

AcqKnowledge® 4 Software Guide

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



Reference Manual for
AcqKnowledge® 4.4.2 Software & MP150/MP36R, BioHarness, B-Alert, Mobita, or Stellar
Hardware/Firmware
on Windows® 10, 8.x, and 7 or Mac OS® X 10.7-10.11



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TABLE OF CONTENTS

PREFACE TO ACQKNOWLEDGE SOFTWARE GUIDE	15
Welcome	15
Supported Platforms.....	15
What's new for AcqKnowledge 4.4.2	16
User Support System.....	19
Where do I find help?.....	20
 PART A — GETTING STARTED.....	 23
Chapter 1 MP Systems Overview	23
MP36R support	24
MP System Requirements	24
Automator Integration and Scripting Support.....	25
MP System Features.....	26
Application Features	29
Application Notes	30
 Chapter 2 AcqKnowledge Overview	 31
Launching the AcqKnowledge software	32
Setting up channels using Module Setup (MP150 Hardware)	34
Setting up channels manually.....	34
Basic Analog Channel Information.....	35
Basic Digital Channel Information	35
Basic Calculation Channel Information	35
Selecting Hardware	35
Setting Up Acquisitions	36
Starting an Acquisition.....	37
Stopping an Acquisition.....	37
Display Modes	38
Data Views.....	44
Analysis	45
Selecting a waveform.....	47
Show/Hide Channel	47
Collapsing Channels	48
Zoom.....	49
Select an area	49
Keyboard data selection	49
Transform data	50
Measurements	50
Events (Markers).....	51
Grids.....	51
Horizontal Split View	51

Autoscroll Horizontal Axis Controls	52
Journals	53
Saving data.....	53
Format change warnings	53
“Data Snapshot” — Embedded Archive	54
Print.....	55
Chapter 3 User Interface & Context Menu Features	56
Toolbars.....	57
Main, Display and Scaling Toolbars.....	58
Hardware Toolbar	58
Cursor Toolbar	58
Selection Palette.....	62
Start/Stop Toolbar.....	62
Channel Button Toolbar.....	63
Event Toolbar	63
Focus Area Toolbar	63
Measurements Toolbar.....	63
Custom Toolbars for Transformations and Analysis	63
Toolbar Position Retention and Changes.....	64
Axis Controls	64
Enable Cursor Tools During Acquisitions	64
Button Transparency.....	65
Customizable Chart Track Dividers.....	65
Plotting Background Colors.....	65
Spectrum Analyzer Palette.....	65
Keyboard Shortcuts.....	65
Tooltips	69
Mouse Controls.....	70
Mouse Scrollwheel Support.....	70
Modification History.....	70
Cancelling Transformations and Transformation Progress Bar	71
Typed Event Label Drawing Improvements	71
Choose MP150 Help Button	71
Tooltips	71
Channel Label, Units Length and Tooltips	71
Graph Window Tooltip Improvements	72
Menu Item Tooltips	72
Chapter 4 Editing and Analysis Features	73
Scroll bars	73
Scaling	74
Horizontal axis	74
Vertical (Amplitude) axis	75
Adaptive Scaling.....	76
Show Textual Value Display	76
Grid Details.....	78
Grid Options	81
Journal Details	83
Journal Contextual Menu.....	83
Rich Journals.....	84
Journal Toolbar Buttons.....	84
Journal Numerical Table Tools.....	85
Example of Sum, Mean or Standard	86
Example of Evaluate Expression	87

Adding a hyperlink to the Journal	87
Embedding PDFs in Journals	88
Select a waveform / channel	88
Channel Labels	88
Show/Hide Channel	89
Focus Areas	89
Creating Focus Areas	89
Measurements	91
Measurement Display	92
Measurement Area	92
Measurements and Measurement Presets	94
Measurement Validation	94
Measurement Info / Parameters	94
Measurement Interpolation	95
Exporting measurements	95
PART B—ACQUISITION FUNCTIONS: THE HARDWARE MENU	106
Overview	106
Set Up Data Acquisition > Data Acquisition Settings	107
Chapter 5 Set Up Channels	109
Set Up Channels—The Basics	109
Module-based analog channel setup	109
View by Channels	111
Set Up Channels—Advanced	114
Analog channels	114
Increased Channel Count Support (AcqKnowledge 4.3 and above)	115
Analog channels MP36R	116
Offset	116
Adjustable, user defined, digital IIR filters for MP36R	117
High Pass Filters MP36R	117
Additional controls in MP36R Input Channel Parameters	118
MP36R Advanced Preset Settings	118
MP36R Transducer SSID Table	121
Digital Channels	122
Calculation Channels	122
Metachannel	123
Chapter 6 Calculation Channel Presets	126
Integrate Calculation	127
Smoothing Calculation	132
Rate Calculation	134
Signal Parameters Tab	135
Output Tab	136
Function Calculation	138
Filter IIR Calculation	139
Expression	141
Delay Calculation	148
Fourier Linear Combiners: FLC, WFLC, CWFLC Calculations	153
Basic FLC	153
Weighted-Frequency FLC	153
Coupled WFLC/FLC	153
Adaptive Filtering Calculation	154
Comb Band Stop Filter Calculation	154
Metachannel	154
Rescale Calculation	155

Slew Rate Limiter	156
Filter - FIR	157
Chapter 7 Data Acquisition.....	158
Data Acquisition—The Basics	158
Multiple Hardware	161
Averaging (MP150 Hardware only)	162
Overview	162
Averaging Setup	164
Advanced Averaging—P300	165
Repeating	167
Starting an acquisition.....	169
Stopping an Acquisition.....	169
Rewind	169
Saving acquisition data	169
Timers (Stop watches and Elapsed timers)	170
Timer Types	170
Electrode Checker	171
Chapter 8 Set Up Triggering	173
Digital Triggers (MP150 only)	173
Analog Triggers	174
Chapter 9 Set Up Stimulator.....	176
Analog Output for MP150 Users	180
Dual Stimulation	181
Square waves	182
Tone Stimuli	183
Ramp Waves.....	183
Arbitrary Waveform.....	184
MP150 Stimulator Sample Rates	185
Analog Output Upper Limits Summary	186
Chapter 10 Output Control	187
CH# to Output.....	189
MP36R Input > Output Scaling	190
Digital Outputs Control.....	191
Pulses Output Control.....	192
Stimulator – BSLSTM Output Control.....	192
Stimulator – Low Voltage Output Control.....	192
Stimulator Human Stimulator (STMHUM) Output Control.....	192
Pulse Sequence Output Control	194
Visual Stim Controllable LED – OUT4 Output Control.....	198
Arbitrary Wave Output	199
Sound Sequence Output Control.....	201
Pulse Definitions.....	203
Output Control Panel Descriptions	204
Usage Guidelines & Setup Summary for BSLSTM Output Control	213
Chapter 11 Set Up Event Marking.....	215
Events (Markers).....	215
Event (Marker) Overview	215
Event Toolbar	216
Event Tooltips.....	216
Preferences for Events	216
Event Marking Setup	218
Create/Toggle Focus Area Action.....	219

Event Palette	220
Audio	225
Event Type Options	225
Printing Events	230
Events and Waveform Editing	231
Constructing Graph Selections from Events	231
Event Plotting and Variable Sampling Rate	231
Chapter 12 Other Hardware Menu Commands	232
Show Input Values	232
Manual Control (MP150 only)	233
Set Up Linked Acquisitions	235
Limitations on Linked Acquisitions synchronization methods	236
Manage Hardware Connections	237
MP150 Info	238
Segment Labels	238
Sound Feedback	238
Gauge	240
Gauge Preferences	240
Segment Timer “Stopwatch” option	242
Autoplotting, Scrolling and Sweep Display Modes	244
Warn on Overwrite	245
Organize Channel Presets	245
PART C—ANALYSIS FUNCTIONS	247
Toolbars	247
Shortcuts	247
Chapter 13 File Menu Commands	248
New	248
Graph Window	248
New > Graph-specific Journal	248
New > Independent Journal	248
New > Data View	248
New > Batch Acquisition	249
Batch Errors	249
Open	251
Open Recent	257
Open for Playback	257
SMI BeGaze Import	257
Importing SMI Begaze Data into AcqKnowledge	258
Using the Software Timestamps Option to Align Data	258
Dataquest Import	258
Close	260
Save	261
Save As	261
Save Selection As	267
Save Journal Text As	268
File Format prompts	268
Send Email Attachment	269
Copy to Dropbox – Open from Dropbox	269
Page setup	270
Print	270
Quit	271
Chapter 14 Edit Menu Commands	272
Undo / Can’t undo	273

Cut.....	273
Copy.....	274
Paste.....	274
Clear.....	274
Clear all.....	274
Select All	275
Insert waveform.....	275
Duplicate waveform.....	275
Remove waveform.....	275
Remove last appended segment	275
Create Data Snapshot.....	275
Merge Graphs	276
Merging graphs as data segments	277
Clipboard	277
Journal.....	279
Chapter 15 Transform Menu Commands.....	282
Recently Used Transformations	283
Digital Filters	283
FIR Filters.....	286
Digital filter dialog.....	286
IIR Filters.....	288
Adaptive Filtering	289
Comb Band Stop Filter	289
Fourier Linear Combiners.....	292
Basic FLC	292
Weighted-Frequency FLC	292
Math Functions	294
Template Functions.....	296
Set Template	296
Remove mean	297
Template algorithms	298
Adaptive Template Matching.....	300
Integral	301
Derivative	302
Integrate	303
Output Reset	303
Smoothing.....	306
Difference	307
Resample.....	308
Resample Graph.....	308
Resample Waveform.....	308
Expression.....	309
Delay.....	309
Rescale	310
Waveform Math.....	310
Slew Rate Limiter	311
Chapter 16 Analysis Menu Commands	313
Histogram	313
Autoregressive Modeling.....	314
Nonlinear Modeling	315
Power Spectral Density.....	317
AR Time-Frequency Analysis	317
FFT Fast Fourier Transformation	318
Inverse FFT	321
DWT/SWT	323

Inverse DWT.....	323
Principal Component Analysis.....	323
Inverse PCA.....	324
Independent Component Analysis.....	324
Inverse ICA.....	324
Find Cycle (Peak Detector).....	325
Cycles/Peaks tab.....	325
Find Next Cycle.....	326
Find All Cycles in Graph.....	326
Find in Selected Area.....	326
Find All Cycles in Focus Areas.....	326
Find First Cycle.....	326
Preview (Selection tab).....	326
Find Cycle definitions.....	326
Selection tab.....	329
Output tab.....	330
Output Measurements.....	330
Output: Averaging—Offline.....	330
Output 3D Surface.....	331
Output Events.....	332
Event definition.....	332
Event Location Table.....	334
Output Focus Area.....	335
Output: Clustering.....	335
Algorithm Overview.....	335
Clustering Settings.....	336
Number of clusters.....	336
Locate Cluster Centers.....	337
Manually.....	337
By Learning.....	337
Training Set Definition.....	337
Max. iterations.....	337
Tolerance.....	337
Remove Outliers.....	338
Clustering Criteria.....	338
Clustering Output.....	338
Find Rate.....	341
Modes of Operation.....	341
Additional Find Rate Dialog Settings, Output Tab.....	346
Specialized Analysis.....	347
Chapter 17 Specialized Analysis.....	348
Detect and Classify Heartbeats.....	351
Locate Human ECG Complex Boundaries.....	351
Locate Animal ECG Complex Boundaries.....	352
Gastric Wave Analysis.....	352
Gastric Wave Coupling.....	352
Chaos Analysis.....	353
Detrended Fluctuation Analysis.....	353
Optimal Embedding Dimension.....	353
Optimal Time Delay.....	353
Plot Attractor.....	354
Correlation Coefficient.....	354
Electrodermal Activity.....	354
Derive Phasic EDA from Tonic.....	355
Event-related EDA Analysis.....	356
Sorting Options.....	358
Locate SCRs.....	361
EDA Measurements.....	362

Electroencephalography.....	364
Compute Approximate Entropy.....	364
Delta Power Analysis.....	364
Derive Alpha RMS.....	365
Derive EEG Frequency Bands.....	365
EEG Frequency Analysis.....	366
Seizure Analysis.....	367
Seizure Analysis Parameters.....	368
Remove EOG Artifacts.....	369
Preferences.....	370
Electromyography.....	371
Derive Average Rectified EMG.....	371
Derive Integrated EMG.....	371
Derive Root Mean Square EMG.....	372
EMG Frequency and Power Analysis.....	372
Locate Muscle Activation.....	372
Preferences.....	373
Ensemble Average.....	374
Epoch Analysis.....	375
Focus Areas between Events and Segments.....	376
Hemodynamic Analysis.....	376
ABP Classifier.....	377
Arterial Blood Pressure.....	377
ECG Interval Extraction.....	378
Estimate Cardiac Output from ABP.....	379
Left Ventricular Blood Pressure.....	380
LVP Classifier.....	381
Monophasic Action Potential.....	382
MAP Classifier.....	383
Preferences.....	383
HRV and RSA Analysis.....	384
Multi-epoch HRV – Statistical.....	384
Multi-epoch HRV and RSA – Spectral.....	385
R-R Poincare Plot.....	386
Respiratory Sinus Arrhythmia (RSA Time-series).....	387
Single-epoch HRV – Spectral.....	388
Frequency Bands.....	390
PSD Options.....	390
Improvements to PSD Options (AcqKnowledge 4.3 and higher).....	392
Impedance Cardiography Analysis.....	394
Body Surface Area.....	394
dZ/dt Derive from Raw Z.....	394
dZ/dt Classifier.....	394
ICG Analysis.....	397
Ideal Body Weight.....	400
PEP Pre-ejection Period.....	400
dZ/dt Remove Motion Artifacts.....	401
VEPT.....	401
Preferences.....	402
Magnetic Resonance Imaging.....	403
Artifact Frequency Removal.....	403
Artifact Projection Removal.....	405
Median Filter Artifact Removal.....	405
Signal Blanking.....	406
Neurophysiology.....	407
Amplitude Histograms.....	407
Average Action Potentials.....	407
Classify Spikes.....	408
Dwell Time Histograms.....	408
Find Overlapping Spike Episodes.....	409

Generate Spike Trains	409
Locate Spike Episodes	409
Set Episode Width and Offset	410
Preferences	410
Noldus Format	412
Principal Component Denoising	413
Remove Mean	413
Remove Trend	413
Respiration	414
Compliance and Resistance	414
Penh Analysis	416
Pulmonary Airflow	418
Preferences	419
Spectral Subtraction	419
Stim-Response	420
Digital Input to Stim Events	421
Stim-Response Analysis	422
Waterfall Plot	423
Wavelet Denoising	423
ECG Analysis Algorithm References	425
Chapter 18 Display Menu Commands.....	427
Tile Waveforms	428
Autoscale Waveforms	429
Autoscale Single Waveform	430
Overlap Waveforms	430
Compare Waveforms	431
Autoscale Horizontal.....	431
Show All Data	431
Show Default Scales	431
Zoom Back / Forward	431
Reset Chart Display	432
Reset Grid	432
Adjust Grid Spacing.....	432
Set Wave Positions.....	432
Set Channel Visibility	433
Wave Color	433
Active Slice Color.....	433
Horizontal Axis	434
Show	434
Annotations	435
Channel Buttons	435
Channel Input Values	435
Chart.....	435
Display Mode Toolbar	435
Dot plot	435
Dot size	435
Events.....	435
Event Bar	435
Event Palette	435
Focus Areas	435
Focus Areas Bar	435
Grid	435
Grid Options.....	435
Hardware.....	435
Journal.....	435
Last Dot Only.....	435
Line Plot.....	436

Line Thickness	436
Main Toolbar	436
Measurements	436
Scaling Toolbar	436
Scope.....	436
Selection Palette.....	436
Spectrum Analyzer Palette.....	437
Timers	437
Location Palette	437
Stacked Plot Options.....	439
Step plot.....	439
Toolbar.....	439
X/Y	439
Customize Toolbars	440
Spectrum Analyzer Palette Details	441
Channel Information	444
Preferences.....	444
Measurements Preferences.....	448
Waveforms Preferences	449
Event Summary Preferences	450
Graph Preferences.....	450
Journal Preferences	451
Hardware Preferences	451
Performance Preferences	451
Networking Preferences.....	452
Other Preferences.....	452
Window Preferences	453
Focus Areas Preferences	453
Location Preferences.....	453
Resetting All Preferences to Factory Default.....	453
Scroll options	454
Size window.....	454
Cursor Style	454
Create Data View.....	454
Create Focus Area.....	455
Organize Data Snapshots.....	455
Show All Data Snapshots	455
Load All Data Into Memory	455
Chapter 19 Program & OS Menus.....	456
AcqKnowledge menu	456
Window menu.....	456
Bring All to Front	456
Help menu.....	456
Chapter 20 Media Menu	458
Synchronization Tip.....	459
Media > Set Up.....	460
Linked Media.....	461
Media > Capture	461
Playback Preview.....	461
Media Playback Example	462
Media Capture Setup with CAM-HFR-A High Speed Camera	464
PART D — LICENSED FUNCTIONALITIES	466
Chapter 21 Licensed Functionality: Network Data Transfer	467

Data Connections	468
Variable Sampling Rates	468
Transfer Types	468
Single Connection	468
Multiple Connection	469
XML-RPC	470
Transport Protocol	470
TCP/IP	470
UDP	470
XML-RPC	471
Real-time Delivery Guarantees	471
Data Formats	472
Default Data Connection Settings	472
Locating AcqKnowledge Servers	473
Control Connections	473
TCP Port	473
Control Procedure Calls	473
Channel Index Parameter Structures	473
Querying Acquisition Parameters	474
Data Connection Configuration Commands	475
Reading Data During Acquisition	478
Other Control Connection Commands	479
Chapter 22 Licensed Functionality: Vibromyography.....	481
Sampling Rate Restrictions	481
Transducer Setup	481
Post-Analysis Selection Adjustment	482
Data Modification History Name	482
VMG Calculation Channel Preset	482
VMG Sample Data Files	483
Chapter 23 Licensed Functionality: Scripting	484
Scripting Menu	485
Script Editor	485
Variables Explorer	486
Example Scripts	486
Run Macro Calculation Channel	486
More Scripting References	487
Chapter 24 Licensed Functionality: Remote Monitoring.....	488
About Remote Monitoring	488
Remote Monitoring in AcqKnowledge Networking Preferences	488
Remote Monitoring Client	489
Remote Monitoring Client Browser	489
Open Graphs Page	491
Configuration Settings Page	491
Data Monitoring Page	492
Controls in Visible Range (Change Range) dialog	494
Chapter 25 Licensed Functionality: B-Alert	495
Data Acquisition and Analysis with B-Alert™	495
Acquisition Setup	497
Channel Setup	497
B-Alert-specific Hardware Menu Options	498
Assign Definition File	501
Output to ABM File Format	502
Opening the ABM Data File	503
Linked Acquisitions in B-Alert	504

Cognitive Analysis Calculation Channels.....	504
Data Output.....	505
Chapter 26 Licensed Functionality: PV Loop Analysis	506
Loop Location.....	506
PV Loop Analysis Preferences	506
Baseline Analysis.....	507
Locate ES and ED Boundaries.....	507
Realtime Display.....	507
Full PV Loop Analysis.....	509
Multiple loop measures.....	510
Chapter 27 Licensed Functionality: Baroreflex Analysis	515
Baroreflex Sequence Analysis	515
Sequence Analysis Setup Dialog	515
Baroreflex Slope Analysis	516
Slope Analysis Setup Dialog	516
Baroreflex Sequence Method Description	518
Baroreflex Slope Method Description	518
Chapter 28 Licensed Functionality: Actigraphy.....	519
Actigraphy User Interface.....	519
Creating Actigraphy Files.....	519
Importing Raw Accelerometer Data	520
Opening an Existing Actigraphy File.....	520
Actigraphy Analysis Settings.....	522
Actigraphy Analysis Settings Controls	522
Sadeh Scoring Algorithm for Wake/Sleep Classification	523
Sleep Derived Measures (Sleep Analysis)	524
Activity Level Measures	524
Actigraphy Specialized Analysis	525
Chapter 29 BioHarness Bluetooth.....	527
Chapter 30 Stellar Telemetry	528
Stellar Telemetry System.....	528
Stellar Experiment Interface in <i>AcqKnowledge</i>	528
Description of the Stellar Calendar Controls	529
Stellar-specific Setup Window Menus.....	532
Running a Stellar Experiment.....	538
Import and Display of Stellar Data in <i>AcqKnowledge</i>	540
Saving Graphs and Settings from Stellar Experiments	540
Stellar Analysis in <i>AcqKnowledge</i>	541
Chapter 31 Mobita	544
<i>AcqKnowledge</i> Interface in Mobita	544
Selecting or Adding Mobita Hardware in <i>AcqKnowledge</i>	545
Mobita Menu.....	545
Mobita Analog Channels Setup	546
Analog Channel Digital Filters	546
Mobita Calculation Channels.....	547
Enable Common Average Value Removal	547
Mobita Acquisition (Length/Rate) Settings	547
Changing Acquisition Modes or Resetting Hardware.....	548
Mobita Network Connection Utility	549
Chapter 32 FaceReader	552

How Does FaceReader Work?	553
Using FaceReader with AcqKnowledge.....	553
Creating a FaceReader Project and Recording in AcqKnowledge	554
Creating AcqKnowledge Graphs from a Saved FaceReader Analysis	555
FaceReader Signals	555
Valence and Arousal	555
Connection Issues	556
PART E — APPENDICES.....	558
Appendix A - Frequently Asked Questions	558
Appendix B - Filter characteristics	560
Filter types	560
Window Functions	561
Appendix C - Hints for Working with Large Files	563
Appendix D - Customizing Menu Functionality	564
Appendix E—Locking/Unlocking the MP150 for Network Operations	565
Appendix F—Firmware Upgrade	567
Firmware Rollback Switch.....	567
INDEX.....	568

Preface to AcqKnowledge Software Guide

Welcome

Welcome to the AcqKnowledge Software Guide. The MP System (MP150 or MP36R) is a complete data acquisition system that includes both hardware and software for the acquisition and analysis of life science data. The MP System is used for data acquisition, analysis, storage, and retrieval.

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

AcqKnowledge software not only makes data collection easier, but also performs analyses more quickly and easily than a chart recorder. Easily edit data, cut and paste sections of data, perform mathematical and statistical transformations, and copy data to other applications (such as a drawing program or spreadsheet) for reports and publication.

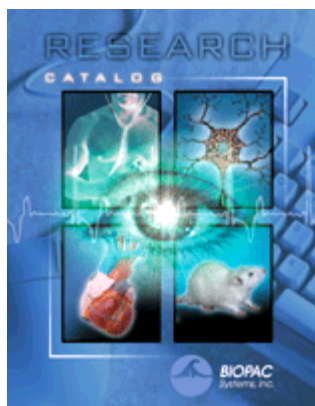
All BIOPAC data acquisition hardware with AcqKnowledge 4.4.2 is compatible with Windows® 10/8/7 or Mac OS X® 10.7-10.11

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

This manual covers use of AcqKnowledge software with MP150/MP36/BioHarness/B-Alert/Mobita/Stellar hardware and details BIOPAC equipment available for a variety of applications. If a desired application is not addressed, just visit the BIOPAC web site at www.biopac.com to download one of our many Application Notes, or call to request a hard copy or talk to an Applications Specialist.

See also:

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



MP Research Catalog 



MRI catalog 



VR & Stimulus Catalog 

Supported Platforms

AcqKnowledge 4.4.2 is supported on the following:

Operating Systems

Windows 10, 8, 7

Mac OS X 10.9-10.11

Hardware

MP150 UDP

MP36R

BioHarness BT (Windows only)

B-Alert (Windows only)

Mobita (Windows only)

Stellar (Windows only)

What's new for AcqKnowledge 4.4.2

BONUS! AcqKnowledge includes a courtesy copy of our new Analysis package.

See the Analysis chapter for details.

The following features have been added since AcqKnowledge 4.4.1 was released.

- OS X 10.11 support
- FaceReader Integration – Licensed feature supporting integration of facial emotional state recognition data with AcqKnowledge physiological data.
- B-Alert – Improved baseline recording in shorter durations
- MP36R Arbitrary Wave Stimulation – new output control panel that allows the MP36R to be used to generate arbitrary waveform output. The arbitrary waveform output is similar to the MP150, allowing for generation of square, sine and ramp signals or arbitrary signals from another open graph window.
- Stellar v2 Hardware Support – new hardware support for the next generation of Stellar transmitters. This supports extended memory, transmitters that have customized signal types, real-time data previews to assist in implantation, accelerometers, mini-mouse units, and other functionality.
- Enhanced Discrete Wavelet Transformation Analysis – now includes a Stationary Waveform Transformation option and multi-channel output of transformed data
- Sweep Display Mode - This mode is similar to an oscilloscope sweep display. Data is plotted left to right but when new data is incoming, earlier data remains visible on the screen.
- Module Setup improvements
- Find Cycle improvements
- Bug fixes

The following features have been added since AcqKnowledge 4.4 was released.

- Windows 10 support
- Support for new BioNomadix Data Logger
- Enhanced support for B-Alert Wireless EEG System
- Enhanced support for Stellar Telemetry System
- New Stellar Specialized Analysis options
- RSA Time-series option added to HRV & RSA Specialized Analysis
- Dropbox support – save/retrieve AcqKnowledge files to/from a Dropbox account
- Collapsible channels – quickly hide and unhide single or multiple channels with one click
- Updated installer
- Bug fixes

The following features have been added since AcqKnowledge 4.3.1 was released.

Automated Analysis Enhancements

- EEG Seizure Analysis – new routine for locating seizures in long-term small animal EEG recordings
- Estimated Cardiac Output from Blood Pressure – new Hemodynamics specialized analysis option
- HRV and RSA automation enhancements – Statistical analysis: Multi-epoch HRV; Spectral Analysis: Multi-epoch HRV and RSA; Single-epoch HRV; R-R Poincare Plot; RSA Time-series

New Licensed Feature Options

- Baroreflex Analysis
- Actigraphy Analysis – correlates wireless accelerometer data for sleep studies

New Hardware Integration

Visit the online support center at www.biopac.com

- Mobita 32-channel wireless data support
- Stellar Telemetry System support for wireless ECG and blood pressure
- GPS Integration – import GPS data to synchronize physiological data with physical location
- FIR Filter Calculation Channel – apply high quality FIR filters in real time
- Slew Rate Limiter – precise real-time or offline tool for denoising and removing motion artifact
- Event-based Rate Measurements – extract the mean, median and standard deviation of online and offline Rate outputs
- Elapsed timers – stopwatch, elapsed timers and alarm to time experiment protocols
- Embedded PDF Integration – embed PDFs of procedures, analysis, etc. into graph files and journals
- Sequential File Merge – merge separate graphs into appended segments within the same graph
- Dataquest file format import
- Simplified User Interface and UI updates
- Simplified installation with new Product Care Center
- New sample data files
- Bug fixes

 For a detailed look at what's new in *AcqKnowledge* 4.4, watch the [Tutorial video](#).

