel A1, and to plot and list values for this channel. Usually, you will want to check all three boxes for each channel you acquire data on.
- 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. Calculation channels are used for online computations and transformations of other channels. These channels are set up just as analog and digital channels but also have additional dialog boxes for you to specify what types of transformations and computations you would like to perform. For a detailed summary of Calculation channel options, see the Calculation Channel section beginning on page 61.
- In contrast to analog data, Digital channels collect binary data that represent when a measuring instrument is “on” or “off.” An example of when this could be useful is for recording whether a switch is open or closed, as in reaction time studies or control applications. You can control whether digital channels are acquired, plotted, and have values listed the same way you do for analog channels.
- Label** To the right of each channel number is an editable label for each channel, where you can type in a label (up to 38 characters) that identifies what each channel is measuring.
- Presets** 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. See page 56 for details and a list of available presets.
- Channel Sample 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 “MP150 >Set up Acquisition”). The options are a specific power of 2 less than the acquisition sample rate. Channel sample rate info is included in the Display>Statistics dialog. Use the pull-down menu to set the channel sample rate. See page 57 for details.

Setting up acquisitions

Once you have set up the channel parameters, the next step is to specify the acquisition settings. You can do this by choosing Set up Acquisition from the MP menu. This generates a dialog box that will describe the type of acquisition about to be performed. There are a number of options here, but the basic parameters involve specifying:

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



Storage Record and Save once to Memory is the default acquisition option. Under this option, the MP System automatically records data into a single continuous file, and stores the data in computer memory (RAM) during the acquisition.

The third popup menu at the top of the dialog (which defaults to Memory) allows you to specify where the data should be stored during the acquisition. You will probably want to choose Memory or Disk storage. Computer memory (RAM) is usually faster (but less abundant) than disk space. If your system uses any virtual memory, *AcqKnowledge* will use as much as possible. You may also store data directly to the MP acquisition unit; the MP150 can store 4MB, the MP100 can store up to 16,367 samples of data.

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

The other option under storage is Averaging, which allows you to take repeated trials of the same data. For more information on this feature, see the averaging section on page 99.

Rate Acquisition Sample Rate is analogous to “mm/sec” on a chart recorder, and refers to how many samples the MP System should take each second. As the MP System takes more and more samples per second, the representation of the signal becomes more accurate. 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 MP System’s sampling rate has a lower bound of 2 samples per hour, and an upper bound of 400 kHz aggregate for the MP150 or 70 kHz aggregate for the MP100. The MP100 will accept Custom rates, but the MP150 must use a pre-defined rate.

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. You can 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 you have specified which channels will contain data and have defined the channel characteristics, the next step is to start the acquisition. If a file window is not already open, choose File > New (or File > New > Graph on a Mac).

Status

In the lower right corner of the screen, next to the Start button, you should see a circular status light. The status light indicates the communication link between your computer and the MP acquisition unit.

- If the MP acquisition unit is properly connected to the computer and is turned on, the circle will be solid and green (on monochrome displays, the circle will appear solid).
- If the MP acquisition unit is not properly connected or not communicating with the computer, under Windows® OS the circle will be solid and gray (on monochrome displays, the circle will appear unfilled) and under Mac OS® X the circle may not appear at all or a different symbol, such as double arrows, may be used if the application crashed during acquisition.

Start

To start an acquisition, position the cursor over the Start button and click the mouse button, or select “Alt + Spacebar” on the PC or “Ctrl+ Spacebar” on the Mac. If there are no input devices (e.g., electrodes or transducers) connected to the MP System, it 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 MP System, see the *BIOPAC MP Hardware Guide.pdf*.
- You may also start an acquisition using a variety of “triggers,” which are discussed on page 104.
- Graphs that open without a Start Button
 - Advanced Averaging Experiment
 - Compressed Graphs
 - *Mac OS X only:* 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 (Mac GLP Only)
 - Text Files
 - Transformations: FFT (phase and Magnitude); IFFT; Rate (new graph option) Off-Line Averaging; Filter Response Histogram

Once an acquisition has started, the Start button in the acquisition window will change to Stop, and two opposing arrows will blink, indicating that data is being collected. Also, the “BUSY” indicator light on the front of the MP acquisition unit will illuminate, showing that data is being collected.

Stopping an Acquisition

To stop an acquisition at any time, click on the Stop button in the lower right corner of the screen or select “Alt + spacebar” on the PC or “Control + Spacebar” on the Mac.

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 the Save command from the File menu.

Display modes

The three main display modes are Chart mode, Scope mode, and X/Y mode. Data can be displayed in a number of different modes. You may change the way data appears on the screen at any time, even during an acquisition. To change the display mode, click on the corresponding icon in the toolbar.



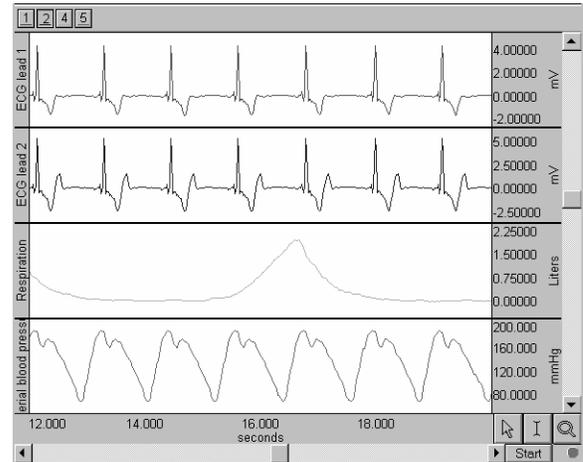
Chart mode

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 *AcqKnowledge* will select the “best fit” for waveforms to their tracks.



Scope mode

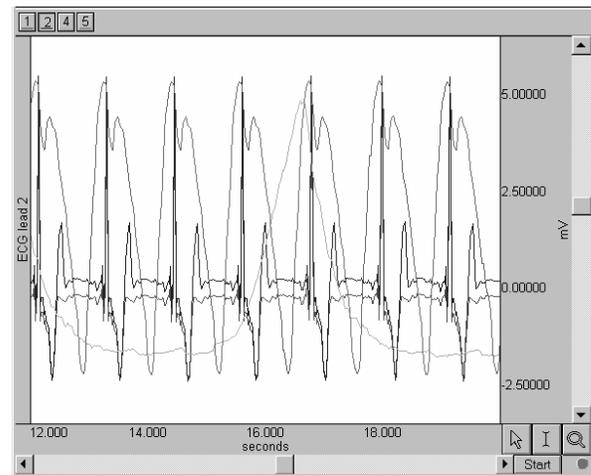
Scope mode plots data much as it might appear on an oscilloscope, with time on the horizontal axis.

Scope mode is similar to Chart mode, except that 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.

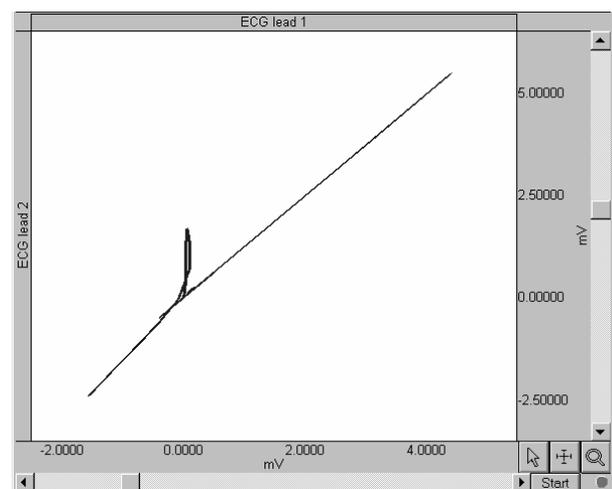


X/Y mode

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: You can select Display > Show >Last dot only to plot only the most recently acquired data point. This is most useful when viewing data as it is being collected and when this data is displayed in X/Y mode.





X/Y mode continued

Plotted channels

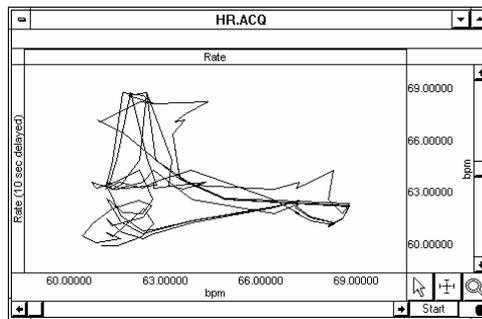
To change the channel being plotted along the X-axis, click in the channel label area *above* the waveform. To change the channel being plotted along the Y-axis, click in the channel label area *left* of the waveform. A popup menu of all currently plotted channels will be generated. Choose a channel from the list to plot it on the selected axis.

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 coordinate of the crosshair in terms of the horizontal axis, and the Y value describes the location of the cursor in terms of the vertical scale.



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

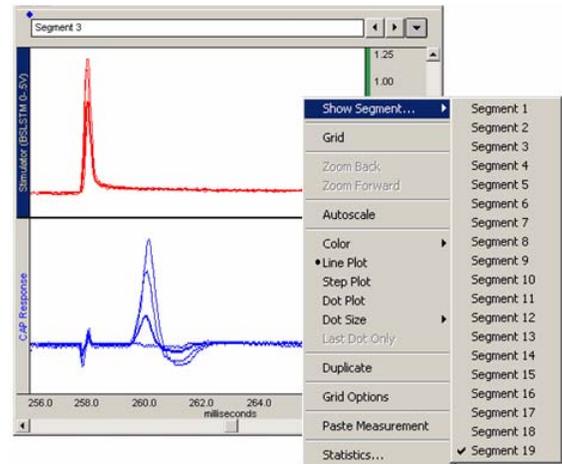
- Autoscale** In X/Y mode, the Autoscale waveform function changes to read Autoscale vertical, which plots the vertical channel so that it takes up two-thirds of the vertical channel space. This function controls the “height” of the data being plotted in the graph window. Similarly, the Autoscale horizontal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



Overlap Segment mode

Windows Only—The Overlap Segment mode is enabled for acquisitions set to Append (except when in X/Y mode). When this option is selected from the Toolbar, all appended segments are overlapped in the display, but only one segment is selected (“active”). Set the selected segment color via Display > Active Segment Color.

- Right-click and drag Show Segment... to generate a menu of segments and change the selected segment.
- Display > Show segments will also generate a list of segments.
- To view an individual segment, click on the Chart mode icon.



For Mac equivalent, see Stacked Plot mode on page 33.

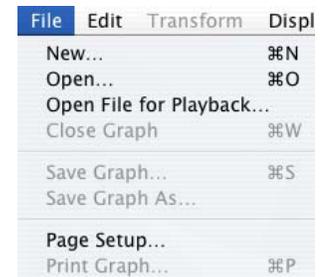
The selected segment is used for all enabled software functions. This means that autoscaling can easily create what looks like a mess if the selected segment is not appropriate for scaling the largest segment. In compound action potential graphs in Overlap Segment, the last segment will most often be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



Playback Mode (Replay)

Mac only—Playback mode will replay a graph file stored on disk in real time to simulate acquisition. Analog and digital channels are replayed as stored in the graph file, but calculation channels can be reconfigured to reproduce online calculation channels that have no offline equivalents. Calculation channels from the original graph can be modified, extended, or removed without affecting the data stored on disk in the original graph file.

1. Select File > Open File 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 light orange “Replay.”
4. Press Replay to begin playback.
5. Select Playback > Exit Playback mode to return to acquisition status.



Use *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.

See the *AcqKnowledge Demo* file under the Help menu as a sample of data playback.



Mac only—For Windows equivalent, see *Overlap Segment mode* on page 33.

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



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 than 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 (similar to the “overlap mode” feature) 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.

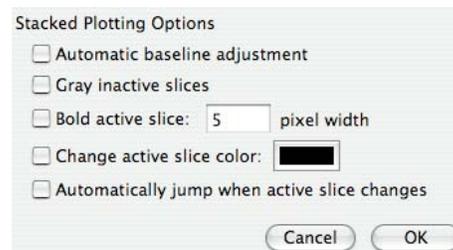
Active slice In stacked plot mode, there is a single slice that is called the “active slice.” By default it is drawn in a black color (which can be changed in the stacked plotting drawing options). The values on the axes in the graph, grid, displayed events and text annotations, selections, and any transformations 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



Display > Show > Stacked Plot Options > Drawing Options

Display > Show > Stacked
Plot Options

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 will be 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.

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.

Automatically jump... 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 (similar to the “Relative zoom hold” feature of Windows Overlap mode).

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 the visible data of the active slice only. It will not be possible to perform autoscaling operations using the 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 from $t = 0$ to the final data sample of the graph 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 sheet to be dismissed.

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

Data Views

A “Data View” window is used to provide an alternate view of the same data. You can present 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 > New Data View or
- Display > Create Data View

This will generate a new window displaying the active graph’s data, and will name the new window “Data View of ‘Filename’” 

TIP Mac AcqKnowledge 3.9.1 and later users can use the Jump-to tool (see page 144) to correlate data views.

Data Views share fundamental data characteristics such as channel labels, markers, 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
- marker 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 configuration of any Data Views that are open 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.
- *Windows:* Journal and modification logs will be displayed with the data files.

Toolbars

Many of the most commonly used features in *AcqKnowledge* can easily be executed with a mouse click. The toolbar contains shortcuts for some of the most frequently used *AcqKnowledge* commands; icons are grayed out when they are not applicable. Click Display > Show > Tool Bar to view the icons.

Icons vary slightly between PC and Mac but functionality is the same. Click on an icon to activate it.



PC	MAC	FUNCTION
		Change display to scope mode.
		Change display to chart mode (default).
		Change display to X/Y mode.
		PC = Change display to Overlap Segment mode (see page 33). Mac = Change to Stacked Plot mode (see page 33)
		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).
		Find the peak of a selected area.
		Find the next peak (after peak has been defined).
		Show/Hide gridlines in the graph window.
		Show/Hide measurement pop-up windows.
		Show/Hide channel selection boxes.
		Channel selection boxes appear above the data window and indicate the channel(s) being used to record data.
		➤ <u>To select a channel</u> , depress the corresponding channel number box (CH 1 is selected here).
		➤ <u>To hide a channel</u> , Ctrl-click (PC) or Option-click (Mac). A slash mark will cover the channel box and the channel will be hidden.
		Show/Hide markers and marker menu icons.
		Marker menu icons: PC— Mac—
--		Text Annotation display (see page)
		Show/Hide graph-specific journal. Mac—Journal must be open for icon to work.
		Produce a list of Student Lab-type files in the current folder. Other folders can be selected by: PC—choosing “Browse” from top of the list. Mac—choosing the “Select” folder.
		Rewind—deletes the last recorded segment. Ctrl+Rewind (Windows) or Option+Rewind (Mac OS X) deletes all recorded data, similar to the Append “Reset” button.
		Show/Hide Hardware “Connected to:” in the graph display; also functions via Display > Show > Hardware.

Keyboard shortcuts

Menu	Windows	Mac OS X
<i>AcqKnowledge menu</i>	n/a	
	Exit	⌘ Q
	Hide AcqKnowledge	⌘ H
<i>File menu</i>		
New Graph	Ctrl-N	⌘ N
Open	Ctrl-O	⌘ O
Close	Ctrl-W	⌘ W
Save (graph)	Ctrl-S	⌘ S
Print	Ctrl-P	⌘ P
Quit	Ctrl-Q	
<i>Edit menu</i>		
Undo (when applicable)	Ctrl-Z	⌘ Z
Cut	Ctrl-X	⌘ X
Copy	Ctrl-C	⌘ C
Paste	Ctrl-V	⌘ V
Clear (journal)	del	none
Duplicate Waveform	none	⌘ D
Select All	none	⌘ A
Journal>Paste meas.	Ctrl-M	⌘ M
Journal>Paste wave	Ctrl-D	⌘ /
<i>Transform menu</i>		
Find peak/cycle	Ctrl-F	⌘ F
Find next peak/cycle	Ctrl-E	⌘ E
Find all peaks/cycles	Ctrl-R	⌘ R
Find rate	Ctrl-A	none
<i>Display menu</i>		
Zoom back	Ctrl-“-” (minus key from num pad)	⌘ -
Zoom forward	Ctrl-“+”(plus key from num pad)	⌘ +
<i>Start/Stop Acquisition</i>	Alt-spacebar	Ctrl -spacebar
<i>MP menu</i>		
Autoplot on	Ctrl-T	⌘ T
<i>Cursors</i>		
I-beam	Ctrl-I	⌘ I
Arrow (pointer)	None—Ctrl-B will close program	⌘ B
Zoom	Ctrl-G	⌘ G
<i>Cursor Location</i>	<i>Mac only</i> —In chart, scope, or stacked plot mode (e.g., all but X/Y) these keyboard shortcuts can be used to scroll to various parts of the graph:	

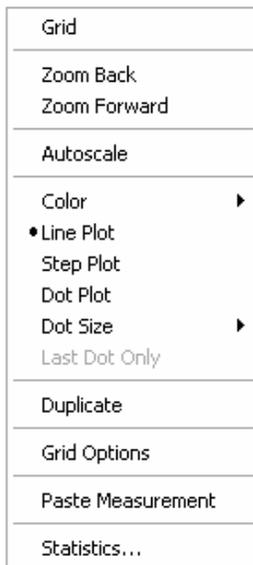
Menu	Windows	Mac OS X
Home	Jumps to $t = 0$ (e.g. places first sample of data flush with left of screen)	
End	Jumps to the end of the currently selected waveform (e.g. places last sample of data of the selected waveform flush with right of screen)	
Page Up	Scrolls backward in time one full screen (e.g. places leftmost sample of previous visible area at the right of the new visible area)	
Page Down	Scrolls forward in time one full screen (e.g. places rightmost sample of previous visible area at the left of the new visible area)	

Mouse Controls

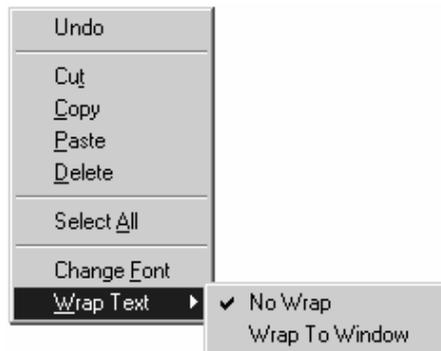
Right-click Shortcuts—*Windows only*

The following options can also be located via the right mouse button.

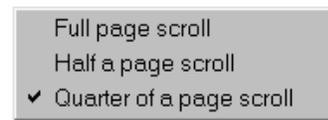
Graph window:



Journal window:



Horizontal scale:



(Update screen interval options)

Mouse Scrollwheel Support—*Mac only*

The scrollwheel operates on whatever window is underneath the mouse; this window does not need to be the topmost window. This makes it convenient to use scrollwheels when multiple graph windows are open or when the scrollbars in a graph window are unavailable due to a sheet being displayed for the graph. Many third-party mice and some Apple mice sport scrollwheels (or 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.

AcqKnowledge now 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 (Mac only), and a number of other dialogs and sheets that contain scrollable lists. To increase the scroll speed, hold down the “Option” key while using the scrollwheel.

Contextual Menus



Mac OS X only The graph window has contextual menus (similar to right-click functionality on a PC). To access these menus, hold down the Control key and click the mouse button.

- 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.

The contextual menus available are:

Waveforms	Set plot mode, select transformations, show Statistics
Measurements	Copy to clipboard or journal, toggle interpolation on/off
Markers	Insert, delete, paste summary to Journal



Horizontal Scroll	Change update interval
-------------------	------------------------

Contextual menu items correspond to the *AcqKnowledge* main menu state.

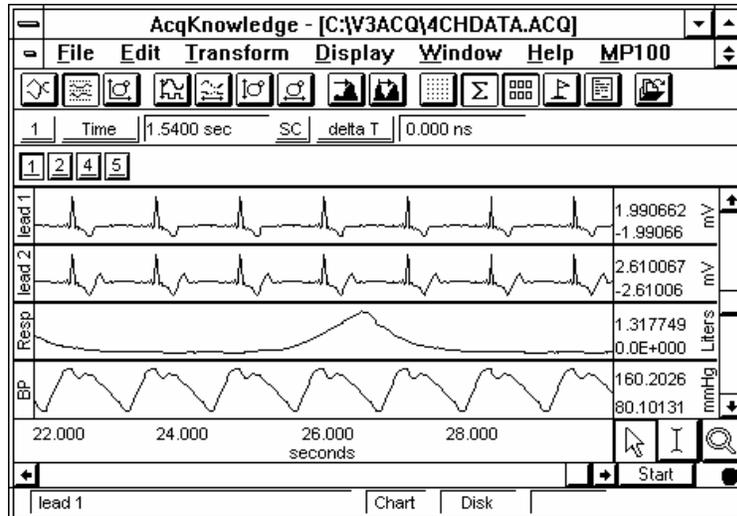
Application menu customization has a corresponding effect on contextual menu display. If a contextual menu item does not have a corresponding application menu item, the menu customization file identifier will begin with “IDM_CM.”

Analysis

For purposes of illustration, you should open an existing file that contains actual data. Sample files were installed with the software. Select File > Open and choose a file from the list in the dialog box.

- If you have the MPWS (Mac), open the file called 4chData
- If you have the MPWSW (PC), open the file called 4chData.acq

The screen should resemble the following sample file display.



Sample File Display

The sample graph displays four 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.

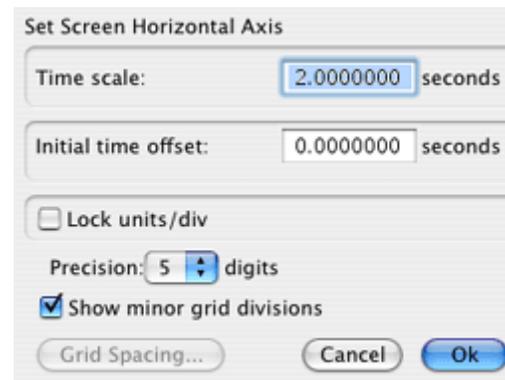
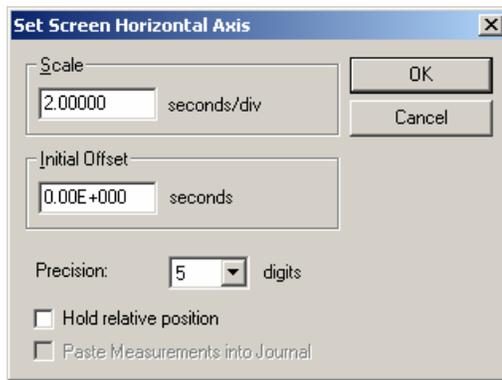
The maximum vertical scale range is from +10 to -10 Volts.

- This reflects the maximum input voltage the MP can accept and is a greater range than you will usually encounter.
- 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. If you choose Statistics from the Display menu (on the menu bar), you can determine the total length of the record.

To view data that was collected earlier in the record, you can use the horizontal scroll bar to move to different points in the record. The horizontal scroll bar allows you to move around in a data file, just as the scroll bar in a word processor allows you to move to different points in a document.

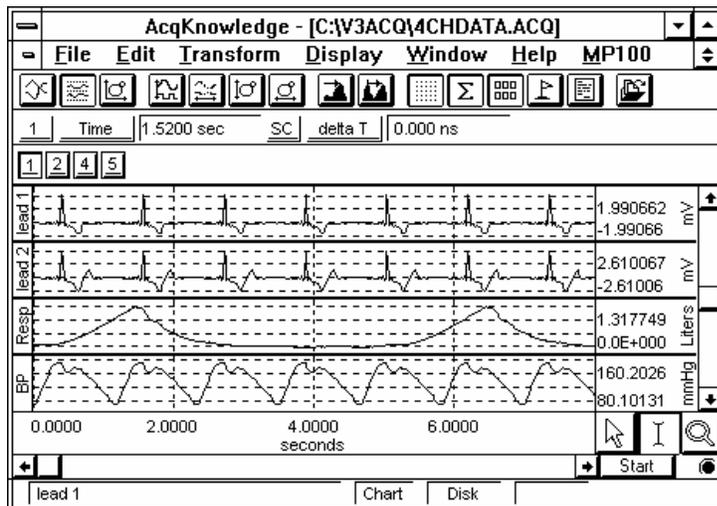
Alternatively, you can position the cursor in the horizontal scale area (where the numerical values are listed) and click the mouse button. This will generate the following dialog box (see page 137 for details).



The (Time) Scale box allows you to change the amount of data that appears on the screen at any given time. In the sample dialog box, 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.

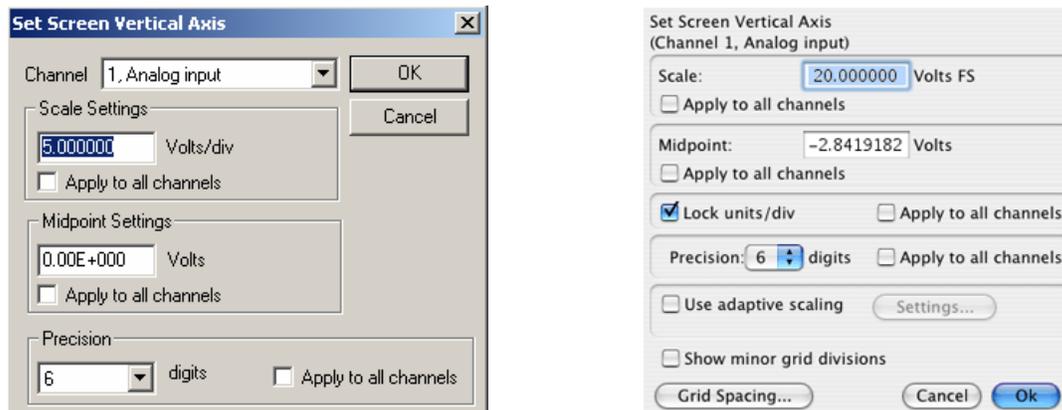
The Initial Offset box lets you “jump” to a different point in the time display. Changing the value in this box allows you to display data beginning at a certain point in the record. For instance, if you want to see the data at the beginning of this record, you would tell *AcqKnowledge* to display data with an initial offset of 0 seconds, which would result in the following:



As you can tell from 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. If you click 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.

Hold relative position is an option available only in the Append acquisition mode. When checked, the display for appended acquisitions will show the same relative position with respect to the start of acquisition (see unlocked grids section for more detail).

All of the options described thus far describe ways to change the time scale of data in one way or another. *AcqKnowledge* also allows you to change the vertical scaling, or amplitude of each waveform. Clicking on the vertical scale area produces a dialog box (see page 139 for details).



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

Scale—In the sample dialog box, the units are set to 3 mVolts per division. As with the horizontal scale, there are four divisions on the vertical axis, so this setting should show 12 mVolts range of data.

Midpoint—The box below this controls the midpoint of this range. In this case, the midpoint is set to 2 mVolts, which means that this channel will display the range from - 4 mVolts to + 8 mVolts.

You can 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.

As with the time scale, you can have *AcqKnowledge* automatically come up with 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 changes you make in terms of rescaling (either horizontal or vertical) will only affect the way data is displayed, and will not change the basic characteristics of your data file.

Selecting a waveform

Although all four waves are displayed at once, you may want to operate on only one channel at a time. To do this, you need to select the channel you wish to work with. Selecting a channel allows you to highlight all or part of that waveform, and enables you to perform 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 28). In the sample waveforms shown previously, 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 box that corresponds to the channel you wish to select and click the mouse button.

You can also select a channel by positioning the  cursor on the waveform of interest and clicking the mouse button.

Hide a Channel

To “hide” a waveform, hold down the appropriate key and click on the channel box:

- Hold down CTRL key on PCs
- Hold down OPTION key on Macs

You may view a hidden waveform by keeping the appropriate key pressed and clicking on the channel box again.

Zoom

Another way to examine data is to use the “zoom” tool. The zoom tool allows you to select any portion of any wave and magnify it as much as possible. To use the zoom tool, click on the  icon in the lower right portion of the screen. As you move the mouse into the graph area, you will see it change 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 you need to zoom in on. When you release the mouse button, *AcqKnowledge* will automatically adjust the horizontal and vertical scales. To “unzoom,” choose Zoom back from the Display menu.

Selecting an area

Once you have selected a channel, you can “edit” parts of that channel by selecting a section of the waveform. The options available to you include cutting, copying, and pasting sections of waveforms. You can also transform and analyze entire waveforms or specific sections of waveforms.

For any of these functions, you will need to select (or highlight) an area to be operated on. If you want 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 that you wish to select. As you move the cursor into the graph area, you will see it change 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 you wish to select and hold down the mouse button. Now move the mouse to the right until you have selected the desired area.

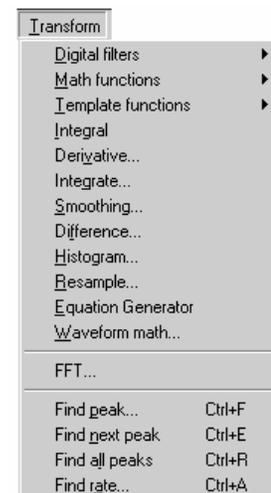
To select more than one screen of data, position the  cursor at the left edge of the section to be highlighted, then click and hold the mouse button. Use the scroll bars to move to a different point in the record, and when you reach the desired endpoint (right edge) of the selected area, hold down the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

Once a channel has been selected and a section of that area highlighted, you can operate on and edit that section of the waveform. The editing commands behave much the same way as the editing functions in a word processor. You can cut, copy, delete or paste sections of data as defined by the selected area. In most cases (depending on available memory) you may undo an edit by choosing Undo from the Edit menu, or by using the shortcuts of  + Z on Macs (MPWS) or CTRL + Z on PCs (MPWSW).

Selecting a portion of a waveform also allows you to apply transformations to a particular area, rather than the entire area or all waveforms. Selecting an area also allows you to take snap measurements for parameters such as delta T, mean, standard deviation, frequency, and so forth. The measurement options are discussed in the next section.

Transforming data

AcqKnowledge includes a vast library of functions, which can transform data or perform mathematical Calculations on waveform data. All of these options can be found under the Transform menu, and are discussed in detail in the Transform Menu Commands section beginning on page 217.



When performing transformations, keep in mind that when a section of a waveform is highlighted, the transformation will apply to that section. Also, if no area is defined, AcqKnowledge will always select a single data point. Some transformations (spectral analysis and digital filtering, for instance) can only be performed on a selected area, so if a single point is selected the entire waveform will be transformed.

Measurements

Once you have selected a channel to work with, you can quickly and easily take measurements on each wave. The measurements appear in the row of boxes across the top of the graph window. You can specify the number of measurement boxes to show and the display precision 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.

Results

SC	time	17.28000 sec	SC	delta t	0.00000 sec	SC	freq	0.10157 Hz	SC	bpm	6.09446 BPM
----	------	--------------	----	---------	-------------	----	------	------------	----	-----	-------------

Pull-down channel selection

Pull-down measurement menu

In this example, results for the selected channel (SC) are:

Time	17.28 sec
delta t	0.00000 sec
freq	0.10157 Hz
bpm	6.09446 BPM.

The pull-down channel selection allows you to calculate a measurement either for the selected channel (SC) or from a numbered channel in the record. To switch between the channel options, click in the channel window. The pull-down 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.

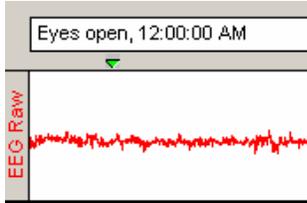
The pull-down measurement menu allows you to choose between different types of measurements. To choose a measurement, click on the measurement popup menu and select a measurement from the list.

- 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 147. 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..

Markers (Events)



In many instances it is useful to have the software “note” an occurrence or event during an acquisition so it can be referenced later. For instance, you may want to note when a treatment began or when an external event occurred so you can examine any possible reaction. The software uses “markers” which are placed above the data to record events.

AcqKnowledge distinguishes between Append Markers and Event Markers, and allows you to pre-program and automate each. Markers appear at the top of the graph window, and can be edited, displayed, or hidden from view.

- “Append markers” are automatically inserted each time you record a segment in “Append” mode
- “Event markers” can be inserted during an acquisition or after recording (off-line)

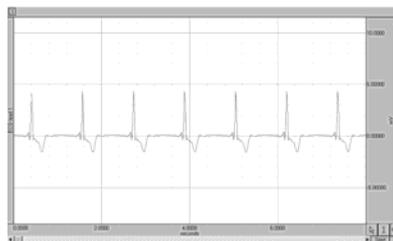
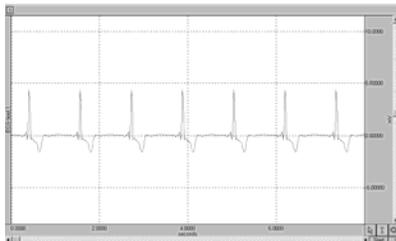
You can automatically insert event markers during an acquisition by pressing the F9 key on a PC or Esc on Mac. This will insert a marker at the exact time the key is pressed and will activate the text line entry so you can immediately enter a comment to be associated with the marker. Use Marker Preferences to change or add function key assignment(s).

To enter an event marker after recording, click the cursor in the area beneath the marker area. This will insert a marker. To add text describing the event, click the cursor in the marker box and key the desired text. To view the text associated with a marker, position the selection tool over the marker and click the mouse button. To move from marker to marker, paste marker information to the journal, etc., use the Marker tools.

For a detailed description of markers and marker functions, including options to pre-establish marker labels and set function keys for different labels, see Markers on page 161 for Windows/PC and Events on page 164 for Mac OS X.

See also: Text Annotation, page 144.

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 on the  toolbar icon.

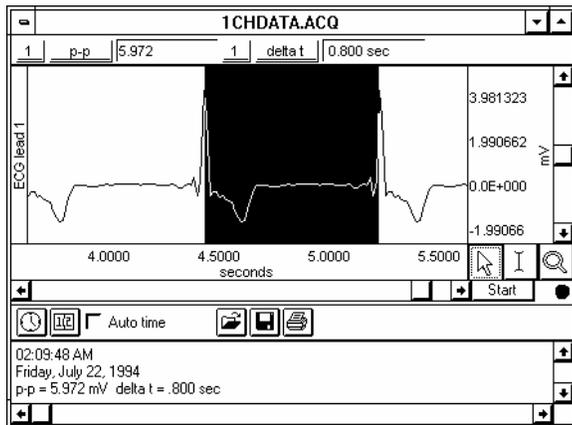
- To display minor grid lines, use Ctrl-.
- To customize grid line and color and optimize the display and print features, choose Display > Show > Grid Options.

For more information about using and printing grids, see page 179 for Windows/PC and page 183 for Mac OS X.

Note: The Scale dialogs change when grid lines are locked. See page 137 for details on Horizontal Scale and page 139 for details on Vertical Scale.

Journals

The Journal is a general-purpose text editor built into *AcqKnowledge* that works like an “electronic notepad” for you to record notes and data and save text and/or numeric values to review later.



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—*Mac only* 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.

To display the Journal, select the  icon from the toolbar (toggles graph-specific journal only), or

Windows: Choose Display > Show > Journal

Mac: Choose File > New > Graph-Specific Journal or Independent Journal

Once a Journal is open, you can enter text, data, or both. To enter text, just begin typing when the journal is open. *AcqKnowledge* will automatically “wrap” the text to fit the screen width.



There are Time Stamp, Date Stamp and Auto Time functions available in the journal window. The Time and Date stamps refer to the computer’s clock to record the time and date, respectively, directly into the Journal. The Auto Time function records the time at the instant the carriage return is pressed, which is useful for tagging commands as data is collected. Additional icons are available for:



Clear the journal without saving



Save journal as a text file



Open a text file to add to the existing journal



Print the journal

You may also paste measurements and data 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.

Additionally, by changing the Journal Preferences (page 312), you can simultaneously record measurement name and units. For Marker Journal Summary preferences, see page 163.

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 your wave data pasted into your active journal.

A useful feature of the Journal is that it works in connection with the 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 216 for more information on how to paste information to Journal files.

Mac only: Use Save as/Open Journal Template to retain SOP text or standardize lab and/or computer details for record keeping.

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 *AcqKnowledge* 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 *AcqKnowledge*, 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 you to examine the data using other programs, such as a spreadsheet or statistical analysis package. Saving data as a graphic (.WMF for MPWSW or PICT for MPWS) enables you to work with the data in graphic format.

One of the most useful applications of this is the ability to edit and place *AcqKnowledge* data as it appears on the screen. You can 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 197.

Embed Archive “Snapshot”

Each embedded archive is essentially a “snapshot” of the original acquired data that is stored with the graph file so you can easily view them together at a later time to compare results to original waveforms or intermediate stages of analysis. Append markers are not preserved in Embedded Archive files.

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. You cannot use this feature to recover lost or damaged original data.

There are two ways to create an embedded archive:

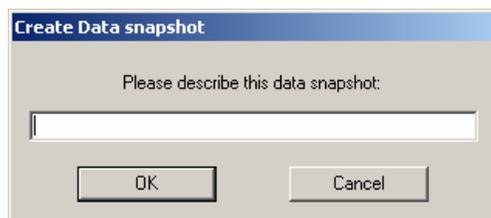
1. **Backup data after acquisitions** Automatic after acquisition: Display > Preferences > General > Snapshot data after acquisition

Toggle the “Snapshot data...” option in Display > Preferences > General. 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.

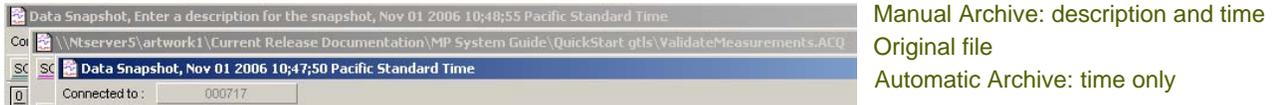


2. **Manual:** Edit > Create Original Data Snapshot



A snapshot is then taken of the data at that point in time and stored with the graph. Manual archives allow you to preserve intermediate stages in a complex analysis for future reference. You will be prompted for a comment to describe the archive. This description will be used in the header when you display the archive.

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 you cannot save a file with colons in the filename). The “Data Snapshot from...” graph will open with no Start button.



Mac 3.9.2 and later only—Snapshots will also retain the following in addition to the data:

- Events - Text annotations
- Graph-specific journals
- AcqKnowledge GLP Modification logs (ACK100W-G and ACK100M-G only)

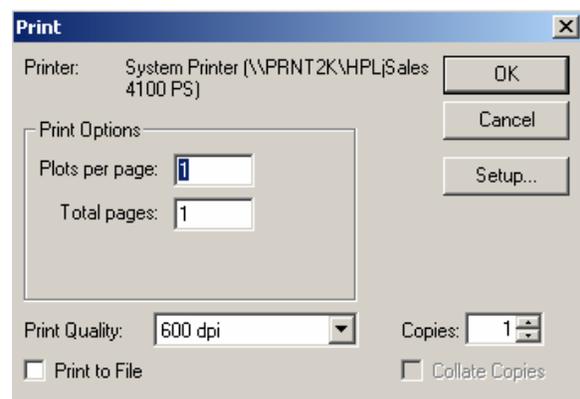
Printing

In some cases, it is important to have a hard copy of the data. AcqKnowledge allows you to produce high-resolution plots of graphs 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.

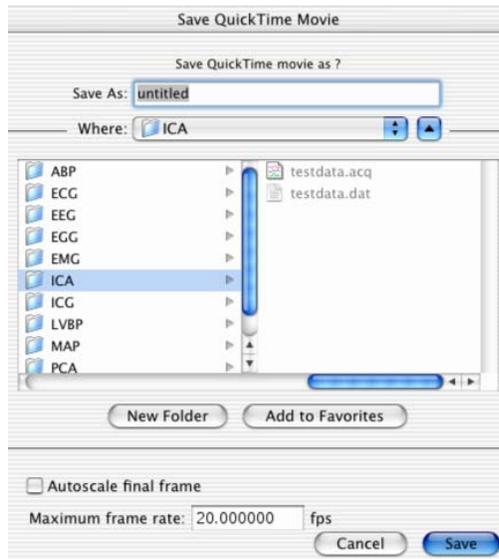
You must print a journal as a separate command from print graph file.

An example of the print dialog is shown here. Often, you may want to instruct AcqKnowledge to print the contents of a file across several pages. To do that, change the value in the Total pages box (under Print Setup > AcqKnowledge 3.9 on Mac OS X). Entering “4” in this box, for instance, will place the length of the page evenly across four pages when printing.

To find out more about the print command, turn to the Print section beginning on page 207.



QuickTime Movies of Acquisitions



You can create a QuickTime movie of *AcqKnowledge* window content during or after acquisition (from a graph file saved on disk). Capture waveform plotting, results of autoscaling, autoscrolling, and any other visual changes to the graph window that occur during acquisition.

- By postponing QuickTime creation, you can make sure data is clean and optimize settings to reduce file size—QuickTime movies can be gigabytes in size and it's a hassle to accidentally run out of disk space in the middle of an acquisition.

Flattening—QuickTime movies are generated in the “Animation” format with no compression codec used and flattened at the end of the acquisition. Flattened movies are cross-platform compatible with Windows™ PCs. Due to limitations of QuickTime 6, flattening may take 10 minutes.

Save Quick Time Movie Options

Location—The disk where the movie is saved should have several gigabytes free space available for movies longer than 3 minutes.

Autoscale final frame—Creates the last frame of the movie after an Autoscale Horizontal operation so the last frame of the movie shows all of the data from the start of the acquisition to the end.

Maximum frame rate—Sets an upper bound for the frame rate at which screen shots of the graph window will be taken.

- Higher frame rates generate larger movie files.
- This is only a maximum frame rate—the actual frame rate will vary. A lower frame rate may result from CPU load, network latencies, other programs running in the background, or any operation that causes a hitch in the smooth plotting of data or autoscrolling.

Optimize graph size and display settings

The actual dimensions of the movie will be taken from the size of the graph window, so optimizing the display will help reduce file size and emphasize signal representation(s).

- Optimize graphs size
 - Select Display > Size Window and enter the smallest reasonable size for the visual dimensions of the movie (e.g. 400x300).
 - The smaller the size of the graph window, the smaller the resulting movie will be (in both size on disk and visual dimensions).
 - Do not resize the graph window while a QuickTime capture is in process.
- Optimize display settings for the reduced graph size
 - Hide toolbars, events, hardware menu, measurements, etc.
 - Set the scales such that details of the waveform(s) will be discernable in the small graph window plotting area.
 - Perform autoscaling as necessary to get appropriate vertical scales for the entire data file.
 - Optimize the horizontal scale for the reduced display region.
 - Set precision of the axes (usually 2-3).
 - Set the “Initial time offset” of the horizontal axis to zero, either through clicking on the axis or scrolling all the way to the left.

Create a QuickTime file from a Saved Graph File

Preferred Method —This procedure requires two acquisitions

Stage 1

1. Select File > Open File for Playback (the MP menu will change to “Playback”).

2. Select the file containing the source data for the video.
3. Disable (uncheck) Playback > Capture to QuickTime.
4. Set the acquisition storage mode to “Save once to Memory” (Playback > Set Up Acquisition).
5. Press “Replay” in the graph window and wait for acquisition to terminate.
 - This acquires all of the original data into the graph window so all of the data is present for determination of vertical scaling appropriate for the entire acquisition.

Stage 2

6. Optimize graph window size and display settings to reduce movie file size.
7. Select Edit > Select All.
8. Select Edit > Clear All.
9. Enable (check) Playback > Capture to QuickTime.
10. Press “Replay” in the graph window.
11. Set options in the “Save QuickTime Movie” dialog and then click Save.
 - Watch for error dialogs and wait for playback acquisition to finish.
 - Wait for the QuickTime file to flatten (may take 10 minutes).
12. Open the movie in QuickTime Player and check for any problems.
13. If necessary, go back to the playback graph window and repeat from Step 6.

Create QuickTime file during Acquisition

Riskiest method—You are more likely to run out disk space

1. Enable MP1#0 > Capture to QuickTime.
2. Optimize graph window size and display settings to reduce movie file size.
3. Press Start in the AcqKnowledge graph window.
4. Set options in the “Save QuickTime Movie” dialog and then click Save.
5. Stop acquisition (automatically or via the Stop button).
 - a. The QuickTime file will automatically be saved (separately from the acquisition).
 - b. Save the graph file.

Playback

Use Playback mode to replay (or simulate) acquisition using a previously acquired graph file. The data in a graph file can be used to simulate an MP unit that returns the data of the analog and digital channels stored in the graph file; calculation channel settings can be altered from the ones contained in the graph file. See the AcqKnowledge Demo file under the Help menu as a sample.

1. Select File > Open File 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 light orange “Replay.”
4. Press Replay to begin playback.
5. Select Playback > Exit Playback mode to return to MP menu and acquisition options.

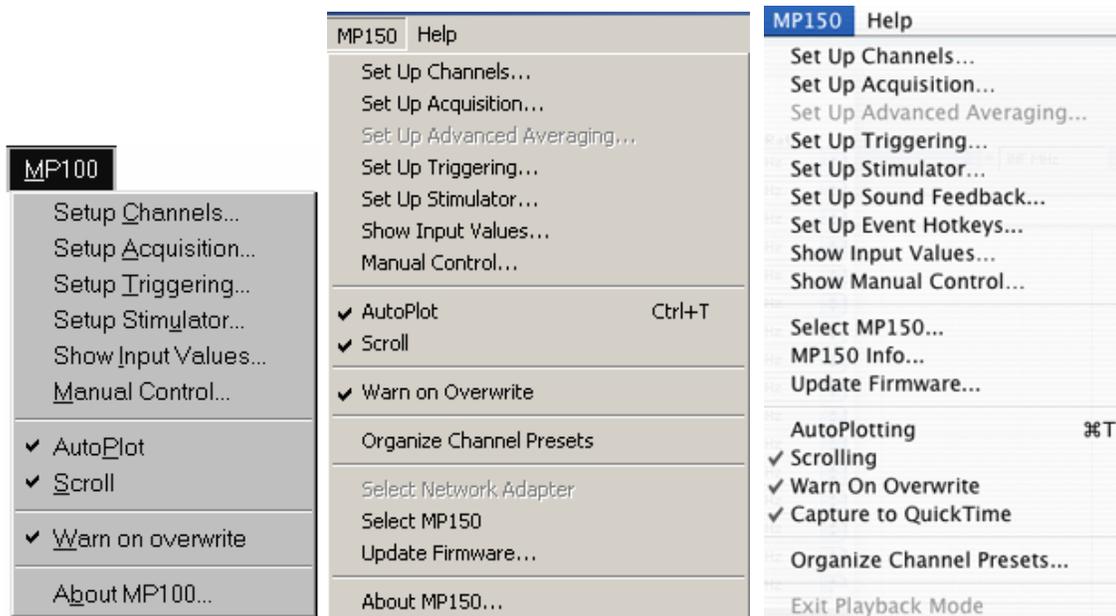
Part B—Acquisition Functions: The MP Menu

Overview

The *AcqKnowledge* software adds acquisition and control capability to the complete MP System. This section describes the commands and procedures used to establish the various acquisition parameters for the MP System, 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 the commands covered here can be found under the MP menu.



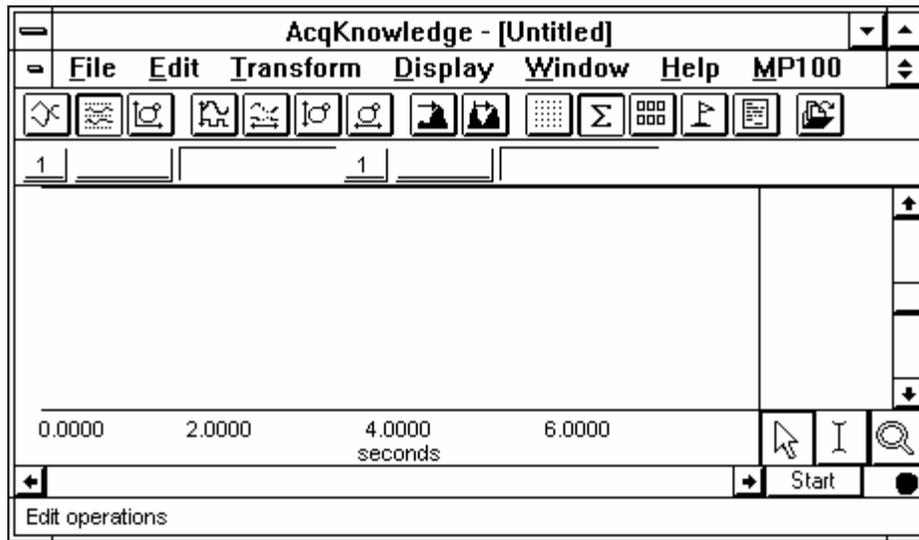
Acquisitions

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

- Before you begin an acquisition, make sure the MP acquisition unit is turned on and connected to your computer. Please refer to the BIOPAC Hardware Guide for more information on connections.

To begin collecting data:

1. Launch the *AcqKnowledge* application (you can double click on the *AcqKnowledge* icon).
2. Open a new graph window that will display data as it is being collected.
 - To do this on the MPWSW (PC), choose New from the File menu.
 - To do this on the MPWS (Mac), choose New from the File menu and then select the Graph Window option.
3. You should see a window similar to the following:



4. After you have opened up a new graph window, you must setup the specific channels you want to acquire before starting the acquisition.
 - See the Set up Channels chapter (page 55) for details.
5. In addition to setting up channels, you must setup the acquisition parameters (such as sampling rate, acquisition length, and data storage options).
 - See the Set up Acquisition chapter (page 89) for details.

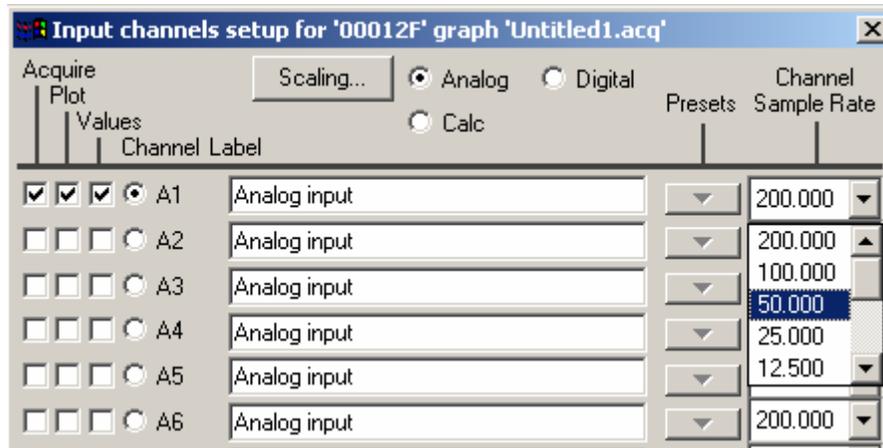
Edit menu functionality during acquisition

Mac OS X only—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 3 Set up Channels

Set up Channels—The Basics

Before you collect data, you need to specify how many channels you will be collecting data on, and at what rate data is to be collected. Both of these functions are accomplished through menu items and dialog boxes. To enable collection on a given channel, select Set up Channels from the MP menu.



Notice that the checkboxes next to Analog channel 1 are already selected. This is the default at startup. For each additional channel you wish to collect data on, there are three options for channel setup: acquire, plot, and values. These options appear as boxes on the left side of the Input Channels dialog box. There are 16 rows of boxes, which correspond to the 16 Analog inputs the UIM100C can accept. To change the options for any channel, click in either the channel label box or the acquire/plot/values boxes. As you do this, a solid circle will appear between the Values box and the label area. This indicates that the options for that particular channel can be edited.

Channel Type

To specify the channel type—Analog, Calculation or Digital—click in the circle next to its name.

Acquire

The first option is whether or not you wish to collect data on that channel. Unless you specify otherwise, the MP System will only collect data on channel 1. To collect data on other channels, position the cursor over the Acquire box (on the far left) and click the left mouse button.

With the MP System, To leave hardware connected to the MP acquisition unit, but have the software essentially “ignore” the channel by leaving the acquire box unchecked. Thus, 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. You will need to specify a Plot option for each channel. 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 your computer’s screen.

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

In most cases, you will want to check this option. However, in large-scale acquisitions (i.e., many channels and/or high sampling rates) you may want to uncheck this option for some channels to allow for faster display rates (see Appendix B—Hints for working with large files).

Values

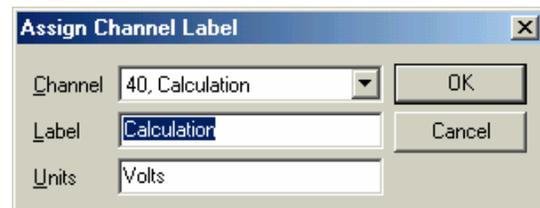
The third option enables incoming data values to be displayed either numerically and/or in a “bar chart” format in a separate window during an acquisition. Checking this option allows you to open a window (by selecting Show Input Values... under the MP menu) that displays the numeric value for each input with the “Values” option checked. This option 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 118.

Channel

Click in the circle next to the channel designation (i.e. A1) to make that channel active (“selected”) so its settings can be established or edited.

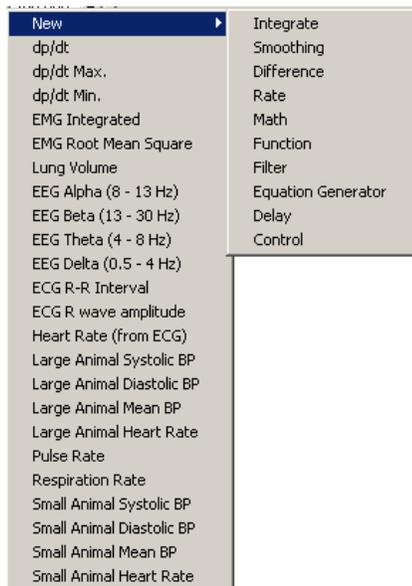
Label

You may attach an editable “label” to each channel. These labels allow you to provide a brief name for 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. You may key up to 38 characters on PC or 40 on Mac and these labels will appear next to the channel label boxes in the graph window. You can change the label in the Set up Channel dialog at any time, or right-click on the active channel label in the graph window to generate the Assign Channel Label dialog after acquisition.



Mac: Click on label to change label text. Click on vertical scale to change units text.

Presets



Calculation Presets are like “templates” for calculation channels. Each Preset stores:

- Calculation channel type
- parameters for that Calculation
- channel-specific scaling
- channel-specific sampling rate
- channel name.

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

Just click on the icon under the Presets head and scroll to select the desired preset.

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 you select 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. For instance, if a Difference Calculation channel is being configured, all Presets for the Difference Calculation will be listed.

When you select 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.
- You can create a new Preset from existing Calculation channels. Click on “Setup” to display the Calculation Setup dialog and click on the “New Preset” button. The settings will be applied to the current channel, and you will be prompted to enter a name for the new Preset. You cannot duplicate a Preset name, which also means that you cannot use the default name of a Calculation channel type (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 “Organize Channel Presets” from the MP150/100 menu. A dialog will be generated and you can drag items to the desired position or use the up/down and top/bottom buttons as appropriate (see page 128).
- Presets are not applicable to and therefore not selectable on Analog or Digital channels.

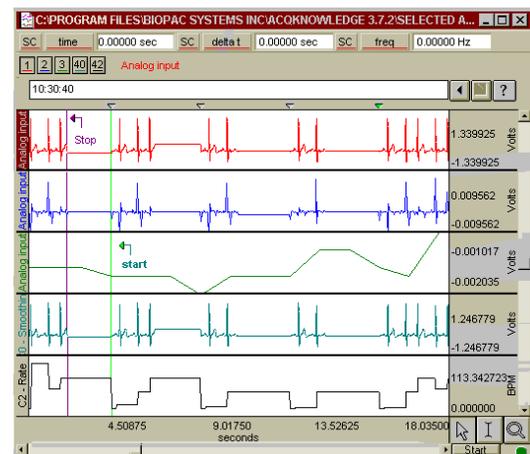
Channel Sample Rate

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 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 (channels with a lower sampling rate will snap to the left).
- To set an arbitrary channel sample rate for analysis, use Transform > Resample (see page 247).
- There is no restriction on the acquisition length when using Variable Sampling Rates on a Mac.
- Averaging is not allowed with Variable Sampling Rate enabled under AcqKnowledge for Windows.
- 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 57). 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 10Hz or higher, or
- Don’t use Variable Sampling Rates.



AcqKnowledge QUICK STARTS

Quick Start templates (.gtl graph template files) were installed to the Sample folder for PC users. You can use a **Quick Start** file 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 193 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	Evoked Response	Nerve Conduction Studies
5	Evoked Response	Auditory Evoked response & Jewett Sequence
6	Evoked Response	Visual Evoked Response
7	Evoked Response	Somatosensory Evoked Response
9	Evoked Response	Extra-cellular Spike Recording
10	Psychophysiology	Autonomic Nervous System Studies
12	Psychophysiology	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	Plethysmography	Indirect Blood Pressure Recordings
18A	Plethysmography	Arousal - Female
18B	Plethysmography	Arousal - Male
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	<i>In vitro</i> Pharmacology	Tissue Bath Monitoring
33	<i>In vitro</i> Pharmacology	Pulsatile Tissue Studies
34	<i>In vitro</i> Pharmacology	Langendorff & Working Heart Preparations
35	<i>In vitro</i> 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

→ See Appendix G for detailed applications and features

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 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.

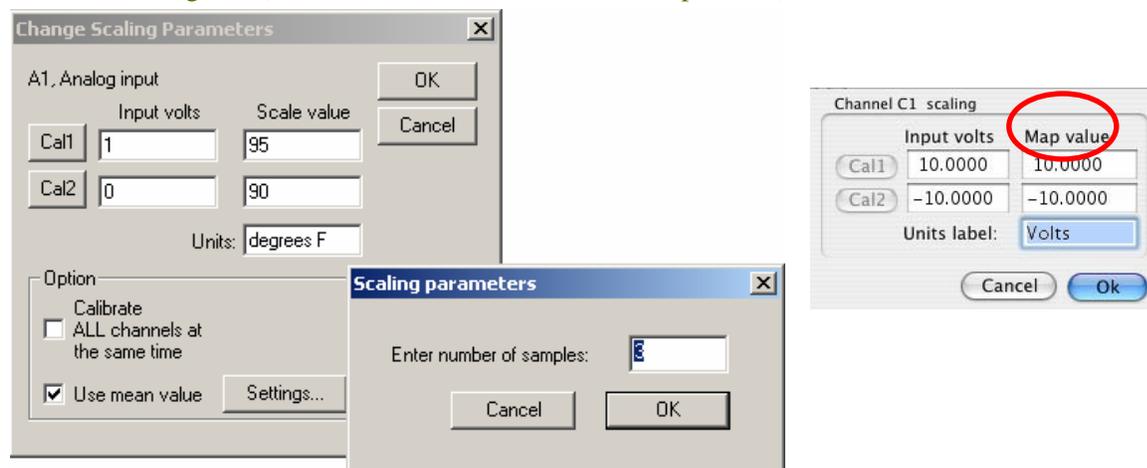
In the upper right hand corner of the Set up Channels dialog box, you will see the words Analog, Digital, and Calc. These refer to (respectively) analog channels, digital channels, and Calculation channels. The general features (acquiring, plotting, and the like) are the same for each type of channel, although there are considerable differences between the type of data each channel is designed to handle. You may acquire up to 16 channels each of analog, digital, and Calculation channels. Analog and digital channels may be acquired in any combination, and the only requirement for Calculation channels is that you have at least one input channel (either analog or digital).

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.

AcqKnowledge also allows you to rescale the signal on analog channels to more meaningful numbers. As an example, imagine a temperature transducer is connected to an SKT100C amplifier with a gain setting of $5^\circ/\text{Volt}$, and output set to channel 1. Ordinarily, the values from the amplifier would be read in as Volts or milliVolts. For this acquisition, you need to express the signal from the transducer 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 MP menu (see page 118 for a description of the Show Input Values options). At 90° F , you will get a reading of 0 Volts. The transducer is then brought to a temperature of 95° F , and you will get a reading of +1 Volts.

To have *AcqKnowledge* scale the incoming signal to degrees F, click in the Scaling button in the *Input Channels* dialog box (on the Macintosh, click on the Setup button).



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

The Input Volts and Scale value (MAP value on Mac OS X) 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 . *AcqKnowledge* 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 Change scaling box, type in “degrees F” for Units, and click the OK button.

As a shortcut for scaling channels, use the Cal 1 and Cal 2 buttons. Clicking on either one of these buttons will read the current voltage for the channel you have selected. In the above example, you could have simply set the transducer to a known temperature, clicked on the Cal 1 button, and then entered the temperature in the Scale value (MAP value) box for Cal 1.

You would then need to bring the transducer to another known temperature that is considerably higher or lower than the first and click Cal 2 and again enter the new known temperature in the Scale value (MAP value) box for Cal 2. *AcqKnowledge* 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 MP acquisition unit and power up the MP System, and then perform your 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, the “Input Volts” box will be updated for all active channels.

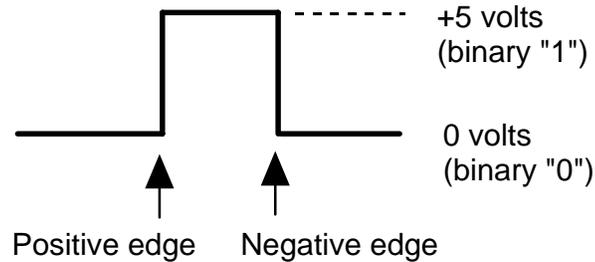
- For example, if recording from 10 force transducers, all 10 transducers could be loaded with a specific weight, and then all the channels could be simultaneously calibrated by pressing the Cal 1 or Cal 2 button.

The Use mean value option is useful if the input voltage signal is noisy around a mean value. The “Input Volt” value returned will be the mean value over the specified number of samples. When this option is selected, a Settings... button is activated generates a Scaling parameters prompt for the number of samples.

The data is sampled at approximately 10,000 Hz. If 100 samples are selected, it will take about a second to collect that number of samples. It may be helpful to use a larger number of samples as long as the signal has a Gaussian distribution around a mean value. If the signal is drifting slowly or otherwise unstable, a larger number of samples in the mean may result in an inaccurate sampling.

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 MP 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.

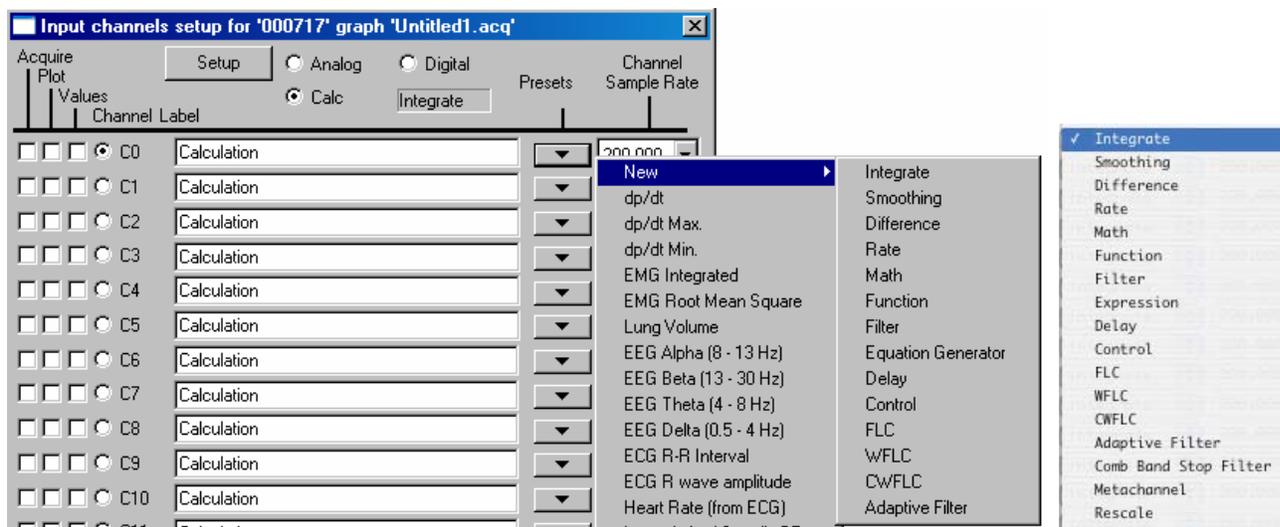


Calculation channels

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.

You can use Calculation channels 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 acquire a Calculation channel, click on the Calc button and check the Acquire box for each Calculation channel you want to compute (the Plot and Value boxes are optional). By default, all Calculation channels have the label “Calculation” and entering more descriptive channel labels might prove useful, especially when multiple Calculation channels are being acquired.



Windows/PC

Mac OS X

Each of these functions requires some additional parameters to be specified, and these options can be set by clicking on the Preset (Setup on Mac) button in the Input Channels dialog box. For any Calculation channel, you will (minimally) need to specify the source channel to be transformed and the nature of the transformation.

Up to 16 Calculation channels can be acquired, and you may use the output of one Calculation channel 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 is 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.

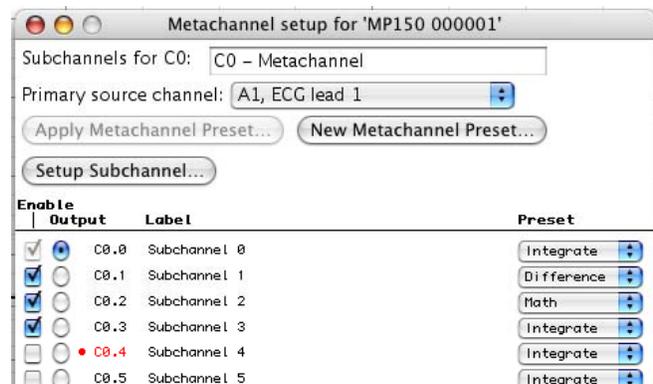
Although Calculation channels can be useful in many cases and indispensable in others, each Calculation channel acquired will somewhat reduce the maximum possible sampling rate, and add to the amount of memory required to store data both during and after an acquisition. Thus, you may want to consider performing some of these functions after the fact if high sampling rates are needed for your particular application.

TIP: All of the operations that can be performed online can also be performed after an acquisition has been completed. These options are available under the Transform menu.

Metachannel

Mac *AcqKnowledge* 3.9.2 and later only— 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.

- *AcqKnowledge* 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.

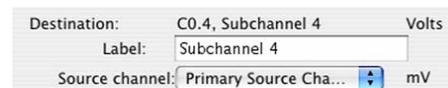
Metachannels labels display in the graph as C#.#

Primary Source

The primary source for a metachannel can be set to any analog, digital, calculation, or subchannel with a lower index (index 0-15, with 15 being lowest).

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.

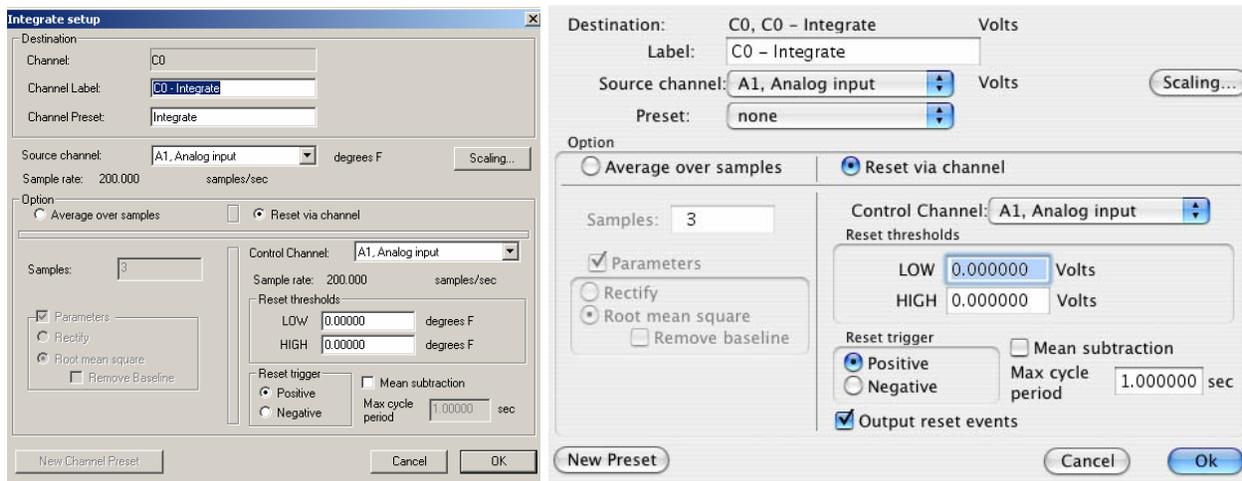


Source channel: Each subchannel can be set to use the primary source channel as its data source or another channel (analog, digital, or lower-index calculation channel). When the primary source channel for the metachannel is changed, the source channel of each subchannel will implicitly be changed.

Integrate Calculation

The online Integrate Calculation offers two basic operations:

1. Perform a moving average (and associated processing) over a fixed number of sample points. This option is useful for:
 - a) Smoothing noisy data
 - b) Real-time “integration” of EMG
 - c) Real-time “root mean square” evaluation of EMG.
 - d) Real-time windowed standard deviation.
2. Perform a real-time integration over a potentially variable number of sample points. This option is useful for:
 - 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.



Calculation channel set to integrate across 3 samples

Destination

Determined by the calculation channel selected when the Scaling button was pressed.

Source

The source channel is selected from a popup menu that includes any channels being acquired and any enabled Calculation channels.

Sample rate

Provides the sample rate for the selected channel (may be different than the acquisition sample rate).

Option

As mentioned previously, the Integrate setup dialog is divided into two sections:

1. Average over samples will calculate the moving average (mean) of the specified number of samples. Additional parameters (Rectify; Root mean square) add further functionality. Used typically, these features allow you to process EMG signals and will display the integrated (rectified, then sample averaged) or Root mean square calculation on the original raw EMG data.
2. Reset via channel permits real-time integration of input data over a data-defined time interval. This feature 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.

Average over samples option

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.

Since an average represents the sum of a series of data points divided by the number of data points present, you can use the Average over samples calculation to provide the information needed to create a moving average.

Samples

To specify the number of data points to average across, enter a value in the Samples box. The number you select will depend in large part on the sampling rate you select and the type of noise present. All things being equal, for slower sampling rates you will probably want to mean average across a smaller number of samples. As you increase the sampling rate, you will probably want to 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.

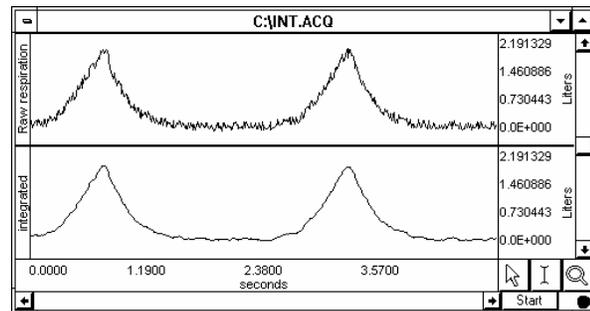
Parameters

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, *AcqKnowledge* 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.

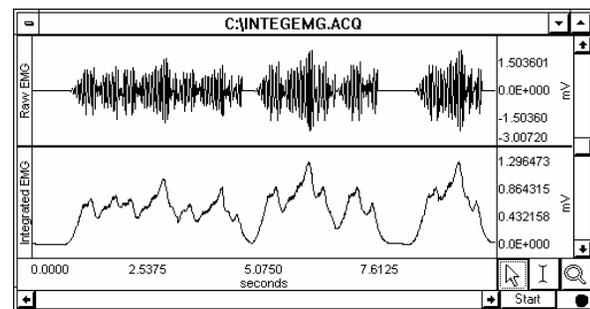
Typically, this option is only used for processing raw EMG and similar types of applications. The signal for Rectify is normalized by a factor of (# samples averaged)/(Channel sampling rate).

Root mean square—This feature provides the exact root mean square (RMS) of the input data (typically EMG) over the specified number of samples.

Remove baseline—This feature 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.

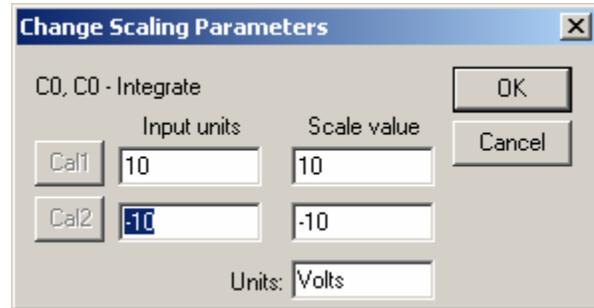


Integration used to smooth noisy data



Online “Average over samples” feature used as an envelope detector

Scaling... button—Since the integration values are going to be on a different scale than the original units, you need to change the scale of the integration channel to reflect the new units. When you click on the Scaling... button, a Change Scaling Parameters dialog will be generated.

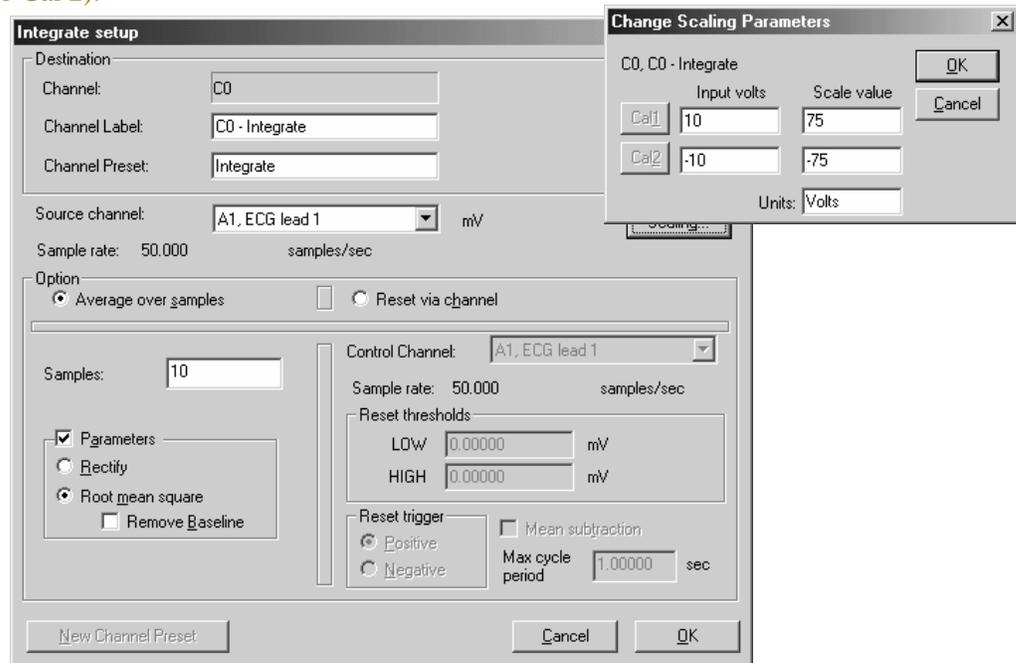


The rescaling involves multiplying the “Input units” values by a factor determined by the sampling rate and number of samples mean averaged across.

$$\text{Scale value} = \text{Input units} \times \frac{\text{Sampling rate}}{\text{Number of samples to be mean averaged}}$$

As an example, if data were being acquired at 75 samples per second, and you wanted to integrate across an interval of 10 samples, you would set the Integration Setup Scaling parameters so that +10 Volts corresponded to a Scale (MAP) value of 75 and a Scale (MAP) 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).

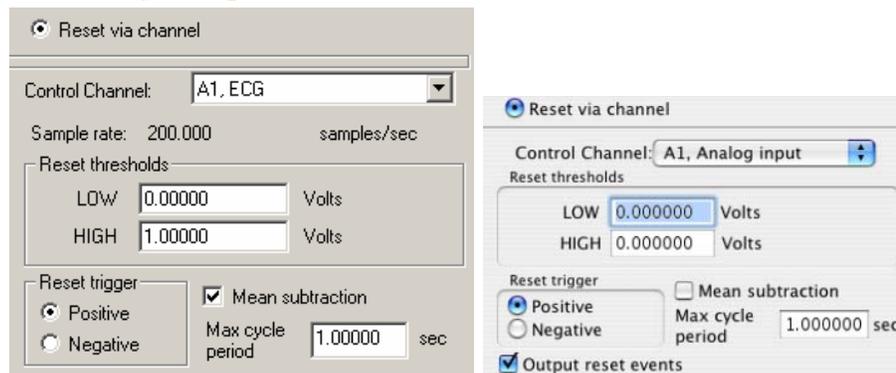


Integrate Calculation and Scaling dialog boxes for 10 point averaging

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.

Reset via channel 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.

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 \uparrow or Negative \downarrow) 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 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 that are inserted. Offline processing may reset from threshold crossing in the control channel.

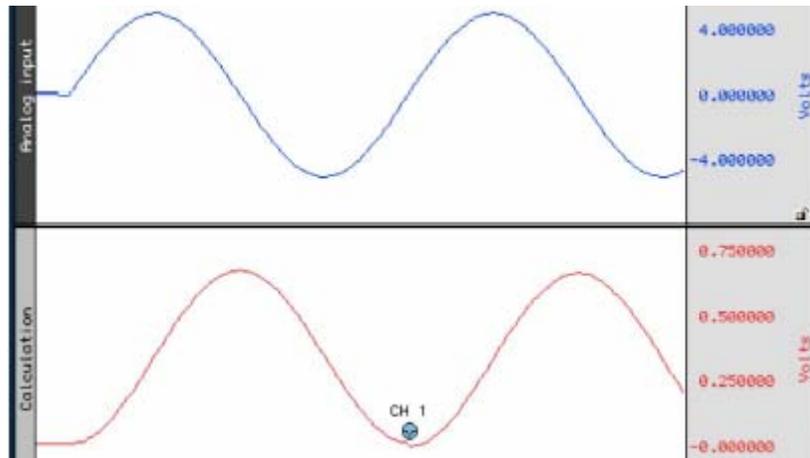
Max cycle period

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. However, the units may need to be changed (i.e., liters/sec to liters) via the Scaling option.

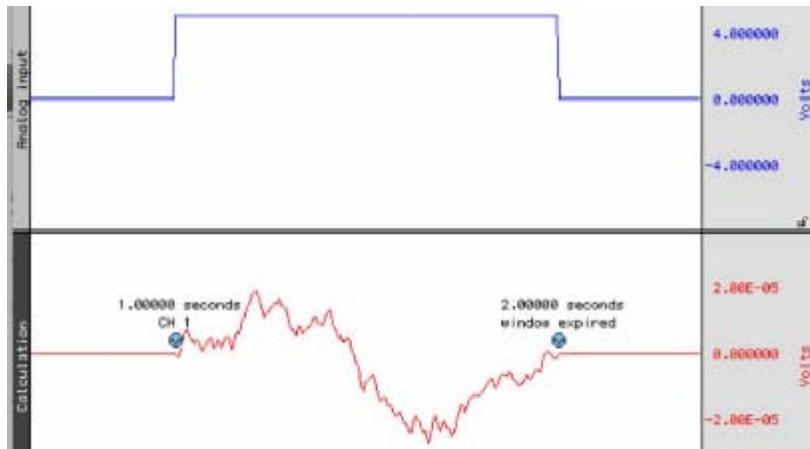
Output reset events—Mac only (not available for metachannels)

Add Events markers to show where Reset occurred and distinguish why the channel reached zero.

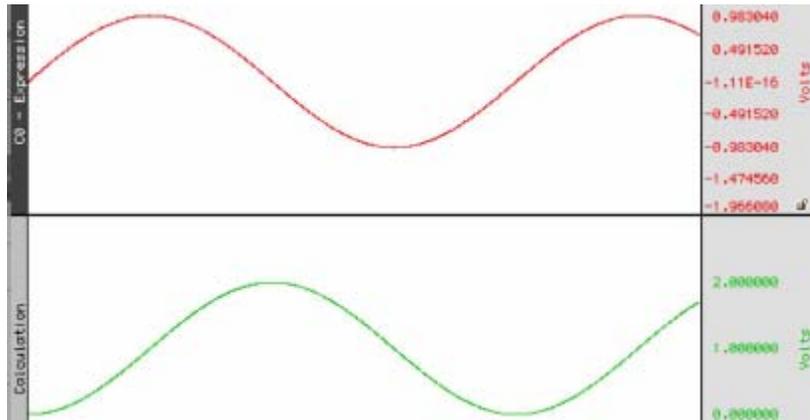
- Threshold crossing on the control channel
For example: Calculation channel resetting on positive crossings of 0V on CH 1.



- 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.



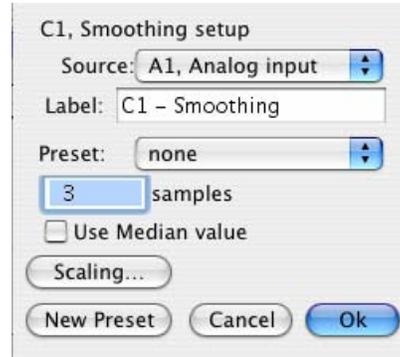
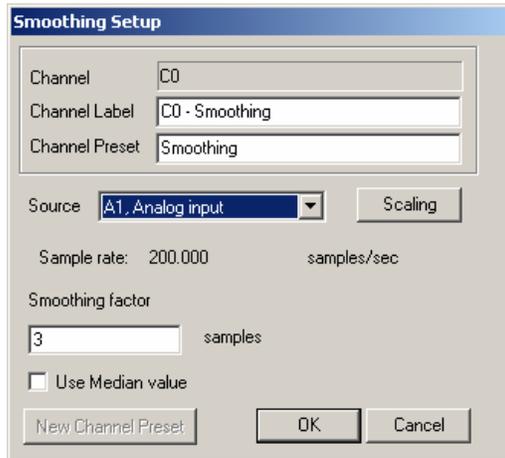
- Zero value due to “true” zero being achieved due to mathematical results
For example: Mathematical Source is sine wave, integral is cosine. Input (10V) never crosses threshold levels. Signal reaches zero mathematically; no reset events appear on output.



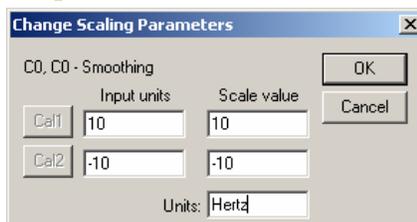
Windows/PC users can overlap the signals to identify reset occurrences but will not be able to identify the cause of the reset.

Smoothing Calculation

The Smoothing Calculation functions online and permits. This function is very useful if you are trying to remove noise of varying types from a data set. (Off-line Smoothing is available as the Smoothing option of the “Transform” menu.)



- Source** Source is a pull-down menu of the available channels.
- Sample rate** provides the sample rate for the selected channel (may be different than the acquisition sample rate).
- 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.
- Windows only*—For a given sequence of wave data, $x = \{x_1, x_2, \dots, x_n\}$, 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 on the Scaling button for access to options that allow you to modify the units or linearly scale the output.



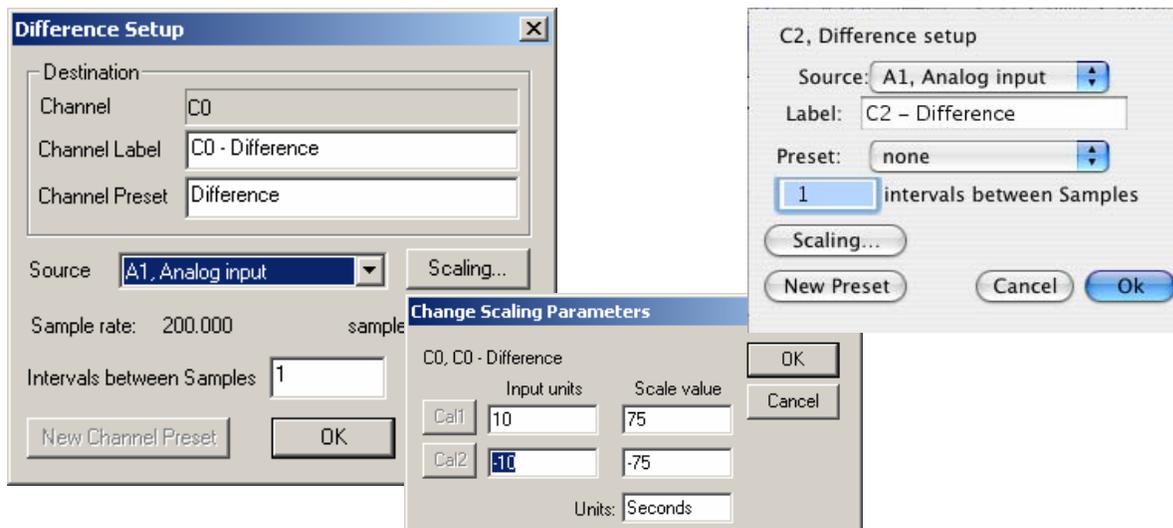
Difference Calculation

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 AcqKnowledge perform a Difference calculation in real time, click on the button next to Calc in the Input Channels dialog box. A popup menu will appear with Integrate at the top of the list. Scroll to choose Difference and then check an Acquire box for the Calculation channel you wish to contain the difference data. You may also check the Plot and Values boxes as appropriate for each channel.

The Difference Calculation dialog allows you to specify the source channel and the number of intervals between samples over which the difference is to be taken, and also includes the option of rescaling the channel to reflect different units.

Click on the Setup button in the Input Channels dialog box to generate the Difference dialog box:



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.

Sample rate This line provides the sample rate for the selected channel (may be different than the acquisition sample rate).

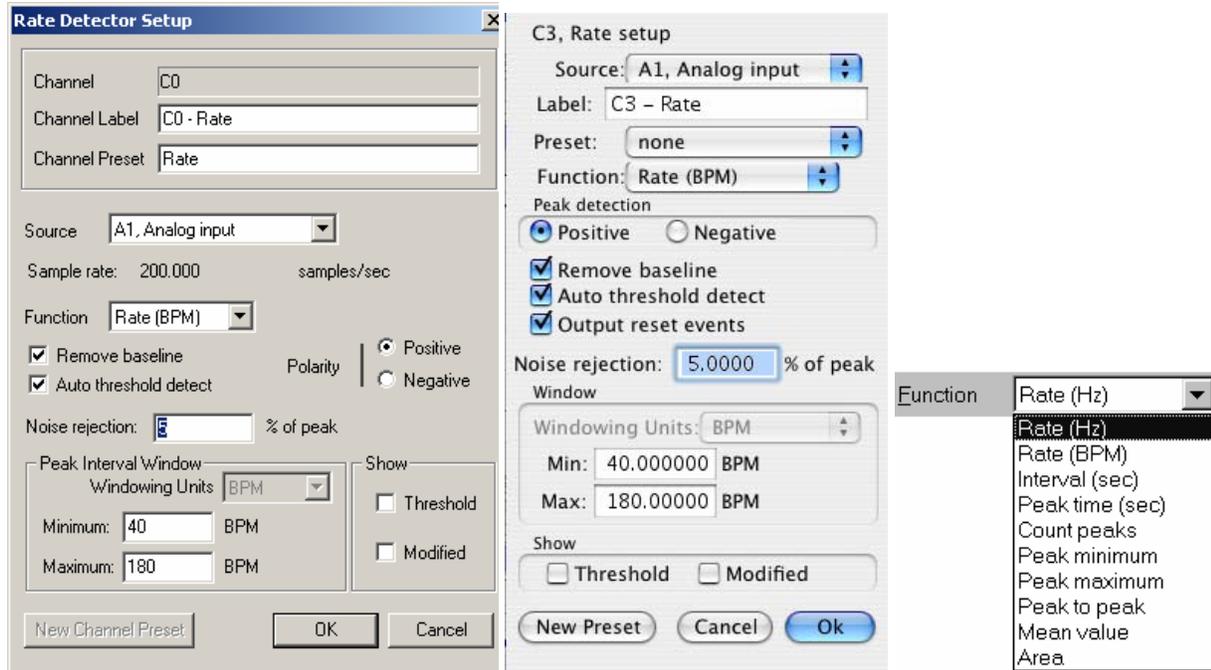
Intervals Difference is calculated with respect to the number of intervals between points (rather than the number of sample points). For instance, two sample intervals span three sample points:

$$\text{POINT}<\text{interval}>\text{POINT}<\text{interval}>\text{POINT}$$

A 1-interval difference transformation applied to a blood pressure (or similar) waveform will result in the widely used “dP/dT” waveform.

✓ See page 245 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 you to record the 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, you have the option of specifying the threshold manually or having *AcqKnowledge* automatically compute the threshold value (which is the default). 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 286.

To perform a Rate Calculation in real time, click on the button next to Calc in the Input Channels dialog box. A popup menu will appear with Integrate at the top of the list. Scroll to select Rate and then check an “Acquire” checkbox for the Calculation channel you wish to contain the rate data. You may also check the “Plot” and “Values” checkboxes as appropriate for each channel. To further specify the calculation parameters, click on the Setup button in the Input Channels dialog box to produce the Rate setup dialog.

Destination—determined by the Calculation channel that was selected when the “Setup” button was pressed.