The following features have been added since *AcqKnowledge* 4.3 was released:

- Horizontal split view – allows viewing of two independent horizontal axis areas in same graph
- Journal hyperlinks and page setup tool
- High frame rate camera support
- MP150 communication improvements
- Labels for append events may be edited
- Preferences may be cleared by holding Shift key down while launching application
- File-specific output control presets for MP36R
- Files may be opened for Playback from the Startup Wizard
- New scripting commands for: changing output control preset, get acquisition sampling rate, change active output control, callback for window activation, toggling output control, calibrate a channel of the graph
- Epoch Analysis option to start first interval at beginning of each focus area
- Support for MPMS200 and OXY300-MRI hardware
- New measurement validation sample data files with accompanying spreadsheets for verifying measurements

The following features have been added since *AcqKnowledge* 4.2 was released.

- | | |
|--|--|
| - Windows 8 supported | - ICG Analysis improvements |
| - OS X 10.8 supported in Mac version | - Pressure Volume Loop Analysis tools |
| - Linked acquisitions supporting multiple hardware types | - Find Cycle enhancements |
| - Increased channel count support – up to 15,000 channels | - Rate Detector enhancements |
| - Consolidated and multiple hardware support | - Graph Textual Value Display and Toolbar |
| - Improved compatibility for standard user account presets/specialized analysis settings | - Original data restored after canceling transformations |
| - Bluetooth integration for BioHarness® | - Focus Area feature |
| - Scaled ECG boundary selection | - Tabbed graph interface |
| | - Noldus import/export |
| | - SMI BeGaze data import |

- Improved software controls for B-Alert® wireless EEG system
- Higher resolution cameras supported in Media Capture/Playback
- Media Capture/Playback now supports linking to earlier-format AcqKnowledge 3.9/BSL 3.7 files
- Selection palette toolbar icon
- Linked selection option from the I-beam tool
- Measurement column selection
- Rate/Expression Presets
- Automated analysis changes to EEG - analyze multiple channels in one go
- Additions to the ICG analysis
- Journal docking options
- New preference to “pin” dialog windows on top of application
- New MP150 Modules for Heel/Toe Strike, Dyno Clench Bulb and Goniometer setups

Using this Manual

The AcqKnowledge Software Guide is divided into four parts:

Part A *Getting Started*

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

Part B *Acquisition Functions*

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

Part C *Analysis Functions*

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

Part D *Appendices*

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

See also:

BIOPAC Installation Guide

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

Hardware Guide

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

User Support System

User Support System files can be found in the following hard drive location; BIOPAC Systems, Inc/*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)

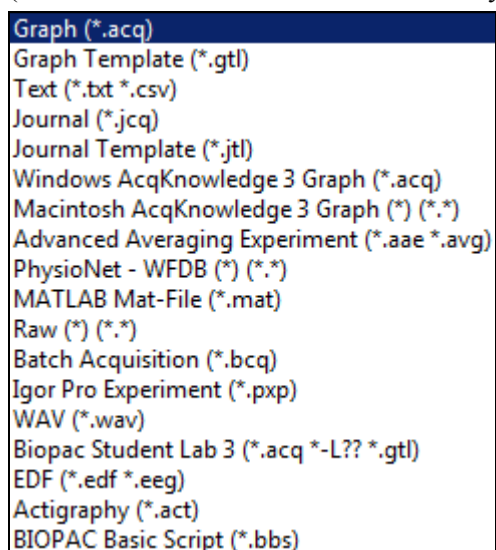
The User Support files can also be opened directly from the CD.

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

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



A screenshot of a file type selection dialog box. The list of file types includes:

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

Where do I find help?

The Introductory sections are intended to provide enough information to get up and running with the MP System, and become familiarized with some basic *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*

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

You may also visit [BIOPAC's Tutorial Video page](#) for instructional screencasts of many analysis routines and software features.

➤ *Application Notes*

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

➤ *Acquiring data*

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

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

➤ *Working with large files*

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

➤ *Troubleshooting*

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

IMPORTANT SAFETY NOTICE

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

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

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

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

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

Human Anatomy & Physiology Society Position Statement on Animal Use

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

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

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

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

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

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

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

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

Used with permission of:

The Human Anatomy & Physiology Society (HAPS)
251 S. L. White Blvd., P. O. Box 2945, LaGrange, GA 30241-2945
800-448-HAPS (4277) Fax: (706) 883-8215 www.hapsweb.org

Part A — Getting Started

Chapter 1 MP Systems Overview

Part A - *Getting Started* covers the basics of data acquisition and analysis with the MP System (MP150 or MP36R), since this is the most commonly-used BIOPAC hardware system. All of the material in this section is covered in more detail in subsequent sections (see *Using this Manual*, page 18).



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

Overview

The MP System (MP150 or MP36R) 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 program 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.

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

The MP System utilizes the same hardware, excepting the computer interface. The software has the same “look and feel” on computers running Windows® or Mac® OS X.

- The system is referred to as “MPWSW” for Windows® or “MPWS” for Mac.

The MP System consists of several major components, including hardware and software. The *AcqKnowledge* software included with the MP system allows full control over editing data, 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 converts incoming physiological data into digital signals that can be processed and displayed on a computer interface. The MP150 data acquisition unit connects via Ethernet, the MP36R connects via USB.

The MP150 System also includes a Universal Interface Module (UIM100C) for connecting external devices to the MP150 data 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 MP150 data 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 MP150 data acquisition unit.

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

MP36R support

The MP36R is a four-channel data acquisition unit designed to work with AcqKnowledge 4.1 and above for the research market. AcqKnowledge support for the MP36R unit includes:

- Standard data acquisition and data acquisition features (triggering, multiple channels, variable sampling rate, input values)
- Output control functionality for controlling stimulators, digital channel, and channel redirection to output.
- Standard analog presets for all SS series transducers
- Electrode Check support
- Multiple-MP device support. Similar to multiple MP150 support, each graph may acquire from a maximum of one unique MP device.
- Control channel support for changing digital output lines based on calculation channel analysis

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

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

AcqKnowledge software does not support MP36 units from the Biopac Student Lab product line (without the “R” designation).

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



MP System Requirements

Suggested minimum system requirements are detailed below. Recommendations are included to optimize system performance; more memory and a faster system will enhance MP System performance. If planning to acquire data for more than a few hours and/or are sampling at more than 1,000 samples per second, see the [Disk Space](#) note.

For AcqKnowledge 4.4.2	
OS	Requires Windows 10/8/7 or Mac OS X 10.9-10.11
MP150 Requires Ethernet (UDP), MP36R requires USB.	
Port	Note To use an MP150 with UDP communication on a network with a non-Windows DHCP server, it is necessary to use firmware rev. 1.1.12 or greater in order for the MP150 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 1 GB to store the software and online manuals; additional 1 GByte recommended for data storage
RAM	1 GB recommended
Processor	PC: Pentium 4 or higher Mac: Intel Core Duo or higher

Disk Space

With any program, adequate disk space is necessary for storage of data files. Some users may generate data files of several hundreds of megabytes. To acquire data for long periods (more than a few hours) while sampling at relatively fast rates (more than 1,000 samples per second), as much disk space as possible should be available. (A removable drive may also be used). See the Appendices for hints on working with large files.

Windows XP Compatibility

AcqKnowledge 4.4 is officially released for Windows 10, 8, 7, and Vista operating systems. *AcqKnowledge* 4.4 is not supported on Windows XP.

Automator Integration and Scripting Support

Mac OS X 10.4 and greater 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 the creation of workflows specific to an individual user account or to one 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.

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

<http://support.apple.com/kb/HT2488>

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 computer users are accustomed to. Since the MP System (MP150 or MP36R) software runs under these Windows and Mac OS environments, you can run other applications while you are collecting data. In terms of hardware setup the MP System (MP150 or MP36R) 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 (MP150 or MP36R) 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
Arbitrary Sample Rates	Apply different sample rates between channels or operate the STM100C stimulator at a different rate than the acquisition sample rate
Calculation Channel Presets	Customize your recording for specific measurements.
Template files	AcqKnowledge “ Quick Start ” templates are available for over 40 applications. Just open the template file and start the acquisition—appropriate settings are established for the selected application.
Online Calculation	Although 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	Validate measurements with the ValidateMeasurements.acq sample file that was included with the software. The measurement definitions (page 95) 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. AcqKnowledge 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. AcqKnowledge 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 or expressions.
Annotation	AcqKnowledge 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 60.

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 event function allows you to insert symbols in the record and add text for each event. These can be added either while data is being collected or after the fact. Event functionality can be automated for sequential application or customized for Function keys.
File compatibility	Data can be saved and viewed in a number of different formats. For word processor programs like Microsoft Word [®] , use Copy to Clipboard and then paste into the document. Use Save as Excel for Microsoft Excel [®] . 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.
Cycle/Peak detection	AcqKnowledge has a built-in algorithm to find cycle data, such as positive or negative peaks, from any size data file. You can even search for all the cycles/peaks with one command and automatically log statistics like 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 MP System (MP150 or MP36R)s run on Windows or Mac OS, 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, event 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

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 System (MP150 or MP36R)s	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	Visual Attention
FFT for Frequency Analysis	Online Analysis	Visual Evoked Response
Field Potential Measurements	Online ECG Analysis	VO2 Consumption
Fine Wire EMG	Orthostatic Testing	Volume/Flow Loop Relationships
Forced Expiratory Flow & Volume	Peripheral Blood Flow	Working Heart Preparations

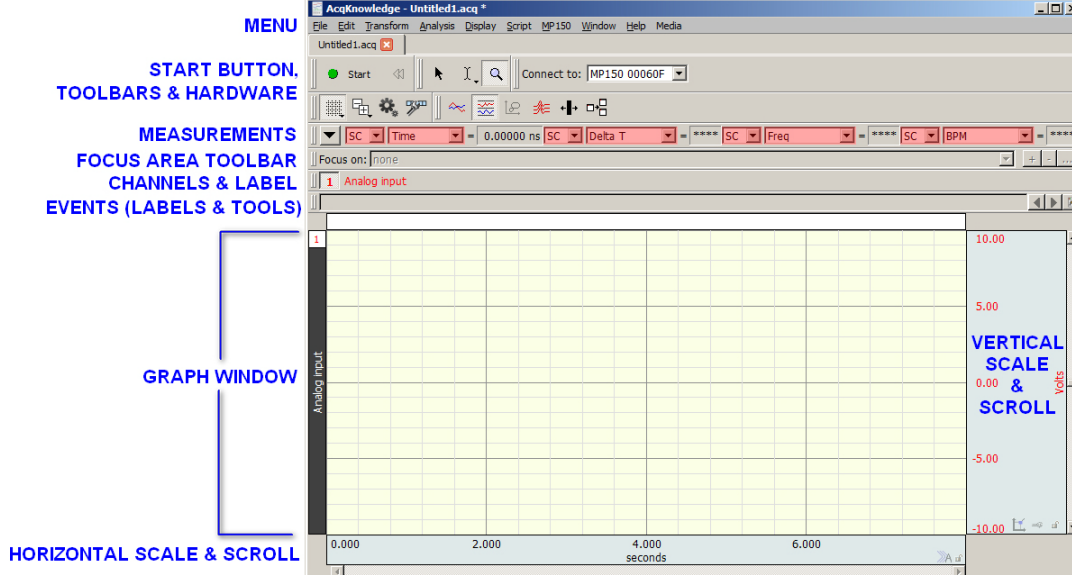
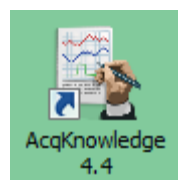
Application Notes

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/c	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
#AH249	Online Averaging Latency Parameters (ISI, ABR)

Chapter 2 AcqKnowledge Overview

Overview



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

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

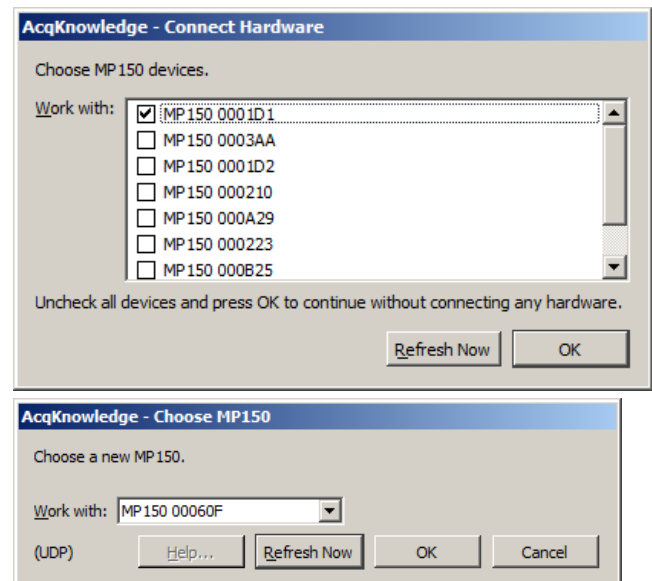
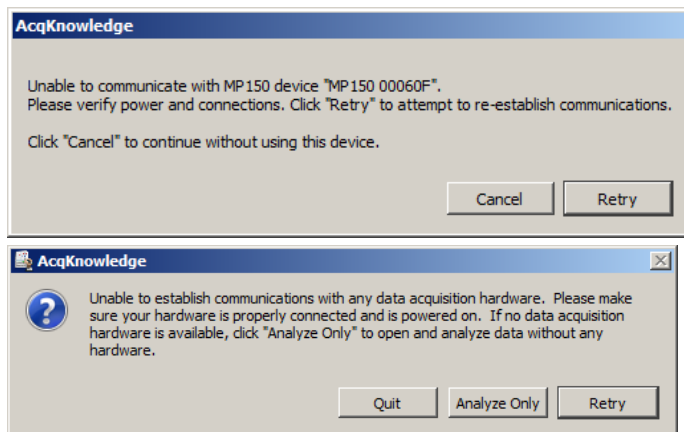
Menu	Functionality	See Page
File	New, Open, Open Recent, Open for Playback, SMI BeGaze Import, Close, Save, Save As, Save Selection As, Save Journal Text As, Send Email as Attachment, Page Setup, Print, Quit	248
Edit	Undo, Cut, Copy, Paste, Clear/Clear All, Remove Last Appended Segment, Insert Waveform, Duplicate Waveform, Select All, Remove Waveform, Create Data Snapshot, Merge Graphs, Clipboard (Copy Measurement, Copy Wave Data, Copy Graph, Copy Acquisition Settings, Copy Data Modification History for All Channels, Copy Data Modification History for Graph, Copy Focus Area Summary, Copy Event Summary), Journal (Paste Measurements, Paste Wave Data, Paste Acquisition Settings, Paste Modification History for All Channels, Paste Modification History for Selected Channel, Paste Focus Area Summary, Paste Event Summary, Manage PDFs, Show Journal)	272
Transform	<i>operations that primarily modify the data in the graph</i> Recently Used, Digital Filters, Fourier Linear Combiners, Math Functions, Template Functions, Integral, Derivative, Integrate, Smoothing, Difference, Resample Waveform, Resample Graph, Expression, Delay, Rescale, Waveform Math, Slew Rate Limiter	282
Analysis	<i>operations that derive data & measurements from the graph</i> Recently Used, Histogram, Autoregressive Modeling, Nonlinear Modeling, Power Spectral Density, Autoregressive Time-Frequency Analysis, FFT/IFFT, DWT Discrete Wavelets, Principal Component Analysis/Inverse PCA, Independent Component Analysis/Inverse, Find Cycle, Find Rate—plus a courtesy copy of the Specialized Analysis package with classifiers and automation routines	313

Display	Tile Waveforms, Autoscale Single Waveform, Autoscale Waveforms, Optimize Ranges, Overlap Waveforms, Compare Waveforms, Autoscale Horizontal, Show All Data, Show Default Scales, Zoom, Reset Chart Display, Reset Grid, Adjust Grid Spacing, Set Wave Positions, Set Channel Visibility, Wave Color, Horizontal Axis, Show, Customize Toolbars, Channel Info, Preferences, Size Window, Cursor Style, Split View, Create Data View, Create Focus Area, Organize Data Snapshots, Show All Data Snapshots, Load All Data Into Memory	427
MP150 MP36 B-Alert* BioHarness* Mobita*	Set Up Data Acquisition, (Channels, Length/Rate, Event Marking, Segment Labels, Stimulator, Trigger, Sound Feedback), Set Up Advanced Averaging, Show Input Values, Show Manual Control, Show Gauge, MP150 info, Update Firmware, AutoPlotting, Scrolling, Sweep, Warn on Overwrite, Organize Channel Presets, Set Up Linked Acquisitions, Exit Playback Mode, Manage Hardware Connections *Not all MP hardware menu items listed above will be available with B-Alert, BioHarness, Mobita or hardware.	106
Playback	Replaces the hardware menu when Playback mode is active (use File > Open for Playback and Playback > Quit playback to toggle playback and acquisition modes)	43
Window	Controls the position of windows on the monitor	456
Help	Provides online support files (PDF format and web links).	456
Media	Capture or Playback media files(.avi, .wmv, or mpg) and synchronize with .acq data	458



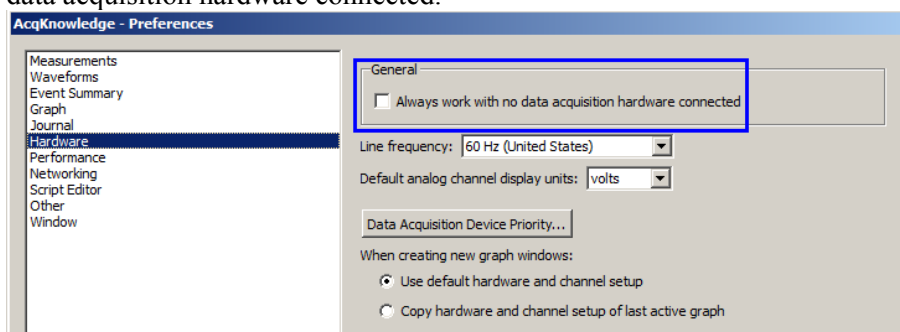
Launching the AcqKnowledge software

The first step is to launch the software by double-clicking on the AcqKnowledge icon. If hardware is not properly connected, you may receive connection messages resembling the following examples. (Examples shown are from the commonly-used MP150 hardware.)

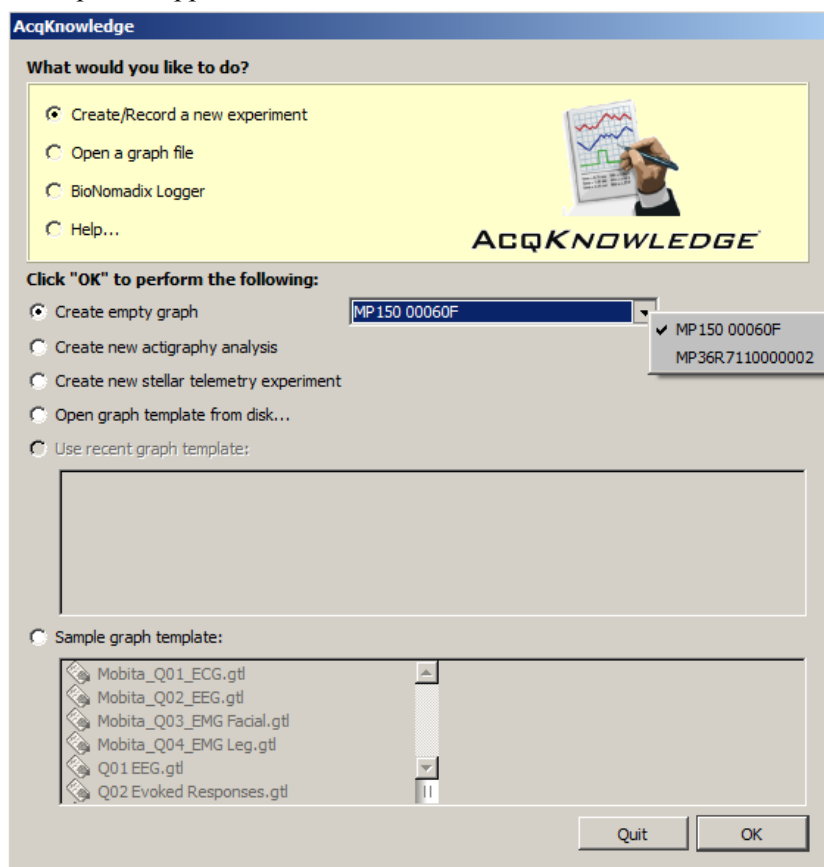


If you receive a hardware prompt when you launch AcqKnowledge, there are two possibilities: You have not properly connected everything and/or you have not powered up the hardware system.

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



Assuming everything is properly connected and there are no conflicts, *AcqKnowledge* will launch the Startup Wizard (see next page). Use this wizard to choose whether to create a new experiment, open a saved graph for analysis or access the Help and support files.



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

- **Open a graph file** Presents similar options for analyzing existing graphs, including a checkbox option to launch graphs in Playback mode. Playback mode will “replay” previously recorded graph data in real time.
- **BioNomadix Logger** Presents options for importing BioNomadix Logger data from the Logger device or from disk. Not applicable unless the wireless BioNomadix Data Logger is being used. For further information about the Logger, click [here](#).
- **Help** Launch various help and support options, including Web screencast tutorials. Upon first application launch, this selection is displayed by default.

NOTE: The Startup Wizard may be disabled following launch if desired. Choose “Display > Preferences > Other > When application is launched,” change the default from “Show Startup Wizard” to “Create new empty graph window” and click OK.)

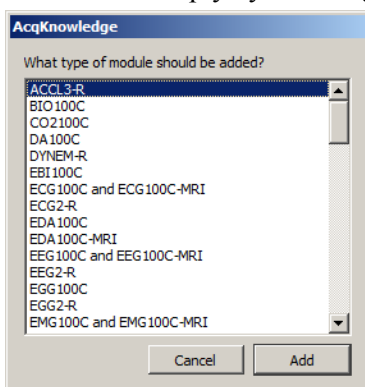
A “window” is the term used for the area on your computer’s screen where data is displayed and/or manipulated. The graph window on the screen is designed to provide you with a powerful yet easy-to-use interface for working with data.

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

It’s a good idea to create a new graph window for each acquisition. To create a new graph window after the original launch, choose “File > New.”

Setting up channels using Module Setup (MP150 Hardware)

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



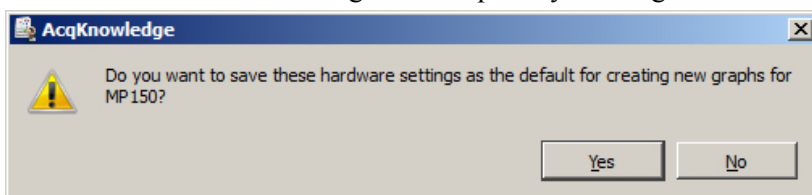
For further details on Module Setup, see page 109.

Setting up channels manually

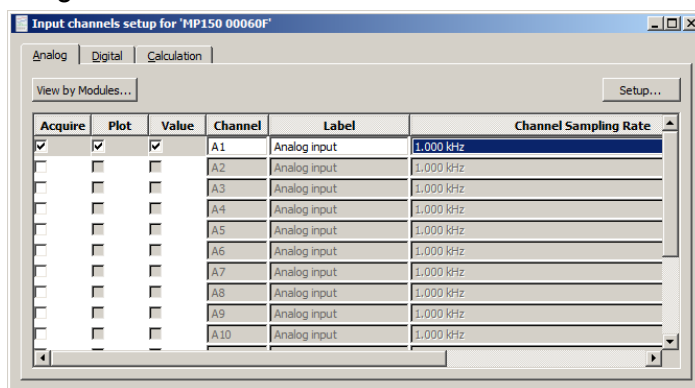
If manual setup of channels independent of hardware is preferred, click “Cancel” in the Module Setup dialog and choose the “View by Channels” option at the bottom of the channel setup screen. This will display the manually-configured Input Channels Setup dialog.

NOTE: You may also disable the default factory channel setup by going to “Display > Preferences > Hardware” and changing the “**When creating new graph windows use:**” option from “Minimal channel setup” to “User-defined default channel setup.” (For full details on this preference, see page 451.)

Also note that, when using this setting, the following message will appear upon closing the setup dialog until all user-defined default settings are accepted by clicking “Yes.”



Basic Analog Channel Information



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

By default, all channels are deselected on new graph windows. Usually, you will want to check all three boxes (Acquire, Plot, and Value) for each channel selected to acquire data.

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

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

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

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

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

Channel Sampling Rate The channel sample rate is a function of the acquisition sample rate: all channel sample rate options are equal to or less than the acquisition sample rate (as established via “Hardware > Set Up Acquisition”). The options are a specific power of 2 less than the acquisition sample rate. Use the pull-down menu to set the channel sample rate. See page 113 for details.

Basic Digital Channel Information

In contrast to analog data, Digital channels collect binary data that represent when a measuring instrument is “on” or “off.” (For example, records whether a switch is open or closed, as in reaction time studies or control applications.) Digital channels are acquired, plotted, and have values listed the same fashion as analog channels. For more details about Digital channels, see page 122.

Basic Calculation Channel Information

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

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

When a new Calculation channel is enabled, a simple setup dialog corresponding to the selected preset is presented, which helps facilitate proper setup. Choose from the list of available presets or create a custom preset; see page 112 for details.

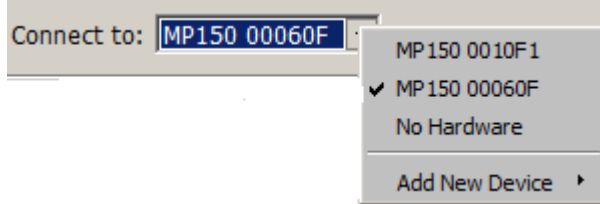
For a detailed summary of Calculation channel options, see the Calculation Channel section beginning on page 122.

 For a detailed look at launching and setup of *AcqKnowledge* software, watch the [Tutorial video](#).

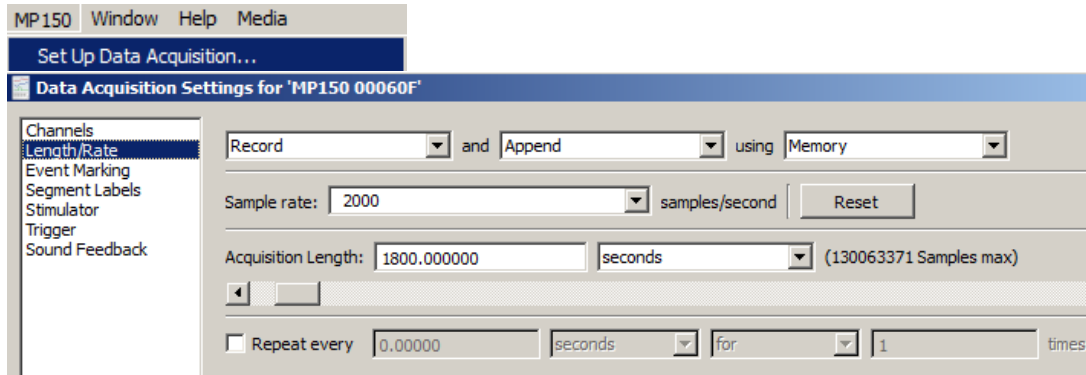
Selecting Hardware

When *AcqKnowledge* is first launched, you may select an available data acquisition device from the “Connect to:” dialog. The dialog lists all devices that are powered ON and sitting on the same local area network. When using more than one MP150 device or working across a network, it will be necessary to lock/unlock an MP150 to acquire data (see Appendix E on page 565 for details). The selected MP150 unit will be listed in the upper left of the graph display as “Connect to:” if the Hardware toolbar display is enabled.

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



Setting Up Acquisitions



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

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

Storage

Record and Append 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) specifies where data should be stored during the acquisition. You will probably want to choose Memory or Disk storage. If your system uses any virtual memory, AcqKnowledge will use as much as possible. You may also store data directly to the MP150 data acquisition unit, which can store 4 MB; you cannot store data directly to the MP36R or other BIOPAC hardware types.

- The advantage of storing to the MP data acquisition unit is that much faster sampling rates may be obtained.
- The disadvantages of saving data to the MP data 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 162.

Rate

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

The MP150 sampling rate has a lower bound of 0.1 samples per second, and an upper bound of 400 kHz aggregate. The MP150 must use a pre-defined rate; it does not accept custom rates.

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

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

Duration

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

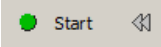
Starting an Acquisition

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 > Graph window.

Status light

Next to the Start button, you should see a circular status light. The status light indicates the communication link between your computer and the data acquisition hardware unit.

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

To start an acquisition, position the cursor over the  button and click the mouse button, or select **Ctrl+ Spacebar**. If there are electrodes or transducers connected to the data acquisition unit, 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 Hardware Systems, see the *BIOPAC Hardware Guide.pdf*.
- To start an acquisition using a variety of “triggers,” see page 173.
- Graphs that open without a Start Button
 - Compressed Graphs
 - Igor Pro Experiment
 - PhysioNet
 - DWT, IDWT
 - PCA, IPCA,
 - ICA, IICA,
 - AR Model separate graph output
 - Nonlinear Modeling separate graph output
 - HRV tachogram output
 - Chaos > Plot Attractor
 - Chaos > Detrended Fluctuation Analysis
 - MatLab Graphs
 - Merge Graphs
 - Original Data Snapshot
 - Raw Data Files
 - Text Files
 - Transform menu operations: Off-Line Averaging; Filter Response
 - Analysis menu operations: Histogram; FFT (Magnitude and Phase); IFFT; Rate (put result in new graph option)

Once an acquisition has started, the Start button in the acquisition window will 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 data acquisition unit will illuminate, showing that data is being collected.

Stopping an Acquisition

To stop an acquisition at any time, click the  button or select **Ctrl+ Spacebar**.

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

The double-arrow icon to the right of the Start/Stop button is the rewind segment button. Use this button to remove any unwanted recording segments from the graph. For more details, see page 169.

Display Modes

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



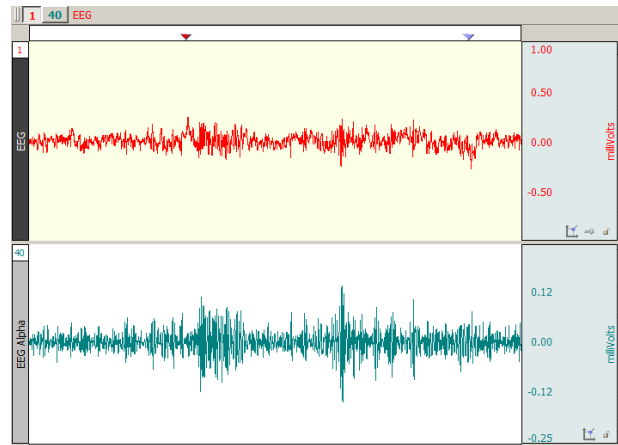
Chart mode

Chart mode is the default display mode.

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

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

If a waveform is plotted off the scale of the channel track, choose autoscale waveforms and AcqKnowledge will select the “best fit” for waveforms to their tracks.



Scope mode

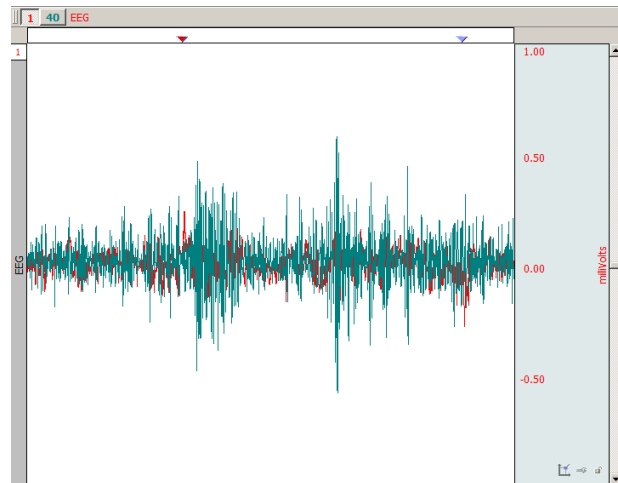
Scope mode plots data much as it might appear on an oscilloscope, with time on the horizontal axis.

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.



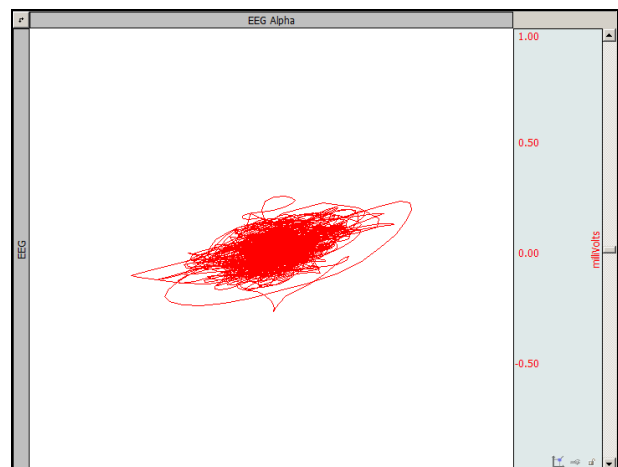
X/Y mode

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

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

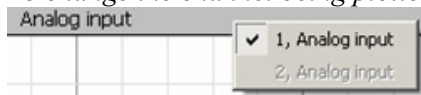




X/Y mode continued

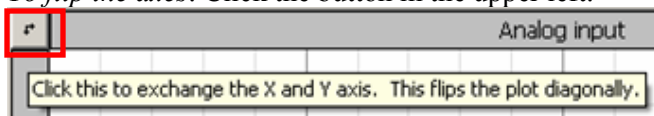
Plotted channels

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

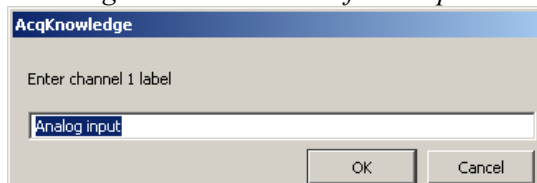


X-axis, click *above* the waveform; Y-axis, click *left* of the waveform.

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



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

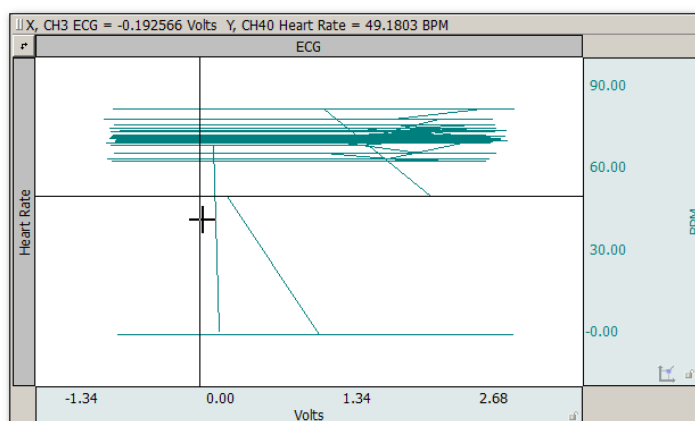


Toolbar icons

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

Tools

Cursor: In X/Y mode, the I-beam tool in the lower right hand corner of the graph window changes into a crosshair. When the crosshair is moved into the graph window, the coordinates of the crosshair are displayed in the upper left corner of the graph window. The X value refers to the 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. By pressing the mouse, a crosshair is drawn over the closest data point and the measurement toolbar “snaps” to that position to show the amplitudes of the actual pair of data samples plotted on the screen. In AcqKnowledge 4.2 and higher, the Channel number and label are also displayed next to the measurement values.



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

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

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

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.

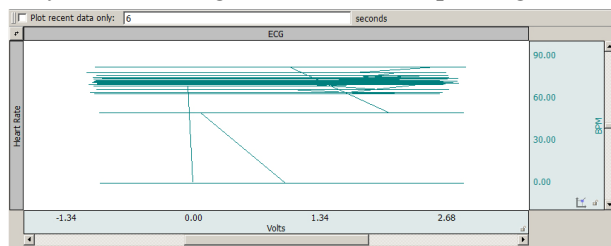
Ch. # Box: In X/Y mode, the channel numbering boxes are disabled.

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

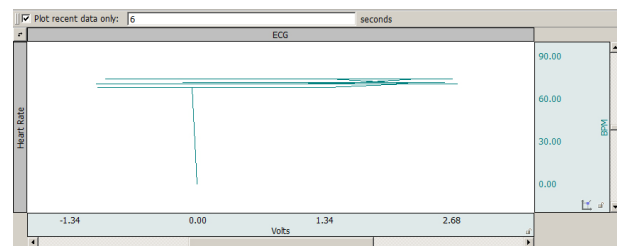
Plot Recent Data Only



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



Plot recent data option not applied



Plot recent data option applied with 6 sec. value



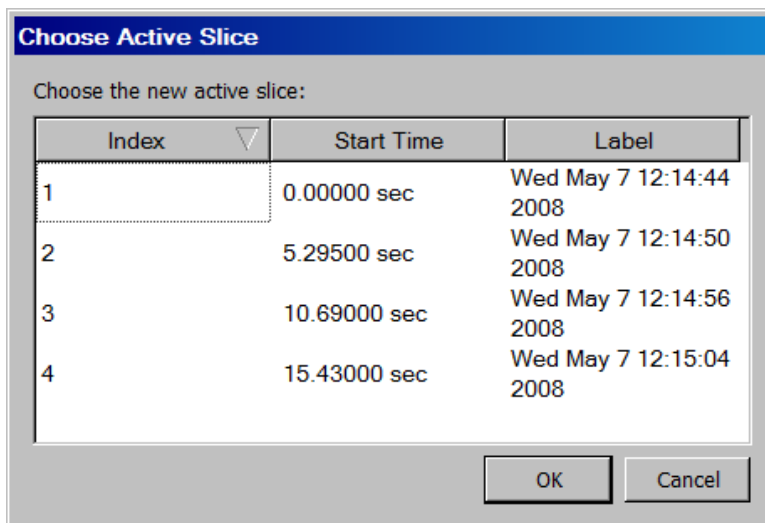
Stacked Plot mode

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

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



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



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

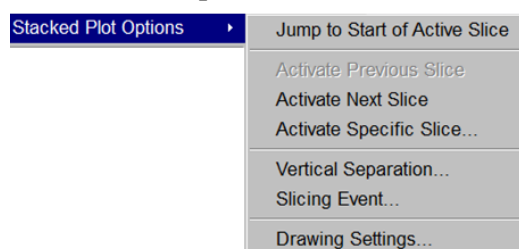
A commonly used data visualization technique for examining the evolution of waveform morphology is the 2D waterfall plot or “stacked plot.” A stacked plot draws multiple traces for a single waveform on top of each other, or “slices.” Each individual slice is a time-shifted plot of the original waveform.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

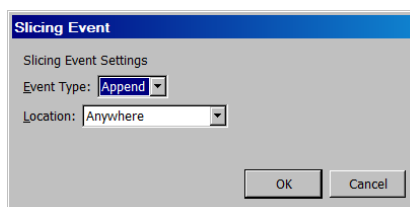
The slices can be aligned at any type of events in the graph. This allows for alignment at appended segments but also at locations found through other means. For example, an ECG waveform can be aligned at the start of the T-wave to examine how the T wave evolves in time.

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

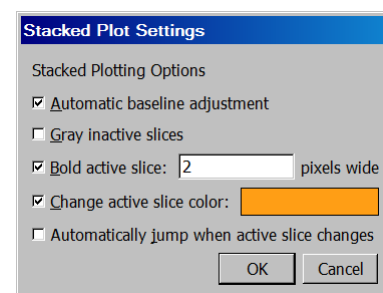
Stacked Plot Options



Display > Show > Stacked Plot Options



Slicing Event...

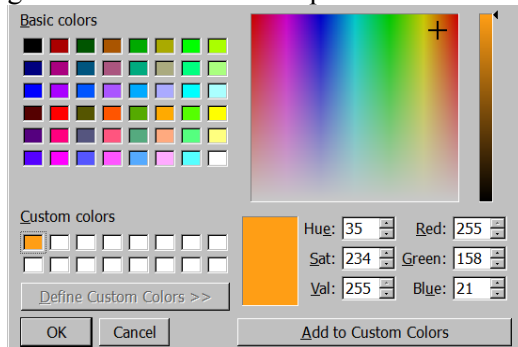



Drawing Settings...

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

Automatic baseline	Adjusts the baseline of each inactive slice to overlap the baseline of the active slice prior to the application of any vertical separation. This helps compensate for baseline drift in a signal. If it is disabled, no baseline compensation 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, so you may need to zoom in to see the effect.
Bold active slice	Draws the active slice with a thicker pen. In step and line plot modes, plotting normally occurs with a one pixel wide pen. Inactive slices will remain one pixel wide while the active slice will have the thicker pen as indicated in the edit field. When the waveform is in dot plot mode, the pixel width will be added to the waveform's default dot size to increase the dot size for the active slice.

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



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

Functionality in Stacked Plot mode

Autoscaling

When a graph is displayed in stacked plot mode, all autoscaling and related display operations (tile, compare, overlap) will examine 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.”

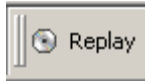
The previous/next/choose slice graph toolbar buttons and “Display > Show > Stacked Plot Options” menu items will be disabled.

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 window to be dismissed.

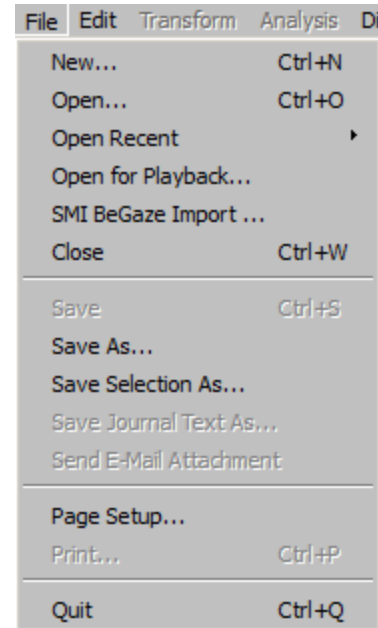
The slicing event, vertical separation, and drawing menu items and toolbar controls will remain active.



Playback Mode (Replay)

Playback mode will replay a graph file stored on disk in real time to simulate acquisition. Analog, digital and calculation channels are replayed as stored in the graph file. AcqKnowledge 4.2 and higher allows calculation channels to be reconfigured, including adding channels without an offline equivalent. Calculation channels from the original graph can be modified, added, or removed without affecting the data stored on disk in the original graph file.

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



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

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

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


Do not record data while playing back a data file. If one data file is open in "Playback" mode and is 'replaying' and a second data file is open in hardware mode and is acquiring data, clicking back and forth between graph windows causes the hardware device menu to flip to the Playback menu (even though 'Connected to' shows communication with an MP150 unit).


▶ Watch the [AcqKnowledge Playback Mode](#) video tutorial for a detailed demonstration of this feature.

Data Views

A “Data View” window is used to provide an alternate view of the same data. 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 and select type Data View
- Display > Create Data View
- Click the Data View toolbar icon 

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

TIP Use the Jump-to tool (see page 60) to correlate data views.

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

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

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

When a file is saved to disk, the display configurations of any open Data Views are saved into the graph file.

When the graph file is reopened, all of the Data Views and their display settings will be restored.

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

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



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.

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



Sample File Display

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

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

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

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

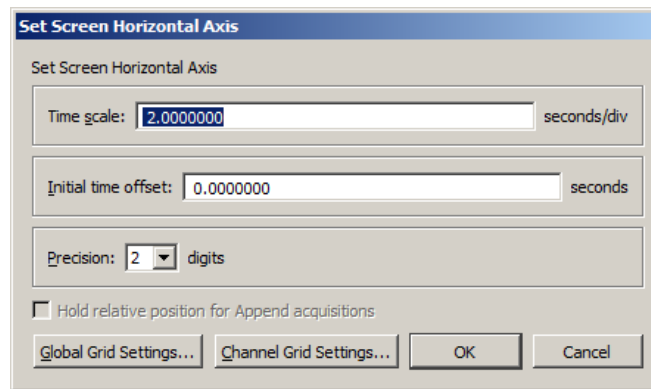
The maximum vertical scale range is from +10 to -10 Volts.

- This reflects the maximum input voltage the hardware unit can accept and is a greater range than 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, you can determine the total length of the record.

To view data that was collected earlier in the record, use the horizontal scroll bar to move to different points in the record. 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, position the cursor in the horizontal scale area (where the numerical values are listed) and click the mouse button. This will generate the following dialog (see page 74 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, 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. (Above screenshot is from AcqKnowledge 4.2)

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



The Initial time offset box 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.

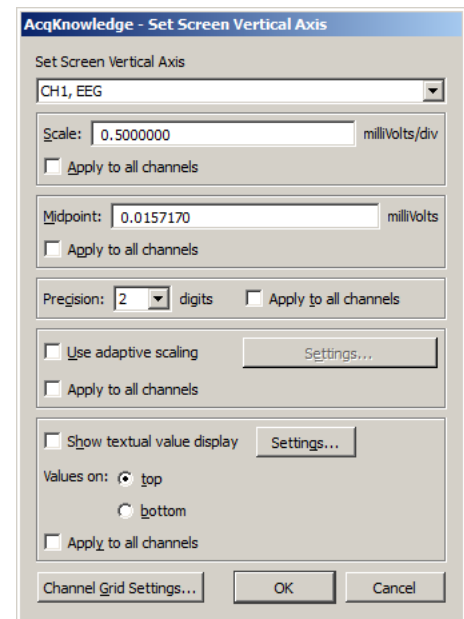
If you click in the horizontal scale area again, the same dialog will appear, and this time the value in the start box should have changed to reflect the new section of data being displayed on the screen.

AcqKnowledge also allows customization of the vertical scaling, or amplitude, of each waveform. Clicking the vertical scale area produces a dialog (see page 75 for details).

The vertical scale dialog 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).

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.

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



As with the time scale, 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.


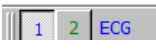

Any changes you make in terms of rescaling (either horizontal or vertical) will only affect the way data is displayed, and will not change the basic characteristics of your data file.

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 34). 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 channel box  that corresponds to the channel you wish to select and click the mouse, or
- Position the  cursor on the waveform of interest and click the mouse.

Show/Hide Channel

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

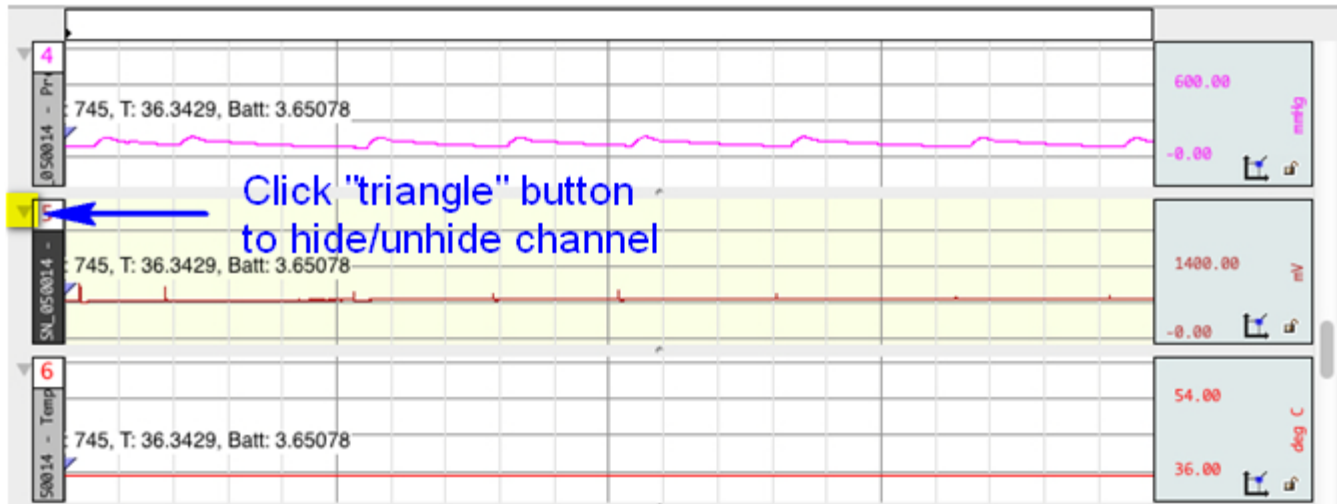
Or, Alt+click on the channel number at the top of the channel label region. 

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

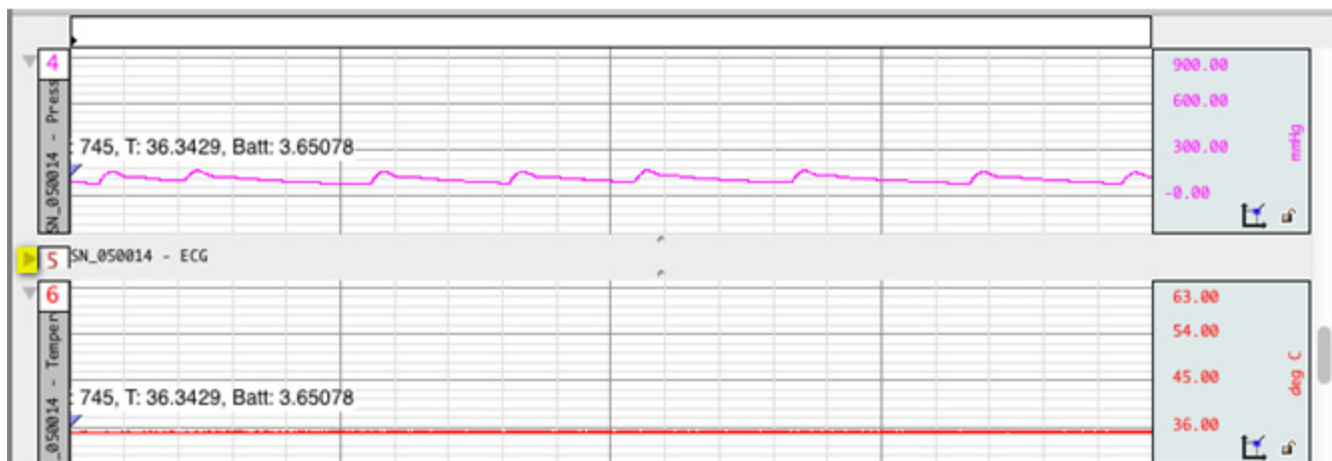
Alternatively, you can show/hide a channel via Display > Channel Visibility and checking/unchecking the channel boxes in the Channel Visibility dialog. (See this Display menu option on page 433.)

Collapsing Channels

In AcqKnowledge versions 4.4.1 and higher, individual or multiple channels may be hidden from view or “collapsed” by simply clicking the triangular button appearing in the upper left region of each channel. When a channel is collapsed, all data is retained but simply hidden from view. Collapsing a channel allocates more vertical space to remaining channels, enhancing the view of the visible data. The examples below illustrate use of this tool when applied to Channel 5.



Channel “Collapse” button (highlighted)





Channel 5 collapsed

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

NOTES:


- Collapsing or expanding channels is supported in Chart or Stacked Plot mode only.
- Pressing the Alt/Option key while clicking any triangle button will collapse or expand all visible channels.
- Collapsed channels are retained when a graph is saved and reopened.


Zoom


Another way to examine data is to use the “zoom” tool. The zoom tool allows you to select any portion of any wave and magnify it as much as possible. To use the zoom tool, click 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.

Select 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 **CTRL + Z** for Windows or **⌘ + Z** for Mac.

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.

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

Keyboard data selection

Keystroke combinations can similarly used to select or deselect graph data on a sample-by-sample basis. This helps add an enhanced level of precision to the selection operation. See data selection keyboard shortcuts on the following page. (AcqKnowledge 4.2 and higher)

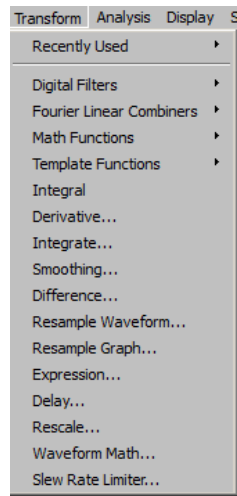
Keyboard Shortcut	Description
Windows: Shift + Ctrl + Left Arrow Mac: Shift + Command + Left Arrow	Subtracts one sample interval from the right edge of the selection. If the selection is empty, no action is performed.
Windows: Shift + Ctrl + Right Arrow Mac: Shift + Command + Right Arrow	Subtracts one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

Transform data

AcqKnowledge includes a library of functions to transform data or perform mathematical calculations on waveform data. All of these options can be found under the Transform and Analysis menus, and are discussed in detail in the Analysis section beginning on page 313.