Source—selected from the Source popup menu at the top of the dialog box.

Sample rate—provides the sample rate for the selected channel (may be different than the acquisition sample rate).

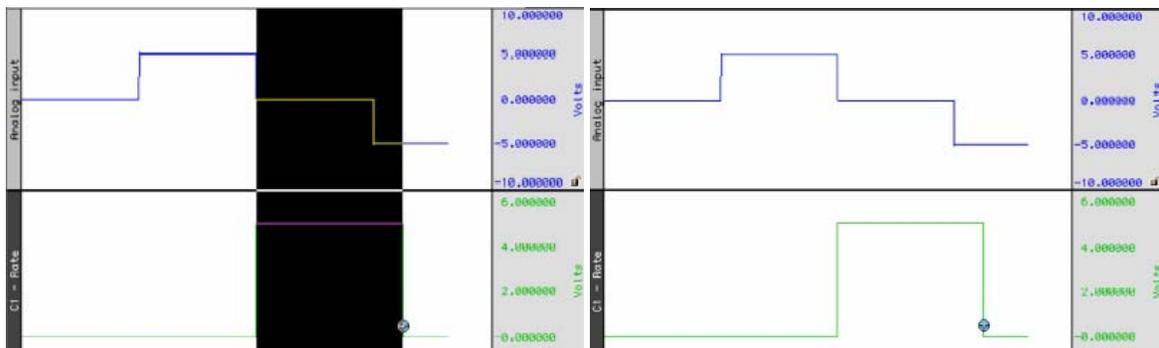
Function —The popup menu includes options to scale the rate in terms of Hz, BPM, Interval, Peak Time, Count Peaks, Peak Minimum/Maximum, Peak-to-Peak, Mean Value, or Area.

- For more information on each of these functions, see the Calculation Channels section beginning on page 286.
- 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 Transform>Find rate function

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.

Auto Threshold detect—The most convenient way to calculate a Rate channel online is to have *AcqKnowledge* 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.

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.



Polarity—For Rate Calculations involving data with positive peaks (such as the R-wave in ECG data), click on the button next to “Positive” in the Polarity section of the dialog box.

Noise rejection—*AcqKnowledge* 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.

Peak 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 Windowing units option is only activated when the selected function can have variable units (i.e., count peaks, mean value, area).

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 *MP Hardware Guide*.

Show Threshold—Plots the threshold used by the Rate calculation function. This feature is useful to help the rate detector performance on any given data.

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 in the Rate Detector Setup dialog.

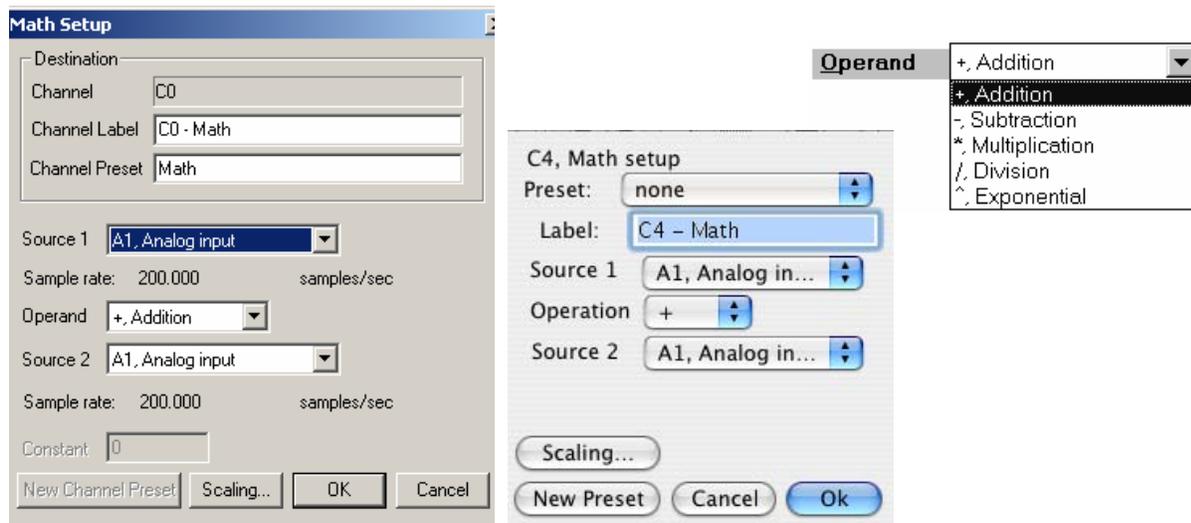
Math Calculation

The Math Calculation performs standard arithmetic calculations using two waveforms or one waveform and a constant. It is also possible to use other Calculation channels (such as a Rate Calculation channel) as an input channel for a Math Calculation channel, as long as the Calculation channel used as a source channel has a lower channel number than the Math Calculation channel.

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 Operand 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.



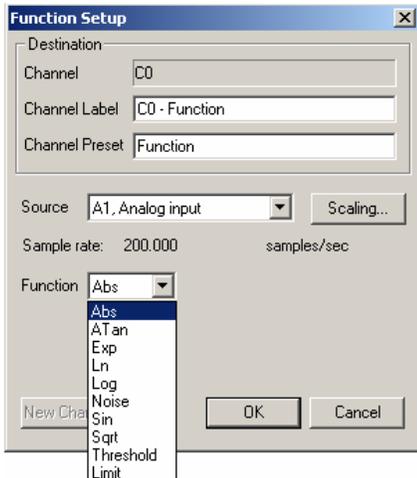
The “Constant” entry is activated when “K” is selected as a Source.

As an alternative to creating an additional Calculation channel for dividing the summed waveform, you can use the scaling function to perform the same task. To do this, click on Scaling... button and then set the Scale value (MAP 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 libraries of online Calculation options, consult the sections on Function Calculation channels and the online Equation Generator (page 77). These types of Calculation channels can be used to perform more complex operations on waveforms. Although Calculation channels can be “chained” together (so that the output from one serves as the input for another) to form more complex calculations, a separate channel must be used for each function. Since only sixteen Calculation channels are available, not all calculations can be performed. Additionally, chaining more than three or four channels together can require considerable system resources.

For complex calculations (such as squaring a waveform then adding it to the average of two other waveforms) the Equation Generator is a more efficient solution. All of the features available online in the Math Calculation channels can also be computed after an acquisition using the Waveform Math option (see page 250), which will eliminate the problem of system overload.

Function Calculation



The Function calculation can be used to perform a variety of mathematical functions using two waveforms or a waveform and a constant. Function Calculation channels compute new waveforms in a manner similar to the math Calculation functions, but provide access to higher order functions. 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 *AcqKnowledge* for *post-hoc* operations. Many of these functions can also found in the online Equation Generator (see page 77 for details on this feature).

To have *AcqKnowledge* perform a Function Calculation in real time, click on the button next to Calc in the Input Channels dialog box. A popup menu will appear with Integrate at the top of the list. Scroll to choose Function and then check an “Acquire” box for the Calculation channel you want to contain the function Calculation data. You may also check the “Plot” and “Values” boxes as appropriate for each channel. To further specify the Calculation parameters, click on the Setup button in the Input Channels dialog box to produce the dialog shown to the left.

Other Functions are available in the online Equation Generator (see page 77). Function Calculations can be chained together to produce more complex Calculations, although it is more efficient to program complex functions using the Equation Generator.

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 $t \in \{t_{start}, t_{start} + 1, t_{start} + 2, \dots\}$

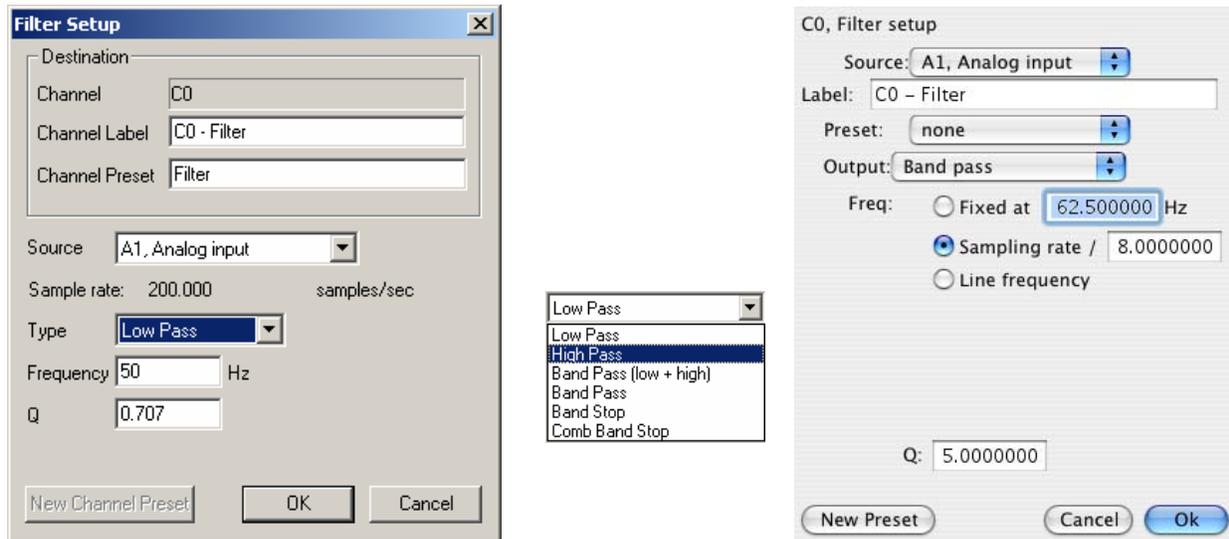
with t_{start} being an integer, a real-valued signal $y(t)$ defined for all t , and two real valued levels y_{low} and y_{high} satisfying the relation $y_{low} \leq y_{high}$.

Define the Threshold function $thresh(t)$ function such that:

$$thresh(t_{start}) = \begin{cases} 1 & y(t_{start}) \geq y_{low} \\ 0 & y(t_{start}) < y_{low} \end{cases} \quad thresh(t) = \begin{cases} 0 & y(t) < y_{low} \\ 1 & y(t) > y_{high} \\ thresh(t-1) & y_{low} \leq y(t) \leq y_{high} \end{cases}$$

Filter Calculation

The Filter Calculation channel allows you to perform real time digital filtering on analog, digital, or calculation channels. To have *AcqKnowledge* apply a digital Filter Calculation in real time, click on the button next to Calc in the Input Channels dialog box. A popup menu will appear with Integrate at the top of the list. Scroll to choose Filter and then check an “Acquire” box for the Calculation channel you want to contain the filtered data. You may also check the “Plot” and “Values” boxes as appropriate for each channel. To further specify the type of filter, click on the Setup button in the Input Channels dialog box to produce the following dialog box:



Filter Setup (Windows and Mac) & Type Options

In the dialog box 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 118). 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. |
| Sample rate | provides the sample rate for the selected channel (may be different than the acquisition sample rate). |
| Type (Output) | Lists the filter options: low pass, high pass, band pass, band pass (low + high), band stop, and comb band stop. See <i>About Filters</i> in this section for more details on filter types. |
| Frequency | Fixed value—Type a value in the entry box.
Sampling rate—Mac <i>AcqKnowledge</i> 3.9.2 and later Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.

Line frequency—Mac <i>AcqKnowledge</i> 3.9.2 and later Uses the line frequency at which the data was recorded. |
| 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 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 you wish, you may change the Q. A more detailed explanation of this parameter, and digital filters in general, can be found in Appendix D. |

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 you to set a cutoff point (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 you to specify 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, you need 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 F_0/Q , so the bandwidth of this filter centered on 50Hz (with the default $Q=5$) would be 10Hz. 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 227.

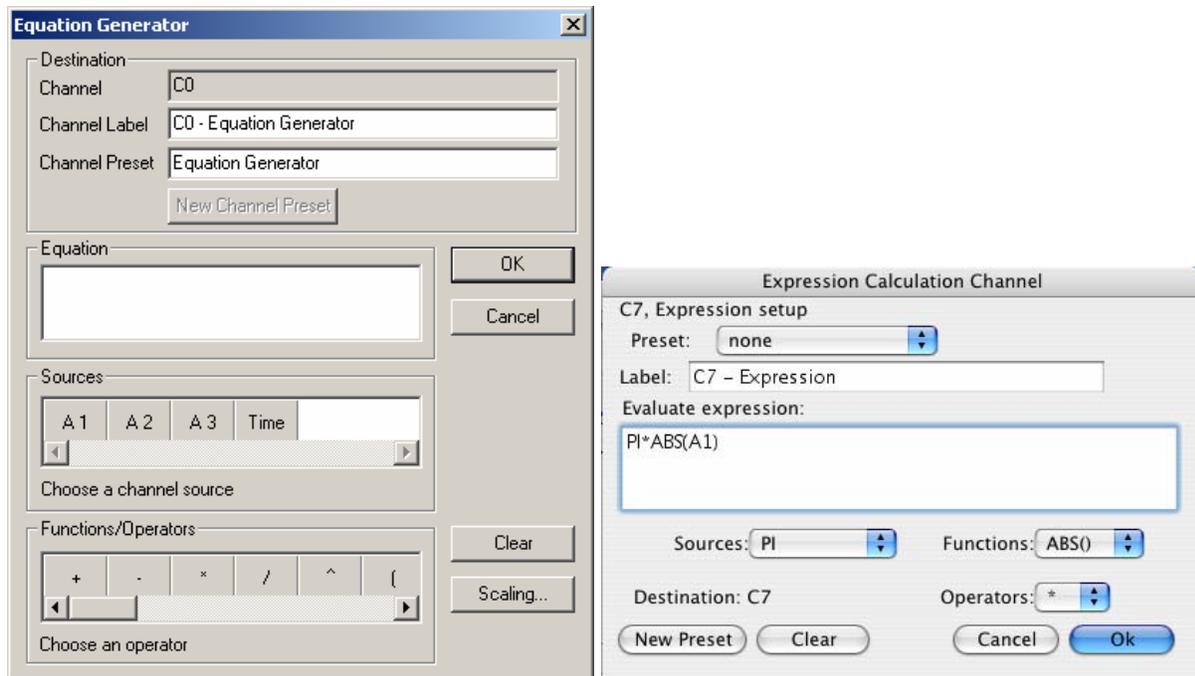
Off-line filtering

Apart from these online filter options, similar filters can be applied after an acquisition is terminated. Many of the biopotential amplifiers available from BIOPAC have selectable filters, which allow you to filter certain frequencies (including 50Hz or 60Hz 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. You can 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 219 or Appendix B.

Equation Generator (Expression)



The online Equation Generator is available for performing computations more complex than possible in the Math and Function Calculation options. The Equation Generator will symbolically evaluate complex equations involving multiple channels and multiple operations.

- *AcqKnowledge 3.9* for Mac 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 Equation Generator can combine data from multiple analog channels, and allows you to specify other Calculation channels as input channels for Equation channels. Also, computations performed by the Equation Generator eliminate the need for “chaining” multiple channels together to produce a single output channel. While the Equation Generator is more powerful than other Calculation channels, each Equation 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 in the selection (or first sample acquired, for calculation channels) and is then evaluated once for each subsequent sample in the selection (or each successive acquired sample).

- *AcqKnowledge 3.9* for Mac 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 dividing one channel by another (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 Equation Calculation channel is more efficient than chaining five Math and Function Calculation channels together.

Save to Calculation Channel

To evaluate an expression and save the result to a Calculation channel in real time:

1. Click on the MP menu and select Set up Channels.

2. Click on the preset pull-down menu in the Input Channels dialog box. A menu will be generated with “Integrate” at the top of the list.
3. Choose New > Equation Generator (Windows) or Expression (Mac OS X).
4. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
5. Click on the Setup button in the Input Channels dialog box. This will produce a dialog box, where you can enter the expression to be evaluated:

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 box, or by typing commands directly into the Equation box. The Equation Generator uses standard mathematical notation.

For each expression, you need to specify at least one source, the function(s) to be performed, and any operators to be used. Sources are typically analog channels, although you may also select Time from the source button row and AcqKnowledge 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 Equation Generator Calculation, it is important to keep in mind that while different channels, functions, and operators can be referenced, the Calculation cannot reference past or future sample points. That is, data from waveform one can be transformed or combined in some way with data from waveform two at the same point in time, although data from one point in time (on any channel) cannot be combined with data from another point in time (on any channel). See the section on post-acquisition expression commands (beginning on page 249) 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	<i>Mac OS X only</i> 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	<p><i>Mac OS X only</i> 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.</p> <p>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 Equation Generator/Expression calculation channel will result in an error.</p> <p>CHn(x) Returns the value of channel with index n x samples away from the current evaluation position.</p> <p>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.</p> <p>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</p>

to the current evaluation position. Only allowed for Measurement Expressions (see below); not allowed for Calculations or Transformations.

Recursive notation *Mac OS X only* 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:

$$SC(-1)+SC(-2)$$

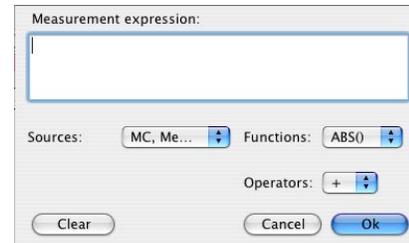
Note that to actually get the Fibonacci sequence the selected channel would need to have a constant value of one prior to the transformation.

Expression Measurement

Mac OS X only 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 “info” button is clicked.

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 indices 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

Mac OS X only To function correctly, AcqKnowledge requires real-valued data. You are encouraged to ensure that your 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 Equation Generator 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 (F low). If the destination channel for the result has an assigned rate other than (F low), the operation will not be permitted. If the destination channel is set to a new channel, the operation will always be permitted.

On Mac OS X, 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.

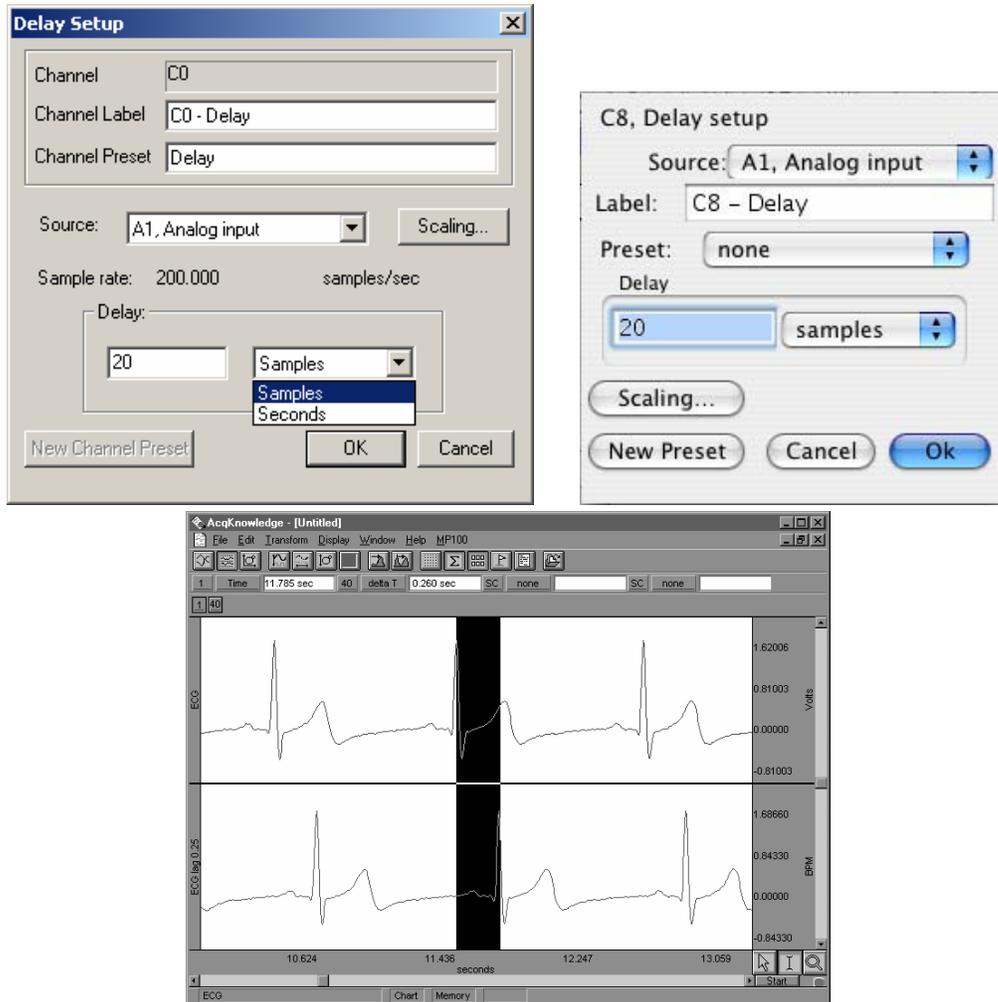
Source	Description
ACQLENGTH <i>Mac only</i>	<i>Calculation only</i> Acquisition length from Set up Acquisition; keeps Appended segments the same whereas “Sample” would increase with each segment.
CH	Value of the designated channel (CH n) at the current evaluation step.
Primary Source Channel <i>metachannels only</i>	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	<i>Measurements only</i> 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 <i>Mac only</i>	<i>Transformation and measurement only</i> 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

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.
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.
ATAN	Computes the arc tangent of each sample point.
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: <code>COND(test_expr, neg_test_value, zero_test_value, pos_test_value)</code> 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.
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: <code>IF(test_expr, true_value_expr, false_value_expr)</code> 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 AcqKnowledge 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
MMT(<i>row,col</i>)	<p><i>Transformation and measurement only</i> Evaluates to the result of a measurement being displayed in the graph, as specified by row and column. Use to scale by a result without having to manually enter the result. Row and Column for a measurement start as 0,0 for the top left measurement box; the fourth argument on the first row is accessed by MMT(0,3). For this function, the required measurement box must be displayed in the graph. Since the values of measurements may change during the course of an acquisition, calculation channel expressions cannot use this function.</p> <p>If a Model Expression (page 253) 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.</p>
MOD(<i>x,y</i>)	Computes the floating point modulus; returns integer portion of modulus. Example: MOD(5,2) evaluates to "1"
NOT(<i>x</i>)	Computes a logical negation of its argument. Evaluates to 1 if <i>x</i> is zero. 0 if <i>x</i> is non-zero.
OR(<i>x, y, ...</i>)	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(<i>x</i>)	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.
SINH	Computes the hyperbolic sine for each sample point.
SQR	Squares each data point.
SQRT	Takes the square root of each data point.
TAN	Computes the tangent of each sample point.
TANH	Calculates the hyperbolic tangent of each sample point.
TRUNC(<i>x</i>)	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 <i>Note</i> When used with scientific notation, TRUNC(<i>x</i>) 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(<i>x, y, ...</i>)	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 20 sample delay

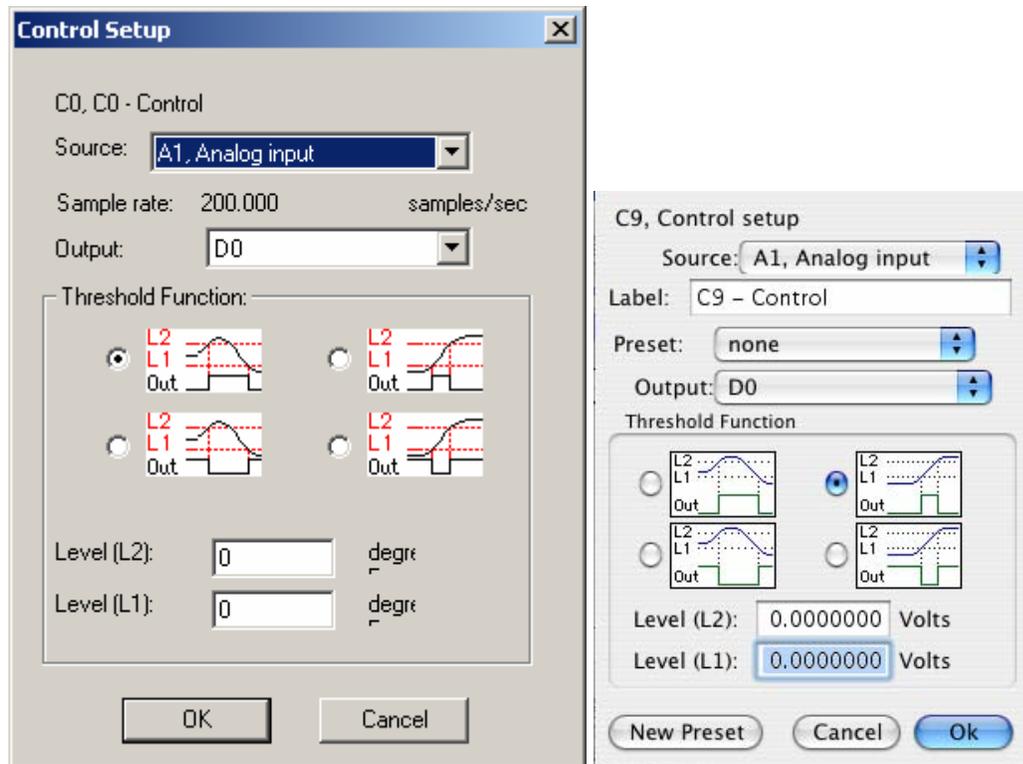
This option allows you to use a Calculation channel to plot another channel lagged (delayed) by an arbitrary interval. The delay interval can be specified either in terms of samples or seconds. These types of plots are useful for producing non-linear (“chaos”) plots in AcqKnowledge’s X/Y display mode (see page 305 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. AcqKnowledge fills this buffer with zeros until the delay channel begins to plot actual data. In the example below, the delay channel contains a 0.25-second interval of zeros at the beginning of data file.

Although there is not a parallel function in post-processing mode, the same effect can be obtained by selecting a section of one waveform equal to the desired delay interval and choosing the Edit>Cut function or the Edit>Clear command to remove a section of the waveform.

The Sample rate line provides the sample rate for the selected channel (may be different than the acquisition sample rate).

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.

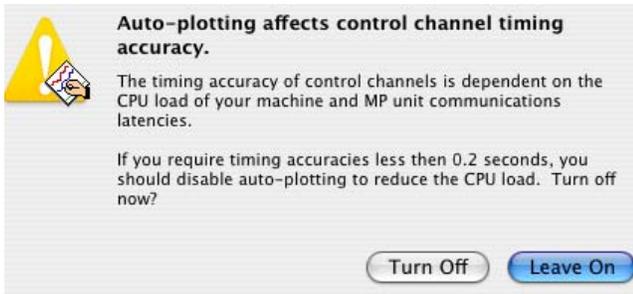
In addition to outputting a signal on a digital channel, the Control Calculation will also plot an analog version of the digital signal on the Calculation channel you specify. For instance, in the example below, Calculation channel C0 is used to perform a control function using analog channel 1 (A1) 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 MP 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.

There are four parameters that need to be specified for each Control channel:

- | | |
|-------------------|-------------------------------|
| a) Source channel | c) Type of threshold function |
| b) Output channel | 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 Sample rate line provides the sample rate for the selected channel (may be different than the acquisition sample rate).



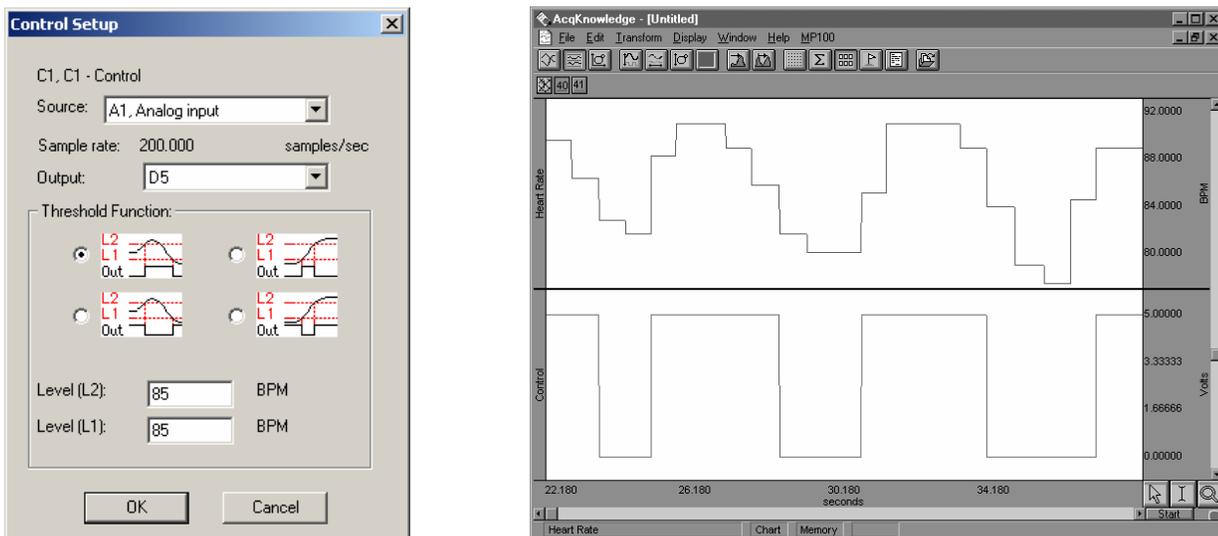
The channel selected in the Output Channel section determines which digital channel the pulse will be sent to. The digital channels range from 0 to 15 (D0 through D15) and external devices can be connected as described in the section on UIM100C connections in the *MP System Hardware Guide*. In the sample dialog box 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. You can specify threshold conditions such that the digital I/O line goes to +5 Volts when the conditions are met, or you can 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. *AcqKnowledge* also allows you to create a single level threshold or a “wide” threshold.

Tip Mac OS X only 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.

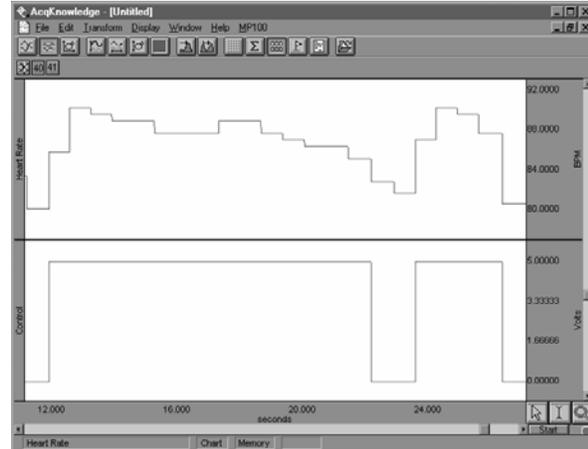
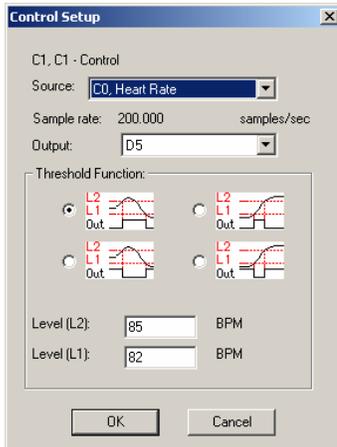
For example, suppose you want to set a Control channel to switch digital line 5 from low to high whenever the signal for Calculation channel one (C0) exceeds 85 BPM. Set the source channel to C0 and the output to D5. Select the upper left graph in the control dialog box and set L2 and L1 to 85, as shown:



Control dialog and graph showing result of BPM control example

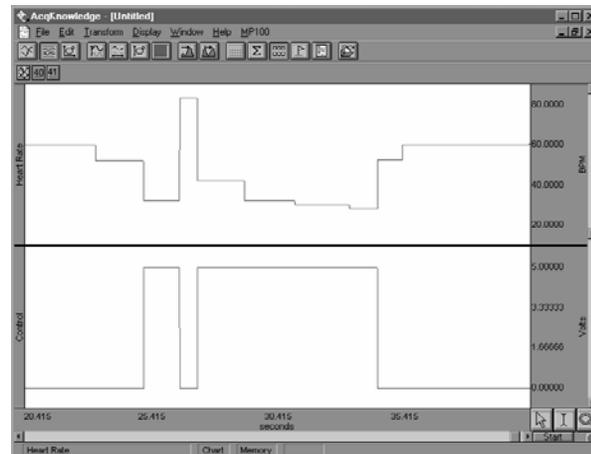
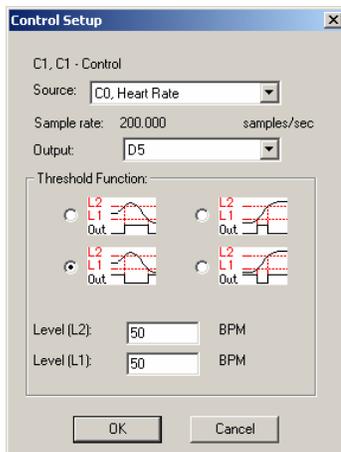
As you can tell from the preceding graph, there are a number of instances where C0 (heart rate) exceeds 85, usually for a short period of time. When it does drop below 85, it appears to return to a value greater than 85 within a second or two. In instances such as this, it might be useful to “widen” 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.

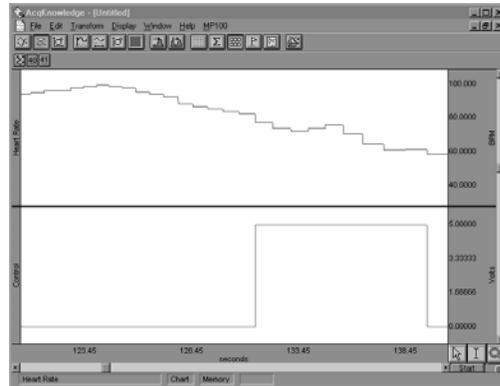
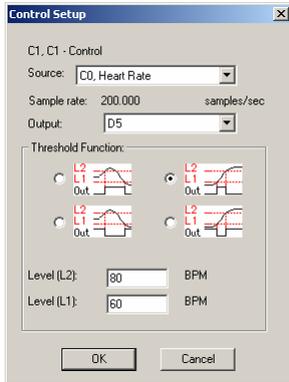


Control dialog and graph showing control channel detecting source channel levels less than 50 BPM

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. You can 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 you to vary the default setting for the digital channels (whether the default is zero or +5 Volts) depending on what types of devices are connected.

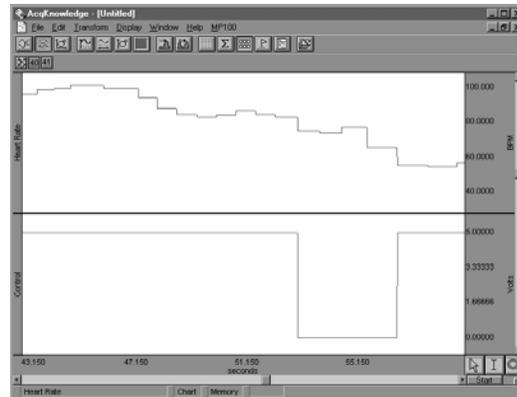
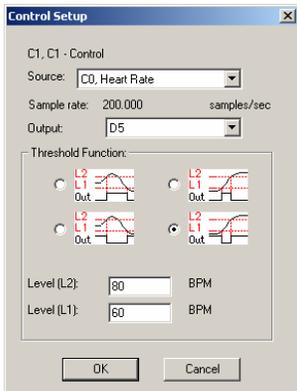
(For a description of how to connect various digital devices, see the section on UIM100C connections in the *MP System Hardware Guide*.)

In addition to setting “above and below” type thresholds, you can 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

You can also program the digital line 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).

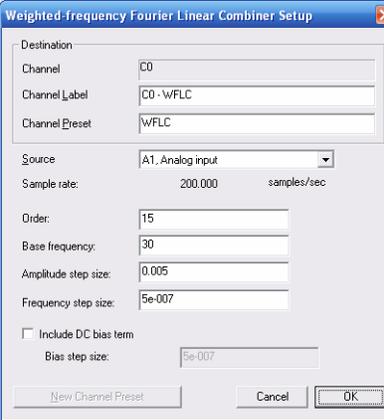
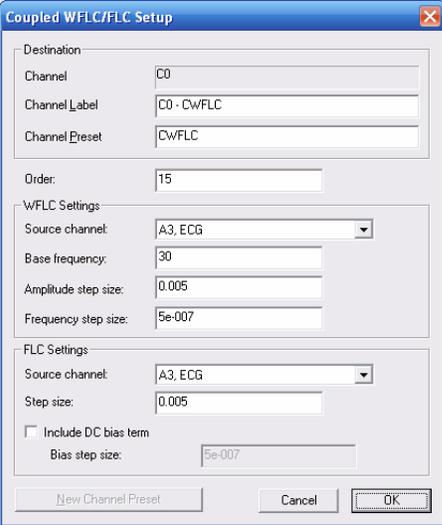


Control dialog and graph showing control channel switching from high to low when source channel is between 60 BPM and 80 BPM

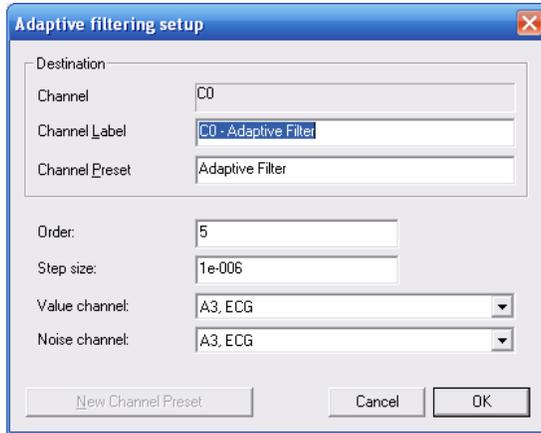
Fourier Linear Combiners: FLC, WFLC, CWFLC Calculations

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 μ , 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.

➔ See FLC Transform options, including *Scaled FLC*, on page 228.

FLC	WFLC	CWFLC
		
<p>Basic FLC</p> <p>Simple summation of fixed numbers of sines and cosines; uses harmonics of a fixed frequency and adjusts weighting coefficients of the mixture.</p> <p>Operates on a single channel at a time.</p> <p>Well suited for extracting data of a known frequency band from a signal with a stable frequency.</p> <ul style="list-style-type: none"> Use as an adaptive noise filter to remove non-periodic and semi-periodic noise uncorrelated to the base harmonic frequency. 	<p>Weighted-Frequency FLC</p> <p>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.</p> <p>Operates on a single channel at a time.</p> <p>Well suited for modeling periodic signals of an unknown and potentially varying frequency and/or amplitude.</p> <ul style="list-style-type: none"> No cycle boundaries or frequencies need to be pre-determined. 	<p>Coupled WFLC/FLC</p> <p>Runs a WFLC on the signal to determine the harmonic frequency and then runs the result through an FLC using the computed harmonic.</p> <p>The second FLC can be run on the same or a different channel.</p> <p>Well suited for real-time extraction of information from one signal based upon the frequencies contained in another signal.</p> <ul style="list-style-type: none"> 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



➤ See the Adaptive Filtering transform on page 224.

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.

The weights within an adaptive filter are modified on a step-by-step basis. AcqKnowledge 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 μ , 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).

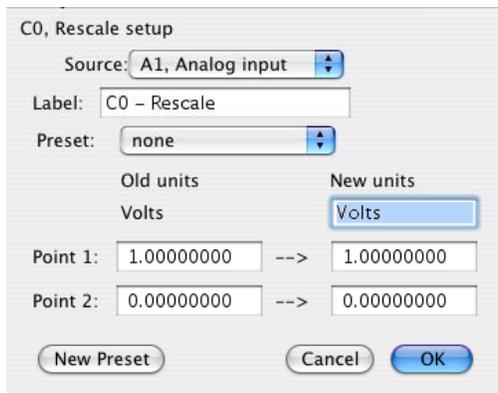
Comb Band Stop Filter Calculation

See page 75 for details.

Metachannel

See Metchannel details on page 62.

Rescale Calculation



Mac AcqKnowledge 3.9.2 and later only—Rescale applies two-point linear mapping and allows users to change the measurement units (for example, to change temperature from Celcius to Fahrenheit). The text corresponding to the new units can be manually entered.

- 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 rescale formula is:

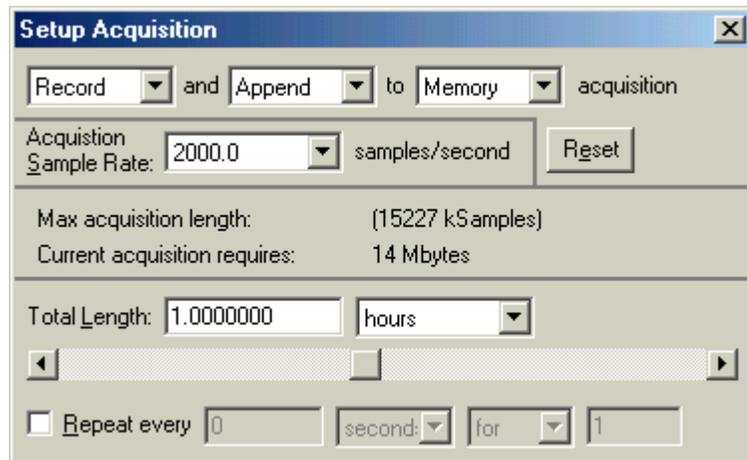
$$v_{new} = \frac{y_{new} - y_{old}}{x_{new} - x_{old}} v_{old} + \left(y_{new} - \frac{y_{new} - y_{old}}{x_{new} - x_{old}} x_{new} \right)$$

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 When rescaling only a selected area of the waveform, the manual entry of new units is not available unless “Transform entire wave” is checked since it is not possible to display different units for different time ranges in the same channel.

Chapter 4 Set Up Acquisition

Set Up Acquisition—The Basics

Once you have selected the channels to be acquired, the next step is to set up the acquisition parameters. Among other things, these options control the data collection rate, where data will be stored during an acquisition, and the duration of each acquisition. The dialog box that allows these options to be set is found under the Set Up Acquisition menu item of the MP menu.



Storage Mode

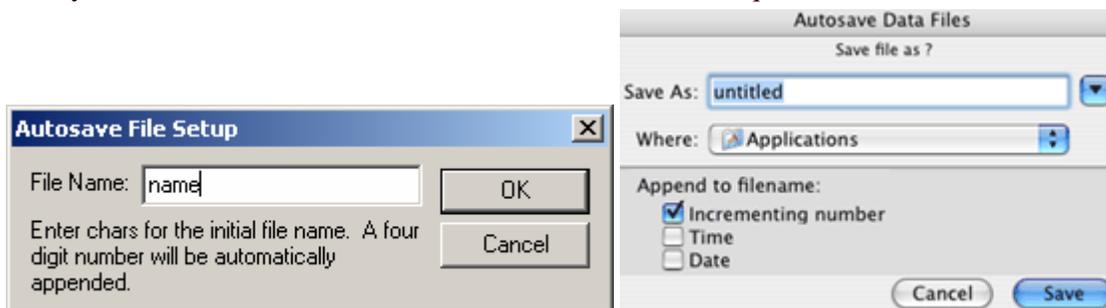
At the top of the dialog are three popup menus that allow you to control a number of aspects for storing the data from each acquisition.

The first option, Record/Record last allows you to control whether the software saves all the data or only the most recent segment of the data.

- When Record is selected, the MP System will store data for the amount of time that is specified in the acquisition length box. This is the default and is appropriate for almost all types of acquisitions.
- When Record last is selected, the MP System will acquire data continuously, but will only store the most recent segment of data equivalent to the duration in the acquisition length dialog box. That is, if the value in the acquisition length box is 30 seconds and record last is selected, the MP System will acquire data ad infinitum, but will only store the most recent 30 seconds of the data.

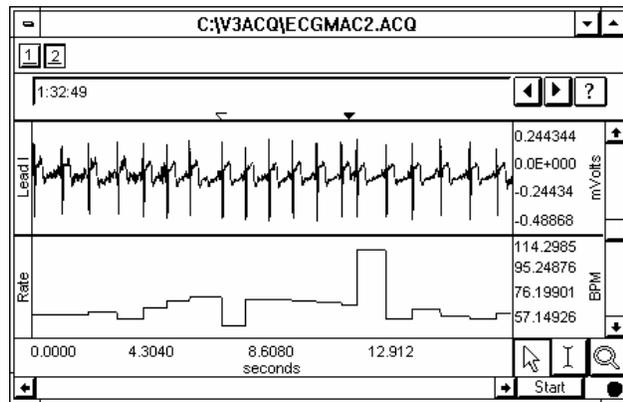
The second option, Save once/Autosave file/Append allows you to vary how the data is saved to a file. By default, *AcqKnowledge* will save the data to a single continuous file.

- When Save once is selected, *AcqKnowledge* will begin an acquisition when the mouse is clicked on the start button, and will stop either when the acquisition length has been reached or when the stop button is clicked with the mouse.
- Autosave file mode allows you to perform several acquisitions one after another, and save the data from each acquisition in a separate file. When the Autosave option is selected, a File button will appear to the left of the sample rate dialog box. Clicking on the File button generates a modified Save dialog that allows you to choose the root file name for the data from each acquisition.



- Append mode is similar to the Save Once mode, except that the Append mode allows you stop and restart acquisitions 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 on the Start button.

In Append mode, each time an acquisition is restarted, a marker is inserted into the record showing the time (hh:mm:ss) at which the MP System started acquiring data; see page 161 for marker details. Although you can pause for any period of time, the MP System 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 computer memory, disk, or the MP acquisition unit (but not in Averaging mode).



*Sample data Acquired in “Append” mode.
Markers indicate where Acquisition was paused.*

Append plus external trigger: An acquisition that takes place over a long period of time with brief events which are few and far between can be set up in the following manner: the researcher watches for these event, triggers the acquisition to start, and then lets the pre-defined acquisition length run out. When another event of interest occurs, the researcher triggers the next acquisition. This acquisition will be “appended” onto the end of the first acquisition. Memory is the only limit as to how many “appendages” can be added.

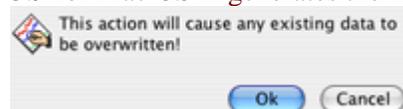
Append plus Variable Sampling Rates: If the mode is started and stopped manually, it is statistically possible that, prior to the next pass of the Append, extra data points may be inserted in various data channels to “line up” the data (see sample on page 57). These extra data points simply replicate 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 10Hz or higher, or don’t use VSR.

Appended segments can be stored to disk, memory, MP1XX or averaging.

- **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. If channels are sampled at different rates, append to disk operation will cause the software to rewrite all data files in the graph and add “extra” data to the “uneven” waves. This extra data will be a continuation of the same data point at the end of each uneven wave. This operation may take some time to complete for very long data files.
 - You can append to existing files—just open them, change the storage mode to “Append to Disk” and Start the acquisition.
 - On the Macintosh, Append functions only work on AcqKnowledge 3.9 Macintosh format files. If you open any other file format, you will be prompted to translate the file.
- **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 does not have 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 on the Reset button to erase the acquired data file and start a fresh acquisition file (this is essentially the same as saying yes to an “Overwrite existing data?” prompt). AcqKnowledge 3.9 for Mac OS X generates the following prompt for Reset commands:



The Rewind button on the toolbar will delete the last recorded segment. Ctrl-Rewind (Windows) or Option-Rewind (Mac OS X) will delete all recorded segments (similar to the Reset button).

The third option in the popup menu tells *AcqKnowledge* where to store data during an acquisition. The options here are Disk/Memory/MP/Averaging. 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 (RAM) during an acquisition. After the acquisition is finished you will have to select Save As... from the File menu to permanently save this to your 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, since most computers have more hard disk space free than free RAM. 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 be recovered, whereas the data is deleted if it is being saved to computer memory.

IMPORTANT

If you are saving files in Disk mode, always be sure to save your files under a different name BEFORE you start each acquisition. Otherwise, any previous data in that file will be overwritten. In Memory mode, you simply go through the standard procedure of saving the file after the acquisition.

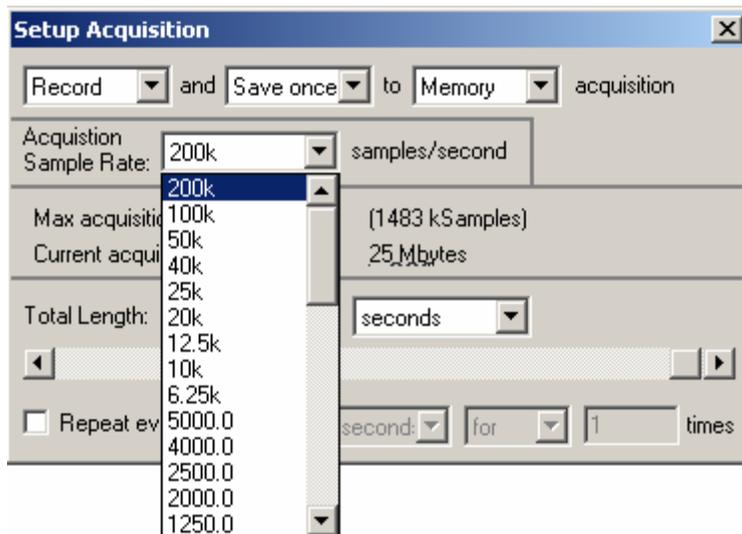
- MP stores a small amount of data on the MP acquisition unit itself.
 - The MP150 is limited only by internal memory, with storage estimated at 4 MB and 400kHz aggregate sampling rate.
 - The MP100 can save up to 16, 000 samples at up to 70, 000 samples per second.

Obviously, data cannot be sampled this fast for a very long period of time if it is to be stored in the MP acquisition unit. Also, as more and more channels are acquired, the duration of acquisition to the MP acquisition unit will shorten. Another drawback of storing data to the MP acquisition unit is that the data 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.

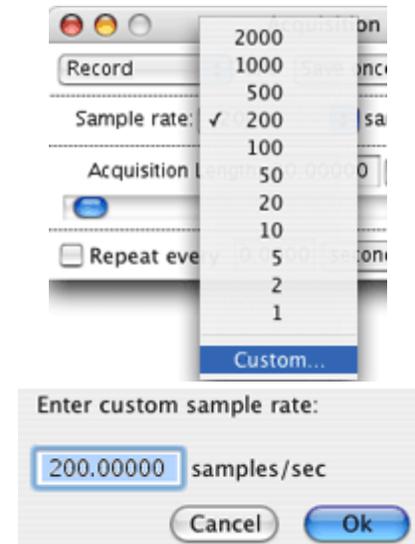
- Averaging is used exclusively for acquisitions involving repeated trials and is discussed in detail on page 99.

Acquisition Sample Rate

The value in the box labeled “Sample rate” indicates how many samples the MP System should take per channel during each second of data acquisition. The sample rate can be changed by clicking on the pull-down menu. To allow for variable sample rates, the rate options are constrained so that channel sample rates are equal to or a specific power of 2 less than the acquisition rate. New sample rates can be chosen at the selected increments for the MP150 and set between 1Hz and 2000Hz for the MP100, with a Custom option on Mac OS X.



MP150 rate options (High-speed options)



MP100 rate options

Sample Rate pull-down menu

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 phenomenon you are interested in observing has frequency components (which are of interest) of 100Hz, you should sample at least 200 times per second. Fourier analysis (FFT) can be used to determine what frequency components are present in the data (see page 257 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).

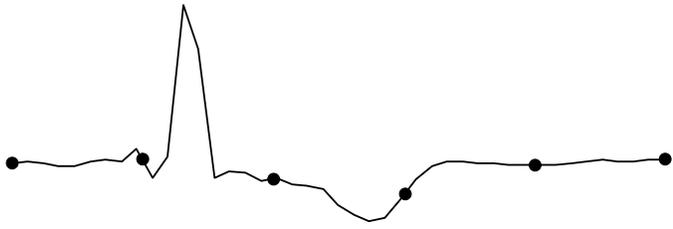
The maximum allowable sampling rate will automatically adjust itself according to the storage mode, how many channels are being acquired in the channel setup window and the type of computer being used. You can try this by entering a large value (say 99, 999) in the sample rate box. Now click the mouse button or press return and AcqKnowledge will automatically return the maximum allowable sample rate given the computer’s throughput and the acquisition parameters.

If data is being stored to disk or computer memory (RAM) during an acquisition, To set a sample rate that is too high. The acquisition will begin normally, but AcqKnowledge 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 the sample rate must be set to a smaller value if you wish to complete an entire acquisition.

The sample ECG waveforms below illustrate the effect of different sampling rates on obtaining varying levels of fidelity when reproducing the data.

- Top waveform: data is sampled relatively slowly; difficult to make out the shape of the waveform.
- Middle waveform: sampled at the faster rate; more samples are taken in the same period of time, which results in higher resolution for some components of the waveform.

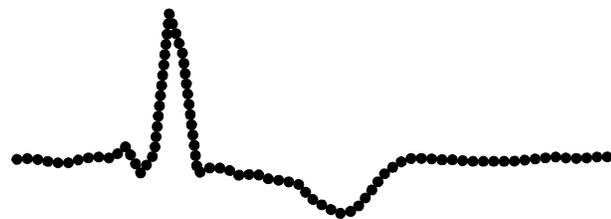
- Bottom waveform: sampled at a relatively high rate; increased resolution of the waveform. Waveform components that were obscured at slow sampling rates are now well defined, and measurements taken on this waveform would be able to better establish the maximum amplitude, time between different ECG complexes, etc.



Representation of ECG waveform sampled with relatively few samples per second "True" ECG wave is superimposed over dots that indicate sample points.



Preceding waveform as it would look if plotted in AcqKnowledge (with data points superimposed).



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.

The disadvantage of acquiring data at high sampling rates is that each sample point takes up memory, whether it is RAM or disk space or MP memory. Moreover, once the file is saved, it will require more disk space than a file of similar duration sampled at a slower rate.

Note for variable sample rate processing:

The Equation Generator 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 (F low). If the destination channel for the result has an assigned rate other than (F low), the operation will not be permitted. If the destination channel is set to a new channel, the operation will always be permitted.

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.

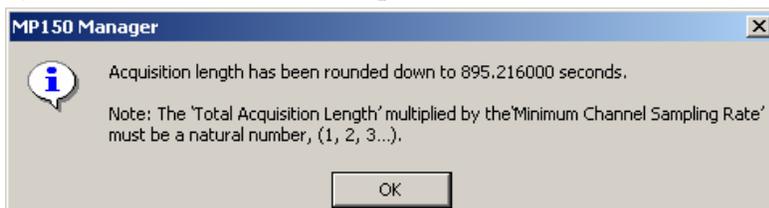
Acquisition length

To set the duration of an acquisition, enter a number in the acquisition length box. By default, 30 seconds of data will be recorded. The popup menu right of the length box allows you to scale the duration of the acquisition in terms of 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 you can describe the same acquisition 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 what scale you use to determine the length of acquisition, *AcqKnowledge* will end an acquisition when the value in the total length box is reached. You may also stop the acquisition at any time by clicking on the stop button in the lower right hand corner of the graph window.

The MP will automatically limit the maximum recording length to the amount of available memory on the target storage device (memory, disk, or MP). The default is to record one acquisition of the duration specified in the acquisition length box. The acquisition length parameter has a somewhat different interpretation in the *Record Last* and *Averaging* modes. See pages 92 and 99 (respectively) for more information on these features.

Windows only *AcqKnowledge* will round Acquisition length so that the “Total Acquisition Length” multiplied by the “Minimum Channel Sample Rate” is a natural number (1, 2, 3...).



Multiple Hardware

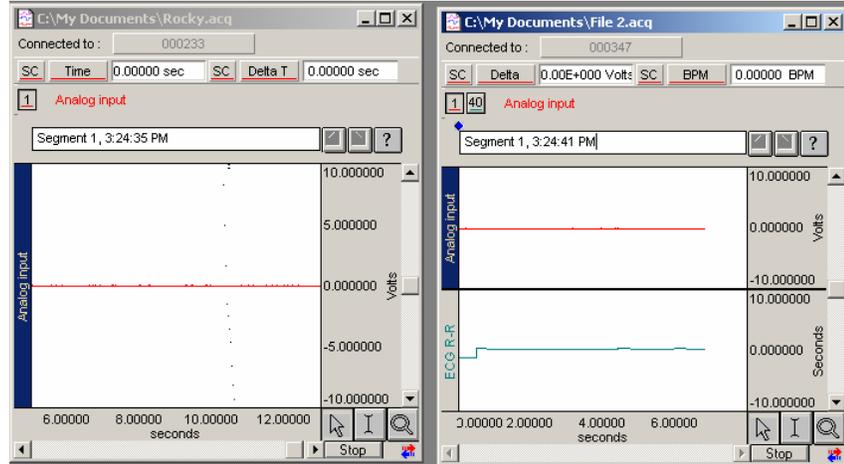
AcqKnowledge can be used with multiple MP150 data acquisition units to

- 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 up to 60 channels of data into one file, use the Merge Graphs feature (see page 213).

Each graph window can support a different MP150 unit. To add an MP150 unit for acquisition, open a New Graph (not a Data View).



To show/hide the “Connected to:” information, toggle the Show/Hide Hardware icon in the Toolbar.



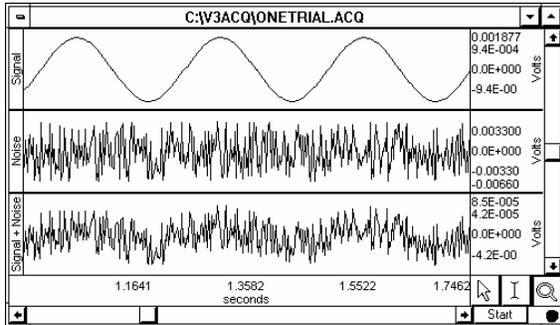
To switch the MP150 unit associated with a graph window, click on the “Connected to:” box and drag to select an available unit or Add new hardware.



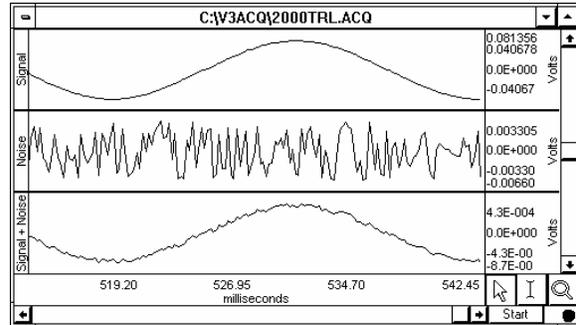
Averaging

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

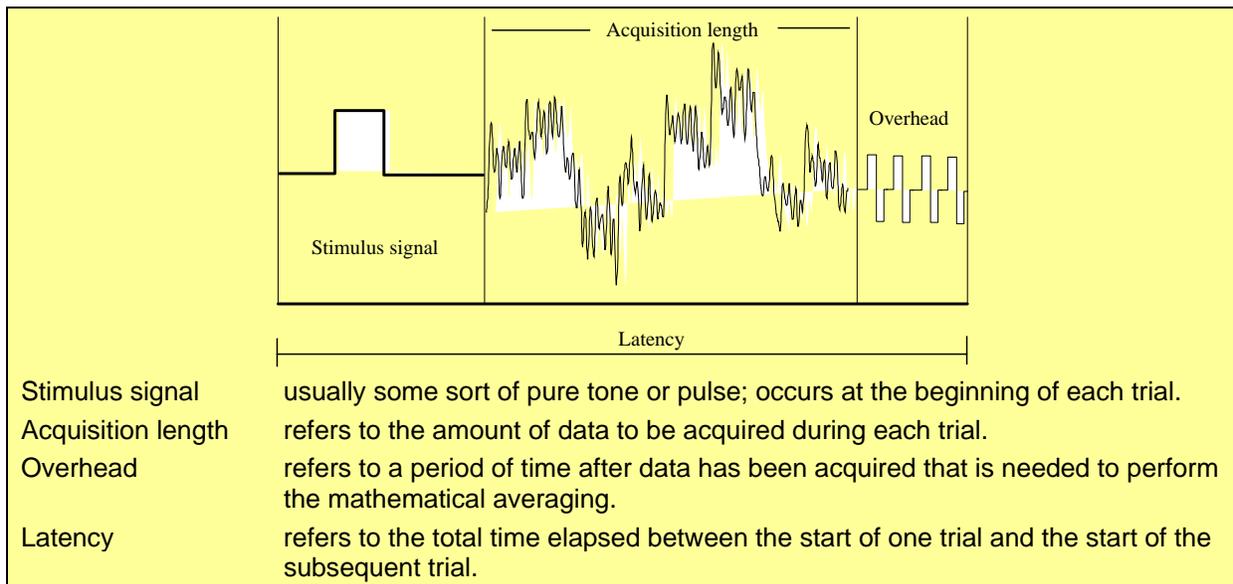


Same signal averaged in the presence of noise over 2,000 trials to produce the lower waveform.

Any averaging acquisition consists of three general components:

- the stimulus signal
- the duration of the acquired data, and
- 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.

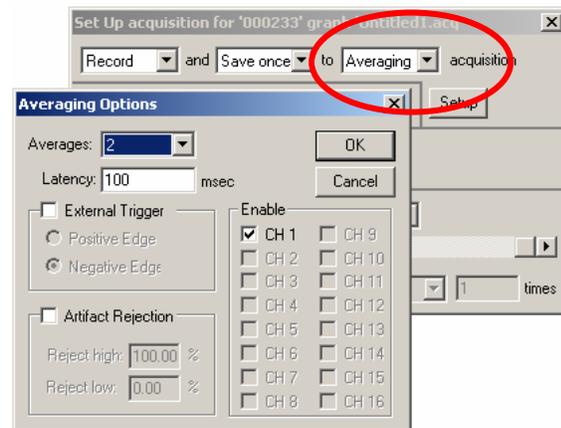


Averaging Setup

- For Advanced Averaging, see page 102.

To set up Averaging:

- Use Set up Acquisition to select the Averaging option.
- Click the Setup button to generate the Averaging Options dialog.
- Set the Averaging Options as detailed below.
- Click OK to close out of the dialog.
- Set the Stimulus (see page 107).
- Use the buttons in the graph window to Start, Stop, and save the averaging acquisition.



Note In AcqKnowledge for Windows, averaging is not allowed when Variable Sampling Rates are used.

Averaging Options

Averages

Select the number of averages to perform from the pull-down menu, to a maximum of 10,000.

- This option is disabled for Advanced Averaging because you must use the Advanced Averaging Setup dialog (page 102) to set the number of averages.

Latency

The individual components of stimulus signal, acquisition length, and overhead are, in sum, equal to the latency of the acquisition. As a rule, you should set the latency to at least three times the acquisition length. In some cases—such as when you want to allow a subject to return to a baseline state or condition—you may want to set the latency to a value much larger than this. By default, each trial is initiated when the latency value is reached (in the sample dialog box shown, a new trial is initiated every 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 on a signal from an External Trigger, enable this option and select positive or negative edge. When this option is checked, a new trial will be acquired each time a trigger circuit is closed. For more information on triggers, see page 104.

Averaging Options continued

Artifact rejection

Occasionally during an acquisition, extreme levels of artifact will be present for one reason or another. Checking artifact rejection allows you to determine what signal levels constitute artifact, and have 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 you to “re-try” a trial that was rejected due to the presence of artifact.

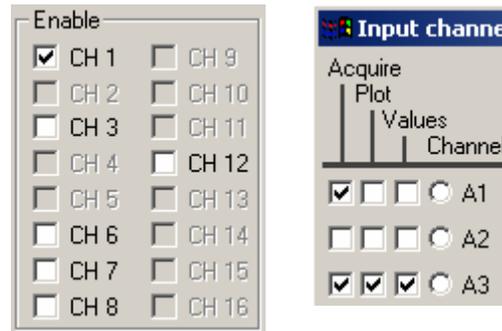
To set these parameters, you need to set a high threshold and a low threshold. Both thresholds refer to the scale limits (normally ± 10 Volts). If the high and low artifact rejection thresholds are set to 80% and 30% (respectively), the MP System will reject any trial where the signal exceeds +8 Volts or -3 Volts.

When the channel scaling feature is used to change the range of scale (MAP) values to something other than ± 10 Volts, the artifact rejection thresholds reference the scale (MAP) value associated with +10 Volts (for the high threshold) or with -10 Volts (for the low threshold). If the channel scaling for a particular channel is set so that +10 Volts scales to 400 mVolts, and the artifact rejection is set to 80%, then the MP System will reject any trial which contains a value greater than the equivalent of 320 mVolts or less than the equivalent of -320 mVolts.

Enable Channels

To add analog channels to the average, check additional channels in the Enable list.

- Channels must be set to “Acquire” under MP150 > Set Up Channels to be selectable here; otherwise the channel box will be grayed out.



Stimulus Signal

Although *AcqKnowledge* 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. You can create pulse waveforms, tone waveforms, ramp waveforms, and arbitrarily shaped analog waveforms. Use MP menu > Stimulator Setup to set all of the stimulus output functions (see page 107).

Mac OS X: When you start Averaging, 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 is included in the Samples folder.

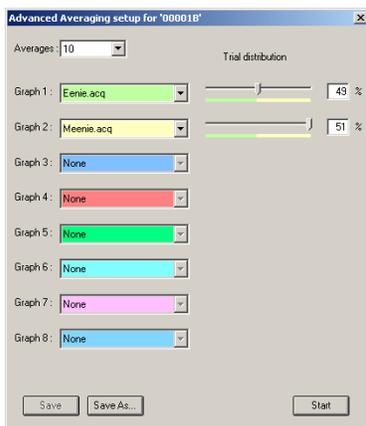
To set up Advanced Averaging:

1. Open two or more graph files.
2. Use Set up Acquisition to set each graph file for Averaging (see page 99).
3. Click the Averaging Setup button and set Averaging Options as desired for each graph file.
 - Advanced Averaging will use the defaults if you choose not to set Averaging Options for Latency, Artifact Rejection, or Enabled channels.
4. Use Setup Stimulator to establish the desired stimulus output for each graph file (see page 107).
 - Set the 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 MP150 > 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 to assign a percentage for each graph; the total will adjust to 100%

Note The software counts 0 as 1, so the percentage of the active graph should be entered as one less than the desired output (for 50% enter 49%).

8. Click the Start button in the Advanced Averaging setup dialog to begin acquisition.
9. Review the status in the “Completed” bar that is activated when Start is pressed and/or in the status display at the bottom of the *AcqKnowledge* software window.

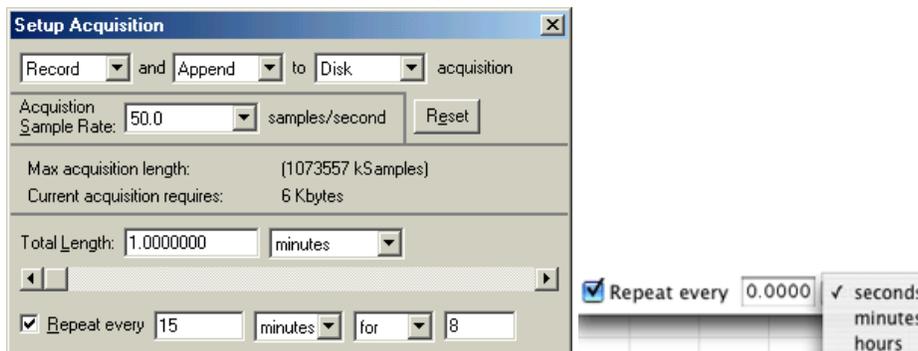


10. Save each graph file.
11. Make sure that the Graph names are correct in the Advanced Averaging setup dialog, and then use Save or Save As to save the setup as an AVG file.



Repeating

The Repeat mode allows you 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 a series of dialog boxes and popup menus at the bottom of the dialog box. These allow you to control 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 *AcqKnowledge* 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 second 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
- 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 box. In the above example, each trial of data will be sampled at 50Hz and will last 1 minute; the trials will be repeated every 15 minutes for a total of 8 trials.

By default, each acquisition will delete the data from the previous acquisition. You can change this by selecting the Autosave file option from the Save once/Autosave file/Append option at the top of the acquisition setup dialog box. When the repeating option is checked and Autosave is selected, *AcqKnowledge* will save the data from each trial using the file name and extension indicated by the autosave feature. See page 92 for a more detailed description of Autosave.

Network Data Transfer

Mac *AcqKnowledge* 3.9.2 and later— *AcqKnowledge* can be set to allow applications running on other computers attached to the same network to gain access to data as it is being acquired. For more information, see page 313.

Chapter 5 Set up Triggering

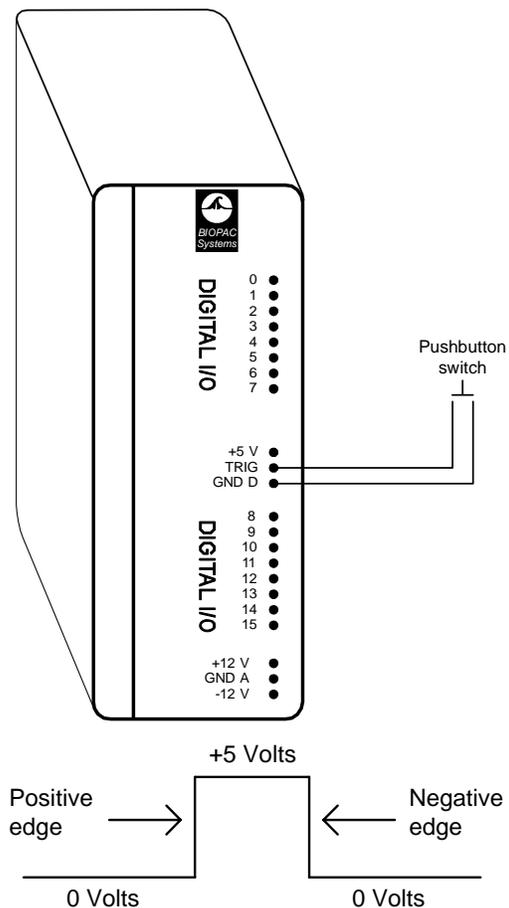
During a normal acquisition, the MP System will begin collecting data following a mouse click on the start button. It is also possible to begin acquisition using a trigger. Using a trigger allows you to start an acquisition “on cue” from a variety of different trigger sources. All trigger options are set in the Set up Triggering dialog box, which can be selected from the MP menu. By default, the trigger is Off, and acquisitions are started by clicking on the Start button in the graph window. Other options can be selected from the popup menu in the Triggering Setup dialog. To begin an acquisition with a trigger, first choose the trigger options most appropriate for your application and then click the Start button. After the Start button has been pressed, 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

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 instance, it is sometimes useful to have an acquisition begin when a subject presses a button or when a signal generator sends out a pulse. These are typical digital signals and the trigger devices that emit these signals can be connected via the UIM100C. Most stimulus generators are equipped to output a digital pulse simultaneously with the stimulus signal.

In a simple trigger design, an external switch is connected to the TRIG and GND D input as shown above. Since this switch will be either open or closed, the data will be digital and have 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. In the setup above, when the switch is closed (i.e., the button is pressed) the signal changed from +5 Volts to 0 Volts, creating a transition or “edge.”

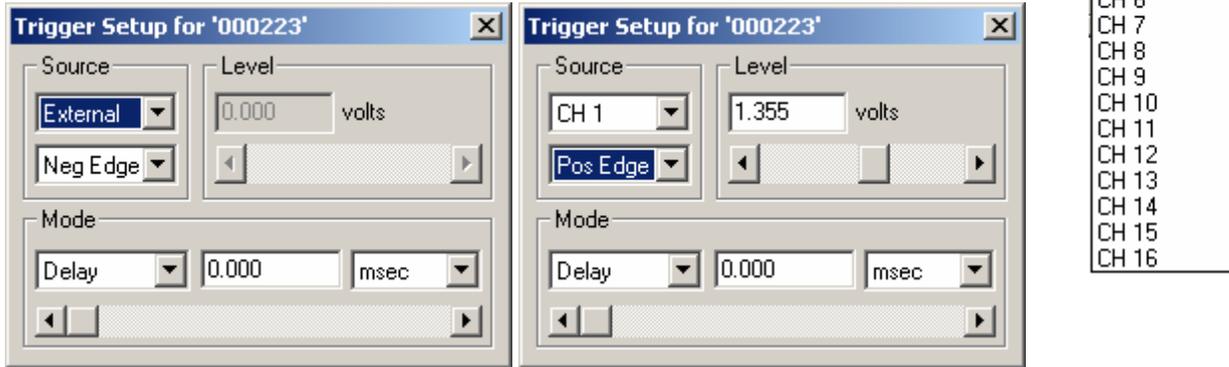
If the trigger is set to external, and the edge is set to positive, the acquisition will begin as soon as the push-button is pressed anytime after the start button in the graph window is pressed. Once the button is pressed, the acquisition will proceed according to the acquisition parameters you have set (acquisition length, sampling rate, and the like).



Analog Triggers

Initiate an acquisition when an analog channel reaches a certain level. To enable the analog trigger feature, data must be acquired to either memory (RAM) or disk, and a value must be entered in the Mode Delay box (although the delay may be set to zero). The channel containing the data to be used as a trigger does not require the acquire/plot/values boxes to be checked in the Set up Channels dialog box. Leaving these boxes unchecked will allow the incoming data to trigger an acquisition but will not cause the trigger channel to be acquired or plotted.

When you select Setup Trigger from the MP menu, the following dialog box will appear:



Digital Trigger Setup

Analog Trigger Setup

Source Off: Disables Triggering while maintaining the established setup.

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, you would set “Source” to CH 1 and then set the Level when the entry box is enabled.

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 3 V, set the trigger level just under 3 V).

Edge Triggers can have a positive or negative edge, defined as follows:

Edge	Digital	Analog
Pos	signal changes from 0 to 1	signal crosses from a baseline to a peak
Neg	signal changes from 1 to 0	signal crosses from a peak to a baseline

- For ECG data (and other types of data with peaks of relatively short duration) there will be only minor differences between the two edges, although the positive and negative edges can be widely separated in time for data with slowly changing values (such as GSR 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 MP System 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. You can change the default by using the Delay option in the Trigger Setup dialog box. This feature allows an acquisition to begin a specified period after the trigger level is reached. If you want 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.

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. To do this, select the Pretrigger option from the Delay/Pretrigger popup menu in the Trigger Setup dialog (enabled when data is being stored to the MP acquisition unit; as opposed to disk, memory, or averaging).

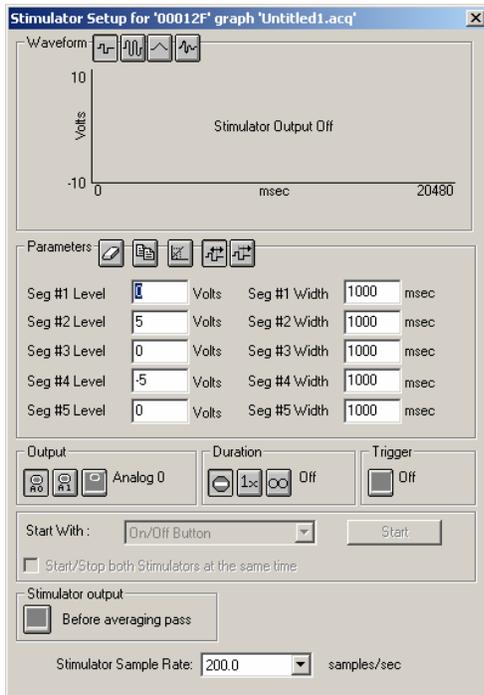
When the Pretrigger function is enabled, you start an acquisition by clicking on the Start button. The MP System will begin collecting data once you click the Start button. When the internal memory in the MP acquisition unit is full, the MP System will start replacing the oldest data with the newest data (similar to the record last feature). This process continues until the trigger event occurs. Following the trigger, the MP System 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 box.

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.

Chapter 6 Set up Stimulator



Although data acquisition is the primary function of the MP System, you may also output a signal through one or two analog channels while data is being acquired. This is handled through a window similar to the standard *AcqKnowledge* graph window.

Four types of signals can be output:

1. Square waveforms—page 113
2. Tone waveforms—114
3. Ramp waveforms—115
4. Arbitrary waveforms—115

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 Setup stimulator from the MP menu. This generates a window that allows you to control the type of signal output by the MP System. Like the standard graph window, this plots time on the horizontal axis and amplitude on the vertical axis.

You can use this window to create and shape waveforms to be 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, you need to specify the type of stimulus, the “shape” of the signal, the output channel to be used, and how many times the stimulus should be output.

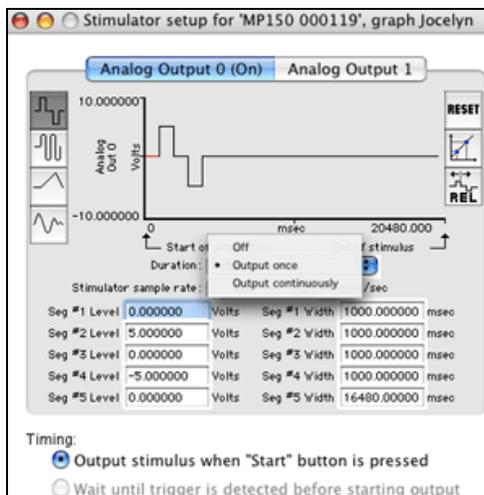
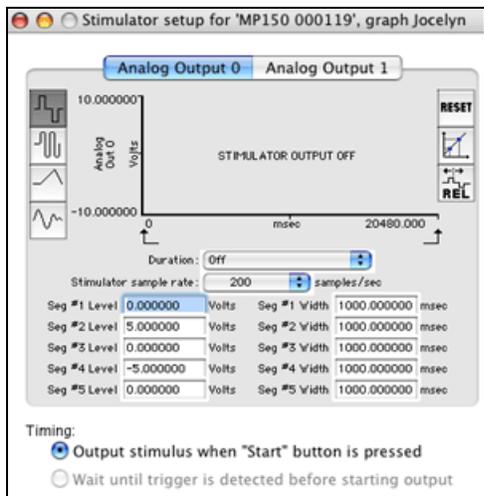
All of these parameters can be set from within the Stimulator Setup dialog. Regardless of the type of waveform you select, stimulus signals will normally be output when an acquisition is initiated, either as a result of clicking on the start button or a trigger being activated.

Stimulator Sample Rate—MP150 only

A very powerful feature intrinsic to the MP150 unit is the ability to set a stimulation signal output rate that is different than the acquisition rate, thus permitting considerable flexibility for a variety of physiological applications.

Use the 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



Parameters

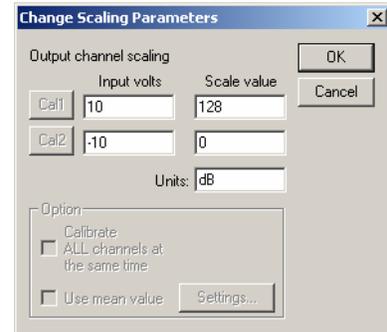
Reset  Reset button—Refresh the display; use after the time scale has been adjusted.

Copy  Copy button—Copy a stimulus waveform from the Stimulator Setup window to the Graph window. Use in any situation where you might want a square wave or tone wave to be inserted into a Graph window. To use this feature, simply click on the icon when you have the desired waveform and it will automatically be copied to a clipboard where it can then be pasted into a graph window using the Edit>Paste command.

Scaling  Scaling button—Rescale stimulus signals to units other than Volts according to the Change Scaling Parameters.

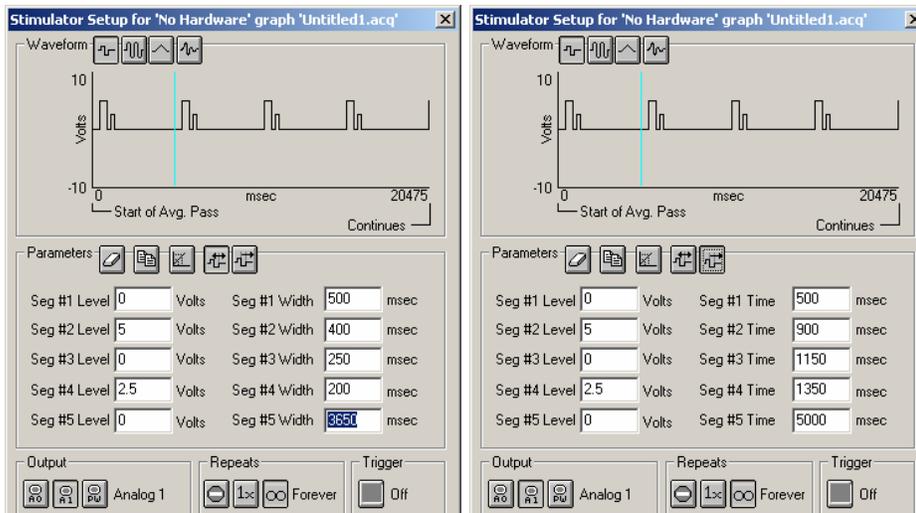
This type of rescaling does not change the amplification of the signal, it is useful for recalibrating the output signal to more meaningful units.

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

Absolute  As an alternative, you can enter an exact Seg # Time for each segment of the output waveform. This mode can make it easier to control the overall timeline of the stimulus output because you can review the setup as the total time. Enter the precise Time for each segment change. To create the same 5000 msec output as used in the Relative example, you would enter Seg # 2 Time as 900 (to mimic 500 + 400 in Relative mode), and end the last segment at 5000 (the Seg # Time reflects the time associated with the last sample point of each segment, rather than the duration of the segment itself).



Relative mode

Absolute mode

Output

A# Analog Output You can 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 the UIM100C.

- For dual stimulation and independent control, connect an output device to A0 and A1.
- **MP150 Users:** See *Analog Output for MP150 Users* notes on page 111.

The maximum resolution of a stimulus signal output through an analog channel is 22 μ sec; this means that the shortest segment in the stimulus signal must be at least 22 long.

PW Pulse Width *AcqKnowledge* allows you to output a single digital pulse through digital channel I/O 15, with a resolution of 1 μ sec. Since this is a true digital channel, pulse output has only two levels (0 Volts and +5 Volts), which cannot be edited. The segment that can be edited is the pulse width (duration), which can be set to any value greater than 1 μ sec.

Repeats

Set independently for A0 and A1.



Turn Output OFF (no stimulus signal output).

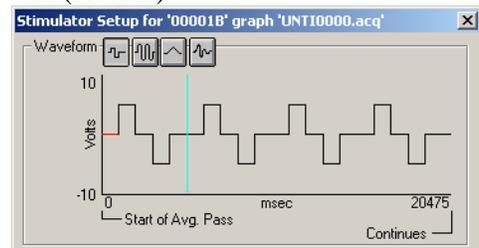


Output the stimulus signal once.



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.



Trigger

When a trigger option is selected (in the Trigger Setup window), *AcqKnowledge* allows you to select from additional menu items with respect to when the signal is output. By default, the stimulus signal will be output when you click on the start button. When a trigger is enabled, however, you have the option of either outputting the signal when the start button is pressed or when the trigger is initiated. The trigger option is added to the stimulator window when a trigger is enabled in the Setup Trigger box (described on page 104).

Manual Stimulator Control *MP150 only*

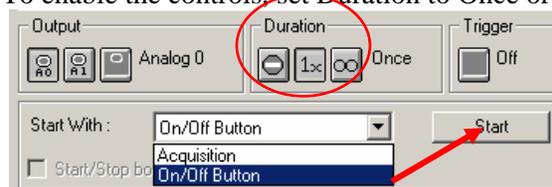
- Only available with MP150 units running firmware 1.1.14 or higher

When an MP150 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 can not be used if the MP150 is set to acquire in averaging mode.

Windows

The “Start With” function controls stimulator output before, during or after acquisition. To enable the controls, set Duration to Once or Forever.



- Acquisition will start the stimulator when the acquisition starts.
- On/Off button will start the stimulator when the Start button in the Stimulator Setup window is pressed. The Start button toggles to a Stop button.

If Dual Stimulator settings are active, “Start with” applies to both stimulators.

Mac OS X

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

Wait until trigger is detected before starting output

Use manual stimulator controls:

Analog Output 0: Off On 
 Analog Output 1: Off On 

LOCKED—Both channels Start/Stop together

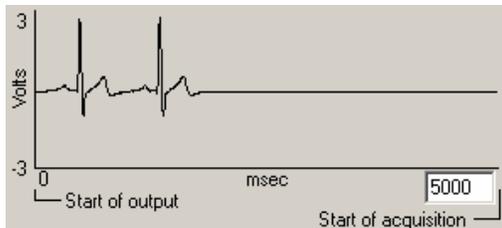
Use manual stimulator controls:

Analog Output 0: Off On 
 Analog Output 1: Off On 

Stimulator Output

You can set “Stimulator Output” to start before or during an averaging pass. For Advanced Averaging, we recommend presenting the stimulus within the Averaging window.

- For Averaging details, see page 99.
- For Advanced Averaging details, see page 102.



Before Averaging Pass



During Averaging Pass

Recommended for Advanced Averaging

Analog Output for MP150 Users

The two MP150 Analog Output channels can independently output static or dynamic values:

- Static output: Use “Manual Control” (page 125) to set the output level for each channel in the range -10V to +10V.
- Dynamic output: Use “Stimulator Setup” (page 107) to define the output level and pattern.

The MP150 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 MP150 will only use the “Stimulator Setup” value if:

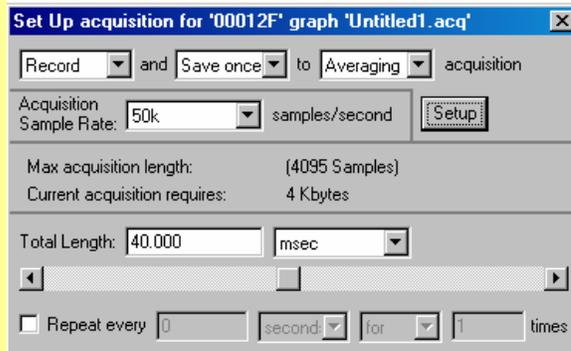
- Acquisition is in progress (or before Averaging pass) AND
- Stimulator is enabled via the “Stimulator Setup” dialog.

When the stimulator is in use:

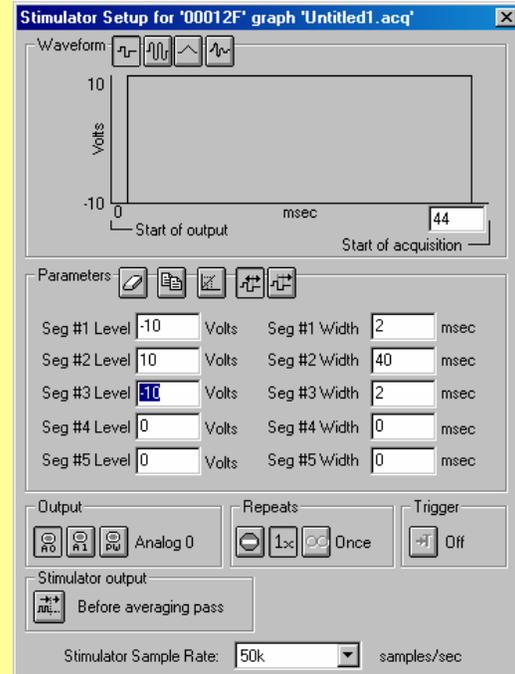
1. Any Stimulator Output starts (from before Time = 0) with the value established for “Manual Control”.
2. If Segment # Width = 0 the stimulator ignores the associated Segment # Level.
3. If the stimulator is in 1x mode, after the output waveform is sent, the value of the last segment is fixed until 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 MP150 is used:

Acquisition parameters:



Stimulator parameters:



Manual Control list box:

Stimulator Output pattern (using MP150):

The image displays two screenshots of the AcqKnowledge software interface, each showing manual control for '00012F' and a corresponding voltage waveform.

Top Screenshot:

- Manual control for '00012F':** The interface shows digital I/O controls for Stim 100. The 'Analog outputs' section has 'Out 0' set to 0.0000 Volts and 'Out 1' set to 0.0000 Volts. The 'Read' buttons for digital I/O are all set to 0.
- Waveform:** A square wave pulse. It starts at 0V at 0ms. At 2ms, it jumps to +10V. At 42ms, it drops to -10V. At 44ms, it returns to 0V. At 84ms, it returns to 0V. Key events are marked: 'Start STIM' at 0ms, 'Start ACQ' at 42ms, and 'Stop ACQ' at 84ms.