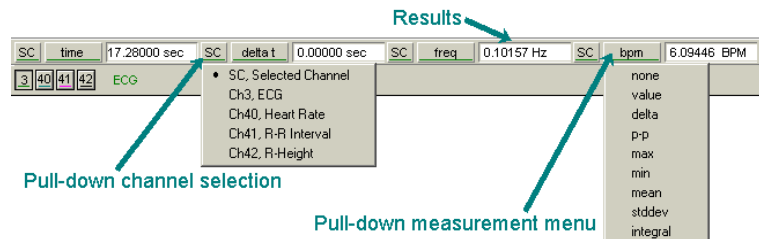
When performing transformations

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



Measurements

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.



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 the measurement popup menu and select a measurement from the list.

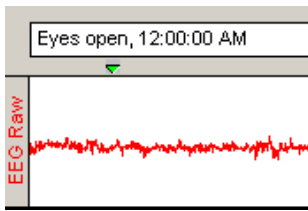
- Some measurements (such as Time or Value) look at only a single data point whereas other measurements (such as mean and delta T) examine a range of data on the selected channel.
- Some of the measurements that depend on a selected area (such as delta T) look at differences in the horizontal axis measurement 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 91.

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

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

Events (Markers)



In many instances it is useful to have the software mark an occurrence or event during an acquisition so it can be referenced later. For instance, 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 “Events”, which are marked in the data to record events.

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

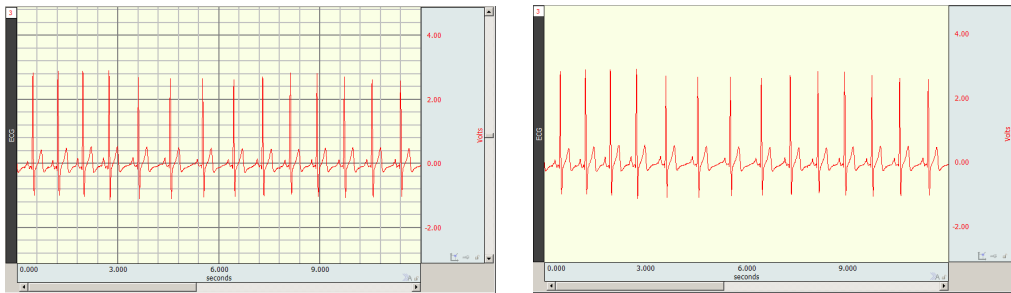
You can automatically insert event markers during an acquisition by pressing the Esc key. This will insert an event at the exact time the key is pressed and will activate the text line entry so you can immediately enter a comment to be associated with the event.

For a detailed description of events and event functions, including options to pre-establish event labels and set function keys for different labels, see Set Up Event Hotkeys (page 215).


 Watch the [AcqKnowledge Events video tutorial](#) for a detailed demonstration of this feature.


See also: Text Annotation, page 60.

Grids



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

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

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


For more information about using and printing grids, see page 78

Note: The Scale dialogs change when grid lines are locked. See page 74 for details on Horizontal Scale and page 75 for details on Vertical Scale.

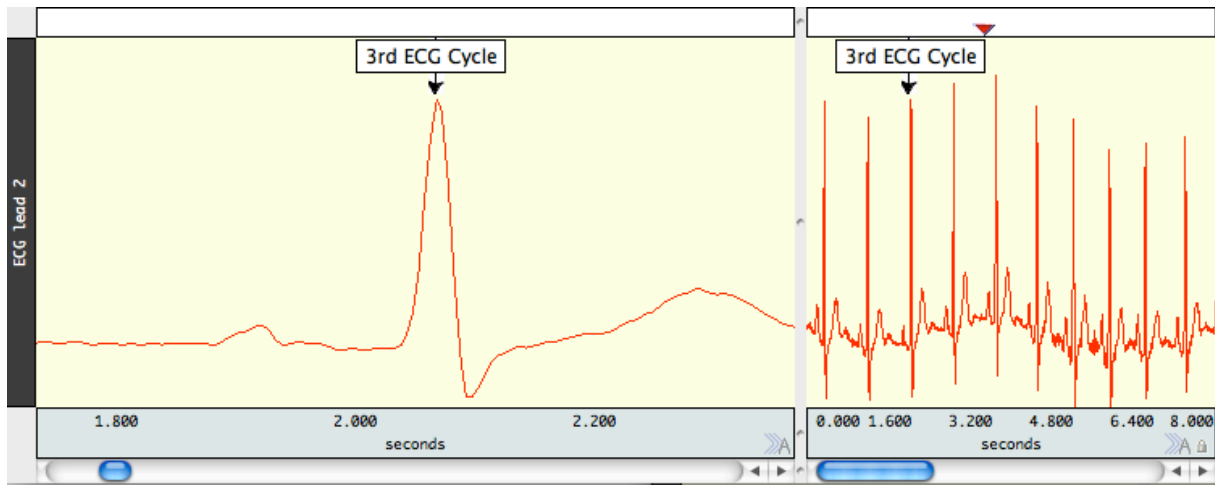
Horizontal Split View

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

Split View can be activated via the following methods:

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

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







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

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

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

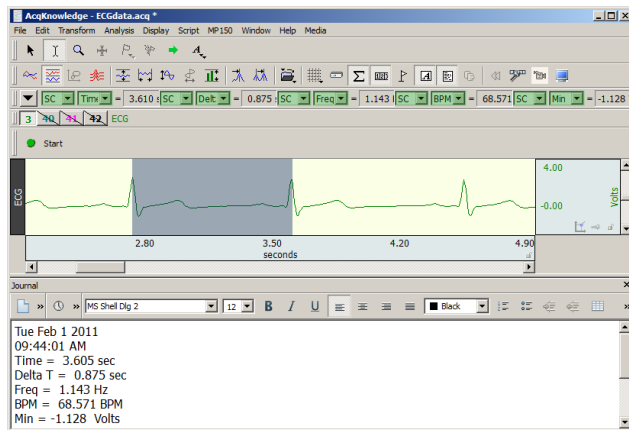
Autoscroll Horizontal Axis Controls

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

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

Journals

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



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

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

For more information on using Journals, see Journal Details on page 83.

Saving data

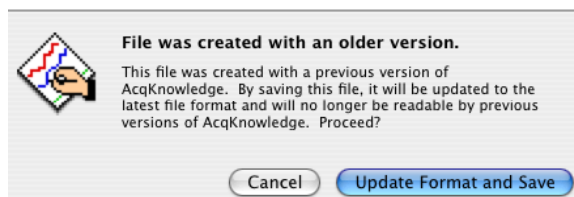
Once data has been collected, it can be saved as a file and opened later. The data file can be moved, copied, duplicated and deleted just like any other computer file. By default, files are saved as *AcqKnowledge* (.ACQ) files, which are a proprietary format designed to store information in a format as compact as possible. Although these files can only be opened from within *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 (.JPG) enables you to work with the data in graphic format.

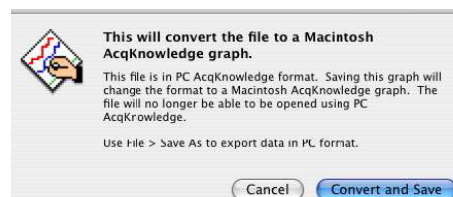
One of the most useful applications of this is the ability to edit and place *AcqKnowledge* data as it appears on the screen. You can use this feature to paste graphs into word processors, drawing programs, and page layout programs. To learn more about these options, turn to the Save As section beginning on page 261.

Format change warnings

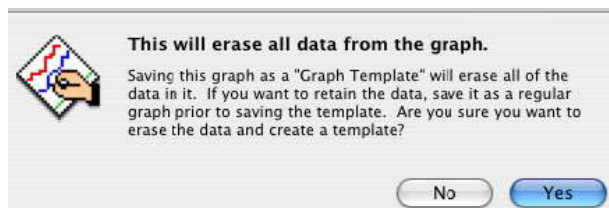
When a file save function requires a format change for compatibility or alters file content, a prompt will be generated to require the user to confirm the option to update format or convert and save.



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

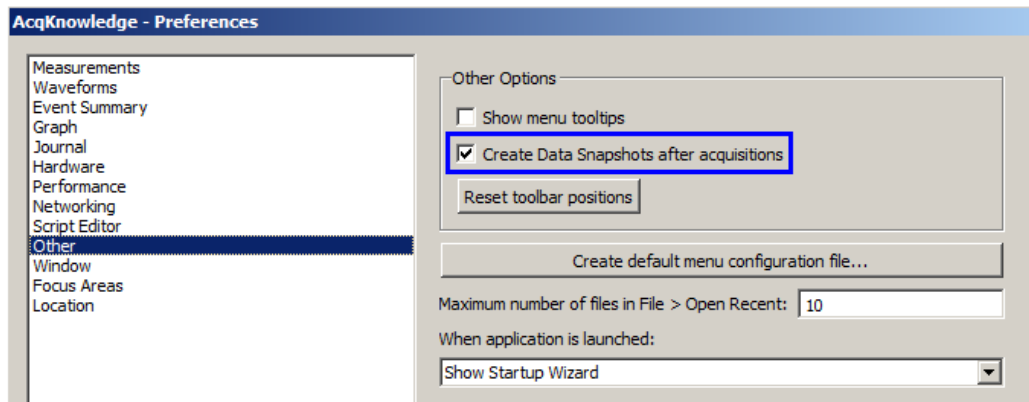
“Data Snapshot” — Embedded Archive

“Data Snapshots” are essentially embedded archives of the original acquired data that are 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.

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.

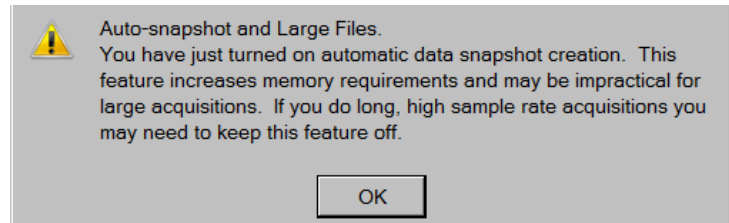
There are two ways to create a snapshot:

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

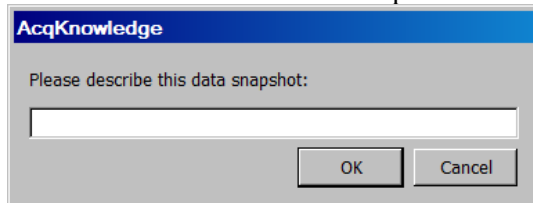


When this is enabled, a date-stamped archive of the data in the graph when acquisition stopped is created. In Append mode, the entire graph is archived with each Append, old data as well as the newly acquired data.

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



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



A snapshot is then taken of the data at that point in time and stored with the graph. Manual archives allow 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.

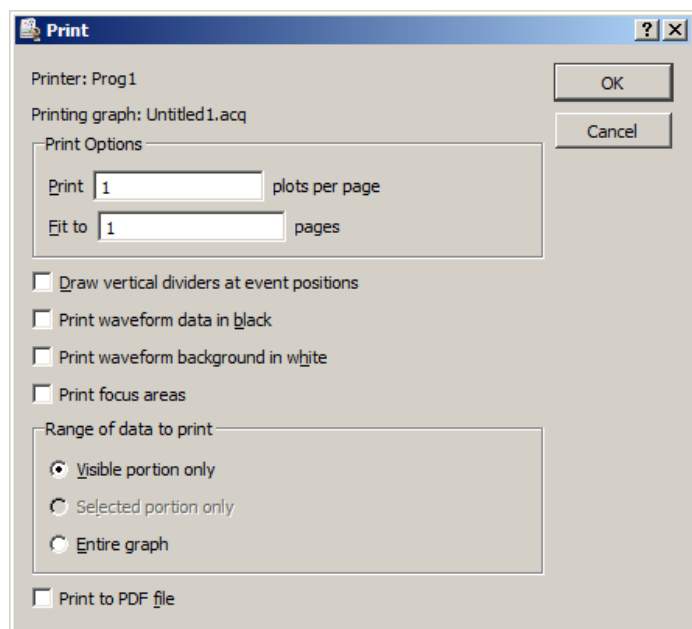


Manual Archive: description and time
Original file
Automatic Archive: time only

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

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

Print



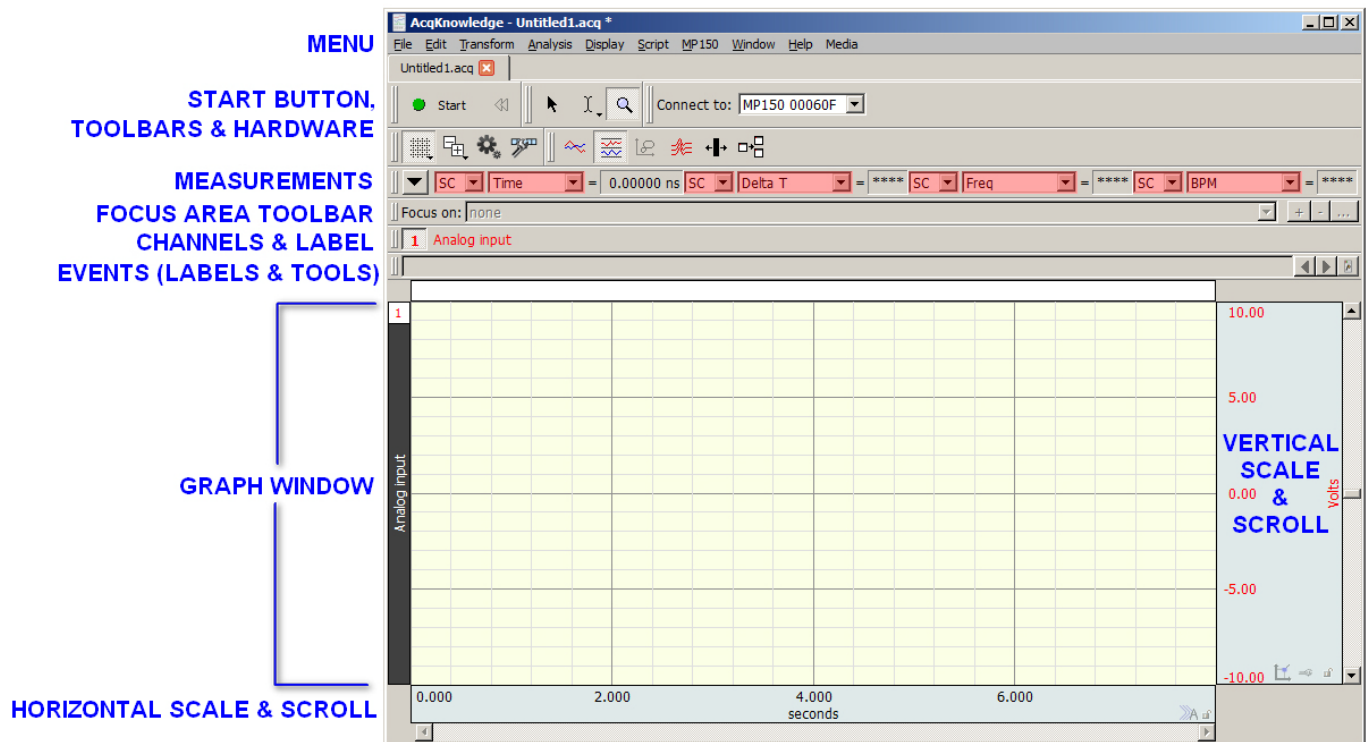
AcqKnowledge allows high-resolution printing of hard-copy graph plots much as they appear on-screen.

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

You may instruct AcqKnowledge to print the contents of a file across several pages by entering a value in the Fit to box. Entering “4” in this box, for instance, will place the length of the page evenly across four pages when printing.

Print options are available after you click OK in the initial File > Print dialog; see page 270.

Chapter 3 User Interface & Context Menu Features

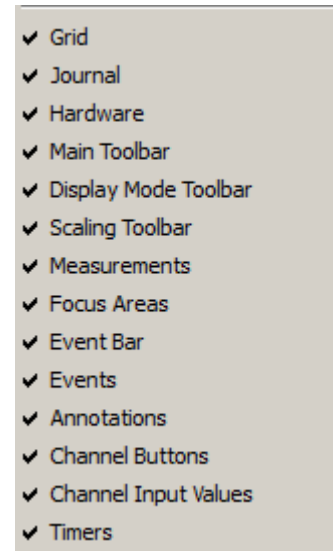
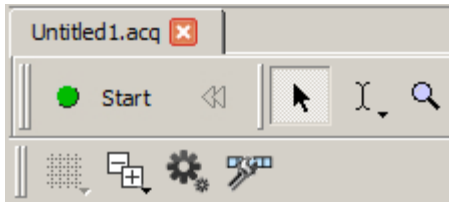


- Toolbars
- Keyboard Shortcuts
- Mouse Controls
- Custom toolbars for transformations and analysis
- Toolbar position retention and changes
- Event tool enhancements
- Typed event label drawing improvements
- Choose MP150 Help Button
- Button Transparency
- Customizable Chart Track Dividers
- Plotting Background Colors
- Vertical axis scaling buttons
- Long channel labels and units
- Graph window tooltip improvements
- Menu item tooltips
- Channel Info
- Transformation history
- Canceling Transformations
- Transformation Progress Bar
- Focus Areas

Toolbars


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

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



The default toolbars consist of:

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

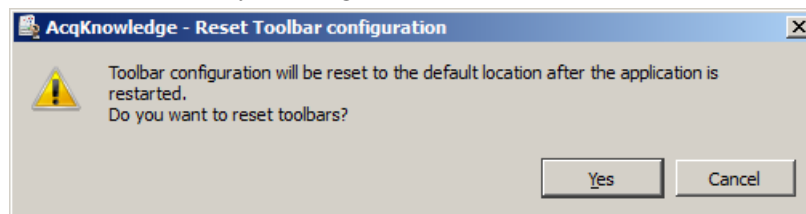
The full range of available toolbars can be displayed by enabling the checkbox options in the Toolbar Display shortcut button , or via Display > Show and enabling the desired options. Once the toolbar options have been selected, this will be the default toolbar display for all new graphs. All toolbars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

Saved graphs created with different toolbar configurations will open with those toolbar options displayed.


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

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

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

















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

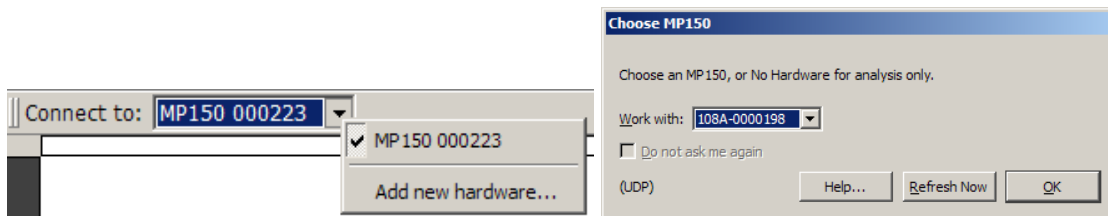
(Use the Toolbar Display shortcut button , or Display > Show.)

You may also reset the toolbars to the default minimal configuration by holding down the Shift key while launching *AcqKnowledge*, but this is a “nuclear” option.” Choosing this option will reset ALL program defaults to the factory configuration. Do not choose this option if your configuration contains custom settings that you’d like to save.

Main, Display and Scaling Toolbars

Main Toolbar	Display Mode Toolbar	Scaling Toolbar
TOOLBAR ICONS	FUNCTION	
	Show/Hide gridlines in the graph window. Click and hold the mouse to display various grid preset options.	
	Opens popup menu for showing/hiding individual toolbar options.	
	Opens the Preferences dialog.	
	Opens the customize toolbar menu.	
	Change display to scope mode.	
	Change display to chart mode (default).	
	Change display to X/Y mode.	
	Toggle Stacked Plot (overlap segment) mode; see page 40.	
	Horizontal Split View; see page 51.	
	Create Data View; see page 44.	
	Autoscale selected waveform only.	
	Autoscale waveforms along the horizontal axis.	
	Center waveforms vertically in the active window.	
	Center waveforms horizontally in the active window (X/Y mode only).	

Hardware Toolbar



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

Cursor Toolbar














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

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

Cursor Tools

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

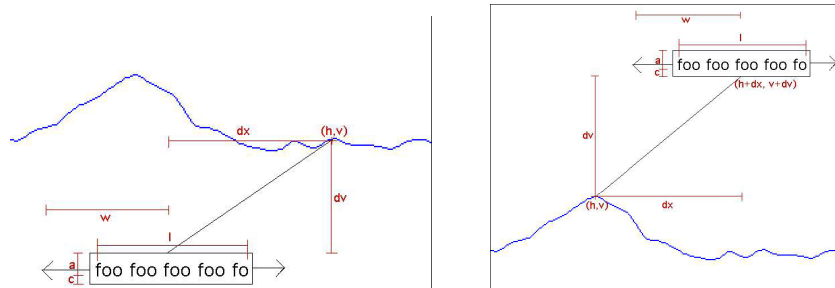
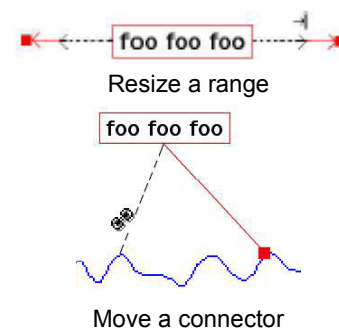
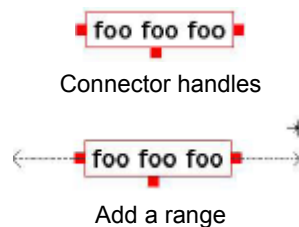
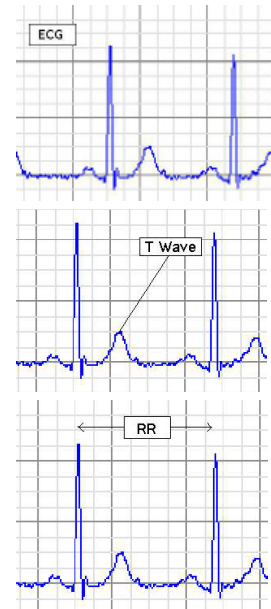
	<p>This is a general-purpose “arrow” cursor tool, used for selecting waveforms, scrolling through data, and resizing the chart boundaries between waveforms when in chart mode. All other cursors default to this mode when the cursors are moved outside the graph area. Use Alt-click to step through the channels; each click makes a new channel “active.” The arrow cursor can also be activated by the Ctrl+B keystroke.</p> <p>Holding down the left mouse button with the arrow tool positioned over a graph channel will activate a single data point, which displays as a solid black vertical line. This is known as “spot measurement” mode. Dragging the mouse will then update selected measurement values to the new horizontal locations of the arrow’s position in the graph. The mouse button should be depressed for approximately 0.5 seconds in order for spot measurement mode to become active. Releasing the button restores the arrow cursor to its normal status.</p>
	<p>This is a standard “I-beam” editing tool. This tool is used for selecting an area of a waveform (or waveforms) to be edited or transformed. However, editing of the selected area is limited to the channel currently selected in the graph. Click to I-beam icon to activate it. Now move the cursor toward the waveform. Notice that the cursor changes from an arrow to an I-beam when it is placed over the graph area.</p> <p>When this cursor appears, select an area of data by holding down the mouse button and dragging the mouse to either the left or right. Extend the selected area to include data that is not on the screen by positioning the cursor at the left edge of the area to be selected and clicking the mouse button. Next, use the scroll bars to scroll through the data until the desired data appears on the screen. Hold down the shift key while positioning the cursor to select the right edge of the area to be selected. Click the mouse button to select the area. To extend the selection, hold the Shift key and move the cursor or the arrow keys. The I-beam cursor can also be activated by the Ctrl+I keystroke.</p> <p>Clicking and holding on the I-beam tool will generate a pop-up menu for displaying the Selection Palette or linking selections between Data Views.</p> <div data-bbox="381 1150 789 1236"> <p>Show Selection Palette</p> <p>Link Selections Between Data Views</p> </div>
	<p>When “Link Selections Between Data Views” is selected, the standard I-beam cursor icon will change to one with a link appearing across it. When enabled, any area selected in a Data View or source graph will also be applied to any other associated data view. For more details, see Data Views on page 44.</p>
	<p>This is a standard “zoom” tool. The zoom tool is used for selecting and magnifying any portion of any wave. Click the  icon to use the zoom tool. 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 to be zoomed in. Release the mouse button, and AcqKnowledge will automatically adjust the horizontal and vertical scales. To “unzoom,” choose Zoom back from the Display menu or use the Ctrl+minus keystroke.</p> <p>Hold the “Alt” key to change the zoom mode to zoom out (“–” in the magnifier). The zoom tool can also be activated by the Ctrl+G keystroke.</p>
<p>Grid Control</p> 	<p>Adjust the grid lines horizontal and vertical. Hold the option key for locked grids to drag to the end.</p>
<p>Event Definition</p>	<p>Inserts an event at the mouse click location. See page 223 for Event details.</p>

	<ul style="list-style-type: none"> On a plot, the horizontal location matches the 'x' coordinate of the click <ul style="list-style-type: none"> In Chart mode, the event will be placed on the channel track where the click took place. In Scope mode, the event will be defined on the active channel. Within the events bar, clicks define global events. <p>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.</p> <p>The Event Definition tool is disabled in X/Y mode and if events are not visible.</p>
<p>Event Removal "Zap"</p> 	<p>Deletes event(s) from a graph with the mouse. It allows for quick editing to eliminate misclassified events found through visual inspection.</p> <ul style="list-style-type: none"> 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. <p>When Event Removal is active, the cursor changes to a lightning bolt.</p>
<p>Jump-to</p> 	<p>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.</p> <p>Use the "Jump-to" tool to correlate data.</p> <ul style="list-style-type: none"> Click the Jump tool on a data point to "jump" all of the open data views for that graph to the same time. Click the Jump tool on a point in an X/Y plot to jump data views in chart or scope mode to the point in time corresponding to the point in the X/Y plot. This can be useful for correlating PV loops back to other acquired signals. Rate analysis output graphs will jump back to the corresponding point of source data at the start of that cycle. Clustering scatterplots will select the appropriate segment of the source graph corresponding to the chosen data point. Change the active segment in Stacked Plot mode; once a trace is selected the display will adjust to show the new active segment.
<p>Text Annotation</p> 	<p>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.</p> <p>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.</p> Bold', ' <input type="checkbox"/> Italic', and ' <input type="checkbox"/> Underline'. At the bottom are 'OK' and 'Cancel' buttons." data-bbox="208 773 476 901"/>

Text Annotation



continued



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

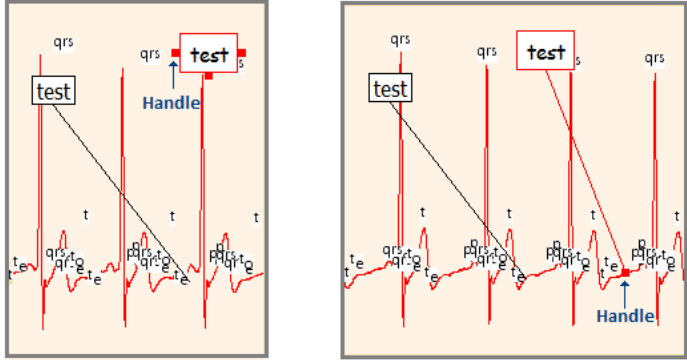
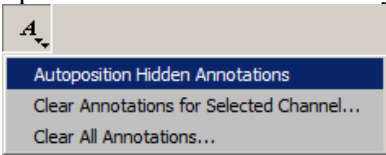
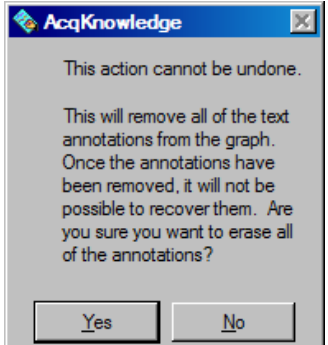
Although text annotations are tied to horizontal locations like events/markers, they are displayed in a relative fashion. The relative pixel distance between the text annotation outline boundary and the sample of data remains the same under zoom and autoscaling operations.