Bottom Screenshot:

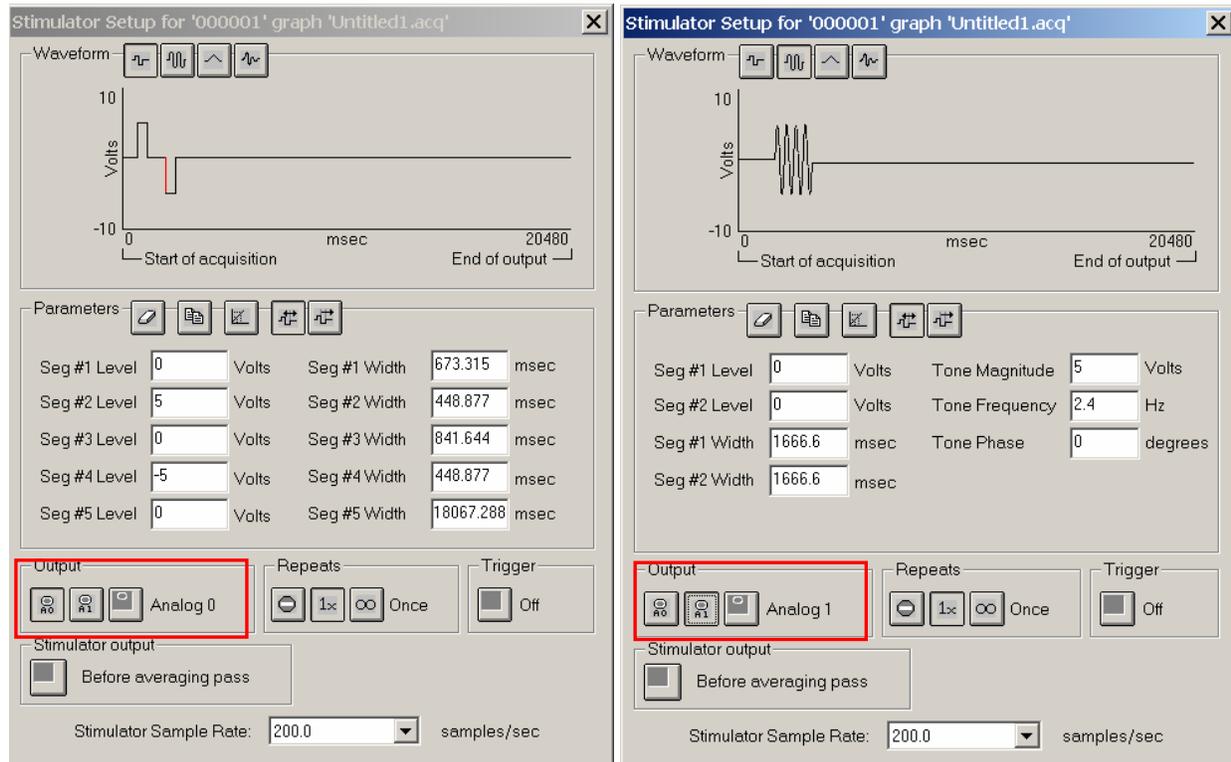
- Manual control for '00012F':** The interface is identical to the top screenshot, but 'Out 0' is set to -10.0000 Volts and 'Out 1' is set to 0.0000 Volts.
- Waveform:** A square wave pulse. It starts at 0V at 0ms. At 2ms, it jumps to +10V. At 42ms, it drops to -10V. At 44ms, it returns to 0V. At 84ms, it returns to 0V. Key events are marked: 'Start STIM' at 0ms, 'Start ACQ' at 42ms, and 'Stop ACQ' at 84ms.

Dual Stimulation

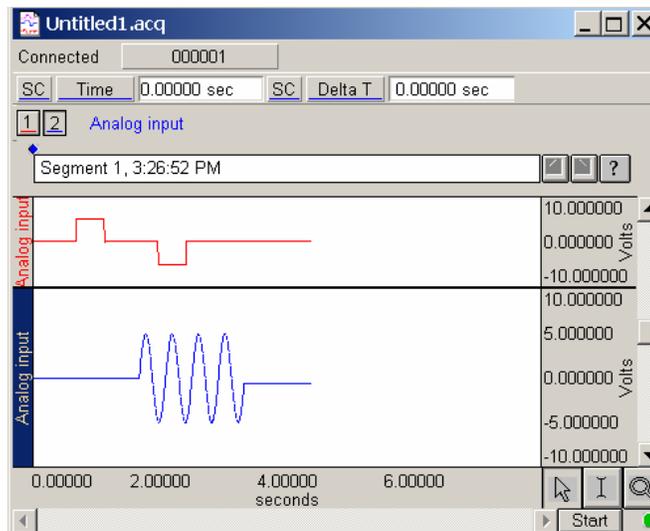
For independent control of two stimuli (such as sound and electrical output), set stimulator functions for Output to A0 and A1 for each MP150 unit.

- For additional stimulus paradigms, add MP150 units (see Multiple Hardware, page 98).
- To output varying stimulus on one channel (i.e., short tones and long tones to headphones), use Advanced Averaging with each stimulus set to the same channel (see page 102).

Sample setup and result for dual stimulation:



The above Stimulator Setup dialogs are for AcqKnowledge under Windows OS. To configure different output under Mac OS X, click on the desired output channel at the top of the Stimulator Setup dialog.



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  icon in the “Repeats” section. You should see a rectangular wave appear the window. You can control the shape of the wave by manipulating the various segments of the wave. A square wave has five segments, and AcqKnowledge allows you to set the level (amplitude) and width (duration) of each segment.

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, you can tell from the box at the bottom of the screen that the level (vertical offset) of the first segment is 0 Volts, and the width of the first segment is 500 msec.

To adjust the level of a segment, either:

- enter the desired level in the box that says Seg # Level; or
- 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:

- Enter a value in the Seg # Width box at the bottom of the Stimulator Setup dialog; or
- 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 pulse wave can be “edited” in this way.

Tone Stimuli

 Tone waveforms allow you to create 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.

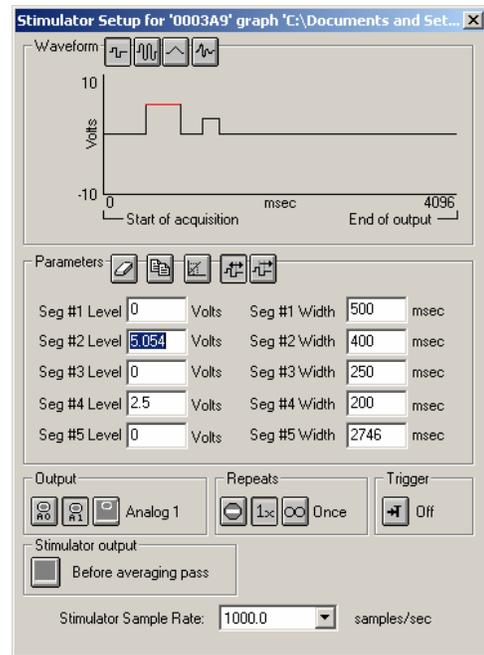
A tone waveform is comprised of two segments, with only the second segment being the actual tone itself. This allows you to include a pre-signal delay (by setting the level for Segment #1 to 0 Volts and the duration to a desired value).

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).

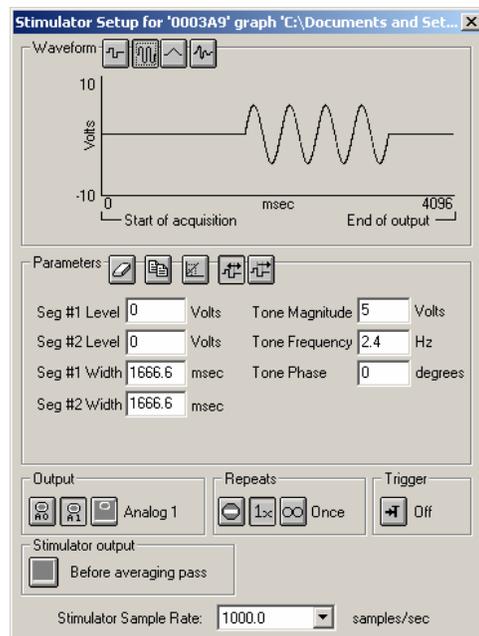
There are three additional parameters for Tone waveforms: frequency; magnitude; and tone phase.

- Tone frequency refers to the frequency of the second segment of the waveform. This can be set to

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in



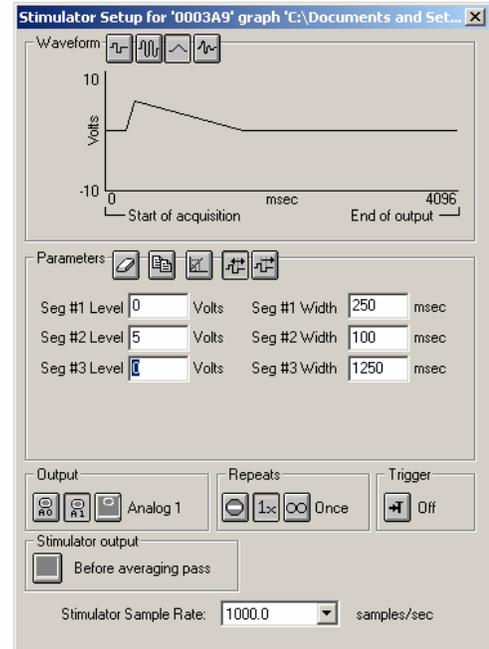
any value, although the most common settings are between 20Hz and 20,000Hz.

- 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 when you need to construct a monotonically increasing or decreasing stimulus signal. Ramp waves are comprised of three segments and the amplitude and duration can be set for all three sections.



Arbitrary Waveform



The Arbitrary waveform option allows you to set a waveform's shape and length using standard AcqKnowledge editing functions.

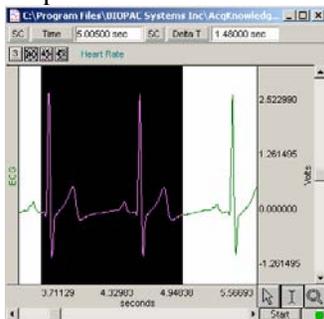
- See Application Note #AH162 for performance specifications.
- The length of an arbitrary waveform is only limited by the available memory (if recording in Memory/Disk mode; it will be limited to 4096 samples if recording in MP150 mode).

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.

There are two methods 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 you wish to output.

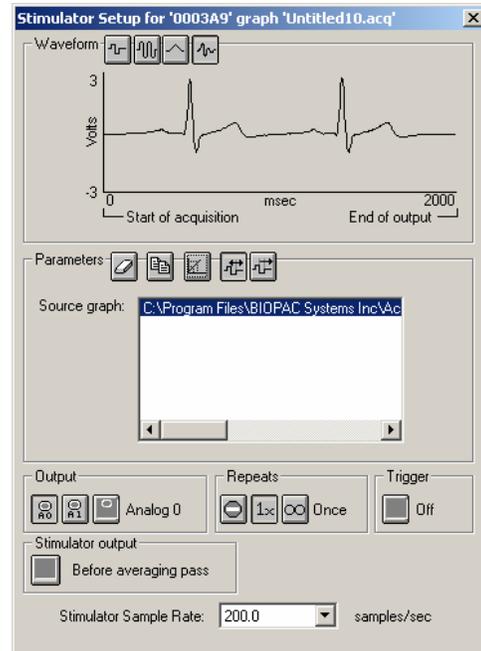


3. Return to the Stimulator Setup dialog—the selected area will automatically be pasted into the dialog.

B. Create waveform

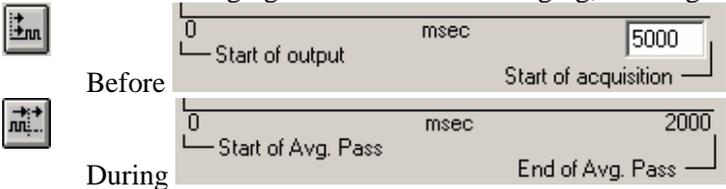
You can also construct an Arbitrary waveform by copying and pasting predefined stimulus waveforms (e.g., square waves or ramp waves) into a standard graph window. This is useful when a pure signal needs to be modified by adding noise or modifying waveform parameters such as rise time or decay. It also allows you to combine complex sequences of existing stimulus waveforms, such as a pulse followed by a tone.

1. Create a waveform in the Stimulator setup (as described above) of the desired duration and shape.
2. Choose Edit>Copy.
3. Switch to an empty graph window.
4. Choose either Insert waveform or Paste from the Edit menu.
5. Modify the waveform characteristics as desired.
6. Choose Edit>Copy.
7. Switch to the original graph window and paste into the Stimulator Setup window.
8. Output as an arbitrary waveform.



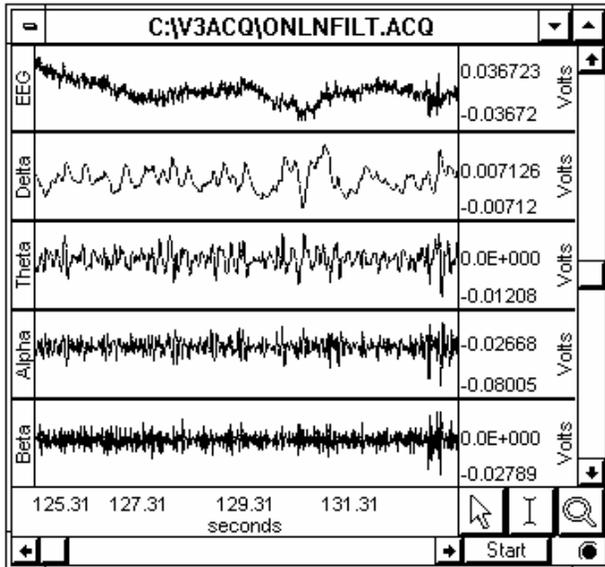
Stimulator Icons

- Waveforms:*
 -  Square wave
 -  Tone (sine) wave
 -  Ramp wave
 -  Arbitrary wave
- Parameters:*
 -  Reset the display (use after adjusting the time scale)
 -  Copy a stimulus waveform from the Stimulator Setup window to the Graph window
 -  Scaling (rescale Stimulus signals to different units)
 -  Set time base to relative
 -  Set time base to absolute
- Output:*
 -  Output to Analog Output channel 0 (default)
 -  Output to Analog Output channel 1
 -  Pulse Width outputs a true digital signal: 0 Volts and +5 Volts
- Repeats:*
 -  Toggle the selected Stimulator Output ON and OFF
For dual stimulator setup, Output is independent for A0 and A1
 -  Output stimulus signal once
 -  Output stimulus signal for duration of acquisition
- Trigger:*
 -  Toggles between “Off” and “Wait for” if MP > Set Up Triggering is active
Off—Output stimulus signal when Start button is pressed
Wait for—Output stimulus signal when trigger is initiated
- Stimulator output:*
 -  Toggles between “Before” and “During” Averaging Pass if Set Up Acquisition is set to Averaging. For Advanced Averaging, “During...” is recommended.

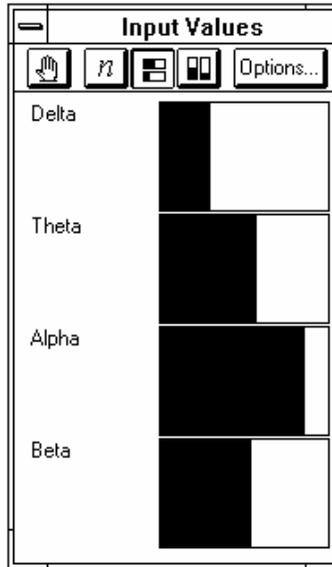


Chapter 7 Other MP Menu Commands

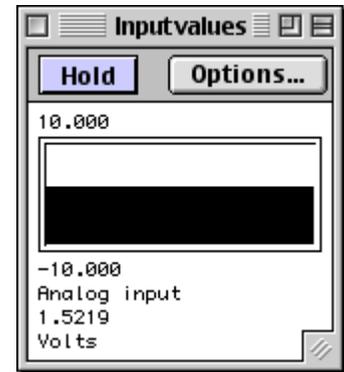
Show Input Values



EEG data filtered into four bands using online filtering option



Spectra displayed using Show Input Values

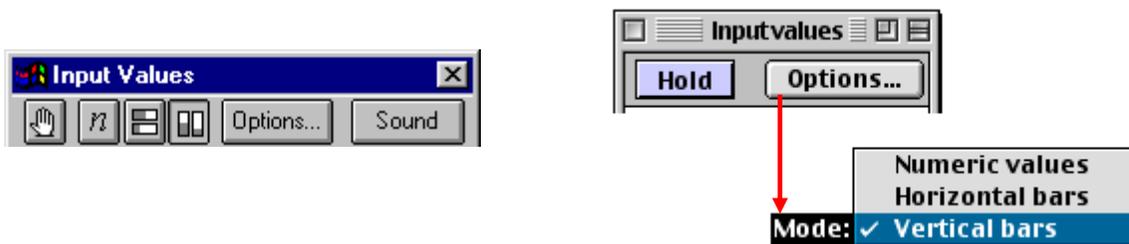


SIV window on the Mac

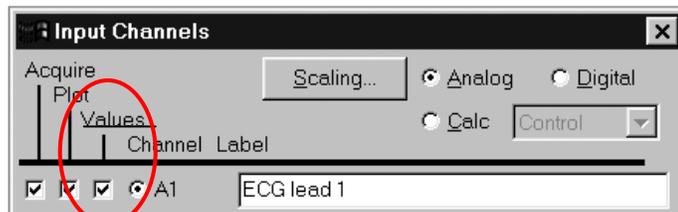
The Show Input Values option of the MP menu generates an Input Values window, which displays channel values in real time, whether an acquisition is in progress or not—which allows you to display values prior to or after an acquisition.

- In the example above, a single channel of EEG data was passed through four different online band pass filters. This created four new Calculation channels, each designed to retain data only within a given range. The Input Values window displays a spectral plot in real time.

The Input Values display can be set to numeric, horizontal or vertical bar graph format, and it can be resized and moved to any position on the screen. To set the display mode on a PC, use the icons under the *Input Values* title bar; on a Macintosh, use the “Mode” menu generated via the “Options” button.

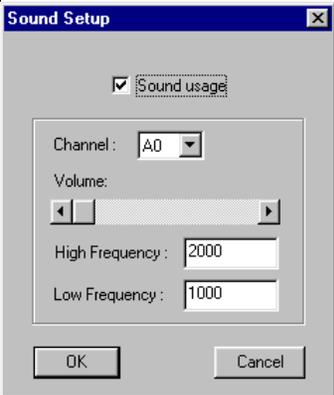
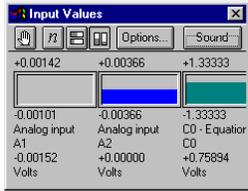
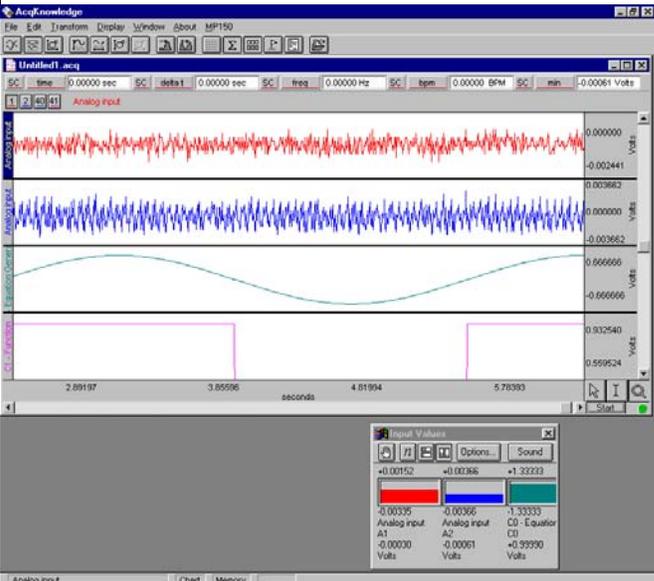


Note: The Input Values window only displays values for channels that were set up with the “Values” box checked (see page 56 for more information on the “Values” checkbox).



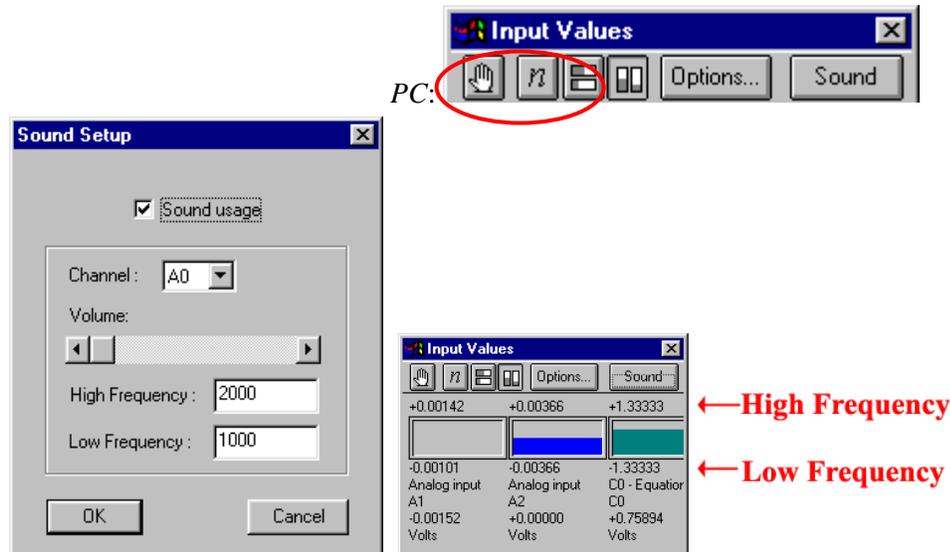


MODE	ICON	EXPLANATION
Hold	 PC	Regardless of the display options selected, the display can be “frozen” at any point in time by clicking on the hand icon (PC) or the Hold button (Mac). Clicking this icon will hold the values at their level(s) when the icon was pressed. The window will remain frozen until the icon is clicked again. Once the values are “unfrozen,” the values will return to the standard real time display mode.
Numeric	 PC	When data are displayed in numeric value mode, the voltages of the appropriate channels are displayed numerically.
Bar chart	<p>➤ Horizontal</p>  PC	Data can be displayed in either Horizontal or Vertical bar chart formats. 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, increase the units per division in the graph window for that channel. Conversely, to have a bar take up more of the window space, decrease the units per division in the graph window.
➤ Vertical	 PC	
Options	Options...	<div style="display: flex; justify-content: space-around;"> <div data-bbox="488 1318 1008 1682"> <p>Input Values Setup</p> <p>Precision <input type="text" value="5"/> digits</p> <p>Show <input checked="" type="checkbox"/> Channel Numbers <input checked="" type="checkbox"/> Labels <input checked="" type="checkbox"/> Units <input checked="" type="checkbox"/> Min/Max <input checked="" type="checkbox"/> Values</p> <p>OK Cancel Font</p> <p style="text-align: center;">PC</p> </div> <div data-bbox="1016 1318 1442 1682"> <p>Input Values Setup</p> <p>Mode: <input checked="" type="checkbox"/> Numeric values <input checked="" type="checkbox"/> Horizontal bars <input checked="" type="checkbox"/> Vertical bars</p> <p>Font: <input type="text" value="Monaco"/></p> <p>Size: <input type="text" value="9"/></p> <p>Precision: <input type="text" value="5"/> digits</p> <p><input type="checkbox"/> Show channel numbers <input checked="" type="checkbox"/> Show units <input checked="" type="checkbox"/> Show labels <input checked="" type="checkbox"/> Show Min/Max <input checked="" type="checkbox"/> Show values</p> <p>Ok Cancel</p> <p style="text-align: center;">Macintosh</p> </div> </div> <p>Mode (on the Macintosh) controls the format of the values display.</p> <p>Precision—On a PC, Precision controls how many significant digits of data are displayed <i>after the decimal place</i> (a setting of 5 digits might display data from one channel as 1206.70425 and data from another channel as -.97159). On a Macintosh, Precision controls <i>the total number of digits</i> displayed.</p> <p>Show controls the amount and type of information displayed regarding each channel. Click in the box next to each option to activate it.</p>

MODE	ICON	EXPLANATION
		<ul style="list-style-type: none"> ➤ Channel Numbers will display the channel numbers (A1 for the first analog channel, for example). ➤ 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. ➤ Units will display the units for each channel (as indicated in the main graph window). By default, each channel's display units are scaled in terms of Volts, but this can be changed by clicking in the amplitude scale units area in the graph window. ➤ 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. <p>The Font button will generate a standard font control dialog.</p>
<p>Sound</p> <p>On the Mac, the Sound option is accessible under the MP menu.</p> <p>See page 121 for Sound Control details.</p>		<p>The Sound button generates a "Sound Setup" dialog, which allows you to turn sound on or off, select the sound source channel, control the volume, and assign the <i>High Frequency</i> and <i>Low Frequency</i> values to establish the desired sound output.</p>   <p>← High Frequency</p> <p>← Low Frequency</p>  <p>You can also use calculation channels to control the sound patterns.</p>

Sound Feedback

Sound Feedback can be used to generate an audio signal based on a channel's data values. Use the Sound dialog to turn sound on or off, select the sound source channel, control the volume, and assign the *High Frequency* and *Low Frequency* values to establish the desired sound output. On the Macintosh, you can also control the output sampling rate.



A sine wave is generated that ranges between user-specified frequencies. As the input value changes, the generated tone shifts in response to the input value.

The amount of change in the tone is dependent on the channel scale and mirrors the percentage of change of the gauges in the Input Values dialog “bar” display mode. The sound frequency and sampling rate for generation can both be adjusted. Lower sampling rates require less processing time to generate, while higher sampling rates can generate higher frequency tones.

There is an option to silence the tone if the input signal falls out of specified range (if the value would not be plotted, no sound is emitted).

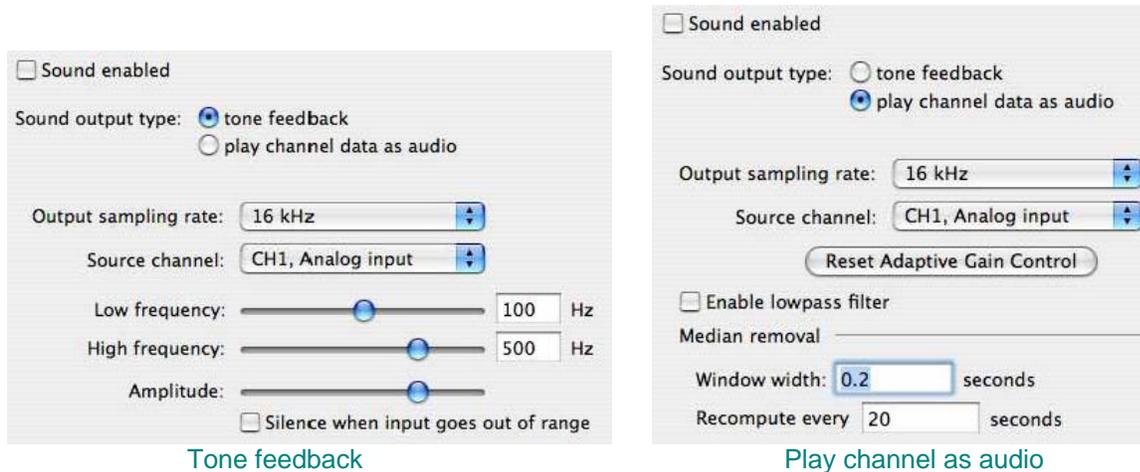
See also: [Sound Patterns](#), page 124.

Sound Feedback Settings *Mac OS X*

On the Macintosh, the audio signal is generated with 16 bits of resolution, providing a frequency resolution equivalent to CD.

Because of processing overhead, the actual audio output may be delayed. Changes occurring on the actual input may not appear in the audio output until a few seconds later. This delay may be dependent on the speed of the host computer.

Whenever any of the settings for the lowpass filter, data source channel, output sampling rate, or median removal are changed, the audio playthrough will be halted and re-started. Settings that are modifiable by edit fields will have changes applied only if the edit field loses focus (tab, shift window focus) or when return is pressed.



Sound Output Type

- Tone generates a sine wave between the specified frequencies. The frequency is varied with the amplitude of the source channel. The minimum value on the vertical axis for the channel corresponds to the low frequency, the maximum value to the high frequency. As the value of the channel changes, the frequency of the tone is adjusted accordingly. *See also: Sound Patterns*, page 124.
- Play channel as audio allows the signal to be listened to directly; this is useful in EMG analysis, speech analysis, etc. Audio can be generated only when there is an acquisition in progress. All audio output goes to the default audio device. The default output device is set in the Sound System Preferences. To change the output device, exit the application, change the sound output device in the System Preferences, and restart the application. The playthrough audio will not be generated on the device until the start of the next acquisition.

Output sampling rate

The sampling rate the sound hardware uses to generate the signal. Options are determined by the audio parameters of the computer, up to 44Hz. The output sampling rate controls the rate at which the data is generated as well as the maximum frequency value that can be used for the low or high frequency (half the sampling rate). Choosing a lower sampling rate will reduce processor overhead but will limit the range of frequencies that can be reproduced.

Source channel

Provides the channel whose data is either played back directly or used to adjust the tone frequency. The menu will list all analog, digital, and calculation channels that have the Acquire box checked in the Channel Setup dialog.

Amplitude

Tone feedback only—The amplitude slider controls the overall volume.

Reset adaptive gain control

Play channel data as audio only—Use after audio playthrough has started to re-adjust the level after accidental spikes or other large artifacts. Shift the scaling factor m back to a very large value. An adaptive gain control mechanism maximizes the volume of the signal being output to match the dynamic range of the input. To change the volume of the audio output, use the volume control in the System Preferences. During an acquisition, high amplitude artifacts (e.g. an accidentally unclipped lead) may result in the sound output becoming too quiet. If this happens, clicking the “Reset Adaptive Gain Control” button in the MP > Sound Feedback control window will reset the audio gain to maximum.

Enable lowpass filter

Play channel data as audio only—The source channel data is processed before it is sent to the audio device. The audio signal is output at a sampling rate that may not match the acquisition sampling rate. If the acquisition sampling rate is lower than the audio rate, upsampling of the audio data will be performed. A lowpass filter can be optionally applied to remove artifacts from this upsampling process. The artifacts sound like a “buzz” imposed on top of the real signal. Enabling the lowpass filter will remove this “buzz.” This filter can be disabled if data is being acquired at rates equal to or greater than the audio output sampling rate.

Median Removal

Audio signals are AC coupled. Physiological data may exhibit DC offset, however. Median removal is applied to all source channel data to AC couple it prior to generation of audio. The window width controls the amount of information used to compute the median and should be longer than a single cycle of information in the data. The recomputation interval controls how often the median should be recomputed and is useful for signals that have significant baseline drift over time.

Units correspond to the axis setting; changing the axis type will change the units.

<u>Axis</u>	<u>Units</u>
Time	Seconds
Frequency	Hz
Arbitrary	Arbitrary

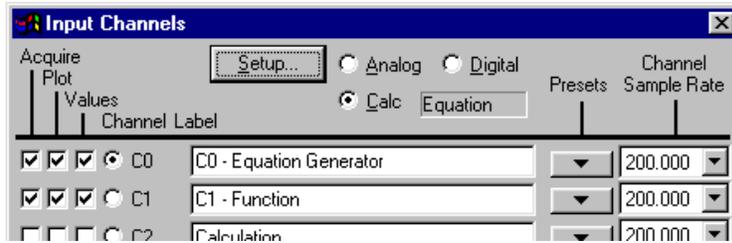
The default window width is 0.2 seconds and the default recomputation interval is 20 seconds.

Silence

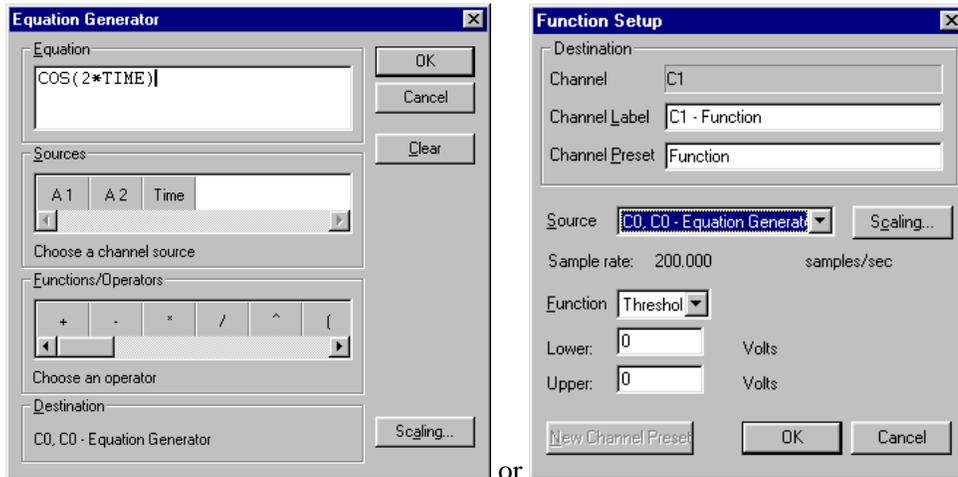
Tone feedback only—The frequency is usually adjusted based upon the position of the voltage of the source channel versus the visible range in the graph window, similar to the bars of the input values display. If the signal goes outside the visible range, it will either be fixed to the low or high frequency or, if “Silence when input goes out of range” is checked, the tone will go silent.

Sound Patterns

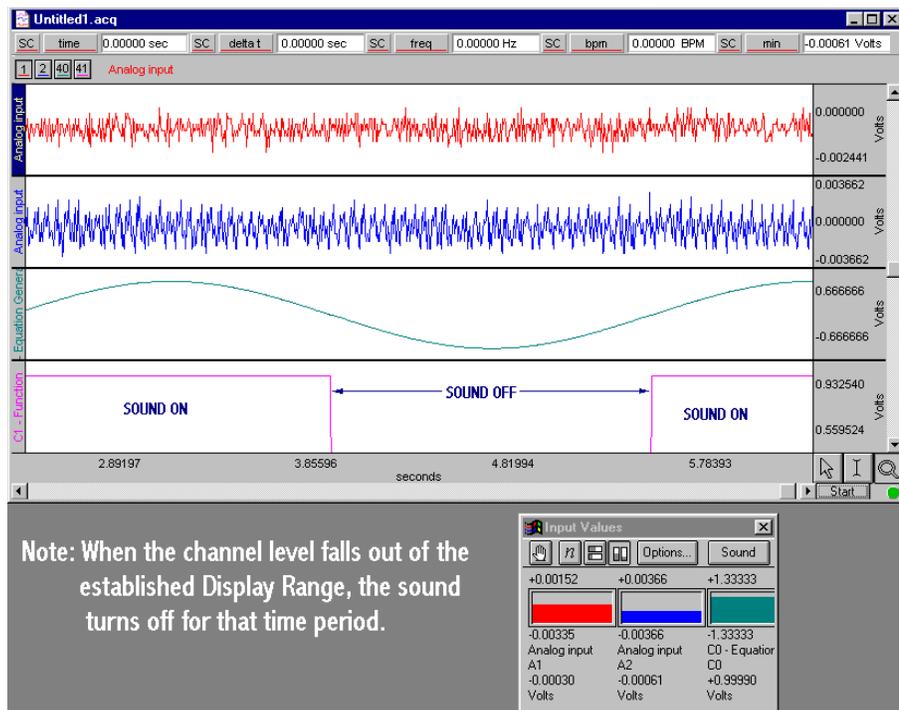
You can use Calculation channels to control the sound patterns. Begin in the MP >Set up Channels dialog. Select a calculation channel Preset and make sure the “Values” option is checked for each channel you want to use sound on.



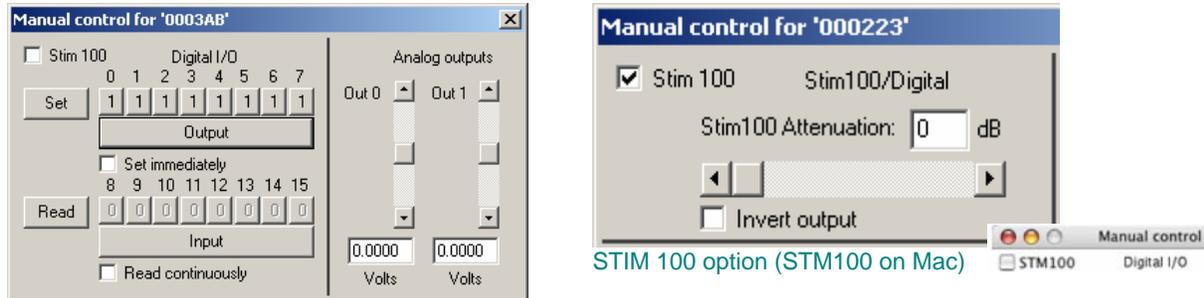
After you’ve selected a Preset, click on Setup... and then establish the desired settings. One possible set up is demonstrated on the following page.



When you click on the “Start” button, the Calculation channels will display the sound pattern.



Manual Control



The Manual Control dialog box allows you to monitor and/or output pulses through the digital input/output (I/O) channels, as well as 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

- if the wide range of waveform output options available in the Stimulator Setup dialog cannot match your specifications.
- for pre-stimulation and post-stimulation.

MP150 users: See page 111 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.
 - In other words, the lower block can be set to input data while the upper block outputs data. You can set channels in the lower block to either read in data or do nothing (as opposed to outputting data) while channels in the upper block either output data or do nothing (as opposed to reading data).

To read incoming values for a given block of digital channels, click on the Input button below the row of channels for which you wish to have 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 the Read Continuously box is checked (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 on the bar below the channel boxes so the button reads “Output.” You can then program the individual channels within that block. 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 box would be setup as shown above.

The function buttons toggle as follows:

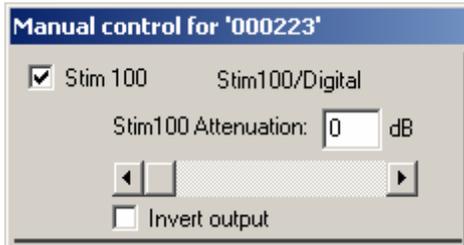
- | | |
|-------------------------|--------------------------------------------------------------|
| Input toggles to Output | When Input is selected, the checkbox is “Read continuously.” |
| Set toggles to Read | When Output is selected, the checkbox is “Set immediately.” |

To output a signal on Channel 3, click on 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.

STIM 100 option (STM100)



STIM 100 option (STM100 on Mac)

When the STM100C stimulator module is connected to an MP System, the output level can be controlled via the Stim 100 option of the Manual Control dialog (“STM100” under Mac OS X).

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 *BIOPAC MP Hardware Guide.pdf*.

Autoplot and Scroll

Both Autoplot and Scroll control how data appears on the screen. By default, *AcqKnowledge* 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.

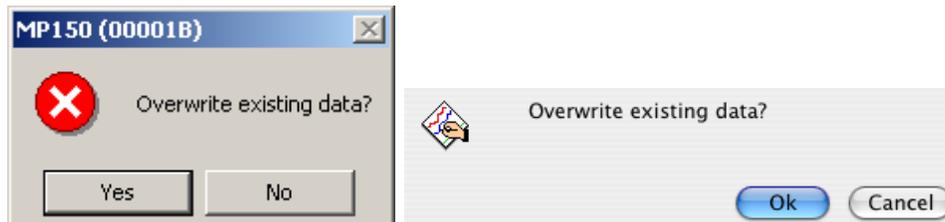
When Scroll is deselected and Autoplot is checked, the screen will be cleared when the data reaches the right edge of the screen, and plotting continues from the left again.

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 MP will display the first eight seconds of the data record, but this can be reset manually by changing the horizontal scale. To turn Autoplot ON or OFF in the middle of an acquisition:

- For the MPWSW (PC)—select Ctrl+T on the keyboard to toggle Autoplot.
- For the MPWS (Mac)—pull down the MP menu and check “Autoplot” ON or OFF or use the keyboard shortcut Command+T

Warn on Overwrite

Selecting the “Warn on overwrite” option from the MP menu will cause the following dialog box to appear each time you start a new acquisition:



If you click on “Yes,” then *AcqKnowledge* will erase your current file and overwrite with a new acquisition. If you don’t want to erase the file you’re working in, click on “No” and then open up a new file to work in.

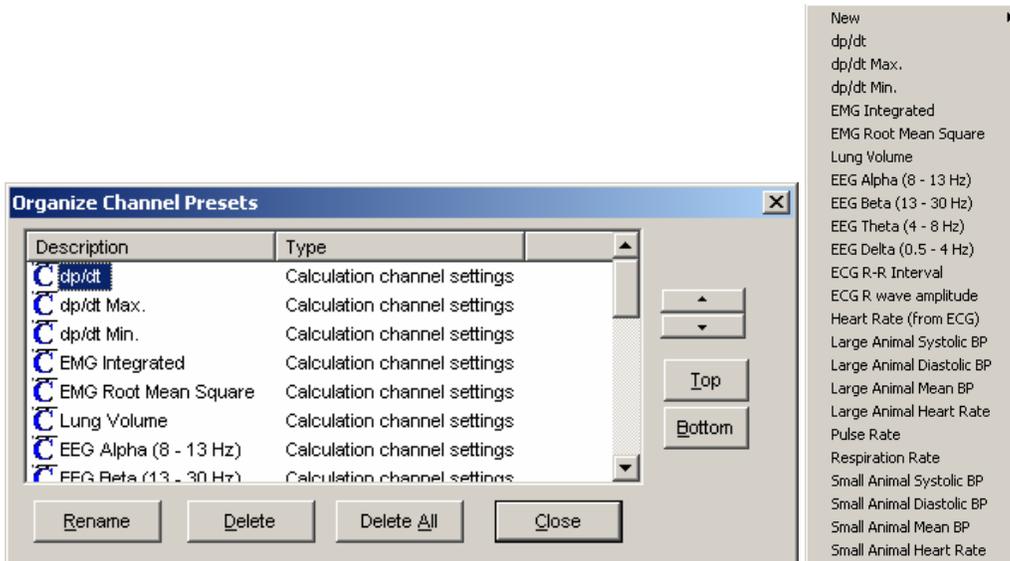
This prompt will appear at the beginning of each acquisition when the MP System is in Repeating/Autosave mode, so you will probably want to uncheck the “Warn on Overwrite” under the MP menu.

Organize Channel Presets

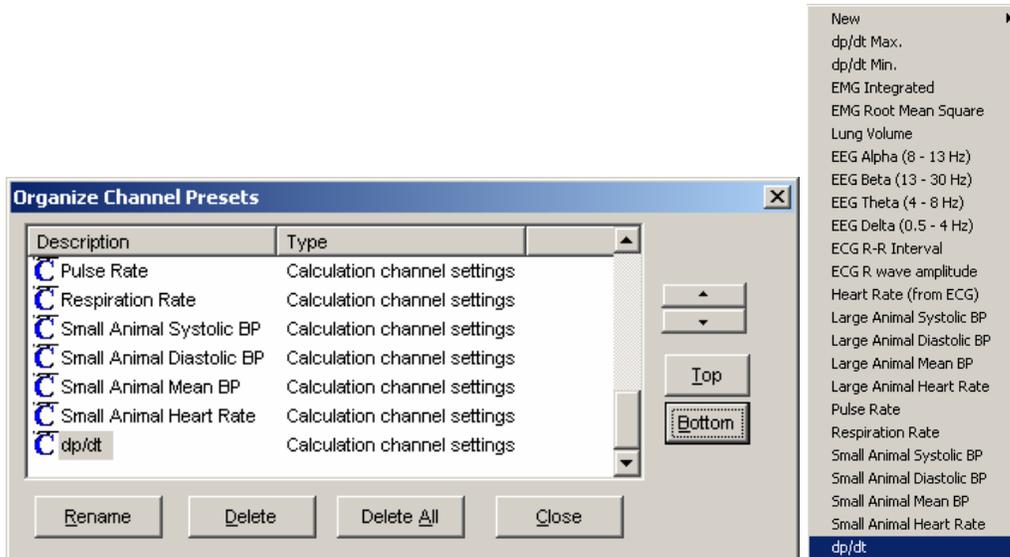
The Organize Channel Presets option controls the channel presets (established or new) in the MP > Set up Channels dialog; you can rename, rearrange or delete Presets. You might use this option to place the most frequently selected Presets at the top of the menu or group related Presets, such as established ECG Presets and new channel Presets you've created.

Click on a Preset description to select it, and then use the buttons to organize the Presets. The up and down arrows will move your selection one space at a time, and the Top and Bottom buttons will jump to the start or end of the list.

Mac OS X users can drag items to reorder them on the Presets list.

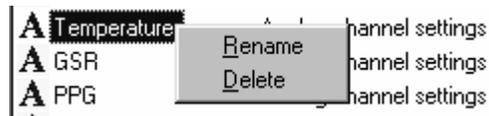


Organize Channel Presets dialog and resulting Presets menu display



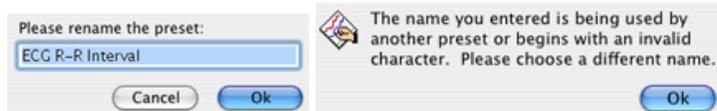
Revised Organize Channel Presets dialog and resulting Presets menu display

To delete or rename a Preset, select the Preset name from the listing and click on the Delete or Rename button. Or, click the right mouse button to select the Preset from the listing and scroll to the desired option.



Rename a Preset by typing in a new description and clicking OK.

- You can't use any name currently used by a Preset or any name that matches a Calculation type (Integrate, Rate, etc.).



Delete a Preset by selecting that option. You cannot delete the Default Analog Input preset. When you delete a Preset, you will be asked to confirm the request because it is an irreversible action.

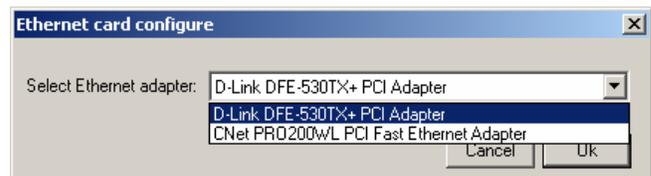


Select Network Adapter

Windows only, MP150 only

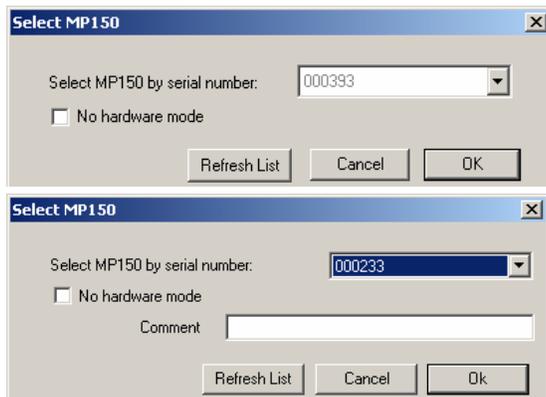
The Select Network Adapter option generates the Ethernet card configure dialog, which prompts you to select an Ethernet adapter to use with the MP System.

Mac OS X only Access to multiple network adapters is provided in the "Connected to MP" window when DLC is in use; see page 303 for details.



Select MP150

MP150 only



The “Comment” option is available when you choose Select MP150 (not Connected to). You can enter a comment to help you identify each MP150 unit, i.e. “Main Lab” or “Station 12.”

The pull-down menu lists all MP150 units that are powered ON and sitting on the same local area network. The software can’t determine the lock status until a user attempts to communicate directly to a MP150 unit—each MP150 unit needs to be tried to determine if it is locked or unlocked.

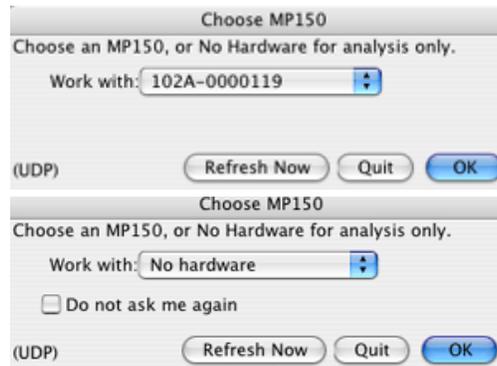
The fact that MAC (Ethernet) addresses appear in the user’s “Select MP150” dialog does not imply that the MP150 unit is, in fact, unlocked and available. If a user attempts to connect to a locked MP150, an error message will be generated to advise that the MP150 unit is locked to a different computer.

AcqKnowledge locks an MP150 as soon as it connects to it, which tells the MP150 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 MP unit receives a command from the computer that locked it. To locate MP150s in the local network, AcqKnowledge sends a broadcast packet to the local area network that asks all the MP150s in the network to respond. All the MP150s—whether locked or unlocked—will respond to this prompt. This means that the “Select MP150” menu may allow a user to select an MP150 that is locked. In such cases, AcqKnowledge will fail to connect (to a locked MP unit, as expected). To resolve this issue, unlock or power cycle the MP unit. See Locking/Unlocking the MP150 (Appendix E—page 328) for more details.

When “No Hardware mode” is selected, the menu of available MP150 units is grayed out and becomes unselectable.

Exit Playback Mode

Mac OS X only—Enabled when Open File for Playback (see page 33) has been selected. Select to resume acquisition functionality (Playback menu to MP menu, Replay button to Start button).



Mac OS X only: To set No Hardware as the default, click “Do not ask me again.”

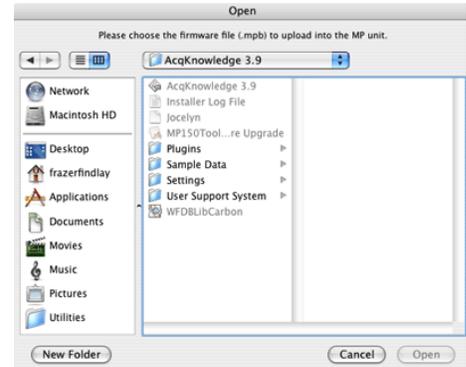
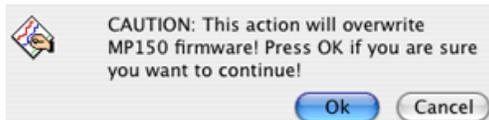
Update Firmware

Generates a Firmware Update routine.

- Windows users, see page 330.

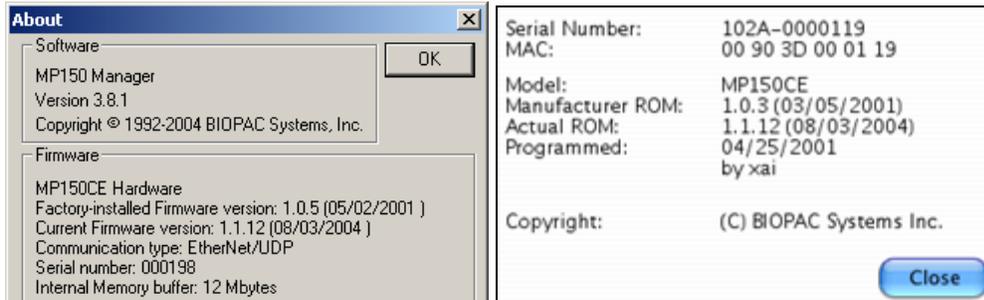


- Mac users, see page 332.



About MP / MP150 Info

Select About MP (Windows/PC) or MP1X0 Info (Mac OS X) from the MP1X0 menu to generate a dialog with information about the software and firmware versions being used by *AcqKnowledge*:



The Factory-installed Firmware version (“Manufacturer ROM” on Mac OS X) is provided in case you have to “Reset” the MP150 unit for a Firmware Rollback (see page 332).

- Factory-installed Firmware version 1.1.2 or previous (purchased approximately November 2002 or before) may not reset to a level compatible with UDP communication. In such cases, you will need to install *AcqKnowledge* 3.7.2 or previous (non-UDP) and update to UDP in stages; contact BIOPAC for additional support.
- To use an MP150 with UDP communication on a network with a non-Windows DHCP server, you must use firmware 1.1.12 or greater for the MP 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 X, and other DHCP-aware devices.

Note: For information about *AcqKnowledge* software, click Help > About *AcqKnowledge*.

Chapter 8 Video

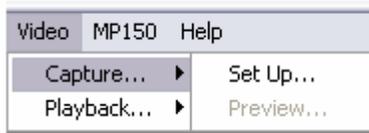
AcqKnowledge can record and synchronize a video signal with an acquisition.

AcqKnowledge control of video capture—Acquisition can be delayed or advanced (with 1 ms resolution) for tight synchronization to the start of a video. Users can view a video file in post-processing and link the video frame to the position of the AcqKnowledge data cursor. When the video file frame is advanced, the AcqKnowledge data cursor advances the corresponding period of time (and vice versa).

AcqKnowledge synchronization to existing video—The Video Capture and Playback functions are independent. This permits the user to link otherwise recorded video files to an AcqKnowledge data graph. This flexibility permits the user to acquire video in a camcorder, transfer the camcorder video to the computer, and then time synch the digitized video to an AcqKnowledge data graph.

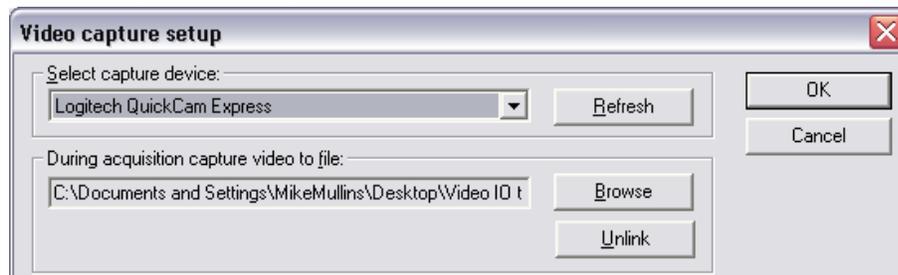
Video Capture will create an *.avi file format; Video Playback supports only *.avi, *.mpeg, and *.mpg file formats.

Capture



Setup

Choose Capture > Set up from the Video menu:



Select capture device

- Use the pull-down menu to link AcqKnowledge to any video capture device connected to the computer (typically via a USB port).
- Click Refresh to update the capture device menu after connecting a video capture device to the computer (typically via a USB port).

During acquisition capture video to file

- Click Browse and select an existing video file location to link the acquisition to or create a placeholder for a new video file to be created along with the new acquisition.
- If a location has been selected, Unlink will disconnect the acquisition and allow the user to link to a different video file or create a new one.

Preview

Choose Capture > Preview from the Video menu to generate an image of the video frame to be recorded. Use this image to determine proper camera alignment.

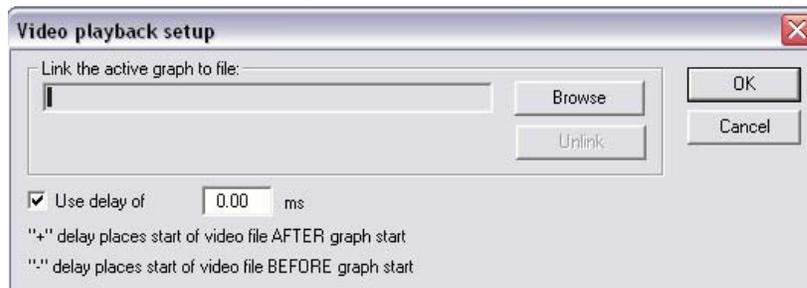


Playback



Setup

Choose Playback > Set up from the Video menu:



Link the active graph to file

- Click Browse and select an existing video file to link to.
- If a video file has been selected, Unlink will disconnect the video file and allow the user to link to a different video file.

Delay

Use the Delay option to adjust for any time offset (positive or negative) between the video recording and the *AcqKnowledge* data file. The settings can establish a tight correlation between the start of data acquisition and the start of the video device. This correlation is important because the delay in video device start (upon program command) often exceeds the delay in *AcqKnowledge* acquisition start.

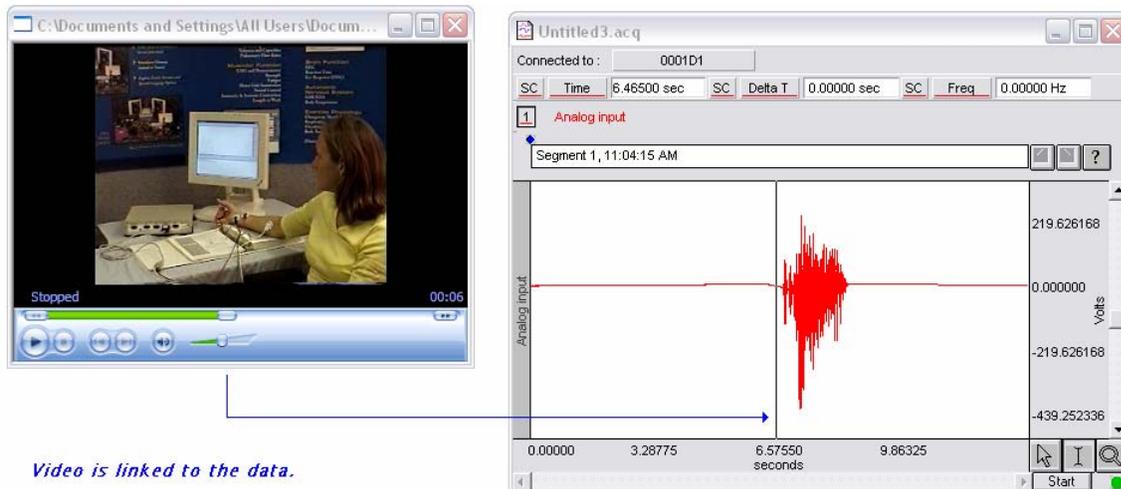
Use Delay of __ ms

- Click in the box to toggle the Delay option ON/OFF.
- Enter a value in milliseconds for the delay.
 - The default is positive, which starts the video AFTER the graph playback starts.
 - For example: with a positive delay of +1,000 ms, (1 second), entered as "1000", events occurring in the video playback will not become visible until the cursor in the *AcqKnowledge* file is placed in advance of 1,000 ms.
 - Include "-" for negative, which starts the video BEFORE the graph playback starts
 - For example: with a negative delay of 1,000 ms (1 second), entered as "-1000", the waveform in the video does not begin to appear until the cursor is placed at or beyond the 1,000 ms mark of the associated data file.

Synchronize

To synchronize the video stream optimally to the *AcqKnowledge* data graph, use the stimulator function to drive an LED to illuminate the video field just after the start of the recording. Set the Delay value for exact alignment (subject to video time resolution) between the presentation of the video stream and the *AcqKnowledge* data. The point that the LED turns ON is paired to the transition, from low to high, of the stimulation signal driving the LED.

Show



Video is linked to the data.

Choose Playback > Show from the Video menu to display the recorded video in your computer's default media player. Since the video time base in the playback pane is linked to the AcqKnowledge data time base, shifting frames in the video pane will correspondingly shift the cursor in the AcqKnowledge data graph and vice versa.

To shift the entire video recording forward or backwards with respect to the AcqKnowledge time base, use the Delay option. This option is used in post-processing only, to properly align the video and AcqKnowledge data to compensate for setups when the video device did not start at the exact same time as AcqKnowledge.

- The video can be viewed independent of the associated acquisition.

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 *AcqKnowledge*, turn to the *Editing and Analysis Features* chapter that follows. 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 187	General file management commands, including opening, saving, and closing files. Export data files.
Edit	Page 209	Cut, copy, and paste between and within files. Export data files.
Transform	Page 217	Mathematical transformations and functions, from simple arithmetic to digital filtering and spectral analysis.
Specialized Analysis	Page 333	A courtesy copy of the new Specialized Analysis package is included under the Transform menu for <i>AcqKnowledge 3.9</i> for Mac OS X.
Display	Page 294	Control how data appears on the screen either during or after an acquisition.

Toolbars

Many of the most commonly used features in *AcqKnowledge* can easily be executed with a mouse click. The toolbar contains shortcuts for some of the most frequently used *AcqKnowledge* commands; icons are grayed out when they are not applicable.

Click Display > Show > Tool Bar to view the icons. Click on an icon to activate it.

See page 37 for Toolbar icon definitions.

Shortcuts

Keyboard shortcuts are detailed on page 37.

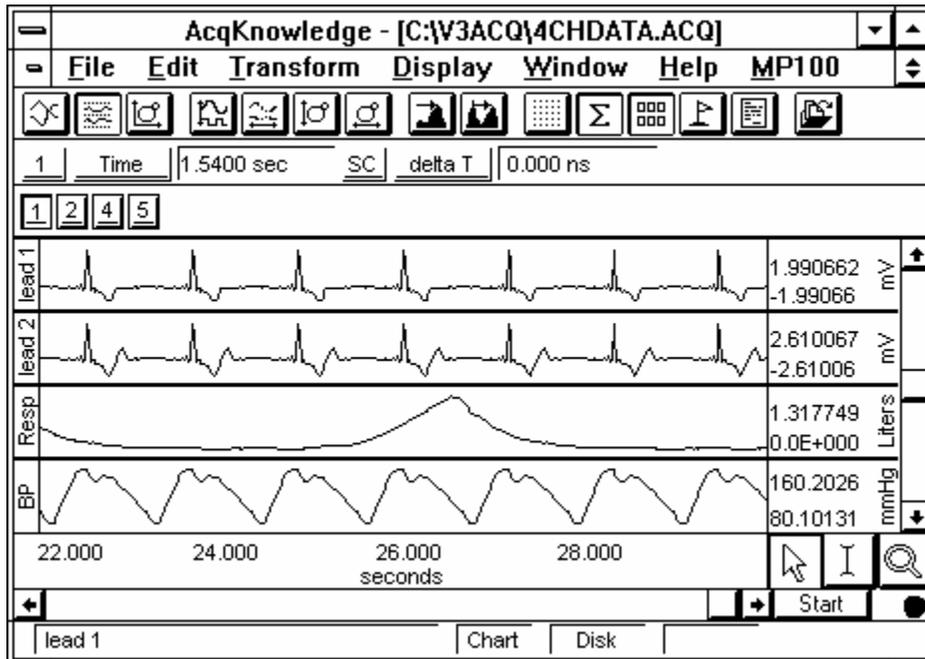
Mouse shortcuts are detailed on page 39, including right-click options for Windows and contextual menus for Mac OS X.

Chapter 9 Editing and Analysis Features

Overview

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

If you are not currently running AcqKnowledge, double click on the AcqKnowledge icon to start it. Choose Open from the File menu and select the file called “4chData.acq” (or “4chData” for MPWS). Your screen should look like this:



Edit menu functionality during acquisition

Mac OS X only—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.

Using the scroll bars

As you can see, there are four channels of data in this file (BP, Resp, Lead 1, Lead 2). Although this record is 30 seconds long, only a few seconds are displayed on the screen at one time. You can move to different locations in the record by moving the scroll box at the bottom of the screen. Dragging the box left moves you 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 you to move to different points in time at smaller increments.

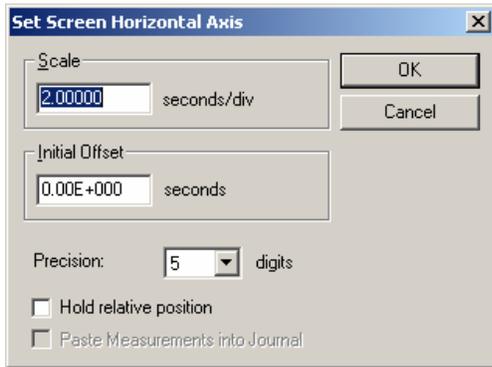
A vertical scroll bar is on the right side of the screen, and. If you click on the scroll arrow at the top of the box, you'll see that one waveform appears to move down within its “track” on the screen. Moving this scroll box changes the amplitude offset of a selected channel. As with the horizontal scroll bar, you may either move the box or click on the arrows.

Changing the scale

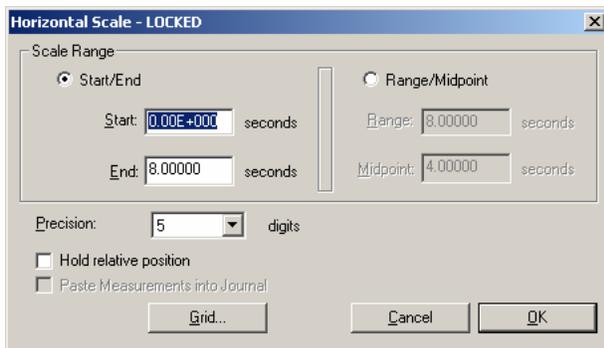
Horizontal scale

As an alternative to the scroll bar, you can click the mouse button with the cursor in the area just above the horizontal scroll bar or just left of the vertical scroll bar. Clicking in the horizontal scale area (where it says “seconds”) generates a dialog box that allows you to enter a value for units per division and horizontal scale offset. This dialog varies based on the lock status of the grid, which is established in the Display > Show > Grid Options dialog.

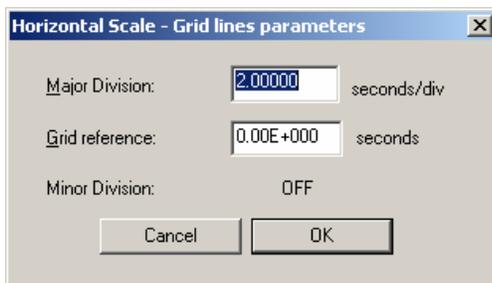
AcqKnowledge 3.8 Windows/PC



Unlocked



Locked, with Grid... button



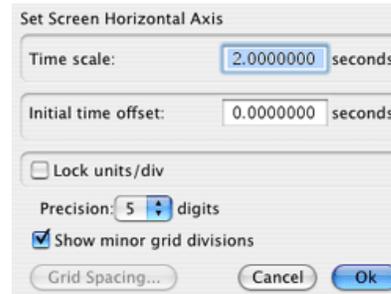
Grid control from Grid... button

Unlocked

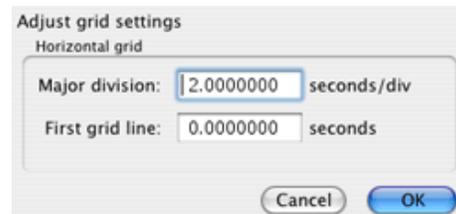
Scale refers to the time interval (units per division) between the on-screen grid marks. There are four vertical divisions per screen, and the default is 2.00 seconds per division, so eight seconds of data will be displayed on the screen display. Entering a larger value will display more of the record,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

Initial offset refers to 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.

AcqKnowledge 3.9 Mac OS X



Unlocked and Locked
(when Locked, Time scale will be seconds/screen)



Grid control from Grid Spacing button

Hold relative position is an option available only in the Append acquisition mode. When checked, the display for appended acquisitions will show the same relative position with respect to the start of acquisition. This is convenient when doing short-duration, high-speed acquisitions where you want to be able to zoom in on the signal of interest and have the relative position (from the start of acquisition) stay the same. The relative position will not be preserved if the selected area falls within two or more appended segments.

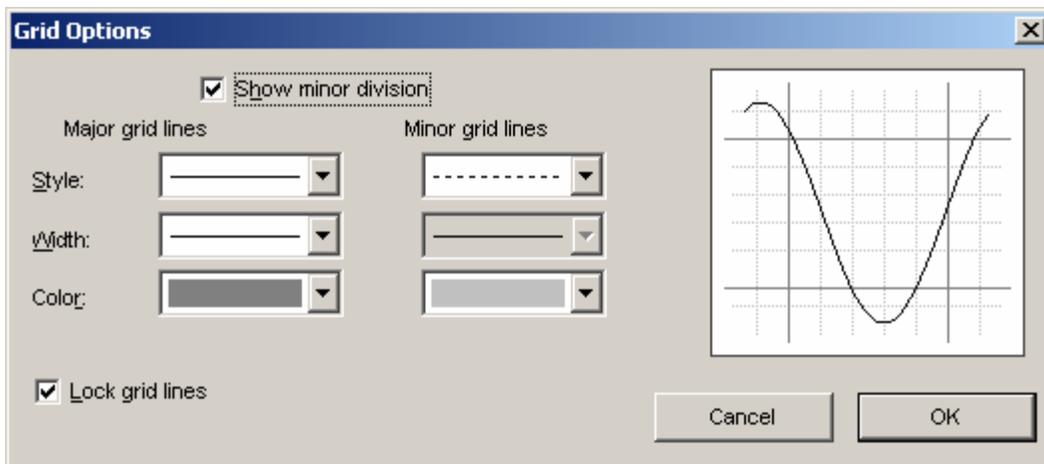
When Hold relative position is checked, if you zoom in on a section of data that has been selected (highlighted) and is completely within one appended segment, the scale of the selected area changes with each appended segment such that it remains relative to the start of acquisition for that segment and updates the measurements. If the selected data area falls within two or more appended segments, this feature is not implemented.

Locked

Scale Range determines the limits of the viewable scale. Horizontal scale parameters can be established with *Start/End* values or *Range/Midpoint* values. You cannot enter a value less than 0.

Hold relative position is an option available only in the Append acquisition mode. When checked, the display for appended acquisitions will show the same relative position with respect to the start of acquisition (see unlocked grids section for more detail).

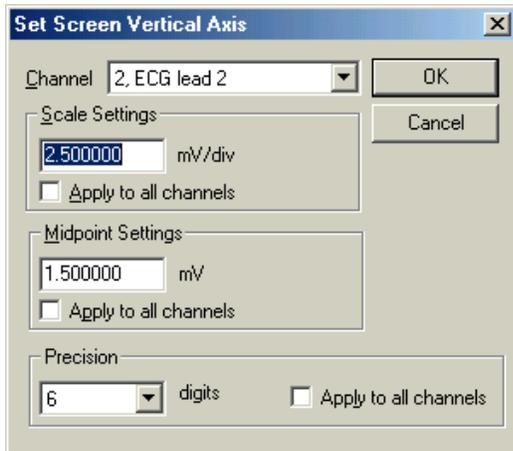
The Grid... button generates a *Grid line parameters* dialog. Set the scale for the Major Division and the Grid reference, which is the point from which the first grid line will be drawn. To turn minor grids ON, check "Show minor division" under Display > Show > Grid Options.



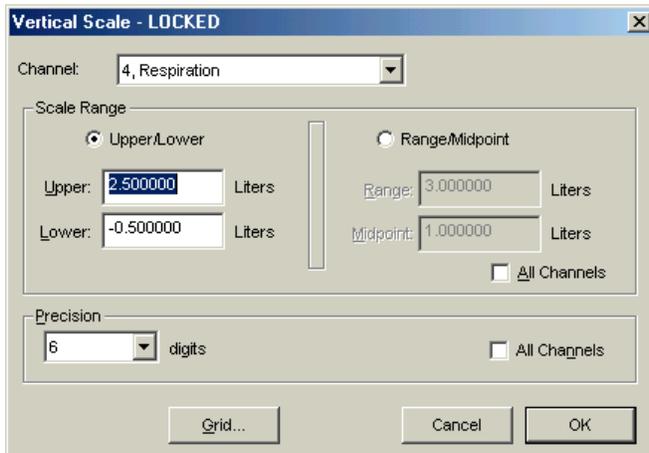
Amplitude (vertical) scale

Clicking the mouse in the vertical scale area (where the amplitude of each channel is displayed) generates a similar dialog box. This dialog varies based on the lock status of the grid, which is established in the Display > Show > Grid Options dialog.

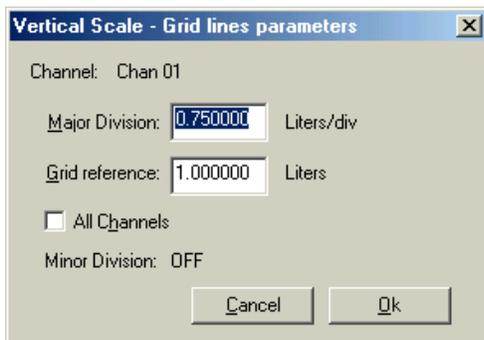
AcqKnowledge 3.8 Windows/PC



Unlocked

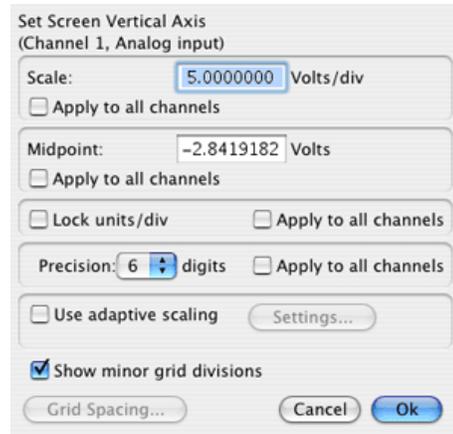


Locked, with Grid...button



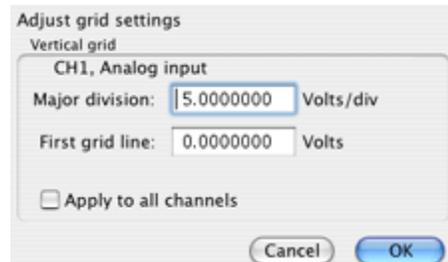
Grid control from Grid... button

AcqKnowledge 3.9 Mac OS X

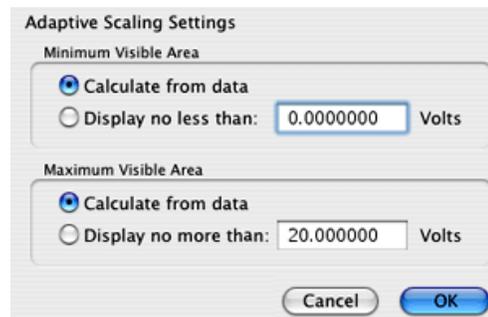


Unlocked and Locked (when Locked, scale will be units/screen)

Scale determines the limits of the viewable scale on the horizontal axis. When grids are locked, the Scale changes from *units/div* to “*units/screen*” and establishes the total units per screen. The total units will be displayed on the screen, with grid divisions at the unit interval entered in Grid Spacing.



Grid control from Grid Spacing button



Adaptive Scaling Settings

Unlocked

Scale determines how many units (usually Volts) are displayed for each division. As with the horizontal scale, AcqKnowledge 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 you to apply these scaling options to all channels. By default, the scaling options you choose will only apply to the channel indicated in the dialog box. If you want to apply these to all channels, click all the checkboxes.

Friendly Grid Scaling—Mac OS X only

Too much precision can create numbers that are difficult to quickly interpret. 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.

Locked

Scale Range determines the limits of the viewable scale on the vertical axis. When grids are locked, the Scale changes from *units/division* to “*units/screen*” and establishes the total units per screen. The total units will be displayed on the screen, with grid divisions at the unit interval entered in Grid Spacing.

Start/End is normally used for data not centered on 0.00 (i.e. data falls from 0-50 grams).

Range/Midpoint is normally used for data that is centered on 0.00 (i.e. AC-coupled data).

The Grid... button generates a *Grid line parameters* dialog. Use this to establish scale for the Major Division and the Grid reference, which is the point from which the first grid line will be drawn. Check the “All Channels” box to use these parameters on all channels.

Adaptive Scaling—*Mac OS X only*

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. The vertical scale dialog includes a checkbox to “Use adaptive scaling” and a “settings” button is activated when it is enabled. The Unlimited option results in no minimum or maximum range setting, and is equivalent to min 0 and max infinity.

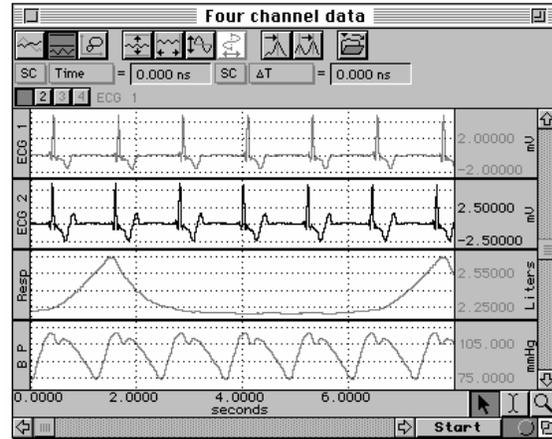
Changes to the scale will be applied whenever the domain of the plot area is changed. This includes manual changes to the horizontal scale, horizontal scrollbar use, horizontal auto-scrolling when dragging out a selected area, auto-scrolling or auto-plotting during acquisition, initial enabling of adaptive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

Adaptive scaling can be unique for each Data View.

Selecting 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 you to highlight all or part of that waveform, and enables you to perform transformations on a given channel.

In the upper left corner of the graph window there is a series of numbered 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 28). In the sample file, ECG channels are represented by channels 1 and 2, with respiration on channel 3 and blood pressure on channel 4.



To select a channel, position the  cursor over the channel box 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.

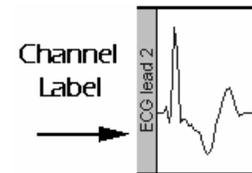
Additionally, the channel label in the display (on the left edge of the track) will be highlighted for the active channel.

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 boxes.

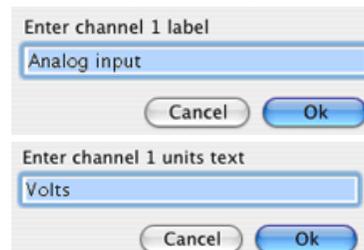
To change the label for a given channel

- during or before acquisition (including Append mode)
 - revise the MP menu> Set up Channels label text
- post-acquisition / analysis only
 - click on the left label enter the desired text in the dialog box

Mac OS X: Label and Units change prompts are separate. Click on the left to change the label and on the right (vertical scale) to change the units. The label can be up to 40 characters.



AcqKnowledge 3.8 Change Label and Unit



AcqKnowledge 3.9 Change Label and Unit

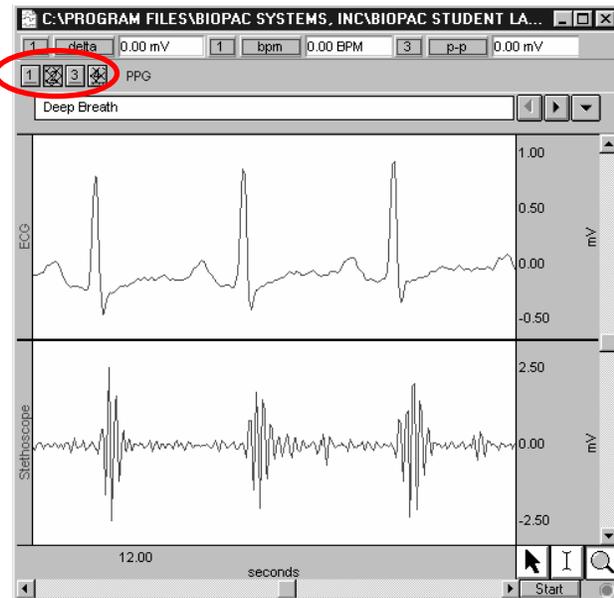
Hide a channel

You can “hide” a waveform display without changing the data file. To hide a channel,

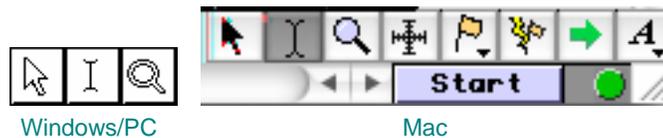
Windows: Ctrl+click in channel box.

Mac OS X: Option+click in channel box.

When a channel is hidden, the channel box will have a slash through it. You may view a hidden channel by holding down the Ctrl or Option key and clicking in the channel box again. Channels 2 and 4 are hidden in the following display:



Cursor Tools



The cursor tool icons are in the lower corner of the graph window. These cursor tools are used in many of the on-screen functions described below, including editing, measurements, and the amount of data displayed.



This is a general-purpose 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.



This is a standard “I-beam” editing tool. This tool is used to select an area of a waveform (or waveforms) to be edited or transformed. To select it, click on the middle button in the lower right hand corner of the screen. Now move the cursor toward the waveform. You’ll notice that the cursor changes from an arrow to an I-beam when it is placed over the graph area. Using this tool to edit data is analogous to editing text with a word processor.

When this cursor appears, you can select an area of data by holding down the mouse button and dragging the mouse to either the left or right. You can 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 you position the cursor to select the right edge of the area to be selected. Click the mouse button to select the area.

Lock

Toggle the lock state of the grid for horizontal axis or the channel.



This is a standard “zoom” tool. The zoom tool lets you select and magnify any portion of any wave. Click on the  icon (in the lower right portion of the screen) to use the zoom tool. As you move 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 you need to zoom in on. When you release the mouse button, *AcqKnowledge* will automatically adjust the horizontal and vertical scales. To “unzoom,” choose Zoom back from the Display menu.

Grid

Adjust the grid lines horizontal and vertical.

Control



Event Definition



Inserts an event at the mouse click location. See page 164 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 marker 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.

Event Removal
“Zap”

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 on 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.

Jump-to



Mac only—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.

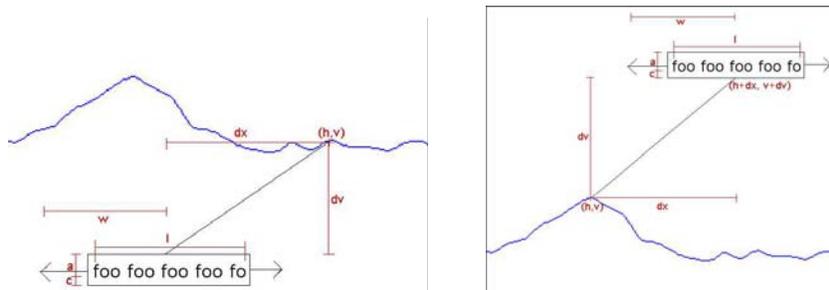
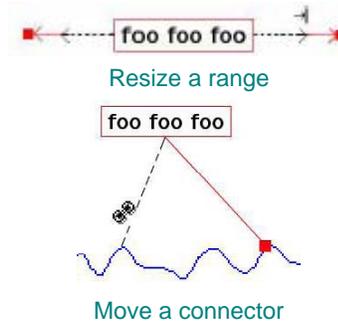
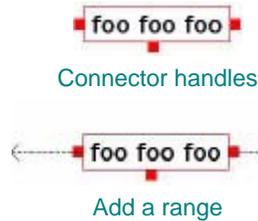
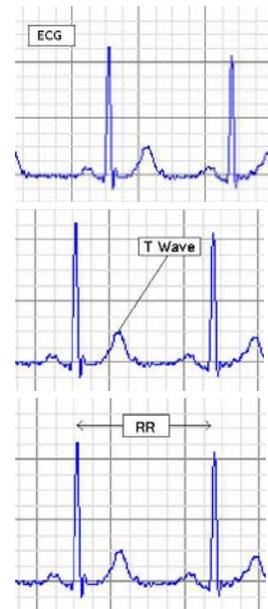
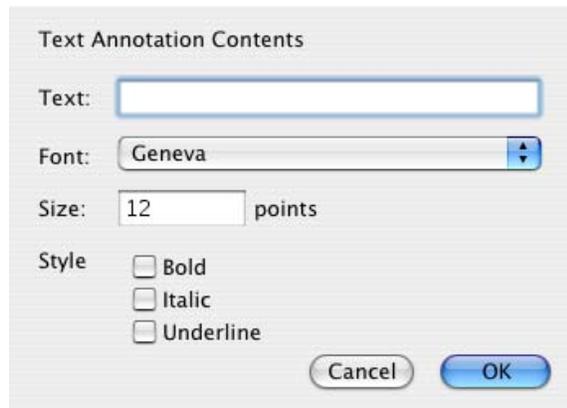
- Click the Jump tool on a data point to “jump” all of the open data views for that graph to the same time.
- Click the Jump tool on a point in an X/Y plot to jump data views in chart or scope mode to the point in time corresponding to the point in the X/Y plot. This can be useful for correlating PV 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.

Text Annotation



Mac only—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.



Text annotations are short pieces of text that float above channel data and markers 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 specific 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.

- Create** Insert using the text annotation cursor tool. 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” entry will automatically reposition all annotations so they are visible.

Measurements

A convenient feature in *AcqKnowledge* is the popup measurement windows. A variety of different measurements can be taken, and you can display different measurements from the same channel and/or similar measurements from different waveforms. *AcqKnowledge* can display measurements for the selected channel or for any other channel. By default, *AcqKnowledge* 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. 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.

The screenshot shows the measurement window with four measurement boxes: 'time' (17.28000 sec), 'delta t' (0.00000 sec), 'freq' (0.10157 Hz), and 'bpm' (6.09446 BPM). Each box has an 'SC' label. A pull-down menu is open for the 'SC' of the 'bpm' box, showing a list of channels: 'SC, Selected Channel', 'Ch3, ECG', 'Ch40, Heart Rate', 'Ch41, R-R Interval', and 'Ch42, R-Height'. Another pull-down menu is open for the 'bpm' box, showing a list of measurement options: 'none', 'value', 'delta', 'p-p', 'max', 'min', 'mean', 'stddev', 'integral', 'area', 'slope', 'lin_reg', 'median', 'time', 'delta t', 'freq', 'bpm' (checked), 'samples', 'delta s', 'median T', 'max T', 'min T', 'calculate', and 'correlate'. A third pull-down menu is open for the 'freq' box, showing a list of measurement options: 'Skew', 'Kurtosis', 'Moment...', 'Cap_dim...', 'Corr_dim...', 'Inf_dim...', 'Lyapunov...', 'Mut_inf...', 'Expression...', 'NLM...', 'Evt_count...', 'Evt_loc...', and 'Evt_ampl...'.

Results

Pull-down channel selection

Pull-down measurement menu

For a complete description of each of the measurement functions and the minimum samples for each, turn to page 131.

Mac only

Windows & Mac

Some of the values are single point measurements while others require at least two points to be selected.

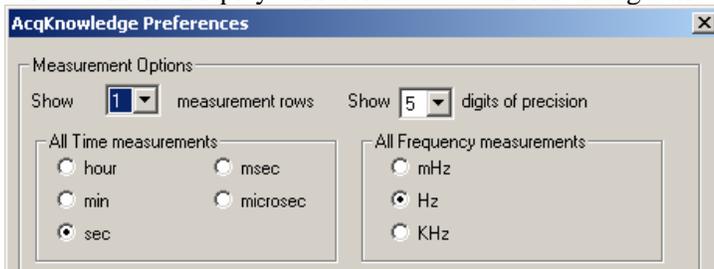
In some cases, the computations involved in the measurement can produce nonsensical results (such as dividing by zero, or calculating a BPM from a single point). In those cases, you may get a measurement value like INF (for infinite). This means that the result was undefined at this point.

Mac OS X only:

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

Measurement Display

The number of measurement windows depends on (a) the width of the screen and (b) the number of rows selected in the Display > Preferences > General dialog box.



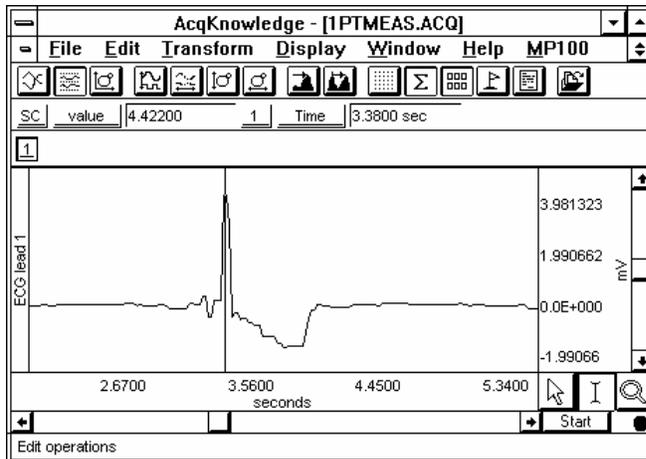
As the screen gets wider, more measurement windows will be displayed in the area above the graph windows. By default, only one row of measurement windows is displayed. To display more than one row of measurements, select a number from the measurement rows popup menu in the Display > Preferences > General dialog box.

Measurement Area

It is important to remember that AcqKnowledge 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.

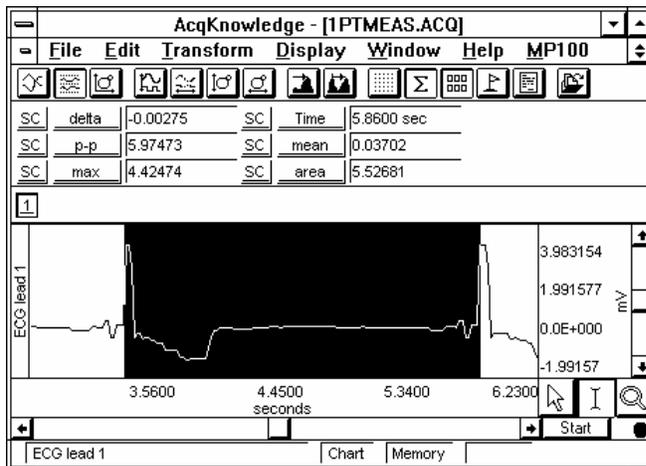
- Single-point measurements

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



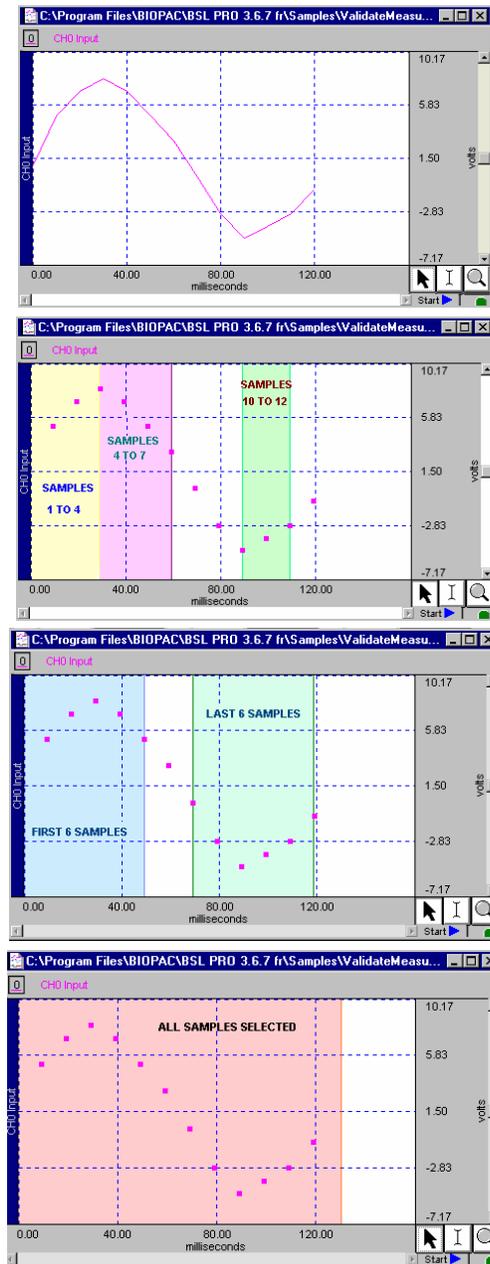
- Selected range measurements

Drag the cursor to select an area; the selected area will be highlighted. The graph on the right shows how the I-beam is used to select an area for measurement.