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

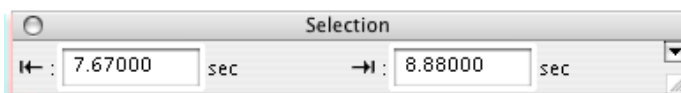
Text annotation controls

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

Select Click an annotation once to select it.

	<p>Reposition Drag a selected annotation to reposition it.</p> <p>Add Connector Connectors or range indicators can be added to selected annotations by using the editing handles on the edges of the selected annotation.</p> <p>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.</p>
	
	<p>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.</p>
	<p>Autoposition Resizing windows or adding channels may reposition text annotations outside of the visible area. Click and hold down the text annotation tool to activate the text annotation popup menu. The “Autoposition Hidden Annotations” option automatically repositions all annotations so they are visible.</p>
	
	<p>Clear all Click and hold down the text annotation tool to activate the text annotation popup menu. The “Clear annotations” option will clear annotations for a selected channel or for all annotations. This action cannot be undone so you will be prompted to confirm your selection:</p> 

Selection Palette



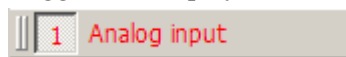
Many of the tools within the AcqKnowledge environment are based around the selection. The selected range of data in the graph is used as the source for measurements, waveform editing, transformations, and other operations. The Selection Palette is a floating dialog that can be used to precisely enter the selection. See page 436 for Selection Palette guidelines.

Start/Stop Toolbar



Channel Button Toolbar

Toggles the display of channel number and label region.



Event Toolbar



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

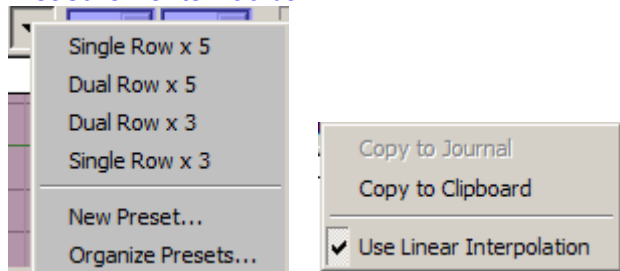
Click the event palette icon to generate the event palette.

Focus Area Toolbar



Use the Focus Area feature to isolate portions of data that are of particular interest within a graph. Focus Areas can be defined, added, labeled and deleted within any portion of the graph. For more details on creating and using Focus Areas, see page 89.

Measurements Toolbar



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

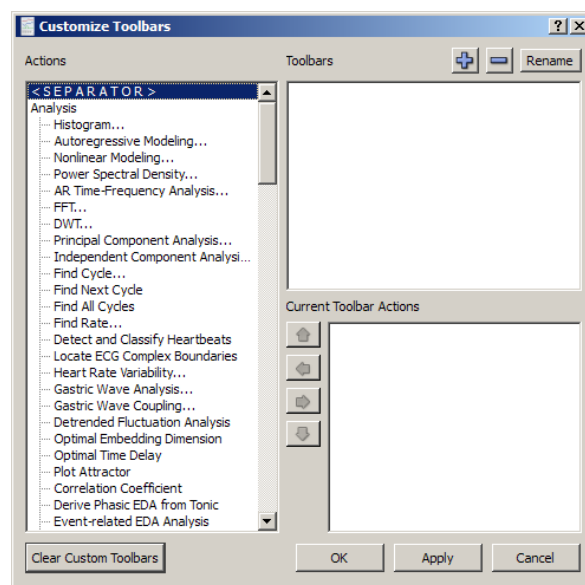
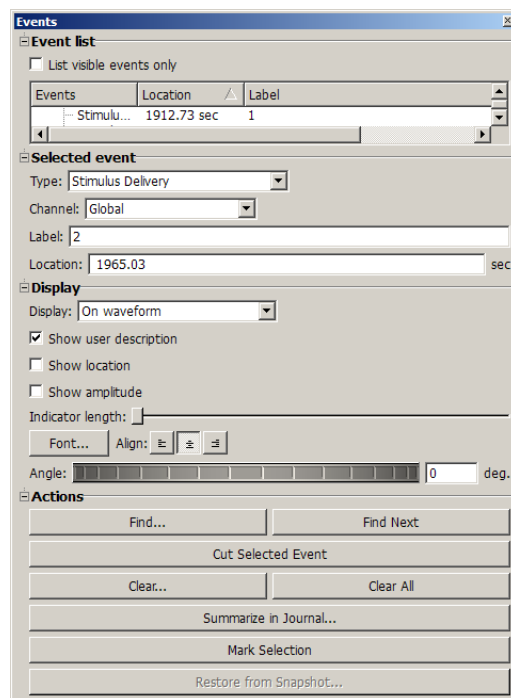
Right-click in the measurement bar for quick access to options for copying measurement and using linear interpolation.

Custom Toolbars for Transformations and Analysis

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



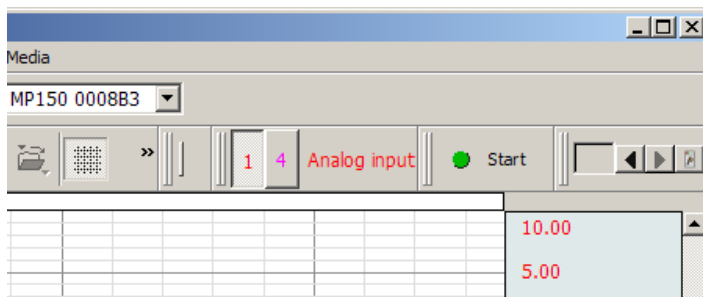
Transformation toolbars may be accessed via the "Customize Toolbars" button.



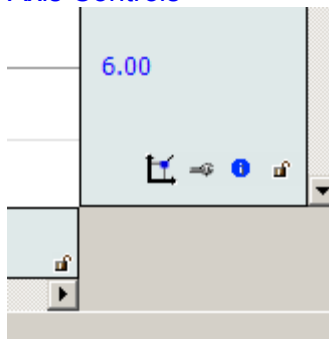
Toolbar Position Retention and Changes

Toolbars can be rearranged within the graph window or detached and turned into floating tool windows. Any modifications made by the user to the position of most toolbars within the graph window will be stored as an application preference and used for new graph windows as they are created and graph files that are opened from disk. Default

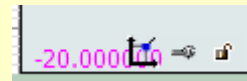
toolbar positions have changed to move the Start button and cursor tools to the top of the graph window; users preferring the ordering in previous versions may manually reposition the toolbars. **Toolbar Tooltips** may be deactivated when toolbars are detached from a graph.



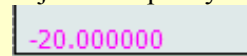
Axis Controls



If axis controls interfere with scale values,







adjust the opacity slider in Preferences > Graph



to hide the icons until the cursor passes over them



	A “scaling” button acts as a shortcut for opening the grid and visible range dialog, similar to double-clicking the axis. If a channel corresponds to an analog channel that has calibration steps, a calibration wrench button be displayed and will open the hardware calibration dialogs. This allows visual access to commonly used operations for channels.																								
	Module dependent: Generate the scaling or calibration dialogs for the channel input or calculation. Analog inputs will open to the scaling dialog and channels that require calibration will initiate a repeat calibration routine.																								
	<div><div><div>Channel Information</div><div>Line frequency: 60 Hz</div><div>Channel: A2, Phasic EDA (CH 1) Min: -1.70921 umho</div><div>Interval: 5 samples/sec Max: 1.80546 umho</div><div>Length: 3765 samples, 12.55 min Mean: 0.000340889 umho</div><div><table><thead><tr><th></th><th>Transformation</th><th>Date</th><th>Time</th></tr></thead><tbody><tr><td>1</td><td>IIR Filter</td><td>Wed, May 27, 09</td><td>11:26:54.000</td></tr><tr><td>2</td><td>Resample Graph</td><td>Fri, July 17, 09</td><td>13:13:40.000</td></tr></tbody></table><table><thead><tr><th>Parameter</th><th>Value</th></tr></thead><tbody><tr><td>Filter Type</td><td>High Pass</td></tr><tr><td>Frequency Cutoff</td><td>0.05</td></tr><tr><td>Q</td><td>0.707</td></tr><tr><td>Starting sample position to t...</td><td>1</td></tr><tr><td>Ending sample position to tr...</td><td>3907179</td></tr></tbody></table></div><div>Paste Selected Channel to Journal Paste All Channels to Journal Close</div></div></div>		Transformation	Date	Time	1	IIR Filter	Wed, May 27, 09	11:26:54.000	2	Resample Graph	Fri, July 17, 09	13:13:40.000	Parameter	Value	Filter Type	High Pass	Frequency Cutoff	0.05	Q	0.707	Starting sample position to t...	1	Ending sample position to tr...	3907179
	Transformation	Date	Time																						
1	IIR Filter	Wed, May 27, 09	11:26:54.000																						
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Parameter	Value																								
Filter Type	High Pass																								
Frequency Cutoff	0.05																								
Q	0.707																								
Starting sample position to t...	1																								
Ending sample position to tr...	3907179																								
	Use Display > Channel Info or use the channel’s contextual menu to display the Channel Information.																								
	Toggle the lock icon at the right edge of the window to change the lock state of the grid for horizontal axis or the channel. Unlocked is open (latch to right); locked is closed.																								

Enable Cursor Tools During Acquisitions

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

Button Transparency

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

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

Customizable Chart Track Dividers

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

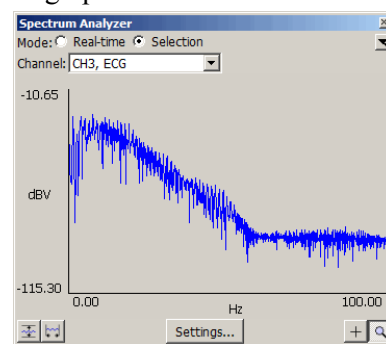
Plotting Background Colors

Starting with AcqKnowledge 4.2, customizable background colors for individual graph channels are available in Preferences > Graph > Plotting Background Colors.

Spectrum Analyzer Palette

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

See page 441 for details.



Keyboard Shortcuts

Menu Option	Windows OS	Mac OS X
Program info		
Help > About AcqKnowledge	Help > About AcqKnowledge	Help > About AcqKnowledge
Quit	Ctrl + Q	⌘ Q
Hide AcqKnowledge	minimize (corner box)	minimize (corner box)
File menu		
New	Ctrl + N	⌘ N
Open	Ctrl + O	⌘ O
Open for Playback		
SMI Begaze Import		
Close	Ctrl + W	⌘ W
Save	Ctrl + S	⌘ S
Save As		
Save Selection As		
Save Journal Text As		
Send E-Mail Attachment		
Page Setup		
Print	Ctrl + P	⌘ P
Quit	Ctrl + Q	⌘ Q
Edit menu		
Undo (when applicable)	Ctrl + Z	⌘ Z
Cut	Ctrl + X	⌘ X

Menu Option	Windows OS	Mac OS X
Copy	Ctrl + C	⌘ C
Paste	Ctrl + V	⌘ V
Clear (journal)	none	none
Clear All		
Remove Last Appended Segment	Use the Rewind toolbar icon	
Insert Waveform		
Duplicate Waveform	Ctrl + D	⌘ D
Select All	Ctrl + A	⌘ A
Remove Waveform		
Create Data Snapshot		
Merge Graphs		
Clipboard > Copy Measurements > Copy Wave Data > Copy Graph > Copy Acquisition Settings > Copy Data Modification History for All Channels > Copy Data Modification History for Selected Channels > Copy Focus Area Summary > Copy Event Summary	Ctrl + K Ctrl + L Ctrl + U	⌘ K ⌘ L ⌘ U
Journal > Paste Measurements > Paste Wave Data > Paste Graph > Paste Acquisition Settings > Paste Modification History for All Channels > Paste Modification History for Selected Channels > Paste Focus Area Summary > Paste Event Summary > Manage PDFs > Show Journal	Ctrl + M Ctrl + / Ctrl + J	⌘ M ⌘ + / ⌘ J
Transform Menu		
Recently Used		
Digital Filters		
Fourier Linear Combiners		
Math Functions		
Template Functions		
Integral		
Derivative		

Menu Option	Windows OS	Mac OS X
Integrate		
Smoothing		
Difference		
Resample Waveform		
Resample Graph		
Expression		
Delay		
Rescale		
Waveform Math		
Slew Rate Limiter		
<i>Analysis menu</i>		
Find Cycle	Ctrl + F	⌘ F
Find Next Cycle	Ctrl + E	⌘ E
Find All Cycles	Ctrl + R	⌘ R
<i>Display menu</i>		
Tile Waveforms		
Autoscale Single Waveform	Ctrl + Shift + Y	⌘ Shift Y
Autoscale Waveforms	Ctrl + Y	⌘ Y
Overlap Waveforms		
Autoscale Horizontal	Ctrl + H	⌘ H
Show All Data	Ctrl + Shift + D	Shift ⌘ D
Show Default Scales		
Zoom Back	Ctrl + - (minus key)	⌘ -
Zoom Forward	Ctrl + = (equal key)	⌘ +
Reset Chart Display		
Reset Grid		
Adjust Grid Spacing		
Set Wave Positions		
Wave Color		
Horizontal Axis		
Show > Selection Palette	Ctrl + Shift + =	⌘ + Shift + =
> Location Palette	Ctrl + Shift + L	⌘ + Shift + L
Customize Toolbars		
Channel Info		
Preferences		
Size Window		
Cursor Style > Arrow	Ctrl + B	⌘ B
> Selection	Ctrl + I	⌘ I
> Zoom	Ctrl + G	⌘ G
Create Data View		

Menu Option	Windows OS	Mac OS X
Create Focus Area		
Organize Data Snapshots		
Show All Data Snapshots		
Load All Data Into Memory		
<i>Script Menu</i>		
Script Step	Ctrl + Shift + T	⌘ + Shift + T
<i>Hardware Device Menu</i>		
Set Up Data Acquisition > <ul style="list-style-type: none"> • Channels • Length/Rate • Event Marking • Segment Labels • Stimulator • Trigger • Sound Feedback Set Up Advanced Averaging Show Input Values Show Manual Control Show Gauge MP150 Info		
Autoplotting	Ctrl + T	⌘ T
Scrolling		
Warn On Overwrite		
Organize Channel Presets		
Set Up Linked Acquisitions		
Exit All Playback Graphs	Ctrl + Exit Playback Mode	Option + Exit Playback Mode
Manage Hardware Connections		
<i>Start/Stop Acquisition</i>	Ctrl + spacebar	Ctrl + spacebar
<i>Delete recorded data</i> Deletes all recorded data segments	Ctrl + Rewind button	Option + Rewind button
<i>Window menu</i> Select Next Tab Select Previous Tab	Ctrl + Tab Ctrl + Shift + Tab	⌘ Tab ⌘ Shift + Tab
<i>Help</i> Tutorial Screenscasts from the Web Open AcqKnowledge Tutorial Application Notes from Web		

Menu Option	Windows OS	Mac OS X
Open AcqKnowledge Manual Open Hardware Guide About AcqKnowledge		
<i>Cursors</i> I-beam Arrow (pointer) Zoom Grid Event Jump to Annotation	Ctrl + I Ctrl + B Ctrl + G	⌘ I ⌘ B ⌘ G
<i>Horizontal Scroll Location</i>	In chart, scope, or stacked plot mode (i.e., all but X/Y) these keyboard shortcuts can be used to scroll to various parts of the graph.	
Home	Jumps to t = 0 (i.e., places first sample of data flush with left of graph window)	
End	Jumps to the end of the currently selected waveform (i.e., places last sample of data of the selected waveform flush with right of graph window)	
Page Up	Scrolls backward in time one full screen (i.e., places leftmost sample of previous visible area at the right of the new visible area).	
Page Down	Scrolls forward in time one full screen (i.e., places rightmost sample of previous visible area at the left of the new visible area).	

Tooltips

Tooltips is an 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. Tooltip visibility can be controlled by selecting or deselecting the “Show Menu Tooltips” checkbox in “Preferences > Other.”

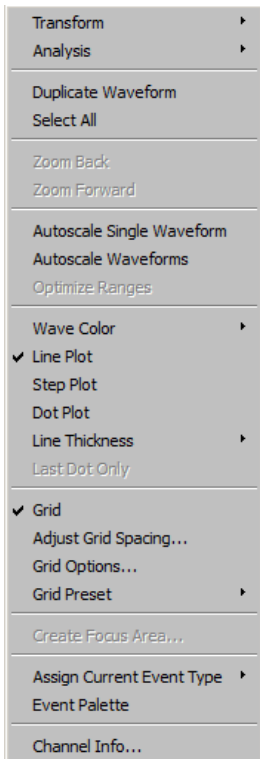
Mouse Controls

Contextual menu items correspond to the AcqKnowledge main menu state.

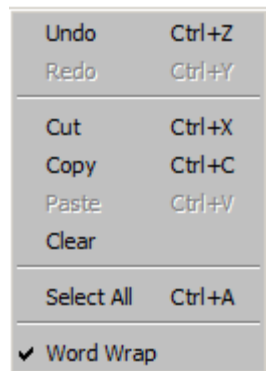
The following options can be accessed with a right-click for Windows or Control-click for Mac.

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

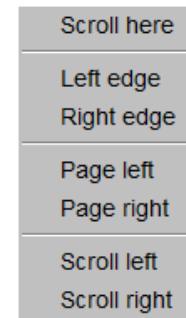
Graph window



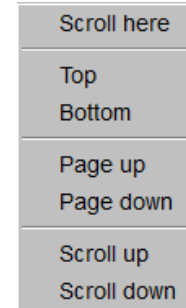
Journal window



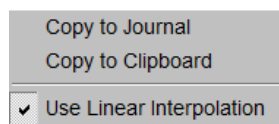
Horizontal Scroll



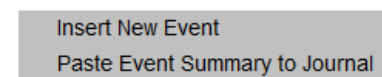
Vertical Scroll



Measurements



Events



Mouse Scrollwheel Support

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

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

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

Modification History

Modification history functionality provides the ability to track transformations that are performed on channel data. This gives a visual indicator of whether transformations have been applied to a channel and a record of the sequence of transformations and the parameters for the transformation. The history for the channel is viewed in the "Channel Info..." dialog. This dialog is accessible via the Channel Info option of the context menu or the Display > Channel Info menu item. This dialog replaces the "Statistics" dialog used in earlier versions.

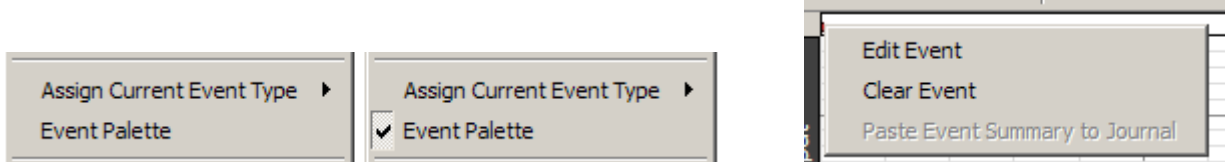
Cancelling Transformations and Transformation Progress Bar

In *AcqKnowledge* 4.1 and higher, transformation cancel support has been restored to the software to offer Cancel buttons in progress dialogs that indicate the completion status of threaded transformations.

Progress dialogs have also been enhanced so the textual message includes a graphical progress bar with the percentage that is completed. If the progress message does not contain a percentage, an indeterminate progress bar will be displayed.

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

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

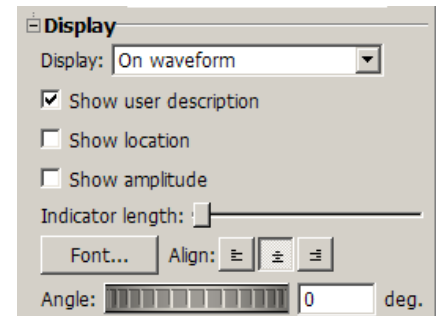


- Assign Current Event Type: Right-click an area with no data to set the type of event that will be inserted on the next left-click of the mouse.
- Event Palette: Toggles event palette displays.
- Edit event: Right-click a specific event to open the event palette to Selected Event controls for the event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

Typed Event Label Drawing Improvements

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

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



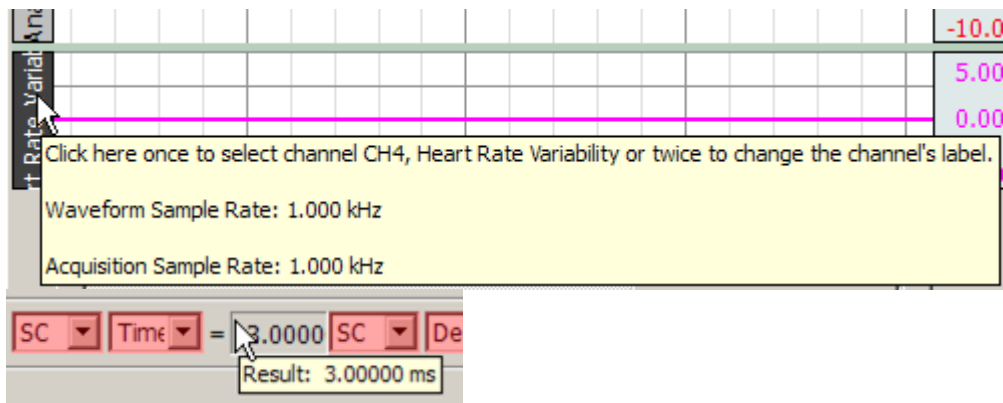
Choose MP150 Help Button

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

Tooltips

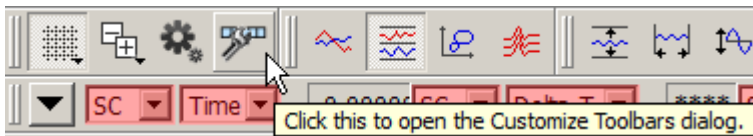
Channel Label, Units Length and Tooltips

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



Graph Window Tooltip Improvements

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



Menu Item Tooltips

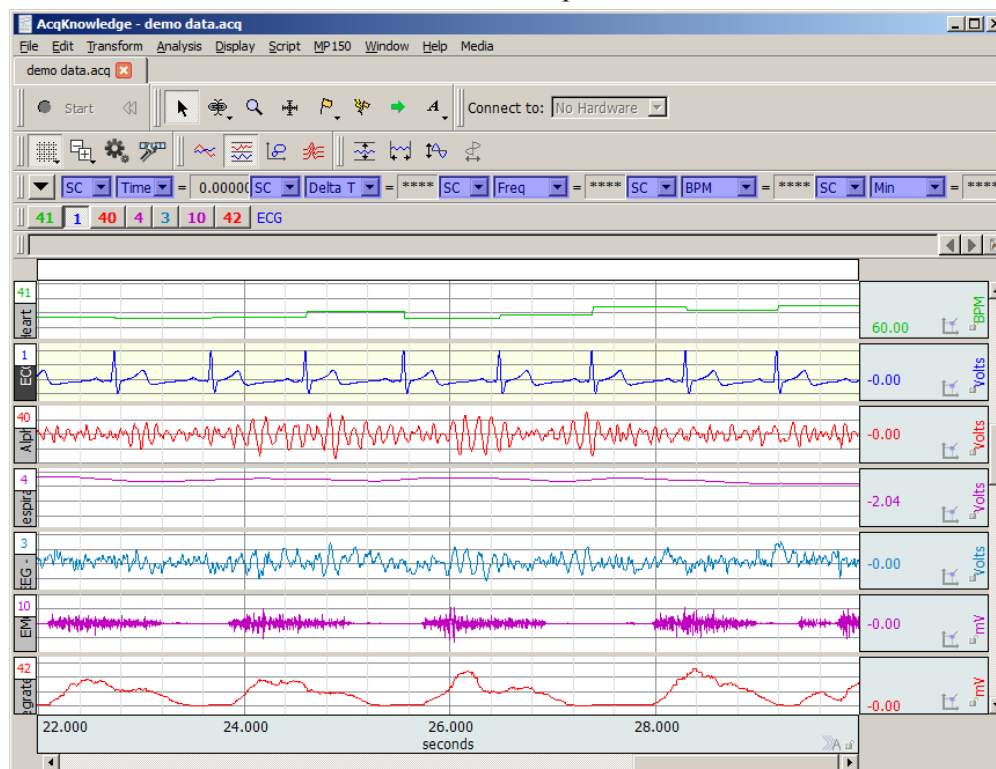
Menu item tooltips display informational text about how menu items may be used. (Similar text was displayed in earlier versions of *AcqKnowledge* for Windows in the status area and in earlier versions of *AcqKnowledge* for Mac as Balloon Help). Analysis menu tooltips have been expanded to provide more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

Chapter 4 Editing and Analysis Features

Overview

This section provides a brief overview of some of the most frequently used *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 the *AcqKnowledge* icon to start it. Choose Open from the File menu and select the file called “demo data.acq.” Your screen should look like this:



Edit menu functionality during acquisition

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

Scroll bars

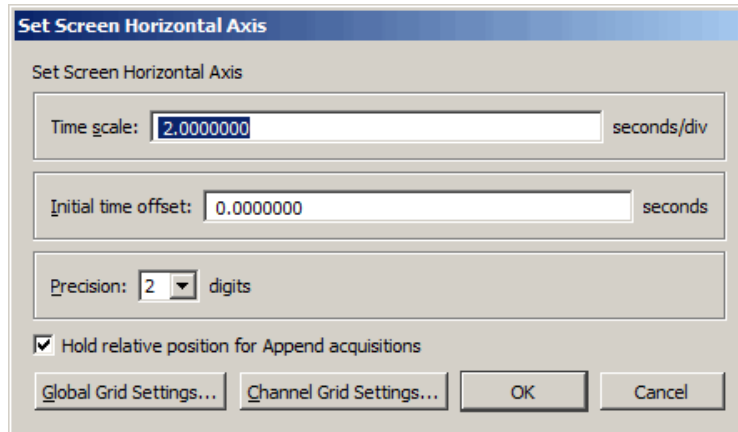
As you can see, there are four channels of data in this file (Heart Rate, ECG, EEG, Resp, EMG Raw, EMG, Integrated EMG). Although this record is 30 seconds long, only a few seconds are displayed on the screen at one time. You can move to different locations in the record by moving the scroll box at the 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 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 the arrows.

Scaling

Horizontal axis

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



Time Scale

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

Initial offset

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

Precision

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

Hold Relative Position for Append acquisitions

This option is available in AcqKnowledge 4.2 and higher, and active only in **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. If the acquisition is started with the horizontal scale such that it falls between acquisition segments, this feature is not implemented.

When **Hold relative position** is checked; after zooming 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.

Global Grid Settings

Opens dialog for applying master grid settings for all channels. For more details, see Grids on page 78.

Channel Grid Settings

Opens dialog for selectively applying grid settings to one or more channels. For more details, see Grids on page 78.

Vertical (Amplitude) axis

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

Scale

Determines the limits of the viewable vertical axis scale (usually Volts). *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. If you want to apply these to all channels, click all the checkboxes.

Precision

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

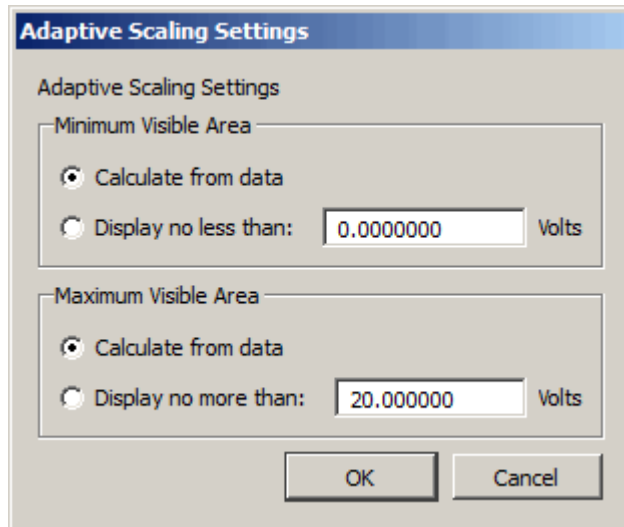
Apply to all channels

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

Adaptive Scaling

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

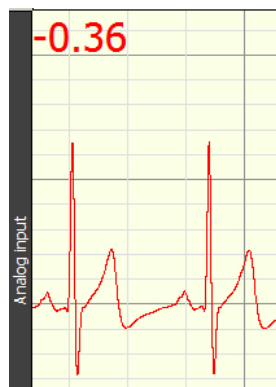
Adaptive scaling can be applied to channels individually and can be unique for each Data View. A “settings” button is activated when to “Use adaptive scaling” is enabled.



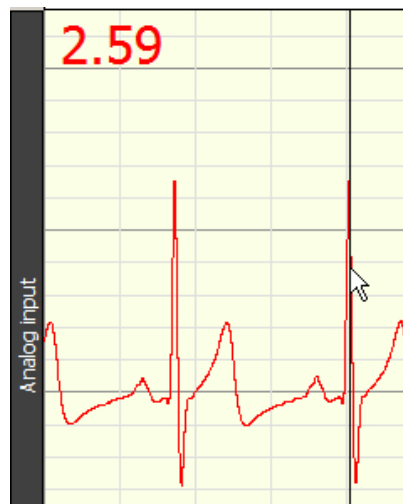
Scaling changes will be applied whenever the domain of the plot area is changed. This includes manual changes to the horizontal scale, horizontal scrollbar use, horizontal auto-scrolling when dragging out a selected area, auto-scrolling or auto-plotting during acquisition, initial enabling of adaptive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

Show Textual Value Display

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



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



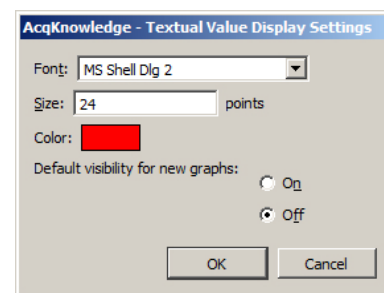
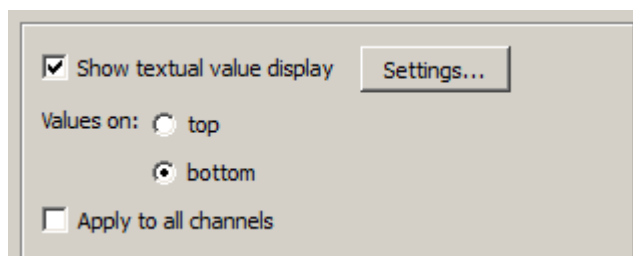
Textual value display in spot measurement mode

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

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

To enable textual value display:

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

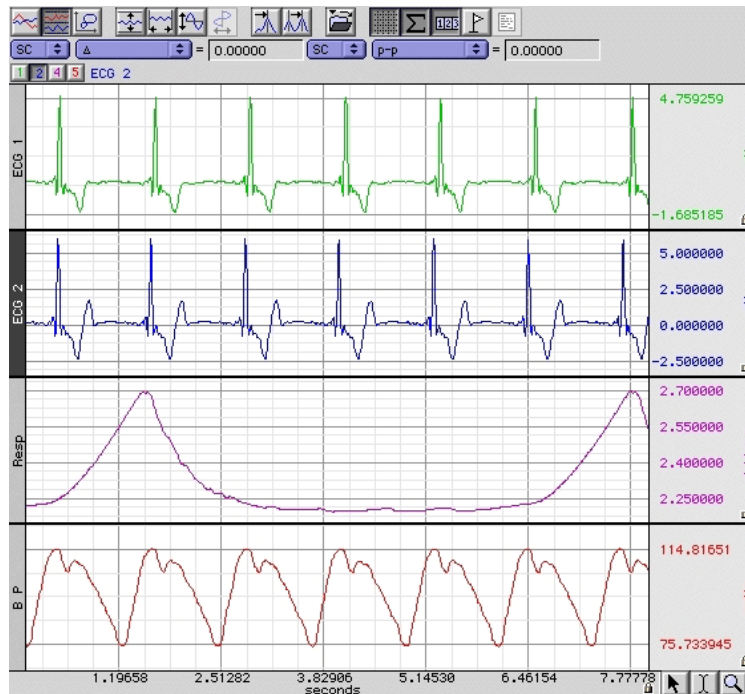


Channel Grid Settings

Opens dialog for selectively applying grid settings to one or more channels. For more information, see Grid Details on page 78.



Grid Details

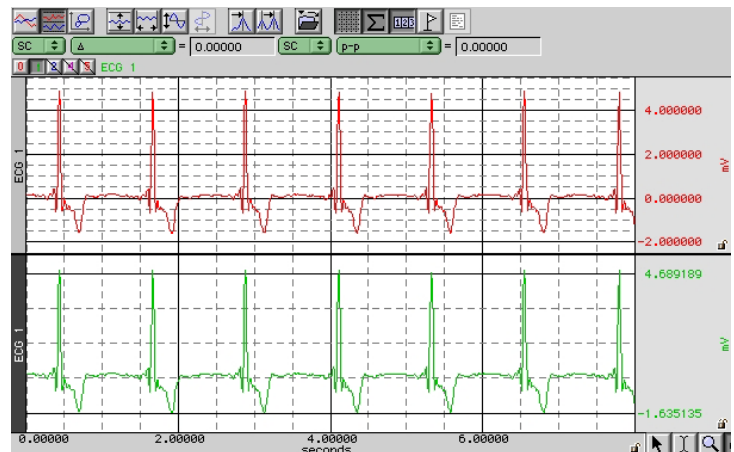
You can customize the grid behind the waveforms displayed in graph windows in a number of ways.



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.

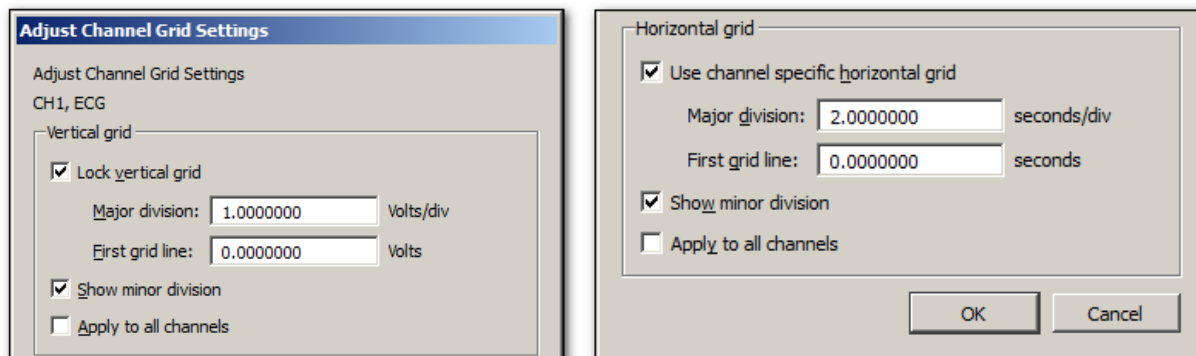
☒ Lock units/div

NOTE: All grid screenshots are from AcqKnowledge 4.2.

Grid Scaling

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

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



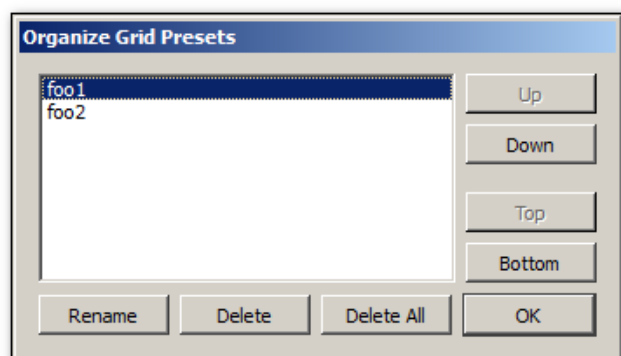
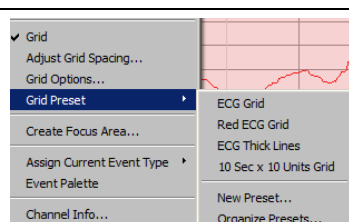
- Vertical grid: the total range of vertical units displayed per track is specified (Major division) along with the first value that should be displayed (First grid line).
- Horizontal grid: the scaling factors are specified in how many seconds of data should be visible on the screen (Major division)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

Adjust Grid Spacing

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

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

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

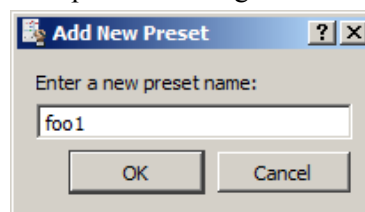


Grid: Toggles Grid display on and off.

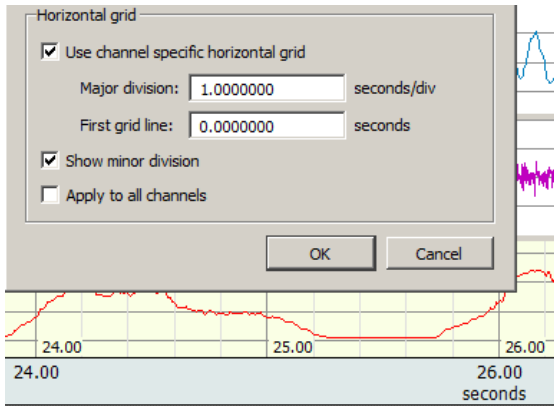
Adjust grid spacing: Use to change Grid spacing for one or all channels (divisions between gridlines and position).

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

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

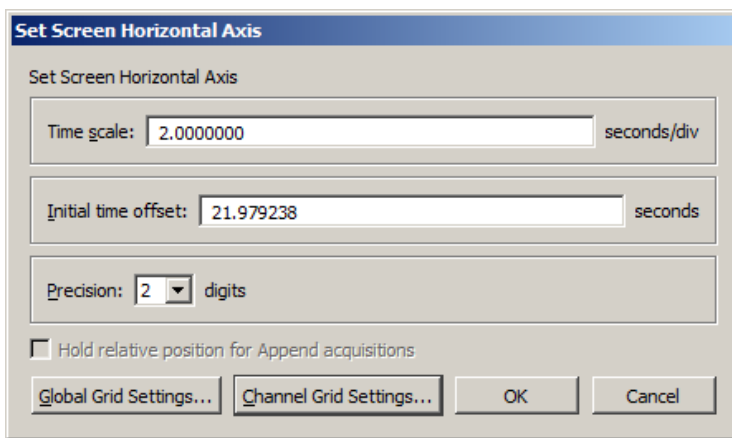


Example of channel specific horizontal grid



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

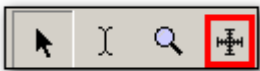
Horizontal Axis Grid Controls







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

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

Grid Tool



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

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

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



- Based on lock status, the dialog will allow 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.

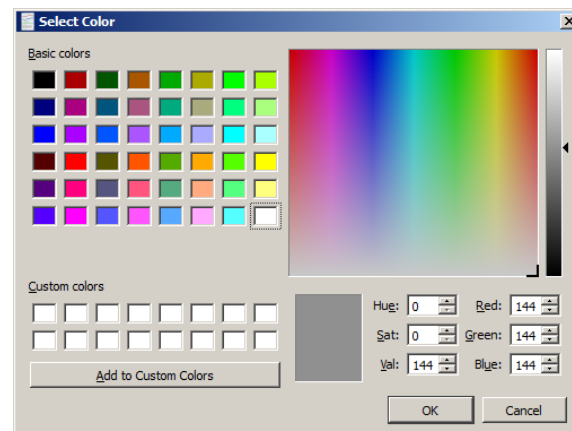
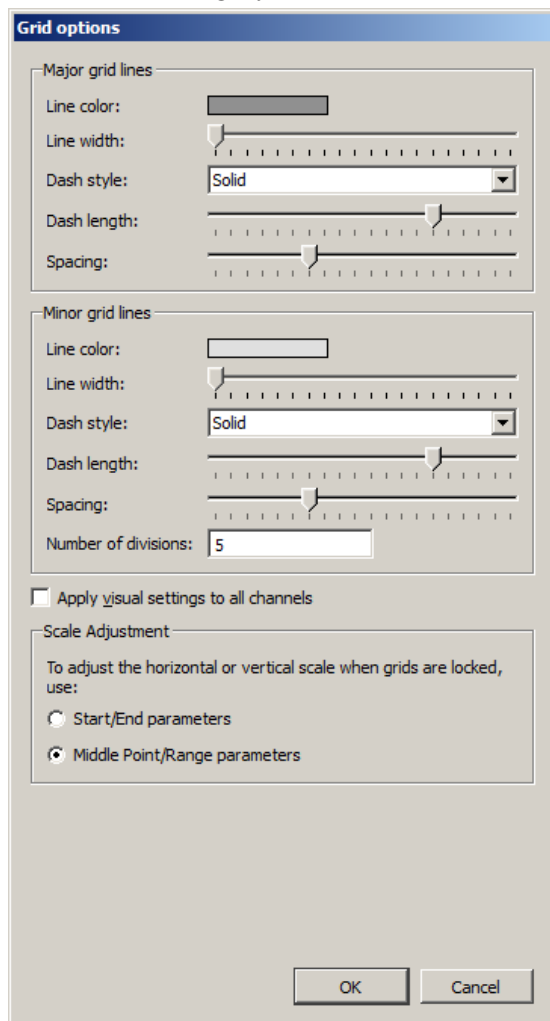
Grid Reset

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 spacing, number of divisions, and different colors and dashing styles. These are modified under the dialog generated via Display > Show > Grid options.



Line color	Click the color well to generate a color chooser.
Line width	Adjust the corresponding slider.
Dash style	Select a style (solid or broken) from the pop-up menu.
Dash length	Adjust the corresponding slider (for any dash mode that is not a solid line).
Spacing	Adjust the corresponding slider (for any dash mode that is not a solid line).
# of Divisions	Enter a value in the text field to set the maximum number of minor grid lines to be displayed in a single major grid division.
Apply visual settings to all channels	When checked, the visual settings for major and minor grid lines are applied to all channels. When unchecked, the settings will be applied to the selected channel only.

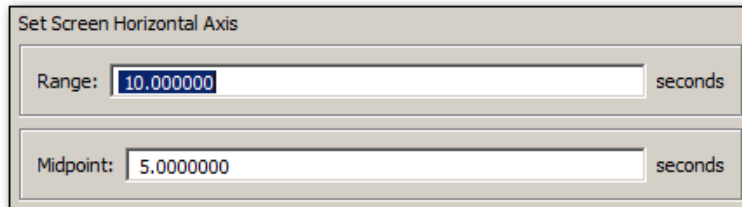
Scale Adjustment

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



The screenshot shows a dialog box titled "Set Screen Horizontal Axis". It contains two input fields. The first field is labeled "Start:" and has the value "0.000000" entered, with a "seconds" unit label to its right. The second field is labeled "End:" and has the value "10.000000" entered, also with a "seconds" unit label to its right.

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



The screenshot shows a dialog box titled "Set Screen Horizontal Axis". It contains two input fields. The first field is labeled "Range:" and has the value "10.000000" entered, with a "seconds" unit label to its right. The second field is labeled "Midpoint:" and has the value "5.000000" entered, also with a "seconds" unit label to its right.

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

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.

Friendly Grid Scaling

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

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

Displayed in the application: 0.00000 7.50000 15.00000 22.50000

Printed: 0.00000 7.50125 15.00250 22.50375

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

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

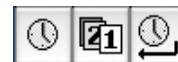
 Watch the [AcqKnowledge Grids video tutorial](#) for a detailed demonstration of this feature.

Journal Details

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

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

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



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

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

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

Set the Journal Preferences (page 451) to simultaneously record measurement name and units or control Event (marker) paste functionality and detail.

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

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

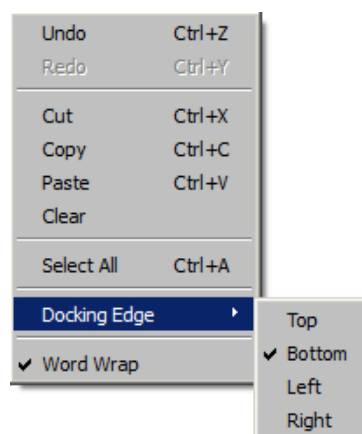
A useful feature of the Journal is that it works in connection with the Cycle/Peak Detector and other measurement functions to paste in values from waveform data for further analysis.

In the example above, the *peak-to-peak* and *delta t* measurements were pasted from the open graph window to the Journal. See the Journal paste section on page 279 for more information on how to paste information to Journal files.

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

Journal Contextual Menu

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



Rich Journals

The AcqKnowledge 4.2 Journal adds powerful rich text editing tools, offering advanced functionality common to most word processing programs. The following toolbar options are available within the Journal window:

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

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

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












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

Journal Toolbar Buttons

The Journal toolbar controls all formatting functions within the Journal window. Although the settings customized in this toolbar are retained within a saved Journal, global default settings for subsequent Journals are not overridden. To change the global defaults, the overall Journal Preference settings must be modified. (Edit > Journal > Preferences). For more information, see Journal Preferences on page 451.



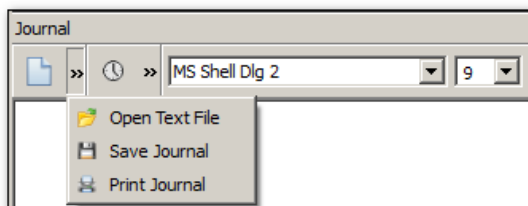
Journal Toolbar Icon	Function	Explanation
	Clear	Clears text from Journal window
	Replace	Replaces Journal text with contents of external text file
	Save	Saves selected or full Journal text to an external text file
	Page Setup	Opens dialog for modifying Journal text print configuration
	Print	Prints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

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

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

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

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

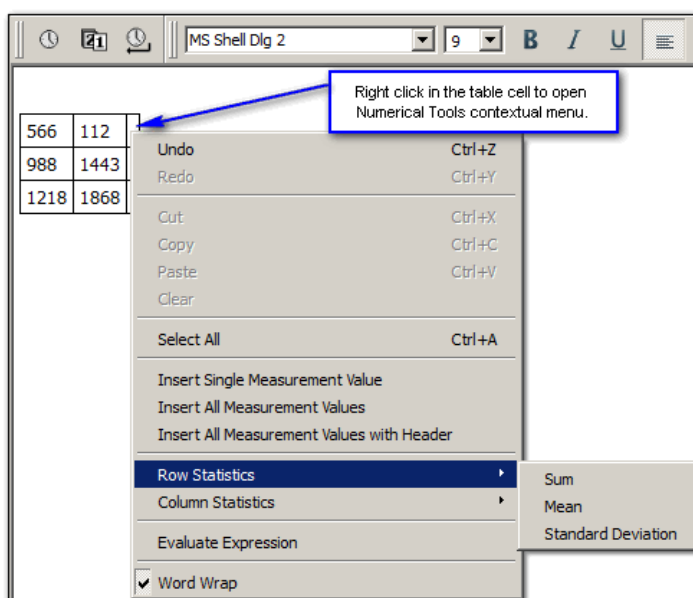


Journal Numerical Table Tools

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

Numerical Tools operations permitted within a Journal table:

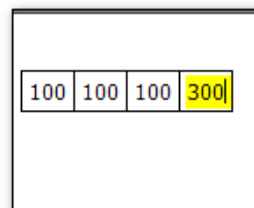
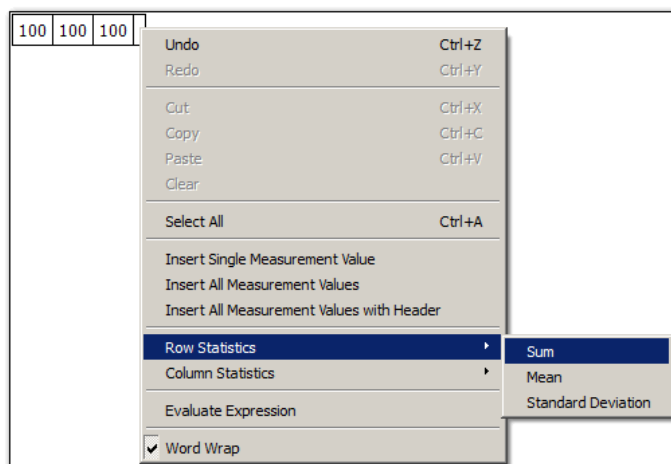
- Insert a single measurement value
- Insert all measurement values
- Insert all measurement values with header row
- Sum, Mean and Standard Deviation statistics for table rows and columns
- Expression evaluation



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

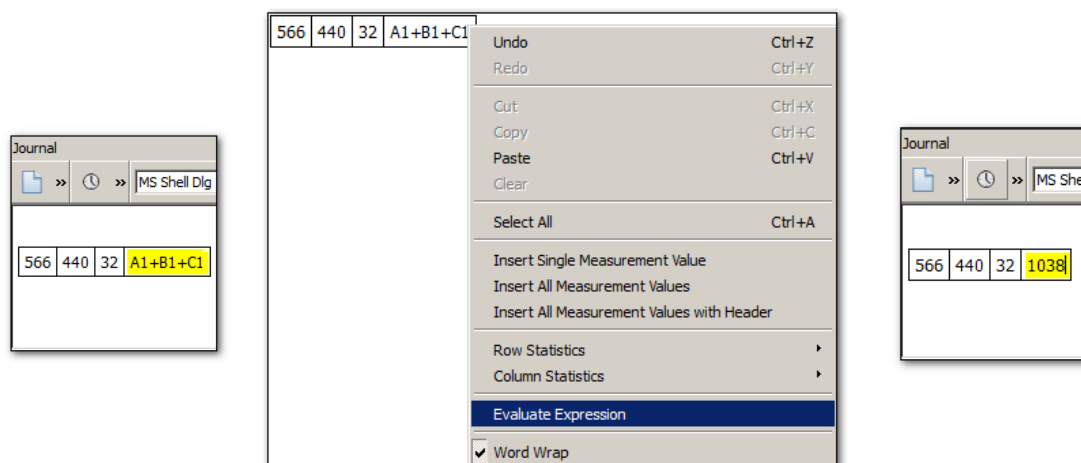
Example of Sum, Mean or Standard

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

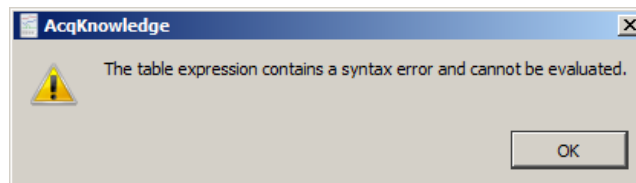


Example of Evaluate Expression

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




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



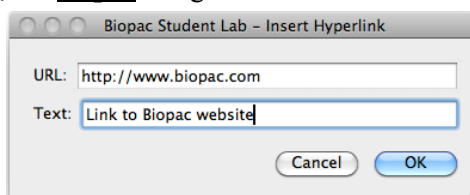
TIP: To correct a mistake, use the Ctrl+Z (PC) or Command+Z (Mac) keystroke to restore the previous cell data. Multiple levels of undo are supported.

Adding a hyperlink to the Journal

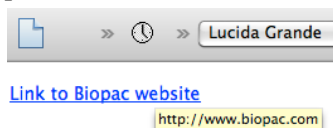
Use the Journal hyperlink  toolbar button to insert a link to a web address into the Journal. This operation is very similar to adding regular text.

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

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



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



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

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

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

Embedding PDFs in Journals

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

TIP: You may also embed PDFs while in the Journal by right-clicking in the Journal window and choosing “Manage PDFs” from the contextual menu.



For more details on managing embedded PDFs, see page 281.

 Watch the [AcqKnowledge Journal video tutorial](#) for a detailed demonstration of this feature.

Select a waveform / channel

Although multiple waveforms can be displayed, only one waveform at a time is considered “active.” Most software functions only apply to the active waveform, which is also referred to as the “selected” channel. Selecting a channel allows 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 buttons that represent each channel of data. The numbers in the buttons correspond to the channel used to acquire the data (the specifics of setting up channels are discussed on page 34). In the sample file, ECG channels are represented by channels 1, with respiration on channel 2.