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.

**Measurement Validation**

You can validate measurements with the `ValidateMeasurements.acq` sample file that was included with the software. Pay attention to the “*Sample data file*” section of the measurement definitions that begin on page 151, 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).

Measurement Info / Parameters—*Mac only*



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

Measurement Interpolation—*Mac only*

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.

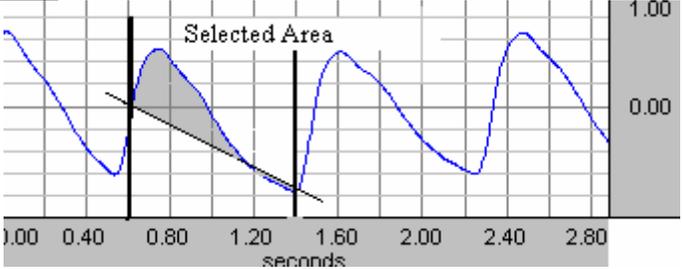
Exporting measurements

One of the most important reasons to take measurements is to save them; *AcqKnowledge* allows you to store and export 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; you can change the settings 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; you can change the settings to include the measurement name and other options via Display > Preferences under Windows or Display > Preferences > Journal under Mac OS X.

Measurement Definitions

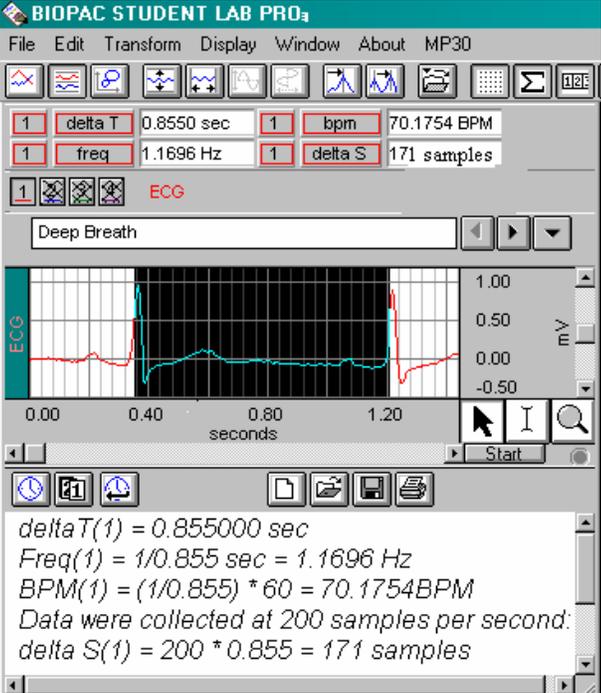
The table below explains the measurement options available and the range required for each. The default option is for time to be displayed on the horizontal axis, although it can be set to display frequency or arbitrary units (see page 301 for details on how to change the horizontal scaling options). Unless otherwise noted, all of the measurements described here relate to those displayed when the horizontal scale reflects time.

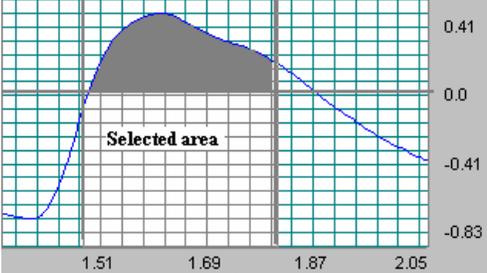
Measurement	Area	Explanation
Area	<p><u>Minimum area:</u> 3 samples</p> <p><u>Uses:</u> All points of selected area</p>	<p>Area computes the total area among the waveform and the straight line that is drawn between the endpoints. Area is expressed in terms of (amplitude units multiplied by horizontal units) and calculated using the formula:</p> $Area = \sum_{i=1}^{n-1} (f(x_i) - y(x_i) + f(x_{i+1}) - y(x_{i+1})) * \frac{\Delta x_i}{2}$ <p><u>Where:</u> <i>n</i>—number of samples; <i>i</i>—index (<i>i</i> = 1..<i>n</i>-1); <i>x_i</i>, <i>x_{i+1}</i> - values of two neighboring points at horizontal axis (<i>x₁</i> – the first point, <i>x_n</i> – the last point); <i>f(x_i)</i>, <i>f(x_{i+1})</i> - values of two neighboring points of a curve (vertical axis); <i>y(x_i)</i>, <i>y(x_{i+1})</i> - values of two neighboring points of a straight line (vertical axis). At the endpoints <i>y(x₁) = f(x₁)</i> and <i>y(x_n) = f(x_n)</i>. $\Delta x_i = \frac{\Delta X}{n - 1}$ - 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></p>  <p>The area of the shaded portion is the result.</p> <p><u>Note:</u> The Area measurement is similar to the <i>Integral</i> measurement except that a straight line is used (instead of zero) as the baseline for integration.</p>

Measurement	Area	Explanation
		<p>Area under any curve may be found as the sum of areas of several rectangles that may be found as:</p> $\frac{ f(x_1)-y(x_1) + f(x_2)-y(x_2) }{2} * (x_2-x_1)$ <p>Results: This calculation will always return a positive result. Units: Volts - sec. Sample data file: "ValidateMeasurements.ACQ" Result: 0.4533 Volts - sec.</p>
<p>BPM (Time domain only)</p>	<p>Minimum area: 2 samples</p> <p>Uses: Endpoints of selected area</p>	<p>BPM (<u>b</u>eats per <u>m</u>inute) 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:</p> $BPM = \left(\frac{1}{ x_n - x_1 } \right) * 60$ <p>Where: x_1, x_n - values of the horizontal axis at the endpoints of selected area.</p> <p>Note: As mentioned, this measurement provides essentially the same information as the <i>Delta T</i> and <i>Freq</i> measurement.</p> <p>Results: Only a positive value. Units: BPM.</p>
<p>Calculate</p>	<p>Minimum area: 2 sources</p> <p>Uses: Results of measurements used in calculation</p>	<p>Calculate can be used to perform a calculation using the other measurement results. For example, you can divide the mean pressure by the mean flow. When Calculate is selected, the channel selection box disappears.</p> <p><input type="text" value="2"/> <input type="text" value="median"/> <input type="text" value="-0.183716 m/v"/> <input type="text" value="calculate"/> <input type="text" value="Off"/></p> <p>The result box will read "Off" until a calculation is performed, and then it will display the result of the calculation. As you change the selected area, the calculation will update automatically.</p> <p>To perform a calculation, generate the "Waveform Arithmetic" dialog via PC: Ctrl-Click or right mouse click on the Calculate measurement type box Mac OS X: click "info" button next to measurement type box.</p> <p>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.</p> <p>Mac users: Calculation measurement Source operands are updated before</p>

Measurement	Area	Explanation								
		<p>a Calculation is performed, which means that Calculations can be based on measurements that are located after them in the measurement row/column ordering.</p> <p>Also, Calculation measurements can include other Calculation measurements as their operands.</p> <ul style="list-style-type: none"> ▪ If a cyclic dependency is introduced, the measurement 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). <p>PC users: You cannot perform a calculation using the result of another calculation, so calculated measurement channels are not available in the Source menu.</p> <p>The Operand pull-down menu includes: Addition, Subtraction, Multiplication, Division, Exponential.</p> <p>The Constant entry box is activated when you select "Source: K, constant" and it allows you to define the constant value to be used in the calculation.</p> <p>To add units to the calculation result, select the Units entry box and define the unit's abbreviation.</p> <p>Click OK to see the calculation result in the calculation measurement box.</p>								
Cap_Dim		<p>Capacity Dimension; fractal dimension estimate. (Fractals measure the amount of self-similarity in a data set. <i>AcqKnowledge</i> 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.)</p>								
Corr_Dim		<p>Correlation Dimension; fractal dimension estimate. Always greater than capacity if parameters are the same. (See fractals note at Cap_Dim.)</p>								
Correlate	<p><u>Minimum area:</u> 2 samples</p> <p><u>Uses:</u> All points of selected area</p>	<p>Correlate provides the <i>Pearson</i> 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). You can use Correlate to determine whether two ranges of data move together.</p> <table style="width: 100%; border: none;"> <tr> <td style="text-align: center;"><u>Association</u></td> <td style="text-align: center;"><u>Correlation</u></td> </tr> <tr> <td style="text-align: center;">Large values with large values</td> <td style="text-align: center;">Positive correlation</td> </tr> <tr> <td style="text-align: center;">Small values with large values</td> <td style="text-align: center;">Negative correlation</td> </tr> <tr> <td style="text-align: center;">Unrelated</td> <td style="text-align: center;">Correlation near zero</td> </tr> </table> <p>The formula for the correlation coefficient is:</p> $\text{Correlate} = \frac{n * \sum_{i=1}^n (x_i * f(x_i)) - \left(\sum_{i=1}^n x_i \right) * \left(\sum_{i=1}^n f(x_i) \right)}{\sqrt{\left[n * \sum_{i=1}^n (x_i)^2 - \left(\sum_{i=1}^n x_i \right)^2 \right] * \left[n * \sum_{i=1}^n (f(x_i))^2 - \left(\sum_{i=1}^n f(x_i) \right)^2 \right]}}$ <p><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).</p> <p><u>Results:</u> Returns a dimensionless index that ranges from -1.0 to 1.0 inclusive.</p> <p><u>Units:</u> None</p> <p><u>Sample data file:</u> "ValidateMeasurements.ACQ" Result: -0.74825(for whole wave) and 0.95917 (for first four sample points).</p>	<u>Association</u>	<u>Correlation</u>	Large values with large values	Positive correlation	Small values with large values	Negative correlation	Unrelated	Correlation near zero
<u>Association</u>	<u>Correlation</u>									
Large values with large values	Positive correlation									
Small values with large values	Negative correlation									
Unrelated	Correlation near zero									

Measurement	Area	Explanation								
Delta	<p><u>Minimum area:</u> 2 samples</p> <p><u>Uses:</u> Endpoints of selected area</p>	<p>Delta returns the difference between the amplitude values at the endpoints of the selected area.</p> $\text{Delta} = f(x_n) - f(x_1)$ <p><u>Where:</u> $f(x_1), f(x_n)$—values of a curve at the endpoints of selected area.</p> <p><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.</p> <p><u>Units:</u> Volts</p> <p><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.</p>								
Delta S	<p><u>Minimum area:</u> 1 sample</p> <p><u>Uses:</u> Endpoints of selected area</p>	<p>Delta S returns the difference in sample points between the end and beginning of the selected area.</p> <p><u>Results:</u> This calculation will always return a positive result.</p> <p><u>Units:</u> Samples</p>								
Delta T(time) Delta F (frequency) Delta X (arbitrary unit)	<p><u>Minimum area:</u> 2 samples</p> <p><u>Uses:</u> Endpoints of selected area</p>	<p>The Delta T/F/X measurement shows the relative distance in horizontal units between the endpoints of the selected area. <i>Only one of these three units</i> will be displayed in the pop-up menu at a given time, as determined by the horizontal scale settings.</p> <table border="0"> <tr> <td><u>Measurement</u></td> <td><u>Horizontal Axis</u></td> </tr> <tr> <td>Delta T</td> <td>Time</td> </tr> <tr> <td>Delta F</td> <td>Frequency (FFT)</td> </tr> <tr> <td>Delta X</td> <td>Arbitrary units (Histogram Bins)</td> </tr> </table> <p>The formula for Delta T/F/X is:</p> $\text{Delta T} = x_n - x_1$ <p><u>Where:</u> x_1, x_n - values of horizontal axis at the endpoints of selected area.</p> <p><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.</p> <p>For Delta T measurements with the horizontal axis format set to HH:MM:SS.</p> <ul style="list-style-type: none"> ✓ For values less than 60 seconds, you will get a value in decimal seconds. ✓ For values greater than 60 seconds, you will see an HH:MM:SS format value <p>(See page 137 for details on how to change the horizontal scaling).</p> <p><u>Units:</u> Delta T: Seconds (sec.) Delta X: "arbitrary unit" Delta F: Hz</p> <p><u>Sample data file:</u> "ValidateMeasurements.ACQ" Result: 0.12 sec. (for whole wave).</p>	<u>Measurement</u>	<u>Horizontal Axis</u>	Delta T	Time	Delta F	Frequency (FFT)	Delta X	Arbitrary units (Histogram Bins)
<u>Measurement</u>	<u>Horizontal Axis</u>									
Delta T	Time									
Delta F	Frequency (FFT)									
Delta X	Arbitrary units (Histogram Bins)									

Measurement	Area	Explanation
Evt_amp <i>Mac only</i>		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 175 for details. <ul style="list-style-type: none"> The amplitude is always taken from the measurement channel, which may be different from the channel on which events are defined. Evt_amp can be useful for extracting information such as the average T wave height within the selected interval.
Evt_count <i>Mac only</i>		Evaluates the number of events within the selected area. The measurement result is unitless. Specify Type and Location; see page 176 for details.
Evt_loc <i>Mac only</i>		Extracts information about the times of events. The measurement result uses the units of the horizontal axis. Specify Type, Location, and Extract; see page 176 for details.
Expression <i>Mac only</i>		Generates the Expression transformation dialog (page 77) 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.
Freq (time domain only) <div style="background-color: red; color: white; padding: 2px; display: inline-block;">It is important to note...</div> This does not compute the frequency spectra of the data. To perform a spectral analysis, use the FFT function (see page 257).	<u>Minimum area:</u> 2 samples <u>Uses:</u> 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: $\text{Freq} = \left(\frac{1}{ x_n - x_1 } \right)$ <p><u>Where:</u> x_1, x_n - values of horizontal axis at the endpoints of selected area.</p> The information provided by this measurement is directly related to the <i>Delta T</i> and <i>BPM</i> measurements, and is related to a lesser extent to <i>Delta S</i> measurement. That is, if the <i>Delta T</i> interval between two adjacent peaks is calculated, the <i>BPM</i> and <i>Freq</i> measurement can be extrapolated. If the sampling rate is known, the <i>Delta S</i> can also be derived. In the following example, you can see <i>Delta T</i> , <i>Freq</i> and <i>BPM</i> measurements for the particular area. The <i>Delta S</i> can also be derived.  <p style="text-align: center;"><i>Selected area with measurements that describe the same interval in different terms.</i></p> <p><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 257). <i>Freq (or frequency) is only available in time domain windows.</i></p>

Measurement	Area	Explanation
		<p><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).</p>
<p>Inf_Dim</p>		<p>Information Dimension; fractal dimension estimate. (See fractals note at Cap_Dim.)</p>
<p>Integral</p>	<p><u>Minimum area:</u> 2 samples</p> <p><u>Uses:</u> All points of selected area</p>	<p>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.</p> <p>Integral is expressed in terms of (amplitude units multiplied by horizontal units) and calculated using the following formula.</p> $\text{Integral} = \sum_{i=1}^{n-1} [f(x_i) + f(x_{i+1})] * \frac{\Delta x_i}{2}$ <p><u>Where:</u> <i>n</i>—number of samples; <i>i</i>—index (<i>i</i> = 1..<i>n</i>-1); <i>x_i</i>, <i>x_{i+1}</i> - values of two neighboring points at horizontal axis (<i>x₁</i>—the first point, <i>x_n</i>—the last point); <i>f(x_i)</i>, <i>f(x_{i+1})</i> - 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.</p> <p>The following plot graphically represents the Integral calculation.</p>  <p>The area of the shaded portion is the result.</p> <p><u>Results:</u> The Integral calculation can return a negative value if the selected area of the waveform extends below zero. <u>Units:</u> Volts—sec. <u>Sample data file:</u> "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).</p>
<p>Kurtosis</p>		<p>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</p> $\text{kurtosis} = \frac{\sum_{i=1}^n (x_i - \bar{x})^4}{\left(\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n} \right)^2}$ <p>Where from a signal (x) containing n points:</p>

Measurement	Area	Explanation
Lin_reg	<p><u>Minimum area:</u> 2 samples</p> <p><u>Uses:</u> All points of selected area</p>	<p>Linear regression is a better method to calculate the slope when you have noisy, erratic data.</p> <ul style="list-style-type: none"> For advanced modeling options, see Nonlinear modeling on page 253. <p>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:</p> $\text{Lin_reg} = \frac{n * \sum_{i=1}^n (x_i * f(x_i)) - \left(\sum_{i=1}^n x_i \right) * \left(\sum_{i=1}^n f(x_i) \right)}{n * \sum_{i=1}^n (x_i)^2 - \left(\sum_{i=1}^n x_i \right)^2}$ <p><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).</p> <p><u>Note:</u> For a single point, Lin_reg computes the linear regression of the line drawn between the two samples on either side of the cursor.</p> <p><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.</p> <p><u>Units:</u> Volts/sec. This value is normally expressed in unit change per second (time rather than samples points) since high sampling rates can artificially deflate the value of the slope. If the horizontal axis is set to display <i>Frequency</i> or <i>Arbitrary units</i>, the slope will be expressed as unit change in corresponding vertical axis values (frequency or arbitrary units, respectively).</p> <p><u>Sample data file:</u> “ValidateMeasurements.ACQ” Result: 230.00 Volts/sec. (for 1-4 samples) and –170.00 Volts/sec. (for samples 4-7).</p>
Lyapunov		<p>Lyapunov exponent describes the exponential rate of divergence of a system when perturbed from its initial conditions. For instance, 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.</p>
Max	<p><u>Minimum area:</u> 1 sample</p> <p><u>Uses:</u> All points of selected area</p>	<p>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—you can easily see the maximum peak values or paste the results to the journal. Also, since you can simultaneously obtain measurements for different channels, you can easily compare maximum values for different channels.</p> <p><u>Note:</u> For a single point, Max shows the amplitude value in this point.</p> <p><u>Units:</u> Volts</p>
Max T	<p><u>Minimum area:</u> 1 sample</p> <p><u>Uses:</u> All points of selected area</p>	<p>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.</p> <p><u>Note:</u> For a single point, Max T shows the time value in this point.</p> <p><u>Units:</u> Seconds</p>
Mean	<p><u>Minimum area:</u> 2 samples</p> <p><u>Uses:</u> All points of selected area</p>	<p>Mean computes the mean amplitude value of the data samples between the endpoints of the selected area, according to the formula:</p> $\text{Mean} = \frac{1}{n} * \sum_{i=1}^n f(x_i)$ <p><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</p>

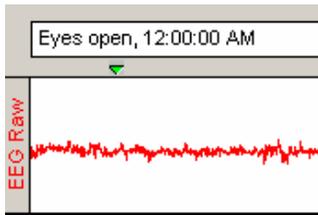
Measurement	Area	Explanation
		<p>point); $f(x_i)$- values of points of a curve (vertical axis). <u>Units:</u> Volts <u>Sample data file:</u> "ValidateMeasurements.ACQ" Result: 1.538462 Volts (for whole wave).</p>
Median	<p><u>Minimum area:</u> 2 samples</p> <p><u>Uses:</u> All points of selected area</p>	<p>Median shows the median value from the selected area. <u>Note:</u> The median and calculation is processor-intensive and can take a long time, so you should only select this measurement option when you are actually ready to calculate. Until then, set the measurement to "none." <u>Units:</u> Volts</p>
Median T	<p><u>Minimum area:</u> 2 samples</p> <p><u>Uses:</u> All points of selected area</p>	<p>Median T shows the time of the data point that represents the median value of the selected area. <u>Note:</u> The median and calculation is processor-intensive and can take a long time, so you should only select this measurement option when you are actually ready to calculate. Until then, set the measurement to "none." <u>Units:</u> Seconds.</p>
Min	<p><u>Minimum area:</u> 1 sample</p> <p><u>Uses:</u> All points of selected area</p>	<p>Min (minimum) shows the minimum amplitude value of the data samples between the endpoints of the selected area. <u>Note:</u> For a single point, Min shows the amplitude value in this point. <u>Units:</u> Volts.</p>
Min T	<p><u>Minimum area:</u> 1 sample</p> <p><u>Uses:</u> All points of selected area</p>	<p>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. <u>Note:</u> For a single point, Min T shows the time value in this point. <u>Units:</u> Seconds.</p>
Moment	<p><u>Uses:</u> All points of selected area</p>	<p>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:</p> $\mu_m = \frac{\sum_{i=1}^n (x_i - \bar{x})^m}{n}$ <p><u>Where:</u> x—signal; n—points; m—order.</p>
Mut_inf		<p>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.</p>
NLM <i>Mac only</i>		<p>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 253 for nonlinear modeling details.</p> <ul style="list-style-type: none"> ▪ 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 270), the NLM measurement can be useful for extracting cycle-by-cycle best fit models for an entire waveform.
None	n/a	<p>None does not produce a measurement value. It's useful if you are copying a measurement to the clipboard or journal with a window size such that several</p>

Measurement	Area	Explanation
		measurements are shown and you don't want them all copied.
P-P	<p><u>Minimum area:</u> 2 samples</p> <p><u>Uses:</u> All points of selected area</p>	<p>P-P (peak-to-peak) shows the difference between the maximum amplitude value and the minimum amplitude in the selected area.</p> <p><u>Results:</u> The result is always a positive value or zero.</p> <p><u>Units:</u> Volts</p> <p><u>Sample data file:</u> "ValidateMeasurements.ACQ" Result: 13 Volts (for whole wave).</p>
Samples	<p><u>Minimum area:</u> 1 sample</p> <p><u>Uses:</u> All points of selected area</p>	<p>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 149 for examples of selected area Samples.</p> <p><u>Note:</u> When an area is selected, the measurement will indicate the sample number at the last position of the cursor.</p> <p><u>Units:</u> Samples.</p>
Skew		<p>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.</p> <ul style="list-style-type: none"> • 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 <p>The following formula is used to extract skew:</p> $skew = \frac{\sum_{i=1}^n (x_i - \bar{x})^3}{\left(\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n} \right)^{3/2}}$ <p>Where a signal (x) contains n points:</p>
Slope	<p><u>Minimum area:</u> 2 samples</p> <p><u>Uses:</u> All points of selected area</p>	<p>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:</p> $\text{Slope} = \frac{f(x_n) - f(x_1)}{x_n - x_1}$ <p><u>Where:</u> $f(x_1), f(x_n)$—values of a curve at the endpoints of selected area. x_1, x_n - values of horizontal axis at the endpoints of selected area.</p> <p>This value is normally expressed in unit change per second (time rather than samples points) since high sampling rates can artificially deflate the value of the slope.</p> <p><u>Note:</u> Lin_reg (linear regression) is a better method to calculate the slope when you have noisy, erratic data.</p> <p>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.</p> <p><u>Results:</u> 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.</p> <p><u>Units:</u> Volts/sec. (or corresponding to Freq or Arbitrary setting)</p> <p><u>Sample data file:</u> "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).</p>
Stddev	<p><u>Minimum area:</u> 2 samples</p>	<p>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.</p>

Measurement	Area	Explanation												
	<p><u>Uses:</u> All points of selected area</p>	<p>The formula used to compute standard deviation is:</p> $\text{Stddev} = \sqrt{\frac{1}{n-1} * \sum_{i=1}^n \left(f(x_i) - \bar{f} \right)^2}$ <p><u>Where:</u> <i>n</i>—number of samples; <i>i</i>—index (<i>i</i> = 1..<i>n</i>); <i>x_i</i> — values of points at horizontal axis (<i>x₁</i> — the first point, <i>x_n</i> — the last point); <i>f(x_i)</i> - values of points of a curve (vertical axis);</p> $\bar{f} = \frac{1}{n} * \sum_{i=1}^n f(x_i)$ <p>- the mean amplitude value of the data samples between the endpoints of the selected area.</p> <p><u>Results:</u> The result is always a positive value or zero. <u>Units:</u> Volts <u>Sample data file:</u> "ValidateMeasurements.ACQ" Result: 3.09570 Volts (for samples 1-4), 1.000 Volts (for samples 10-12).</p>												
Time	<p><u>Minimum area:</u> 1 samples</p> <p><u>Uses:</u> All points of selected area</p>	<p>See the X-axis: T measurement for explanation.</p>												
Value	<p><u>Minimum area:</u> 1 sample</p> <p><u>Uses:</u> All points of selected area</p>	<p>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).</p> <p><u>Units:</u> Volts</p>												
X-axis:T/F/X (horizontal units)	<p><u>Minimum area:</u> 1 sample</p> <p><u>Uses:</u> All points of selected area</p>	<p>The X-axis measurement is the exact value of the selected waveform at the cursor position, based on the Horizontal Axis setting:</p> <table border="0"> <thead> <tr> <th><u>Measurement</u></th> <th><u>Horizontal Axis Setting</u></th> <th><u>Units</u></th> </tr> </thead> <tbody> <tr> <td>X-axis: T</td> <td>Time</td> <td>Sec.</td> </tr> <tr> <td>X-axis: F</td> <td>Frequency</td> <td>Hz.</td> </tr> <tr> <td>X-axis: X</td> <td>Arbitrary units</td> <td>Arb. units</td> </tr> </tbody> </table> <p>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 155.</p> <p><u>Note:</u> If a range of values is selected; the measurement will indicate the horizontal value at the last position of the cursor. <u>Results:</u> This calculation will always return a positive result.</p>	<u>Measurement</u>	<u>Horizontal Axis Setting</u>	<u>Units</u>	X-axis: T	Time	Sec.	X-axis: F	Frequency	Hz.	X-axis: X	Arbitrary units	Arb. units
<u>Measurement</u>	<u>Horizontal Axis Setting</u>	<u>Units</u>												
X-axis: T	Time	Sec.												
X-axis: F	Frequency	Hz.												
X-axis: X	Arbitrary units	Arb. units												

Markers on Windows/PC

- This section describes Marker functionality for AcqKnowledge 3.8.1 for Windows/PC only. See Events on page 164 for Mac OS X functionality.



In many instances it is useful to have the software “note” an occurrence or event during an acquisition so it can be referenced later. For instance, you may want to note when a treatment began or when an external event occurred so you can examine any possible reaction. The software places “markers” above the data to record events.

AcqKnowledge distinguishes between Append Markers and Event Markers, and allows you to pre-program and automate each. Markers appear at the top of the graph window, and can be edited, displayed, or hidden from view.

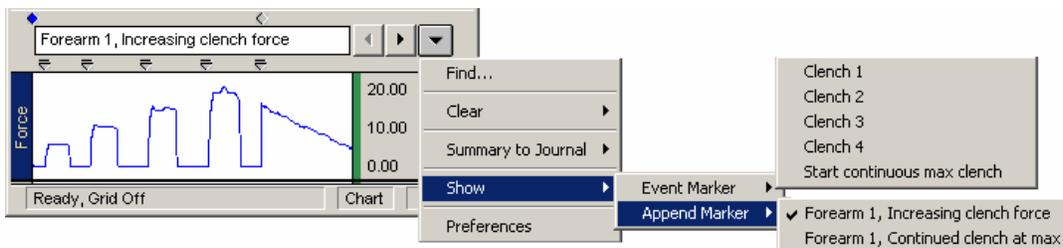
- “Append markers” are automatically inserted each time you record a segment in “Append” mode
- “Event markers” can be inserted during an acquisition or after recording (off-line)

You can automatically insert event markers during an acquisition by pressing the **F9** key on a PC. This will insert a marker at the exact time the key is pressed and will activate the text line entry so you can immediately enter a comment to be associated with the marker. Use Marker Preferences to change or add function key assignment(s).

To enter an event marker after recording, click the cursor in the area beneath the marker area. This will insert a marker. To add text describing the event, click the cursor in the marker box and key the desired text.

To view the text associated with a marker, position the selection tool over the marker and click the mouse button.

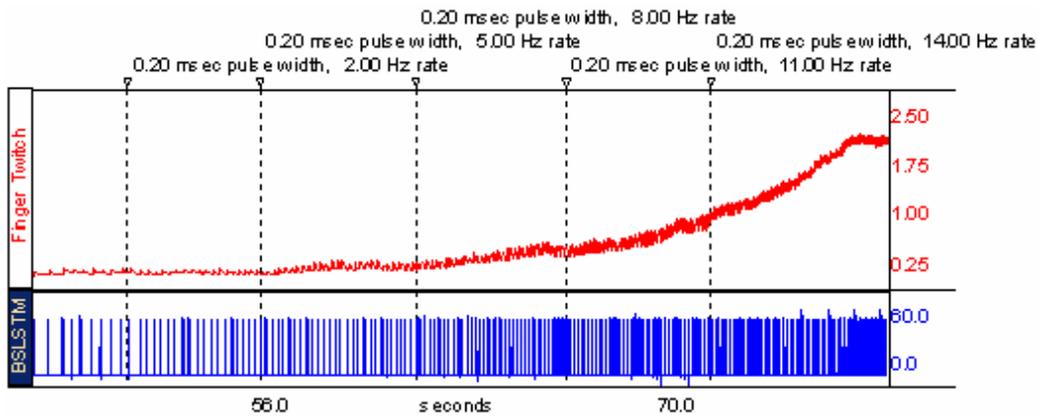
Marker Tools



- | | | | | | | | | | | |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-------------|--------|----------|--------|------------------------|----------|---------|--------------------------|
| Find | Activates a standard Find function and searches marker labels to locate matching text. | | | | | | | | | |
| Clear | Active Event Marker or All Event Markers. <ul style="list-style-type: none"> ○ It is not possible to clear Append markers from the marker pull-down menu. | | | | | | | | | |
| Summary | All Markers, Event Markers, or Append Markers. Will paste marker information to the Journal, with order, header and label as set on the Preferences > Journal Summary tab. <p>Markers Summary:
Event Markers:</p> <table border="0"> <tr> <td>Marker Index:</td> <td>Time(sec.):</td> <td>Label:</td> </tr> <tr> <td>Event 1:</td> <td>3.1470</td> <td>Eyes open, 12:00:00 AM</td> </tr> <tr> <td>Event 2:</td> <td>24.8080</td> <td>Eyes closed, 12:00:00 AM</td> </tr> </table> | Marker Index: | Time(sec.): | Label: | Event 1: | 3.1470 | Eyes open, 12:00:00 AM | Event 2: | 24.8080 | Eyes closed, 12:00:00 AM |
| Marker Index: | Time(sec.): | Label: | | | | | | | | |
| Event 1: | 3.1470 | Eyes open, 12:00:00 AM | | | | | | | | |
| Event 2: | 24.8080 | Eyes closed, 12:00:00 AM | | | | | | | | |
| Show | Event Marker or Append Marker. The list of markers is shown in the sub-menu. The menu can support 239 markers. | | | | | | | | | |
| Preferences | Use to pre-establish marker labels and set function keys for different labels, or format marker information for pasting to the Journal. See page 162 for details. | | | | | | | | | |

Printing markers

The markers will be printed when the marker display is enabled. To keep the markers from being printed, hide the markers before printing. If the display is compressed, marker labels and/or indicators will be layered when printed to prevent overlapped text.



Marker Preferences



Marker Preferences has three tabs of options to auto-label markers, and one to format marker data summarized to the Journal

Selecting the Display > Preferences > Markers or “preferences form the Marker tools will generate the Marker Preferences dialog. There are four tab options in the Marker Preferences dialog: Append Markers, Events Markers (Fixed), Event Markers (Sequential), and Journal Summary.

The software generates three types of markers:

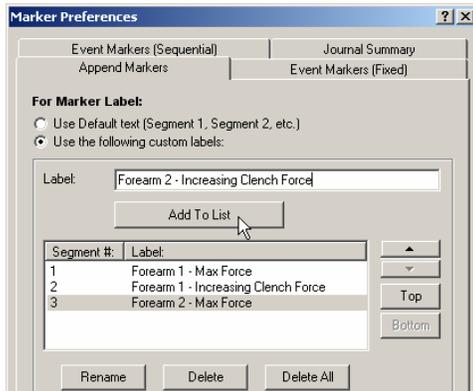
1. Append Markers appear as triangles located above the marker label region and will be automatically inserted at the start of each recording segment in the Append acquisition mode. Append markers are blue when active.
2. Automatic Event Markers appear as green inverted triangles located below the marker label region and use labels that are generated automatically when the assigned function key is pressed. Event markers are yellow when active.
 - o You can pre-establish Automatic Event marker labels as sequential or fixed.
3. Manual Event Markers appear as inverted triangles with a line above them and are located below the marker label region (in the same region as the Automatic Event Markers). Event markers are yellow when active.

System Time Stamp

Tabs include the option to Automatically add a system time stamp to Append Marker labels and Event Marker labels generated during an acquisition.

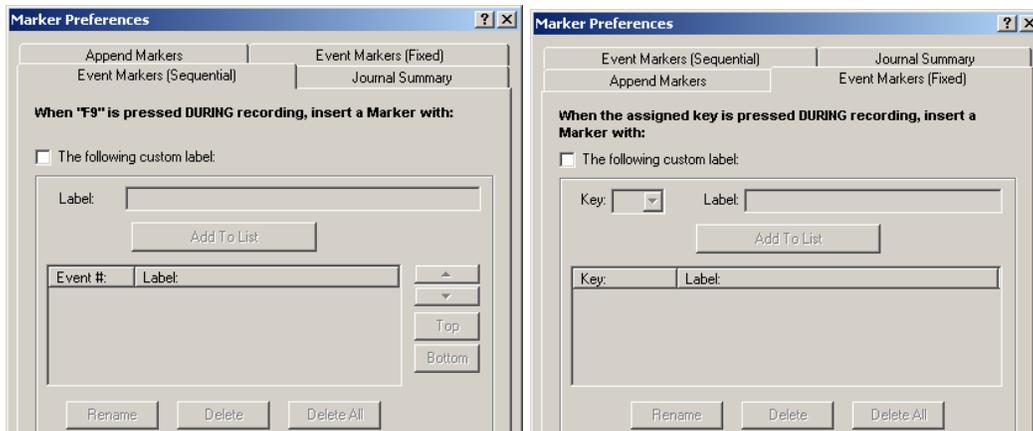
Pre-establish Labels

Append Markers - Automatically generate the Append Marker labels as Segment 1, Segment 2, etc., or generate labels from a pre-established list that will be applied sequentially each time the recording continues.



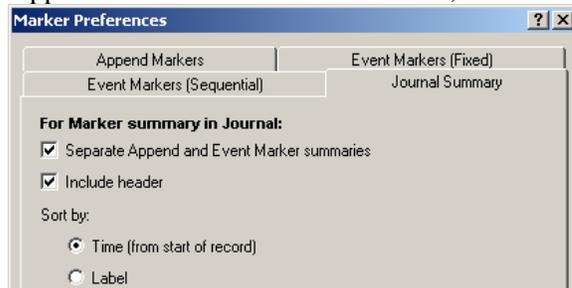
Automatic Event Marker Labels - Generate Sequential or Fixed labels.

- *Sequential* - generate labels from a pre-established that will be applied sequentially each time the F9 key is pressed during a recording.
- *Fixed* - generate labels based on pre-established function key assignment that will be applied according to the function key pressed (different function keys have different labels).



Journal Summary

You control how the marker summary is presented in the Journal. Choose to separate or combine Append and Event marker summaries, show or hide the header information, and sort by time or label.



For Journal details, see page 48; for Journal Preferences, see page 312.

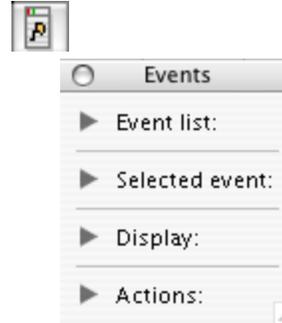
Events (Markers) on Mac OS X



Event Toolbar



Event Insertion



Event Control

Event (Marker) Overview

- This section describes Event (Marker) functionality for AcqKnowledge 3.9 for Macintosh. See Markers on page 161 for Windows/PC functionality.

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 classification from a PhysioBank file, or even detailed user notes. AcqKnowledge 3.9 for Macintosh 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, AcqKnowledge can use the event information for analysis, including measurement (page 178) and cycle detection (page 270).

- 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.
- 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 Hotkeys (see page 166) 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 166)
 - Cycle Detector Output Events option (see page 270)
 - Contextual menu in Event region
 - Specialized Analysis (see page 333) to automatically insert markers according to complex analysis algorithms

Event Toolbar



The event toolbar displays global events and provides a quick editing area for event descriptions. The right button toggles visibility of the Event Palette for detailed control (see page 168). 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.

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 marker bar at the top of the screen, if X/Y mode is in use, or if events are not currently visible.

Event Preferences



Display > Preferences

Use the “Event summary options” section of the Preferences dialog to set options for pasting summaries of events into the journal

- List events
 - Sequential listed in order of increasing time
 - 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).
- 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 171).

Mark...with events

Selection events and time stamp events can be automatically inserted when Paste Measurements to Journal and/or Paste Wave Data to Journal are activated using the Journal Preference settings.

Choose “Mark selection with events in graph” from the “Other options” box to create events at data selection bounds. This will include selection events (selection begin and selection end) for global events when measurements or waveform data are pasted. When selected, measurement pasting will result in an automatic execution of the “Mark Selection” feature manually accessible from the Event Palette.

- “Include timestamp” will 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.
- “Include Time values” will include the time value (relative to start = 0) for the paste.

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.

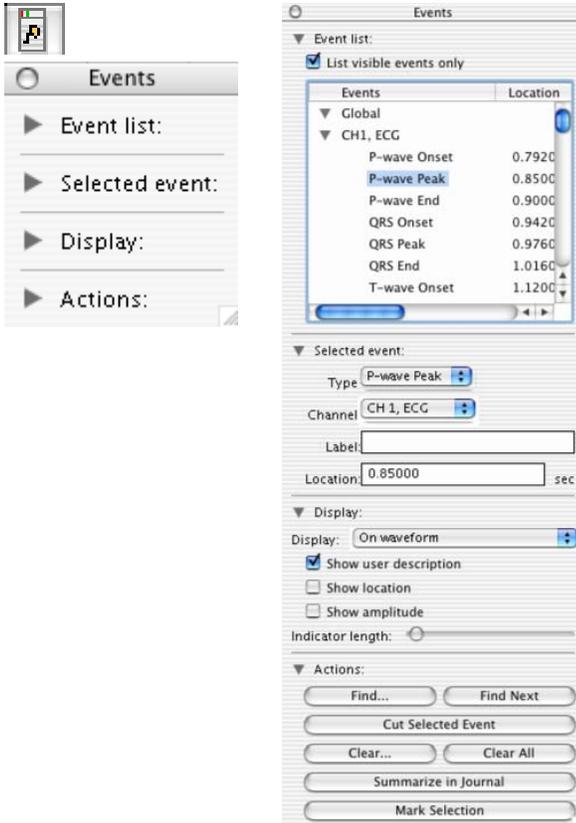
Both paste event setting options are off by default. Any change to these settings will be retained within a saved graph file and will become the default for newly constructed graphs.

Event Hotkey Setup

Events of different types can be inserted during acquisition, whether or not 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 “MP1#0 > Set up Event Hotkeys...” 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.
Event type	Lists the standard hierarchical menu of available event types; Types are detailed on page 172. 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. <ul style="list-style-type: none"> ▪ “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.”

Event Palette

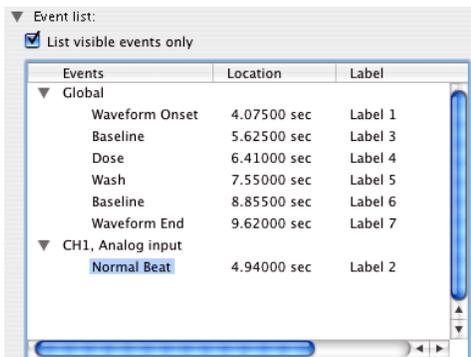


The event palette is a floating window that provides a quick summary of events for the top most graph and can be used to examine, search, and modify events. Events can be extracted in a time range for a specific event type and specific channels.

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 168.
- Selected event, see page 168.
- Display, see page 169.
- Actions, see page 171.
 - 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 numerical sample location of each event.

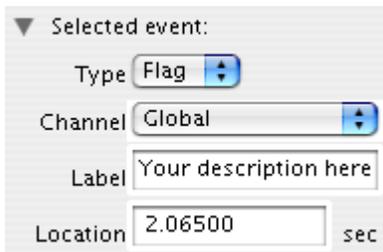
Select a single event from the event list by clicking on a single event. The event will be selected in the graph window and made visible if it is not currently displayed.

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

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Event type options are detailed on page 172.

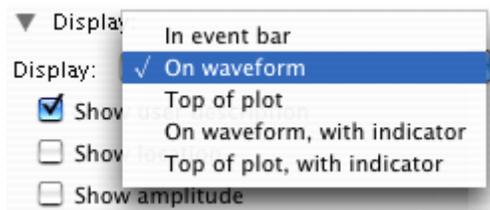
When a single event is selected, the type, channel (or “General” for global events), user-defined label, and location of the event will be filled in and can be edited. The controls can display information about only one event at a time; if no event is selected, the controls will be grayed out.

Event Location

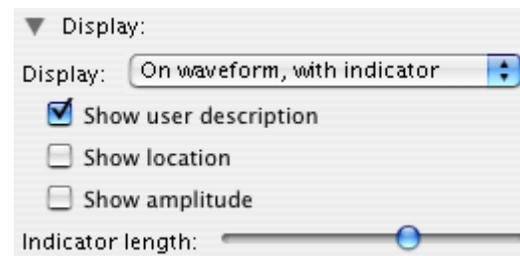
“Location defines the position where the selected event occurs, relative to the first sample in the file. To change the location of an event, change the position entered in the Location box. Precision matches the horizontal axis setting.

Events may also be repositioned using the mouse. Option-click the event icon in the graph and hold down the mouse while dragging; the event will be repositioned at the horizontal position where the mouse button is released.

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 170).
- Detail—the three checkboxes to establish how much information to include with events.
- Indicator—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.”

Location & Display

In event bar

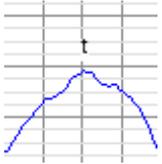


Description

Event icons are displayed in the global marker 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 marker 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.

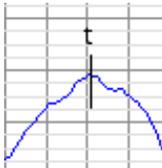
Top of plot



Event icons are displayed at the top of the channel track, either on top of the grid or in a channel-specific marker bar.

- To select the event, click the icon at the top of the channel track.

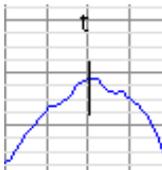
On waveform, with indicators



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



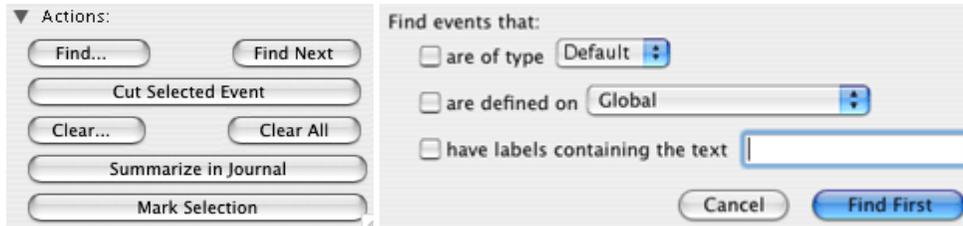
Event icons are displayed at the top of the channel track with a vertical line of configurable length running through the data sample of the source channel at the event's location.

- 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 than one can easily scroll through and locate in a list. Find controls the automatic location of events based on established search criteria.

Click on 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*

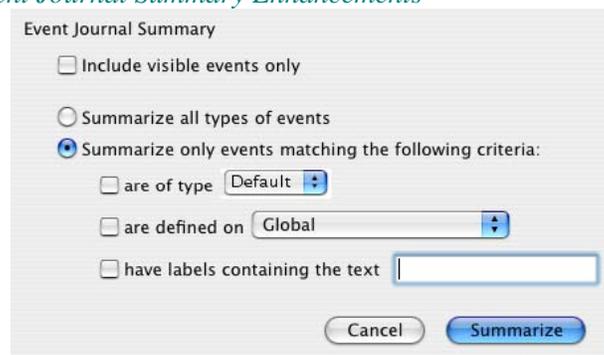
Generates a search criteria dialog (identical to the Find dialog) and removes all matching events from the graph.

Summarize in Journal

Displays a sheet 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 166 for more information about modifications to the traditional marker summary.

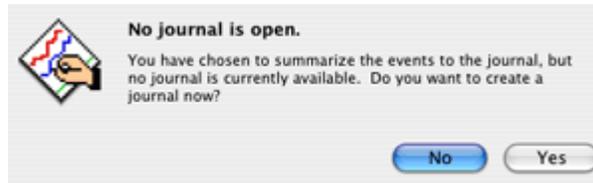
Event Journal Summary Enhancements

Mac only—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.

When “Summarize in Journal” is clicked on the event palette, a sheet will be displayed with controls that affect which events are included in the summary.

If there is no journal for the current graph, you will be prompted to create a

journal.



Mark Selection

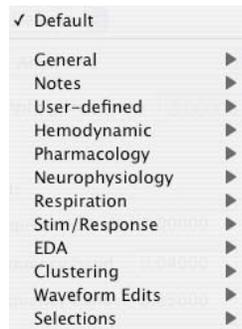
Defines two new Global events in the graph at the precise time locations of the currently selected area (the highlighted wave data section). If there is no selection in the graph, this button has no effect. The events that are inserted will have the “Selection Begin” and “Selection End” event types.

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 333).

Once Event Types are defined, some analysis functions can be automated, including measurement (page 178) and cycle detection (page 270).

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” subclass with pre-ventricular contraction and escape beat event types.

Event type

Classification

Global

This is the same as ‘untyped’ markers from AcqKnowledge 3.6 or earlier. Unrecognized event types will be classified as global events.

Append

Automatically inserted by the program on append operations.

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 Recovery	Maximum and minimum Reset Append
Hemodynamic > Beats	Normal Paced Fusion of paced and normal Unclassifiable Left bundle branch block Right bundle branch block Bundle branch block Atrial premature Aberrated atrial premature	Nodal premature Supraventricular premature Premature ventricular contraction R-on-T premature ventricular contraction Fusion of ventricular and normal Atrial escape Nodal escape Supraventricular escape Ventricular escape
Hemodynamic > Blood Pressure	Systole Diastole	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
User-defined	User Type 1-9	
Waveform Edits	Cut Paste begin	Paste end
Selections	Selection begin	Selection end

Event Measurements

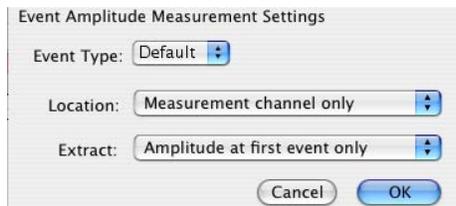
Measurements are a quick way to extract information from a graph. Three measurements extract information from events. When combined with the Cycle/Peak Detector (page 270), they are also powerful data reduction tools. These event measurements can provide quick summaries of event information, compute mean intervals between event types, and detail other operations.

- `evt_ampl` Event Amplitude Measurement (see below)

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- `evt_count` Event Count Measurement (see page 176)
- `evt_loc` Event Location Measurement (see page 176)

Event Amplitude Measurement



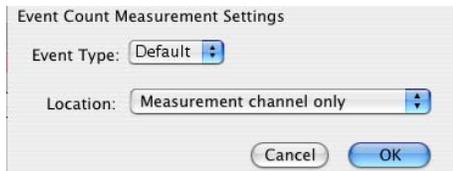
`evt_amp` Extracts measurement results where events are defined. Note that the amplitude is always taken from the measurement channel, which may be different from the channel on which the events are defined. Useful for extracting information such as the average T wave height within the selected interval. 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 172. |
| Location | <p>Determines where the processed events need to be defined. The menu options are:</p> <ul style="list-style-type: none"> ▪ 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 <i>not</i> included. ▪ Global events only—Only extracts amplitude values for events that are defined as global events appearing in the marker bar; changing the measurement channel will not affect the measurement result. Channel events are <i>not</i> 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 | <p>Determines what processing will be performed on the amplitude values extracted from events that match the Type and Location settings. The processing options are:</p> <ul style="list-style-type: none"> ▪ 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. ▪ <i>Mac AcqKnowledge 3.9.2 and later</i>—Minimum amplitude from all events ▪ <i>Mac AcqKnowledge 3.9.2 and later</i>—Maximum amplitude from 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 172.

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 marker 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 172.

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 marker 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, corresponding to the marker printing position of AcqKnowledge 3.7 and earlier versions.
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 <i>or</i> 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 <i>below</i> the event icon
On waveform <i>or</i> 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 <i>above</i> 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.

Event Selection

Individual events can be selected according to click locations.

When an event is selected, the event icon will be drawn based on the graphic type:

- Specific "selected" graphic—the selected graphic is drawn or if none, an inverted global graphic.
- No associated graphics—the global event graphic will be used.

Events and Graph Selections

When an event on a waveform plot occurs within a selected area of the graph, the event icon and indicator line (if present) will be inverted along with the grid, background, and wavedata. Event types that don't have a selected graphic will appear as global events if the events are selected events and they are contained in an I-beam selection.

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, any channel 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). Holding down the Command/Open-Apple key while double-clicking an event icon in the graph window will place a cursor at the event location; this is a zero-width selection, equivalent to single-clicking with the I-beam tool without dragging.

- To create a graph selection from events, hold down the Command key and select an event by clicking on the event icon in the graph window or its entry in the event list.
- To align the boundaries of the graph selection with the time of the previously selected event location and the time of the newly selected event, hold the Command key when selecting the new event.
- To make a graph selection match the time between two events, click once to select the first event, hold down the Command key, click again to select the second event. On this second click, the selected area of the graph will change to align with 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 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 will be 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 will be calculated for the hardware sample location. The interpolated value will be derived from the closest waveform sample to the left and to the right. The vertical position on the waveform of the marker 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*.

Grids on the PC

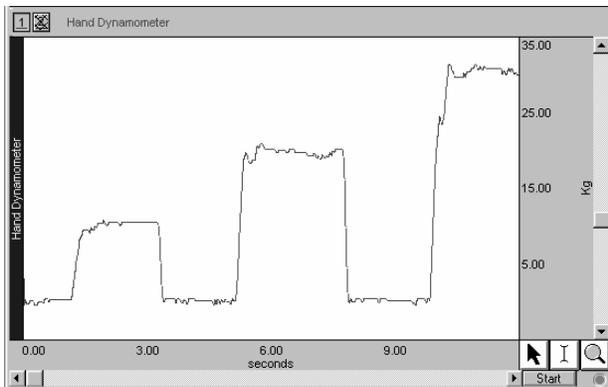
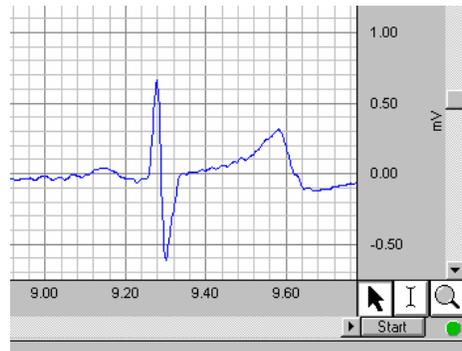
Grid functionality varies between PC and Macintosh. See page 183 for Grids on the Macintosh.

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.

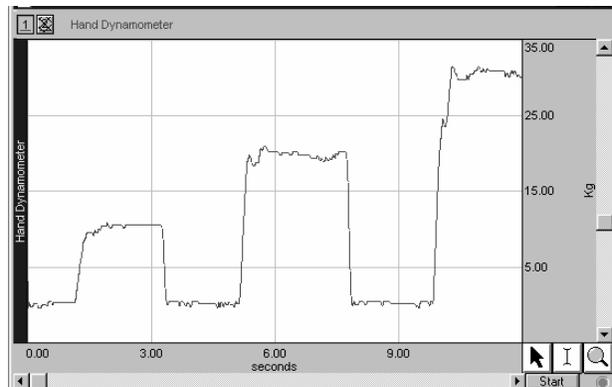
To activate a grid display, click on the  icon in the toolbar or select Display > Show > Grids.

To include minor grid lines in the display, use Ctrl- or select Display > Show > Grid Options and check the “Show minor grid” box.

The horizontal scale grid is always four vertical lines, whether the horizontal scale is set to represent time, frequency or an arbitrary amplitude value.

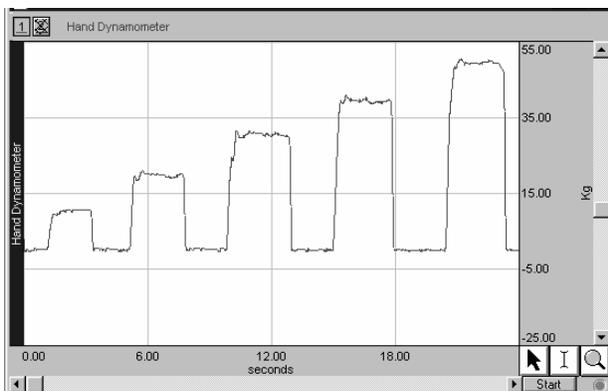


Grid Display Off

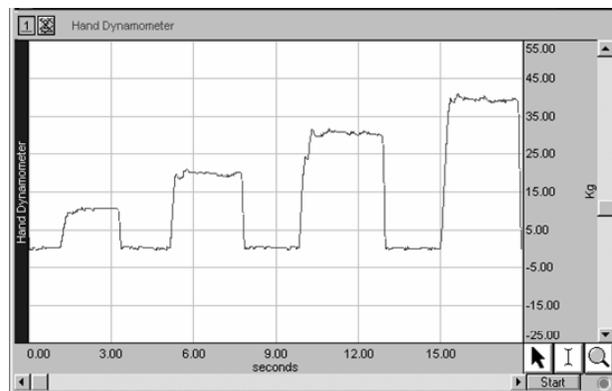


Grid Display On (unlocked)

The grid can be **locked** (analysis, printing) or **unlocked** (visual aid), as checked in the Grid Options dialog (Display > Show > Grid Options).



Unlocked Grid with Scale increased 2x



Locked Grid with Scale increased 2x

You are encouraged to experiment with grid settings to familiarize yourself with the effect each option has on the data display.

Unlocked Grids

Unlocked grids are more of a visual aid than an analysis tool.

Set the lock status in the “Grid Options” dialog (Display > Show > Grid Options).

Unlocked grids help you view the data display on the monitor. The unlocked grid setting displays four grid divisions across the horizontal and vertical axes, and will generate interval numbers as needed to match the zoom factor.

- Horizontal grid: The grid always cuts the horizontal scale into four segments (using four vertical grid lines), regardless of the lower scale (axis) setting, which can be set to represent time, frequency, or an arbitrary amplitude value.
- Vertical grid: In Chart mode, the unlocked grid cuts the vertical scale of *each track* into four sections (using four horizontal grid lines *per waveform channel*). In Scope mode or X/Y mode, the unlocked grid cuts the vertical scale into four sections (four horizontal grid lines across the *graph*).

Beware! Although the unlocked grid will be retained if the waveform is printed, saved as a graphic image (WMF or PICT) or copied to the clipboard, the nature of the grid changes. When a graph is printed, saved, or pasted, AcqKnowledge will dynamically adjust the number of vertical divisions. In effect, this will “round” the vertical scale value so that anywhere from two to nine lines are displayed. Although the number of divisions changes, the process does not affect the nature of the data, only the scale used to plot it.

Locked Grids

Locked grids help more with analysis and printing.

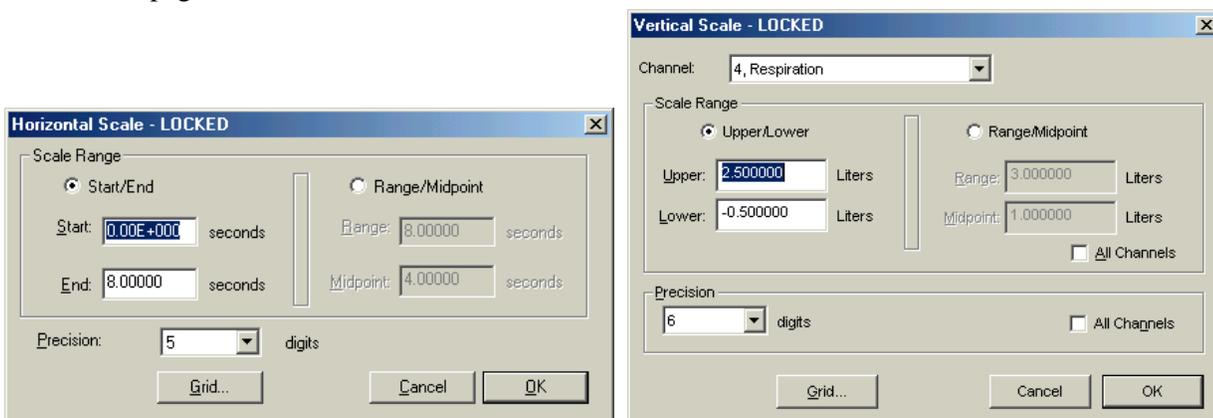


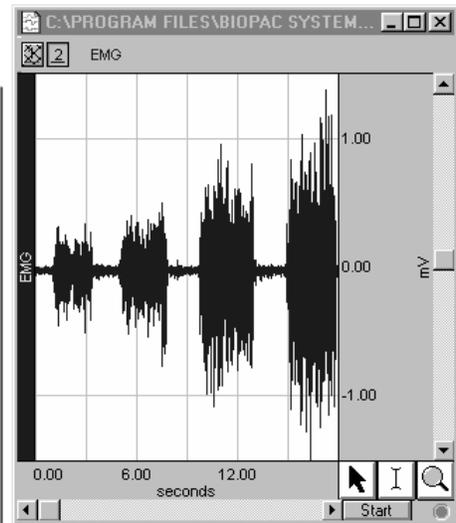
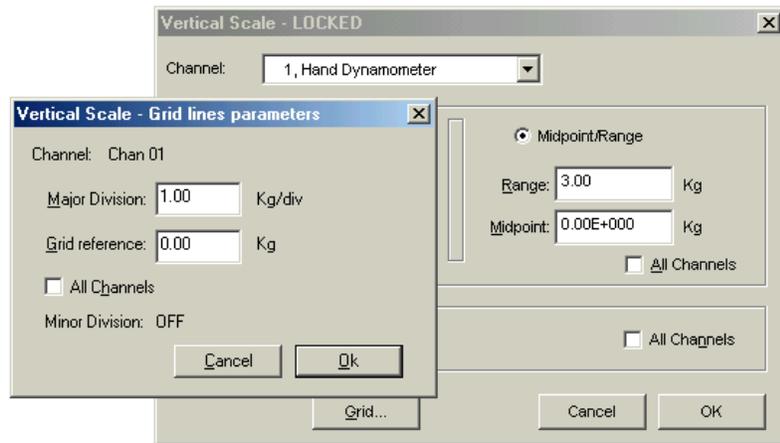
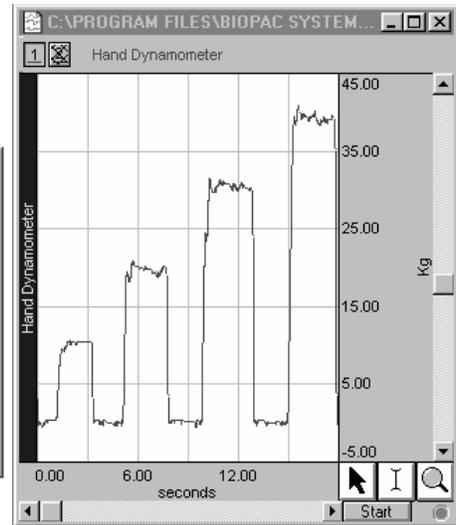
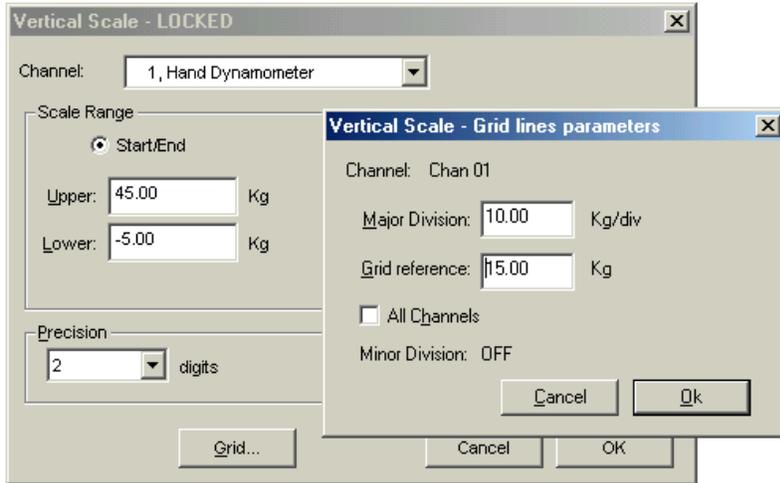
Macintosh displays a lock state icon on horizontal and vertical scales.

Set the lock status in the “Grid Options” dialog (Display > Show > Grid Options).

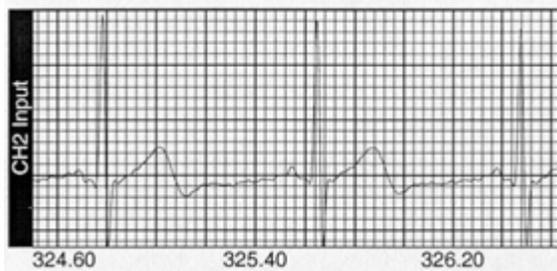
The locked grid setting locks the grid to the data for all functions. It’s easy to set the grid interval using locked grids. Interval parameters (start/end or middle point/range) for the horizontal and vertical scales are determined in the Scale dialogs.

- The Scale dialogs change when grid lines are locked. See page 137 for details on Horizontal Scale and page 139 for details on Vertical Scale.



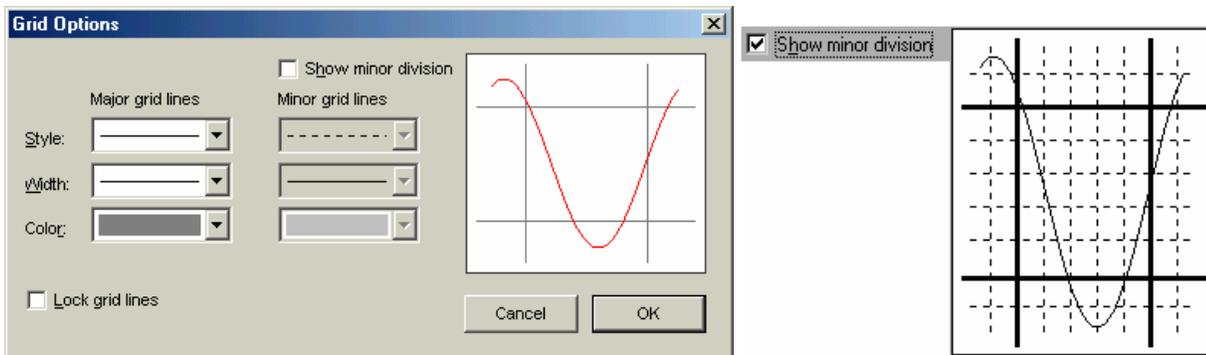


Using the Scale and Print Options on a locked grid, you can very closely match chart recorder output:



Note: Standard clinical grids use major grid divisions of .5 mV vertically and .2 sec. horizontally.

Grid Options on the PC



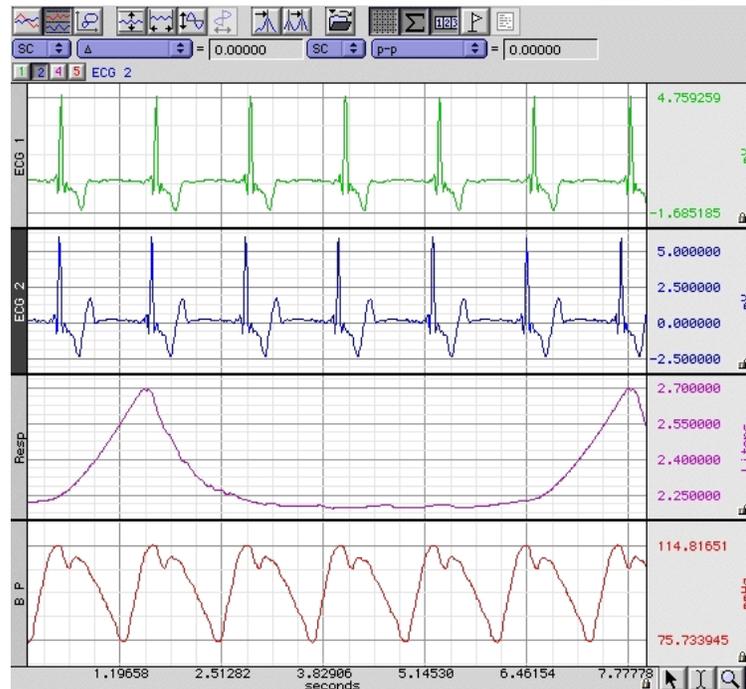
To control the style and functionality of the grid display, select Display > Show > Grid Options. The Grid Options control grid format (line type, style, width and color), grid lock, and grid adjustment.

- Major grid lines** Use the pull-down menus to set the major grid line style, width and color. A sample of the grid line settings is generated within the dialog.
- Minor grid lines** Check whether or not to “Show minor division” grid lines, and set the minor grid line style, width and color. A sample of the grid line settings is generated within the dialog.
- Lock grid lines** Check this option to lock the grid to the data for all functions. Locking grid lines can be useful for analysis and printing.
- See page 180 for details on locked grids.
 - The Scale dialogs change when grid lines are locked. See page 137 for details on Horizontal Scale and page 139 for details on Vertical Scale.

Grid functionality varies between PC and Macintosh. See page 179 for Grids on the PC.

Grids on the Macintosh

You can 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.

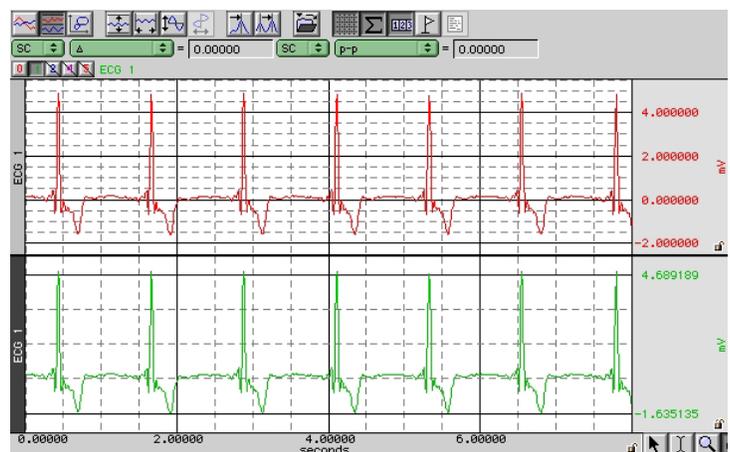
Grids can be locked and unlocked on individual channels.

- 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.

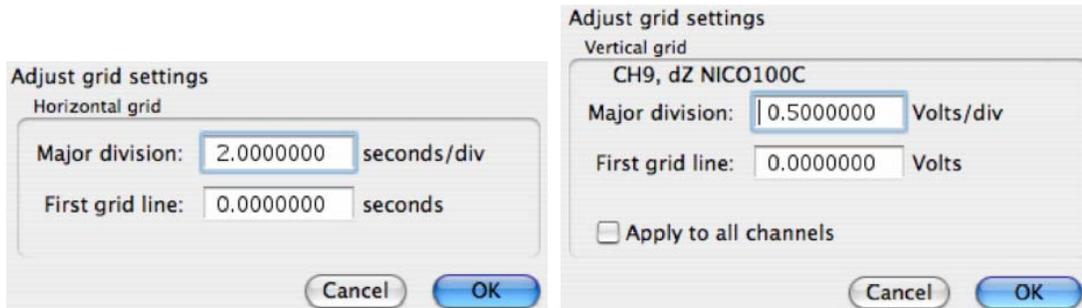
Lock units/div



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...** button in the axis setup dialogs is activated when the grid is locked. Click it to generate a dialog that allows you to specify the scaling factors and whether or not to “Show minor divisions” on that grid display. Changing these values only affects the grid display, not how the waveform is scaled.

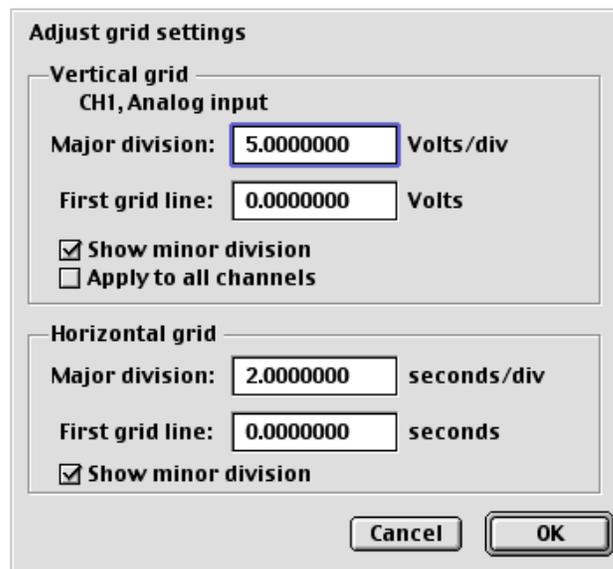


- Horizontally: the scaling factors are specified in how many seconds of data should be visible on the screen (Major division) and the time offset of the left hand side of the display (First grid line).
- Vertically: the total range of vertical units displayed per track is specified (Major division) along with the first value that should be displayed (First grid line).

Adjust Grid Spacing

To modify the horizontal and/or vertical grid spacing, choose “Display > Adjust grid spacing.” This will generate a dialog for you to modify the locked axes of the selected waveform.

- This menu item functions identically to holding down the “Option” key and clicking the selected waveform when the grid tool is active.



Grid Tool

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

	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 “Option” key 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 you to adjust 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.

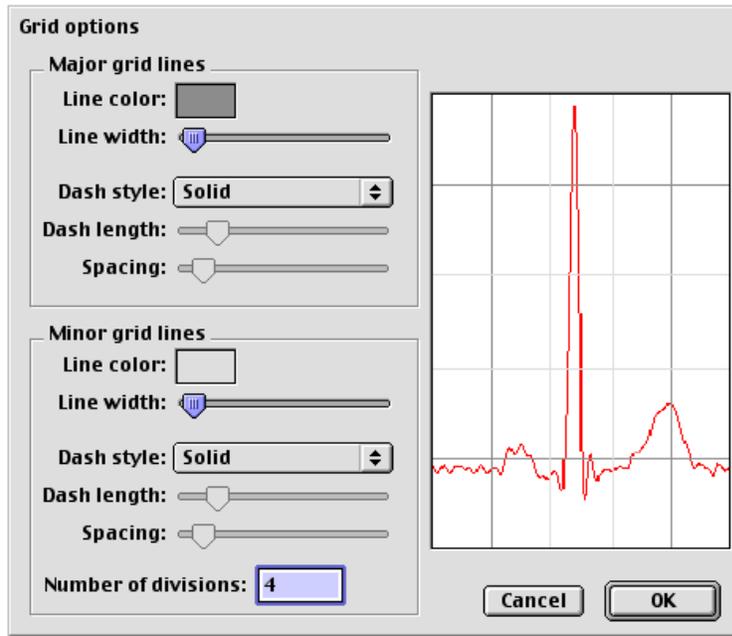
Grid Reset

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.

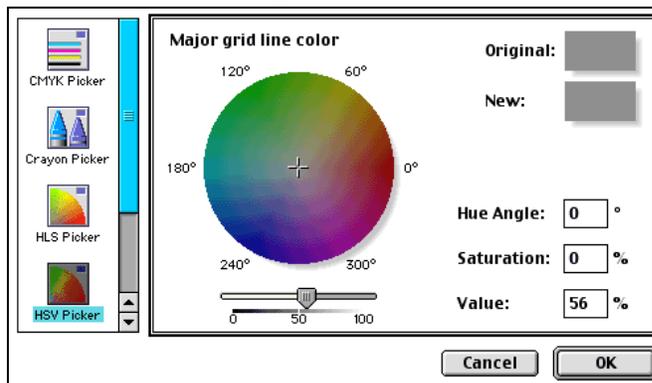
Grid Options

The major and minor grid lines can be further customized with 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).

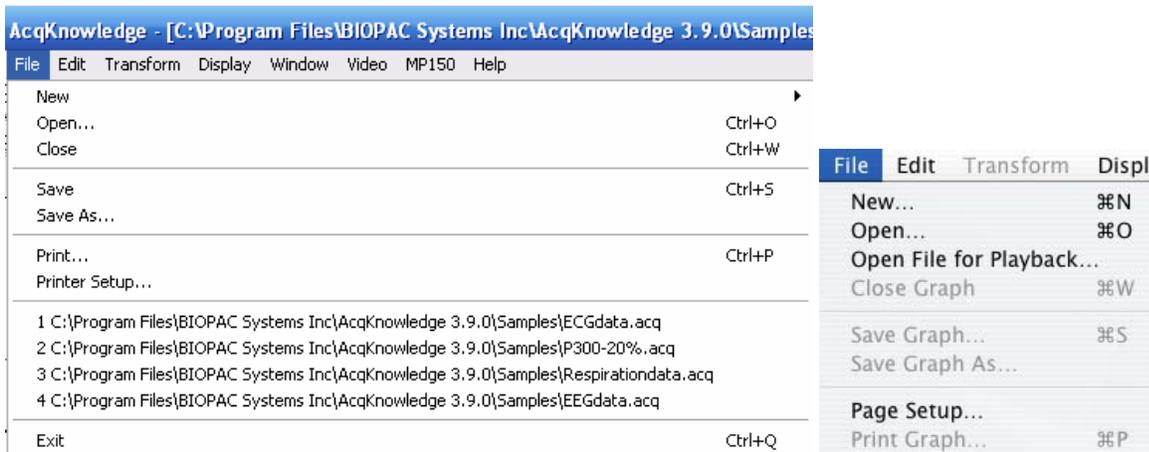
of Divisions

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.

To undo your 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.

Chapter 10 File menu commands

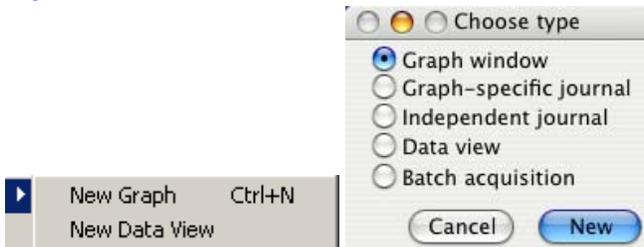
Overview



Most of the items in the File menu are standard menu items and follow the standard Windows conventions (for MPWSW) or Macintosh conventions (for MPWS). By default, all files are created and saved in the *AcqKnowledge* file format, a proprietary format used to store binary data. Data can be read in from either text files or *AcqKnowledge* files, and can be saved in text, graphic, or binary format. As a rule, storing data in the *AcqKnowledge* format saves information in the most compact format possible and takes up less disk space than other file formats. In most cases, you will probably be working with graph windows and saving data in the *AcqKnowledge* format.

AcqKnowledge also supports an online journal that can be used to store waveform data (in numeric format) or to make notations and comments in a text file.

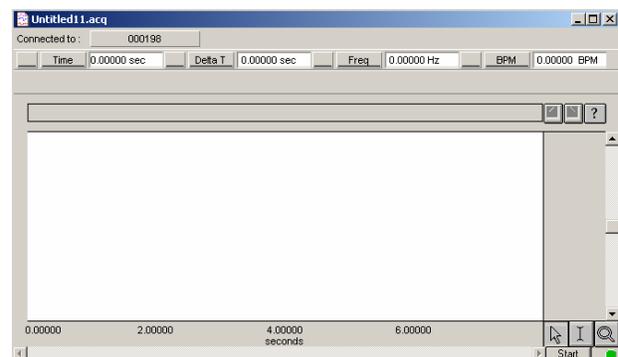
New



New Graph

In almost all cases, you will need to create a new graph window before beginning an acquisition so that the data may be displayed on the screen. To create a new file, choose New from the File menu. When a new graph window is created you should see the following:

You can modify any of the window parameters, including horizontal scale, vertical scale, window size and position. In addition, you can also set the acquisition parameters for sampling rate, number of channels, and acquisition length. These settings take effect once an acquisition begins.



New > 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 35.

New > Graph-specific Journal

Mac OS X only—Creates a graph-specific journal; see page 48 for details.

New > Independent Journal

Mac OS X only—Creates an independent journal; see page 48 for details.

New > Batch Acquisition

Mac OS X only—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 allow you to add, remove, or re-order the templates.

- Double click on 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.”
- Advanced Averaging cannot be used in a Batch.

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

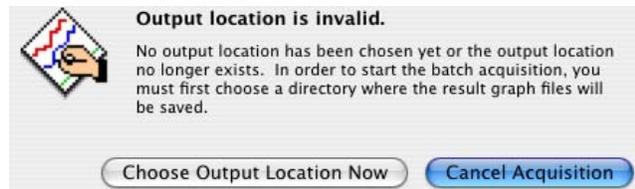
Misconfigured templates and misconfigured averaging templates may generate the Adjust Length/Adjust Latency/Abort Acq warning prior to the start of acquisition. Clicking “Abort” will halt the batch acquisition. Misconfigured templates may result in those rare cases where data was acquired into a graph 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.

Start/Stop Acquisitions

This menu lists all of the available hardware units. Entire menu dimmed out while batch acquisitions are in progress.



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—Mac AcqKnowledge 3.9.2 and later

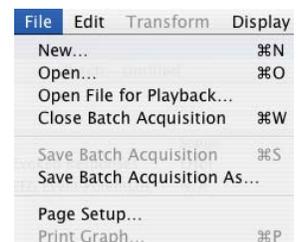
When a batch acquisition is terminated prematurely, the acquisition may be restarted from the first template in the sequence or from where it was stopped (e.g. the template with the error status).

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.”

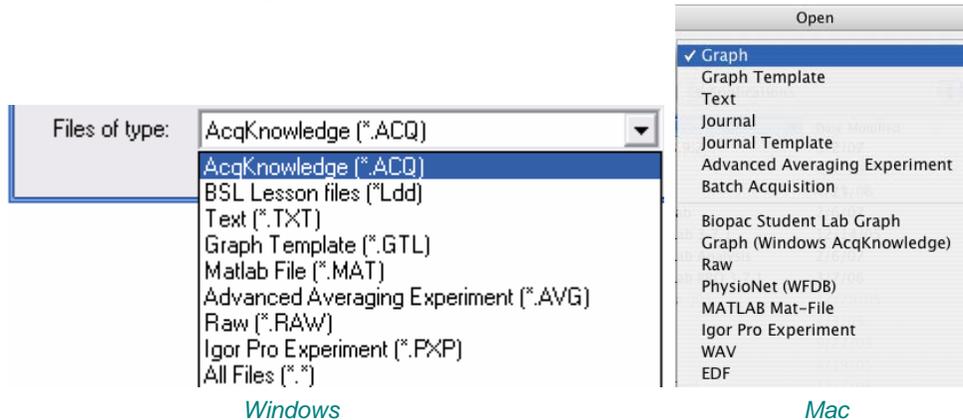
When a batch acquisition is started, the templates will be executed in the order indicated in the batch to acquire data from the specified MP unit. Files are autosaved before the next acquisition is started.

- 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 allows you to open a variety of different file formats from the popup menu at the bottom of the dialog box.



Multiple files

To open multiple files in a single dialog on a Mac, hold the Shift key down and select multiple files. The Command-A key combination will “Select All” files in the dialog. *AcqKnowledge* 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.

ACQ *AcqKnowledge* files

Graph The default file formats (Graph and .ACQ) are referred to as “*AcqKnowledge*” files.

Graph (Windows) The *AcqKnowledge* file format is the standard way of displaying waveforms in *AcqKnowledge*. 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). *AcqKnowledge* files are editable and can be modified and saved, or exported to other formats using the Save as command.

File Compatibility

Windows *AcqKnowledge* cannot open Macintosh *AcqKnowledge* 3.9 files.

Macintosh *AcqKnowledge* 3.9 can open Windows *AcqKnowledge* files.

- Macintosh *AcqKnowledge* 3.9 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.

BSL Import This file format is from files created using the Biopac Student Lab software.

Windows “BSL Lesson Files (*.Ldd)”

Mac “Biopac Student Lab Graph”

BSL File Import Notes

BIOPAC produces two different software lines, the *AcqKnowledge* 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.

AcqKnowledge can directly import data files that were created in Biopac Student Lab Lessons or BSL *PRO*. This allows data acquired with an MP30 or MP35 with BSL to be analyzed using the advanced analysis routines of *AcqKnowledge*.

Hardware and calculation channel settings are also imported. This allows for the

migration of some BSL *PRO* templates to *AcqKnowledge*. 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 *AcqKnowledge*.



When saving files, *AcqKnowledge* must save using the *AcqKnowledge* graph file format or another available export format. It is not possible to open *AcqKnowledge* graph files with BSL Lessons or BSL *PRO*.

Batch *Mac only*

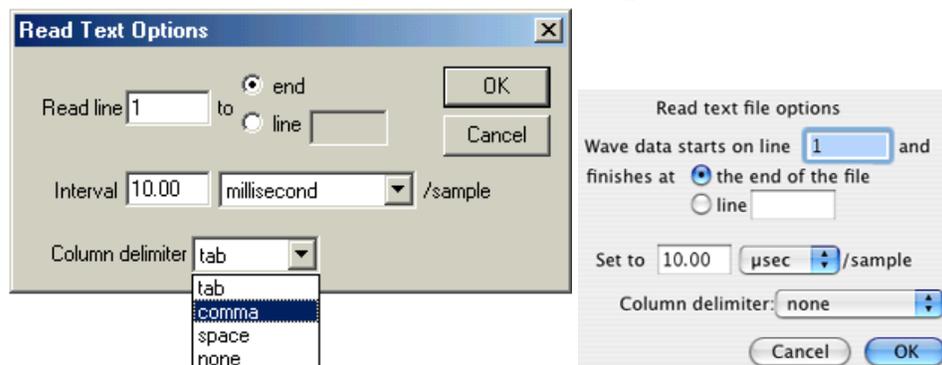


TXT

Text or *.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. *AcqKnowledge* 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 and non-numeric values will be ignored. Each column of data is read in as a separate channel.

Options

When the Files of type: Text option is select, an Options button is activated. Clicking on this button generates another dialog box that allows you to control the amount and type of data to be read in, as well as the time scale for data display.



Read Line

To control how much data is read in, enter a value in the read line box at the top of

the dialog box. This tells *AcqKnowledge* which row contains the first data point in the series. By default, this is set to 1, although you may want to set it to another value since some applications (usually spreadsheets) generate a “header,” or text information at the top of a file. You can also read in a limited amount of data by entering a value in the box to the right of the line box. 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. For example, if data were collected at 50 samples per second, there is an interval between sample points of 0.02 seconds. *AcqKnowledge* 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, if you have 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 60Hz, then the interval would be set to 3Hz per sample.

Column Delimiter

This setting tells *AcqKnowledge* 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 you are not sure which delimiter to use, select auto and *AcqKnowledge* will automatically select a delimiter.

When either tab or comma is selected, *AcqKnowledge* 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.

GTL Graph Template files (*.GTL)

This powerful feature allows you to open a template file with predefined experiment parameters and then simply click “Start” to run the experiment.

The Graph Template option allows you to open a copy of a master file so you can maintain the master settings. Graph template files open to previously saved window positions and setup parameters (as established under the MP menu). See Appendix G for descriptions of a wide array of applications and features.

This feature can be especially useful for recreating protocols in the laboratory. You can 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.

When a Graph template file is opened:

- N
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- The graph window will not contain any data. (Since no data is saved in the template, arbitrary waveform output setups, which require a source data file, will not function in a template.)
 - The journal window will contain text you entered and saved with the template—this is a handy way for you to place instructions or information about the experiment for yourself or others.

AcqKnowledge “**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 then click Start. **Quick Start** files were installed to the Sample folder and can be used to establish the settings required for a particular application or as a good starting point for customized applications.

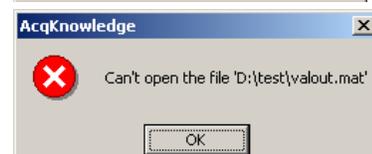
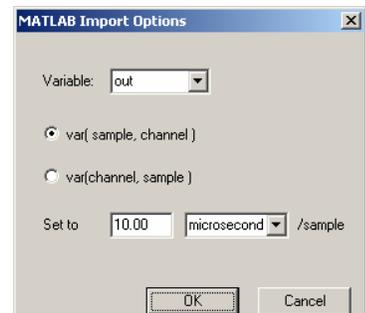
MAT MATLAB® format AcqKnowledge can open files created as a MATLAB work space.

- Windows™ can open MATLAB v6 compatible MAT files, including MATLAB 7 if the “v6” flag is specified in MATLAB before saving.
- Mac™ can open MATLAB v7 compatible MAT files, including V7 format. Only ASCII text is supported; Unicode text within MATLAB v7 is not supported.
- 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, AcqKnowledge 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 AcqKnowledge can’t recognize the file format, an error prompt will be generated and a blank graph window will be opened.

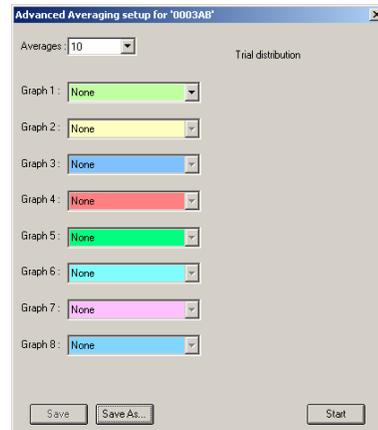


AVG Advanced Averaging Experiment

Open AVG files saved from the Advanced Averaging setup dialog. See page 99 for Advanced Averaging details.

Use the Start button in the Advanced Averaging setup dialog to start the acquisition.

The Sample folder includes a sample P300 setup.



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 *AcqKnowledge* provided that the packed experiment files comply with the following:

- ≤ 59 waves
- all waves in Version 2 or Version 5 format (Igor defaults)
- no text waves
- all waves one-dimensional (vectors)
- no complex waves
- 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.

PhysioNet *Mac OS X only*—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. *AcqKnowledge* 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.

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-generated raw files (default), or to little for 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 μ sec, 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.

Journal *Mac OS X only*—Opens an independent journal; see page 48 for details.

Jrnl Temp *Mac OS X only*—Opens a journal template; see page 48 for details.

WAV *Mac OS X only*—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 *AcqKnowledge* 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 *Mac 3.9.2 and later only*— 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 *AcqKnowledge*, only the following items are imported:

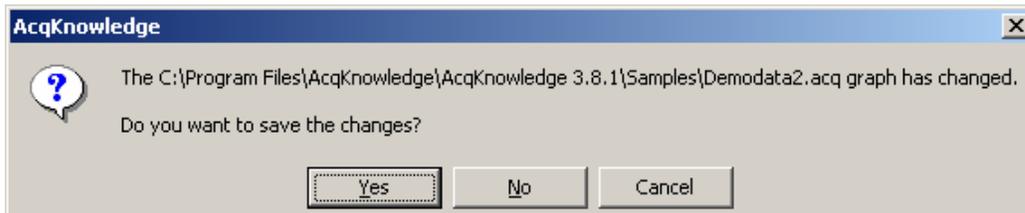
- channel data
- channel labels
- units
- sampling rate (taken from maximum sample rate of all channels)

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.

Close

Close menu command

This File menu command will close the active file window and prompt you to save if necessary.