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

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

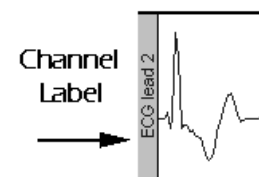
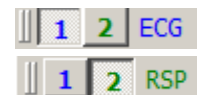
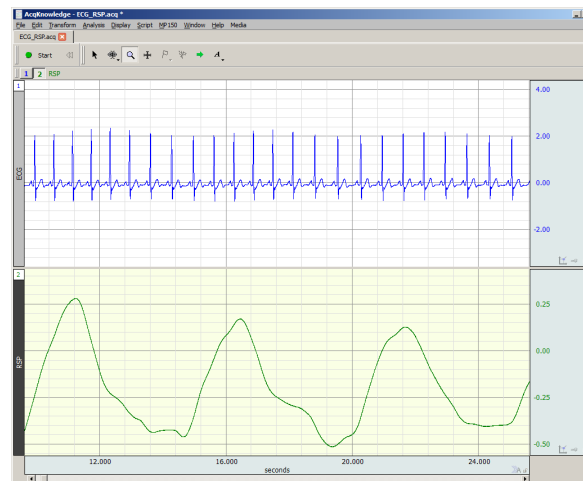
Additionally, the channel label in the display (on the left edge of the track) will be highlighted for the active channel.

Channel Labels

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

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

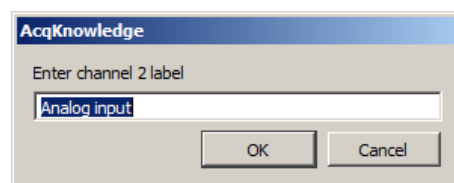
The right label is used to denote the units for each channel’s amplitude scale (usually scaled in terms of Volts).



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

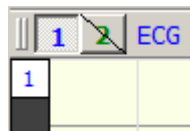
To change the label for a given channel

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



AcqKnowledge 4 Channel label


Show/Hide Channel



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

Windows: Alt+click in channel box.

Mac OS X: Option+click in channel box.

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

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

Alternatively, you can show/hide a channel via Display > Channel Visibility and check/uncheck the channel boxes in the Channel Visibility dialog. (See this Display menu option on page 433.)

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


Focus Areas

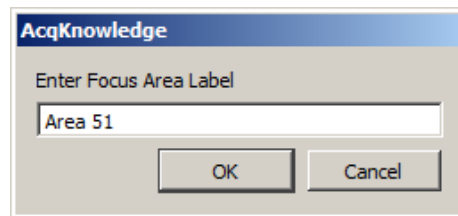
Focus areas are comprised of selected time ranges within the graph. The purpose of the “Focus on” tool is to easily isolate selected areas within the graph window for discrete analysis. This can be useful for identifying areas of interest within a larger data set by highlighting, naming and storing them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

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

Creating Focus Areas

To create a focus area:

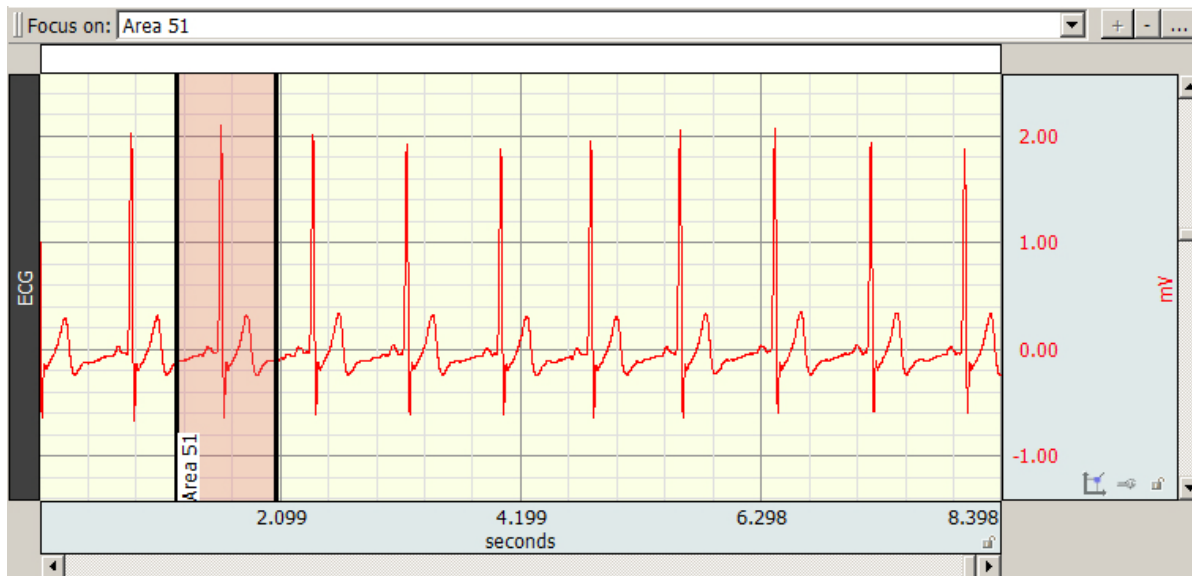
1. Select an area of interest in the graph data using the I-beam tool or selection palette.
2. Create the focus area using one of the following methods:
 - Click on the “add”  button to the right of the “Focus on” toolbar.
 - Choose “Display > Create Focus Area.”
 - Right-clicking in the graph and choosing “Create Focus Area” from the contextual menu.
3. Name the focus area by typing into the label field.




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




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





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


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



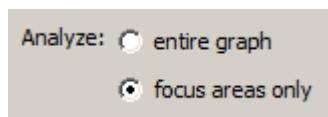
To remove a focus area, use the “minus” “Focus on” toolbar button. 

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

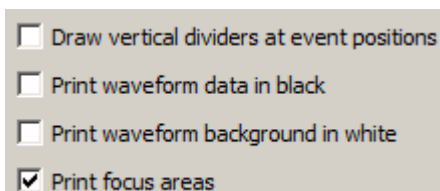
To rename a focus area, use the “ellipses” toolbar button. 

To highlight the current focus area, click the “highlight” button. 

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



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



Focus area preferences can be modified by using Display > Preferences > Focus Areas. For further details see pages 448 and 453.

For Find Cycle focus area options, see the Find Cycle section on page 325.

To create focus areas in analysis mode based on events or appended segments, see the Specialized Analysis > Focus Areas section on page 376.

Watch the [AcqKnowledge Focus Area video tutorial](#) for a detailed demonstration of this feature.

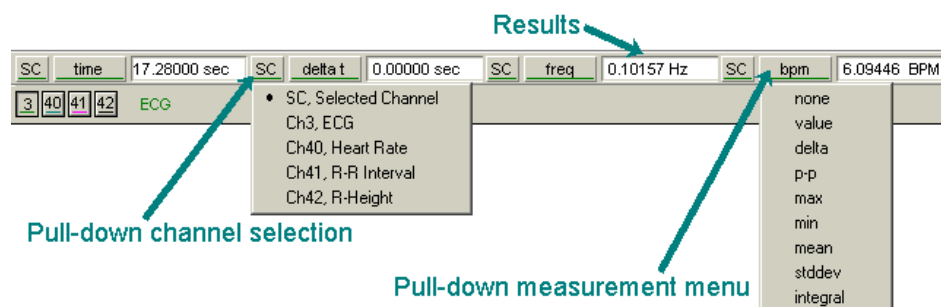
Measurements

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.

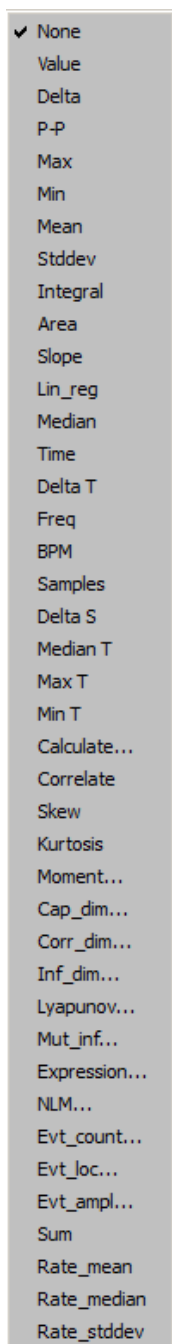
To select a measurement, position the cursor on a measurement box and click the mouse button. Choose a measurement from the pull-down menu; see page 95 for measurement functions and the minimum samples for each (some of the values are single point measurements while others require at least two points to be selected).

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



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

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



Measurement Display

Number of measurement rows:

Digits of precision:

☒ Use linear interpolation

Time units:

Freq units:

Best Match for Value	
Hours	
Minutes	
Seconds	
Milliseconds	
Microseconds	
	Best Match for Value
	Millihertz
	Hertz
	Kilohertz

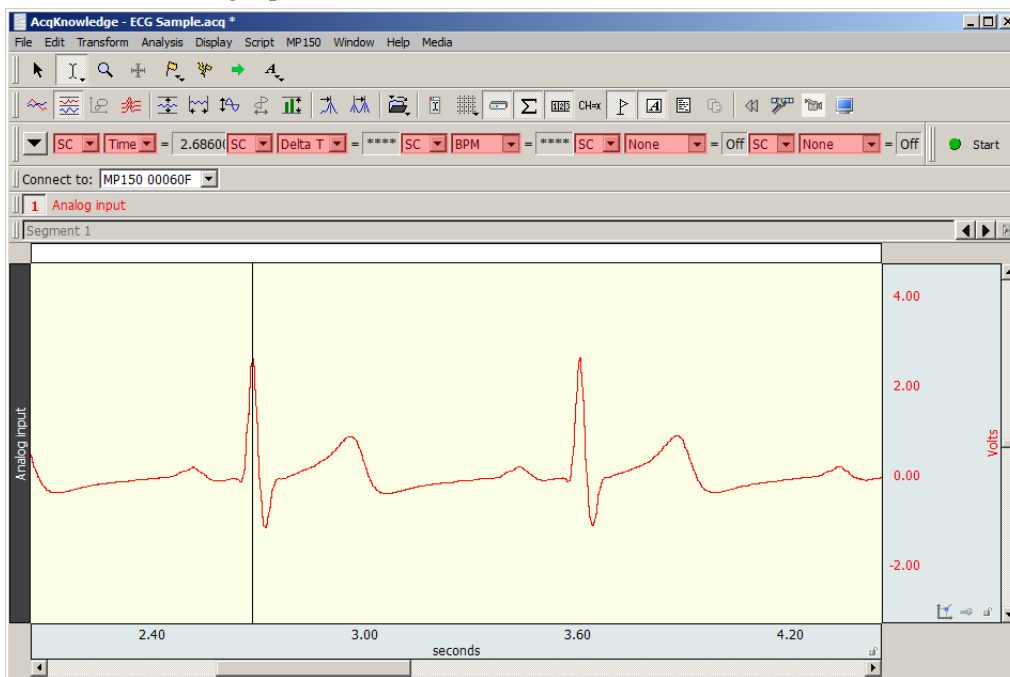
The number of measurement rows is set in Preferences > Measurements, as well as precision of units.

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.

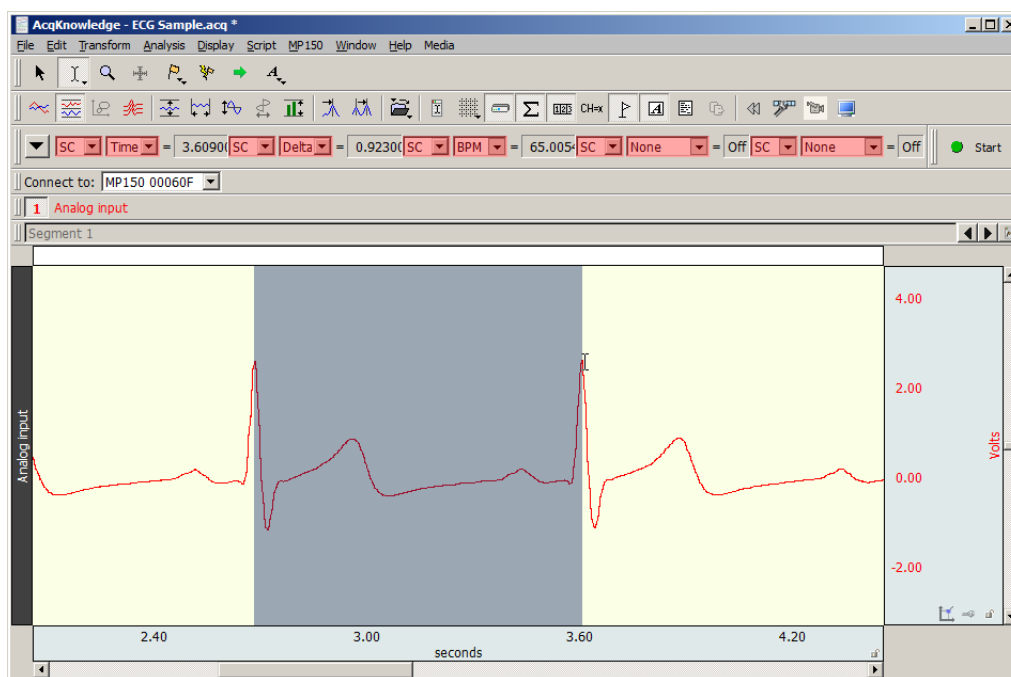
- Single-point measurements

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



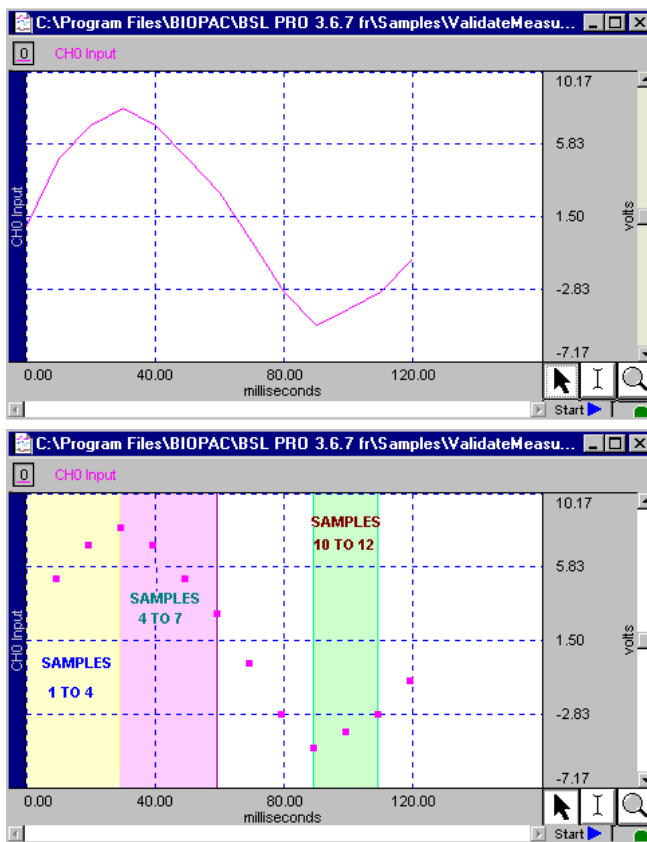
- Selected range measurements

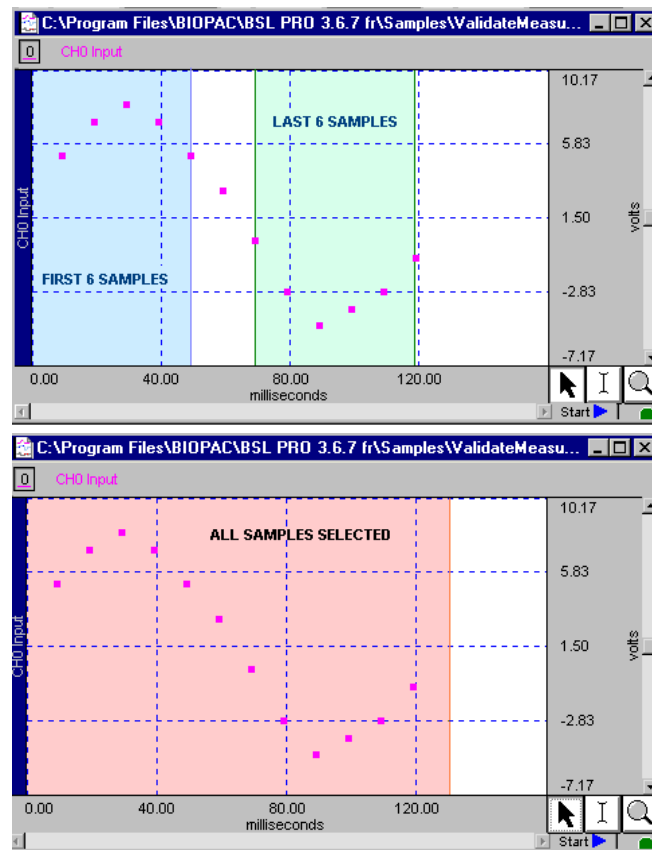
Drag the I-beam cursor to select an area; the selected area will be highlighted.



IMPORTANT!

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





Measurements and Measurement Presets

Measurements are commonly used in conjunction with the cycle detector and other analysis protocols to perform data reduction. In complex data analysis using the cycle detector, often multiple different sets of measurements may be used to perform multiple extraction passes on the data. The measurement presets feature allows users to create multiple predefined measurement configurations and apply them to the graph to change between different configurations. All aspects of the measurement configuration are stored, including measurement functions, any parameters for the measurement, source channel, and number of measurement rows. For more details on this function, see Measurements Toolbar section on page 63.

Measurement Validation

You can validate measurements with the ValidateMeasurements.acq sample file included with the software. Pay attention to the “Sample data file” section of the measurement definitions that begin on page 95, and where included, note which sample points to use for validation (i.e., the first four sample points are used to validate the Correlate measurement using the ValidateMeasurements.acq file).

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

Measurement Info / Parameters



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

Measurement Interpolation

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

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

Exporting measurements

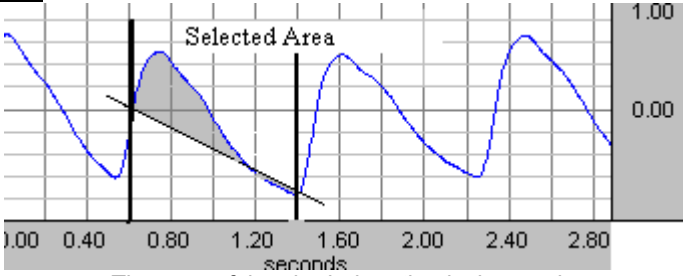
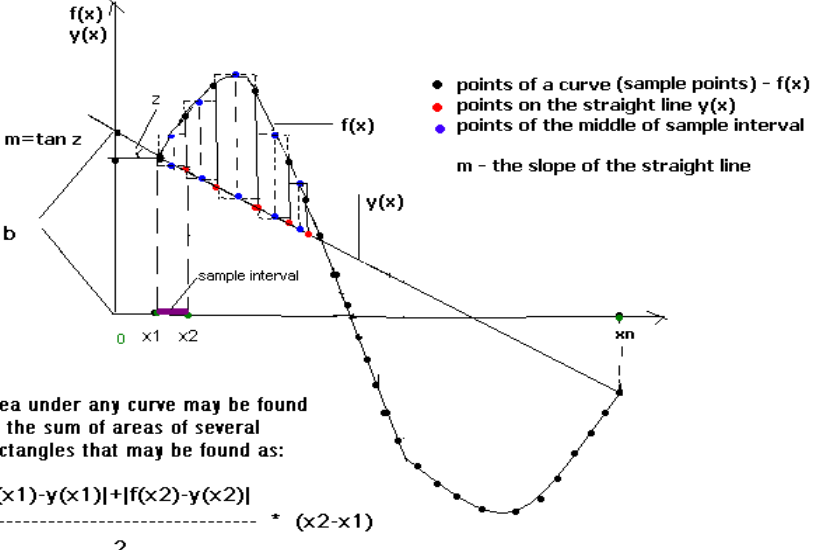
One of the most important reasons to take measurements is to save them; *AcqKnowledge* allows you to store and export these measurements in different formats.


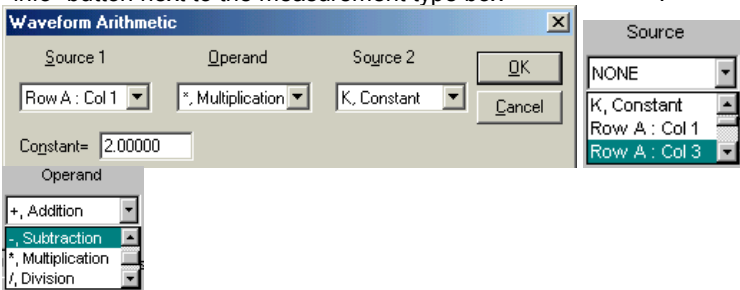
- **Copying measurements to the journal:**
To copy measurements (exactly as they appear in the measurement windows) and paste them to the Journal, select Edit > Journal > Paste measurement. Under the default settings, only the values themselves are copied to the journal; you can change the settings to 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 > Journal.

Measurement Definitions

The table below explains the measurement options available and the range required for each. The default option is for time to be displayed on the horizontal axis, although it can be set to display frequency or arbitrary units (see page 434 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.

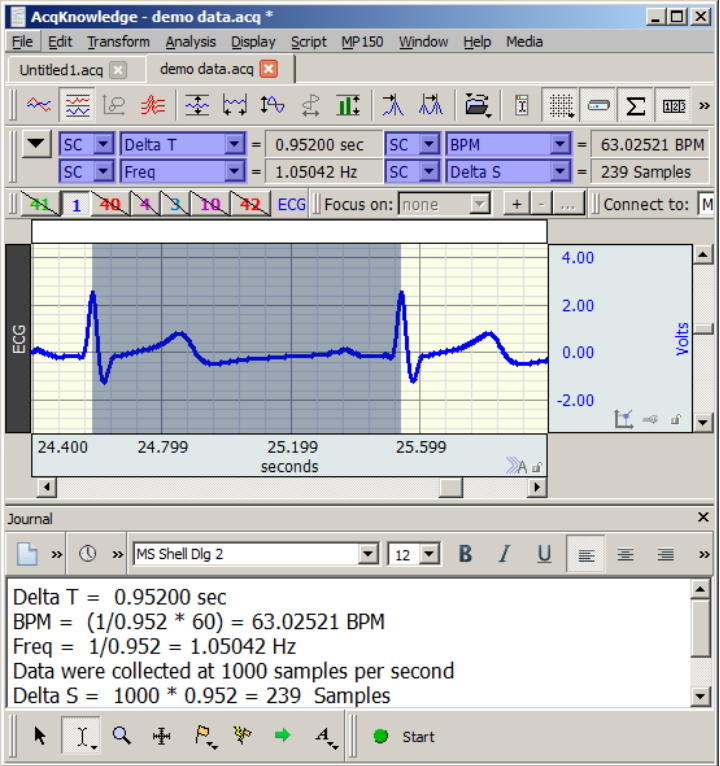
Measurement	Area	Explanation
Area	<p><u>Minimum area:</u> 3 samples</p> <p><u>Uses:</u> All points of selected area</p>	<p>Area computes the total area among the waveform and the straight line that is drawn between the endpoints. Area is expressed in terms of (amplitude units multiplied by horizontal 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>.</p>

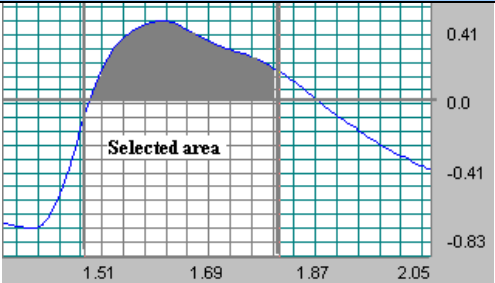
Measurement	Area	Explanation
		<p> $\Delta x_i = \frac{\Delta X}{n-1}$ - horizontal sample interval; The value of a straight line can be found by formula: $y(x_i) = m * x_i + b$ $b = f(x_1) - m * x_1$ - intercept; $m = \frac{\Delta Y}{\Delta X}$ - slope of the straight line; $\Delta Y = f(x_n) - f(x_1)$ - 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>
		 <p> • points of a curve (sample points) - $f(x)$ • points on the straight line $y(x)$ • points of the middle of sample interval m - the slope of the straight line </p> <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><u>Results:</u> This calculation will always return a positive result.</p> <p><u>Units:</u> Volts - sec.</p> <p><u>Sample data file:</u> "ValidateMeasurements.ACQ" Result: 0.4533 Volts - sec.</p>
BPM (Time domain only)	<u>Minimum area:</u> 2 samples <u>Uses:</u>	<p>BPM (beats per minute) computes the time difference between the first and last points and extrapolates BPM by computing the reciprocal of this difference, getting the absolute value of it and multiplying by 60 (60 sec). The formula for calculation of BPM is:</p>

Measurement	Area	Explanation
	Endpoints of selected area	$BPM = \left(\frac{1}{ x_n - x_1 } \right) * 60$ <p><u>Where:</u> x_1, x_n - values of the horizontal axis at the endpoints of selected area.</p> <p><u>Note:</u> As mentioned, this measurement provides essentially the same information as the <i>Delta T</i> and <i>Freq</i> measurement.</p> <p><u>Results:</u> Only a positive value.</p> <p><u>Units:</u> BPM.</p>
Calculate	<p><u>Minimum area:</u> 2 sources</p> <p><u>Uses:</u> 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></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 Ctrl-Click or right mouse click the Calculate measurement type box or click the “info” button next to the measurement type box </p> <p>Use the pull-down menus to select Sources and Operand.</p> <p>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>Calculation measurement Source operands are updated before a Calculation is performed, which means that Calculations can be based on measurements that are located after them in the measurement row/column ordering.</p> <p>Calculation measurements can include other Calculation measurements as their operands.</p> <ul style="list-style-type: none"> • If a cyclic dependency is introduced, the result reads “Error.” • When interpolation is being used, a Calculation measurement can also be an interpolated value. • If either of the operands of a Calculation is interpolated, the result will be displayed as an interpolated value (with a light purple background). <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		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.)
Corr_Dim		Correlation Dimension; fractal dimension estimate. Always greater than capacity if parameters are the same. (See fractals note at Cap_Dim.)
Correlate	<p><u>Minimum area:</u> 2 samples</p> <p><u>Uses:</u> All points of</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).</p> <p>You can use Correlate to determine whether two ranges of data move together.</p>