Close without saving

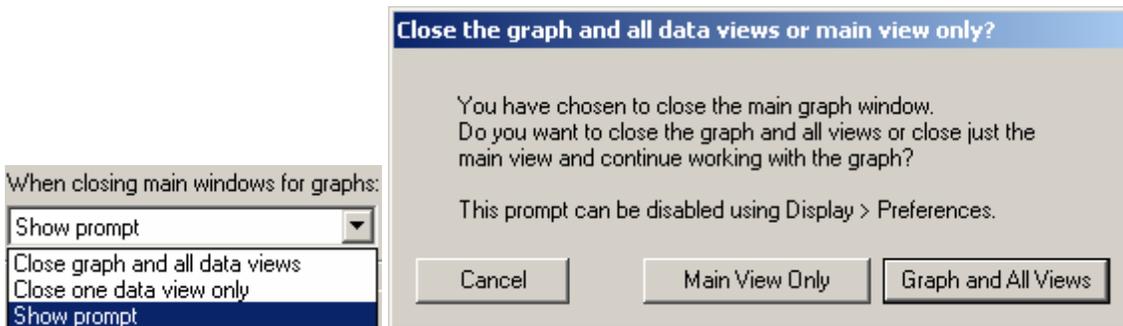
- **Windows**—click on the  in the upper right corner of the file window
 - **Mac OS X**—click on the  in the upper left corner of the file window
- Click “No” when *AcqKnowledge* asks you if you want to save the changes.

Close during acquisition

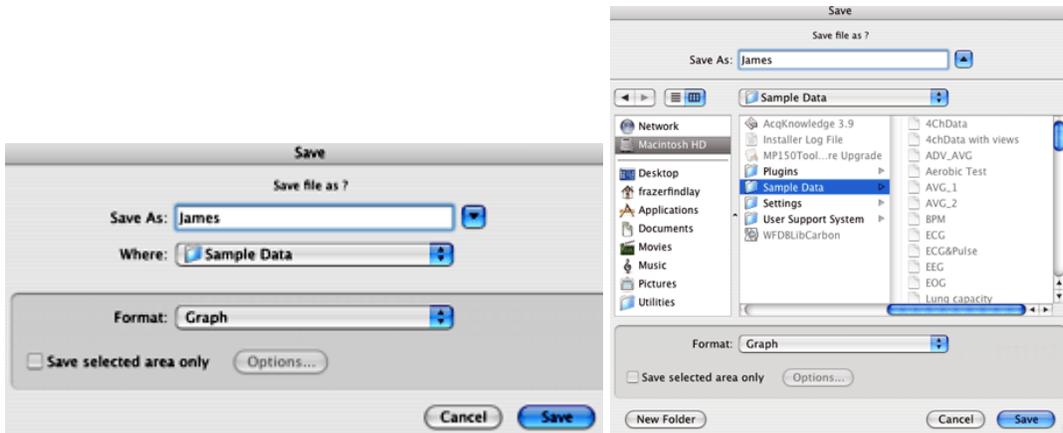


Close multiple data views

Set the level of close functionality under Display > Preferences > General.



Save



This menu command will save any changes made to a file. If more than one file is open, this command only applies to the active window. For untitled files, you will be prompted to name the file you wish the data to be saved in. The file will remain open after you have saved it, allowing you to continue working.

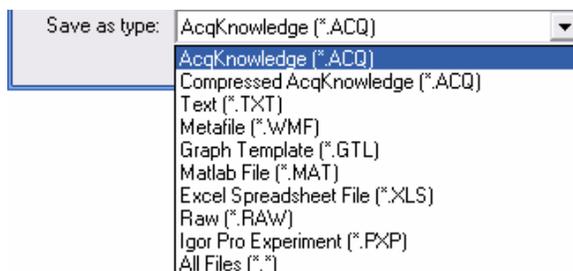
Mac OS X: The Save menu is dynamic and corresponds to the type of file you are trying to save, i.e. Save Graph, Save Journal, Save Advanced Averaging Setup.

Files must be less than 2 GB, except AcqKnowledge 3.9 “Graph” files on the Mac, which can be larger if not compressed.

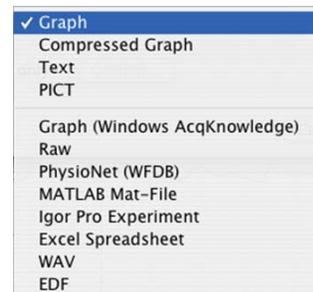
To save data in another format (such as a text file), see the File>Save As section which follows

Save As

Choosing File>Save As produces a standard dialog box that allows you to save data in a variety of different formats and to any location. As with all save last dialog boxes, you can use this to save a file to a different file name or directory than the default settings.



Windows/PC



Mac OS X

ACQ
Graph
Graph
(Windows
AcqKnowl-
edge)

AcqKnowledge format

The default file format for the File>Save as command is to save files as an AcqKnowledge file. Selecting Graph (MPWS) or .ACQ (MPWSW) from the popup menu in the Save As dialog box will save a file as an AcqKnowledge file, which is designed to be as compact as possible. These files can only be opened by AcqKnowledge, but data can be exported to other formats once it has been read in.

The **Options** button generates a dialog box that allows you to save only a portion of your file. When the “Selected Section only” option is enabled, only the data that has been selected with the I-beam tool will be saved. This option saves the selected area to another file and does not affect the current file that you are working in.



File Compatibility

Windows AcqKnowledge cannot save as Macintosh AcqKnowledge 3.9 files.

Macintosh AcqKnowledge 3.9 can save as “Graph (Windows)” files, but it saves in Windows AcqKnowledge 3.7.1 format. In this earlier format, all data is retained, but new Windows AcqKnowledge features (like dual stimulation, data views, embedded archives, etc.) are lost along with any settings specific to Macintosh AcqKnowledge (like events, adaptive scaling settings, etc.).

- Macintosh AcqKnowledge 3.9 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 PC GLP files or compressed PC files.

Files must end on a multiple of the lowest channel sampling rate to be fully PC compatible.

Compressed Saves a compressed AcqKnowledge 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:

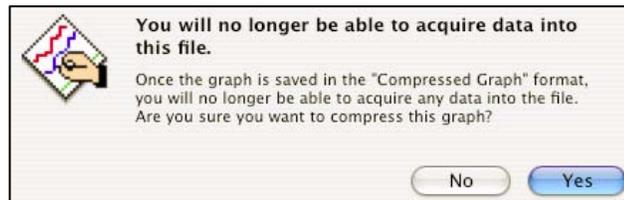
	ECGdata.acq	166 KB
	ECGdata_Compressed.acq	38 KB

Compressed files are only readable by AcqKnowledge 3.8.1 or later. Mac can read PC-compressed files. Windows cannot read Mac-compressed files.

Compressed graphs no longer allow data acquisition and will open with no Start button.

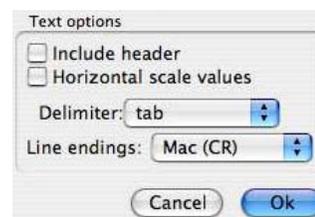
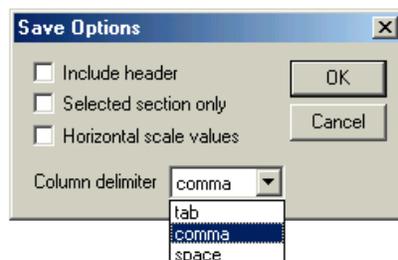
Windows: Resave the compressed file in standard format to enable a Start button.

Mac OS X: A warning prompt will be generated when you try to compress a graph in which data can be acquired (Start button active):



TXT *Text*

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 you to control how much data is saved and the format it is saved in.



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. You may wish to include the header as it can always be edited out later using a text editor or the journal.

Selected Section

Windows only Checking the second box instructs *AcqKnowledge* to save only the selected section of the file. This is useful for saving a brief segment of a long file. When this option is checked, the highlighted area of data will be saved from all channels. When only one data point is selected, the entire file will be saved. If you want to save only a portion of the selected channel, you can either remove other channels or copy the data through the clipboard. See page 215 for more information on how to copy data through the clipboard.

Mac OS X only This option is managed in the Save and Save As dialogs.

Horizontal Scale

The third checkbox allows you to include the horizontal scale (usually time) values in the text file, along with the data to be saved. This allows you to produce time series plots 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). You may wish to consult the section on resampling data after an acquisition is completed (page 247).

Column 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. However, you may also save data in a *comma-delimited* format or a *space-delimited* format.

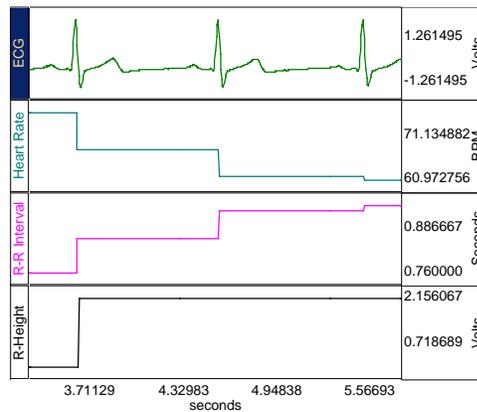
Line endings

Mac OS X only Use to create text files that are compatible with Classic Mac OS applications (Mac), Unix-compatible applications (Unix), or PC-compatible applications (DOS).

WMF or PICT

Metafile (WMF) for the MPWSW or PICT for the MPWS.

AcqKnowledge also supports formats for saving graphical information. Most drawing, page layout, and word processing programs can read .WMF or PICT files. This is particularly useful for writing reports. A WMF or PICT file can be opened in any standard drawing program and can then be embellished or used to highlight any particular phenomena of interest. The following image is an example of a .WMF file.



When data is saved as a graphic, only the data currently on the screen is saved. So, if you have a data file that spans eight hours but only two minutes is displayed on the screen, only two minutes of data will be converted to a graphic file. Since AcqKnowledge 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.

GTL Graph Template

This feature can be especially useful for recreating protocols in the laboratory. You can 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 193 before creating or saving a new template. With over 40 templates provided, you may find one to establish the settings required for your 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 MP menu and window positions. Any window (including the Journal window, Input values, Stimulator, or Manual Control) that was active when the file was saved as a Graph Template will come up with the exact same position and settings when the Graph Template is reopened.

When a file is saved as a Graph Template:

a) No graph data will be saved.

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- Since no data is saved in the template, arbitrary waveform output setups, which require a source data file, will not function in a template.
- You must select Save / Save as and select “File of type .ACQ” to save the graph data.

b) Journal text will be preserved. Any text you entered will be saved to the Journal window and stored with the template—this is a handy way for you to place instructions or information about the experiment for yourself or others.

When this feature is used with the menu.dsc customization feature it is easy to comply with GLP standards and save your protocol as an SOP. When you change the menu.dsc file for a graph template file, save the “menu.dsc” file with the exact same name but save it to the new lesson folder you have created. For full GLP features, contact BIOPAC about the [Lab Assistant GLP System](#).

*.MAT MATLAB

MATLAB® format. Uses the “MAT-file” binary format to save numerical and textual information as Filename.mat.

- Windows™ and Mac™ create MATLAB Version 6 files, which are compatible

with both MATLAB Version 6 and MATLAB Version 7.

- Interoperability with earlier versions of MATLAB is not guaranteed.

The following variables will be in the workspace when the file is opened in MatLab.

<code>data</code>	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 row contains a full channel of data that can be accessed in MATLAB via <code>data(1:length)</code> .
<code>units</code>	This string array contains the textual representation of the units of the samples stored in <code>data</code> , with one element per channel of data.
<code>labels</code>	This string array contains the labels of each of the channels, with one element per channel.
<code>isi</code>	This floating point array of one element gives the number of units of a single inter sample interval of the data.
<code>isi_units</code>	This single string array provides a units string for a single unit of <code>isi</code> . 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.
<code>start_sample</code>	Contains the time offset of the index 0 sample of data in <code>isi</code> units. This will be 0 for many graphs, but if only a selected area of a graph was exported into the MAT file, the <code>start_sample</code> will contain the offset from the original data corresponding to the start of the data array in the MAT file.

AVG (Advanced Averaging)

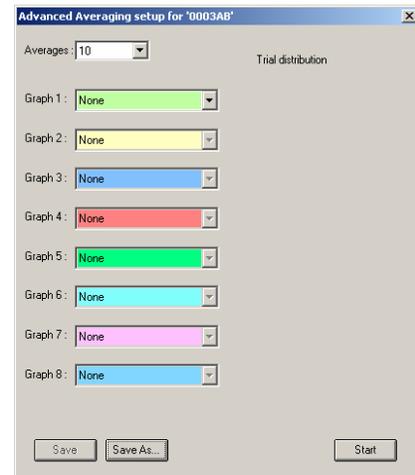
To save an Advanced Averaging Experiment:

1. Use the File > Save or Save As function in each graph to save the graph data.

IMPORTANT: You must save the graph files separately from the Averaging setup. The graph files and templates used in an Averaging setup should be saved in the same directory as the Averaging setup so they can be opened automatically when the Averaging Setup file is opened.

2. Make sure the Graph names are correct and then use the Save and Save As buttons in the “Advanced Averaging setup” dialog to save the setup.

For Advanced Averaging details, see page 99.



Igor Pro Igor Pro Experiment format.
 An AcqKnowledge 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™.

PhysioNet *Mac OS X only* —This format requires that the WFDB library is on your 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. AcqKnowledge 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.

Export Limitations

- Precision* Some precision may be lost due to differences in binary representation between AcqKnowledge 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* If you are exporting a graph that uses variable sampling rates, all of the channels in the exported file will be downsampled to the lowest waveform sampling rate of the source graph.

- 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, set to little endian; to exchange with Mac applications, set to big endian.

Raw Data Export Limitations

- 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 AcqKnowledge 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. (AcqKnowledge uses a 64-bit data type, so this should only be a problem if exporting to 32-bit floating point values.)

Excel Spread- sheet

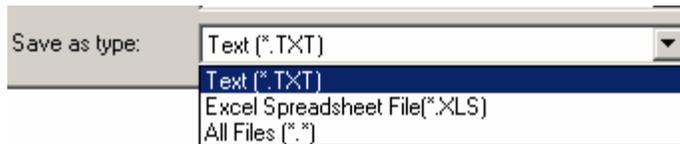
Excel Spreadsheet Export—Graph data can be saved directly to an Excel spreadsheet by using the Excel Spreadsheet format in File > Save As. Each channel will be placed into its own column of the spreadsheet. Only 65K sample points can be exported at a time, however, so long or high sample rate data acquisitions may not be able to be saved in a single spreadsheet.

- Also available for File > Save Journal Text As, Find All Cycles journal, and Specialized Analysis tools.

Journal



note that you have to select the journal save icon for the Excel option



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 *Mac OS X only*, Specialized Analysis tools.

Mac OS X only—Text (*.TXT) Saves an independent journal; see page 48 for details.

Jrnl Temp

Mac OS X only—Saves a journal template; see page 48 for details.

WAV

Mac OS X only

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 AcqKnowledge.

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).

AcqKnowledge 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 *Mac 3.9.2 and later only*

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.

AcqKnowledge does not retain sufficient information to accurately complete an EDF header. When exporting, the following default values will be used:

<i>EDF Header Element</i>	<i>Default</i>
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 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 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.

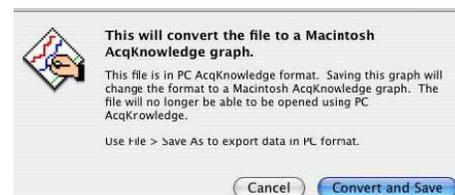
EDF is used by many applications and online recording databases to store information, particularly EEG recordings. EDF is an open file format originally developed for sleep studies. It stores continuous time recordings of data in a binary format. Since its original proposal, EDF has been adopted by a 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.

Format change warnings

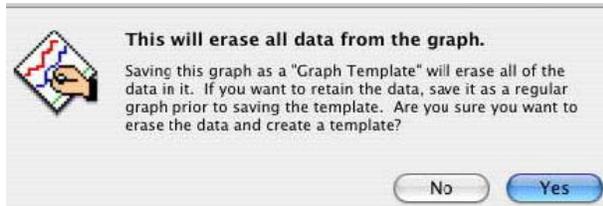
Mac AcqKnowledge 3.9.1 and later only—When a file open or save function requires a format change for compatibility or alters file content, a prompt will be generated to require the user to confirm the option to update format or convert and save.



Created with a previous version of AcqKnowledge



Windows PC AcqKnowledge format



Saving as a "Graph Template" will erase all data



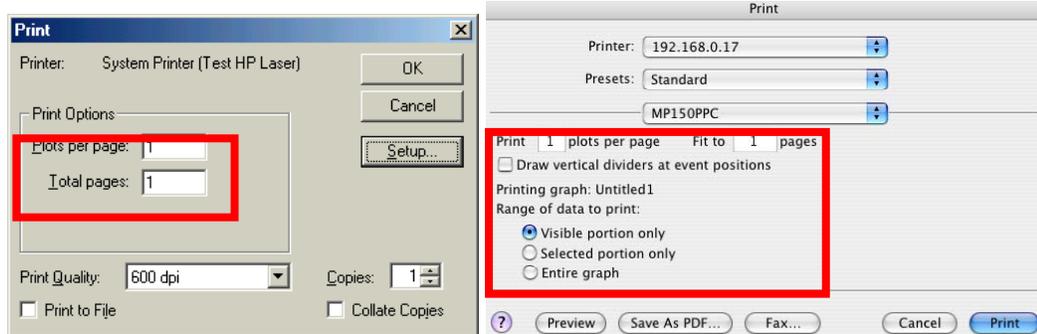
Imported from another file format

Print

The File>Print menu that *AcqKnowledge* uses is similar to the standard computer print dialog box; however, there are two additional box options that add functionality.

Mac OS X The Print menu is dynamic and corresponds to the type of file you are trying to print, i.e. Print Graph, Print Journal.

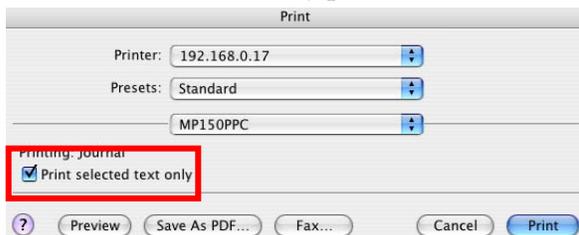
The additional options are activated under Page Setup when the “MP1X0...” option is selected.



- **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, *AcqKnowledge* 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 you to print records on considerably fewer pages than standard printouts, and is most effective when only a few channels of data are being printed.
- **Total pages (Fit to pages on a Mac)**—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 box. 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.

Print selected text from Journals

Mac *AcqKnowledge* 3.9.1 and later only—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.



To print only a portion of a journal or GLP modification log:

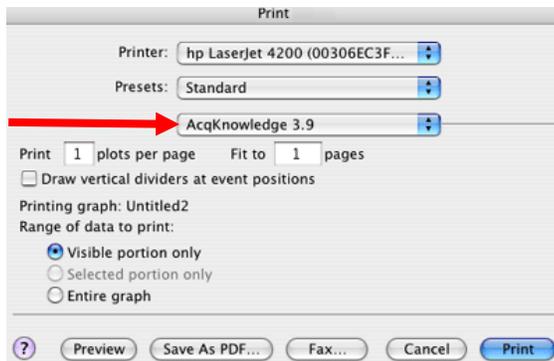
1. Use the I-Beam tool to select the range of text to be printed in the journal.
2. Choose File > Print.
3. Switch to the “*AcqKnowledge*” printing options panel.
 - On MacOS™ X 10.3.9, this may appear as “MP1X0.”
4. Check the “Print selected text only” checkbox.

If there is no selected text, the entire journal or modification log will be printed regardless of this setting.

Printer setup (MPWSW) or Page Setup (MPWS)

Choosing File>Printer Setup on the MPWSW (PC) or File: Page setup on the MPWS (Mac) produces a standard printer setup dialog box that allows you to setup any available printers. All the options in this dialog box function as described in your system manual. There is also an options button that allows you to make several printing adjustments with respect to fonts, image orientation, and graphics presentation.

Range of Data options—*Mac only*



To determine the range of data that will be included in the printout, select one of the print range options.

- 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.
- Entire graph prints all of the data contained in the graph from zero to the maximum length channel.

Select “MP1X0...” for Print range options

Event Divider

Toggle “Draw vertical divider at event locations” to enable/disable this option. See Printing Events on page for 165 details.

Based on the range selection, the software will make appropriate adjustments before printing. For visible area, friendly grid scaling (page 140) will be applied, and onscreen and printed precision will match, even if horizontal grids are unlocked. For selected area and entire area, onscreen and printed precision will not match when grids are unlocked because friendly grid scaling (page 140) is applied on screen, but is not used during printing where the range is fixed to fill the entire page.

The automatic software adjustments before printing will set the horizontal scale as if it had been used to display the relevant data on the screen. When printing is completed, the scale and offset parameters of the graph will be restored to the previous settings.

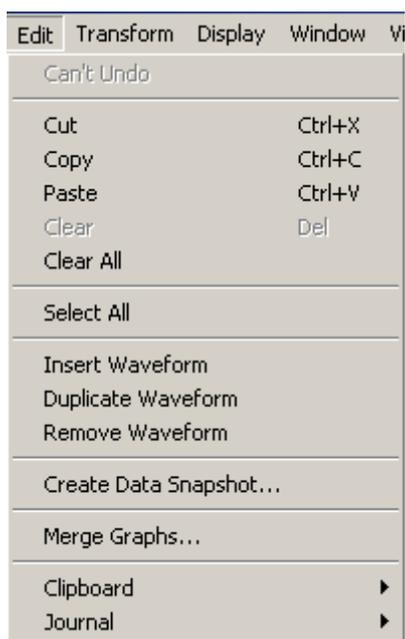
Exit

Selecting Exit from the File menu exits AcqKnowledge software and prompts you to save any open graph files that have been modified since they were last saved.

Mac OS X only—Use Quit under the AcqKnowledge 3.9 menu (page 317) to exit the software.

Chapter 11 Edit menu commands

Overview



One of the most useful features in *AcqKnowledge* is the ability to edit and work with data by cutting sections and copying sections from one window to another. In this sense, the MP System allows you to work with data much as a word processor lets you work with text. When working with data, you will usually want to select a section of data to work with. To select a section of data, use the editing tool to highlight an area. The 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 the tool, click on its icon in the lower right hand corner. You will notice that the cursor changes into the familiar “I-beam” cursor when you move it 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 you have selected a section of a waveform, you can perform such as editing, transformations, saving data to the journal, saving as text, and using the measurement functions 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. You can highlight a larger area by positioning the cursor over the first point you are interested in, holding down the mouse button, and dragging the cursor either left or right to highlight an area. This is similar to highlighting a series of letters or words in a word processor. You can 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. By zooming in (with the zoom tool) on either edge, you can then use the shift key to precisely align the edges of the selected area.

AcqKnowledge also allows you to select an area that spans multiple screens. To do this, first select an area that contains the leading edge of the portion of the graph that you are interested in. Next, use the horizontal scroll bar to scroll to the end of the area that you are interested in. Then place the mouse near the area of interest and click on 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 a word processor. These functions operate only on areas selected by the selection tool.

Edit menu functionality during acquisition

Mac OS X only—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.

Undo / Can't undo

The Undo command allows you to restore 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 you modify the screen scale (or other display parameters) you will still be able to undo your latest data modification, which is much more difficult to recover than a screen parameter change.

TIP: If you accidentally remove a waveform or choose Clear All, one way to recover the data is to close the file without saving the changes. The data file can now be reopened, as it was when it was last saved; any changes made since it was last saved will be lost.

- **Windows/PC:** With some exceptions, the Edit>Undo command will undo the last command carried out by AcqKnowledge.
- **Mac OS X:** Perform multiple levels of undo on a per graph basis; Journal undo remains unchanged at one step. Complex data analysis in AcqKnowledge is rarely performed with a single transformation; multiple transformations are frequently cascaded together to produce a result. AcqKnowledge will “stack” the transformations and the user will be able to undo one step at a time until this stack is exhausted.
 - Undo may move or alter memory and cannot be performed during acquisition.
 - Undo operations may occupy large amounts of memory, particularly for transformations that affect entire waveforms or multiple markers. Users without large amounts of RAM or working with large data sets may require the available computer memory for performing transformations. To accommodate these users, the maximum size of the undo stack can be limited using the *Levels of undo* Preference (Display>Preferences).



- Specialized Analysis (page 333) scripts are complex and undo may not function for all steps.

Cut

When Cut is selected from the Edit menu, the highlighted portion of the active window (Graph, Journal, entry prompt or dialog) is removed and copied to a clipboard, where it is available for pasting into other windows.

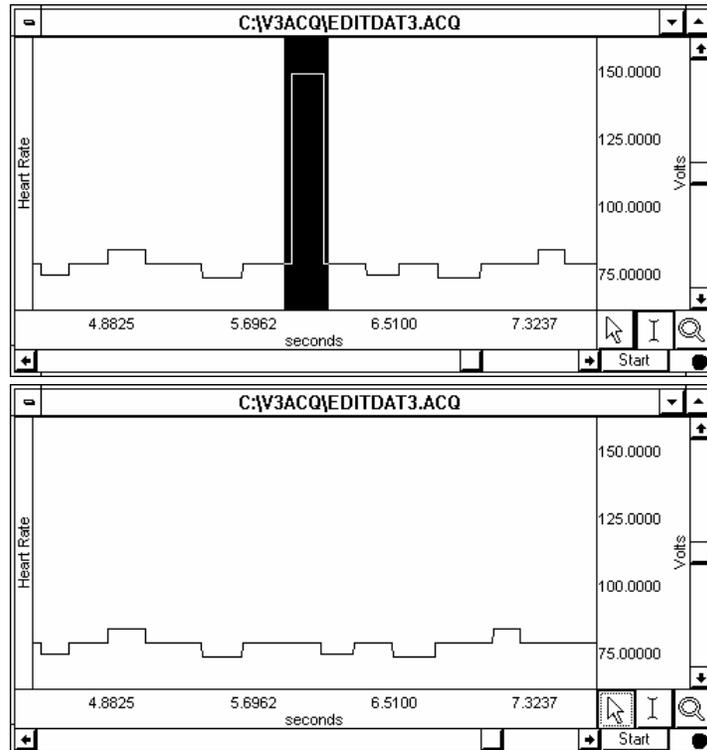
Mac OS X: Cut may move or alter memory and cannot be performed during acquisition.

- 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, you might want 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 forward in time.



Copy

Choosing Edit>Copy will copy the selected area of the active window (Graph, Journal, entry prompt or dialog) to the clipboard without modifying the text/waveform on the screen.

- Once the area has been copied, it can be inserted in another window 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.

Paste

The Edit>Paste command will take the contents of the clipboard and paste it into the currently selected area of the active window (Graph, Journal, entry prompt or dialog).

- 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

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.

Mac OS X: 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.

Mac OS X: 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) from one window to another. To do this, first select the area to be copied using the cursor and the Edit>Copy command. Next open the graph window you wish to insert the waveform into. To insert the waveform into the same graph it was copied from, although the Edit>Duplicate waveform is a much more straightforward way to do this.

Once you have selected the graph you wish to insert the waveform into, choose Insert waveform from the Edit menu. A new (empty) channel will then be created and the data will be copied into the empty channel. The new channel will always take on the lowest channel number available (including zero).

Mac OS X: Insert waveform may move or alter memory and 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.

Mac OS X: 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.

Mac OS X: 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

Mac OS X only—Removes the last appended segment. Equivalent to the  Rewind toolbar icon.



- Edit>Undo does not work for Remove last appended segment.

Create Original 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.
You cannot use this feature to recover lost or damaged graph files.

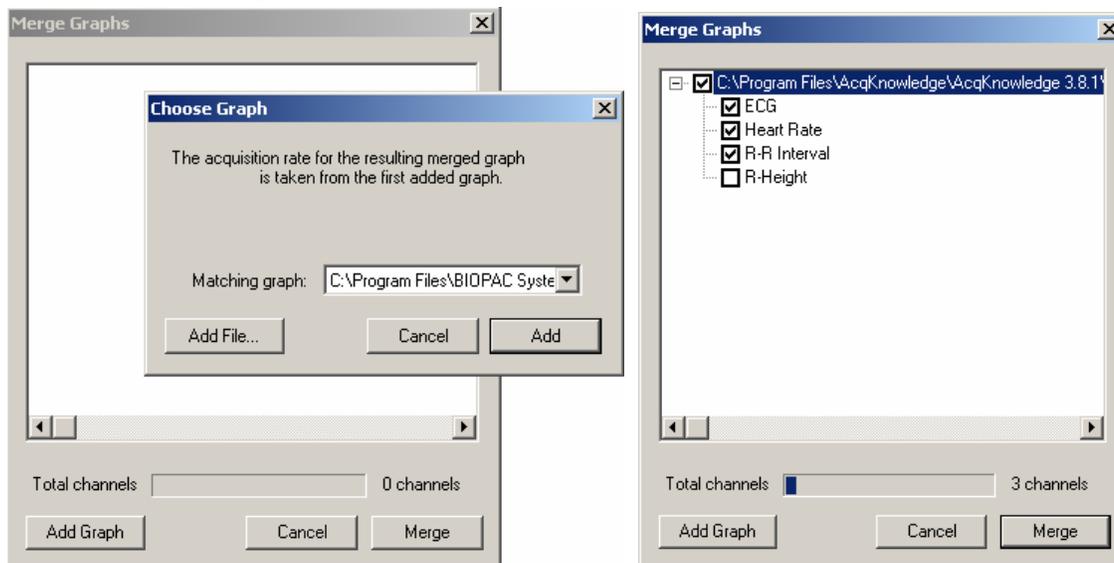
See page 49 for Snapshot details.

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 up to 60 channels from multiple graph files acquired with the same acquisition rate into one merged graph file. On Windows OS, the resulting file size of a merge must be less than 2GB.

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 on the “+” to list individual channels in the graph file.
 - Toggle the checkbox to add or remove the associated channel/graph file.
 - You cannot delete a file name from the list, but you can remove it from the merge.
5. Repeat as desired for multiple files.
6. Click Merge and wait (you can check the status in the Total Channels bar).
7. Save the merged file.



Clipboard



All of the clipboard commands involve copying data from *AcqKnowledge* to the standard Windows clipboard, where the contents of the clipboard are made available for other applications. Transferring data through the clipboard allows you to copy data from *AcqKnowledge* to other applications even after you have closed the graph window and/or quit *AcqKnowledge*.

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 on the screen to the clipboard in WMF (MPWSW) or PICT (MPWS) format.

➤ Copy Measurement

Copies the contents of all visible measurement popup menus, along with the values associated with these windows. By default, three windows are displayed (on most monitors); you can change this by increasing or decreasing the width of the window. 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 *AcqKnowledge* into a word processor 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 *AcqKnowledge* 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, *AcqKnowledge* will insert a delimiter between each column of data. The default delimiter is a tab; you can change the delimiter to either a space or tab in the options dialog box in the File>Save as dialog box. See page 191 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 Windows Metafile (PC) or PICT (Mac) format. You can then place the graphic into a number of different types of documents, including word processors, drawing programs, and page layout programs. Windows Metafile and/or PICT are common to almost all applications, and images saved in these formats can be edited in most graphics packages and many word processors.

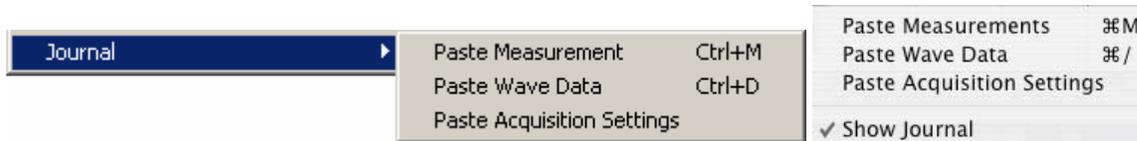
Using the copy graph function is similar to saving a graph window as a Windows Metafile or PICT file (using the File>Save As command), except that using the file save command writes a file to disk, whereas transferring data through the clipboard does not save a file.

➤ 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 configuration of your MP unit along with your data.

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 measurement

Choosing Paste measurement 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 box. You can also change the total number of measurements displayed by adding more rows of measurements. Use the Preferences menu (see page 310) to change the number of measurement rows or the measurement precision displayed on the screen.

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; you can change to comma or space delimiters in the File>Save As>Options dialog box. See the Save As section on page 197 for more information on how to change the column delimiter.

➤ Paste acquisition settings

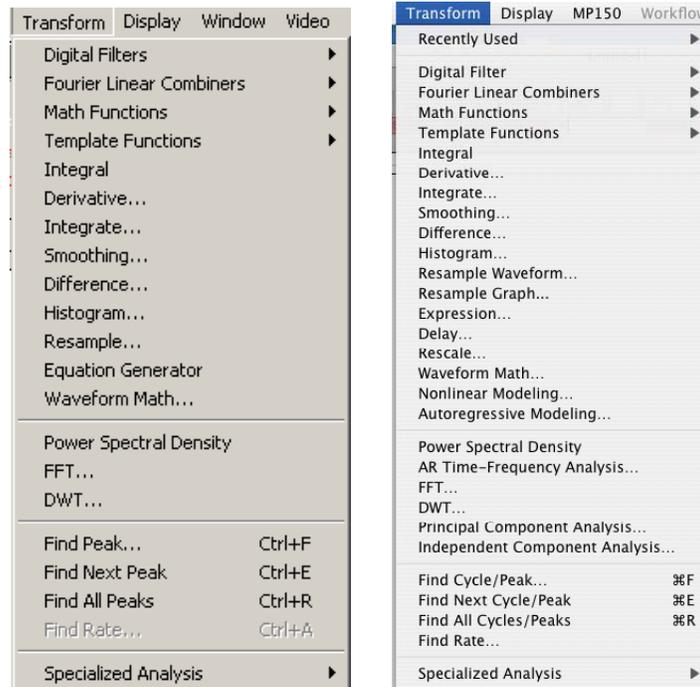
Pastes the acquisition settings to the journal as they were copied via Edit > Clipboard > Copy Acquisition settings.

Show Journal—*Mac OS X only*

To display the Journal on a Macintosh, select Edit > Journal > Show Journal.

Chapter 12 Transform menu commands

Overview



AcqKnowledge provides a number of options for post-acquisition analysis and transformations. These transformations allow you to perform a range of operations on your data, from digital filtering and Fourier analysis to math functions and histograms. All of these options can be found under the Transform menu, and are disabled while an acquisition is in progress. Unless otherwise noted, all of the transformations described here apply to the selected channel only. Some options (such as the expression and math functions) allow you to specify a channel (or channels) to be transformed.

The table below groups all of the transformation functions into four general families or clusters. The first set of functions performs “data cleaning,” in that they perform some sort of filtering or data reduction tasks. The second set of transformations performs calculations or other mathematical operations on the data. The third set of functions allows you to search through the data, either for peaks or patterns of data. The fourth set of functions provides graphical summaries of the data, either in terms of the frequency spectra of the data or the measures of central tendency and dispersion of waveform data.

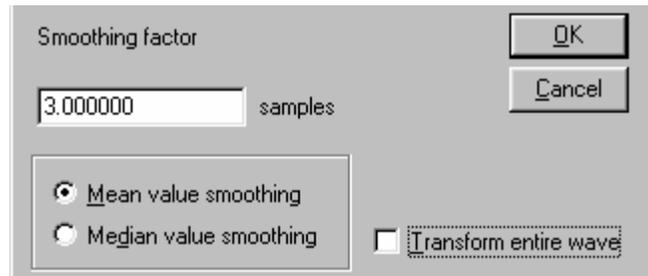
AcqKnowledge Transformation Functions

<i>Isolate data</i>	<i>Calculation/Math</i>	<i>Search</i>	<i>Summary</i>
Smoothing	Equation/Expression	Peak Detection Functions	Histogram
Digital Filtering	Waveform Math	•Find Peak/Cycle	FFT
Resample	Math Functions	•Find Next Peak/Cycle	Power Spectral Density
Fourier Linear Combiners	Difference	•Find All Peaks/Cycles	Find Rate
Principal Component Analysis	Integrate	Template Functions	AR Time-Frequency Analysis
Independent Component Analysis	Derivative		DWT (Wavelet Decomposition)
	Integral		
	Autoregressive Modeling		
	Nonlinear Modeling		

It is important to remember that *AcqKnowledge* 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.

Mac OS X Using Edit > Select All is not necessary when only a single point is selected prior to selecting the transformation because *AcqKnowledge* 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

Mac AcqKnowledge 3.9.2 and later—The Transform > Recently Used submenu allows quick access to a user’s most recently used transformations regardless of a transformation’s fixed position in the transformation menu. 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 (see page 312 for more information).

The recently used transformation listing is saved and restored across subsequent launches of AcqKnowledge. 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.

Digital filtering

The Transform > Digital filters selection includes *FIR* finite impulse response and *IIR* infinite impulse response post-processing filters, with *Adaptive* filtering available only on the Mac.



FIR filters are linear phase filters, which means 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 75).

- 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; see page 224 for 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 $120\text{Hz} \times 2$, 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

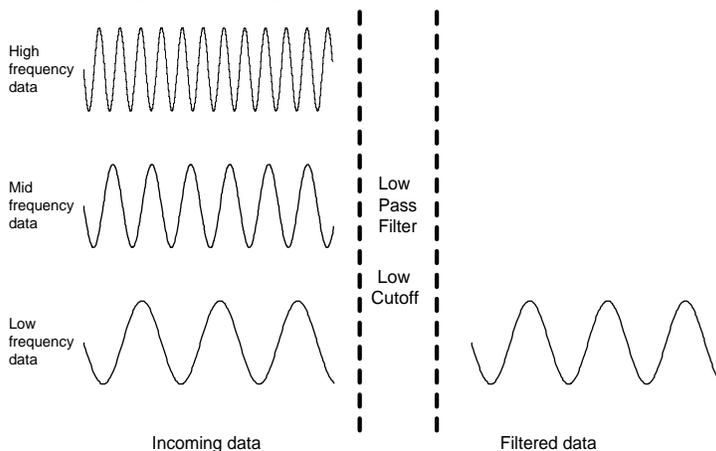
Descriptions of these four classes of filters follow, with visual examples of how these filters work. In each of the four examples, a single channel of data containing frequency components in three ranges (low frequency, mid-range, and high frequency) is acquired.

- 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. As you can tell, 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.

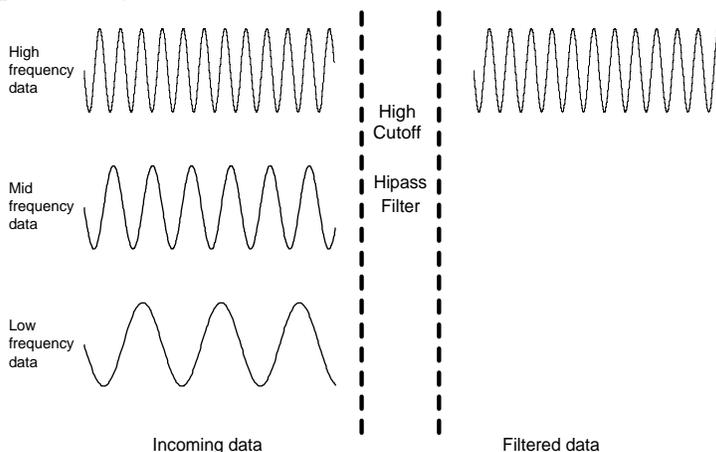
Low pass filtering

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

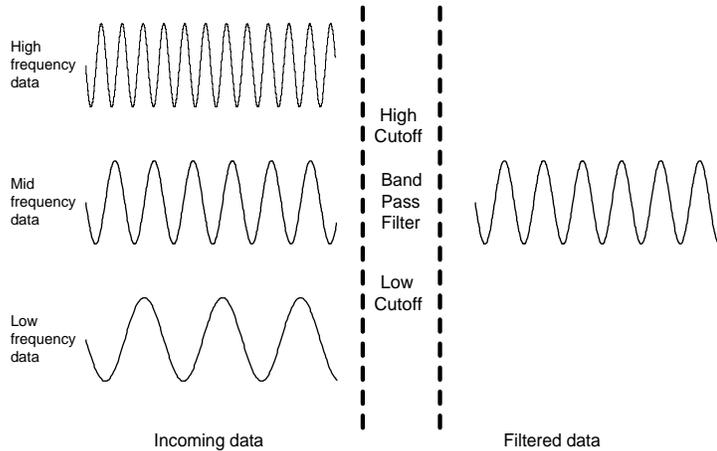
In the example below, a high pass filter removes the low and middle range data, but allows the high frequency data to pass through the filter.



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.

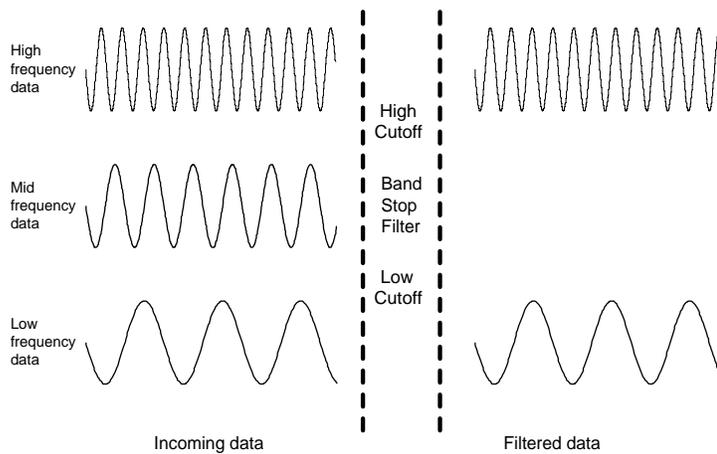
Band pass filter

The band pass filter, allows only the data within the specified range to pass through the filter. A band pass filter is useful when you want to retain only specific waves from an EEG record. For instance, to retain alpha waves, you can 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.

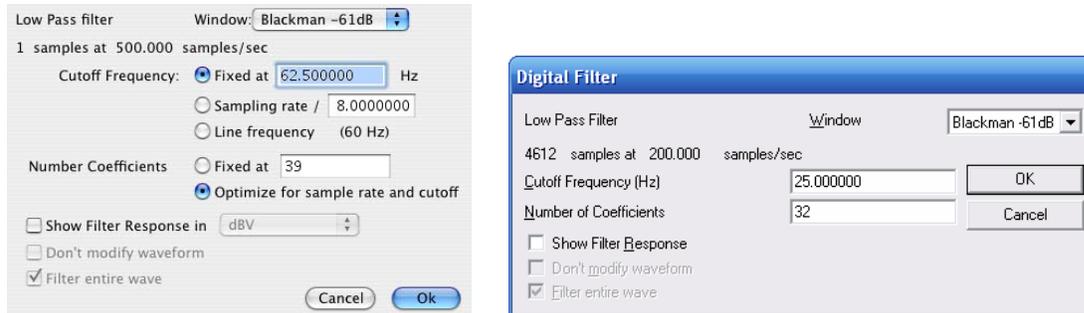


FIR Filters



Digital filter dialog box

When you select an FIR filter type, the corresponding Digital Filter dialog box will pop up, allowing you to specify a number of different filtering options.



1. **Window.** The Window popup menu allows you to choose from a variety of filtering algorithms. The filter default is set to a “Blackman” type. These different Windows (described in detail in Appendix D) allow you to “fine tune” the filter response.
2. **Cutoff Frequency (Hz)** (or threshold). Enter fixed value(s) or set the cutoff to line frequency or sampling rate fraction.

Sampling rate—*Mac AcqKnowledge 3.9.2 and later* Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.

Line frequency—*Mac AcqKnowledge 3.9.2 and later* Uses the line frequency at which the data was recorded.

Fixed—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.

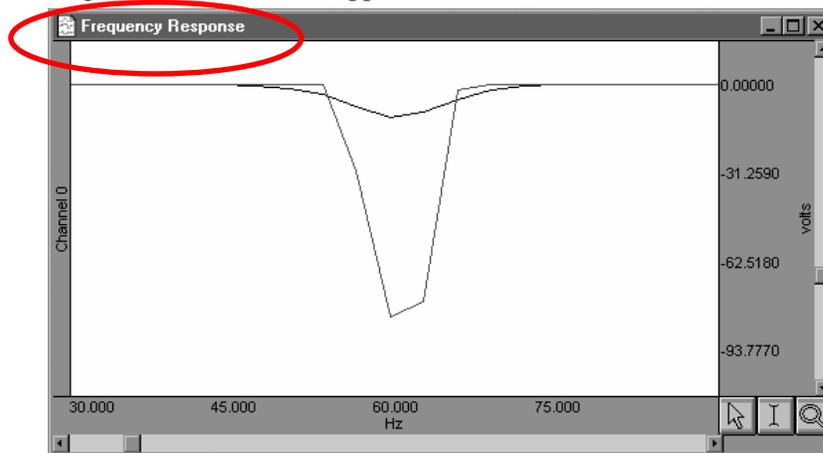
3. **Number of Coefficients.** Enter a fixed value or enable the optimize option.

Fixed—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—*Mac AcqKnowledge 3.9.2 and later* 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.

The default number of coefficients is $(4 \times \text{waveform sampling rate}) / \text{lowest frequency cutoff}$ 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 coefficient value affects the way data is filtered, it can be useful to examine the filter response patterns. In the example below, data was collected at 500Hz and the band stop filter was designed to remove 60Hz noise using a low cutoff of 55Hz and a high cutoff of 65Hz. The same data was band stop filtered using a coefficient of 39 (upper waveform) and then 250 (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.

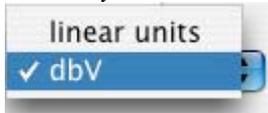
In both filter response waveforms, there is a downward-pointing spike that is centered on 60Hz. The baseline of the filter response corresponds to a value of approximately 0 on the vertical axis, indicating that the signals significantly above or below 60Hz were not attenuated to any measurable extent. As you can tell, however, the filter does not “chop” the data at either 55Hz or 65Hz, 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 $(2 \times 100/1)$ or 200 coefficients in the filter. Additional coefficients will improve the response.

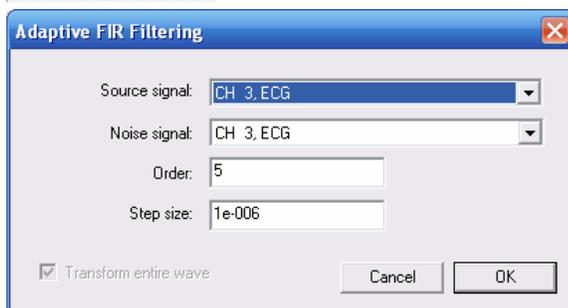
4. **Show Filter Response.** When checked, this option generates a plot of the filter response in a new window, labeled “Frequency Response” (see example above).

- *Mac only:* **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, AcqKnowledge will produce a plot showing the filter response, but will not modify the waveform. This allows you to repeatedly specify different filter options (without modifying the waveform) until the desired frequency response is achieved.
6. **Filter entire wave.** If this option is checked, AcqKnowledge will filter the entire wave and replace the original. If you want to keep the original, duplicate it prior to filtering.

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 89.

The weights within an adaptive filter are modified on a step-by-step basis. AcqKnowledge 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 μ , the rate of adaptation of the coefficients within the FIR filter.

IIR Filters

To access the IIR filter dialog box, click on the Transform menu, scroll to select **D**igital 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 75.



Low Pass and High pass

Pass data that falls below or above the specified standard. The Low Pass default is 0.125 times the waveform sample rate; the High pass default is 0.25 times the waveform sample rate.

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 0.125 times the waveform sample rate and the high default is 0.25 times the waveform sample rate.

- 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 F_0/Q , so the bandwidth of this filter centered on 50Hz (with the default $Q=5$) would be 10Hz. 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 0.125 times the waveform sample rate.

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 = waveform sample rate x 0.125.

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. See dialog details on page 227.

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	Mac AcqKnowledge 3.9.2 and later Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.
Line frequency	Mac AcqKnowledge 3.9.2 and later Uses the line frequency at which the data was recorded.

Comb Band Stop Filter Dialog

Comb Band Stop Filter

1465 samples at 250.000000 samples/sec

Base frequency: Fixed at Hz
 Sampling rate /
 Line frequency (0 Hz)

Q:

Overharmonics: all up to Nyquist
 up to times base freq.

Transform entire wave

Transformation Dialog

C0, Comb Band Stop Filter setup

Source:

Label:

Preset:

Base frequency: Fixed at Hz
 Sampling rate /
 Line frequency

Q:

Overharmonics: all up to Nyquist
 up to times base freq.

Calculation Channel Dialog

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. 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. *AcqKnowledge* 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 *AcqKnowledge* 3.9.2 and later** — 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:

$$y = (F_{\omega} \circ F_{2\omega} \circ F_{3\omega} \cdots \circ F_{k\omega})(x)$$

where F_{ω} 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

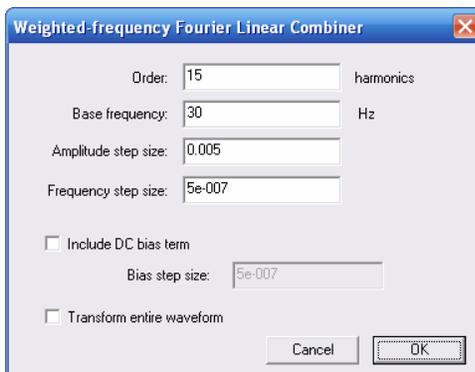
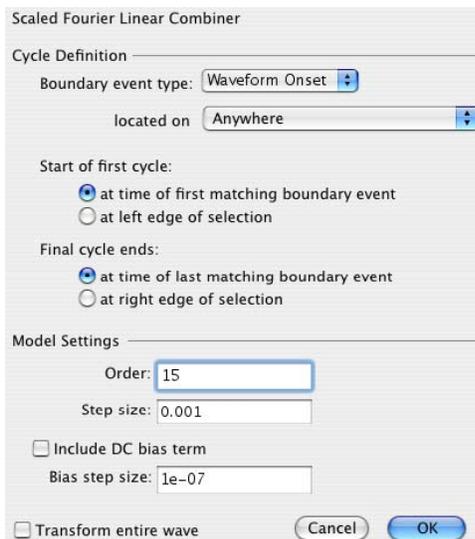
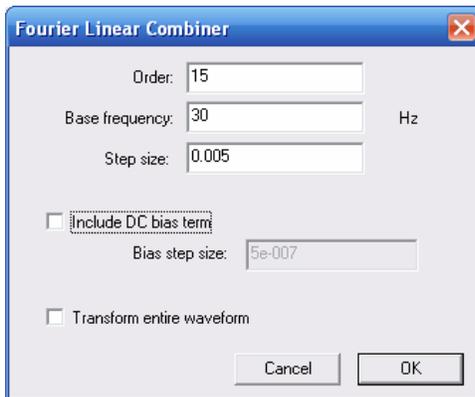
number of samples	Width of the selection.
@ samples/sec	Waveform sampling rate of the source channel. <ul style="list-style-type: none"> The channel sampling rate of the calculation channel can not exceed the channel sampling rate of the source channel. Downsampling will be applied to the source channel 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. <ul style="list-style-type: none"> Must be positive and less than the Nyquist frequency (half the sampling rate). <p>Sampling rate—Mac AcqKnowledge 3.9.2 and later Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.</p> <p>Line frequency— Mac AcqKnowledge 3.9.2 and later Uses the line frequency at which the data was recorded.</p>
Q	Quality factor used when computing the coefficients of the IIR notch filters. <ul style="list-style-type: none"> 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 <ul style="list-style-type: none"> 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. <p>Prior to the start of acquisition, the following will be checked:</p> <ul style="list-style-type: none"> 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. <p>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.</p>
Cancel	Exits 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 “Cn –Filter” where <i>n</i> is the index of the calculation channel. <ul style="list-style-type: none"> 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:

Basic FLC...
Scaled FLC...
Weighted-frequency FLC...
Coupled WFLC/FLC...

- See FLC Calculation Channel options on page 88.
- See FLC references on page 230.



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 μ , 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 – Mac OS X only

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.

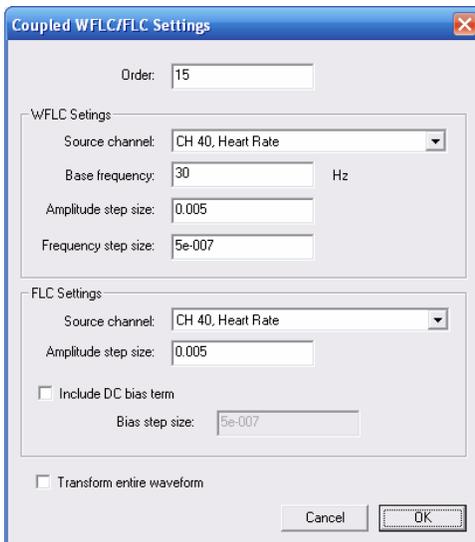
Weighted-Frequency FLC

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 always occur in the source channel for the FLC, not in the active channel; the user cannot specify the destination channel for CWFLC.

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.

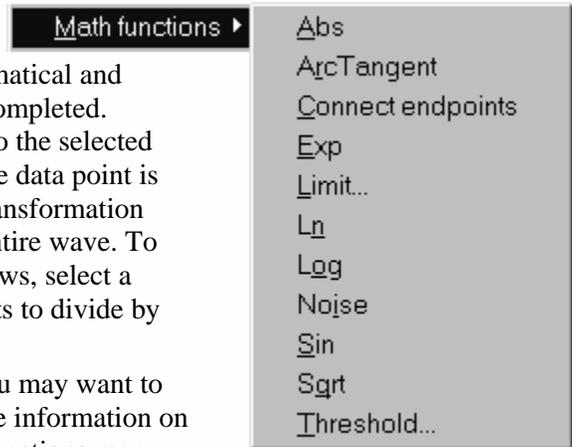
- Allan Kardec Barros, Makoto Yoshizawa, and Yoshifumi Yasuda, "Filtering Noncorrelated Noise in Impedance Cardiography," *IEEE Trans. Biomed. Eng.*, Vol BME-42, pp. 324-327.

Math Functions

AcqKnowledge allows you to perform 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 Windows will apply the transformation only to the selected point, but Mac OS X will transform the entire wave. To perform a math function on the entire waveform under Windows, select a channel and choose Edit>Select all. If a math function attempts to divide by zero, a zero will be returned.

For complex transformations involving multiple functions, you may want to use the Equation Generator/Expression (see page 249 for more information on this feature). Many of the same functions found in the Math functions menu can also be found in the Equation Generator.

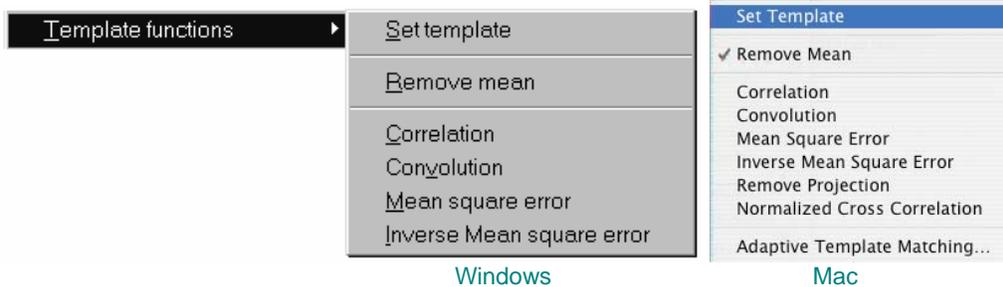
The following table describes the commands available in the Transform>Math functions menu:



Transform >Math	Explanation of Command
<i>Abs (Absolute Value)</i>	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.
<i>Atan (Arc Tangent)</i>	Returns the arc tangent of each data point in radians. This rescales the data such that the range is from $-\pi/2$ to $\pi/2$.
<i>Connect endpoints (Connect the endpoints)</i>	<p>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 <i>connect endpoints</i> function is very useful for removing artifacts in the data or in generating waveforms.</p> <p>In the example below, the “noise spike” in the data is an undesired measurement artifact that should be removed. You could cut the section of data, but then all subsequent data points would shift left. In order to preserve the time series of the data, you could use the <i>connect endpoints</i> command to draw a straight line (although not necessarily flat) that connects the two extreme sample points of the selected area.</p> <div data-bbox="760 1220 1292 1843" data-label="Figure"> </div> <p style="text-align: center;"><i>Area selected before (top) and after (bottom) connect endpoints function</i></p>
<i>Exp Exponential</i>	Computes the function e^x , where x is the waveform data and e is 2.718281828.

Transform >Math	Explanation of Command
	This is the base of the natural logarithms.
<i>Limit (Limit data values)</i>	“Clips” data outside the range specified by the set of thresholds in the limit dialog box. This function will prompt you for an upper and lower limit. Any data values outside these limits will be clipped at the closer limit. Although both a high and low threshold must be entered, To limit only one extreme (high or low) while leaving the other extreme unaffected. For instance, if you wanted to limit data so that all negative values were set to zero but the positive values were left unchanged, you would set the low threshold to zero and the high threshold to 99 (or some other large positive value that exceeds the maximum value for that channel).
<i>Ln (Natural Logarithm)</i>	Computes the natural logarithm of the selected section. The inverse of this function is the exponential function, <i>Exp</i> .
<i>Log (Base 10 Logarithm)</i>	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.
<i>Noise</i>	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.
<i>Sin (Sine)</i>	Calculates the sine of the selected section. The data is assumed to be in radians.
<i>Sqrt (Square Root)</i>	Takes the square root ($\sqrt{\quad}$) of each data point in the selected section.
<i>Threshold (Threshold data values).</i>	<p>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.</p> <p>Threshold Algorithm</p> <p>Assume a domain variable $t \in \{t_{start}, t_{start} + 1, t_{start} + 2, \dots\}$ 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 $y_{low} \leq y_{high}$.</p> <p>Define the threshold function $thresh(t)$ function such that:</p> $thresh(t_{start}) = \begin{cases} 1 & y(t_{start}) \geq y_{low} \\ 0 & y(t_{start}) < y_{low} \end{cases}$ $thresh(t) = \begin{cases} 0 & y(t) < y_{low} \\ 1 & y(t) > y_{high} \\ thresh(t-1) & y_{low} \leq y(t) \leq y_{high} \end{cases}$

Template Functions



The Template Functions are useful for comparing waveforms. Technically, the template functions provide correlation, convolution and mean square error transformations of a template waveform against another waveform.

NOTE: To determine a level of comparison between two waveforms, use the Correlation function.

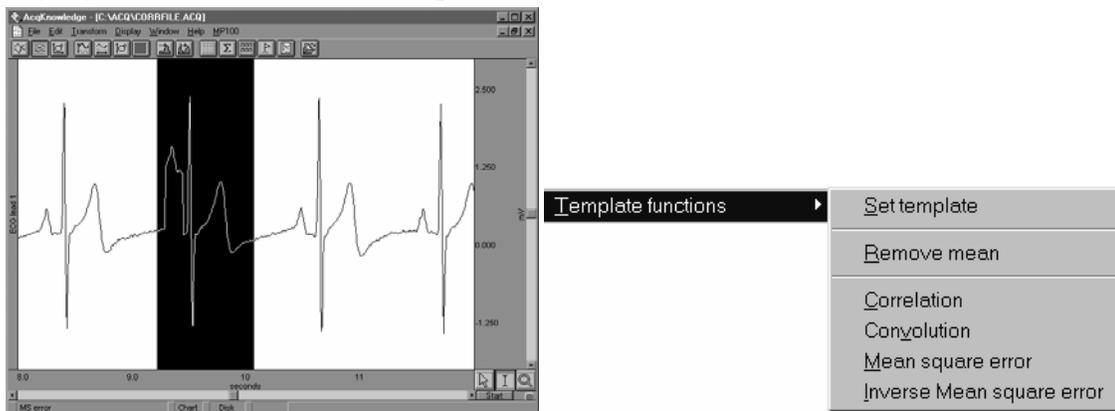
All the template functions perform a mathematical operation of the template waveform on the waveform to be compared, move one sample forward, and repeat the multiplication until the end of the longer waveform is reached.

Set Template

Use the following ECG waveform as an example. An abnormality exists in the record. After detecting an abnormality, you should find out if there are other (similar) abnormalities in the record. To do that, you need to select the pattern you'd like 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:

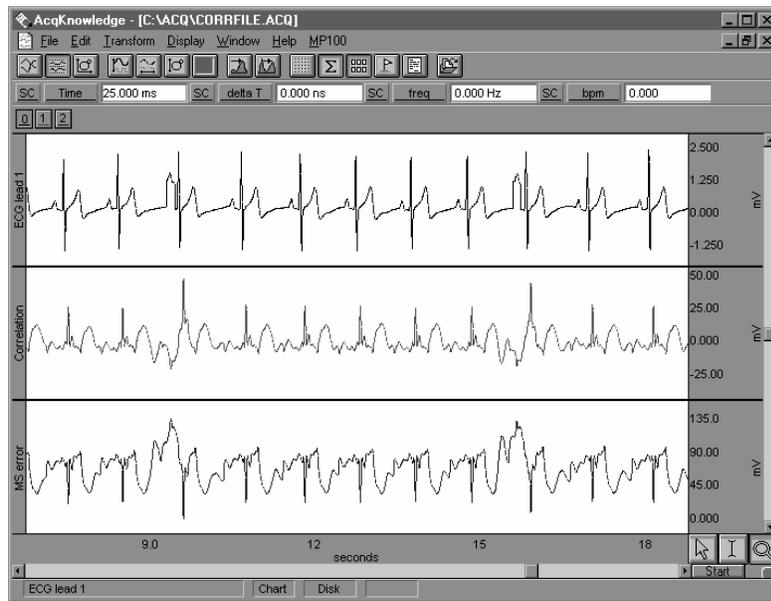
- 1) Highlight the section to be used as a pattern.



- 2) Click on 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 record. The first one appears at about 3 seconds and is the one used as a template; the second one appears at about 11 seconds.



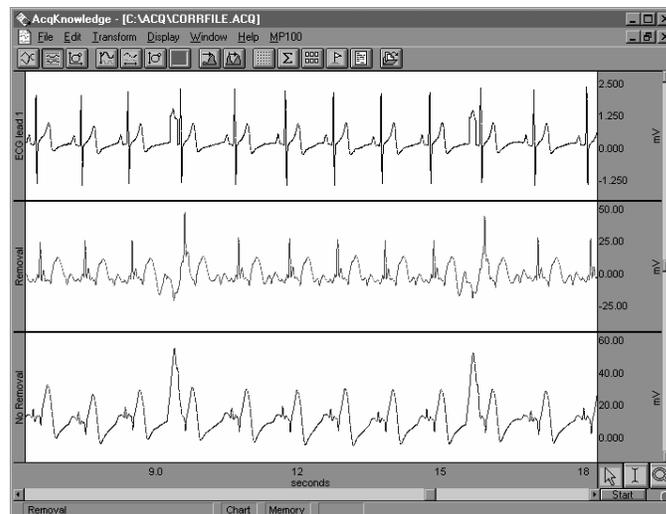
Result of correlation and mean square error functions

- 5) Use the zoom tool to inspect the abnormalities more closely.

Remove mean

A drifting baseline can be a problem in comparing waveforms. If you perform a Template function and the template or the waveform has a slowly moving baseline, you can increase the effectiveness of the comparison by choosing Remove mean from the submenu of the 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, and for Mac OS X only, normalize cross correlation and adaptive template matching.

- a) **Correlation** is a simple multiplication and sum operation (as shown in the preceding example). 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 $f_{\text{output}}(n)$ is the resulting data point, $f_{\text{template}}(k)$ is the template waveform data points, and K is the number of data points in the template:

$$f_{\text{output}}(n) = \sum_{k=1}^K f_{\text{template}}(k) * f_{\text{waveform}}(n)$$

- 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 $f_{\text{output}}(n)$ is the resulting data point, $f_{\text{template}}(k)$ is the template waveform data points, and N is the number of data points in the template:

$$f_{\text{output}}(n) = \sum_{k=-N/2}^{N/2-1} f_{\text{template}}(-k) * f_{\text{waveform}}(n+k)$$

- 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 you are 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 $f_{\text{output}}(n)$ is the resulting data point, $f_{\text{template}}(k)$ is the template waveform data points, and K is the number of data points in the template:

$$f_{\text{output}}(n) = \sum_{k=1}^K [f_{\text{template}}(k) - f_{\text{waveform}}(n)]^2$$

- 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) **Mac AcqKnowledge 3.9.1 and later only 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) *Mac AcqKnowledge 3.9.1 and later only* **Normalized cross-correlation** 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:

$$\gamma = \frac{\sum_{i=0}^L (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=0}^L (x_i - \bar{x})^2 \sum_{i=0}^L (y_i - \bar{y})^2}}$$

where x = template
 y = signal
 L = length
 \bar{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. This 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.

- g) *Mac AcqKnowledge 3.9.1 and later only* **Adaptive Template Matching**

Adaptive Template Matching
(template width: 238 samples)

Average template window size: matches

Correlation threshold:

Normalize matching data before updating average template

Reject matches closer than

Output

Show normalized cross-correlation values

Generate synchronization waveform

Define events at match locations:

Type:

Label:

Transform entire wave

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 features 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 feature is specified as the input template and 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 features. The adaptation consists of a moving average of a number of the most recent matching features. 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 *AcqKnowledge*.

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:

<u>Time (seconds & HH:MM:SS)</u>	<u>Frequency</u>	<u>Arbitrary</u>
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

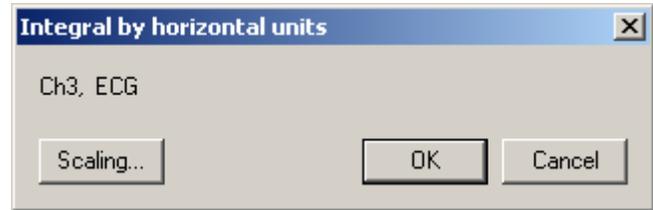
When checked, the entire waveform will be analyzed. When unchecked, only the selected area will be transformed.

Integral

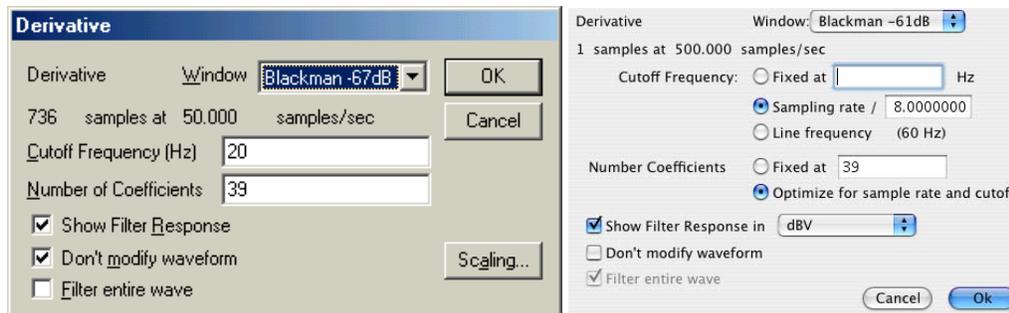
Integral is essentially a running summation of the data. Each point of the integral is equal to the sum of all the points up to that point in time, exclusive of the endpoints, which are weighted by half. The exact formula is below, where $f()$ is the data values and ΔT_s is the horizontal sampling interval:

$$f_{\text{output}}(n) = \sum_{k=1}^{n-1} f_{\text{input}}(k) + [(f_{\text{input}}(n-1) + f_{\text{input}}(n)) / 2] * \Delta T_s$$

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, if you had 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.

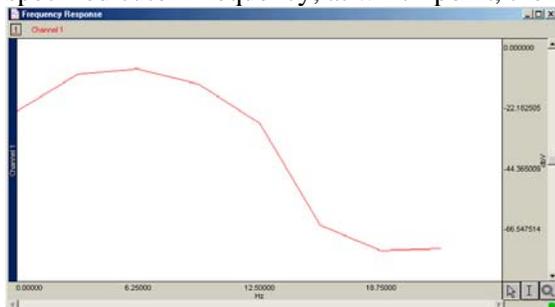


Derivative



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 220 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 as a linear graph, not in (log). 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 can provide a more meaningful result than Difference (which often has a higher than required frequency response, thus processing potentially undesirable data). However, if your data is already “well behaved” (i.e., low pass filtered or contains little or no high frequency information), you can use Difference with a 2-sample interval to quickly generate results very similar to Derivative.

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—**Mac AcqKnowledge 3.9.2 and later** Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.

Line frequency—**Mac AcqKnowledge 3.9.2 and later** Uses the line frequency at which the data was recorded.

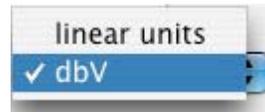
of Coefficients

Fixed—The default number of coefficients is $(4 \times \text{waveform sampling rate}) / \text{Cutoff Frequency}$. 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— **Mac AcqKnowledge 3.9.2 and later** 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.

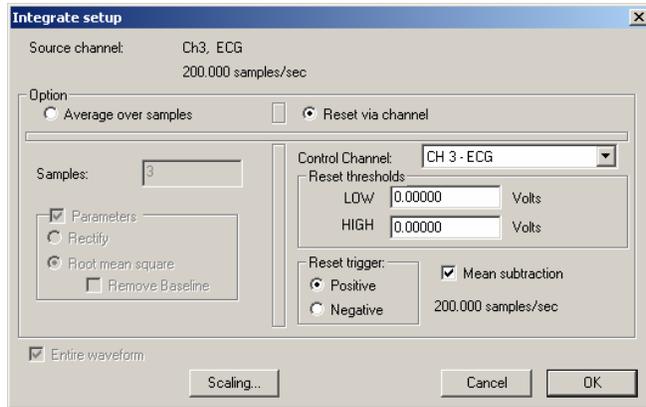
Units

Mac only 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 $(2 \times 100/1)$ or 200 coefficients in the filter. Additional coefficients will improve the response.

Integrate



The Integrate transformation operates the same as the Integrate calculation—see page 63, 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:

$$\text{Sqrt}(\text{sum}(x^2)/(n))$$

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.

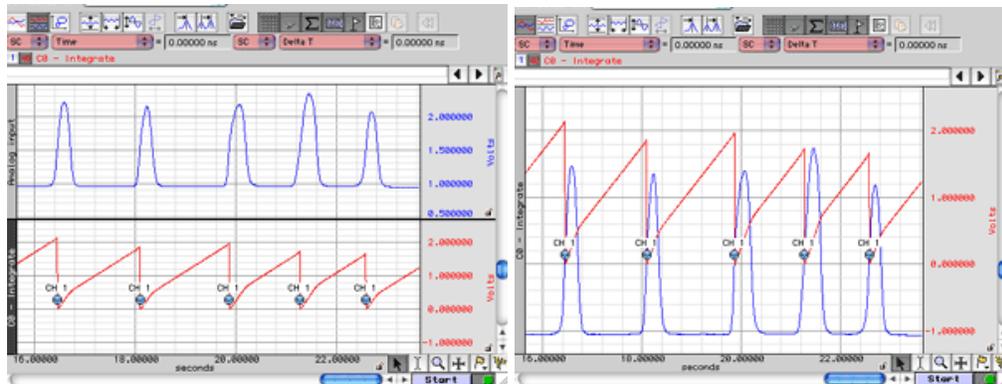
Offline

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

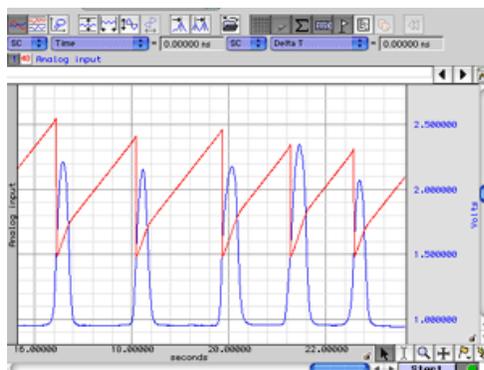
Mac OS X

Enable the checkbox option to create an Event at each signal reset.



Windows/PC

Manually overlap the source and response waveforms to identify signal reset.

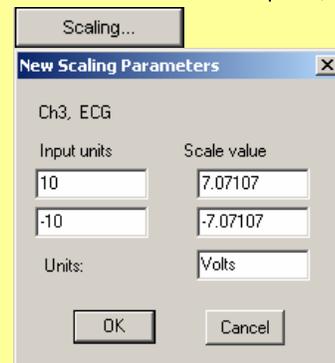


The Integrate formula is the same in the calculation (online, real-time) mode and the transformation (off-line, post-processing) mode; it varies only based on the parameters selected.

Notes

- For the first points, value of index “*i*” will be *less than or equal to zero*; it means that for summation you have only values beginning with $f(x_1)$.
 - For the first point for summation you have: $f(x_{-1}), f(x_0), f(x_1)$.
 $f(x_{-1})$ and $f(x_0)$ - don't exist, so you have only $f(x_1)$.
 - For the second point for summation you have: $f(x_0), f(x_1), f(x_2)$.
 $f(x_0)$ - doesn't exist, so you have only $f(x_1) + f(x_2)$.
- The Integrate formula is implemented as a Standard Deviation formula (see [mathworld.wolfram.com > Wolfram Research > equation 5 at http://mathworld.wolfram.com/StandardDeviation.html](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 as a [pdf](http://www.uic.edu/classes/mba/mba503/971/503nts3.htm) or <http://www.uic.edu/classes/mba/mba503/971/503nts3.htm>.
 - For a window size *n*, to convert from the *n-1* definition to the *n* definition, use $\sqrt{\frac{(n-1)}{n}}$
- The formulas to calculate RMS are optimal for data with a zero mean (typical for biopotential data). For data with a non-zero mean, scaling can be applied. Click the “Scaling” button in the Integrate dialog (or click the channel's vertical scale to generate the Vertical Scale dialog and then click the “Scaling” button), and then enter the following parameters:

<u>Input value</u>	<u>Scale value</u>
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;

$\Delta x = \frac{x_n - x_1}{n - 1}$ - horizontal sample interval;

x_n, x_1 - values at horizontal axis at the endpoints of selected area.

Integrate formulas, continued...

 See *Notes* on page 242

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)

$$F(x_j) = \sqrt{\frac{\sum_{i=j-s+1}^j (f(x_i))^2}{s - 1}}$$

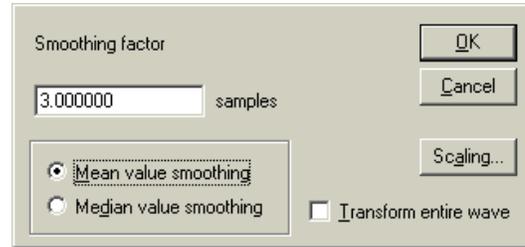
Where: i - index for source values (**the real range is 1..j); j - index for destination values (1..n); n - number of samples; x_i, x_j - values of points at horizontal axis; $f(x_i)$ - values of points of a curve; $F(x_j)$ - integrated values of points of a curve; s - number of samples to average across.

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 $j > s$ $k=s$

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 value of the moving average “window.” This has the same effect as a crude low pass filter, with the advantage being that smoothing is typically faster than digital filtering.

Samples *AcqKnowledge* allows you 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 *AcqKnowledge* will compute the average of three adjacent samples and replace the value of each sample with the mean before moving on to the next sample. For data acquired at relatively high sampling rates, you will probably want to set the smoothing factor to a higher value, since smoothing three sample points when data is collected at 1000Hz 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 box.

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 used 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:

$$f_{\text{output}}(n) = \frac{\sum_{k=n-(m/2)}^{k=n+[m-1]/2} f_{\text{input}}(k)}{m}$$

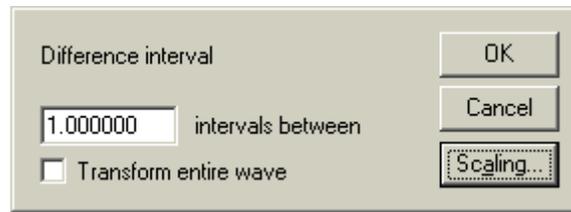
Median value Use Median value smoothing if some data points appear completely aberrant and seem to be “wild flyers” in the data set.

The Median value smoothing formula is shown below, where “m” is the number of points in the window and “n” is the sample number:

$$f_{\text{output}}(n) = \text{median}(n - [m/2]; n + [m/2])$$

Scaling Generates the Scaling Parameters dialog.

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 you select the difference transformation, a difference interval dialog box will be generated and you can enter the number of intervals between samples (default of 1).

For data with no high frequency components, a 1-interval difference transformation approximates a differentiator.

Since it is not implemented as a convolution, Difference is much faster than the derivative function.

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 ΔT_s is the horizontal sampling interval:

$$f_{\text{output}}(n) = \frac{f_{\text{input}}(n + \lfloor m/2 \rfloor) - f_{\text{input}}(n - \lfloor (m+1)/2 \rfloor)}{(\Delta T_s * m)}$$

Example for boundary values when
m = 3:

$$f_{\text{output}}(0) = (f_{\text{input}}(1) - f_{\text{input}}(0)) / (\Delta T_s * m)$$

$$f_{\text{output}}(1) = (f_{\text{input}}(2) - f_{\text{input}}(0)) / (\Delta T_s * m)$$

$$f_{\text{output}}(2) = (f_{\text{input}}(3) - f_{\text{input}}(0)) / (\Delta T_s * m)$$

If you enter an odd number
(K = odd):

$$f_{\text{output}}(K) = (f_{\text{input}}(K+1) - f_{\text{input}}(K-2)) / (\Delta T_s * m)$$

If you enter an even number
(K = even):

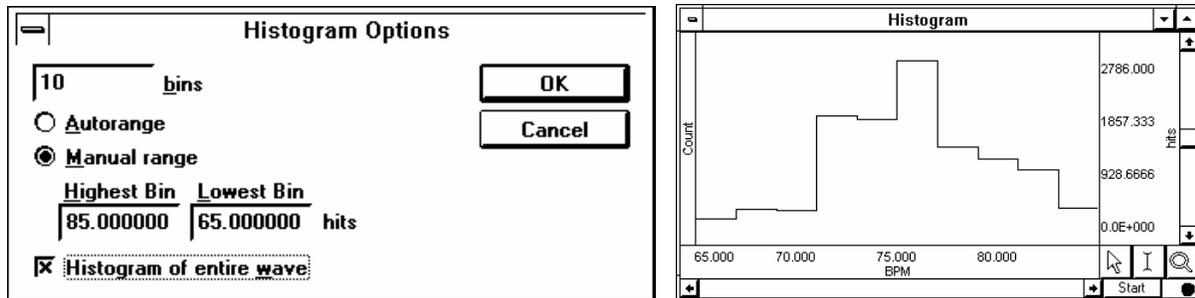
$$f_{\text{output}}(K) = (f_{\text{input}}(K+2) - f_{\text{input}}(K-2)) / (\Delta T_s * m)$$

Note: The online (real-time) Difference calculation is calculated differently because projected values are not available. The online Difference formula is:

$$f_{\text{output}}(n) = f_{\text{input}}(n - m) - f_{\text{input}}(n) / (\Delta T_s * m)$$

Using the default difference setting of 1 interval will produce a “ $\Delta P/\Delta T$ ” waveform when the transformation is applied to a blood pressure or similar waveform.

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. *AcqKnowledge* then counts the number of “hits” (the number of data points) in each bin and plots this number on the vertical axis.

The Transform>Histogram Options dialog box has these 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).
- Manual** Use to fix the bin sizes. Enter values for the Highest Bin and Lowest Bin.

Mac OS X only—Manual and Autorange are toggled instead of radio buttons.

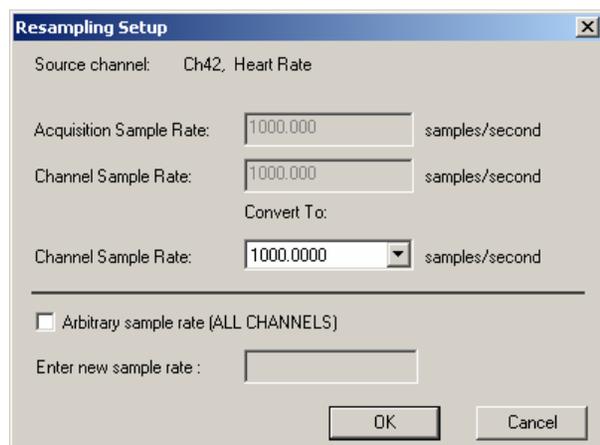
When you click OK, a histogram plot will be generated in a new window. By default, *AcqKnowledge* displays the frequency of occurrence for each bin on the vertical axis. To calculate the cumulative frequency, select the entire histogram waveform and choose Integrate from the Transform menu.

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, you may want 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.

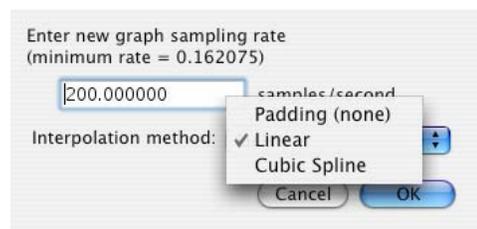
Resample

Resample Graph

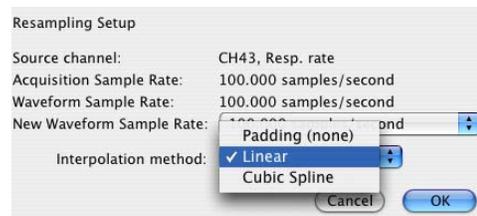
Resample Waveform



Resample – AcqKnowledge Windows



Resample Graph – AcqKnowledge Mac



Resample Waveform - AcqKnowledge Mac

Resample is equivalent to *Mac OS X* Resample Waveform.

This function resamples the active channel to another rate. Resampling data maintains the same time scale but changes the number of samples per second. You can also use Resample to increase the number of sample points per interval (usually samples per second). When this is done, *AcqKnowledge* 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.
 - For instance, a 4-channel data file sampled at 250 samples per second for 15 minutes takes up 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
- Whenever data is resampled to a lower rate, information is lost.
- The highest sampling rate that a channel can be resampled to is the file acquisition rate (MP 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.

TIP: A good rule of thumb is that data should be sampled anywhere from two to ten times the highest frequency component of interest.

The alpha component of an EEG signal has a frequency signature of 8-13Hz, so (assuming you have isolated the alpha component using a band pass filter) you would probably want to sample the data (in this case, isolated alpha waves) at a rate of at least 26Hz and probably no more than 130Hz.

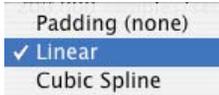
Arbitrary Sample Rate

Arbitrary Sample Rate options are equivalent to *Mac OS X* Resample Graph.

To apply an arbitrary, user-defined sample rate to ALL CHANNELS, enable this option, enter the arbitrary rate into the text box, and then click OK.

- The highest rate you can enter is the Acquisition Sample Rate.
- This option applies the specified rate to ALL CHANNELS, but will adjust as necessary to maintain the established channel rate/acquisition rate proportion.
- You can create channel-specific rates by changing the channel sample rate after Resampling.

Resampling Interpolation Options



AcqKnowledge 3.91 Mac only—Variable sampling rate and the flexible acquisition speeds of MP 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. AcqKnowledge has resampling facilities with

- Transform > Resample Graph
- Transform > Resample Waveform
- Pasting between graph windows of different sample rates when the “Interpolate pastings between windows” Preference is enabled (via Display > Preferences, page 311).

AcqKnowledge provides three interpolation options for resampling data: padding, linear, or cubic spline. The interpolation method can be chosen through popup menus in the graph and waveform resampling sheets for the transformations and through a popup menu in the Preferences dialog for interpolated pasting between windows.

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 wave as the data is resampled. Padding is desirable when it is imperative no new data or data approximations get introduced into an analysis.

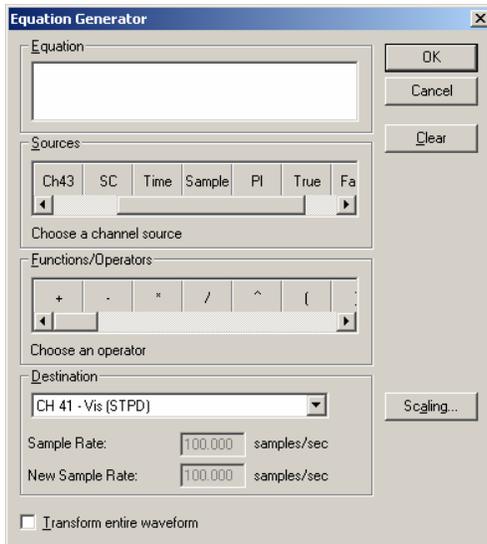
Linear interpolation

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.

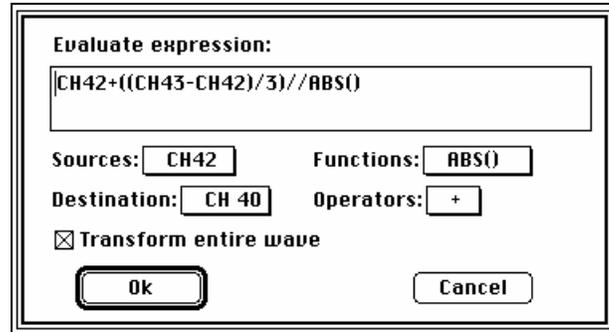
Cubic spline interpolation.

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.

Equation Generator (Expression)



See the tables starting on page 75 for descriptions of sources, operators and functions for the Equation Generator/Expression dialog.



Equation dialog boxes (PC on left, Mac on right)

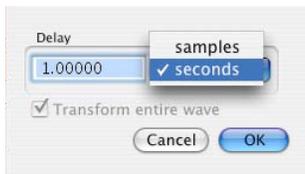
The post-acquisition Equation Generator (Expression) is available for performing computations more complex than available with the Math and Function calculations. The post-acquisition version of the Equation Generator includes all the same features as the online version described on page 77. The Equation Generator 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 Equation Generator can combine data from multiple analog channels, or specify other calculation channels as input channels. Also, computations performed by the Equation Generator eliminate the need for “chaining” multiple channels together to produce a single output channel.

To have *AcqKnowledge* solve an equation/expression and save the result to a new channel, choose Equation Generator from the Transform menu. A dialog box will be generated. For each equation/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 different components of each equation/expression can be entered either by double-clicking items from the pop-up menus (sources, functions, and operators) in the setup dialog box, or by typing commands directly into the box using standard mathematical notation.

You can divide a complex equation into several steps and perform each part of the equation with a separate channel. With up to 60 channels, almost any calculation can be performed.

When using the Equation Generator, both the Mac and PC versions of *AcqKnowledge* can reference past and future points.

Delay



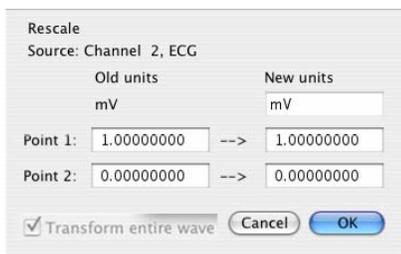
Mac AcqKnowledge 3.9.2 and later only—AcqKnowledge has a calculation channel that can be used to add time delays to signals. The equivalent delay transformation allows the addition of time delays in postprocessing. Similar to the calculation channel, the time delay can be added by introducing zero-valued 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 end of the wave prior to the delay will be lost, with the length equal to the delay. The delay can be applied by using the Transform > Delay menu item.

When inputting the delay amount, the units can be changed between seconds and samples.

- The samples units are relative to the graph sampling rate, the highest possible sampling rate for information in the graph. If using delays on waveforms that have been downsampled, the actual number of samples introduced will be the value in the dialog divided by the waveform's sampling rate divider.

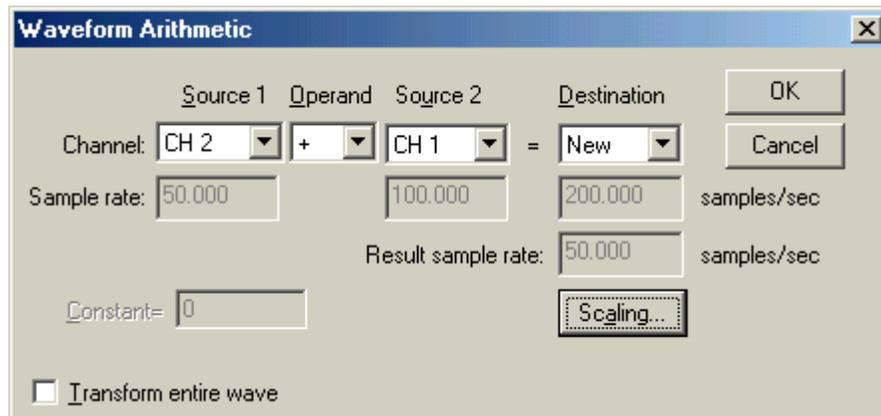
The Automator action allows Delay to be used in Automator workflows. See page 19.

Rescale



The Rescale transformation operates the same as the Rescale calculation—see page 90.

Waveform math



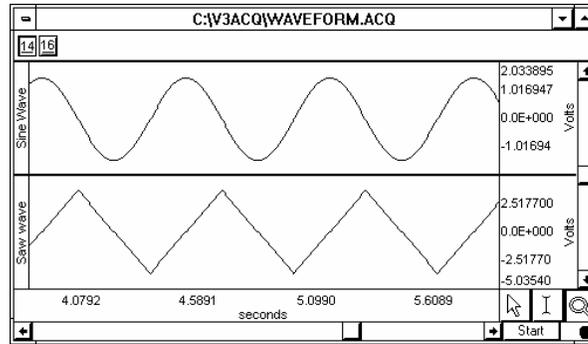
The Waveform math transformation allows arithmetic manipulation of waveforms. Waveforms can be added together, subtracted, multiplied, divided or raised to a power. These operations can be performed using either two waveforms or one waveform and an arbitrarily defined constant. You can operate on the entire waveform by choosing Edit>Select all, 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.

When you select Transform>Waveform Math, the Waveform Arithmetic dialog will be generated.

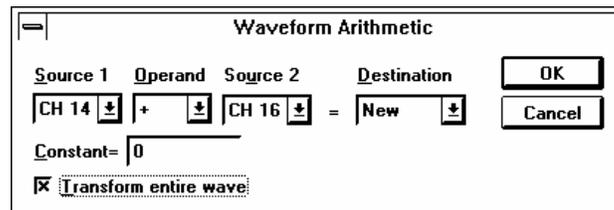
All of the main components of a waveform math calculation can be selected from pop-up menus in the Waveform Arithmetic dialog box.

- 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 allow you to select 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** You can save the results to an active channel, or create a new channel to store the results. 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).
- Result sample rate** When using variable sample rate processing, the Equation Generator 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 (*F* low).
 - If the destination channel for the result has an assigned rate other than (*F* low), the operation will not be permitted.
 - If the destination channel is set to a new channel, the operation will always be permitted.
- Scaling...** Generates the scaling parameters dialog.

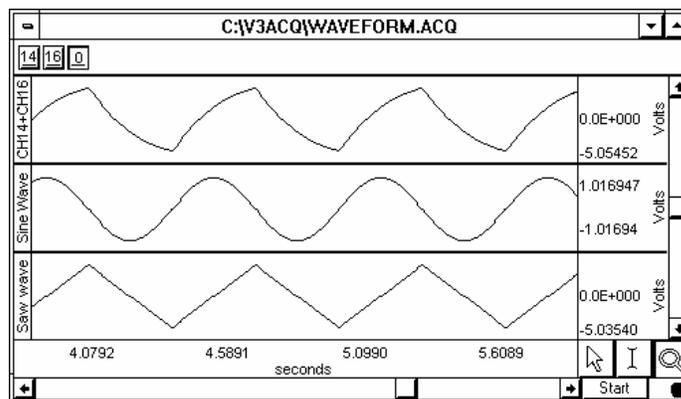
Waveform math can be used many ways. As one example, two waveforms can be added together. The following screen shows a sine wave in channel 14 and a triangle wave in channel 16.



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 you select two waveforms of unequal length 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.

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 *AcqKnowledge* support more advanced physiological analysis than is possible with the linear regression measurement, which is a rudimentary single order linear model.

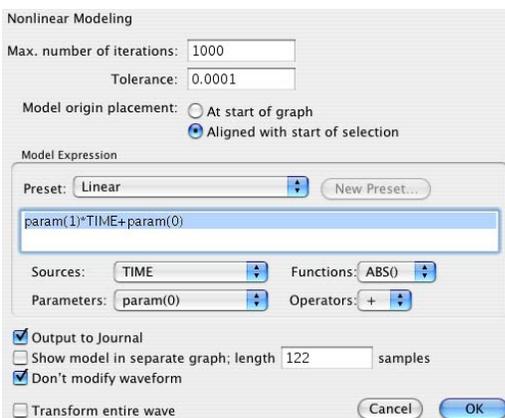
Nonlinear modeling is the process of finding the best fit of a mathematical function to an arbitrary data set. Fitting the function—or model—to the data consists of choosing a set of function parameters that minimize error between the actual data points and the values generated from the model function.

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 *AcqKnowledge* allow researchers to analyze data using the tau constant and potentially develop robust algorithms for its calculation.



See the *NLM measurement on page 158*

Mac OS X only—Nonlinear modeling (also called “arbitrary curve fitting”) determines the “best fit” of an arbitrary function to source data; the function is called a *model*.

AcqKnowledge uses a Nelder-Mead simplex search with a Euclidean distance function. 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

Models are defined through basic expressions, called Model Expressions. See the function tables starting on page 81 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.

Preset	Description	Equation
Cubic	3rd order polynomial.	$\text{param}(3)*(\text{TIME}^3)+\text{param}(2)*(\text{TIME}^2)+\text{param}(1)*\text{TIME}+\text{param}(0)$
Gaussian	Standard Gaussian model; useful for peak fitting.	$\text{param}(0)*\text{EXP}(-((\text{TIME}-\text{param}(1))/\text{param}(2))^2)$
Linear	Basic linear fit of the data.	$\text{param}(1)*\text{TIME}+\text{param}(0)$
Logarithmic	Logarithmic growth and decay; useful for initial rapid growth/decay followed by gradual decline/increase.	$\text{param}(0)*\text{LOG}(\text{TIME}-\text{param}(1))+\text{param}(2)$
Logistic	Logistic LVP relaxation model; T_L given by $a(1)$.	$\text{param}(0)/(1+\text{EXP}(-\text{TIME}/\text{param}(1)))+\text{param}(2)$
Monoexponential	Exponential LVP relaxation model; T_e given by $a(1)$.	$\text{param}(0)*\text{EXP}(-\text{TIME}/\text{param}(1))+\text{param}(2)$
Power Series	Useful for a wide variety of data, e.g. reactant analysis.	$\text{param}(0)+\text{param}(1)*(\text{TIME}^{\text{param}(2)})$
Quadratic	2 nd order polynomial.	$\text{param}(2)*(\text{TIME}^2)+\text{param}(1)*\text{TIME}+\text{param}(0)$
Weibull Distribution	Commonly used in reliability analysis.	$\text{param}(0)*\text{param}(1)*\text{TIME}^{(\text{param}(1)-1)}*\text{EXP}(-\text{param}(0)*\text{TIME}^{\text{param}(1)})$

Sources

All channels except the channel being modeled can be used as Sources; if the channel of data being modeled is inadvertently set as a Source, a syntax error prompt will be generated.

Parameters

Parameters are represented by $\text{param}(n)$ where n is an integer index starting from zero. For example, in the linear model $\text{param}(0)*x+\text{param}(1)$, $\text{param}(0)$ can be interpreted as the “a” in “ $ax+b$ ” and $\text{param}(1)$ can be interpreted as the “b” in “ $ax+b$ ”.

Output to Journal displays the result of the modeling as text in the journal.

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.

Autoregressive Modeling

About autoregressive modeling

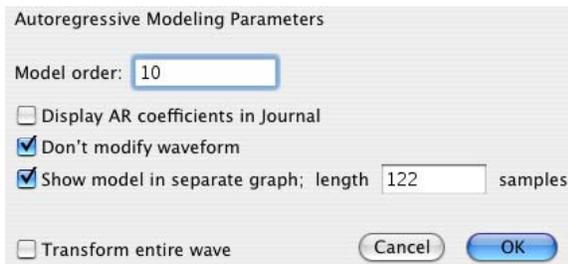
Autoregressive Modeling is a linear mathematical modeling algorithm that represents a signal as a weighted sum of its previous values combined with a noise factor. Autoregressive models are adept at capturing frequency behavior of an input signal and may be useful in generating high-resolution FFTs from undersampled data.

AR models are well suited to operation on discrete series of data and are particularly useful for expressing frequency information of a signal. Consecutive models can be used to perform advanced time series analysis, compression, denoising, arrhythmia detection, and waveform classification. AR models are commonly used on physiological data in advanced spectral analysis, and increasingly for classification of heart rhythms and gastric waves or visual detection of arrhythmias.

AR models can be used to extrapolate spectral features from waveforms at low sample rates.

- Generate high-resolution FFTs without fast acquisition sample rates (quite useful for electrogastrogram analysis).
 - An FFT from a 3,000-point AR Model provides the same result as a 42,000-point FFT.
- Examine spaces of AR parameters for feature extraction.

Since the underlying model is linear, AR modeling is not appropriate for representing signals that are inherently chaotic.



Mac OS X only—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.

[AR Time-Frequency Analysis is on page 256.](#)

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.

Power Spectral Density

The PSD extracts the power present at different frequencies within a signal and is useful for EMG analysis. *AcqKnowledge* uses the Welch approximation algorithm 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. The graph is plotted as horizontal frequency vs. vertical $(\text{units})^2/\text{Hz}$, where *units* are the vertical axis units of the source data. The PSD transformation approximates the same result as squaring the linear FFT magnitude, but does not allow for user-defined settings (windowing, dB/linear, etc.). Not available when the horizontal units of the source graph are set to Frequency.

AR Time-Frequency Analysis

Mac OS X only—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 254) 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.

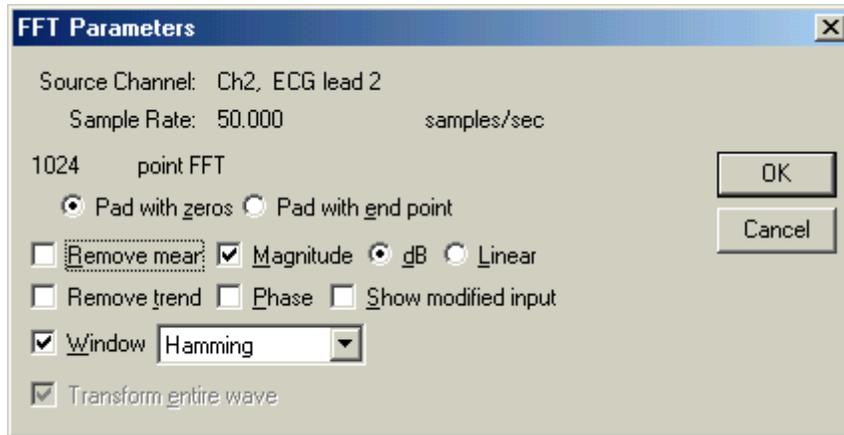
Show 3D Output

Constructs a 3D surface plot of the time-frequency analysis with amplitude vs. frequency vs. time.

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 length of your data 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, you need to include both the positive and negative frequency components. Since it's not physically possible to generate a negative frequency signal, you need to double the amplitude of the corresponding positive frequency component.

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, *AcqKnowledge* 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 118 for more information about real-time frequency information.

Pad If a section of data is selected that is not a power of two, *AcqKnowledge* will always “pad” data up to the next power of two, filling in the remaining data point with either

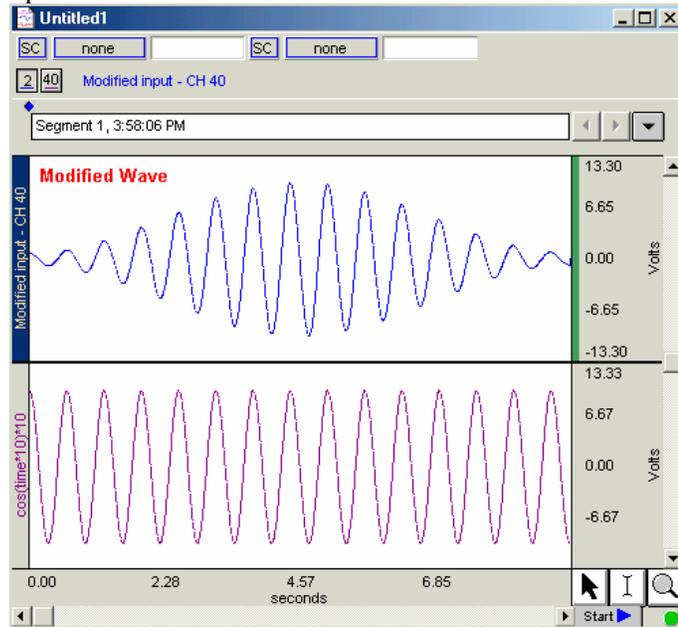
Pad with zeros: a zero

Pad with endpoint: the last data point in the selected area

In other words, if 511 data points are selected, *AcqKnowledge* 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.

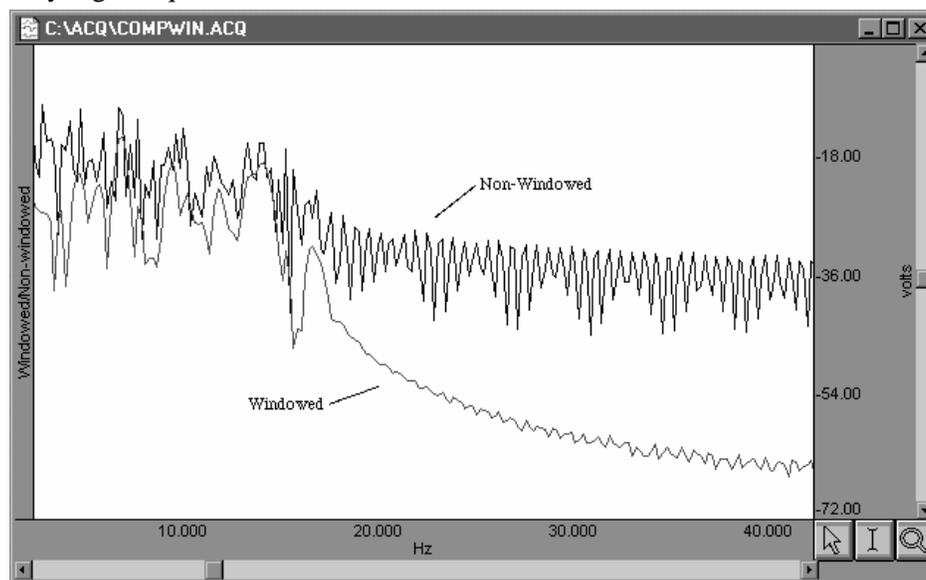
Show Mod.

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, you will get a frequency spectrum with 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.

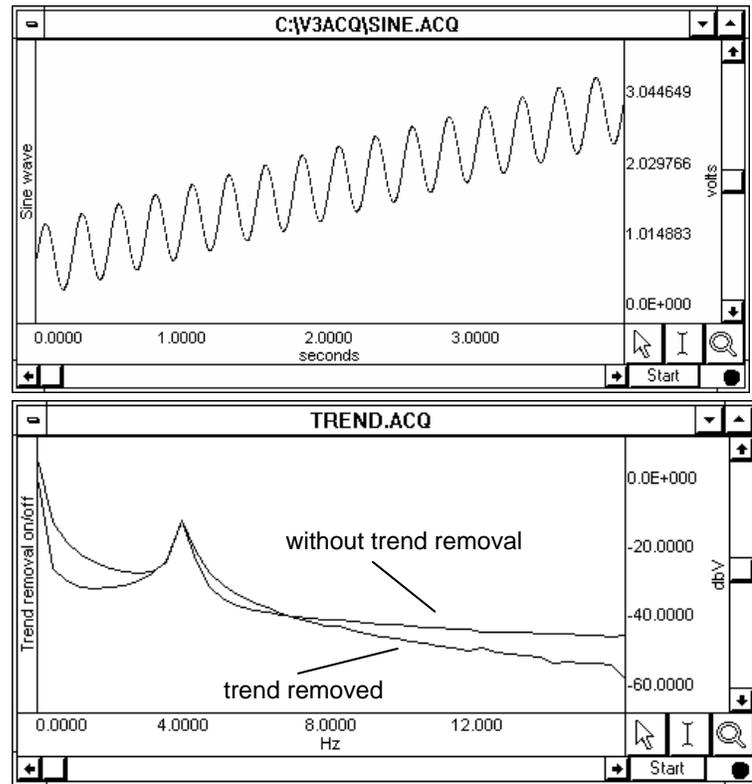


Remove Trend

Sometimes, data contains a positive or negative trend that can cause extraneous frequency components to “leak” into the frequency spectrum. In this case, you could select remove trend when you perform the FFT, which will draw a line through the endpoints, and then subtract the trend from the waveform.

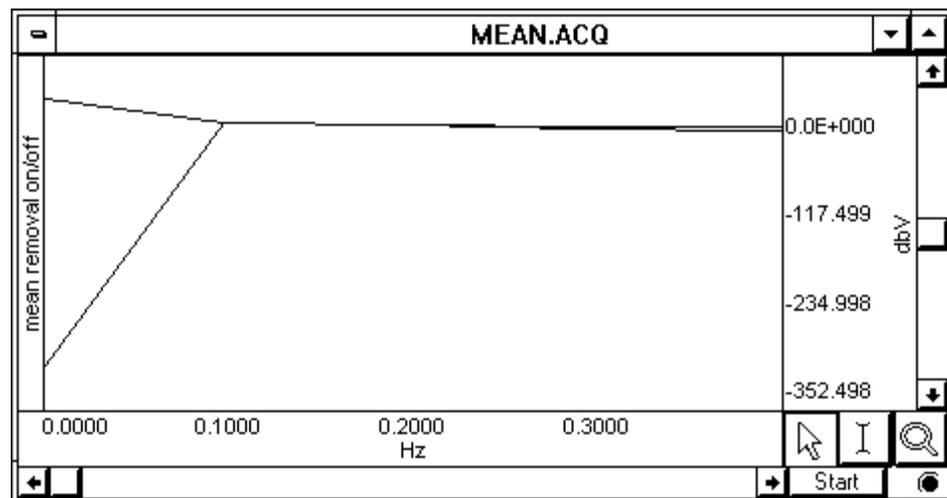
For example, the following sine wave has an upward trend through the data (positive trend component). The lower graph shows FFTs of the skewed sine wave data with and without the trend removed.

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, you might 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 your data has a large DC offset and you plan on windowing the data, you will generally get a more meaningful spectrum if you remove the mean prior to windowing (which is the same order the FFT uses).

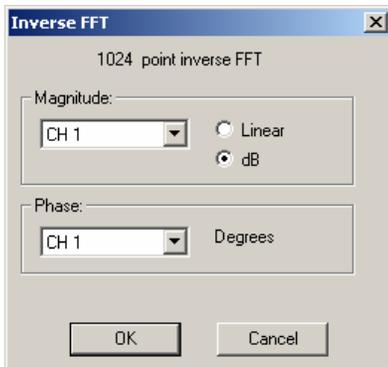
Linear

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 on the button next to linear and check OK. The other options in the dialog box work as they normally do when the dB scaling option is selected. The relationship between log and linear units is: $\text{dBV}_{\text{out}} = 20 \log \text{VIN}$.

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 exclusive of the magnitude option—you can check either independently, or if you check both, two plots will be produced (a magnitude plot and a phase plot).

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.

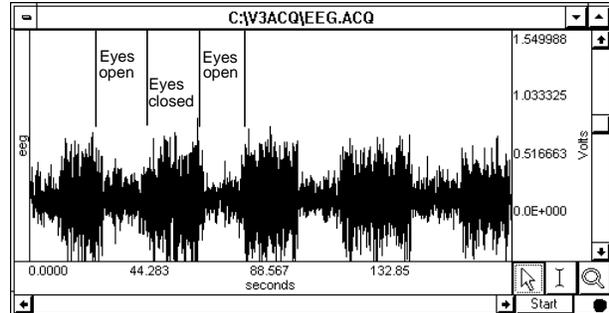
To obtain a meaningful IFFT result you must have a graph window open with at least one magnitude channel and at least one phase channel. With the window open, choose IFFT from the Transform menu to generate the Inverse FFT dialog box.

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...”

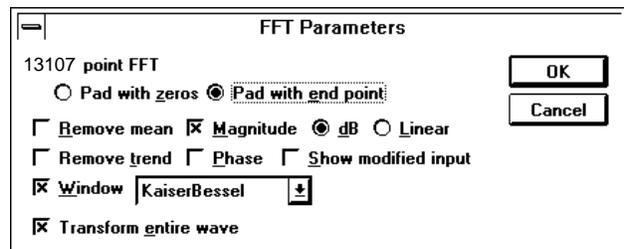
To perform an FFT, you might start with an electroencephalogram (EEG) signal acquired when the subject alternated between eyes open and eyes closed. Typical results suggest that higher levels of alpha activity (activity with frequency components between 8Hz and 13Hz) are to be expected when a subject's eyes are closed.

1. The raw data, prior to FFT, is shown here:



2. Select Transform>FFT from the menu.

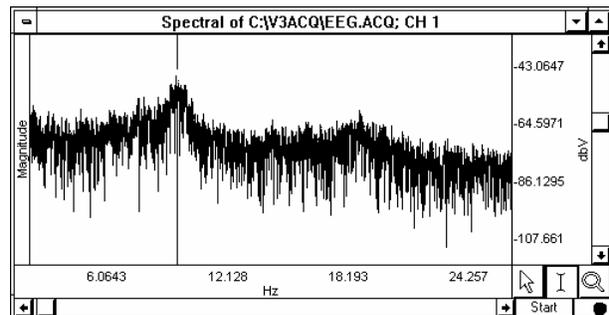
The FFT Parameters dialog will be generated; in this example, the Window function chosen is Kaiser Bessel:



3. Click OK.

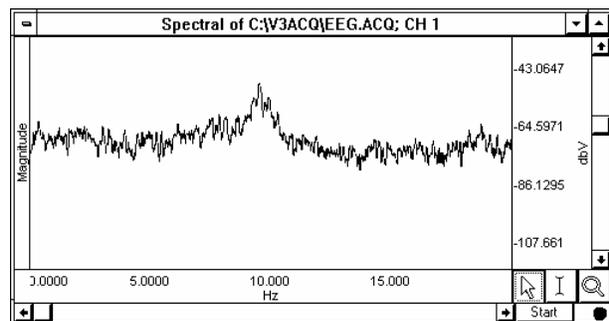
A frequency domain window (a graph window which places frequency along the horizontal axis rather than time) will be created and displayed, showing the spectrum of the input data.

The window is named “Spectral of (the original window name)” and ends with the channel number, as shown here:

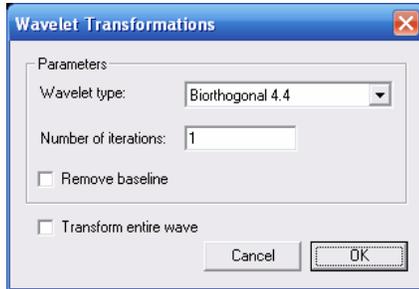


The resulting magnitude value for each component is equal to the peak value of the sine wave contributing to that component. The entire pattern of frequency components is known as the frequency spectrum of the data. The somewhat erratic appearance of the spectrum is usually due to small-scale variations 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 (0-20Hz shown) used 20-point smoothing.



DWT Wavelet Transformation



About Wavelet Transformation

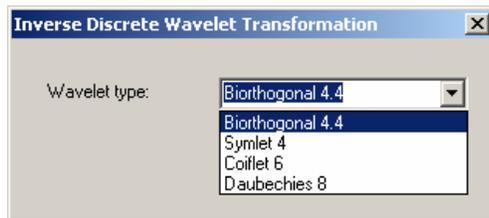
Wavelet transforms are similar to Fourier transforms. Instead of projecting a signal in a space of sines and cosines, wavelet transforms project a signal into a space comprised of orthogonal functions called *wavelets*. Discontinuities are more obvious in wavelet transforms than in sines and cosine analysis, 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 transforms 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-specific 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, or Daubechies 8.

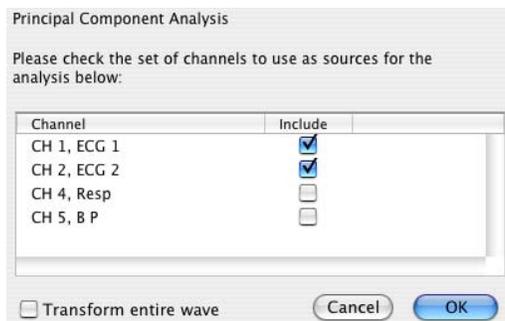
Number of iterations Specify the number of transforms to execute iteratively.

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.

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.

Mac OS X only—AcqKnowledge 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.

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

Independent Component Analysis

Please check the set of channels to use as sources for the analysis below:

Channel	Include
CH 1, ECG Lead 1	<input type="checkbox"/>
CH 2, CH40÷CH3	<input type="checkbox"/>
CH 3, ECG Lead 3	<input type="checkbox"/>
CH40, ECG Lead 2	<input type="checkbox"/>

Tolerance:

Maximum number of iterations:

Transform entire wave

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.

Mac OS X only—AcqKnowledge uses the FastICA algorithm to generate a new ICA graph with each component in a separate channel.

Select two or more channels—all of the selected channels must have the same sampling rate.

Specify tolerance and number of iterations.

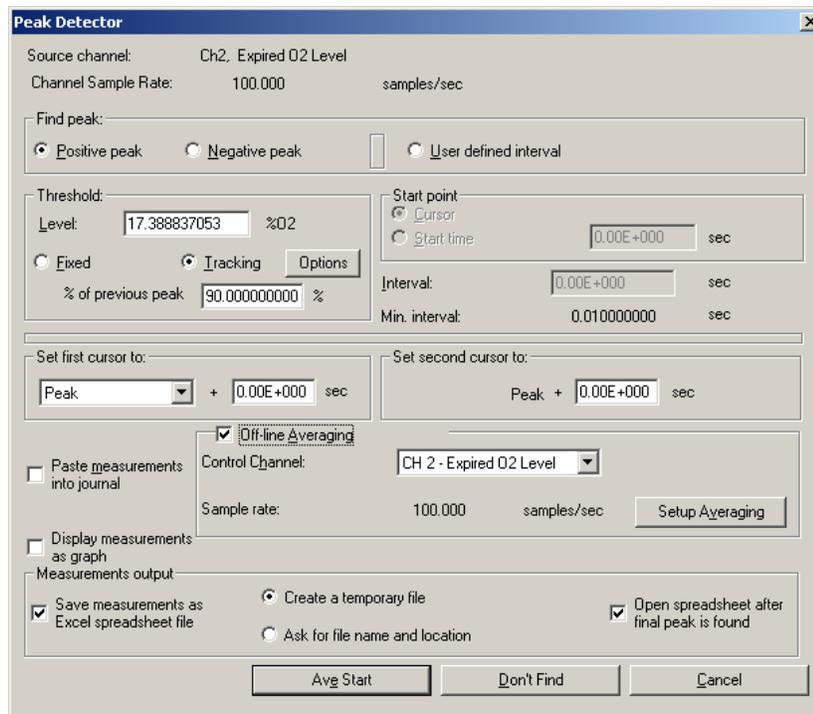
ICA limitations to consider for application and interpretation:

- 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).
- Sources must be statistically independent; highly-correlated signals cannot be effectively separated.
- Sources must have non-Gaussian probability distribution. It is not possible to separate out components like white noise through ICA.
- 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.
- 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 Peak (Peak Detector)—Windows/PC



Overview

- This section describes peak detection functionality for *AcqKnowledge* for Windows/PC only; see page 270 for functionality under *Mac OS X*.

The Find Peak (Peak Detector) function is a software analysis tool that automates measurement tasks. The Peak Detector provides a variety of mechanisms to automatically control the I-beam selection tool to automatically perform specific measurements on data in an *AcqKnowledge* data file which otherwise would have to be performed manually using the I-beam selection tool and the respective pop-up measurements. It is the primary tool used for waveform data extraction or reduction. The Peak Detector can perform automatic measurements on multiple channels simultaneously. The resultant measurements can be printed directly to the Journal or plotted, in graphical form, to a new channel in the *AcqKnowledge* data file.

Peak Detector Measurement Modes

In both of the operational modes, the Peak Detector advances (step-by-step) a single master cursor forward in time. The time jumps made by this master cursor are determined by the operational mode:

- 1) Data driven—The cursor (or selected area) is placed at a specified time offset to locate Positive peaks or thresholds or Negative peaks (valleys) in the data file. The master cursor jumps forward to the next point as defined by the data stream and the kind of feature (Positive peak or Negative peak) identified.
 - A good example of a data driven measurement is the determination of R-R interval in an ECG recording.
- 2) User-defined interval—The master cursor jumps forward by the pre-specified, user-defined interval.
 - A good example of a user-defined interval measurement is the determination of mean blood pressure values over ongoing, consecutive, 1-minute intervals.

The Peak Detector also employs sub-cursors. Sub-cursors can be set to fixed positions, in time, related to the master cursor. For example, the master cursor could be set up to move through the data at 30-second intervals, while the sub-cursors could be configured so that a data measurement would be performed several seconds before and several seconds after the location of each 30-second jump point.

Data Driven Measurements

Use this mode when you want the waveform data itself to drive the waveform data reduction process. In this mode, the algorithm will find positive or negative peaks or thresholds and move the I-beam to that found peak or threshold, offset in time by some fixed time delta. If the pop-up measurements are set to certain functions, the value returned by those functions will be present in the respective pop-up measurement result box.

In this mode, data is extracted from the waveform as mediated by the form of the data itself. In typical physiological recordings, data is often quite cyclic in nature. Data driven measurements are those that employ characteristics of the data cycles themselves to determine the interval over which the measurement is performed. The Peak Detector will simply “hop” from the peak of one R-wave to the next and, in the process of doing so, will automatically extract all the cyclic R-R intervals present in the ECG recording. When performing data driven measurements, the user can specify whether the software should look for positive peaks or negative peaks in the record. If “Positive peak” is selected, the Peak Detector will advance a master cursor, step-by-step, through all the positive peaks in the data file or selected area.

User-defined Measurements

Use this mode when the waveform data reduction requirements necessitate examining the data around many equally sized data segments. The algorithm will reference the I-beam to pre-selected time intervals that can be set to “chop” the waveform data into equal chunks.

In this mode, data is extracted from the waveform as mediated by a pre-defined time interval. The Peak Detector will simply “hop” to the next fixed point in time as indicated by the user-defined time interval. In all user defined interval measurements, the Peak Detector will advance a master cursor, step-by-step, through specific (fixed) time intervals, until the end of the file or selected area is reached.

Averaging

- A good example of this feature is assembling a representative or average blood pressure cycle from a larger collection of cycles.

A special feature of the Peak Detector is the ability to perform averages of data when performing data driven or user-defined measurements. As one example, the Peak detector might automatically identify the high (positive) or low (negative) points of a selected series of blood pressure cycles. The Peak Detector would be set up to look “before” and “after” each positive or negative blood pressure peak. After all the peaks were found, the *AcqKnowledge* software would automatically assemble the identified data to create the averaged beat.

Peak Detector Controls

Data-driven Mode

Find Peak



In data driven mode, the Peak Detector can look for Positive peaks or Negative peaks.

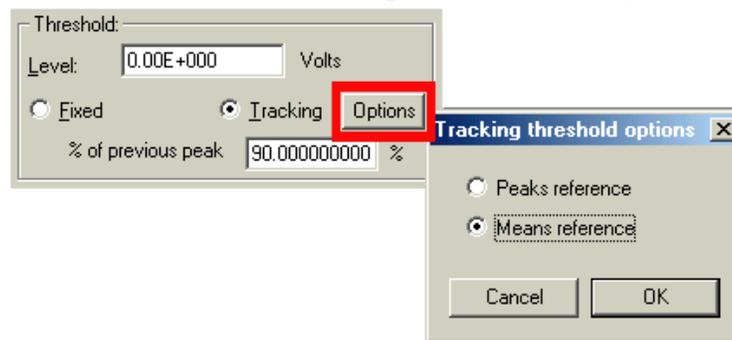
- Positive peak—the highest valued point in the data between crossings when data crosses a Fixed threshold, first positively and then negatively.
- Negative peak—the least valued point in the data between the crossings when data crosses a Fixed threshold, first negatively and then positively.

Fixed mode

In the simplest mode of data driven operation, the user can identify a Fixed value as the threshold point.

Threshold

The next simplest mode of data driven operation employs a Tracking threshold, which adjusts the threshold level each time another peak (Positive or Negative) is found.



Level

If an area is selected before the dialog is opened, the software will determine the optimum Level based on that area (the units are those of the waveform to be peak detected).

You can manually enter a threshold parameter in the threshold Level box to overwrite the software. If an area is selected when you reopen the dialog, the software will overwrite your manual Level entry. To refer back to manual Level entries, you need to note each manual entry before closing the dialog, or make sure only one data point is selected before reopening the dialog.

Tracking mode

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.

- % of previous peak—The value entered here determines the amount that the Tracking mode changes the threshold.
- The Options button generates a dialog with two tracking threshold options:
 - “Peaks reference”
 - “Means reference”

Options

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 probably a better choice.
- If data has an erratic baseline, but consistently sized, positive and negative peaks, the Peaks Reference Tracking Option is probably a better choice.

Means Reference

The default option for Tracking threshold operation employs a Means reference. This option will cause the software to 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 will determine the new threshold (NT) as follows:

For Positive Peaks

$$NT = \text{Mean Value} + (\text{Positive Peak Value} - \text{Mean Value}) \times (\% \text{ factor})$$

For Negative Peaks

$$NT = \text{Mean Value} - (\text{Mean Value} - \text{Negative Peak Value}) \times (\% \text{ factor})$$

Peaks Reference

An alternate option for Tracking threshold operation employs a Peaks reference. This option will cause the software to 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 will determine the new threshold (NT) as follows:

For Positive Peaks

$$NT = \text{Neg. Peak Value} + (\text{Pos. Peak Value} - \text{Neg. Peak Value}) \times (\% \text{ factor})$$

For Negative Peaks

$$NT = \text{Pos. Peak Value} - (\text{Pos. Peak Value} - \text{Neg. Peak Value}) \times (\% \text{ factor})$$

Set first cursor to

The selection area can be modified by the user for a fixed-distance and offset from the reference point. In data-driven mode, the first cursor can be set to any one of the following four options, plus a positive or negative fixed-interval of time:

- | | |
|------------------|-----------------------|
| a) Previous peak | c) Previous Threshold |
| b) Peak | d) Threshold |

Set Second cursor to The second cursor can be set to a threshold plus a positive fixed-interval of time only, as long as the first cursor is also referenced to a threshold.

User-defined Interval Mode

Find Peak

Start Point

The Start Point can be specified at either the existing cursor (I-beam) location or at a specified time.

Interval

The Interval is the reference point of the cursor (I-beam). The cursor will move by the specified time Interval as the Peak Detector algorithm automatically moves the cursor.

Set first cursor

The selection area can be modified by the user for a fixed-distance and offset from the reference point. In user-defined mode, the first cursor can be set to either of the following options, plus a positive or negative fixed-interval of time:

- | | |
|------------------|---------|
| a) Previous peak | b) Peak |
|------------------|---------|

Set second cursor

The second cursor can be set to peak plus a positive fixed-interval of time only. In user-defined mode, “peak” refers to the location of the next user-defined interval.

Paste Measurements into Journal

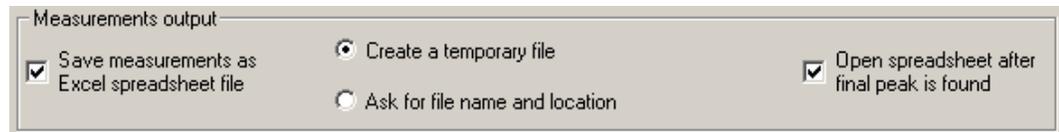
To automatically write values to the Journal, click in the box next to “Paste Measurements into Journal.”

Display Measurements as Graph

This option will plot the measurements as a graph in a new channel. Each measurement is assigned its own channel. As each measurement is calculated, the results can be pasted to the Journal or displayed as a new channel. This function provides a powerful way to summarize large data files for further analysis. For instance, starting with a 24-hour recording, you could use the data reduction tools to take the Mean every 20 minutes and then display the Mean as a graph.

- Measurements are inserted for all Find Peak operations, including Find All Peaks and Find Next Peak.
- A new channel is created for the measurement when:
 - a) a measurement changes between successive Find Peak operations
 - b) the Source channel for a measurement changes between successive Find Peak operations
 - c) a measurement channel is removed from the graph (Edit> Remove waveform)\
- Display Measurements as Graph is not available with Off-line Averaging.

Excel Spreadsheet Export



The cycle detector has also been enhanced to allow for the direct creation of spreadsheets. The cycle-to-cycle values of the measurements can be inserted directly into an Excel spreadsheet file. Each measurement is placed into an individual column and each cycle corresponds to a single row. To generate the spreadsheet a “Find All Cycles” operation is required.

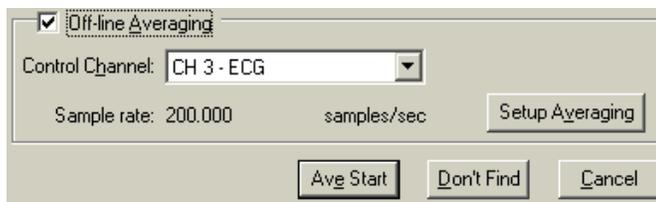
Don't Find

Lets you exit the Peak Detection dialog box and still retain the peak parameters (peak value, valence, and so forth). This is useful for setting parameters using an area of a waveform and then repositioning the cursor at another point in the record.

Cancel

Does not make or save any settings changes.

Off-line Averaging



The Off-line Averaging option works with both Find Peak modes. This option lets the user average waveform data together from different reference points in the complete data record. For instance, when evaluating an ECG record, Off-line Averaging can be used with Find peak: Positive peak to generate a composite ECG cycle—the “average looking” cycle of a specified number of separate ECG cycles.

Control Channel

The Control Channel option lets you detect events in one channel while averaging the response from another channel. Using the Control Channel function, you can perform averaging on one data channel even though the master cursor is synchronized (controlled) by another channel. This means that the average value of one signal can be computed around events in another signal, which is useful for ERP and P300 studies.

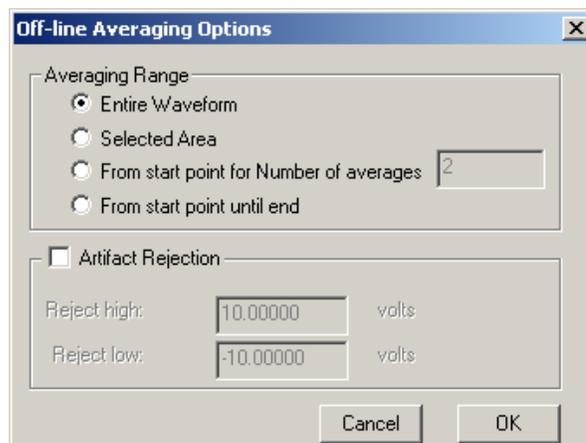
When Averaging is selected, a pop-up menu is activated for Control Channel selection. The default Control channel is the Source channel.

- A good example of this feature revolves around P300 measurements, where two or more Control Channels are used to sequentially average data. Using the SuperLab[®] presentation system, the average response can be determined based on when stimuli were presented to the subject. One Control Channel can correlate to stimulus A, and other Control Channels can correlate to stimuli B, C, D, etc. In this fashion, averaged responses to different types of sequentially presented stimuli can be compared and analyzed.

Setup Averaging

Averaging Range

- Entire Waveform—The average is generated with relevant data from the entire waveform.
- Selected Area—The average is generated with relevant data from only the selected area.
- From start point for Number of averages—The averaging algorithm collects relevant data from the start point and continues until the specified number of averages is reached.
- From start point until end—The averaging algorithm collects relevant data from the start point and continues until the end of the data file is reached.



Artifact rejection

Artifact rejection eliminates suspect data from the averaging process. Suspect data is identified as any sample value in a relevant data block that is higher or lower than the respective Reject high and Reject Low levels.

Ave Start Starts the average procedure per the established settings.

Find Cycle/Peak (Peak Detector) —Mac OS X



Overview

- This section describes peak detection functionality for *AcqKnowledge 3.9* for Mac OS X only; see page 264 for functionality under Windows.

The Find Cycle/Peak Detector uses three tabbed settings panels to define and automate cycle/peak detection.

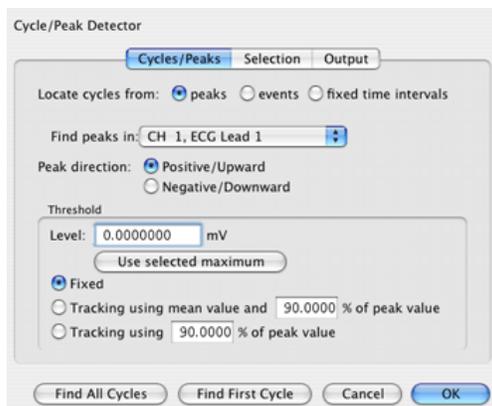
- Cycles/Peaks
- Selection
- Output

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.

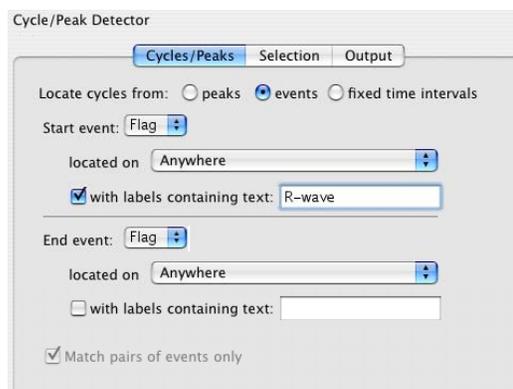
When the Cycle/Peak Detector is first opened for a graph, the sheet will be filled with the values from the last successfully executed find Cycle/Peak operation. Subsequently, changes to the settings will be applied only to that graph.

TIP (Mac only): If you're running the peak detector multiple times and need to put the cursor 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 cursor location.

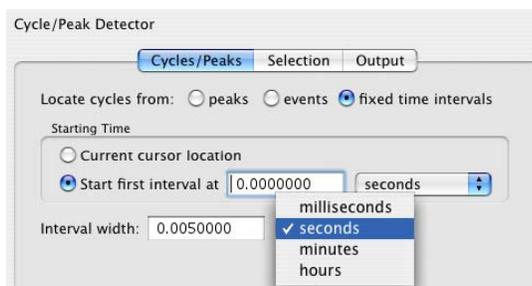
Cycles/Peaks tab



Peaks



Events

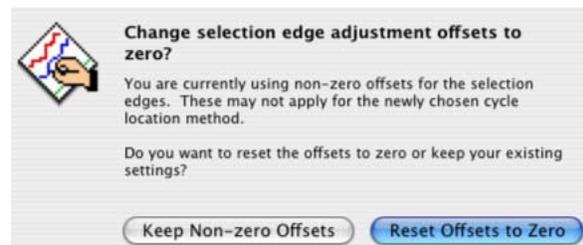


Fixed Interval

A cycle is defined as the interval between two events of user-specified types. The Cycles/Peaks tab offers three general methods for establishing cycle parameters:

- Peaks: Data driven maximum and minimum
- Events
- User-defined fixed time intervals

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 be generated to warn 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 previous cycle location mode.



be

the

Peaks

Peak direction See the Peak definitions on page 266.

Level **Important usage note**—Level is not set automatically when the Cycle/Peak detector is generated. (Automatic Level is used in previous versions of AcqKnowledge 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 on the “Use selected maximum/minimum” button underneath the level. If you change the source channel or peak direction, you can also use this button to re-compute the recommended level based upon your new settings”

Events

Event-based cycle location can extract information from events or define events based upon the output of the peak detector. A cycle is defined as the interval between two events of user-specified types.

- Start / End* Define the event; any of the predefined event types can be explicitly matched.
- Match pairs* “Match pairs of events only” is active when the Start event criteria are identical to the End event criteria. Toggle the checkbox to set this option. For a cycle to be located, a pair of two distinct events that match the criteria must be present. The event occurring earlier in time matches the left edge, later in time matches the right edge. This is the default search mode; this is the only search mode when the criteria are different.
- When unchecked, a single event can be used as the Start event and the End event of a cycle, which will produce a zero width cycle. 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 single-event matching 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 markers 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

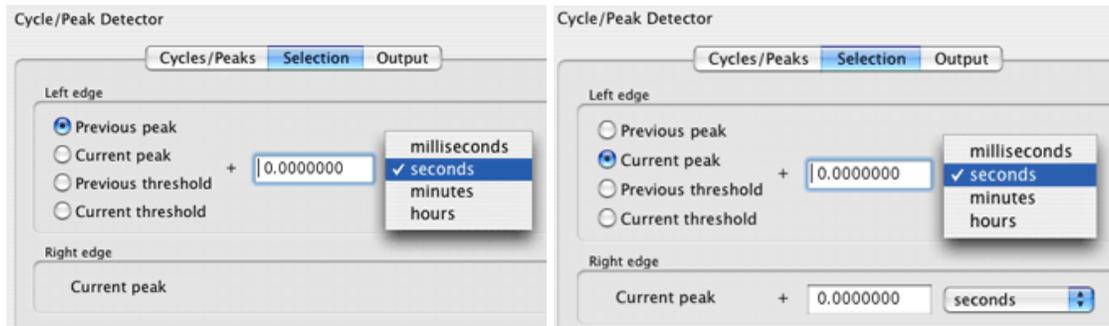
See the interval definitions on page 267 (same as for AcqKnowledge for Windows).

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

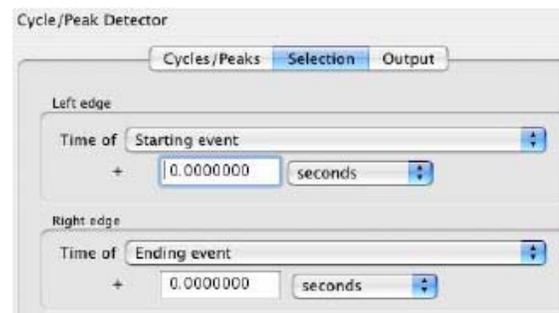
Peak When the Cycles/Peaks location method is “Peaks,” you can adjust the Selection based on the times of the peaks in the data or the times of the threshold crossings prior to the peaks.



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 your settings must place the left edge earlier in time than the right edge for the peak detection to succeed properly.

Event When the Cycles/Peaks location method is “Events,” you can adjust the Selection 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.

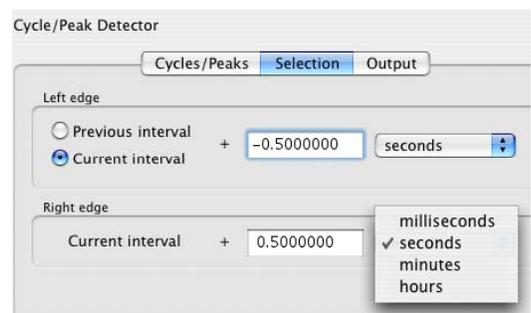


To analyze data over each entire cycle, use the “starting event” to “ending event” setting. To examine fixed-width time windows occurring within each cycle, set the left edge and the right edge to the same event (e.g. “starting event” to “starting event” for time windows at the beginning of each cycle) and adjust the offsets accordingly. Note that your settings must place the left edge earlier in time than the right edge for the peak detection to succeed properly.

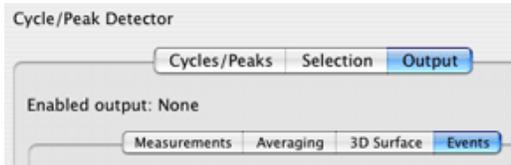
Fixed When the Cycles/Peaks location method is “Fixed time intervals,” you can adjust the Selection based on the endpoints of the time interval.

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 your settings must place the left edge earlier in time than the right edge for the peak detection to succeed properly.

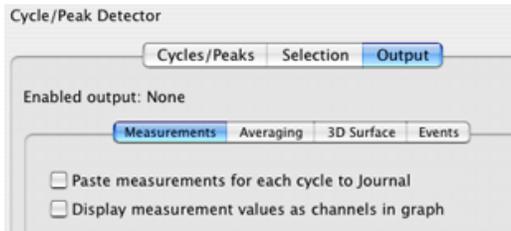


Output tab



The Cycle/Peak Detector includes four Output options, which can be independently enabled: Measurements, Averaging, 3D Surface, and Events. The selected output, if any, is listed at the top of the Output tab as Enabled output.

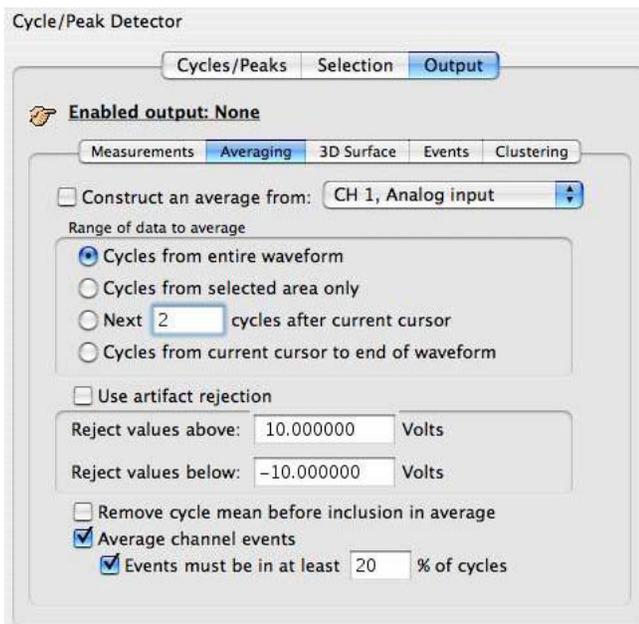
Output Measurements



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.

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.

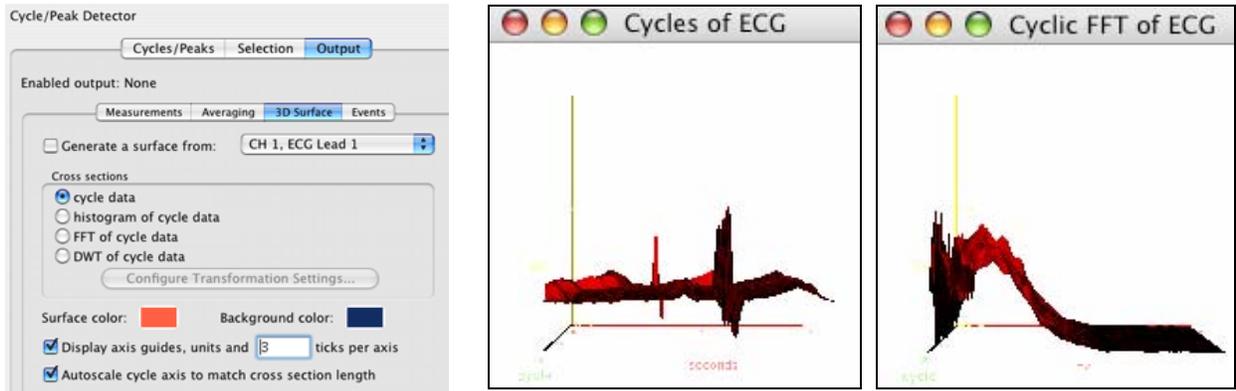
Offline averaging can produce average locations of events within the defined cycle along with the average data. When a cycle is found, any events in that cycle will be noted. Events that are on the channel of data being averaged will be examined for inclusion in the average. (See page 269 for offline averaging details)

- 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.

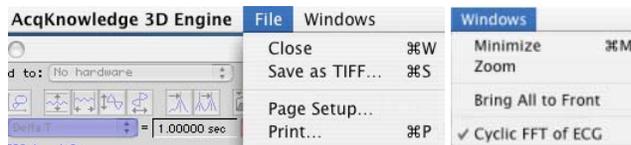
Remove... When mean removal is enabled, the mean value of the data within each cycle is subtracted prior to including it in the overall signal average. This mean removal option is useful for:

- 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.

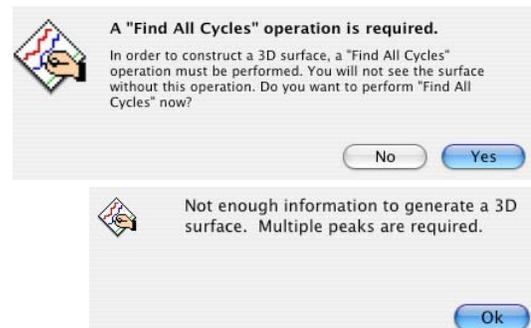
Output 3D Surface



3D Engine menus and prompts



Save as TIFF Choose File > Save as TIFF when 3D output is enabled.



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 cursor 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 on “Configure Transformation” to change the settings.
- 4) Select surface and background colors.
- 5) Set axis options.
- 6) Click OK.

Use the cursor to rotate the 3D image; the magnitude of display response increases as you leave the center of the screen (keep cursor close to center for slow response/display control).

3D Output Example

Compare ECG cycles in 3D Output. The following example shows how to AcqKnowledge 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 cursors to
 - Current Peak
 - Left edge -.5 seconds
 - Right edge .5 seconds
- c) On the **Output** tab

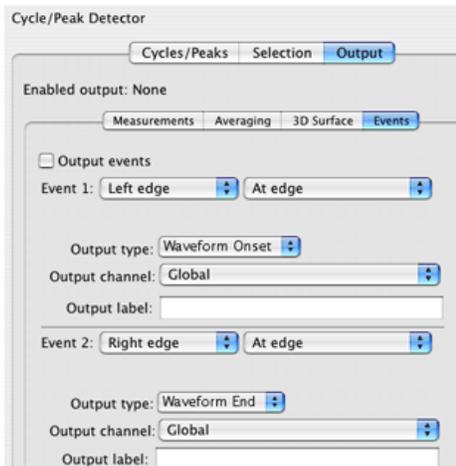
Enable 3D Output

Specify the channel to generate a surface from.

Choose “cycle data” for the cross-section format.

d) Click [Find All Cycles](#).

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 Peak 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 277 for details: At edge place the event directly at the specified edge (left or right). See Edge Adjustment on page 277.

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 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 maximum 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.
- Left edge / Right edge—a pull-down menu is displayed to be used to change between the different offset methods
- Minimum / Maximum

Output label

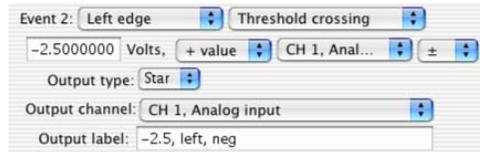
Use this edit field to type in specific label text. Each event that is inserted will have its label set to this text. By default, it is empty (inserted events will not be labeled).

Edge Adjustment

When an “at edge” location method is used, options will be generated to fine-tune event placement relative to that (right or left) edge of the selection.

Offset

Underneath the insertion method pull-down menu, a set of controls will be added that allow the user to specify the percentage, choose whether they want 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 edge. 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 edge, a negative sign can be placed before the offset.

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

<i>Insertion Method</i>	<i>Location Process</i>
Edge, at edge	Place an event at the left or right boundary of the selected area, as specified.
Edge +/- percent offset	<p>Given a particular channel, place an event at the specified time within the selection when the signal increases or decreases by a specific percentage.</p> <p>Left edge + 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.</p> <p>Right edge - 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.</p> <p>If the signal does not increase or decrease by that percentage within the selection, no event will be inserted.</p>
Edge +/- percent peak to peak offset	<p>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.</p> <p>Left edge + 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.</p> <p>Right edge - Place at the time closest to the right boundary. The distance between the event and the right edge 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.</p> <p>If the signal does not increase or decrease by that percentage within the selection, no event will be inserted.</p>
Edge +/- threshold crossing	<p>Starting at the specified boundary of the selection, determine a threshold value. This threshold voltage may be:</p> <ul style="list-style-type: none"> ▪ fixed voltage level ▪ value of signal at the specified edge + offset ▪ mean value in selected area + offset <p>Left edge + Search for the first location where the signal on a particular channel crosses the threshold.</p> <p>Right edge - Examining data from right to left, search for the rightmost location where the signal on a particular channel crosses the threshold.</p> <p>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.</p>
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: Clustering

Mac AcqKnowledge 3.9.1 and later only—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 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 as to match the mean value of all of the members of the set (referred to as expectation maximization).
- D. Determine if the set of clusters and centers is satisfactory. If not, go to step 2 and repeat the clustering process.

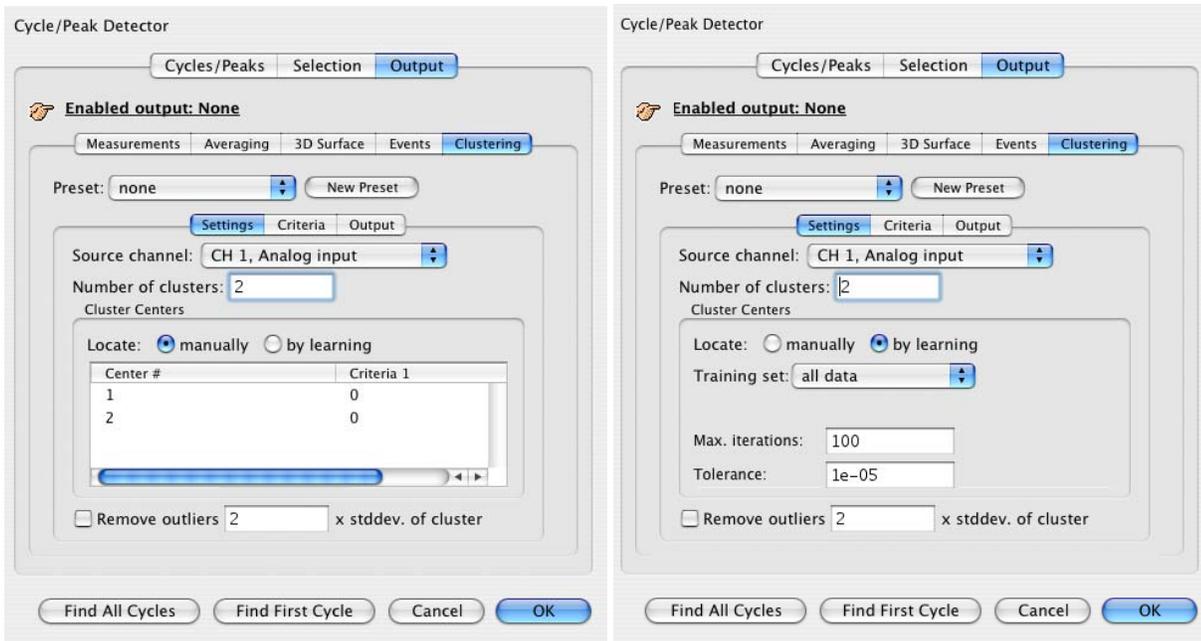
There are many different variations on what constitutes satisfactory ending conditions. The most ideal stopping criteria is when the cluster assignments do not change any longer with successive iterations. If there is no change in the centers, the solution perfectly minimizes the Euclidean distance sum 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 an indefinite amount of time. Approximations of perfect clustering are quicker to compute and usually produce sufficiently accurate results.

A useful termination condition for constructing approximate solutions is to place a tolerance on how much the centers are moved in successive steps. If the total distance between the centers at subsequent steps of the algorithm is less than a specific tolerance, the centers can be assumed to approximate the ideal solution. Another potential termination condition is to limit the maximum number of steps that are executed. This condition does not necessarily produce a usable approximation, but it does provide a way to halt execution. This is required because there is no way to determine if the algorithm can terminate successfully for a given data set.

Feature clustering is a very common data reduction method in use by clustering based spike sorting software. A waveform segment is reduced to a single data point by extracting numerical quantities known as *features*. 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, and so on.

A commonly used feature 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 two dimensional 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 from the data, the data points constructed from the feature will be split up into a number of groups. The number of clustering groups must be provided. Clustering will always partition the data into this number of clusters. The output of a clustering analysis should be verified visually and numerically to determine if the number of clusters matches the data.

Locate Centers

Clustering has a good potential to form the basis for classifiers to score physiological data. The clustering implementation will allow for automatic learning of cluster center positions through expectation maximization or for manually specified cluster center positions.

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 or a subset of the data.

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 of 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, referred to as a *training set*. The clustering algorithm outputs the centers of the clusters as determined from the training set, and other data points that are not members of the training set are subsequently added to the cluster whose center is closest to them. This approach assumes that the training set is a good approximation of the characteristics of each cluster in the entire data set.

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.

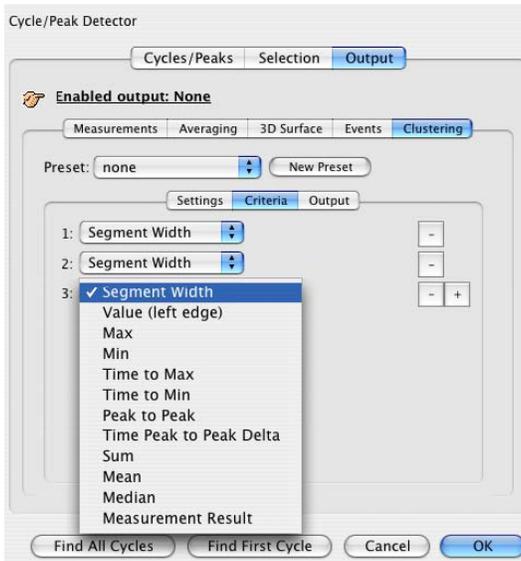
Another use of partial clustering is to construct a *classifier*. A classifier is some method for assigning a particular data point to a specific class. To construct a classifier using k-means clustering a k-means algorithm is run on a training set that has known desirable data properties for splitting 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.

Remove Outliers

One of the deficiencies of k-means clustering is that it is a total partition of the data set. Basic clustering assumes the original data set is ideal and that each cycle belongs to one of the clusters. Rejection of spurious data points is useful in real-world applications, particularly with physiological signals where noise and artifacts are to be expected.

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



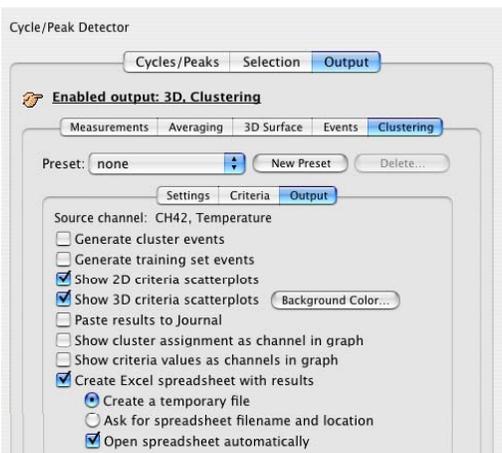
AcqKnowledge can perform feature clustering. For a particular segment of a waveform, features are extracted based upon user-specified criteria.

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

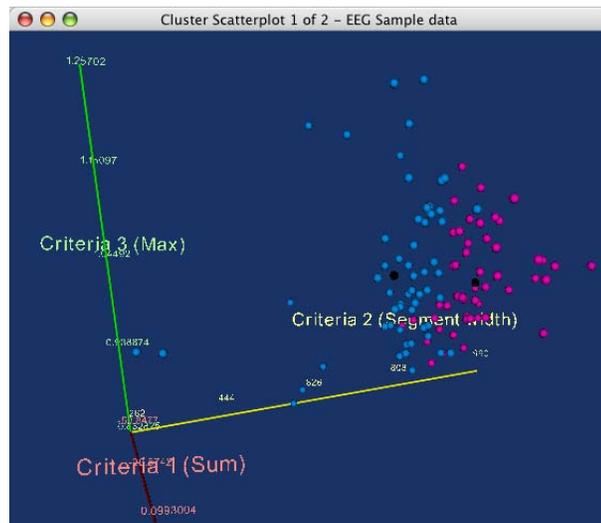
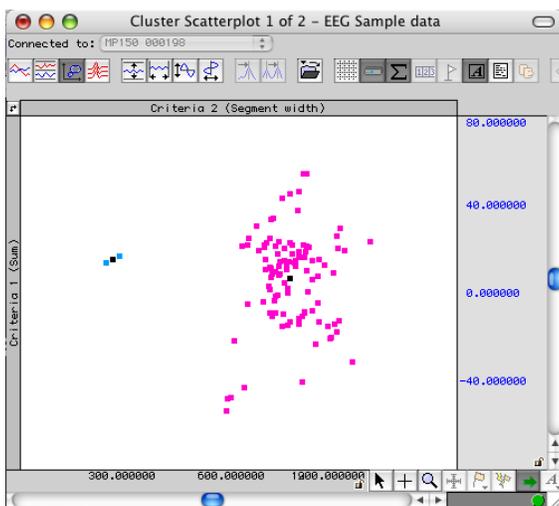
Multiple segments are located using the Find Cycle/Peak functionality. After the criteria have been computed for each segment, clustering is then performed on these criteria. This allows segments to be partitioned based upon their features. For example, “Segment Width” criteria can be used to partition ECG cycles into two clusters of shorter segments and longer segments.

The criteria Segment Widths are reported in milliseconds for time-domain graphs, 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 (Display >Preference), 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 also provide a foundation for further data reduction using other AcqKnowledge 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. To generate 3D criteria scatterplots, select at least three criteria. *Mac AcqKnowledge 3.9.2 and later* includes the option to change the 3D scatterplot background color and export results to an Excel spreadsheet.



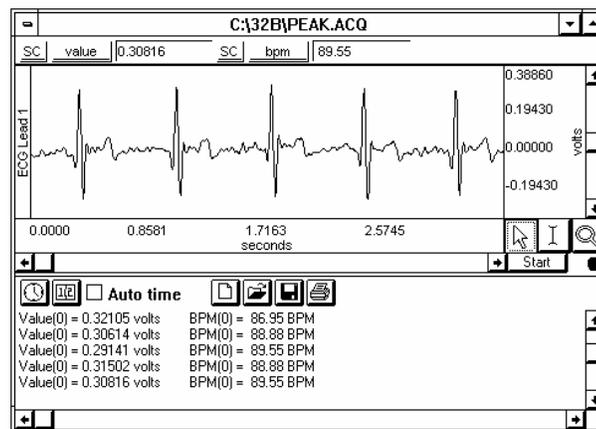
Find Next Peak/Cycle



When you select Find next peak from the Transform menu (or select the toolbar icon), both cursors will move one peak to the right while staying above the threshold.

Find All Peaks/Cycles

When you select Find all peaks from the Transform menu, the software will find all peaks through the end of the file. If your data file is very large, it may take some time to find all the peaks, since AcqKnowledge loads data from disk while it scans for the peaks.



If the “Paste measurement to Journal” option is selected, measurement values will be pasted into the Journal each time a peak is found, as shown above. Each column corresponds to a measurement value (in this case, Value and BPM).

Cursor functions

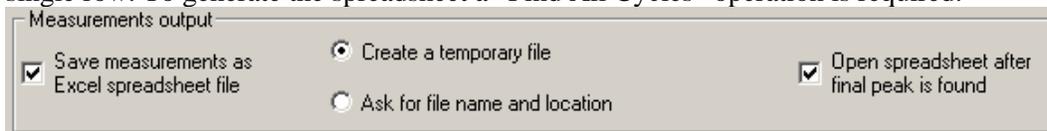
The process uses the default cursor settings to select the area between two adjacent peaks. In this mode, one cursor tracks the current peak location while the other cursor marks the location of the previous peak (these “cursors” are internal to the software and do not appear in the graph window).

A cursor can be based on:

- a currently selected peak
- a peak found immediately prior to the currently selected peak
- the current peak threshold
- the threshold used for the previously selected peak.

To select areas other than the inter-peak interval, enter an offset for these cursors.

Excel Spreadsheet Export—The cycle detector has also been enhanced to allow for the direct creation of spreadsheets. The cycle-to-cycle values of the measurements can be inserted directly into an Excel spreadsheet file. Each measurement is placed into an individual column and each cycle corresponds to a single row. To generate the spreadsheet a “Find All Cycles” operation is required.



- Also available for File > Save As, File > Save Journal Text As, and Specialized Analysis tools.

The following example details how to detect the positive spike in the QRS complex—a typical use of the Find Peak (peak detection) function.

Transform > Find Peak, Find next peak, Find all peaks

Icons:  Find Peak  Find Next Peak

1. Select the area around a peak.
2. Select Find Peak.

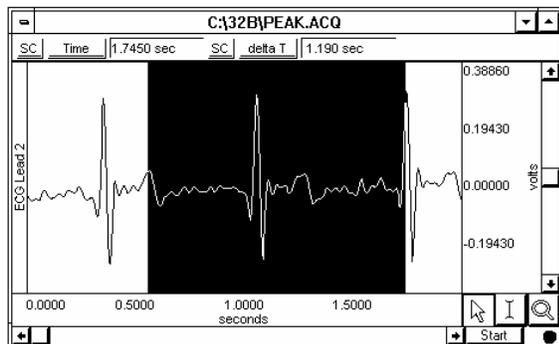
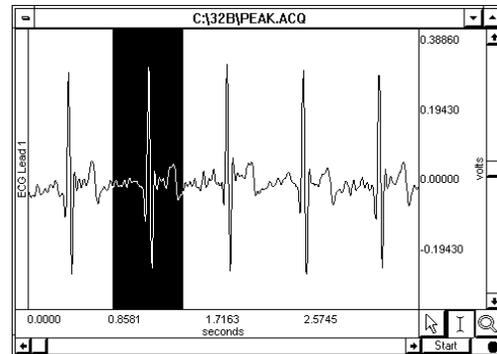
Windows: The Peak Detection dialog will be generated and will automatically compute a threshold value.

- If you don't want the Peak Detector to automatically set the threshold, then make sure that no portion of the waveform is selected prior to choosing Find Peak.

Mac OS X: Enable “Use selected maximum” on the Cycles/Peaks tab to compute an appropriate threshold value.

3. Select Find all peaks or Find next peak.

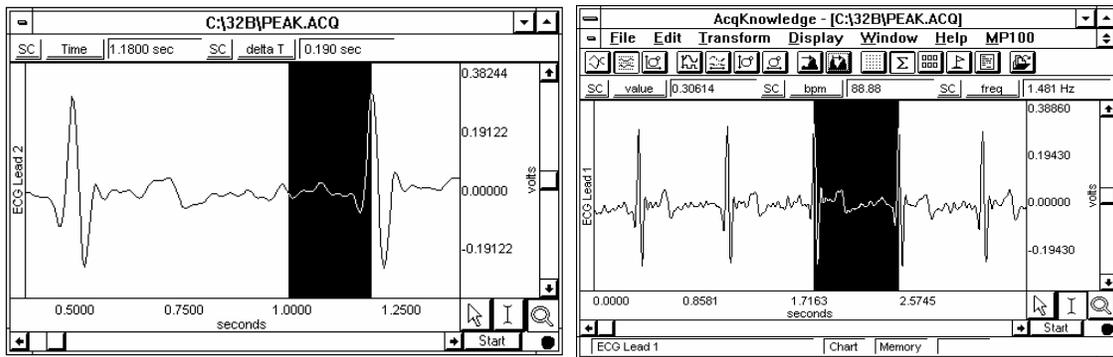
You will see one cursor move to the next peak value above the threshold and the other cursor remain at the current location, as shown here:



4. Select Find next peak. Both cursors will move one peak to the right while staying above the threshold. Note that the measurement values reflect the peak time and the BPM value. You can use any of the other measurements and they will automatically update when each new peak is found.
5. Select the first peak and choose Find peak.
6. Check the Paste measurements into journal option and click OK. The journal will be updated with the measurement values from the new peak.
- Mac OS X:** Measurement output can be configured with the Measurement controls on the Output tab.
7. Choose Find all peaks. This will find all peaks through the end of the file, and paste the measurement values into the journal each time a peak is found.
8. Choose Find peak.
9. Enter a value in the text box next to Set first cursor to to change the time offset of the first cursor.

The preceding examples used the Find peak function with the first cursor set to the “Previous peak” and the second cursor set to the current “Peak.” One measurement option is to change the time offset of the first cursor.

Entering a value of -0.5 will result in the first cursor being set to a point 0.5 seconds *prior* to the previous peak, and when the Find next peak command is selected, the graph should resemble the one shown below left:



Likewise, setting the offset of the first cursor to a positive value will result in a selected area similar to the one shown above right.

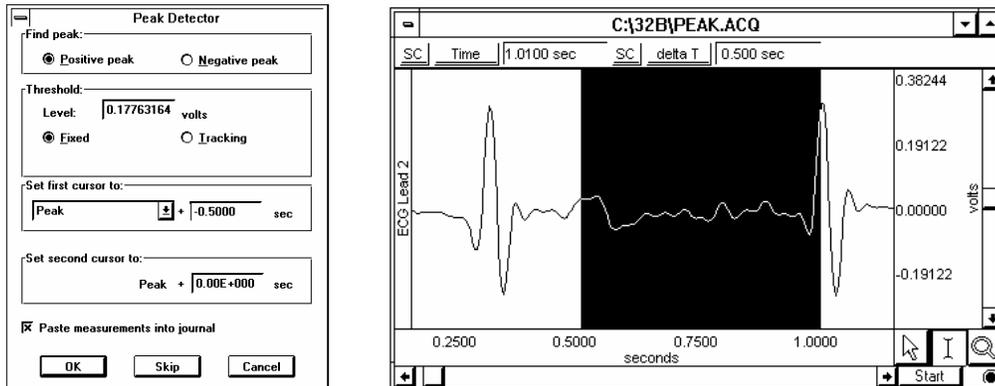
- Define an interval around the peak by locating both cursors at the found peak.

To do this, go to the Set first cursor to: portion of the Find Peak dialog, and select Peak from the Previous peak/Peak popup menu. This causes the options for the second cursor to change by adding a time offset option. When both cursors are set to the found peak and the offsets are each set to zero seconds, the Find peak command will select a single point at the peak maxima of the next found peak.

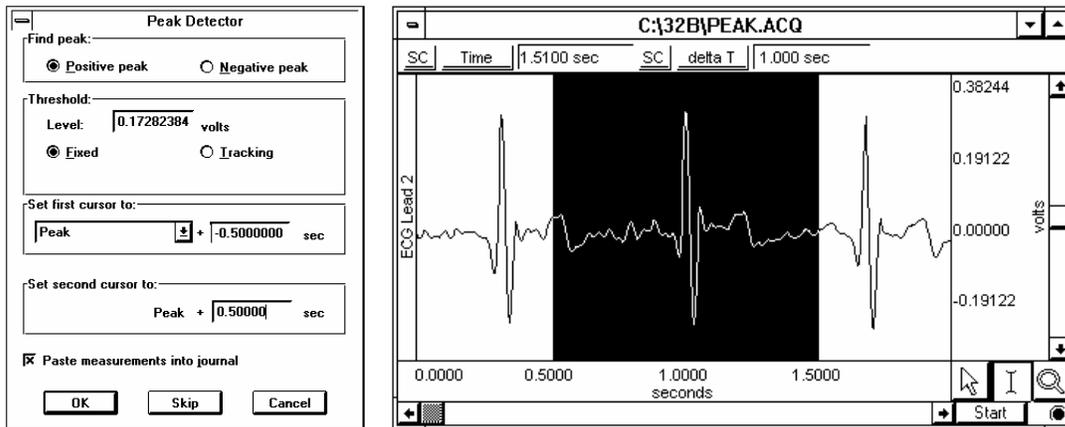
Mac OS X: Use “Current Peak” on the Selection tab and use “left edge” and “right edge” instead of first and second cursor.

- Include a time offset for the first cursor.

This offset may be either positive or negative, and can be set to an arbitrary time value, such as zero. In the following example, the second cursor was set at the found peak, while the first cursor was set 0.5 seconds prior to the peak.

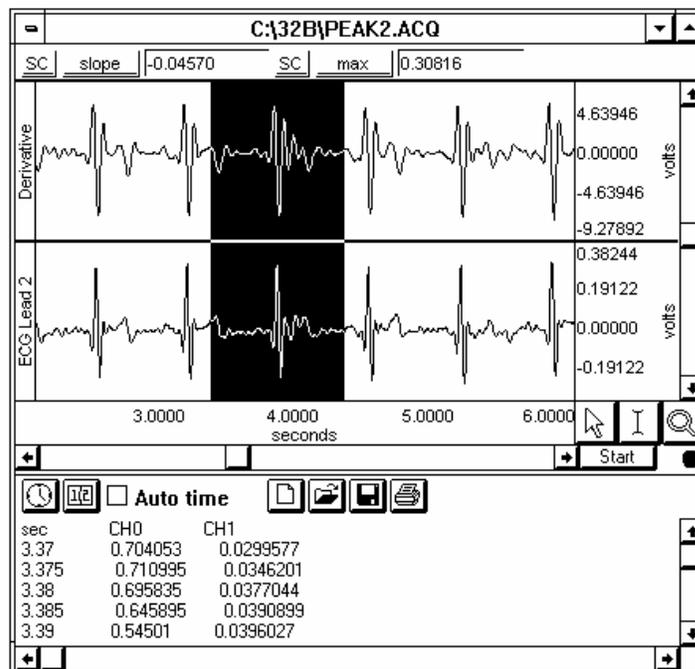


12. Add a time offset to the second cursor, which allows for areas around a peak to be selected.
The time offset associated with the second cursor must be either zero or positive.



13. Highlight an area based on the location of a peak found on one channel and take measurements from other channels (this is possible since a selected area covers all channels).

For example, suppose ECG data was acquired and the Derivative of the data was calculated on channel 0. The Find peak command could be used to locate peaks on the ECG channel, and measurement windows could display a value for the corresponding area on the Derivative channel, as shown in the following graph:



14. Paste data from other channels using only data within the selected area.

In the example shown, an area of +/- 0.5 seconds was selected based on the location of the peak found on the ECG channel. Measurements were displayed for the slope and max of the Derivative channel. Data from both channels was then pasted to the Journal along with the horizontal scale values.

Find Rate

Rate Detector

Function: Rate (BPM) [OK] [Don't find] [Cancel]

Peak detect
 Positive Negative

Remove baseline
 Auto threshold detect

Noise rejection
 5.00 % of peak

Window
 Min: 40.0000 BPM Windowing Units: BPM
 Max: 180.0000 BPM

Put result in new graph
 Find rate of entire wave

The *AcqKnowledge* Rate Detector is critical to *AcqKnowledge*'s ability to extract information from physiological data that has a degree of periodicity. Physiological data that can be investigated using the *AcqKnowledge* 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 allows you to compute 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.

AcqKnowledge 3.9 only

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 sheet 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 *AcqKnowledge* 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

The Rate Detector will eliminate certain options when selecting different modes of operation.

- The Remove baseline function always uses the Auto threshold detect mode.
- Any cyclic measurement relating to amplitude (e.g. Peak-Peak, Maximum, Minimum, Area, Mean) automatically turns off the Remove baseline function.
- If the measurement pertains directly to time (e.g. Hz, BPM, Interval, Peak Time, Count Peaks) the Remove baseline and Auto threshold detect modes are both operational.

Generally, it's best to use the simplest Rate Detector mode that is suitable for your 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 (if possible).

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
- Windowing options
- Output reset events (Mac OS X only)

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

$$0.75 \cdot (\text{Old Peak Maximum} - \text{Old Peak Minimum})$$

Negative peak search

$$0.25 \cdot (\text{Old Peak Maximum} - \text{Old Peak Minimum})$$

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:

$$\text{Hysteresis} = \text{Noise rejection (\%)} \cdot (\text{Old Peak Maximum} - \text{Old Peak Minimum})$$

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 over which difference is performed =

$$0.025 \cdot \text{Sampling Rate}$$

This difference waveform is then passed through the variable threshold:

Positive peak search =

$$0.75 \cdot (\text{Old Peak Maximum} - \text{Old Peak Minimum})$$

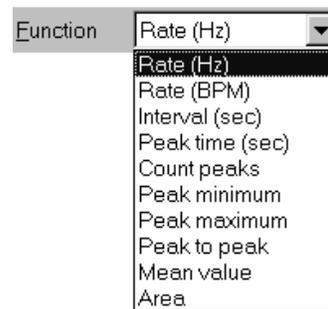
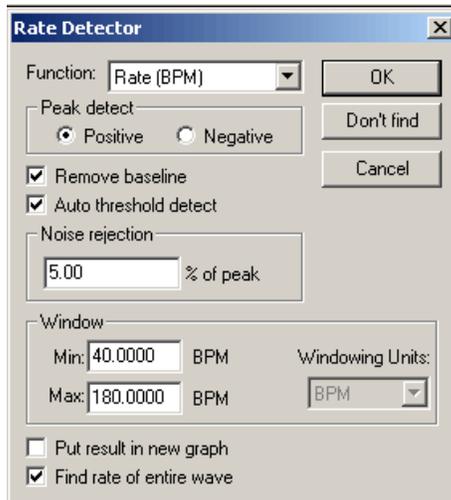
Negative peak search =

$$0.25 \cdot (\text{Old Peak Max} - \text{Old Peak Min})$$

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	<ul style="list-style-type: none"> • 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 (like EMG), and you wish to determine the rate of these crossings
Auto threshold detect option	<ul style="list-style-type: none"> • waveform data has a moving baseline, but the peaks are otherwise larger in magnitude than other parts of the waveform (blood pressure). <p><i>You may need to adjust the Noise rejection (Hysteresis) to optimize performance.</i></p>
Remove baseline <i>and</i> Auto threshold detect options	<ul style="list-style-type: none"> • 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. <p><i>You may need to adjust the Noise rejection (Hysteresis) to optimize performance.</i></p>

Find Rate Dialog Settings



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 (ΔT) 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 ΔT . These measurements are perfectly correlated with the BPM calculation, since BPM is equal to 60 times the frequency calculation, or 60 divided by ΔT .

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 box.

Peak-to-peak

Looks at the vertical difference between the maximum and minimum values of the waveform on a cyclical basis—useful when you want to determine the amplitude of your 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

Computes the area of the signal between two peaks, on a cycle-by-cycle basis.

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, you may have to base the rate calculation on negative peaks (downward pointing). To do this, select Negative peak.

Remove baseline

The Remove baseline option applies the optimal high pass filter based on the other settings. 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, *AcqKnowledge* 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) lets you enter 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.

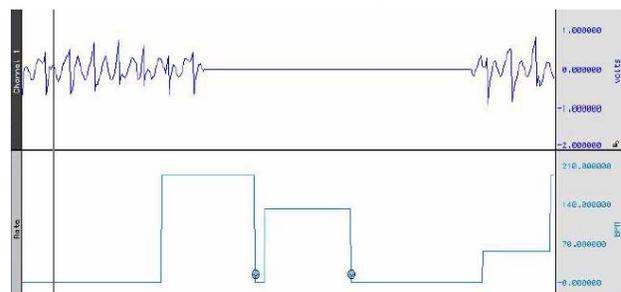


Output reset events

- Auto threshold detect
- Output reset events

Mac OS X only This option is activated when “Auto threshold detect” is enabled and 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



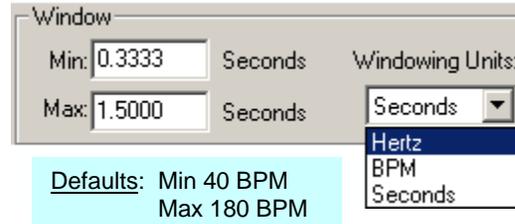
- This helps distinguish zero-valued output due to window resetting and true zero-value output.

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.

Window (Peak Interval)

Window (activated when “Auto threshold detect” is enabled) is used to specify an upper and lower limit for the Rate calculation. Windowing Units (activated only when the selected Function can have variable units) is a pull-down menu of applicable units to choose from.

Setting the upper and lower bounds for the “window” tells AcqKnowledge when to start looking for a peak.

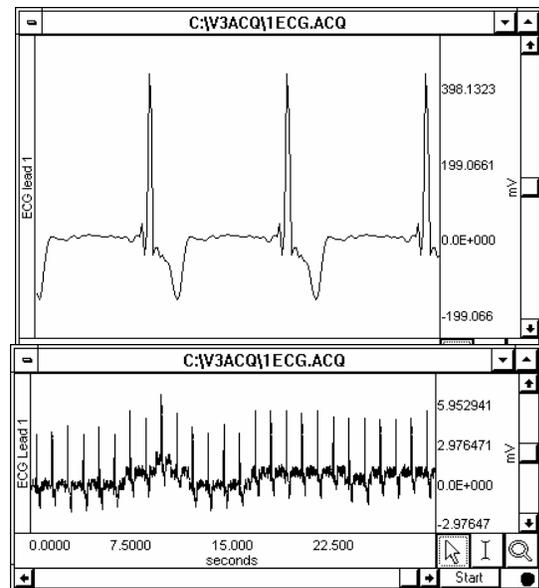


AcqKnowledge will try to locate a peak that matches the automatic threshold criteria within the specified window. If no peak is found, the area outside the envelope will be searched and the criteria (in terms of peak value) will be relaxed until the next peak is found.

For instance, once the first peak is found, AcqKnowledge 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 AcqKnowledge 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, you will probably want 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.

A simple peak detector uses what is called a *threshold-crossing algorithm*, whereby each time the amplitude (vertical scale) value exceeds a given value, peak detector “remembers” that point and begins searching for the next event where the channel crosses threshold. The interval between the two occurrences is computed and usually rescaled in terms of BPM or Hz. This is how the AcqKnowledge rate Calculation functions when all options are unchecked.



the
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Hz.

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and

In the sample waveform shown here, the threshold set to 390 mV to detect the peaks of the waveform 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.

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.

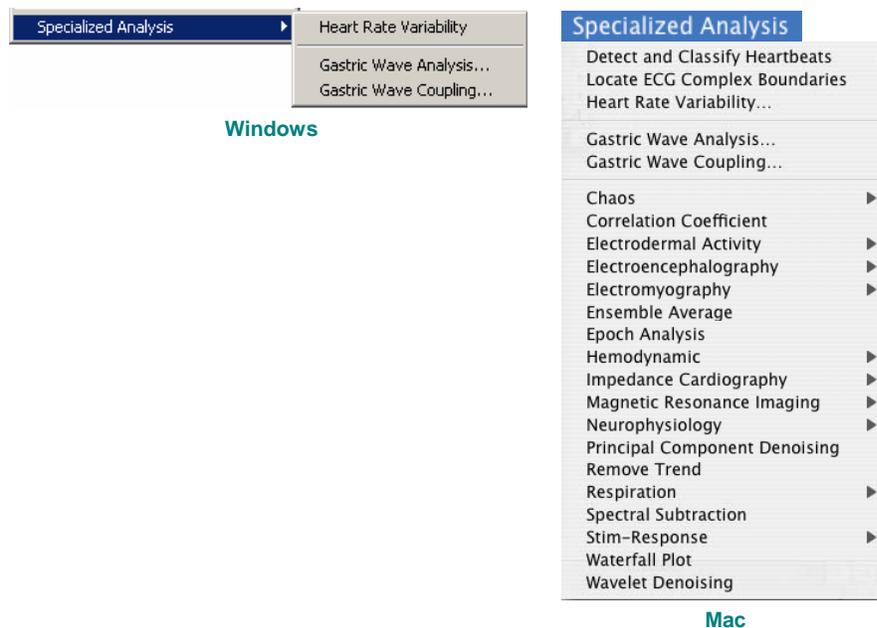
Find Rate of Entire Wave

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

The Don't Find button is useful when you realize you have not selected an area to perform the Find Rate function on, or when you want to change the selected area. When you click on Don't Find, the dialog settings will be saved so that you can close out of the dialog and select an area. When you reopen the dialog, the settings will be established as before you closed out, and you can click on the OK button 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. See Appendix G on page 333 for full details.

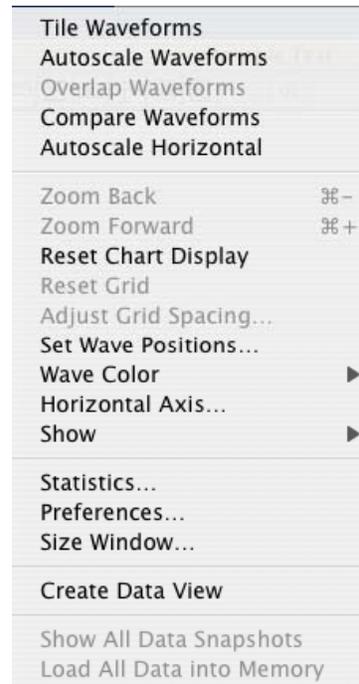
Chapter 13 Display menu commands

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.



Windows/PC



Mac

Although these options change the appearance of the data, they do not change the data itself. In other words, changing the color of a waveform or showing only a portion of the data on the screen will not alter the data stored in the file.

See the following shortcut options for Display menu commands:

- Toolbar shortcuts, page 37
- Right-click shortcuts—Windows, page 39
- Context-sensitive shortcuts—Mac OS X, page 40

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).

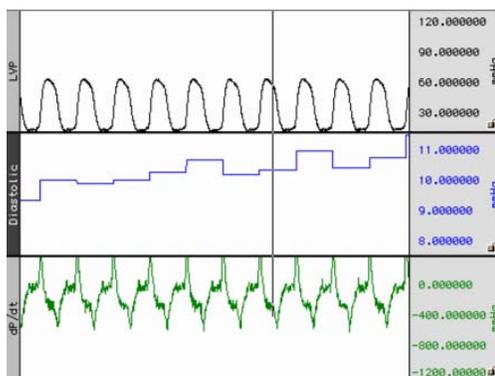
In Scope mode, tiling staggers the midpoint of the channels to visually separate them on the screen while maintaining their scales. In Scope mode, waveforms are spaced evenly along the vertical axis of the screen, and each waveform is centered vertically in its division.

Choosing tile waveforms will center the waveform in the display by adjusting the vertical offset of the selected waveform. If there are multiple waveforms displayed in chart mode, the waveforms will be centered in their “tracks.” To apply tiling only to the selected waveform, hold down the CTRL key on Windows or the Option key on Mac OS X before selecting Tile waveforms. In scope mode, waveforms are spaced evenly along the vertical axis of the screen, and each waveform is centered vertically in its division. Tiling does not affect the vertical scale factor previously set for each channel (whereas Autoscale may affect the vertical scale factor).

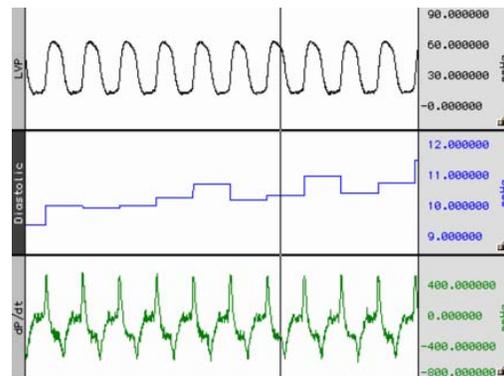
When grids are locked, Tiling will retain the appropriate heights and percentages.

When grids are unlocked

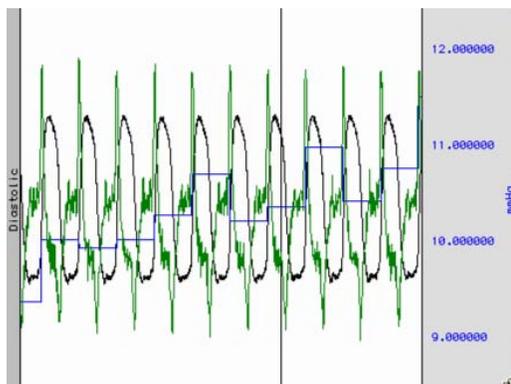
- **Windows:** Tiling will retain the appropriate heights and percentages
- **Mac OS X:** The scale may be slightly larger in order to optimize the tick marks displayed on the vertical axis.



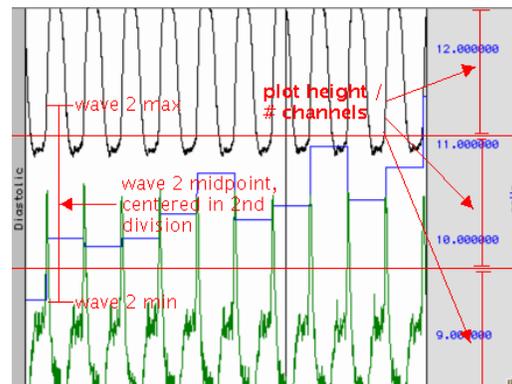
Before Chart mode tiling



After Chart mode Tiling



Before Scope mode tiling



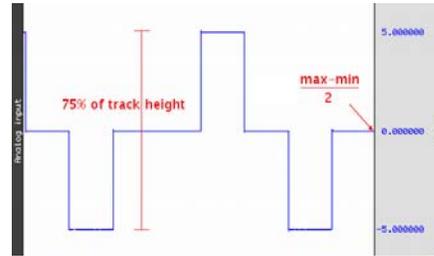
After scope mode Tiling (red lines for illustration only)

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.

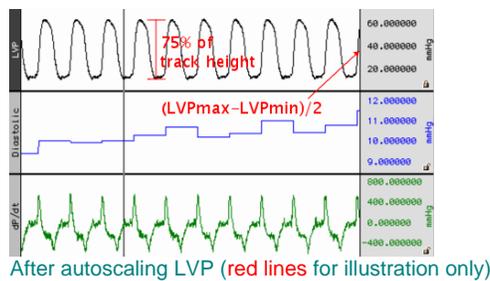
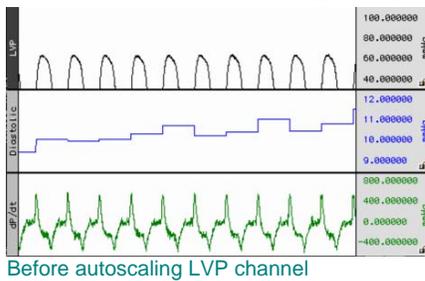
When Autoscale waveforms is selected, AcqKnowledge determines what the “best fit” is for each displayed waveform. The percentages and midpoints are identical whether grids are locked or unlocked.



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. 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.

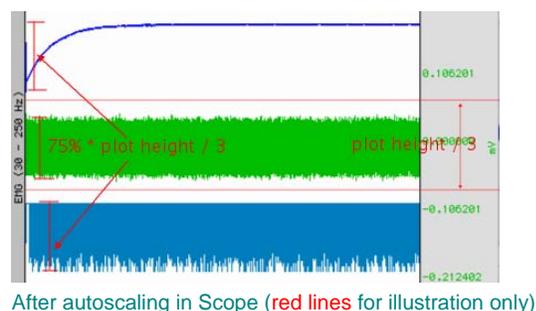
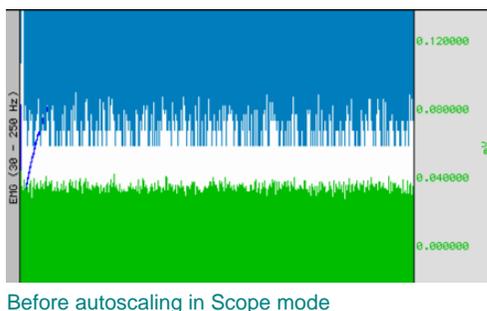


➤ The autoscaling algorithm for Scope mode is:

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. 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.

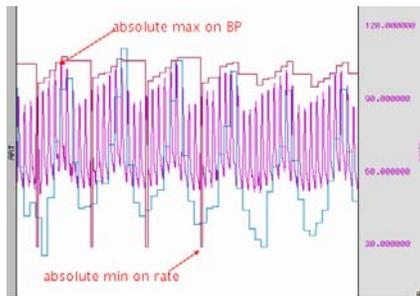
Note: Autoscaling a single channel in Scope mode results in that channel occupying $1 / (\text{num_visible_channels})$ of the overall waveform plotting area. It will be autoscaled into the topmost division of the screen.



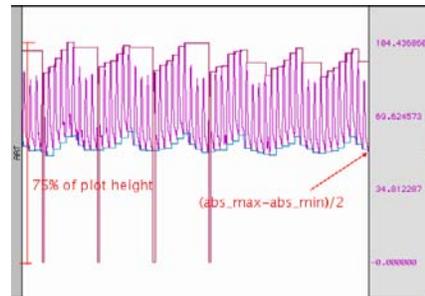
Overlap waveforms

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

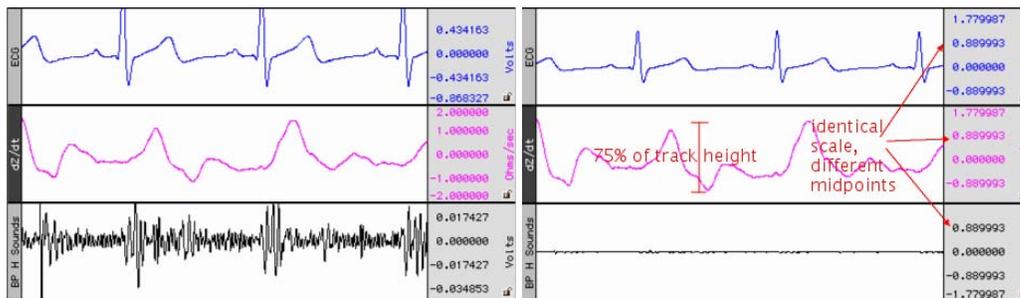


After Overlapping in Scope (red lines for illustration only)

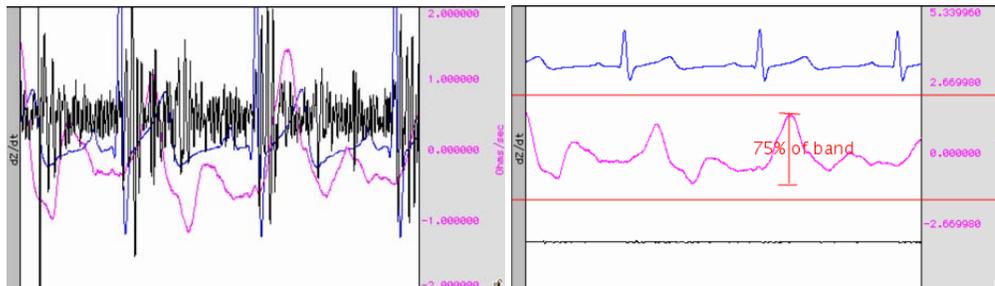
Compare waveforms

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. You can cancel plotting at any time by pressing:

- For the MPWSW (PC)—the escape key (Esc)
- For the MPWS (Mac)—⌘ + “.”

You cannot undo the autoscale horizontal function with Edit>Undo, but you can use the Display>Zoom back command to revert to the previous display settings.

Zoom Forward / Back

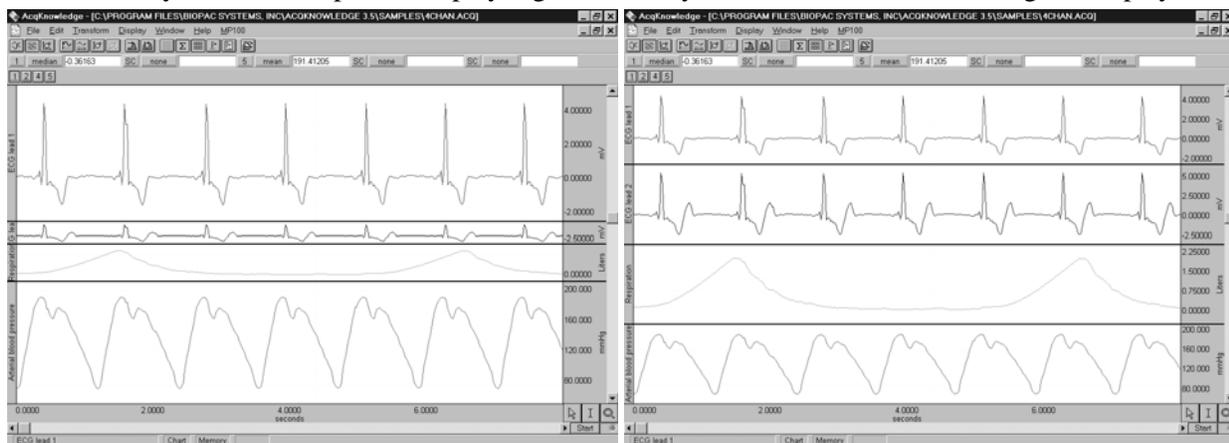
Zoom functions can affect the horizontal scale, the vertical scale, or both. Zoom restoration is functional for the Zoom tool, Autoscaling, and the Tile, Overlap, and Compare Waveform options. Zoom scales are stored until another zoom function is performed. For instance, you cannot Zoom back and then use the Zoom tool and expect Zoom back to take you back two scale levels.

- Zoom Forward will redo a zoom function after it has been undone; you can repeat this selection to restore the latest zoom scales.
- Zoom Back will restore settings one level at a time; you can repeat this selection 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 functions will work for five iterations on a PC and without limitation on a Mac, until another Zoom is performed.

Reset chart display

The Reset chart display option will redistribute the chart displays evenly after you have changed the boundaries so that each channel’s vertical size is the same. This function, which only works in *Chart Mode*, can be useful if you need to expand a display region for analysis and then return to the original display.



Before Reset Chart Display

...and after

Reset Grid—*Mac OS X only*

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—*Mac OS X only*

To modify the horizontal and/or vertical grid spacing, choose “Display > Adjust grid spacing.” This will generate a dialog for you to modify the locked axes of the selected waveform. *See page 184 for details.*

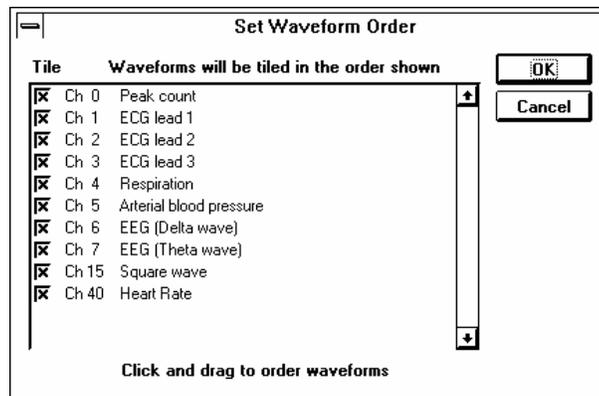
Set wave positions...

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. You can change the ordering so that waveforms are placed in an arbitrary 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.

In addition, in the waveform positioning function, you can set any waveform to ignore the autoscaling and tiling functions. This can be important if you have some waveforms which you don’t want autoscaled with others.

The waveform positioning function is selected through the Set Wave Position in the Display menu. The following dialog box will then appear, with a scrolling list of all stored channels:



If you have more channels than displayed, you can scroll through the list by clicking on the vertical scroll bar at the right. The list will scroll if you move past the top or bottom when 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 on the checkbox to toggle the enable.

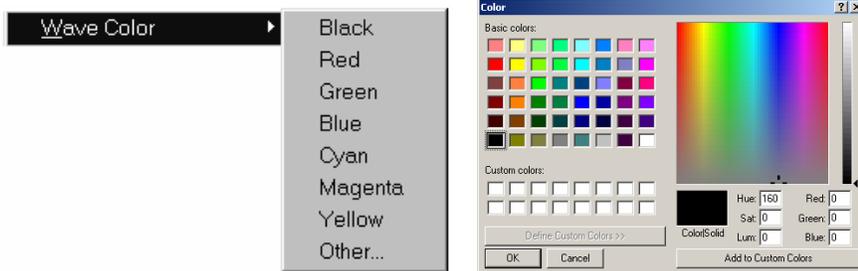
The on-screen position of the waveforms is the same as the ordering shown in the above dialog (from top to bottom). You can reposition the waveforms by reordering the channel labels as they appear in this dialog box. To change the order of any waveform, click on the channel label (e.g., Ch. 4 Respiration), hold down the mouse button, and drag the highlighted label to the desired position. Repeat this operation until the waveforms are ordered the way you want.

- Click OK to apply your selected order to the display screen.
- Cancel will revert all waveform positions to those set before the dialog was opened.

Wave color

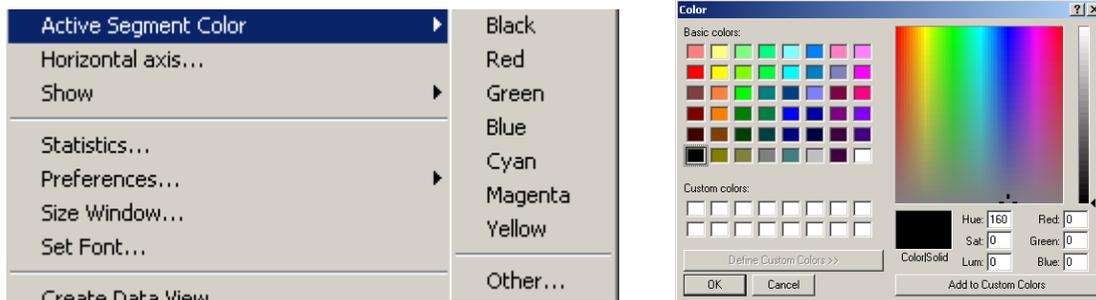
Select Wave color and then set the desired color to discriminate between waveforms. In scope mode, the vertical scale, channel text, channel units and measurement popup menus take on the same color as the selected waveform. When adding new waveforms, *AcqKnowledge* assigns waveform colors in the following order: black, red, blue, green, cyan, and magenta.

You can assign new colors to waveforms by choosing the menu selection **Display>Wave Color**



Or, you can click the right mouse button to bring up a menu, select Color, and then select the desired waveform color from the color palette menu. Depending on the type of graphics adapter on your computer, you may or may not be able to choose “Other” to display a palette of color options.

Active Segment Color

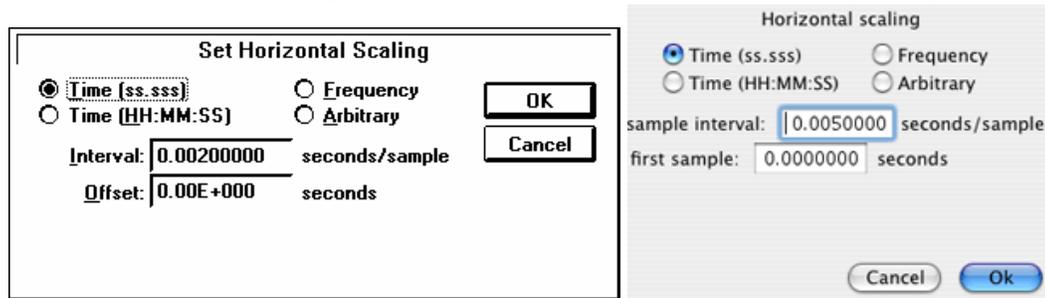


Selecting Active Segment Color generates a menu of color options for the active segment in Overlap Appended Segment mode (see page 33).

1. **Display>Show>Show Segment and Graph Contextual Menu>Show Segment:** This allows the user to select an active segment in Overlap Segment Mode.
2. **Display>Active Segment Color**

Horizontal axis...

Change the sample offset and horizontal sample interval (the amount of time between two sample points) by selecting Horizontal axis from the Display menu, which will generate the following dialog box:



The horizontal scale can be set in terms of time, frequency, or arbitrary units. Time domain scaling has two options, which allow you to store and display data either in terms of absolute seconds (ss.sss) or hours:minutes:seconds (HH:MM:SS). By default, *AcqKnowledge* displays data in the ss.sss mode; however, you can change this by checking the HH:MM:SS button in the horizontal scaling dialog box. When data is displayed in the ss.sss mode, the time scale corresponding with an event occurring 30 seconds into the record would be 30.00 seconds. The time scale for the same event in HH:MM:SS mode would be 00:00:30.

This feature is generally useful for changing the time base (or other horizontal scale) of data that has been imported into *AcqKnowledge* as a text file. For instance, if you want 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 191).

By default, *AcqKnowledge* 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, you would 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 0.0200000 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.

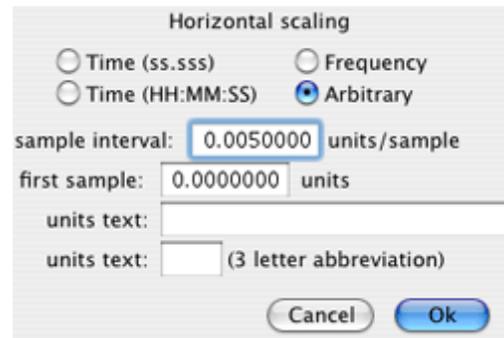
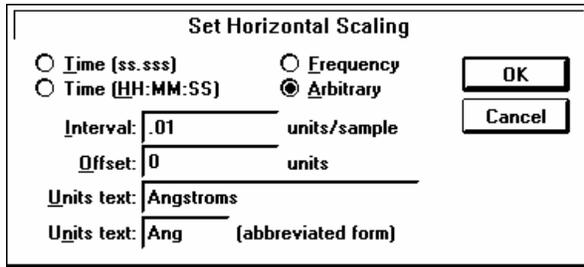
To determine the sample interval for other sampling intervals, divide 1 by the rate at which data was sampled (in terms of samples per second). Thus, a sampling rate of 0.5 Hz would translate into a sample interval of 2.00 seconds between samples, and data collected at 100,000 Hz (100 kHz) would have an interval between sample points of 0.00001000 seconds.

TIP: To confirm that *AcqKnowledge* is storing data in the same time base it was collected in, choose Statistics from the Display menu. This will generate a dialog box that describes (among other things) the sampling rate *AcqKnowledge* uses in analyzing the data. Once data has been saved as an *AcqKnowledge* file, time base information is automatically saved along with the data.

Setting the horizontal scale in terms of frequency allows output from a spectrum analyzer or plots data from a Fourier analysis or other data with a frequency base (rather than a time base). As with the time options, this feature is typically used for importing text files from other applications. For instance, if you were importing a text file with 1,000 sample points that covered a frequency range from 0 Hz to 100 Hz, you would want to 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, you could set the offset to 20 Hz.

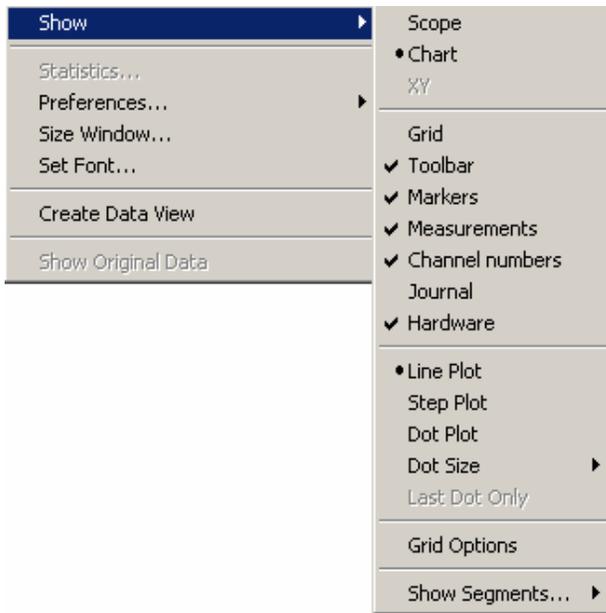
You can attach arbitrary base units to the data (rather than a time or frequency base). This might be useful for data collected from a gas chromatograph. When the horizontal axis corresponds to wavelength, and the data consists of 100 samples covering a range from 1 to 10 Angstroms, the interval should be 0.1 units per sample.

When arbitrary units are selected, two additional text boxes appear at the bottom of the dialog box. The upper Units text box is used to provide a name for the horizontal scale units (in this case, Angstroms), and the lower Units text box is used to provide an abbreviated label for the horizontal units (i.e., Ang).



Show

Selecting Show from the Display menu generates a submenu that allows you to control a number of data display options and what additional information is displayed in the graph window. To enable an option, select it from the submenu; a bullet (•) or checkmark appears next to the menu item when it is enabled. The three display modes and the two plotting modes are mutually exclusive, but the remaining items can be enabled independently.

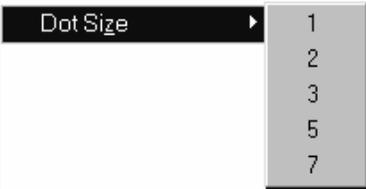
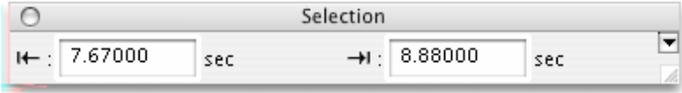


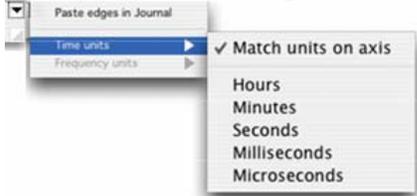
Windows

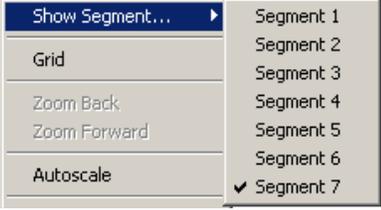
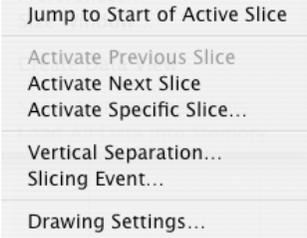


Mac

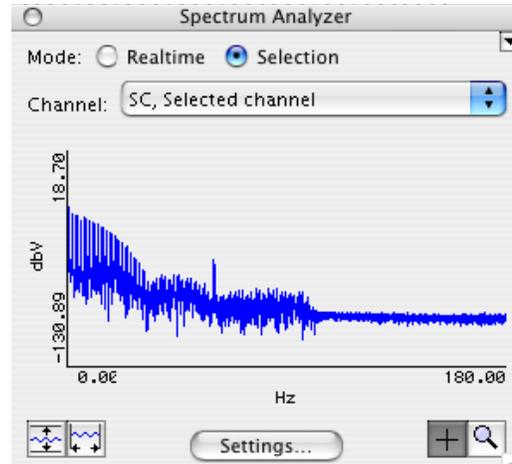
Show Option	Shortcut	Explanation
Channel numbers	PC or Mac	When the Channel numbers option is selected, the channel boxes appear just above and below the graph area. Channel boxes with Channel 1 selected These boxes are useful for selecting channels and “hiding” channels by positioning the cursor over the channel box, holding the CTRL key on the MPWSW or the Option key on the MPWS, and clicking the mouse button.
Chart		Activates the Chart display mode (see page 31).
Dot plot		Dot Plot allows you to view data in a “dot” format. The software will create user-defined, discrete points that map out the selected waveform. This is often useful for demonstrating the concept of discrete digital sampling by dividing the waveform up into data points or “dots.”

Show Option	Shortcut	Explanation
Dot size		 <p>Dot size lets you specify how large each dot will be. Each dot is measured by the number of monitor pixels it occupies.</p>
Events		Enables Event display. See page 164 for Event (<i>Mac OS X</i>) details; see page 161 for Marker (<i>Windows/PC</i>) details.
Grid		Superimposes a Grid on the graph window (see page 47). <i>Windows/PC</i> To increase grid precision, click Ctrl-  . <i>Mac OS X</i> To change grid precision, use the axis scaling dialog of the horizontal or vertical axis.
Grid Options		Activates the Grid Options dialog (see page 47)
Hardware		Show/Hide Hardware “Connected to:” dialog in the graph display; includes network access under <i>Mac OS X</i> .
Journal		Activates the Journal (see page 48).
Last dot only		Plots only the most recently acquired data point. This is most useful when viewing data as it is being collected and when this data is displayed in X/Y mode.
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 246). You can change line options by clicking the right mouse button, which will generate a menu displaying several commonly used features.
Markers		Displays the marker/event region at the top of the graph window, along with any markers/events associated with the data being displayed and the marker/event tools. See page 161 for Marker (<i>Windows</i>) details and page 164 for Event (<i>Mac OS X</i>) details.
Measurements		Displays the measurement popup menus and windows above the graph window (see pages 46 and 147).
Scope		Activates the scope display mode (see page 31).
Selection Palette	<i>Mac AcqKnowledge 3.9.1 and later</i>	 <p>Many of the tools within the <i>AcqKnowledge</i> 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.</p> <ul style="list-style-type: none"> 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 sheets are being displayed for the

Show Option	Shortcut	Explanation
		<p>graph.</p> <ul style="list-style-type: none"> 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. <p>To display the Selection Palette, choose Display > Show > Selection Palette. This small floating 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.</p> <p>The Selection Palette also can be used to manually type in the edges of the selection. Double-click on one of 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.</p> <p>When a graph is displayed in X/Y mode, the Selection Palette can be used to adjust the range of data that is plotted on the screen. Limiting the time range can be useful for generating X/Y plots for different intervals of the graph that can then be compared with each other, such as examining PV loops from different time periods of a recorded signal.</p> <p><i>Mac 3.9.2 Only</i>—Click the small arrow in the top right of the selection palette for the following additional options:</p>  <ul style="list-style-type: none"> 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. 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, and Microseconds. 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, and Millihertz. The frequency submenu will be dimmed unless the graph displays frequency-based measures. <p><i>Note</i> 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</p>

Show Option	Shortcut	Explanation
		boundaries.
Show Segments	<i>Windows only</i>	 <p>For Overlap mode (see page 33), generates a list of segments so you can select a specific segment.</p>
Spectrum Analyzer Palette	<i>Mac AcqKnowledge 3.9.2 and later</i>	Provides a dynamic display of the frequency decomposition of data, in real time or post-acquisition. See page 306 for details.
Stacked Plot Options	<i>Mac AcqKnowledge 3.9.1 and later</i> <ul style="list-style-type: none"> • <i>For Windows equivalent, see Overlap Segment mode on page 33.</i> 	<p>Displays options that can help visually distinguish the active slice from other slices being drawn in Stacked Plot mode. See page 34 for details.</p> 
Step plot		<p>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), it can also be useful for examining the effects of various sampling rates.</p> <p>NOTE: Step plot is mutually exclusive of line plot.</p>
Toolbar		Displays the toolbar (shortcut) icons across the top of the display (see page 37).
X/Y		Activates the X/Y display mode (see page 31).

Spectrum Analyzer Palette



Mac 3.9.2 and later 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; FFT is preferable over Power Spectral Density as the averaged periodogram approach used by PSD is effective only over larger portions of data.
- Other off-line spectral analysis tools include the FFT and Power Spectral Density transformations.

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.

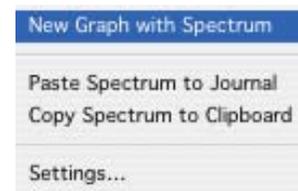
Selection Analyzes the highlighted section of the active channel of a saved graph (post-acquisition). Measurements derived from data on the selected area are useful tools for quickly comparing different portions of data. Choose a specific channel to analyze or “SC” to use the current active channel. Window size does not need to be specified for this mode; the closest power of two above the number of samples in the selected area will be used and padding will be applied in the method specified.

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 MP > Set Up Channels. The channels will be listed in the same format as the Sound window, “{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 realtime mode, the following additional conditions also cause spectra to be unavailable:

- no data acquisition is in progress

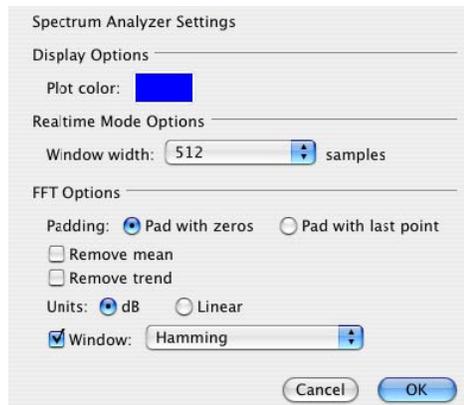
Auto Vert

Click to autoscale the spectrum to fit all amplitudes within the visible spectrum plotting area.

Auto Horiz

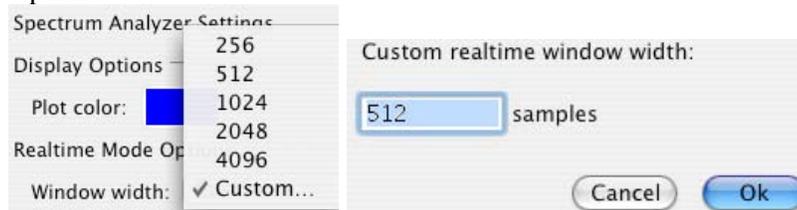
Click to autoscale the spectrum to fit all frequencies within the visible spectrum plotting area.

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 as well as a “Custom...” entry. If a custom width is entered that is not a power of two, padding will be applied during real-time operation according to the FFT Options.



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 AcqKnowledge windowing options, to adjust the data to remove effects resulting from the discontinuities of data at the two edges.

Value

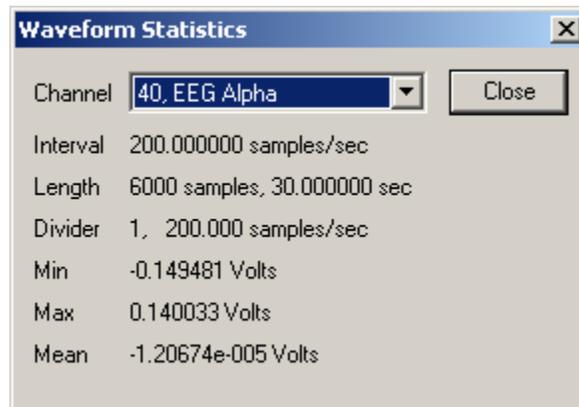
Click the crosshair icon  to display the frequency and amplitude values of the spectrum when moved within the spectrum display. The mouse cursor will change to a crosshair when inside the spectrum plot. The frequency and amplitude values corresponding to the mouse position are displayed above the spectral 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 on 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.

Statistics...

The Display>Statistics command generates an information dialog for the selected channel.

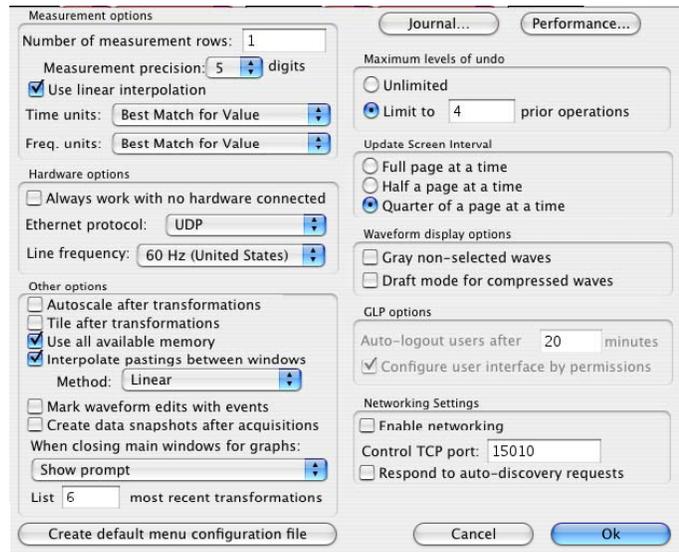
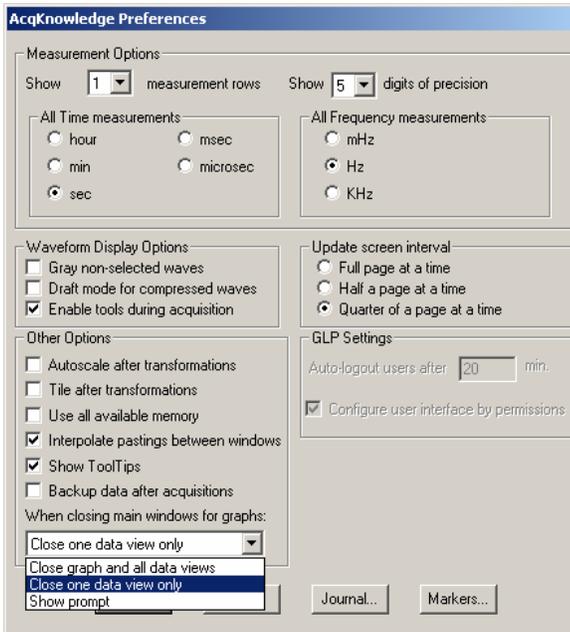


- Channel** This box displays the channel number, channel label (if any).
- Interval** Indicates the acquisition sampling rate. The sampling rate specified reflects the sampling interval *AcqKnowledge* uses to store the data, which is not necessarily the same rate at which it was collected. The sampling rate can be modified by using the resample function (described on page 247), by changing the interval horizontal scale (see page 301), or by pasting data collected at one sample rate into a graph containing data sampled at a different rate.
Mac OS X: Details interval of the finished waveform, i.e. waveform sample rate.
- Length** Indicates the overall length of the channel in samples per second and time. Generally, the waveform length information is the same for all channels, although this is not always the case. To shorten waveforms by editing out sections of the waveform (using Edit>Cut and/or Edit>Clear functions).
- Divider** The divider indicates the ratio between the acquisition rate and the channel sample rate.

$$\text{Divider} = \text{Acquisition Rate} / \text{Channel sample rate}$$
Mac OS X: Divider is not included, but can be determined via the waveform Tooltip.
 Included with the divider ratio (after the comma) is the sample rate for the selected channel.
- 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.

Preferences...

Choosing Display>Preferences generates the general preferences dialog box, which allows you to control measurement options, how waveforms are displayed, and other *AcqKnowledge* features. Clicking the Journal... button will generate a separate Journal preferences dialog box, and the options in each dialog can be set independent of other options. In the MPWS System, the Journal option is located under the File menu.



Measurement Options

- measurement rows determines how many measurement rows should be displayed at the top of the graph window. Use the pull-down menu to set to a value (limited to 8 on Windows).
 - You can use the options in the Display>Show>Measurements menu to hide the measurements altogether. See page 302 for more information on this option.)
- precision controls the accuracy of digits displayed right of the decimal (1-8) for all visible measurement results. For instance, with precision set to 3, one measurement window might show 125.187 while another reads 0.475.
- Use linear interpolation—*Mac OS X only* Toggle the checkbox 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”).
 - Best match—*Mac OS X only* 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.
- Parameters—*Mac OS X only* Use Preferences >Journal > Measurement Options and enable “Include measurement parameters” to capture location and operation detail.

Waveform Display Options

In the center of the dialog box are two options that control how waveforms are displayed on the screen.

- Gray non-selected waves *Mac OS X only* 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. Standard VGA displays are 640 pixels wide, so a compressed waveform on this type monitor 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.”
- Enable tools during acquisition *Windows/PC only* Toggles waveform tool functionality during data acquisition; disable for memory-intensive acquisitions to optimize plotting performance and try to minimize buffer overloads.

Other Options

- ...after transformations The first two options handle the way data appears 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.
 - 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. When waveforms are “tiled” they appear to be stacked on top of each other.
- Use all available memory instructs *AcqKnowledge* 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.
- Interpolate pastings instructs *AcqKnowledge* to interpolate/extrapolate time base information when working with data sampled at two different rates. *AcqKnowledge* will interpolate data to fit the sample rate of the destination window. When doing this, you should copy data to a higher resolution window. Although To copy data in the other direction (from high resolution to low resolution), it is not recommended since some resolution will be lost in the process.
 - *For example*, if you have one 30-second waveform sampled at 50 samples per second, and another 30-second waveform sampled at 2,000 samples per second, you can copy the contents of one window into another using the insert waveform command, and *AcqKnowledge* will interpolate one waveform so that both appear to be 30 seconds long. In this example, data would be copied from the 50Hz (low resolution) window to the 2,000Hz (high resolution) window.
- Show ToolTips—*Windows/PC only* Generates a flag with help text associated with an item when you leave the cursor over the item on the screen. Mac OS X users can toggle this function using Help >Show Tooltips.
- Mark waveform edits with events—*Mac OS X only* Insert an event at points where waveform edit commands have been applied.
- Snapshot data after acquisitions toggles the Embedded Archive feature (see page 49), 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.

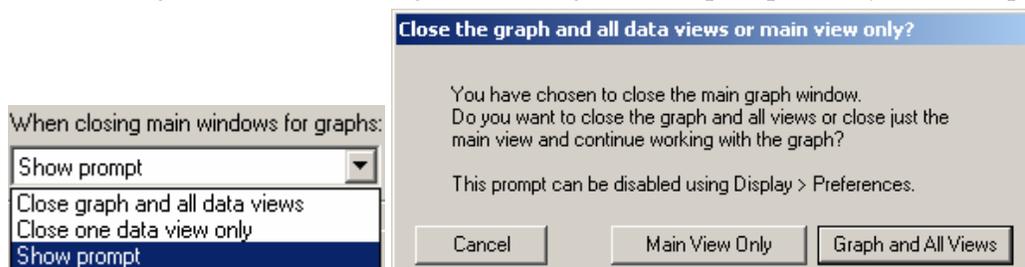
IMPORTANT: Archive functions do not create a new file—they are not backup functions. Original data is copied and pasted to the end of the original file. You cannot use this feature to recover lost or damaged original data.

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.

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



- When closing... determines the degree of closing and what prompts, if any, for multiple data views.



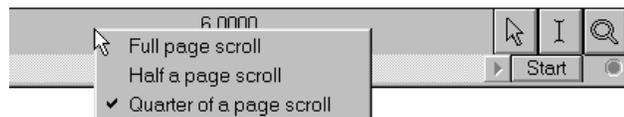
- List ___ recently used transformations—**Mac AcqKnowledge 3.9.2 and later** Change the number of recently used transformations that displays in the Transform > Recently Used submenu.

Maximum Undo

Mac OS X only Set the maximum number of undo operations. Unlimited may be memory-intensive, depending on the detail of each operation.

Update screen interval

The Update screen interval option lets you adjust the rate that the screen is updated, which can be useful when you have a large data file (as in sleep studies) and you want to quickly jump through the data. You can set the interval to update in full page, half page, or quarter page increments. Click in the circle next to the desired interval in the “Update screen interval” section and the screen will update in the selected interval when you click on the horizontal scroll bar.



Shortcuts

- Windows** Right-click in the horizontal scale region
- Mac OS X** Control-click in the horizontal scale region to activate the contextual menu

Hold the mouse button down and scroll to the desired interval, then release the mouse button to activate the new interval.

Hardware options

Mac OS X only—Use the Hardware options to set the MP unit communication preferences:

- No Hardware sets the default communication for no connection so you don't get the connection error each time you launch the software.
- Ethernet protocol is UDP by default, but can be switched to DLC to test communication. If you cannot establish MP unit communication with *AcqKnowledge* under either protocol, check the MP unit firmware (see page 332) and then contact BIOPAC for technical support.
- **Mac *AcqKnowledge* 3.9.2 and later**—Adjust the line frequency specified during software installation. 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 *AcqKnowledge* will be used.

Windows—use the setup utility to change communication modes.

Network Settings



Mac *AcqKnowledge* 3.9.2 and later—Check “Enable networking” to allow applications running on other computers attached to the same network to gain access to data from *AcqKnowledge* as it is being acquired. Data is sent to other applications over a network using TCP (recommended) or UDP connection during acquisitions. All types of channels may be exported, including analog, digital, and calculation channels. *AcqKnowledge* will continue to function normally while data transfer is in progress, displaying the new data in the graph window and performing any autoscrolling.

The network data transfer feature is not intended for strict real-time delivery. It also does not provide direct control over the MP unit. Perform all hardware configurations manually using the *AcqKnowledge* interface.

- For applications that require low latencies, high-data throughput, or direct hardware configuration and control, use BIOPAC Hardware API.

Create default menu configuration file

Create default menu configuration file to customize menu display. See page 325 for customization details.

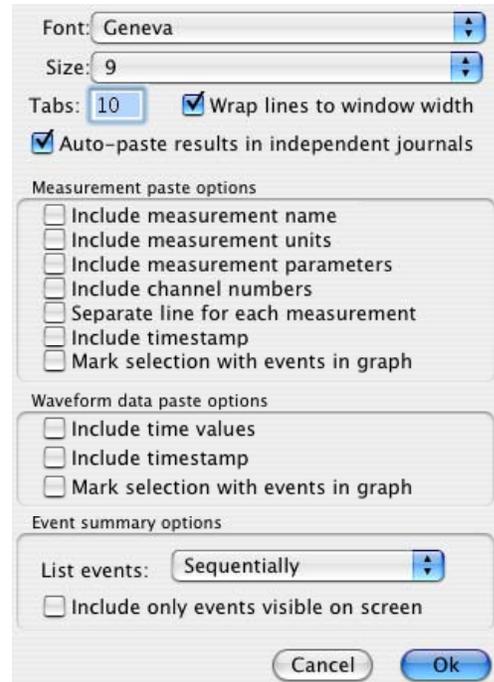
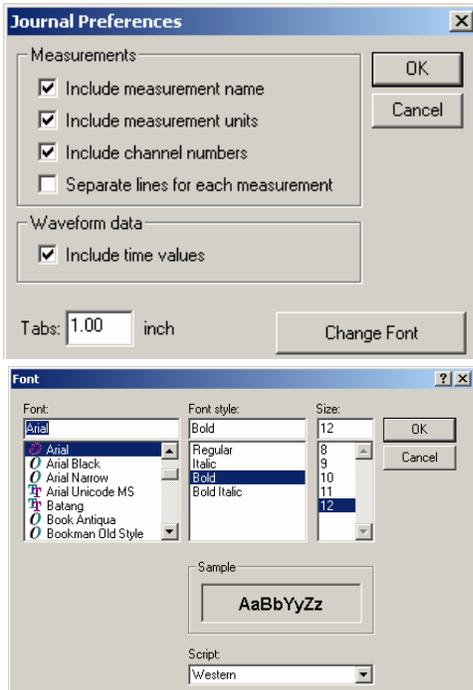
Journal Preferences

The Journal Preferences dialog box has five checkboxes that control the format of data when it is pasted into the journal or clipboard. To generate the Journal Preferences dialog

Windows Select Display > Preferences > Journal.

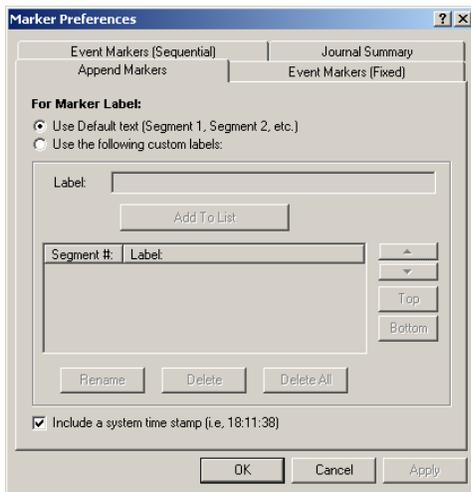
Mac OS X Select Display > Preferences and then Click the Journal...

For Marker Journal Summary preferences, see page 163.



- Include measurement name (i.e., BPM, delta T, Freq, etc.) with the values.
- Include measurement units (i.e., volts, mmHg, and so forth) after the numeric values.
 - *Note* The first two options cause additional text to be pasted into the journal, which can drastically reduce the amount of numeric data that can be pasted into the journal due to limitations on the maximum journal size. See page 48 for more information on working with Journal files.
- Include measurement parameters *Mac OS X only* Include any additional parameters used to compute the measurement function result, such as the operator used for Calculate measurements.
- Include channel numbers at the top of each column of data.
- Use a separate line for each measurement in the journal/clipboard.
- Include timestamp *Mac OS X only* 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—*Mac OS X only*. 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.
- Include time values copies the horizontal scale values along with the waveform data when data is copied to the clipboard. This means that when you paste data from the *AcqKnowledge* screen into a spreadsheet or similar application, horizontal scale information is retained.
- Tabs: Specify the tab interval to make columns more readable when you have a high precision setting.
- Change font to any font installed on your computer; the default font is 8 point Arial type.
- Wrap Journal text—*Mac OS X only*. Wraps text to window size.

Marker Preferences



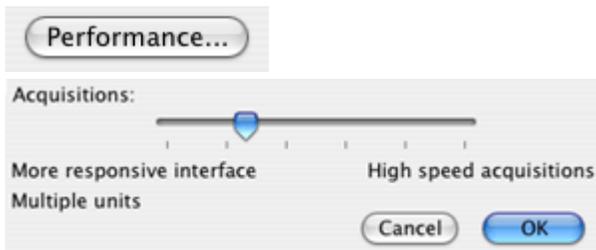
Windows only

Display > Preferences > Markers generates the Marker Preferences dialog; see page 162 for details.

Mac OS X

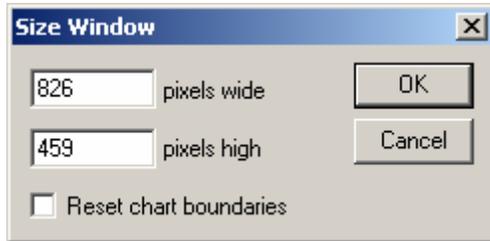
Access Event (Marker) preferences under MP menu> Set Up Events; see page 166 for details.

Performance



Mac OS X only Set the priority for system resource allocation. For a data focus, move right, for a function focus, move left. If you are experiencing Buffer Overloads, move toward High speed. To allow autoscale during acquisitions or jumping between MPs, resizing displays, or working in other programs, move toward More responsive.

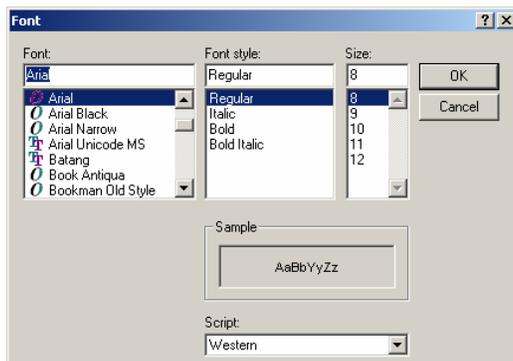
Size window...



The Size Window function lets you specify exact dimensions for the size of the graph window. You can use this to create consistently sized windows for pasting into documents. The two text boxes allow you to enter screen width and height, both of which are scaled in terms of pixels. Standard computer displays have 72 pixels per inch (28.3 pixels/cm), so a graph window that is 360 pixels wide by 216 pixels high would be 12.7cm tall and 7.6cm wide.

When the Reset chart boundaries box is checked, the boundaries between the waveforms will be reset so that each channel “track” is the same size. This function only works in chart mode.

Set Font



Windows only

Allows you to change the font used in *AcqKnowledge*. Select any font installed on your computer. The default is 8 point Arial type. This dialog is also accessible via Display > Preferences > Journal...

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 35.

Show All Data Snapshots



Manual Archive: description and time
Original file
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 you cannot save a file with colons in the filename). 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 you can view the archive at a later time to compare results to original waveforms or intermediate stages of analysis. Append markers are not preserved in the snapshot/embedded archive file. For details on creating snapshots/embedded archives, see page 49.

Load All Data Into Memory

Mac OS X only—Use with large files to improve plotting performance, measurement response, etc. Memory can hold up to two gigabytes of data.

Chapter 14 Other Menus

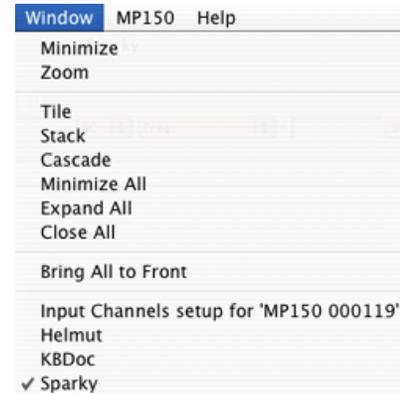
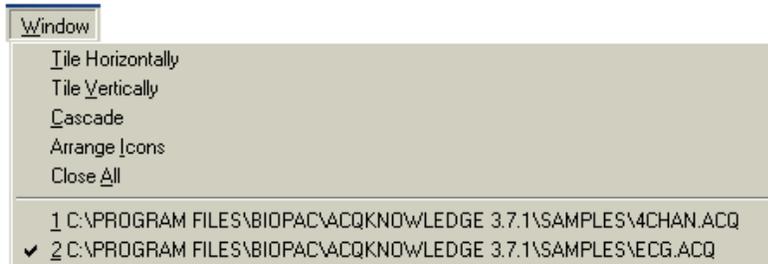
AcqKnowledge menu



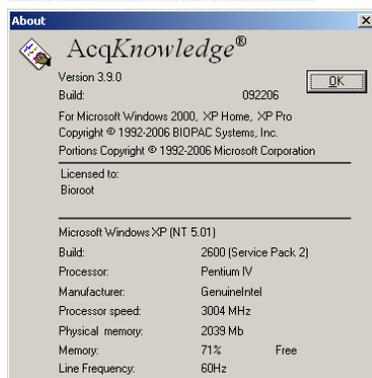
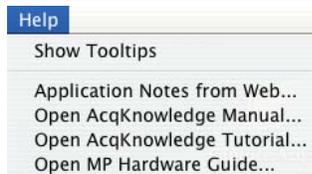
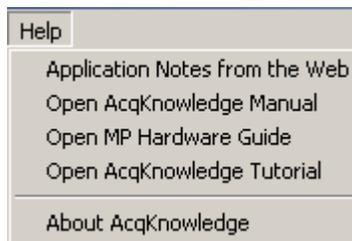
Mac OS X only—System generated menu. Use for About and Quit.

Window menu

The Window menu is a standard OS function. See your Windows or Macintosh OS Guide for details.



Help menu



Use the User Support System pdf files for online help with the software.

When About AcqKnowledge is selected from the Help menu, a screen is generated that provides information about the *AcqKnowledge* software being used and your system parameters, which can be useful if you need to call BIOPAC for any reason. On the Macintosh this item is available under the Apple menu.

- *Mac OS X only*—About AcqKnowledge is under the *AcqKnowledge* 3.9 menu.

Note: For information about the MP acquisition unit and firmware, click MP menu > About MP on Windows/PC or MP menu > MP1#X Info on Mac OS X.

Mac OS X only—Tooltips is an online assistance feature to help novice users learn how to use *AcqKnowledge*. Text is generated to describe the software functionality of the item under the mouse. Unavailable items/controls will indicate why they are unavailable.

- To show Tooltips when you pass the cursor over an item, select Help > Show Tooltips.

Tooltips are not available for context sensitive (Ctrl-click) menus due to operating system limitations.

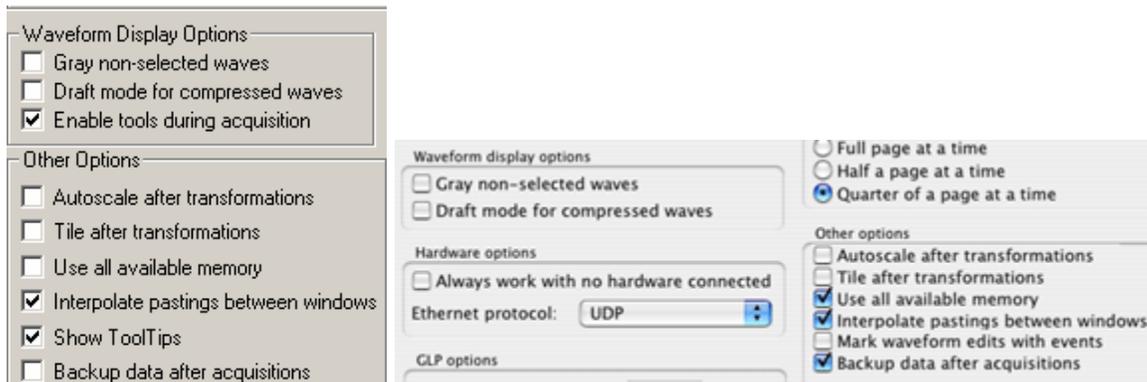
Part D—APPENDICES

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. You can choose from 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 box (shown below). Checking these two boxes will cause *AcqKnowledge* to plot data faster (at the expense of some precision) and use as much available memory as possible. You can cancel the plotting at any time by holding down the ESC key on the MP//WSW (PC) or $\text{⌘} + \text{“.”}$ on the MPWS (Mac).



- (2) You can reduce the time interval per division, which causes less data to be displayed on the screen at one time, and should reduce plot time.
- (3) If the data still takes too much time to redraw and you have a color monitor, try reducing the number of colors displayed.
- (4) If you have a high-resolution video card (one capable of displaying many thousands of colors), you may want to reduce the resolution to speed up plotting time.
- (5) Load all data into memory; see page 316 for details.

Q: Can I use other software with the MP System? Can I use AcqKnowledge to control other data Acquisition hardware?

A: No. The MP System was designed to work with the *AcqKnowledge* software. However, the software can read in previously acquired text files generated by *AcqKnowledge* 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 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, *AcqKnowledge* assumes (by default) that the data was sampled at 100Hz 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, you need to know the rate at which the data was originally sampled. The sampling interval is calculated by dividing one by the sampling rate. You can adjust the sampling interval to the appropriate value via the File>Open dialog box before the data is read in, or if the data is already present, change the time scale in the Display>Horizontal scale dialog box.

For instance, if 20 minutes of data was originally collected at 2Hz and is read into *AcqKnowledge* 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 on the Options button in the File>Open dialog box and change the value in the Sampling Interval dialog box. To change the time scale after data has been read in, adjust the units per division in the Display>Horizontal axis dialog box. If the data are time-domain data, you can adjust the seconds/sample interval at the bottom of the dialog box. 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 have the fastest computer available. Why can't I acquire data to the computer any faster than 11,000Hz on one channel, using an MP100 System?

A: The bottleneck occurs in two places:

1. The first occurs when data is transferred between the MP acquisition unit and the computer. While the MP System can acquire data as fast as 70,000Hz when data are stored directly to the MP acquisition unit memory, the maximum rate drops considerably when data is acquired to the computer memory, and even more so when data is acquired directly to disk.
2. The second bottleneck occurs within the computer itself, and has to do with the time it takes to transfer and process incoming data. Faster computers can perform these tasks more quickly, which is why the maximum possible sampling rate for a Pentium (storing to memory) is faster than a 386SX. With a large number of channels, the aggregate sampling rate can climb to a theoretical maximum of 16,000 samples per second.

To resolve the sampling limitation, use an MP150 System.

Q: I just filtered a waveform and now my data file is huge. Why is that?

A: When *AcqKnowledge* 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. *AcqKnowledge* 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 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 acquisition unit is ON and, if so, that all the connections to the MP acquisition unit were made properly. When the MP acquisition unit is powered up, a light on the front panel of the MP 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 acquisition unit is rated at 12 VDC @ 1 Amp, and using other power supplies may result in damage to the MP 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 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 acquisition unit) illuminates when the MP acquisition unit is powered up. When the MP 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 box correspond to the channel switch settings on the amplifier modules and/or direct analog connections to the UIM100C. When a direct analog input is set to the same channel as an amplifier, the resulting data will appear quite noisy or erratic. You should also 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. You may also want 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 AcqKnowledge?

AcqKnowledge 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 $[2 \text{ to the } 52] \text{ power}$ or approximately $4.5 \text{ E}15$. Accordingly, the effective decimal accuracy will be between 15 and 16 digits.

Appendix B - Filter characteristics

Filter types

AcqKnowledge employs two types of digital filters:

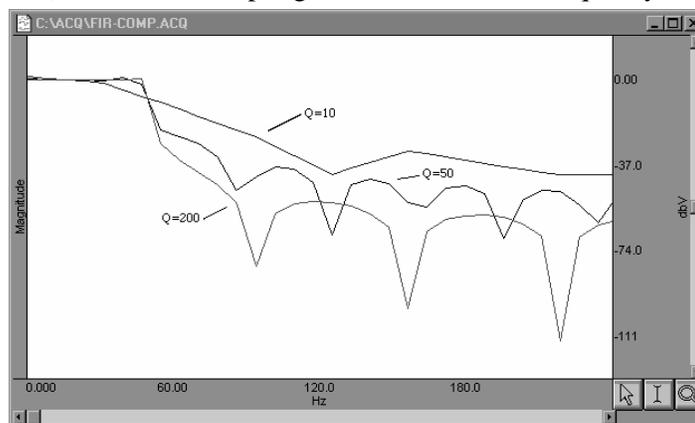
- (a) Finite Impulse Response (FIR) perform post-acquisition filtering
- (b) Infinite Impulse Response (IIR) perform filtering calculations online (during an acquisition) or post-processing (after an acquisition)

Although the similarities between the two types of filters outweigh the differences, some important distinctions remain.

1. First, IIR filters are typically more efficient than FIR filters, which means that IIR filters can filter data faster than FIR filters, which is why IIR filters are used for online Calculations.
2. Second, 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.
3. Third, 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.

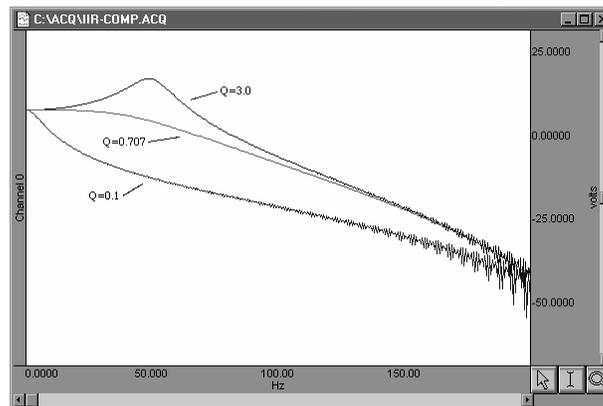
In the examples on the following page, the filter responses of several different types of filters are compared. All of the filters are 50Hz low pass filters operating on the same data.

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 determines 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 *AcqKnowledge*. 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).

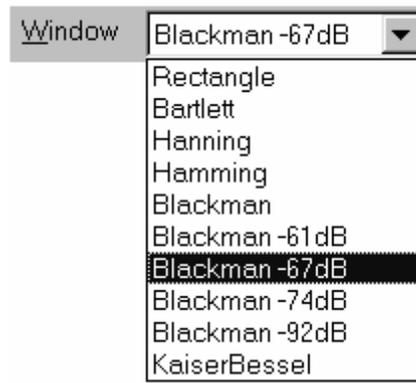
Another way to minimize edge effect with an FIR filter is to increase the number of coefficients used to transform the data.

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. You can check this 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.

- *AcqKnowledge* 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 you are looking at amplitude levels in a linear FFT you need 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 $n = \frac{N-1}{2}$ 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.

Type of Window	Parameter Values			
	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 <i>Windows/PC only</i>	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 megabytes) 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.

The software that comes with your MP System 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.

Note: *AcqKnowledge* 3.8.1 for Windows cannot work with graph files larger than 2GB.

The following tips can help you get the most out of your MP System when working with large data files.

➤ **Use virtual memory**

Since *AcqKnowledge* runs under Windows® XP or Mac® System 7.0 or better, most computers are able to take advantage of the virtual memory feature. While this is slower than conventional memory, it will at least make it possible to load some files that might otherwise be impossible to load.

➤ **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 if you would like to perform transformations of some sort on at least one of the waves.

➤ **Sample slowly**

Theoretical and methodological concerns will, to a large extent, dictate sampling rate. However, if you can reduce the sampling rate, choose to do so. Or, use Transform > Resample (page 247) 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 RAM, acquiring data directly to disk allows you to recover data in the event of a power loss to the MP System. Furthermore, much larger data files can typically be stored directly to disk than to memory.

➤ **Use the Append mode**

The Append mode allows you to pause the acquisition 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.

➤ **Stop plotting**

If the screen is taking a long time to redraw (because the data files are large), you can stop plotting and change the horizontal scale to a smaller number before redrawing. To stop plotting from disk or memory, use the ESC key on the MPWSW (PC) or  + “.” on the MPWS (Mac).

➤ **Compress Files**

Use the File > Save As > Compressed option to store or transfer data

Appendix D - Customizing Menu Functionality

AcqKnowledge now includes a powerful customization feature lets you choose the program features to display as menu options. If you have a specific procedure, you can limit the menu options to list only those functions you need, thereby reducing the chance for confusion or error in your lab. For instance, you might choose to remove the “Setup Triggering” and “Setup Stimulator” options from the MP menu, as shown below:



Default MP menu



Customized MP menu

Follow the simple procedure below to customize menu display for your own needs.

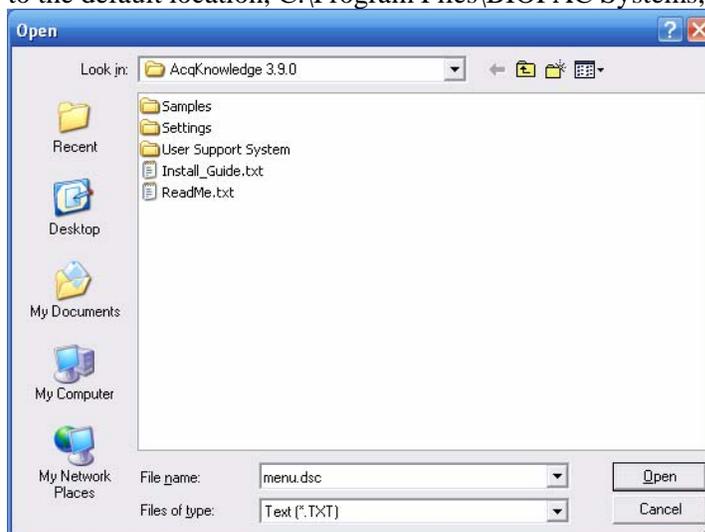
1. Launch AcqKnowledge.
2. **Mac users:**
 - a) Choose Display > Preferences.
 - b) Click on “Create default menu configuration file.”
 - c) Click “Yes” when prompted about editing the file.

PC users: a) Display the Journal window.

-  Use on the Journal icon from the Graph Toolbar
- Click on the Display menu, select Show, and drag to select Journal.

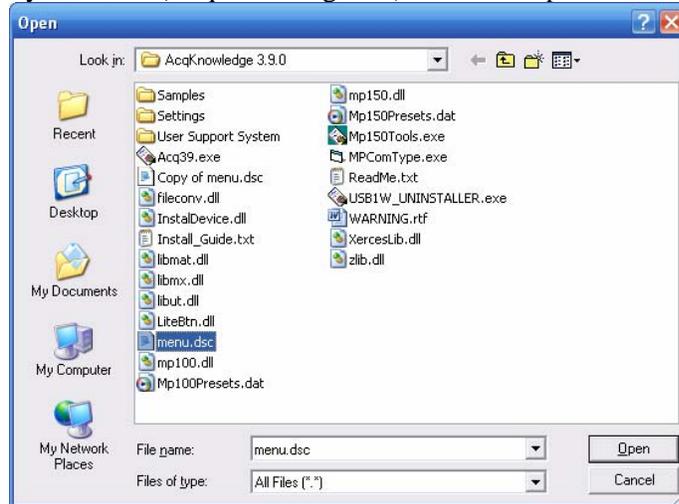
- b)  Click the Journal > Open icon on the Journal Toolbar.

- c) Type “menu.dsc” in the “File name” entry box and click Open. (If necessary, first navigate to the default location, C:\Program Files\BIOPAC Systems, Inc\AcqKnowledge 3.9.)



- Alternately, you can pull down the “Files of type” menu, select “All files” and then select the “menu.dsc” file from the default location *(C:\Program Files\BIOPAC

Systems, Inc\AcqKnowledge 3.9) and click Open.



The “menu.dsc” file will open in the Journal window, as shown below.

- For a complete list of the options included in the “menu.dsc” file, see the end of this section.



- Find the menu and item you want to change (scroll through list as necessary) and type “OFF” to disable the menu display. For example, you might change the File > New option to OFF, as shown below.
 - Note that ON/OFF is case-sensitive and you must type in ALL CAPS.
 - Deleting a file listing instead of typing OFF will not remove the feature; it will default to ON unless you type OFF.



To reactivate a menu item that you have turned OFF, just repeat the above procedure and type “ON” for the menu item you desire.

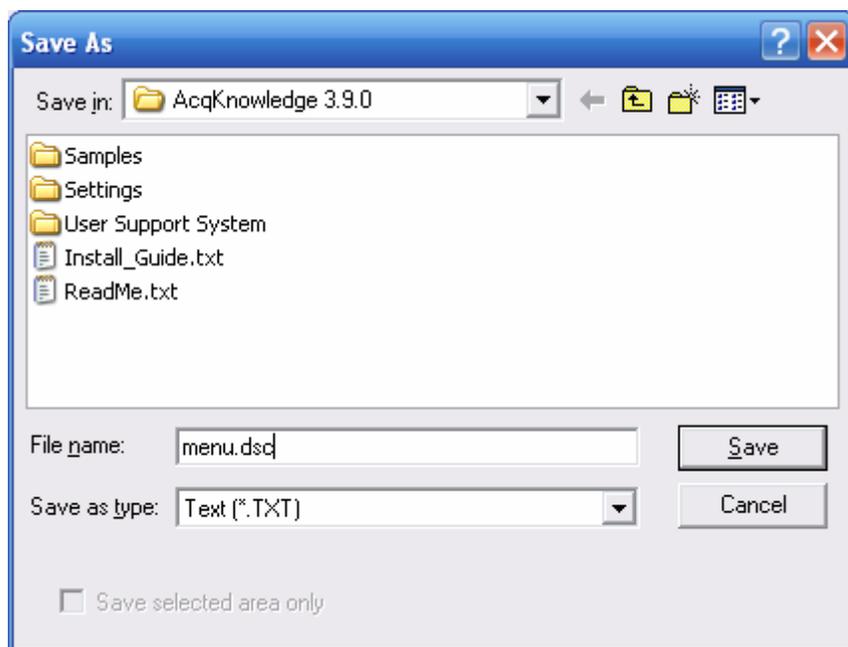
- Activate the Journal Save As dialog.



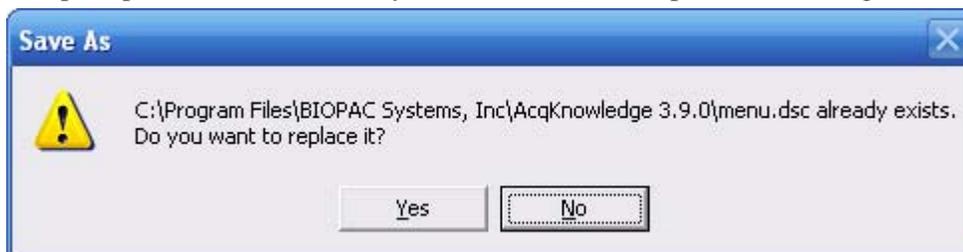
PC: Click the save icon at the top of the Journal.

Mac OS X: File > Save Journal as...

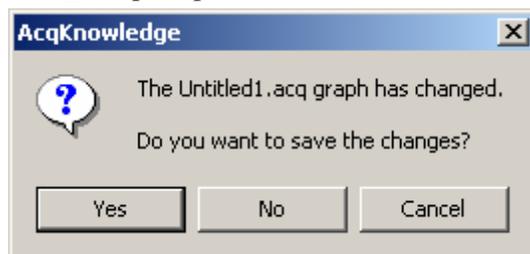
- Save the file in the exact same location by typing “menu.dsc” in the “File name” entry box and clicking Save. Leave “Save as type” set to Text (*.TXT).



6. You should be prompted that the file already exists. Click Yes to replace the existing file.



7. Exit the *AcqKnowledge* program. You do not have to save any graph or journal changes—the “menu.dsc” file has already been saved. Click No if prompted.



8. Restart *AcqKnowledge*.
9. Check your menu listing.

Note: Application menu customization has a corresponding effect on contextual menu display for **Mac OS X**. 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 MP150 for Network Operations

The MP150 is primarily designed to work in Local Area Networks (LAN). In a LAN, each MP150 unit may be accessed from any workstation (PC or Mac) running an Ethernet version of *AcqKnowledge* software.

Theoretically, two or more workstations (WS) could be connected to one MP150 at the same time, but the MP150 cannot perform independent acquisitions simultaneously, so in such cases one or all connected WS would receive corrupted/invalid data and/or crash.

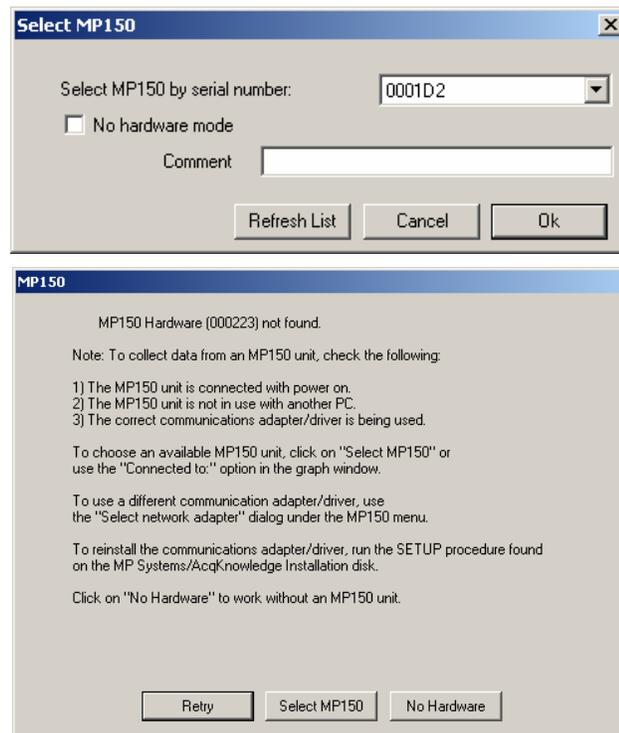
To prevent this, *AcqKnowledge* uses new “lock/unlock” technology that establishes communication between an MP150 and one—and only one—dedicated WS in the Network.

AcqKnowledge locks an MP150 as soon as it connects to it, which tells the MP150 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 MP unit receives a command from the computer that locked it. To locate MP150s in the local network, *AcqKnowledge* sends a broadcast packet to the local area network that asks all the MP150s in the network to respond. All the MP150s—whether locked or unlocked—will respond to this prompt. This means that the “Select MP150” menu may allow a user to select an MP150 that is locked. In such cases, *AcqKnowledge* will fail to connect (to a locked MP unit), as expected. To resolve this issue, unlock or power cycle the MP unit.

Locked An MP150 becomes “locked” in operation to a WS (and unusable to other users) if

- a) An MP150 unit is selected from “Select MP150.” The dialog lists all MP150 units that are powered ON and sitting on the same local area network. Unfortunately, this dialog cannot provide the locked/unlocked status of each MP150 in the LAN. You may refer to the BUSY and ACTIVITY lights on the MP150 to determine the status—if you cannot connect to an MP150 but its lights indicate data traffic or acquisition, the MP150 you are trying to connect to is connected to another WS.
- b) When *AcqKnowledge* is launched, *AcqKnowledge* will “remember” and try to connect the last MP150 used by a WS; if the last used MP150 is not available, the user must pick an available MP150 unit from the “Select MP150” dialog.
- c) With the advent of any new communications or the start of any type of acquisition to the MP150 unit, when a WS communicates with an “unlocked” MP150 unit, *AcqKnowledge* sends a “lock” command.

When an MP150 is locked, its serial number is listed in the Select MP150 dialog but any attempt to select a locked MP150 will generate a Hardware Not Found prompt (shown above).



- Unlocked** An MP150 automatically “unlocks” and becomes available to other users
- When the user exits *AcqKnowledge*.
 - The user selects another MP150 in the Select MP150 dialog.
 - The user selects the “No Hardware” option in the Select MP150 dialog.
- Other, less common conditions that may unlock the MP150 include
- The MP150 is powered OFF and then ON.
 - The MP150 does not receive commands/data from the WS or *AcqKnowledge* for about 5 minutes. This time-out can occur when
 - An *AcqKnowledge* dialog (About, Calculation setup, etc.) is open for a long time.
 - *AcqKnowledge* or the WS crashes for any reason.
 - You turn the connected WS off without exiting *AcqKnowledge*.

If the MP150 becomes **unlocked due to a time-out**, two scenarios are possible:

- The MP150 is locked—If another user has locked the MP150 you had been using, you will see the No Hardware Prompt. Check the MP150 lights to determine its status.
- The MP150 is unlocked—Your WS will “lock” the MP150 as soon as you initiate communication or acquisition; until then, the MP150 remains unlocked and available to others.

No Hardware When a user selects the “No Hardware” option, the menu of available MP150 units is grayed out and becomes unselectable. If a user attempts to connect to a locked MP150, an error message will be generated to advise that the MP150 unit is locked to a different computer.

Cannot lock



If you receive this “cannot lock” prompt, check that no other user on the network is using the MP150, power-cycle the MP150, check the current firmware version (About MP150), and, if necessary, update the firmware using MP150Tools (see next Appendix).

Appendix F—Firmware Upgrade Utility

- Windows: *AcqKnowledge* 3.9.0: use MP150 menu > Update Firmware (details below)
AcqKnowledge 3.8.2 or previous: use MP150TOOLS.EXE Utility (see Application Note AF-228 MP150 Firmware Upgrade)
- Mac: MP150 Tools Firmware Upgrade (see page 331)

You may use the MP150 Firmware Upgrade Utility from any version to any version without limitation. It is a very safe procedure that cannot damage the MP150.

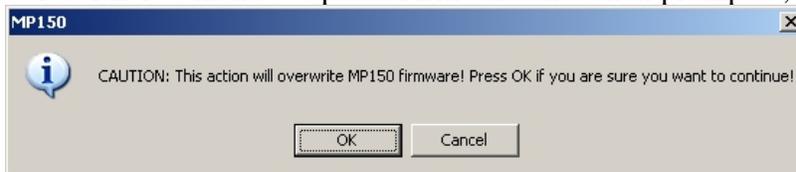
Before performing a Firmware Upgrade, make certain that no other users are connected to or using the MP150 you plan to upgrade. Any attempts to communicate with the MP150 via any user's *AcqKnowledge* software may affect the viability of the upgrade. Fluctuations in the power source during an upgrade may also affect the outcome.

The MP150 is delivered with a factory-programmed firmware version that is not affected by the upgrade procedure—you can always restore the original firmware with the Firmware Rollback Switch (see page 332 for details).

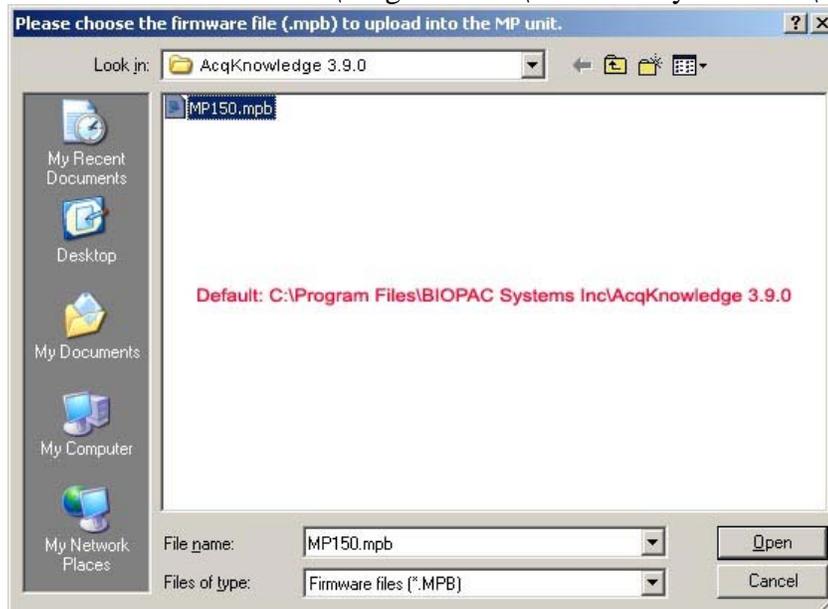
To use an MP150 with UDP communication on a network with a non-Windows DHCP server, you must use firmware 1.1.12 or greater for the MP unit to properly be assigned an IP address. This is also true for any DHCP system with non-Windows operating systems, such as Unix, Linux, Mac OS X, and other DHCP-aware devices.

MP150 > Update Firmware—for Windows users

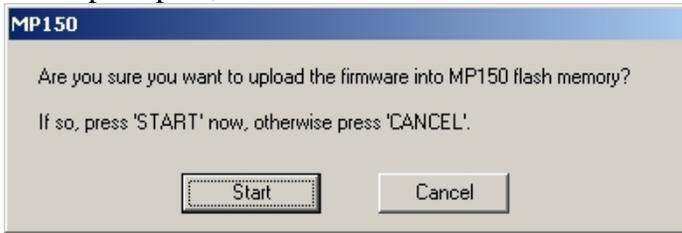
1. Select MP150 menu > Update Firmware and when prompted, click OK.



2. Choose the firmware file (.mpb) from the default location and click Open.
 - The default location is C:\Program Files\BIOPAC Systems Inc\AcqKnowledge 3.9.



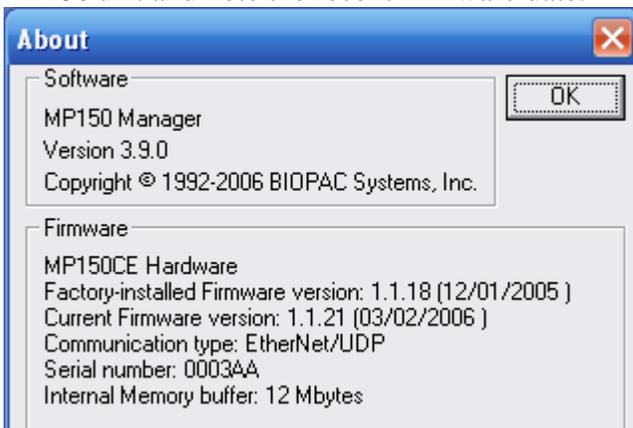
- When prompted, click Start.



- A status bar will show the upgrade's progress, and a prompt will indicate a successful firmware update.



- Optional:* To verify firmware upgrade, close *AcqKnowledge* and launch it again. Select MP150 > About MP150 to generate the About dialog with the MP150 serial number and firmware version. If the firmware version is not as expected, repeat the Firmware Upgrade. If the MP150 fails to operate after downloading a new firmware revision, use the Firmware Rollback Switch on the bottom of the MP150 unit and note the recent firmware date.



MP150 Tools Firmware Upgrade—for Macintosh users

- Find the MP150 Tools Firmware Upgrade file in the BIOPAC program folder and open it.
- Click Next to begin the procedure.
- Use the connect dialog to designate an MP150 to upgrade.
 - You must connect to an MP150 to complete the firmware upgrade.
- Confirm the designated MP150 information and click Yes.
- Click Start to initiate the firmware upgrade.
 - A warning will be generated if the firmware to be installed is older than the current firmware.
- When the upgrade is complete, a success dialog will be generated. Click Quit to close out.
 - If the firmware upgrade was not successful, you will be prompted to “rollback” to an older firmware version. *See* below for details on the Firmware Rollback Switch.

Firmware Rollback Switch

IMPORTANT!

Use the Firmware Rollback Switch only if the MP150 fails to operate after a Firmware Upgrade.

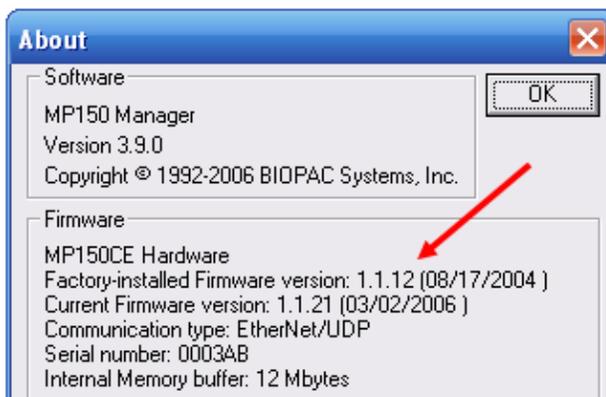
In all other cases, just turn the MP150 power OFF and then ON and check the results of the Start up/Self-Test.

The Firmware Rollback Switch is located on the bottom of the MP150 unit and is recessed to prevent accidental activation.

Activation of the Firmware Rollback Switch will cause the MP150 unit to operate under the factory-installed firmware version. If no upgrades have been performed (the MP150 has only the factory-loaded firmware), the Firmware Rollback Switch will have no effect.

Procedure:

1. Turn the MP150 unit ON.
2. Use About MP150 in the *AcqKnowledge* software to determine the factory-installed firmware version:



IMPORTANT!

Factory-installed Firmware version 1.1.2 or previous (purchased approximately November 2002 or before) may not reset to a level compatible with UDP communication. In such cases, you will need to install a DLC-compliant version of *AcqKnowledge* and update to UDP in stages; contact BIOPAC for additional support if necessary

Mac OS X: Labeled “Manufacturer’s ROM” and “Current ROM”

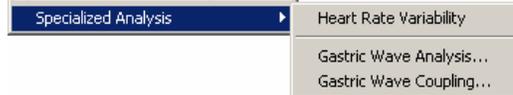
3. Turn the MP150 unit OFF.
 4. Turn the MP150 unit upside down and use a small-tipped device (an unfolded paperclip will do) to depress and hold the switch down.
 5. Continue to hold the switch down, and turn the MP150 unit ON.
 - One green and one yellow LED light will begin to blink simultaneously 5 times.
- ✓ **While the lights are blinking simultaneously, you may cancel the Rollback by releasing the Firmware Rollback Switch. If Rollback is cancelled, the MP150 will try to load the latest firmware upgraded version.**
- Then the MP150 will perform a normal Startup/Self-Test with the factory-loaded firmware.
 6. When the simultaneous blinking stops, release the switch.
 - The MP150 is now restored to the previous version of firmware.
 - You can check the firmware version via the MP150>About MP150 menu item in *AcqKnowledge*.

Appendix G— Specialized Analysis in AcqKnowledge 3.9



The Specialized Analysis package includes comprehensive analysis tools to automate analysis to save hours (or days!) of processing time and standardize interpretation of results. Analyze data collected on MP Systems running on Windows/PC or Mac OS X.

Windows Specialized Analysis is limited to



For other Specialized Analysis functions offered on Mac, please read about File Portability (page 393).

Mac OS X AcqKnowledge 3.9 includes a courtesy copy of the Specialized Analysis Package under the Transform menu.

An analysis package is a bundle of transformations created to assist with analysis in a specific area of research.

A classifier is a 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.

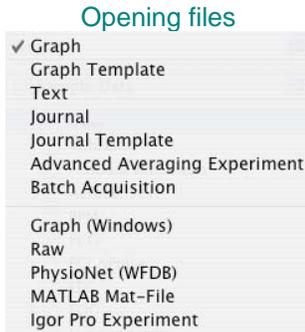
The Specialized Analysis package includes the following Analysis Packages and Classifiers:

Detect and Classify Heartbeats	Hemodynamic Analysis <i>continued</i>
Locate ECG Complex Boundaries	Left Ventricular Blood Pressure
Heart Rate Variability	Monophasic Action Potential
Gastric Wave Analysis	Respiratory Sinus Arrhythmia
Gastric Wave Coupling	Preferences: Output Display Format; LVEDP Location Method;
Chaos Analysis	dP/dt pk-pk %; MAP Plateau Location Method; dP/dt MAP
Detrended Fluctuation Analysis	pk-pk %
Optimal Embedding Dimension	Impedance Cardiography Analysis
Optimal Time Delay	Body Surface Area
Plot Attractor	ICG Analysis
Correlation Coefficient	PEP Pre-ejection Period
Electrodermal Activity	dZ/dt Derive from Raw Z
Derive Phasic EDA from Tonic	dZ/dt Classifier: B, C, X, Y, and O Points
Event-related EDA Analysis	dZ/dt Remove Motion Artifacts
Locate SCRs	Preferences: Output Display Format; C-, B-, and X-Point
Preferences: Output Display Format; Phasic EDA	Location; Stroke Volume Calculation Method; Body
Construction Method: Smoothing Baseline	Measurement Units; Body Surface Area Method; Ideal
Removal or High Pass Filter	Weight Estimation Method; dZ/dt Max Method
Electroencephalography	Magnetic Resonance Imaging
Compute Approximate Entropy	Artifact Frequency Removal
Delta Power Analysis	Artifact Projection Removal
Derive Alpha-RMS	Median Filter Artifact Removal
Derive EEG Frequency Bands	Signal Blanking
EEG Frequency Analysis	Neurophysiology
Remove EOG Artifacts	Amplitude Histograms
Preferences: Output Display Format	Average Action Potentials
Electromyography	Generate Spike Trains
Derive Average Rectified EMG	Find Overlapping Spike Episodes
Derive Integrated EMG	Set Episode Width & Offset
Derive Root Mean Square EMG	Preferences: Detect Spike; Default Episode Width; Default
EMG Frequency & Power Analysis	Episode Offset; Default # of Spike Classes
Locate Muscle Activation	Principal Component Denoising
Preferences: Output Display Format	Remove Trend
Ensemble Average	Respiration
Epoch Analysis	Compliance & Resistance
Hemodynamic Analysis	Penh Analysis
Classifiers: ABP; LVP; MAP	Pulmonary Airflow
Arterial Blood Pressure	Spectral Subtraction
ECG Interval Extraction	Stim-Response
	Digital Input to Stim Events
	Waterfall Plot
	Wavelet Denoising
	Stim-Response Analysis

AcqKnowledge File Portability Windows ↔ Mac OS 10.3 or higher

Use Specialized Analysis to analyze *AcqKnowledge* data files collected on MP Systems running on Windows/PC or Mac OS X. Using *AcqKnowledge* 3.9 for Specialized Analysis allows you to open/save the following file formats:

Opening files for Specialized Analysis



AcqKnowledge 3.9

The default file formats (Graph and .ACQ) are referred to as “*AcqKnowledge*” files. The *AcqKnowledge* file format is the standard way of displaying waveforms in *AcqKnowledge*. 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). *AcqKnowledge* files are editable and can be modified and saved, or exported to other formats using the Save as command.

File Compatibility

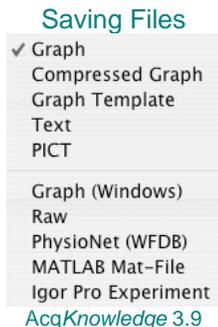
Windows *AcqKnowledge* 3.8 cannot open Mac *AcqKnowledge* 3.9 files.

Mac *AcqKnowledge* 3.9 can open Windows *AcqKnowledge* 3.8 or later files.

- Mac *AcqKnowledge* 3.9 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



AcqKnowledge 3.9

The default file format for the File>Save as command is to save files as an *AcqKnowledge* file. Selecting Graph (MPWS) or .ACQ (MPWSW) from the popup menu in the Save As dialog box will save a file as an *AcqKnowledge* file, which is designed to be as compact as possible. These files can only be opened by *AcqKnowledge*, but data can be exported to other formats once it has been read in.

The **Options** button generates a dialog box that allows you to save only a portion of your file. When the “Selected Section only” option is enabled, only the data that has been selected with the I-beam tool will be saved. This option saves the selected area to another file and does not affect the current file that you are working in.

File Compatibility

Windows *AcqKnowledge* 3.9 files can be opened with Mac *AcqKnowledge* 3.9, but some advanced features may not transfer.

Mac *AcqKnowledge* 3.9 can save as “Graph (Windows)” files, but it saves in Windows *AcqKnowledge* 3.7.1 format. In this earlier format, all data is retained, but newer *AcqKnowledge* features (like dual stimulation, data views, embedded archives, etc.) are lost along with any settings specific to Mac *AcqKnowledge* (like events, adaptive scaling settings, etc.).

- Mac *AcqKnowledge* 3.9 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 PC GLP files or compressed PC files.

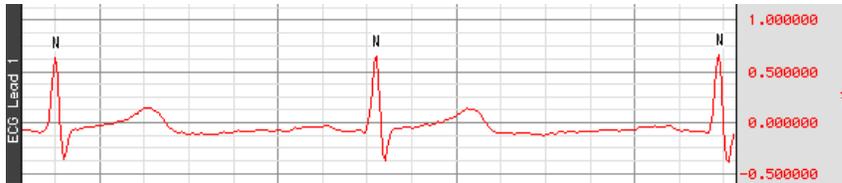
Files must end on a multiple of the lowest channel sampling rate to be fully PC compatible.

Excel Spreadsheet Export *AcqKnowledge* 3.9.1 Mac only—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.

Detect and Classify Heartbeats

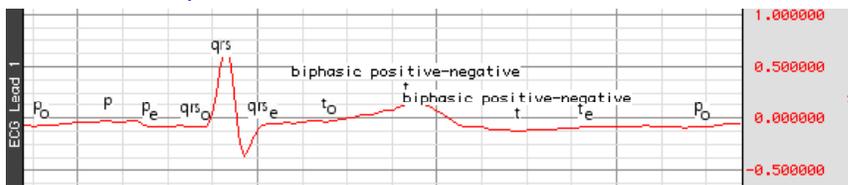


This robust QRS detector is tuned for human ECG Lead II signals. It attempts to locate QRS complexes and places an event near the center of each QRS complex to identify the type of heartbeat event:

- 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.

Locate ECG Complex Boundaries



This classifier performs ECG waveform boundary detection for human ECG Lead II signals. 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 <i>Note:</i> 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 <i>Note:</i> 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.

Heart Rate Variability

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, 199

- See **Application Note 233 Heart Rate Variability—Preparing Data for Analysis Using AcqKnowledge** (online at www.biopac.com)

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 *AcqKnowledge* software. The note explains how to:

- Record good ECG data
- Prepare data for the tachogram
 - Filter the ECG data
 - Transform the data using Template Correlation function
- Create a tachogram
- Identify problems with the tachogram data
- Correct tachogram data

Windows

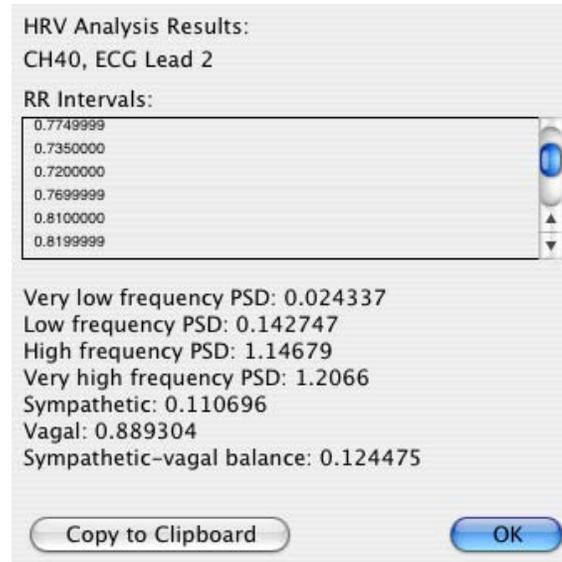
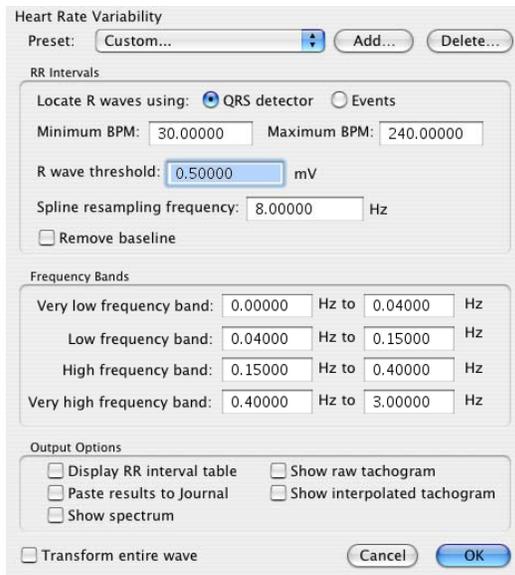
display with Markers selected

The image shows two windows from the AcqKnowledge software. The first window, titled "Heart Rate Variability", has a "Preset" of "Human (Adult)". Under "RR Intervals", "Locate R waves using:" has "Markers" selected (circled in red). Other settings include Minimum BPM: 30.00000, Maximum BPM: 240.00000, R wave threshold: 0.50000 mv, and Spline resampling frequency: 8.00000 Hz. The "Output Option" section has "Display RR interval table" checked. The second window, titled "Heart Rate Variability Results", shows the following data:

ECG	
RR Intervals:	
0.74500	
0.74000	
0.77500	
0.87500	
n 94500	
Very low frequency PSD:	0.01379
Low frequency PSD:	0.08822
High frequency PSD:	1.00978
Very high frequency PSD:	2.01195
Sympathetic:	0.08035
Vagal:	0.91965
Sympathetic-vagal balance:	0.08737

Windows Results

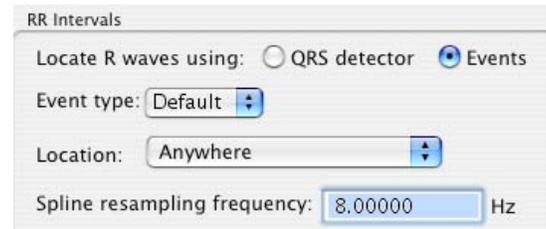
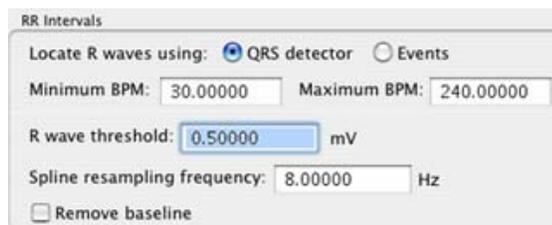
Mac



Heart rate variability is the examination of physiological rhythms that exist in the beat-to-beat interval of a cardiac signal. Heart rate variability assists in performing frequency domain analysis of human ECG Lead II data to extract standard HRV measures. The *AcqKnowledge* 3.9 algorithm conforms to the frequency domain algorithm guidelines as published by the European Heart Journal. HRV processing in *AcqKnowledge* 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).

RR intervals—Select a method to locate R waves



QRS detector

The HRV analysis QRS detector uses a modified Pan-Tompkins algorithm. The algorithm normalizes the ECG data to 1 whereby the peak amplitude of the highest R-wave represents 1. The default threshold level of .5 should place the threshold in the middle of the R-wave. If the R-wave amplitude varies a lot, it might be necessary to adjust the threshold level.

Pan J and Tompkins WJ. A Real-Time QRS Detection Algorithm. *IEEE Transactions on Biomedical Engineering* 32(3):230-236, 1985.

The standard settings should function on a wide range of data sets, but you can adjust the thresholds for your particular data set. Use the tachogram output to examine the output of the QRS detector.

- *Spline resampling frequency*—For highest accuracy, set to no less than twice the topmost frequency of the very high frequency band.

Frequency Bands—Adjust the boundaries of the frequency analysis. They are preset to the frequency ranges recommended by the *European Heart Journal*. Output of derived parameters is presented in a Sheet and may also be pasted as text to the Journal.

Output Options— Create standard result presentation graphs or assess performance of the HRV algorithm. These Options allow access to intermediate computation data for algorithm validation and/or measurements.

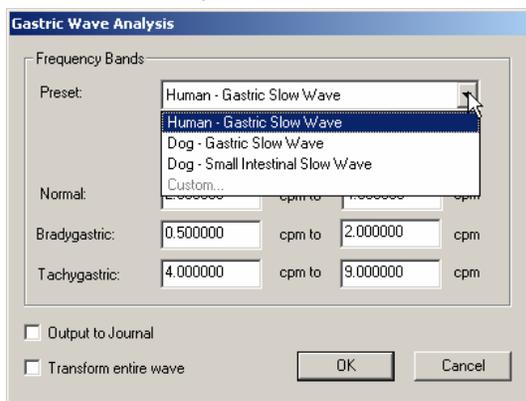
- **Spectrum**—Displays the power spectrum density (PSD) estimation from which the PSD summations and sympathetic/vagal ratios are computed.
- **Raw tachogram**—Plots the raw R-R intervals found by the QRS detector. Perform statistical HRV measures on the R-R intervals without exporting the textual R-R table to excel.
- **Interpolated tachogram**—Plots the resampled R-R intervals after cubic spline interpolation is applied and extracts the PSD from this data.
- **Presets**—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.

Events

Located using events in 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.

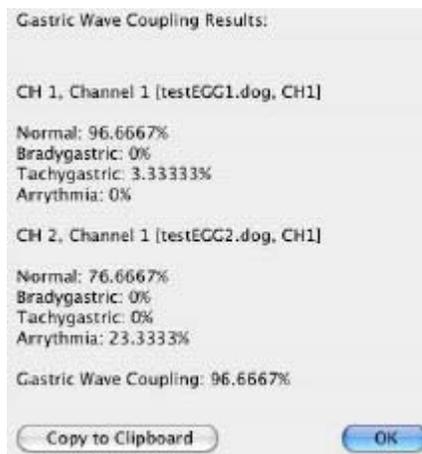
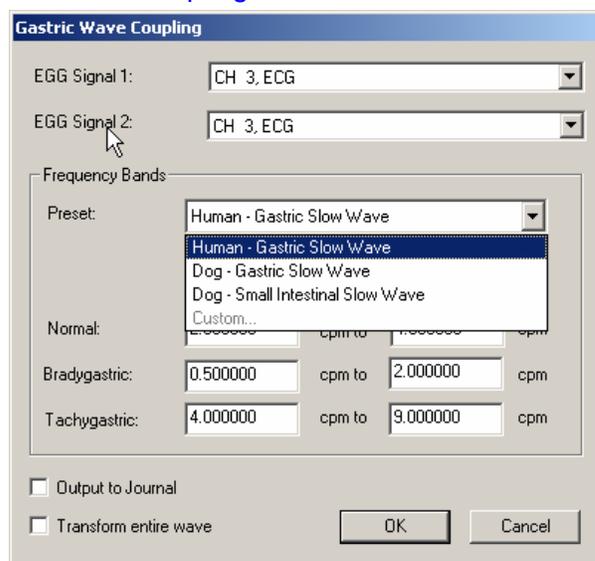
By using events, it is possible to use other QRS detectors within *AcqKnowledge* for performing HRV analysis. It is also possible to apply spectral HRV-style analysis to data in other domains as long as intervals can be reduced to events.

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; you may extend these presets with your own.

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.

Chaos Analysis

Detrended Fluctuation Analysis
Optimal Embedding Dimension
Optimal Time Delay
Plot Attractor

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 n segments of equal length, and 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/>

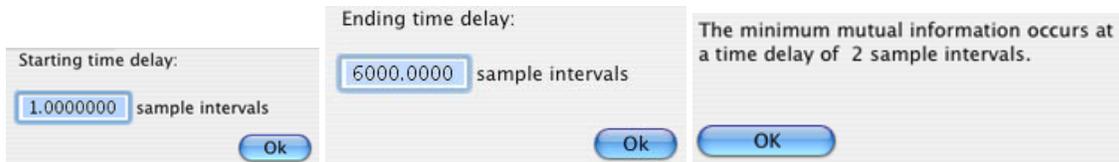
Optimal Embedding Dimension

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.

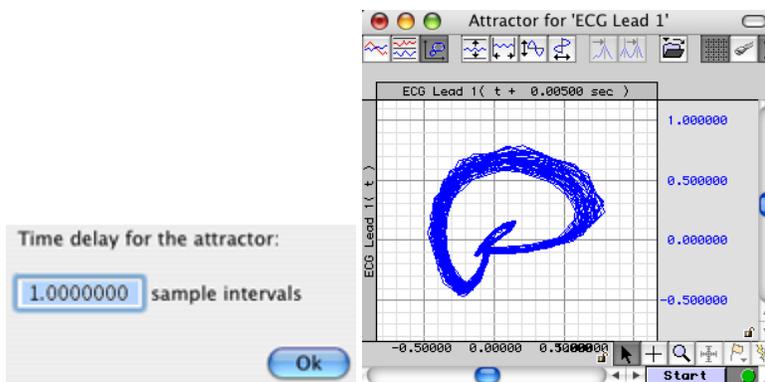
Optimal Time Delay



Assists in picking a time delay that is most relevant for the data. It runs through and 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 new fractal dimension and other chaos-related measurements operate on a single channel of data. During 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 to perform this analysis. The Optimal Time Delay transformation can be used to choose the best value for the parameter.

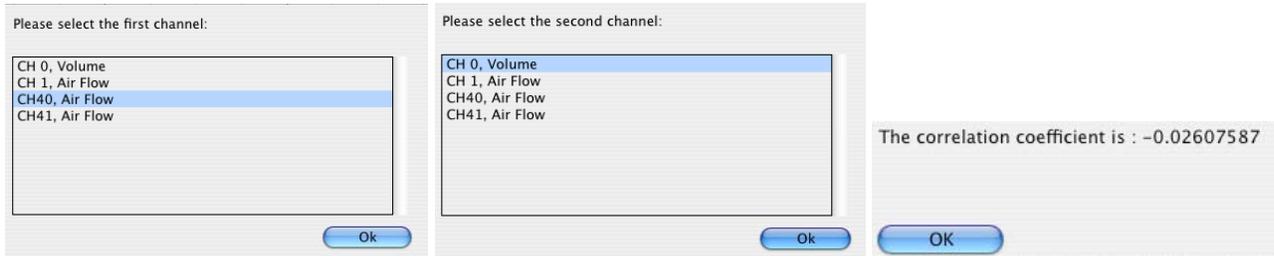
Plot Attractor



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:

$$r = \frac{n \sum x y - \sum x \sum y}{\sqrt{(n \sum x^2 - (\sum x)^2)(n \sum y^2 - (\sum y)^2)}}$$

(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

Derive Phasic EDA from Tonic
Event-related EDA Analysis
Locate SCRs
Preferences...

Definitions

The prompts and analysis results of the EDA analysis package use the following terminology and units:

μmho —the unit abbreviation for microSiemens, used in channel labels and analysis results.

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 over an interval. Tonic EDA is recorded using BIOPAC equipment with the highpass 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 highpass 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.

Derive Phasic EDA from Tonic

Given a tonic EDA signal, this transformation uses baseline smoothing or highpass filtering (the method currently set in Preferences) to construct a new Phasic EDA channel in the graph containing the estimate of the phasic EDA.

Event-related EDA Analysis

Many studies examine how EDA changes in response to certain stimuli. By examining changes in EDA, it is possible to gauge a subject’s psychological response to a certain event. The Event-related EDA Analysis transformation script assists in the extraction of EDA measures that are linked to specific stimuli.

In order to use the Event-related EDA Analysis transformation script, an event must 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. Stimulus delivery events are located by event type and (optionally) by specific channel of the graph. 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.

In addition to the stimulus delivery events, a tonic EDA signal must be present in the graph. If the tonic EDA signal does not already have SCR events defined on it, SCR events will be automatically constructed on the channel in the same fashion as the Locate SCRs transformation script.

Each stimulus delivery event is paired with the closest SCR event. SCRs that correspond to a stimulus delivery are known as “specific SCRs.” SCRs generally occur within a certain timeframe after stimuli. The transformation takes a maximum allowable separation interval between the stimulus and SCR response. 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.

For each specific SCR that is paired with a stimulus delivery event, the following measures are extracted:

Name	Abbrev.	Description	Units
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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.	umho
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 from the time of SCR onset to the maximum tonic EDA amplitude achieved during the SCA: $ EDA(t_{max}) - EDA(t_{onset}) $	umho
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

If text output is enabled, the average value of SCL, Latency, SCR Amplitude, and SCR Rise Time will be included as the final row of the table.

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).

A 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

Locate SCRs

Given a tonic EDA, this transformation defines event triplets for each skin conductive response in the tonic EDA. SCR location is a two stage process.

1. First, all potential SCR occurrences are located on the signal.
2. 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 umho), search for a positive threshold crossing in the phasic EDA signal. This position, t_{onset} is recorded as the start of the potential SCR.

2. Starting at t_{onset} , continue examining the phasic EDA until the first negative threshold crossing of 0 umho occurs. This position, t_{end} is recorded as the end of the potential SCR.
3. Return to step 1 to continue searching for more potential SCRs occurring after t_{end} .

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 m within $[t_{onset}, t_{end}]$. If $m < t$, discard the potential SCR. If $m \geq t$, mark the potential SCR as a valid SCR.

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.

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 t_{onset} . This is the point where the threshold H was crossed in the phasic EDA.
2. “EDA > Skin conductance response” event at the time t_{max} where the tonic EDA reaches its maximum value within the SCR (max in time range $[t_{onset}, t_{end}]$).
3. “General > Waveform end” event at the ending SCR time t_{end} . This is the point where the zero threshold was crossed in the phasic EDA.

Events for SCRs will always occur in the above triplets, in the order shown.

Preferences...

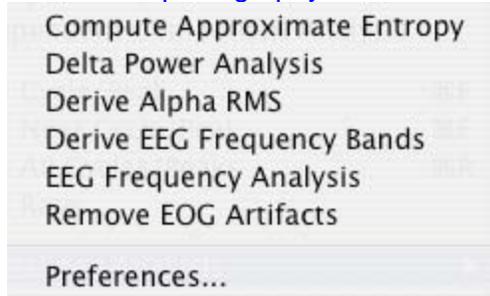
The following preferences can be configured and will be applied to all options in the analysis package:

- Output: text, graph channels, or Excel
- Phasic EDA options: Highpass Filtering or Smoothing Baseline Removal
 - Highpass Filtering—Highpass filtering constructs phasic EDA by applying a digital IIR highpass filter ($f = 0.05$ Hz, $Q = 0.707$) to the tonic EDA signal. This highpass filter essentially AC couples the tonic EDA signal similar to using the highpass hardware filter available on the GSR100C module. When using highpass filtering, the first few seconds of the phasic EDA may not be centered around zero and will appear to contain invalid data.; this artifact is related to the long time constant of this filter and is expected.
 - Smoothing Baseline Removal—Smoothing baseline removal constructs phasic EDA by subtracting an estimate of the baseline conductance from the tonic EDA. The estimate of the baseline is generated using median value smoothing. This is more computationally intensive than highpass filtering but does not illustrate artifact at the start of the signal.

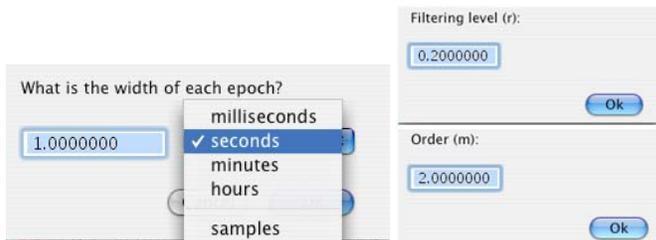
Additionally, its sensitivity can be adjusted by varying the window size. The width of the window is customizable in the preferences.

- Larger windows will decrease the sensitivity and show only large changes.
- Smaller windows will increase sensitivity and show more localized responses.
- SCR detection parameters: threshold detection level H and percentage P
 - The default values are $H = 0.02$ umho, $P = 10$.
 - Setting H to 0 and P to 10% will approximate the referenced SCR detection algorithm.
 - Setting P to 0% will retain all potential SCRs (none will be rejected in the second phase).

Electroencephalography



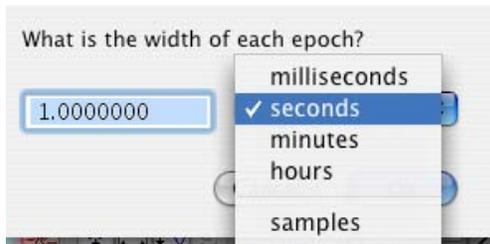
Compute Approximate Entropy



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 an 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, copy and paste the ranges into new graph windows to restrict the approximate entropy computations to that data range; the analysis is performed for all of the data in the graph window regardless of the selected area.

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. To compute delta power for individual frequency bands, they must be derived prior to running the Delta Power Analysis script.

Derive Alpha RMS

The Derive Alpha RMS script constructs a standard alpha RMS waveform from an alpha EEG signal. Alpha RMS is the windowed root mean square value of the signal using a window width of 0.25 seconds.

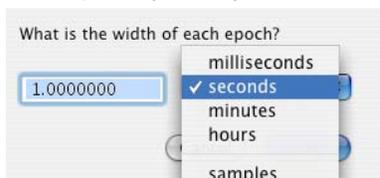
Derive EEG Frequency Bands

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
- Gamma

The frequencies used for each band are taken from the analysis package preferences. Filtering is performed using IIR lowpass+highpass combination filters.

EEG Frequency Analysis

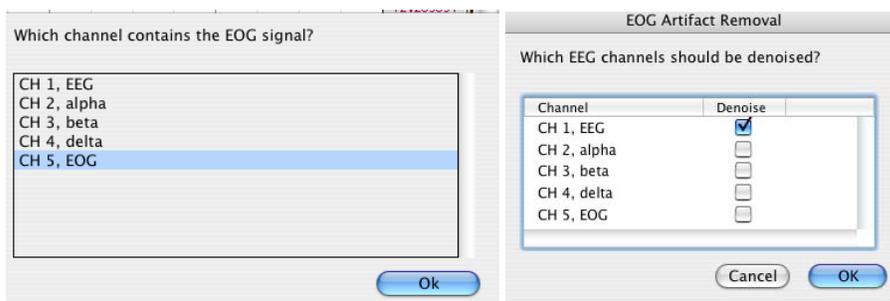


EEG may be characterized in terms of frequency and the power within specific frequency bands. The EEG Frequency Analysis script performs various feature extractions from EEG signals using FFT and other techniques to examine the power within the EEG signals. This analysis may be performed for multiple 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, *AcqKnowledge*'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
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

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...

Display EEG analysis results as:

Text Only
Graph Channels Only
Text and Graph Channels
Excel Spreadsheet Only
Graph and Excel Spreadsheet
All

Cancel OK

Spectral edge frequency percentage:
90.000000 %
Ok

EOG Removal ICA Tolerance:
0.0001000
Ok

EOG Removal ICA Maximum iterations:
1000.0000
Ok

Bands: Delta 0.5- 4.0, Theta 4.0- 8.0,
Alpha 8.0- 13.0, Beta 13.0- 30.0, Gamma
36.0- 44.0
Ok Change Cancel

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.

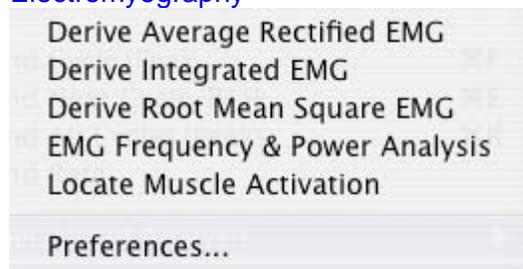
Because ICA is a statistical technique, any filtered data produced with Remove EOG Artifacts should be carefully verified against other information to ensure that the approximations produced via ICA represent information that is truly correlated to the expected ECG.

The spectral edge percentage indicates the cutoff percentage of the total power at which spectral edges will be placed. The default value is 90%.

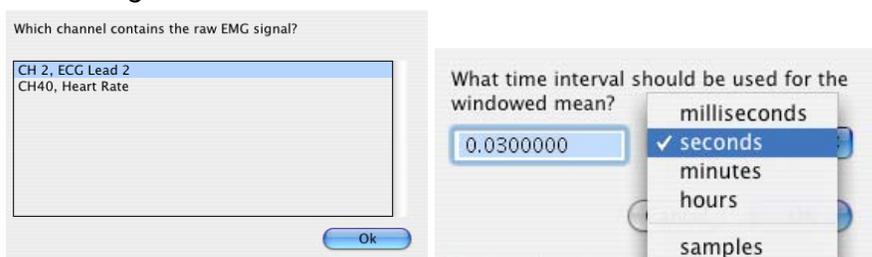
The frequency bands of alpha, beta, delta, and theta may be modified to match different analysis protocols. The default frequency ranges are:

- 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

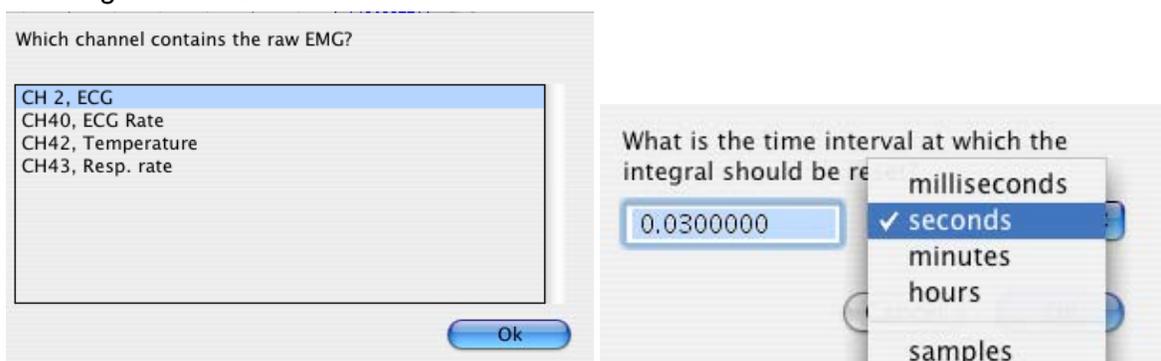


Average rectified value (ARV) is defined as a time windowed mean of the absolute value of the signal. ARV is one of the various processing methods used to construct derived signals from raw EMG data that can be useful for further analysis.

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.

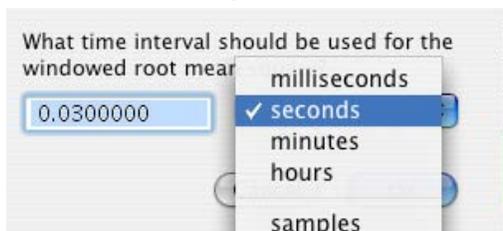
Derive Integrated EMG



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.

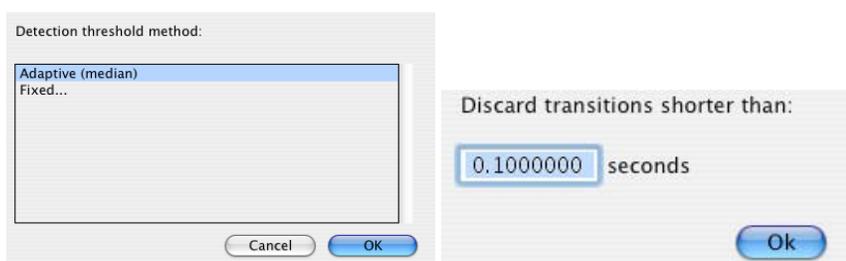
RMS EMG is computed using the Integrate transformation in a Root Mean Square Average over Samples configuration.

EMG Frequency & 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 is important that the muscle being examined is relaxed for the first

0.25 seconds of the recording to provide an estimate of the “background noise” during areas of muscle relaxation. This quarter-second period is used to estimate baseline parameters that affect the entire process.

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 0.25 seconds of the signal.
2. Construct a filtered ARV EMG signal, z .
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 inbetween consecutive muscle contractions.

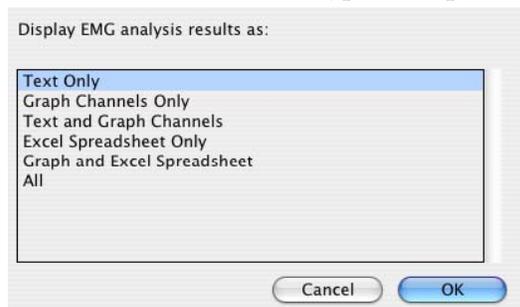
There are two outputs from the Locate Muscle Activation script.

- 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. You can use these events 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

The image shows the 'Ensemble Average' dialog box and a resulting waveform graph. The dialog box has the following sections:

- How do you want to locate areas to average?**
 - At peaks in the data (selected)
 - At events
- Is this peak pointing up or down?**
 - Up (selected)
 - Down
- Which channel contains the peaks?**
 - CH 1, ECG Lead 1 (selected)
 - CH 3, ECG Lead 3
 - CH40, ECG Lead 2
- Average Channels**

Check the channels for which averages should be constructed.

Channel	A...age
CH 1, ECG Lead 1	<input checked="" type="checkbox"/>
CH 3, ECG Lead 3	<input checked="" type="checkbox"/>
CH40, ECG Lead 2	<input type="checkbox"/>

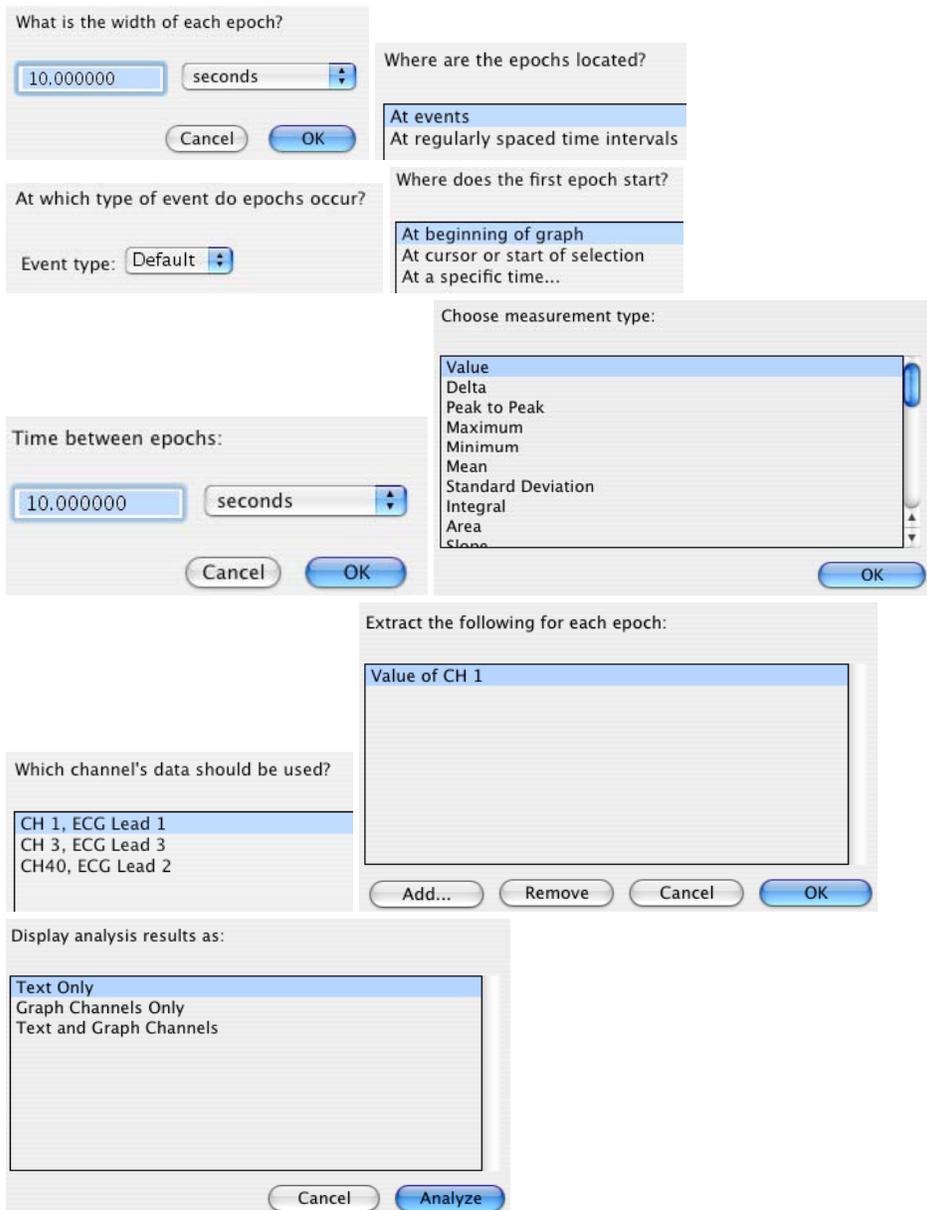
The resulting graph shows a waveform for 'ECG Lead 1' with a peak labeled '40 cycles qrs'. The y-axis ranges from -0.500000 to 1.000000. The x-axis is labeled 'mV'.

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.

This option provides two methods for locating individual members of the ensemble.

- 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.
- 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 of the standard *AcqKnowledge* measurements can be extracted on an epoch-by-epoch basis with the exception of calculation measurements.

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.

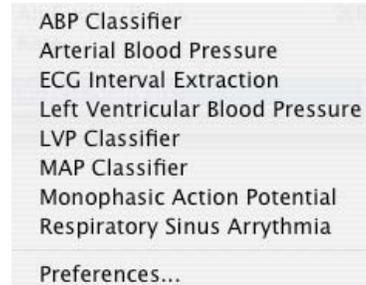
Hemodynamic Analysis

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.

IMPORTANT: These routines are designed specifically for human subjects and may not function well, or at all, on animal subjects, particularly small animals.

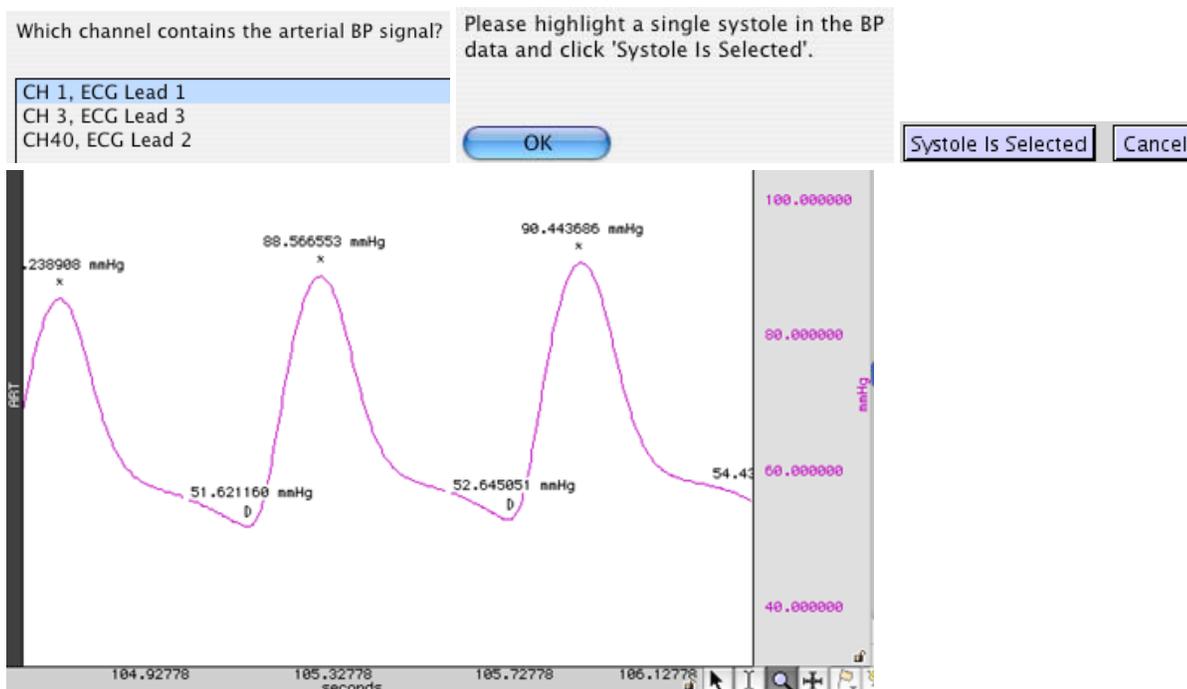
The Hemodynamic analysis package consists of:

- a) ABP Classifier
- b) Arterial Blood Pressure
- c) ECG Interval Extraction
- d) Left Ventricular Blood Pressure
- e) LVP Classifier
- f) MAP Classifier
- g) Monophasic Action Potential
- h) Respiratory Sinus Arrhythmia
- i) 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.

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: $P_{diastolic} + \frac{P_{systolic} - P_{diastolic}}{3}$
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
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	Time interval between the diastolic and the 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

Which channel contains the ECG Lead II signal?

CH 1, ECG Lead 1
CH 3, ECG Lead 3
CH40, ECG Lead 2

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 interval divided by the square root of the RR interval
Heart rate	HR	RR 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.

Left Ventricular Blood Pressure

Which channel contains the left ventricular BP?

CH 1, ECG Lead 1
CH 3, ECG Lead 3
CH40, ECG Lead 2

Recovery percentage:

50.000000 %

Ok

Which channel contains the action potential?

CH 1, ECG Lead 1
CH 3, ECG Lead 3
CH40, ECG Lead 2

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
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<i>Name</i>	<i>Abbrev.</i>	<i>Description</i>
Contractility index	CI	maximum value of dP/dt during the cycle divided by the pressure at that time location
Developed pressure	DP	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	the 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	-	the monoexponential time relaxation constant tau computed on a cycle by cycle basis. See “Computation of Tau” on page 359 for specifics.
Tension time index	TTI	Integral of the pressure between end diastolic and the time of minimum dP/dt

Computation of Tau

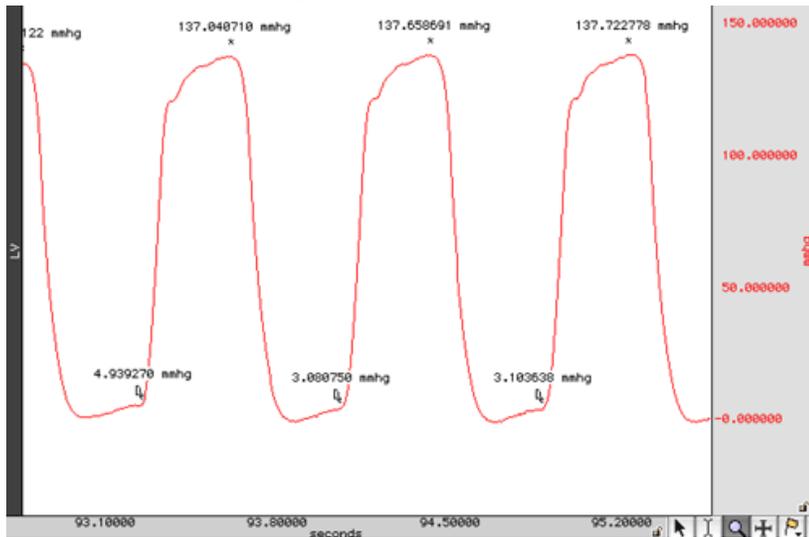
There are many different methodologies used to extract the time constant from LVP data. The time constant is extracted from a best fit parameter of a model to the trailing edge of LVP data on a cycle by cycle basis. This analysis uses a monoexponential model of zero asymptote for computing tau. The relaxation 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 (lowpass 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.

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 lowpass 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.

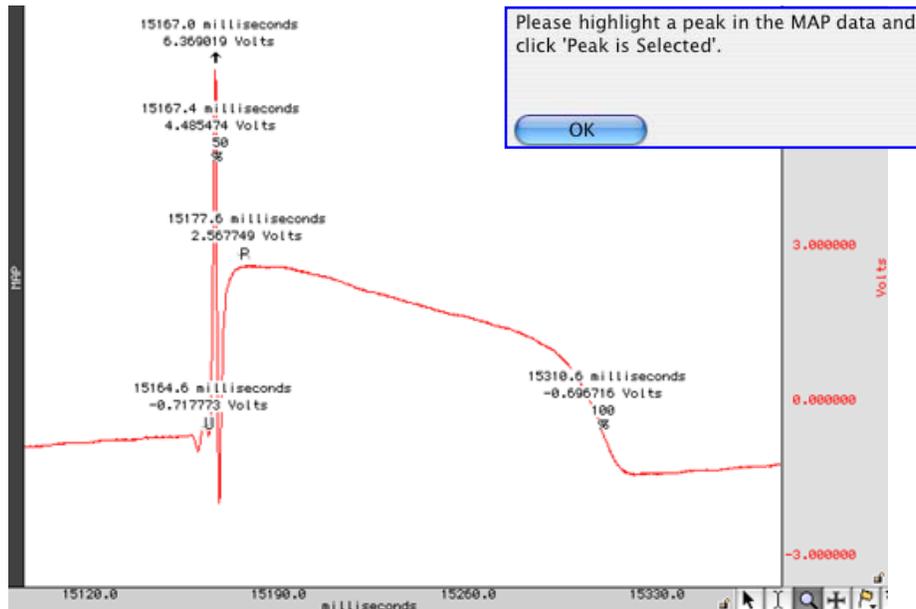
- The first method uses an adaptive threshold of zero plus a percentage of the peak to peak change in the derivative between the maximum and the first zero crossing after the maximum. If the signal remains above the upstroke voltage in this interval, a quick algorithm is used to locate 100% recovery 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

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.

Respiratory Sinus Arrhythmia

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.

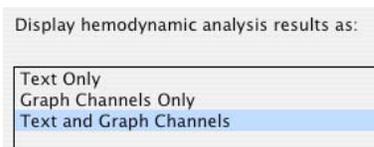
While designed for use with the RSP100C/TSD201 respiration module and transducer combination, it should be possible to use other estimates of respiration. The respiration signal is used to locate periods of inhalation and exhalation. Inhalation begins at valleys in the signal while expiration at peaks. 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.

RSA results are triggered from the respiration cycle. The RSA analysis outputs the following measures:

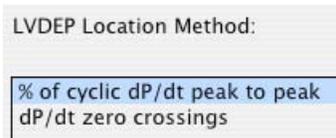
- Cycle* Index of the respiration cycle in the analysis.
- Time* Location of the start of the respiration cycle on the time axis.
- Min Rate* Minimum heart rate occurring during the inspiration window of the respiration cycle, expressed in milliseconds (IBI).
 - If a respiration cycle is invalid, this measure will be set to 0.
- Max rate* 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. Conversion to logarithmic scaling must be performed manually, if desired.
 - If a respiration cycle is invalid, this measure will be set to 0.

Preferences



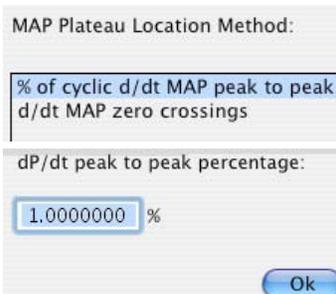
Display results as

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.



LVDEP location method – see page 360

- 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 361

- 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

Impedance Cardiography Analysis

The Impedance Cardiography analysis package assists in the analysis of cardiac output and other hemodynamic parameters using noninvasive bioimpedance monitoring techniques. It offers a variety of approaches for estimation of cardiac measures.

Body Surface Area
Derive dZ-dt from Raw Z
dZ-dt Classifier
ICG Analysis
Ideal Body Weight
Pre-ejection Period
Remove dZ-dt Motion Artifacts
VEPT
Preferences...

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. Prompts require height and weight of the subject in the preferred units. 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.

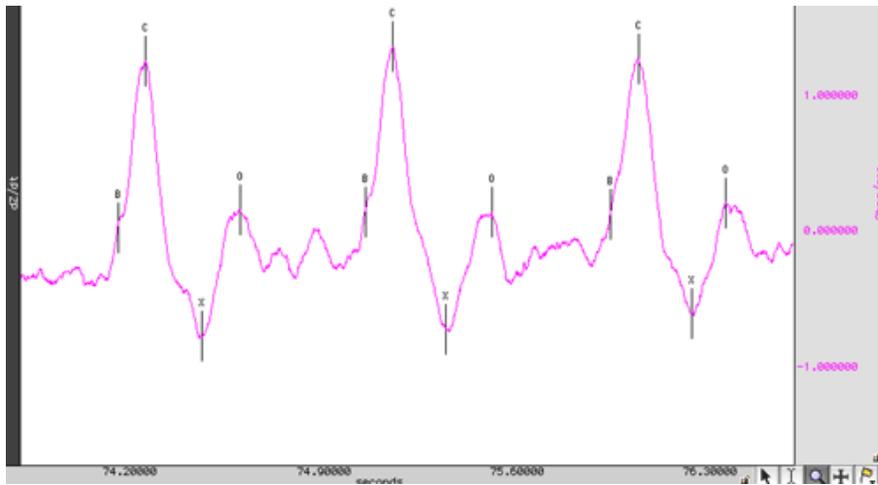
Body Surface Area equation

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	$BSA = \sqrt{\frac{Height(cm) \times Weight(kg)}{3600}}$

dZ/dt Classifier

Places events at common inflection points on a dZ/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 ventricular flow (set location in Preferences)
- X point – Closing of aortic valve (set location in Preferences)
- Y point – Closing of pulmonic valve
- O point – Widest opening of mitral valve

The algorithm for locating these points on the ICG signal examines local minima and maxima in the dZ/dt signal as well as values of its second derivative. Filtering is applied to the second derivative signal to improve accuracy.

- Prefiltering the dZ/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/dt signal may cause the classifier to fail. It is recommended that motion artifacts be removed before running the dZ/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/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 three methods will produce similar results for clean data. ICG Preferences has three 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/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.

C-point Location—Use Preferences to set the dZ/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/dt waveform. The starting point of this process is locating individual cycles on the dZ/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/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/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/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/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/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/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/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/dt minimum may actually occur closer to A than to X, making the first (and default) option of searching for the first turning point a more reliable solution. You may want to acquire a phonocardiogram in conjunction with ICG to help determine which method will be more accurate at locating X.

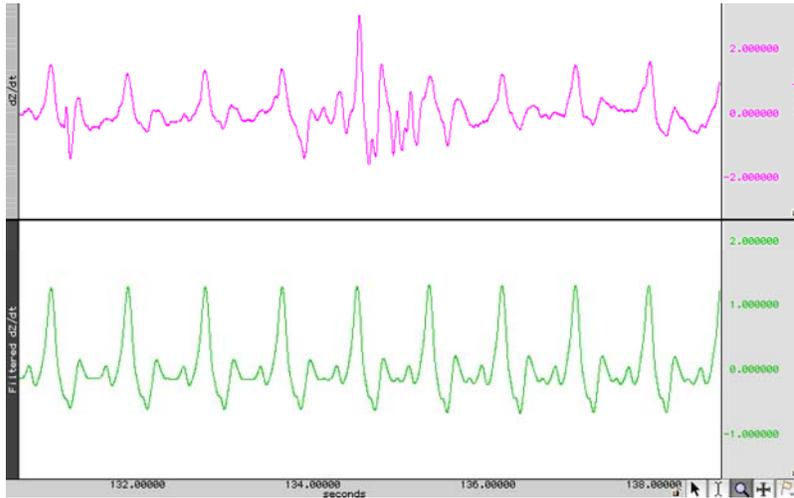
- Search for the first turning point in the dZ/dt signal that occurs after the C point location and place X at the first positive zero crossing in the second derivative of impedance (d^2Z/dt^2). This is the default X point location method.
- Locate the X point at the minimum value of dZ/dt over each cardiac cycle.

dZ/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/dt presentation.

dZ/dt Remove Motion Artifacts

Applies SFLC motion artifact removal to a dZ/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/dt signal, so results derived from a motion filtered dZ/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.

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/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/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/dt signals be acquired to improve analysis accuracy.
- To automatically apply motion filtering to the dZ/dt signal, use Preferences to enable Motion Filtering (see page 372).

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/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.

<i>Name</i>	<i>Abbv.</i>	<i>Description</i>	<i>Units</i>	<i>Formula</i>
Acceleration index	ACI	Maximum blood acceleration	1 / sec ²	$\frac{d^2Z}{dt^2_{\max}}$ <i>TFI</i>
Cardiac index	CI	Normalized cardiac output	m ² / min	$\frac{CO}{BSA}$
Cardiac output	CO	Volume of blood pumped each minute	l / min	$SV \times HR$
Heart rate	HR	Heart rate in BPM as computed from the RR interval.	BPM	$\frac{60}{RR_i}$
Left cardiac work	LCW	Work exerted by the left ventricle each minute	kg m	$(MAP - PAP) \times CO \times 0.0144$
Left cardiac work index	LCWI	Normalized left cardiac work	kg m / m ²	$(MAP - PAP) \times CI \times 0.0144$
Left ventricular ejection time	LVET	Interval between B and X. Time interval between aortic valve open and close.	sec	<i>Not applicable</i>
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	$P_{diastolic} + \frac{P_{systolic} - P_{diastolic}}{3}$
Mean central venous pressure	CVP	Mean central venous pressure over cycle, or default value if no CVP signal is present.	mmHg	<i>Not applicable</i>
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	<i>Not applicable</i>
Pre-ejection period	PEP	Interval between the Q wave of the ECG and the B point of the ICG. Time interval between systole and aortic valve open.	sec	<i>Not applicable</i>
RR interval	RR-i	Interval between R peaks in the waveform.	sec	<i>Not applicable</i>
Stroke index	SI	Normalized stroke volume	(ml / beat) / m ²	$\frac{SV}{BSA}$

Name	Abbv.	Description	Units	Formula
Stroke volume	SV	Volume of blood pumped by left ventricle in a single beat	ml / beat	<p>Set equation in Preferences:</p> <p>Kubicek—Estimates SV from the derivative of the impedance signal and blood resistivity:</p> $SV = \rho \times \frac{L^2}{Z_0^2} \times \frac{dZ}{dt}_{\max} \times LVET$ <p><i>Note</i> $\frac{dZ}{dt}_{\max}$ may be either the absolute maximum or the BC delta in amplitude, as set in Preferences.</p> <ul style="list-style-type: none"> Sramek—Estimates SV from the derivative of the impedance signal and the estimated volume of electrically participating fluid (VEPT): $SV = \frac{VEPT}{Z_0} \times \frac{dZ}{dt}_{\max} \times LVET$ <ul style="list-style-type: none"> In the ICG analysis routines, VEPT is estimated using a truncated cone model. $VEPT = \frac{(0.17H)^3}{4.25}$ <ul style="list-style-type: none"> Sramek-Bernstein—Estimates SV from the volume of electrically participating tissue scaled according to body habitus. The SV equation is: $SV = \frac{\delta(VEPT)}{Z_0} \times \frac{dZ}{dt}_{\max} \times LVET$ <p>where</p> $\delta(VEPT) = \frac{weight_{actual}}{weight_{ideal}} \times \frac{(0.17H)^3}{4.25}$ <p>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.</p>
Systemic vascular resistance	SVR	Afterload; arterial flow resistance	dynes sec / cm ⁵	$80 \times \frac{MAP - CVP}{CO}$
Systemic vascular resistance index	SVRI	Normalized afterload	dynes sec m ² / cm ⁵	$80 \times \frac{MAP - CVP}{CI}$
Systolic time ratio	STR	Ratio between electrical and mechanical systole	none	$\frac{PEP}{LVET}$
Thoracic fluid content	TFC	Electrical conductivity of the chest cavity	1 / Ohms	$\frac{1}{TFI}$

<i>Name</i>	<i>Abbv.</i>	<i>Description</i>	<i>Units</i>	<i>Formula</i>
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	<i>Not applicable</i>
Velocity index	VI	Maximum velocity of blood flow in the aorta.	1 / sec	$\frac{\frac{dZ}{dt}_{\max}}{TFI}$ <p><i>Note</i> $\frac{dZ}{dt}_{\max}$ may be either the absolute maximum or the BC delta in amplitude, as set in Preferences.</p>

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.

<i>Method</i>	<i>Formula</i>
Devine	<i>Men</i> 50 kg + 2.3 kg per inch over 5 feet <i>Women</i> 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 <i>Men</i> 5' 2" and 6' 4" <i>Women</i> 4' 10" and 6' 0"
Miller	<i>Men</i> 56.2 kg + 1.41 kg per inch over 5 feet <i>Women</i> 53.1 kg + 1.36 kg per inch over 5 feet
Robinson	<i>Men</i> 52 kg + 1.9 kg per inch over 5 feet <i>Women</i> 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 367.

To use Pre-ejection Period analysis, both an ECG Lead II and an ICG (dZ/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/dt, use Preferences to enable Motion Filtering (see page 372).

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.

<i>Name</i>	<i>Abbrev.</i>	<i>Description</i>
Heart rate	BPM	The heart rate for the cycle as indicated in BPM. Derived from the RR interval.
Pre-ejection period	PEP	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.

VEPT

Uses the truncated cone method to compute the volume of electrically participating tissue (VEPT) in cubic centimeters of a subject. You will be prompted to enter the height of the subject in the preferred units. It can be used to calculate VEPT independent of any of the other analysis routines, which may be useful for validation purposes or other derived calculations.

Preferences

The following Preferences are available in the following order. You must click through all Preferences to adjust a particular Preference.

Body surface area equation – see page 364

- Boyd; DuBois and DuBois; Gehan and George; Haycock; or Mosteller

Ideal Body Weight method– see page 370

Stroke volume equation – see page 369

- Kubicek, or Sramek, or Sramek-Bernstein

Output display format

- Textual tables in the journal
- Channels of data inserted into the graph.

Unit system for inputting body measurements

- 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.

dZ/dt B-point location – see page 365

dZ/dt C-point location –see page 366

dZ/dt X-point location – see page 366

dZ/dt Motion Filtering Automatic Filtering Preference

The Pre-ejection Period and ICG Analysis transformations have the ability to optionally apply motion filtering automatically to the dZ/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/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 Preference – 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/dt signal.
- “Aggressive” uses a SFLC setting of .0001. The filter will adapt much 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 than zero and much less than 1 for the filter to converge.

dZ/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/dt max. The Preferences offer two settings. “Max dZ/dt in cardiac cycle” will extract the maximum amplitude of dZ/dt as the max value. This is the traditional way of measuring dZ/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/dt max. This will produce different stroke volume results, but is useful for removing motion artifact and improving consistency.

Magnetic Resonance Imaging

Artifact Frequency Removal
 Artifact Projection Removal
 Median Filter Artifact Removal
 Signal Blanking

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 MP 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 $1/10^{\text{th}}$ 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.

Artifact Frequency Removal

MRI > Artifact Frequency Removal

How should artifacts be located?

MRI Trigger Channel

Events

Which channel contains the MRI trigger?

CH 2, ECG

CH40, ECG Rate

CH42, Temperature

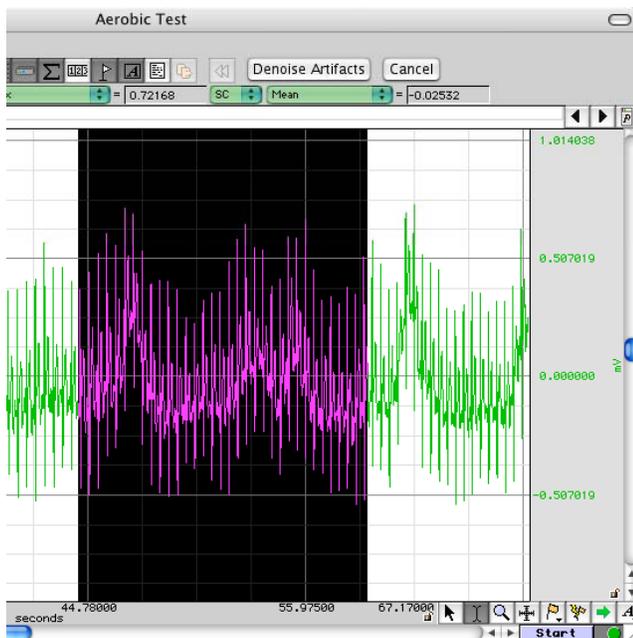
CH43, Resp. rate

Channels to Denoise

Check the channels whose signals should be denoised.

Channel	Denoise
CH 2, ECG	<input checked="" type="checkbox"/>
CH40, ECG Rate	<input type="checkbox"/>
CH42, Temperature	<input type="checkbox"/>
CH43, Resp. rate	<input type="checkbox"/>

Highlight the area containing the MRI artifact. Once the artifact is highlighted, click "Denoise Artifacts" to continue.



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 $1/10^{\text{th}}$ 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 “blinking” 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.

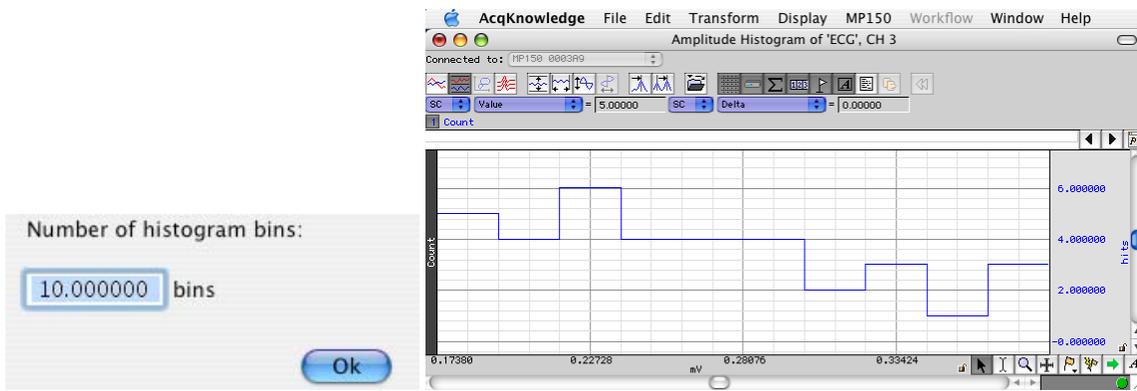
IMPORTANT Signal Blanking requires an MRI triggering signal or artifact onset events to locate artifact positions.

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

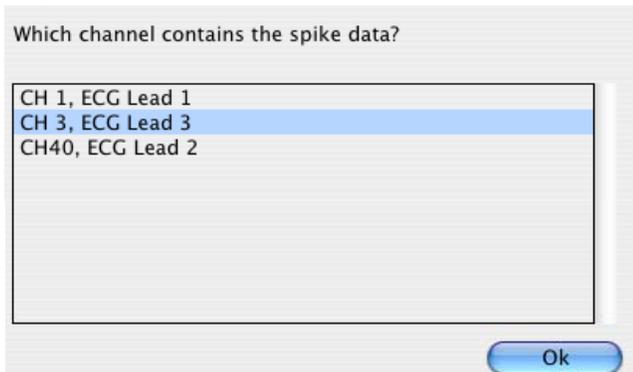


IMPORTANT To run this analysis option, the signal must first be transformed by the Locate Spike Episodes option or the Classify Spikes option.

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

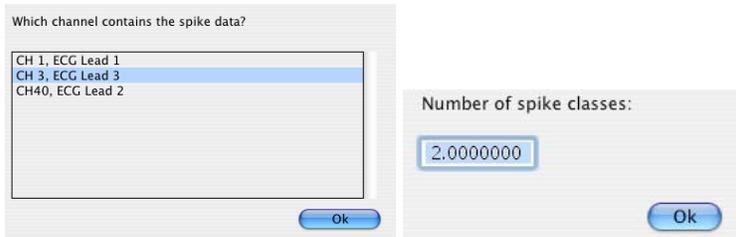


IMPORTANT To run this analysis option, the signal must first be transformed by the Locate Spike Episodes option or the Classify Spikes option.

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.

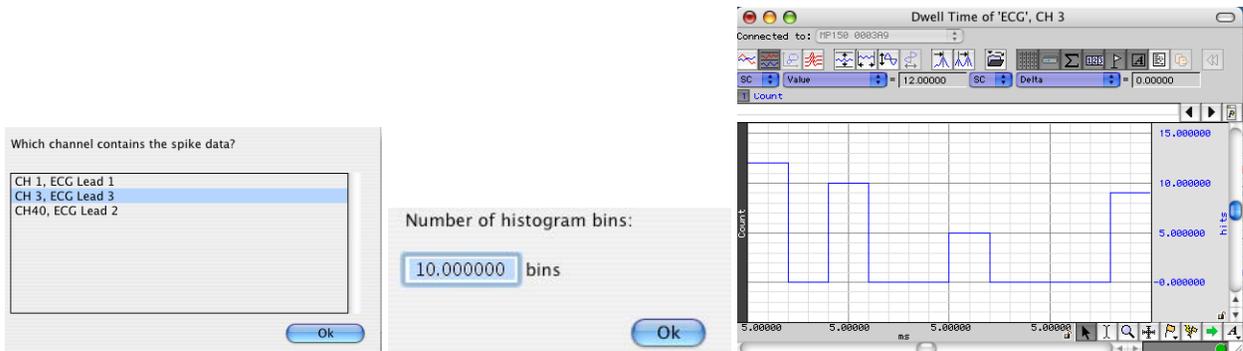
A single-feature k-means clustering classifier is used, and the entire data set is used for the clustering portion of the algorithm. The determining feature is the Sum criteria— that is, the sum of all of the data points within the waveform segment; this was one of the first features used in early action potential classifiers.

If the Locate Spike Episodes option has not been used to find spikes before this option was selected, the Locate Spike Episodes option will be automatically performed prior to the clustering.

The analysis routine will ask for a number of spike classes and then use k-means clustering to group each spike episode into a class. 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 peak detector.

Dwell Time Histograms



IMPORTANT To run this analysis option, the signal must first be transformed by the Locate Spike Episodes option or the Classify Spikes option.

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

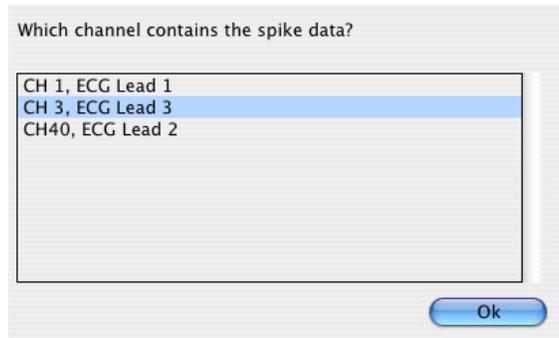
IMPORTANT To run this analysis option, the signal must first be transformed by the Locate Spike Episodes option or the Classify Spikes option.

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 Locate Spike Episodes option or the Classify Spikes option.

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 if no spike is firing and 1 if a spike is firing.

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.

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.
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.

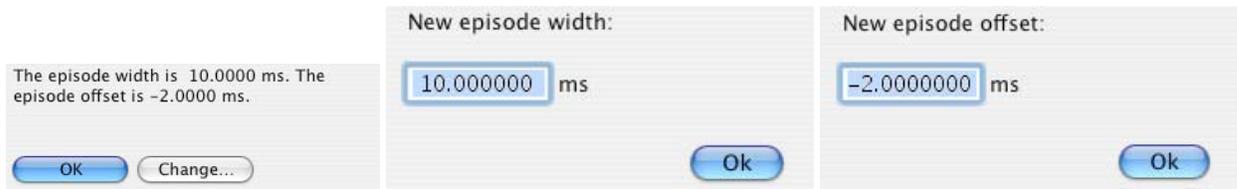
A “Spike Episode Begin” event will be placed at the start of each spike episode and will be located offset milliseconds away from the threshold crossing. A “Spike Episode End” event will be placed at the end of each episode.

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.

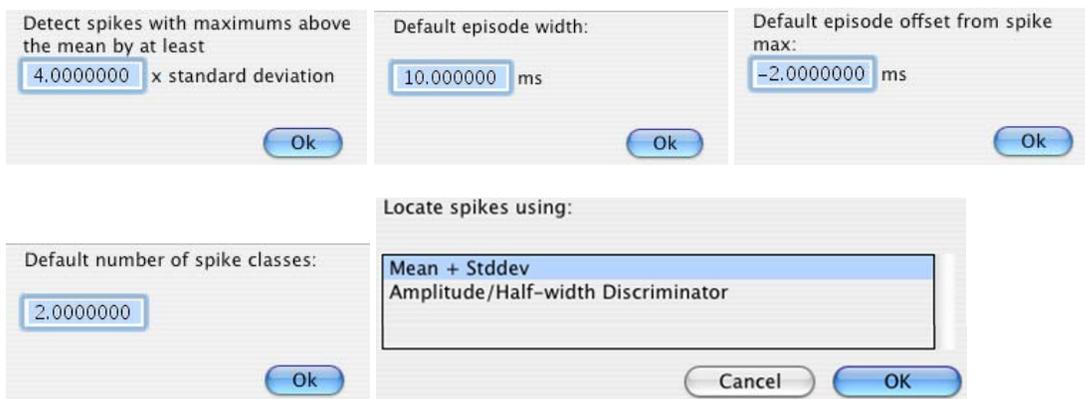
Set Episode Width & Offset



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

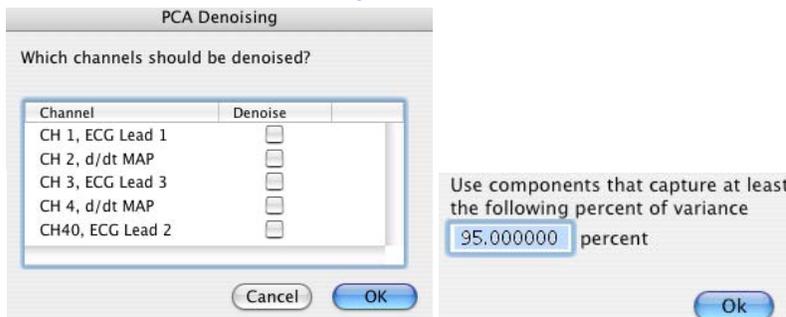


<i>Preference</i>	<i>Description</i>	<i>Default Setting</i>
Output type	Determines whether analysis results will be displayed as graph channels, textual tables in the journal, or Excel spreadsheets. Not all of the output types are applicable for each Neurophysiology analysis option.	Text output to journal only.

Preference	Description	Default Setting
<p>Mac AcqKnowledge 3.9.2 and later—Spike Location Method</p>	<p>Choose how spikes are searched for in the signal.</p> <p>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.</p> <p>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.</p> <p><i>Half-width</i> 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.</p> <p>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:</p> <ol style="list-style-type: none"> 1. Performs regular peak detection on x using a fixed threshold a_{low}. 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. Computes the half-width time interval for each potential spike location p. 3. Accepts the spike for each potential spike location p as a valid spike s if, where a is amplitude and t is time window: $a_{low} \leq x(p) \leq a_{high} \wedge t_{low} \leq t_{half}(p) \leq t_{high}$ 4. For each valid spike location s, positions the spike episode start output at $s+offset$ and the spike episode end output at $s+offset+width$. <p>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.</p>	<p>Mean + Stddev</p>
<p>Spike Detection Level</p>	<p>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.</p>	<p>4 standard deviations</p>
<p>Default Episode Width</p>	<p>The first time that any of the spike detection is run on a graph, the width of each fixed width episode must be specified. This preference provides the default value that is seeded in the dialog.</p> <p>The episode width for an individual graph does not need to match this default.</p>	<p>10 milliseconds</p>

<i>Preference</i>	<i>Description</i>	<i>Default Setting</i>
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 milliseconds
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

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 an 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.

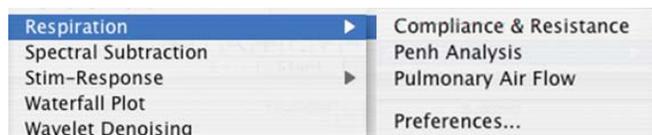
Remove Trend

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.

Select which endpoint will remain fixed:

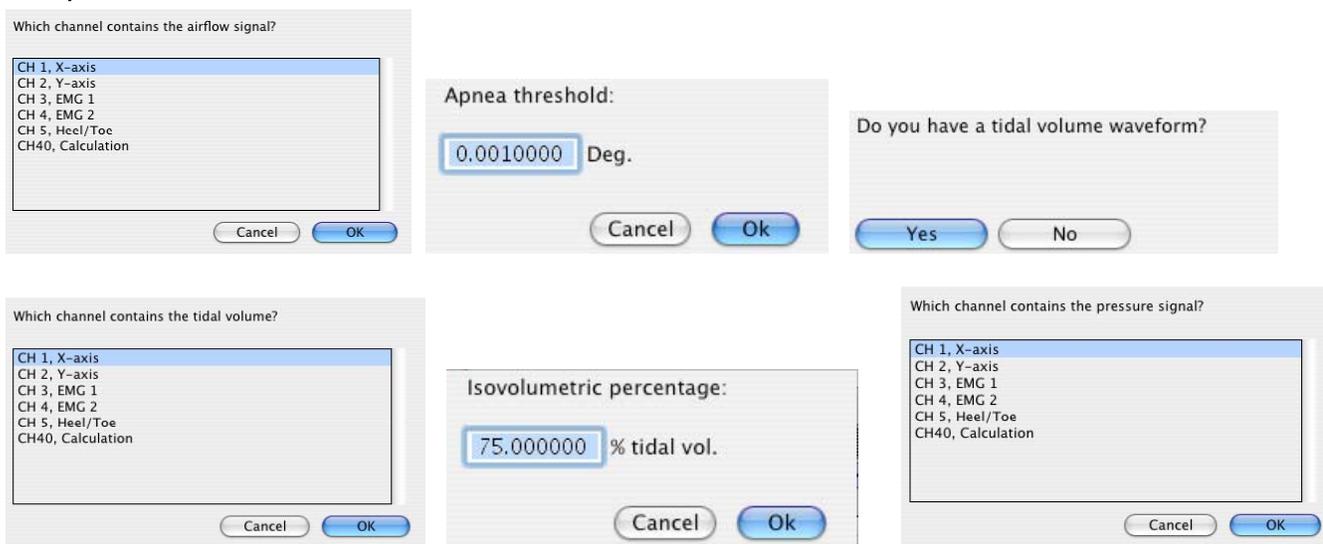
- Left keeps the starting point of the selection fixed at the same voltage. The software adjusts the data from left to right such that the right endpoint is aligned with the initial starting voltage.
- Right keeps the ending point of the selection fixed at the same voltage. The software adjusts the data from right to left such that the left endpoint is aligned with the initial ending voltage.

Respiration



The respiration analysis package helps to analyze respiration- and airflow-related data. Other tools exist for respiration related analysis including *AcqKnowledge* transformations and the Respiratory Sinus Arrhythmia analysis in the Hemodynamics analysis package.

Compliance & Resistance



The Compliance & Resistance 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 Compliance & 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.

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:

<i>Name</i>	<i>Abbrev.</i>	<i>Description</i>	<i>Units</i>
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
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: <ul style="list-style-type: none"> • 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

<i>Name</i>	<i>Abbrev.</i>	<i>Description</i>	<i>Units</i>
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. 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.

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:

<i>Name</i>	<i>Abbrev.</i>	<i>Description</i>	<i>Units</i>
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

<i>Name</i>	<i>Abbrev.</i>	<i>Description</i>	<i>Units</i>
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: $\frac{Te}{Rt} - 1$	
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).

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: $f \in (-a_f, a_f)$. 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.

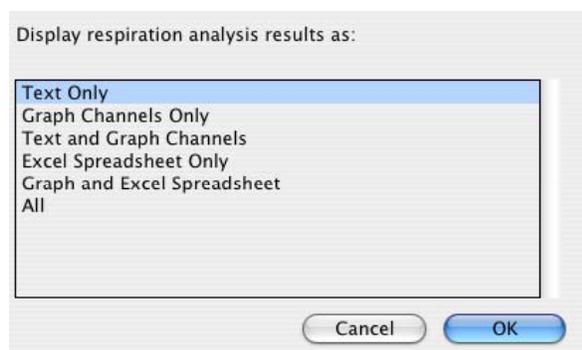
For each breath period, the analysis will extract the following:

<i>Name</i>	<i>Abbrev.</i>	<i>Description</i>	<i>Units</i>
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. <i>TV BPM</i>	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

<i>Name</i>	<i>Abbrev.</i>	<i>Description</i>	<i>Units</i>
Exhalation time	ET	Time interval between the start of exhale and either: <ul style="list-style-type: none"> • 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 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.

Any $F_{denoise}$ 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.

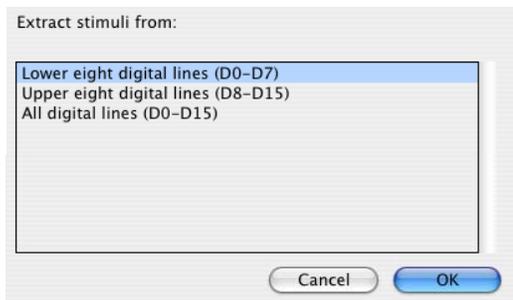
Stim-Response

Digital Input to Stim Events Stim-Response Analysis

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.

Note: Excel spreadsheet generation is only supported with AcqKnowledge 3.9.1 and higher.

Digital Input to Stim Events



Several stimuli delivery applications can either trigger stimulus through TTL level signals or emit synchronized TTL pulses with stimulus delivery. Examples of such software applications include SuperLab and the Inquisit programming environment.

This analysis option converts TTL data acquired on the digital channels of an MP device 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 type of stimulus events by using the Cycle Detector’s label matching capability.

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. 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.

Stim-Response Analysis

Stim-Response Analysis allows for extraction of measurements within fixed width intervals occurring at Stimulus Delivery events. 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 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 Specialized Analysis > Electrodermal Activity.

Waterfall Plot

Assists in configuring the Peak Detector for 3D surface generation. These surfaces showing cycle-by-cycle data of the graph are commonly known as *waterfall plots*. Cycles are located in the graph using the same sequence of steps as the Ensemble Average transformation script. Instead of generating the averaged graph, however, a number of 3D surfaces are generated. One surface is generated for each channel that is selected by the user.

Wavelet Denoising



Sample output

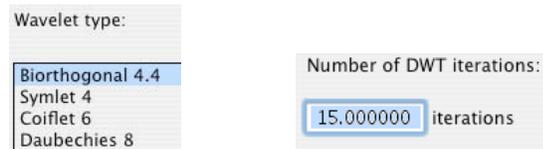
Wavelet Denoising applied to heart sounds data may help clarify S_1 and S_2 , as shown:

Wavelet Denoising uses the forward and reverse wavelet transformations 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.

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 you choose a fixed threshold, an additional window will appear into which you can type your threshold.
 - Adaptive threshold level based on the number of coefficients in the DWT iteration (a VIS shrink procedure).

ECG Analysis Algorithm References

AcqKnowledge 3.9 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

AcqKnowledge 3.9 software 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.

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. This tool is only available on OS X.

AcqKnowledge can automate the process of running ecgpuwave on source data and import its output back into AcqKnowledge. To run ecgpuwave on an ECG signal from within AcqKnowledge, first make the

ECG channel the active channel and then choose Transform > Specialized Analysis > Locate ECG Complex Boundaries. *AcqKnowledge* will execute *ecgpuwave* on that signal and read in its waveform boundary location output, placing events on the channel. You will only be able to see this output if you have events shown.

Alternatively, you can save your 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 *AcqKnowledge* performs.

Source code for *ecgpuwave* detector is released under a [GPL license](#) and can be found on the *AcqKnowledge* CD.

OSEA QRS Detector

➔ OSEA QRS detector and beat classification library

AcqKnowledge 3.9 software 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 for about 15 years; the beat classifier has been developed for about a year or two. 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. *AcqKnowledge* will execute the OSEA beat detector on the source data and output a sequence of events on that channel of ECG data. You will only be able to see this output if you have events shown.

Source code for the QRS detector is released under an [LGPL license](#) and can be found on the *AcqKnowledge* CD.

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>).

A Note About Specialized Analysis for Windows/PC Users



You can unlock powerful analysis tools & automation with

Specialized Analysis

for AcqKnowledge data files

Analyze data collected on MP Systems
running on Windows/PC or Mac OS X

Analyze AcqKnowledge data files collected on MP Systems running on Windows/PC or Mac OS X. These powerful, comprehensive analysis tools automate analysis to save hours (or days!) of processing time and standardize interpretation of results. If you need still 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%.

For a fraction of the cost, you'll have extensive post-acquisition analysis options similar to modules from Mindware Technologies, PONEMAH Physiology Platform, EMKA Technologies, SA and other advanced analysis applications. The **Specialized Analysis** package is detailed on page 333.



Mac



PC/Windows

The **Specialized Analysis** features work with files generated by AcqKnowledge on a PC running Windows or on a Mac. While the data is portable, AcqKnowledge for Windows includes only limited Specialized Analysis tools, so you must use the Mac software to benefit from the full range of **Specialized Analysis** tools. Mac computers are network compatible and Ethernet ready, so it's easy to add one to an existing setup and take advantage of these powerful tools. If you're ready to add **Specialized Analysis** to your AcqKnowledge analysis options, please contact BIOPAC to discuss the possibilities and benefits of this Mac-based solution—or [let us know you're interested](#) and we'll contact you.

- To learn more about Macintosh and Mac OS 10.3 or higher, visit the [Apple Store for Education](#) or [Apple® web store](#).

[Return to Specialized Analysis Overview](#)

Appendix H – Network Data Transfer

Network Data Transfer allows users to access the data being acquired into a graph by *AcqKnowledge* in an external application.

The hardware API was developed to allow customers writing custom applications to control an MP unit directly and obtain data during acquisitions. Using the hardware API requires the application developer to perform appropriate configuration of the MP unit and its channels, visual graphing and data plotting, data analysis (e.g. filtering, beat detection), and persistent data storage within their application.

Some developers do not wish to undertake these additional responsibilities in their own application and prefer the ease of configuration provided by the *AcqKnowledge* graphical interface. Some development environments may also not provide enough facilities for performing all of these tasks.

For these types of situations, integration with the existing *AcqKnowledge* environment may be preferred over the more low-level hardware API.

Objectives

- To develop a basic method for allowing third party applications to tap into the data stream being generated by both the MP unit and *AcqKnowledge* during data acquisitions.
- To provide networking facilities that allow for integration into a distributed application environment.
- To provide basic control facilities to allow external applications to query and control the *AcqKnowledge* application state.

Overview

The real-time data transfer system is split into two types of connections:

Data connections deliver data from *AcqKnowledge* to external applications during acquisitions.

Control connections are made from external applications to *AcqKnowledge* to query application state and adjust data connections.

The *server* refers to the *AcqKnowledge* process and the computer on which it is running. The *client* refers to the custom application that is to receive data from *AcqKnowledge* and the computer on which it is running. Note that the computer used to run the *AcqKnowledge* process and the custom application may be the same computer.

All connections will be made using standard network protocols, either TCP or UDP. Single system image architectures should make connections using the loopback interface. It will be assumed that network implementations will 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 beyond the scope of this document and BIOPAC Systems, Inc.

Data Connections

Data connections are used to deliver data from the *AcqKnowledge* server to the client application. Data connections stream both data acquired from an MP unit and computed data from *AcqKnowledge* 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

AcqKnowledge 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 will be 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 *AcqKnowledge* 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 *AcqKnowledge* 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 will be 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 will allow the client to query the server for the most recently acquired data sample value for a particular channel. This communication method is for clients that do not require continual data streams or that interact with only slow moving data. 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 will 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 will be 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 connections will be 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 *AcqKnowledge* data connection protocol but can be achieved implicitly by requesting a data connection be bound to a broadcast address.

Since UDP is unordered, datagram delivery of data will include an additional four bytes prior to the data contents of the packet. These four bytes will indicate the starting sample position of the samples (or frames for single connection transfer type). The four bytes will always be in network order to allow for platform flexibility. If the client will perform interpretation of the sample index, `htonl()`/`ntohl()` should be used to convert from network order into host endian.

As sample positions are always monotonically increasing, the sample index tag can be used to reassemble datagrams into correct order, if required. The sample index will still need to be swapped to host order from network order for the sequence to be increasing in magnitude.

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 will be 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 will be signaled by the first datagram that is sent to that port. The sample index of the first datagram will correspond to the first hardware sample of data acquired by *AcqKnowledge*. If the graph is initially empty, the index will be 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, *AcqKnowledge* 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 MP 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. If strict real time guarantees or more predictable latencies are required, users may need to consider using the hardware API on their local machine.

Data Formats

It is assumed that the data transfer feature will be 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 will be allowed to be controlled to appear in a variety of different formats for the client:

- **64 bit floating point**—always 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**—always 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 *AcqKnowledge*, so the precision of received data may differ from data as recorded by *AcqKnowledge*. This is equivalent to a C style float data type.
- **Signed 16 bit integer**—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

Analog 16 bit signed integer
 Digital 16 bit signed integer
 Calculation 64 bit floating point
 XML-RPC get most recent sample

Default Data Type

little endian
 little endian
 little endian
 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 will be used:

- Single connection transfer type
- TCP/IP transport protocol
- Port 15020 for single connection
- For multiple connections, each channel type (16 channels per type) will be 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 AcqKnowledge Servers

It is possible that clients and servers may be located on networks with dynamic IP addresses or other feature that make establishing the connection between machines difficult. In this case, a simple UDP broadcast mechanism can be used to locate known servers.

AcqKnowledge 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 will be expressed in base 10 ASCII notation.

It will be possible to configure *AcqKnowledge* to not *acKnowledge* discovery requests for security purposes.

Control Connections

Clients connect to an *AcqKnowledge* 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 *AcqKnowledge* environment.

On the start of an acquisition, all data connections are established to the client that most recently established a control connection.

It will be possible to configure *AcqKnowledge* 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 XMLRPC.

- 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, *AcqKnowledge* 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 *AcqKnowledge* 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 *AcqKnowledge* 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) or one of the following: 100, 150, 35, 45. 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 will be 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 *AcqKnowledge*, 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.

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.

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 will be 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 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 will be returned.

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 will be 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.

“channel” member contains a channel index structure with members set to appropriate type and index information for the channel.

“value” members 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 `AcqKnowledge` graph template

Return value: 0 on success, or fault code

Attempts to open the passed template within the `AcqKnowledge` environment. The parameter is a base 64 encoded `AcqKnowledge` “gtl” graph template file. This command can only be used with templates in `AcqKnowledge 3.7.1-Windows` or `AcqKnowledge-Mac` graph templates. 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 will be used for subsequent data acquisitions. Templates for *AcqKnowledge* 3.9.2-Mac 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 *AcqKnowledge*, 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 *AcqKnowledge* 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.

Implementation Notes

The network data transfer feature will be incorporated into *AcqKnowledge* as a new realtime processing object invoked in fashions similar to audio playthrough engines. The application will be extended with third party libraries to allow for XML-RPC operation. New preemptive threads will be added to the application to handle server discovery requests, control connection requests, and data transfer during acquisitions.

External Libraries

AcqKnowledge will use external libraries to assist in implementing the ability to perform network data transfer and respond to XML-RPC requests.

xmlrpc-c

The XML-RPC layer will be implemented using the `xmlrpc-c` library (<http://xmlrpc-c.sourceforge.net>).

This library is a small layer that allows for implementation of both clients and servers in C and C++ applications. For servers, the library also includes a version of the abyss web server that will handle listening for connections and can use a number of external libraries for posting new XML-RPC requests.

xmlrpc-c will be kept in the Other subdirectory of the repository. An Xcode project will be made for xmlrpc-c to allow it to be included directly as a dependency in other projects. To facilitate builds, the default configuration will be renamed to “Imported CodeWarrior Settings”. The output will be a series of static Universal binary libraries that can be linked directly into applications.

On Mac OS X, the libcurl library is provided at the system level. xmlrpc-c will be configured to use libcurl to perform its client functions.

Licensing

xmlrpc-c is licensed using a variety of licenses including the main xmlrpc-c license, the expat license, the python license, and the abyss web server license. All of these licenses allow for direct linking of the library with a commercial application. Appropriate copyright notices will be added to the About dialog and into the documentation, where appropriate.

Threading Constructs

Wherever possible, the implementation of the network data transfer feature will use preemptive threads. The Carbon Multiprocessing library will be used to spawn the threads. This will allow the threads to use MPRemoteCall to schedule functions for execution on the main thread. Main thread scheduling will be required for any operations that have application state side-effects for non mutex guarded structures or operations that result in user interface change.

Network Configuration Storage

The main preferences dialog accessed through Display > Preferences will allow the user to toggle network access on and off, change the default control connection TCP port, and disable automatic server discovery. These settings will be stored in the user preferences file and will be modifiable on a per user-account basis.

Additional network configuration storage will be stored in a new structure incorporated into the hardware acqStruct. This storage will include the data transfer settings (both global and channel specific), the data type requested for each channel, and other configuration. These settings will be retained in the creator handle and graph files. No visible user interface will be added for these settings and they can only be modified by a client using the XML-RPC requests over the control connection.

The connection settings may be different from graph to graph and can be modified after loaded from a graph file. This allows clients to send over a template with the majority of their settings already intact, leaving clients to change only specific dynamic values such as client IP address.

Since the network configuration storage settings may be accessed from multiple preemptive threads, a preemptive safe mutex will be used to guard all access to the settings from all threads. Additionally, switching of the hardware parameters as different graphs are brought to the front will also respect this mutex and not change any values while they are being read by another thread.

Control Connection Server

Control connections are made from clients to the server through XML-RPC requests. *AcqKnowledge* will implement the control connection server using the xmlrpc-c library with the built-in abyss web server used to listen for connections. To improve both response time for both clients as well as the *AcqKnowledge* application, the server listening for control connections will be implemented on its own preemptive thread. The server will use the runConn() method of the C++ server class while handling its own socket generation with accept in order to keep track of the most recently connected client.

While this limits processing to one RPC at a time, it is the only method that will keep the RPC invocations within the *AcqKnowledge* address space, required to modify settings of in-memory graph structures. If the network server is enabled in the user preferences, the thread will be created when the application is launched and will persist until the application exits. Any changes to listening port for control connections in the application preferences will cause the thread to be stopped and recreated to listen on the new port.

The control connection protocol does not include any type of graph identifier for each call. The procedure calls that are available will always refer to the topmost graph window. There will be no way for clients to change the top graph remotely.

An exception to the graph ordering is the “loadTemplate” command. When issued, the data sent will be decoded by *AcqKnowledge* and will be used to construct a new topmost graph. As the control connection thread is preemptive, this process will be scheduled on the main thread. The XML-RPC call will be treated as blocking and will not return until either the template has opened or the main thread has delivered an error code back to the service. This cross-thread call will be handled at the same location as the scheduling of macro invocations on the main thread.

The toggleAcquisition XML-RPC command will be similarly scheduled onto the main thread as `ToggleAcquisition()` assumes the cooperative threading environment for proper data structure access restrictions.

Server Discovery Thread

The design includes a rudimentary method that clients can use for locating *AcqKnowledge* servers on their LAN. It consists of listening for UDP broadcasts and replying with appropriate UDP broadcasts, similar to the MP150 discovery mechanism. If the server feature is enabled when the application is launched, a new preemptive thread will be spawned to respond to discovery requests. The preemptive thread will live for the duration of application execution while networking is enabled and will be terminated on application exit.

Network Data Transfer Engine

The network data transfer engine will be implemented as a new `NetworkDataTransferEngine` object in corresponding files. This engine will have a `ProcessIncomingData()` method that will be invoked during acquisitions at the same time as audio playthrough. It will examine the graph structure directly, keeping track of buffer lengths of channels inbetween successive calls. When new data is encountered, it will be copied onto a second set of buffers that are private for the network data transfer engine and onto an array holding the most recent sample values.

Similar to the audio processing engines, there will be one network data transfer engine created for each hardware structure and will live for the lifetime of the structure. The engine will use the `AcquisitionEventListener` framework to respond to starts and stops of acquisitions.

At the start of acquisitions, the data transfer engine will be configured to match the network transfer settings as currently stored in the hardware structure. These settings will not be allowed to be modified while the acquisition is in progress.

After initialization, the engine will attempt to establish any requested data connections as BSD sockets, either TCP or UDP as configured by the client. Once all connections are successfully established, a preemptive thread will be spawned to handle the actual data transfer. This thread will examine the private network data transfer buffers. Whenever new data is encountered in these buffers, the preemptive thread will assemble that data for delivery to the client. A single preemptive thread will handle all connections. The preemptive thread will be killed at the end of the acquisition, and any system resources will be gracefully released prior to the thread exit.

To support the XML-RPC get most recent data sample functionality, the engine will maintain an array of doubles with the most recent sample that was copied into the network transfer buffers. This double valued array can be accessed by other threads to obtain the sample values. The actual XML-RPC calls for returning the most recent value will be handled by the XML-RPC thread and not the network data transfer thread.

All buffers that are allocated will be circular buffers and will not be reallocated during the lifetime of the thread. The `ProcessIncomingData()` method called from the acquisition thread will be the producer and the only modifier of the head pointer. The preemptive thread will be the consumer and the only modifier of the tail pointer. This one to one producer/consumer arrangement alleviates the need to perform any mutex locking on the buffers.

GLP Awareness

While the majority of settings can only be configured over the client connection, several settings may be altered by the user in the preferences dialog. As these settings may affect security and network accessibility of the application, new GLP operations will be added for the network data transfer preferences:

<i>Operation</i>	<i>Class</i>	<i>Description</i>
Toggle Networking	Other	Invoked when the user changes the value of the overall enabled network state. This turns the response to network requests on or off.
Change Networking Control TCP Port	Other	Invoked when the user modifies the port on which the application will listen for control connections allowing other applications to modify the data transfer state.
Toggle Networking Auto-discovery	Other	Invoked when the user turns on or off the ability for other applications to locate <i>AcqKnowledge</i> servers via UDP broadcast.

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