Measurement	Area	Explanation								
	selected area	<div><div><u>Association</u> Large values with large values Small values with large values Unrelated</div><div><u>Correlation</u> Positive correlation Negative correlation Correlation near zero</div></div> <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> <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> <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>								
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> <i>f(x₁)</i>, <i>f(x_n)</i>—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><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> <i>x₁</i>, <i>x_n</i> - values of horizontal axis at the endpoints of selected area.</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
		<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. 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 74 for details on how to change the horizontal scaling).</p> <p><u>Units:</u> Delta T: <i>Seconds (sec.)</i> Delta X: <i>"arbitrary unit"</i> Delta F: <i>Hz</i></p> <p><u>Sample data file:</u> <i>"ValidateMeasurements.ACQ"</i> Result: <i>0.12 sec. (for whole wave).</i></p>
Evt_amp		<p>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 228 for details.</p> <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. <p>Evt_amp can be useful for extracting information such as the average T wave height within the selected interval.</p>
Evt_count		Evaluates the number of events within the selected area. The measurement result is unitless. Specify Type and Location; see page 229 for details.
Evt_loc		Extracts information about the times of events. The measurement result uses the units of the horizontal axis. Specify Type, Location, and Extract; see page 229 for details.
Expression		<p>Generates the Expression transformation dialog (page 141) 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.</p> <p>Evaluation rules: When a new selection is made, the first step in evaluation searches through the measurement expression for any MMT() invocations. Any measurement whose value is needed by MMT () is computed at this time prior to the expression evaluation. This behavior is similar to calculation channels and successfully allows measurements to the right and bottom of the expression measurement to be used in the expression. The expression is subsequently evaluated from the leftmost sample in the selection to the right most sample. It is evaluated at the waveform sampling rate of its source channel. Interpolation is not used at the boundaries to maintain a consistent sample interval for the expression. After each expression evaluation, the result is cached in memory for potential negative MC result references. The rightmost value of the final expression becomes the value of the measurement.</p>
<p>Freq (time domain only)</p> <p>It is important to note... This does not compute the frequency spectra of the data. To perform a spectral analysis, use the FFT function (see page 318).</p>	<p><u>Minimum area:</u> 2 samples</p> <p><u>Uses:</u> Endpoints of selected area</p>	<p>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:</p> $\text{Freq} = \left(\frac{1}{ x_n - x_1 } \right)$ <p><u>Where:</u> x_1, x_n - values of horizontal axis at the endpoints of selected area.</p> <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>

Measurement	Area	Explanation
		 <p><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 318).</p> <p><u>Freq (or frequency)</u> is only available in time domain windows.</p> <p><u>Results:</u> This calculation will always return a positive result.</p> <p><u>Units:</u> Hz</p> <p><u>Sample data file:</u> "ValidateMeasurements.ACQ"</p> <p><u>Result:</u> 8.33 Hz (for whole wave).</p>
Inf_Dim		Information Dimension; fractal dimension estimate. (See fractals note at Cap_Dim.)
Integral	<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. 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); x_i, x_{i+1} - values of two neighboring points at horizontal axis (x_1— the first point, x_n — the last point); $f(x_i), f(x_{i+1})$ - values of two neighboring points of a curve (vertical axis); $\Delta x_i = \frac{\Delta X}{n-1}$ - horizontal sample interval; $\Delta X = x_n - x_1$ - horizontal distance of increase at horizontal axis.</p> <p>The following plot graphically represents the Integral calculation.</p>

Measurement	Area	Explanation
		 <p>The area of the shaded portion is the result.</p> <p>Results: The Integral calculation can return a negative value if the selected area of the waveform extends below zero.</p> <p>Units: Volts—sec.</p> <p>Sample data file: "ValidateMeasurements.ACQ" Result: 0.300 Volts -sec.(for first 6 sample points) and – 0.155 Volts -sec.(for last 6 sample points—the wave below zero).</p>
Kurtosis		<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> $kurtosis = \frac{\frac{\sum_{i=1}^n (x_i - \bar{x})^4}{n}}{\left(\frac{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n}}{n} \right)^2}$ <p>Where from a signal (x) containing n points:</p>
Lin_reg	<p>Minimum area: 2 samples</p> <p>Uses: 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 315. <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> $Lin_reg = \frac{n * \sum_{i=1}^n (x_i * f(x_i)) - \left(\sum_{i=1}^n x_i \right) * \left(\sum_{i=1}^n f(x_i) \right)}{n * \sum_{i=1}^n (x_i)^2 - \left(\sum_{i=1}^n x_i \right)^2}$ <p>Where: <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> <p>Note: For a single point, Lin_reg computes the linear regression of the line drawn between the two samples on either side of the cursor.</p> <p>Results: If the data value at the starting location is greater than the data value at the ending location of the cursor, then a negative delta will result. Otherwise, a positive delta will result.</p> <p>Units: Volts/sec.</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. 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</p>

Measurement	Area	Explanation
		or arbitrary units, respectively). <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).
Lyapunov		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.
Max	<u>Minimum area:</u> 2 samples <u>Uses:</u> All points of selected area	Max (maximum) shows the maximum amplitude value of the data samples between the endpoints of the selected area. To compare peak heights, select each peak—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. <u>Note:</u> For a single point, Max shows the amplitude value in this point. <u>Units:</u> Volts
Max T	<u>Minimum area:</u> 1 sample <u>Uses:</u> All points of selected area	Max T shows the time of the data point that represents the maximum value of the data samples between the endpoints of the selected area. <u>Note:</u> For a single point, Max T shows the time value in this point. <u>Units:</u> Seconds
Mean	<u>Minimum area:</u> 2 samples <u>Uses:</u> All points of selected area	Mean computes the mean amplitude value of the data samples between the endpoints of the selected area, according to the formula: $\text{Mean} = \frac{1}{n} * \sum_{i=1}^n f(x_i)$ <u>Where:</u> n —number of samples; i —index ($i = 1..n$); x_i — values of points at horizontal axis; (x_1 — the first point, x_n — the last point); $f(x_i)$ — values of points of a curve (vertical axis). <u>Units:</u> Volts <u>Sample data file:</u> "ValidateMeasurements.ACQ" Result: 1.538462 Volts (for whole wave).
Median	<u>Minimum area:</u> 2 samples <u>Uses:</u> All points of selected area	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
Median T	<u>Minimum area:</u> 2 samples <u>Uses:</u> All points of selected area	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.
Min	<u>Minimum area:</u> 2 samples <u>Uses:</u> All points of selected area	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.
Min T	<u>Minimum area:</u> 1 sample <u>Uses:</u> All points of	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.

Measurement	Area	Explanation
	selected area	
Moment	<u>Uses:</u> All points of selected area	Central Moment is a general-purpose statistical computation that can be used to compute central variance and other higher-order moments of the data within the selected area. Specify the order as an integer (generally). The central moment is computed using the following formula: $\mu_m = \frac{\sum_{i=1}^n (x_i - \bar{x})^m}{n}$ <p><u>Where:</u> <i>x</i>—signal; <i>n</i>—points; <i>m</i>—order.</p>
Mut_inf		Mutual Information determines how much could probabilistically be known about an unknown signal given a known variable. Specify a time delay. Produces a single valued result.
NLM		Nonlinear modeling (also called “arbitrary curve fitting”) determines the “best fit” model for the selected data of the selected channel. The measurement result corresponds to the value of one of the parameters of the best fit. NLM can be used to extract Tau (time delay LVP constant) for assessing cardiac condition. See page 315 for nonlinear modeling details. <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 325), the NLM measurement can be useful for extracting cycle-by-cycle best fit models for an entire waveform.
None	n/a	None does not produce a measurement value. It's useful if you are copying a measurement to the clipboard or journal with a window size such that several measurements are shown and you don't want them all copied.
P-P	<u>Minimum area:</u> 2 samples <u>Uses:</u> All points of selected area	P-P (peak-to-peak) shows the difference between the maximum amplitude value and the minimum amplitude in the selected area. <u>Results:</u> The result is always a positive value or zero. <u>Units:</u> Volts <u>Sample data file:</u> “ValidateMeasurements.ACQ” <u>Result:</u> 13 Volts (for whole wave).
Rate_mean	<u>Uses:</u> All points of selected area	Extracts the mean value of the rate outputs within the selected area. Unless this measurement is used on a rate analysis or calculation channel, this measurement is not defined (****). The units of this measurement will match the amplitude units of the measurement channel.
Rate_median	<u>Uses:</u> All points of selected area	Extracts the median value of the rate outputs within the selected area. Unless this measurement is used on a rate analysis or calculation channel, this measurement is not defined (****). The units of this measurement will match the amplitude units of the measurement channel.
Rate_stddv	<u>Uses:</u> All points of selected area	Extracts the standard deviation value of the rate outputs within the selected area. Unless this measurement is used on a rate analysis or calculation channel, this measurement is not defined (****). The units of this measurement will match the amplitude units of the measurement channel.
Samples	<u>Minimum area:</u> 1 sample <u>Uses:</u> All points of selected area	Samples shows the exact sample number of the selected waveform at the cursor position—the first data point is not displayed, but is plotted at zero. See page 93 for examples of selected area Samples. <u>Note:</u> When an area is selected, the measurement will indicate the sample number at the last position of the cursor. <u>Units:</u> Samples.
Skew		Skew is a statistical measure of the degree of asymmetry in a distribution (away from normal Gaussian distribution), e.g. if the distribution is weighted evenly or trends toward an edge. <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 The following formula is used to extract skew:

Measurement	Area	Explanation
		$skew = \frac{\sum_{i=1}^n (x_i - \bar{x})^3}{\left(\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n} \right)^{3/2}}$ <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><u>Uses:</u> All points of selected area</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> <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> 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>$\bar{f} = \frac{1}{n} * \sum_{i=1}^n f(x_i)$ - the mean amplitude value of the data samples between the endpoints of the selected area.</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: 3.09570 Volts (for samples 1-4), 1.000 Volts (for samples 10-12).</p>

Measurement	Area	Explanation												
Sum	<u>Minimum area:</u> 2 samples <u>Uses:</u> All points of selected area	Sum extracts a mathematical sum of the amplitudes of all of the samples within the selected area. This straight sum can be used as a building block for more complicated formulas. Examples of its utility include HRV measurements, various statistical measurements, and simple criteria for clustering. Sum is available from within the measurement popup menus and from analysis scripts that allow for extraction of measurements.												
Time	<u>Minimum area:</u> 1 samples <u>Uses:</u> All points of selected area	See the X-axis: T measurement for explanation.												
Value	<u>Minimum area:</u> 1 sample <u>Uses:</u> All points of selected area	Value shows the exact amplitude value of the waveform at the cursor position. <i>For the selected area</i> , 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). <u>Units:</u> Volts												
X-axis:T/F/X (horizontal units)	<u>Minimum area:</u> 1 sample <u>Uses:</u> All points of selected area	The X-axis measurement is the exact value of the selected waveform at the cursor position, based on the Horizontal Axis setting: <table> <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> 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 99. <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.	<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												

Part B—Acquisition Functions: The Hardware Menu

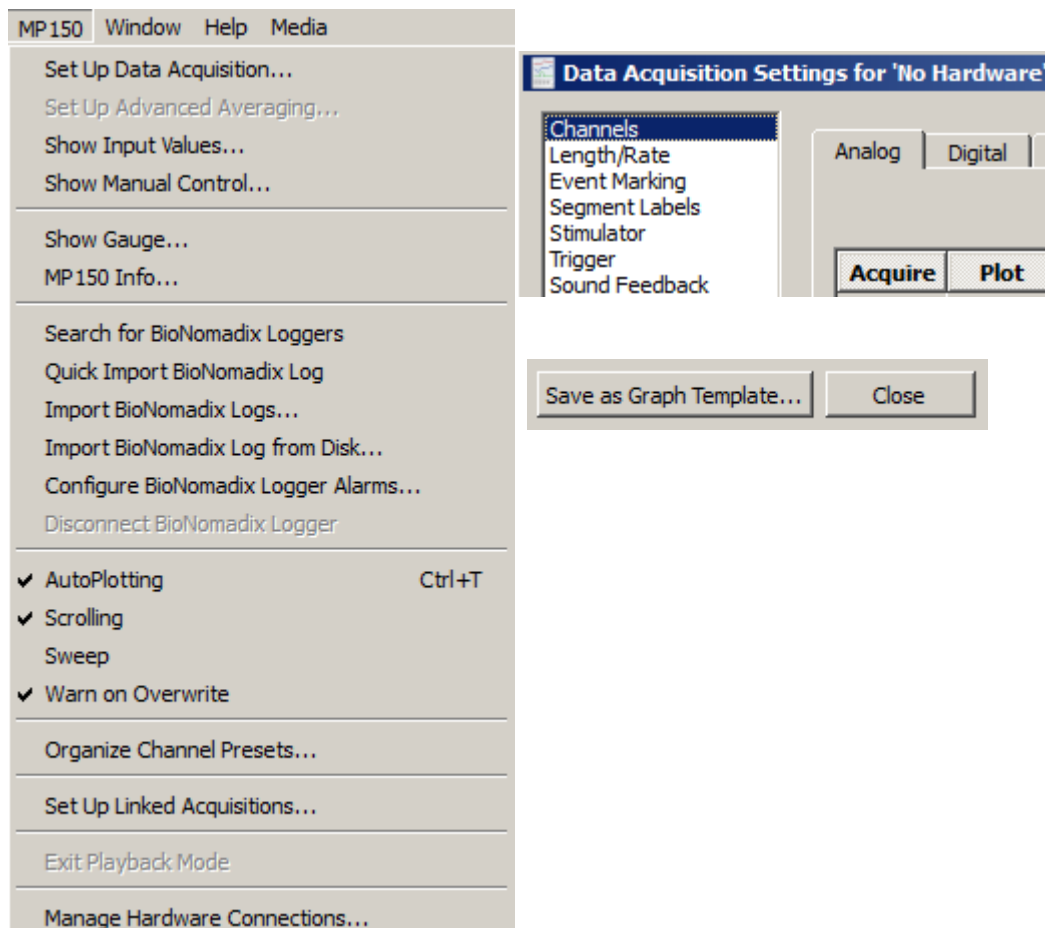
Overview

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

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

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

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



Set Up Data Acquisition > Data Acquisition Settings

In *AcqKnowledge* 4.4 and higher, many key setups are accessed by selecting Hardware menu > Set Up Data Acquisition. This option displays the Data Acquisition Settings window, comprised of the following items:

- Channels – all channel and hardware module setups – see page 109
- Length/Rate – all acquisition setup parameters for the hardware – see page 158
- Event Marking – for setting up hotkeys to insert custom events during acquisition – see page 218
- Segment Labels – for creating custom append segment labels – see page 238
- Stimulator – for configuring all stimulator options – see page 176
- Trigger – for configuring all triggering setups see page 173
- Sound Feedback – for setting up audio output of channel data – see page 238

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

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

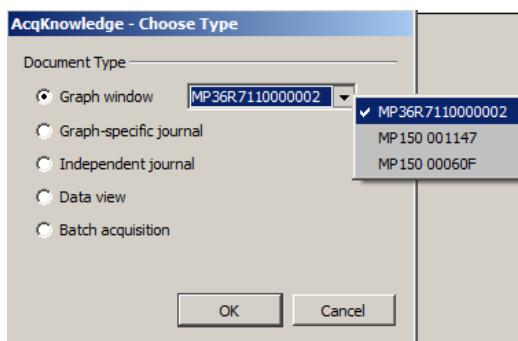
Acquisitions

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

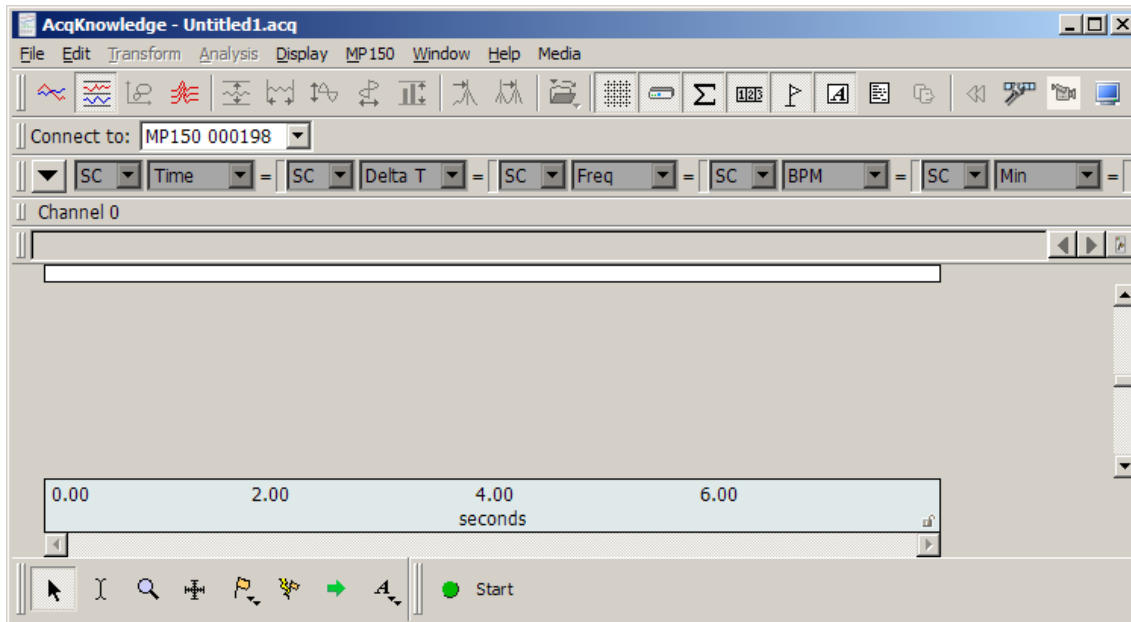
- Before you begin an acquisition, make sure the data acquisition hardware is turned on and connected to your computer. Please refer to the BIOPAC MP Hardware Guide for more information on connections for your particular hardware type.

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

1. Launch the *AcqKnowledge* application (you can double click the *AcqKnowledge* icon).
2. Choose File > New and select document type “Graph Window.”



NOTE: If more than one hardware type has been previously added via the “Connect to” menu, these will also appear in the “Choose Type” dialog (left). For details on connecting additional hardware types, see page 162.



3. Set up the specific channels you want to acquire before starting the acquisition.
 - See the Set Up Channels chapter (page 109) for details.
4. Set up the acquisition parameters (such as sampling rate, acquisition length, and data storage options).
 - See the Set Up Data Acquisition chapter (page 158) for details.

Edit menu functionality during acquisition

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

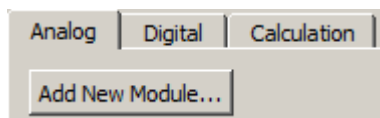
Chapter 5 Set Up Channels

Set Up Channels—The Basics

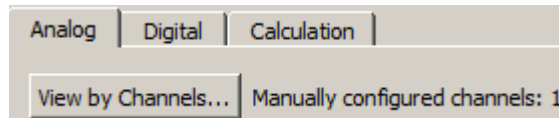
Before you collect data, you need to specify how many channels you will be collecting data on, and at what rate data is to be collected. Both of these functions are accomplished through menu items and dialogues. To enable collection on a given channel, select **Set Up Data Acquisition > Channels** from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

AcqKnowledge 4.1 and higher for MP150 offers two methods of analog channel setup:

Module-based setup



View by Channels *see page 111 for details*



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

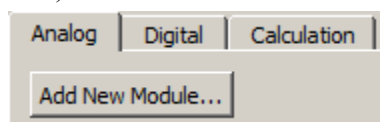
Module-based analog channel setup

For MP150 units, AcqKnowledge 4.1 and higher offers a module-oriented analog channel setup option. In module mode, setup prompts the user to add modules/transducers and establish parameters, plus it detects potential channel conflicts between software assignment and the module channel switch setting and scales the signal to the correct value and units. Module setup is supported in MP150 hardware only.

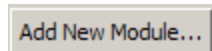
The module setup is recommended for easier setup and automatic scaling. In module mode, setup prompts the user to add individual modules based upon the module number. For modules with transducers, the unique transducers are added. The user is then prompted to input the settings of all of the switches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

1. From MP150 > Setup Data Acquisition > Channels, select the analog tab and click Add New Module...

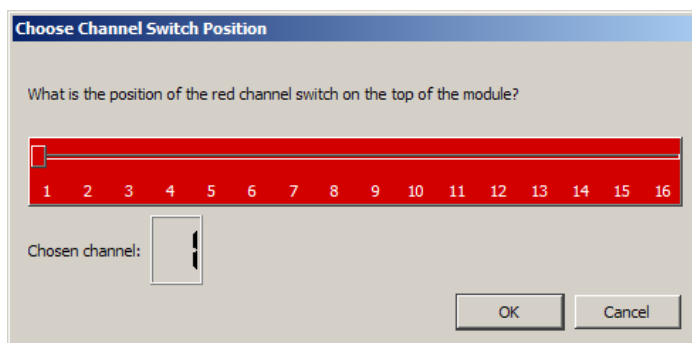
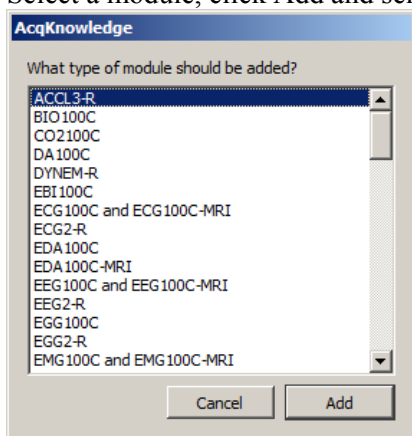
NOTE: Module setup mode is activated by default when the “Create/Record a new experiment” launch option is selected in the Startup Wizard window. (The add module dialog shown in Step 3 is presented first.)



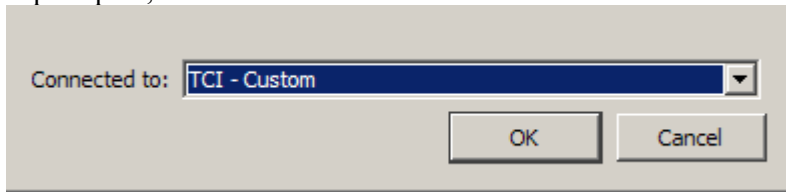
2. Click Add New Module from the bottom of the dialog.



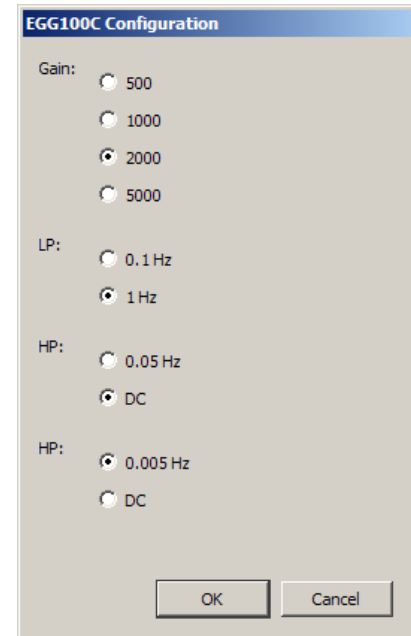
3. Select a module, click Add and select the channel switch position.



4. If prompted, select a transducer and click Add.

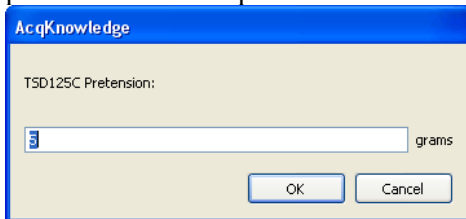


5. Input the settings of the switch on the selected module and click OK. Set the choose channel switch to the number set on the amplifier (some amplifiers, such as the OXY100C, have a switch on the front of the module).
 - Setup detects any potential channel conflicts between software assignment and the module's red channel switch position.
6. Establish the configuration parameters (gain and filters) and click OK. It is important to set the Gain and Filter settings to correspond to the switch settings on the amplifier. The software uses this information to scale the signal to the correct units. If the Gain is not set to match, the signal will be scaled incorrectly.
7. Perform calibration steps, if required. The software will automatically scale certain signals, if they only require a zero setting. However, some signals require a two-point calibration. In this case, the software will generate additional prompts for the scale values.

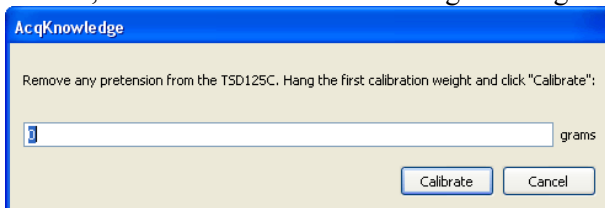


The following examples show the dialogs for setting up a force transducer.

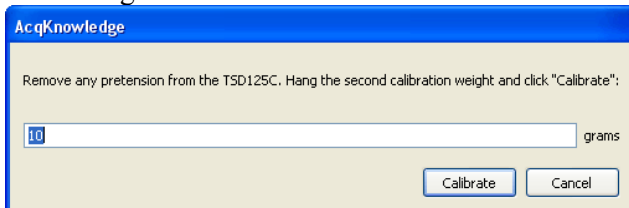
- a. The software prompts the user for pretension amount; enter "0" if pretension is not required.



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



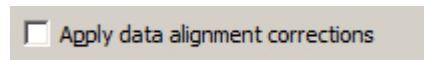
- c. Enter a high calibration value and click OK for the software will take a voltage reading.



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

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

“Apply data alignment corrections” option (AcqKnowledge 4.4.2 and higher)



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

- NIBP100D (via DA100C general purpose amplifier)
- NIBP100D-HD (via HLT100C high level transducer module)
- When combining BioNomadix wireless signals with wired signals.

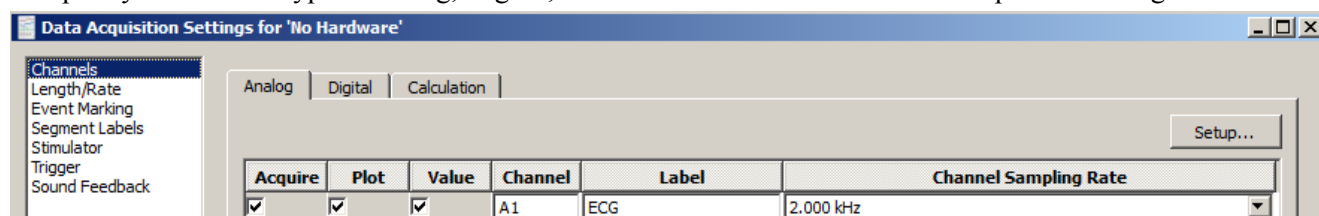
Checking this box automatically adds appropriate delays, ensuring all data will be properly aligned when the above combination of hardware is used. This avoids the need to use calculation channels to manually align data when combining hardware types that apply varying amounts of fixed delay.

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

View by Channels

Channel Type

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



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

Acquire

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

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

Plot

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

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

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

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

Values

The third option enables incoming data values to be displayed either numerically and/or in a “bar chart” format in a separate window during an acquisition. Checking this option enables a bar graph (by selecting Show Input Values... under the Hardware menu) that displays the numeric value for channels with this option checked. This is especially useful for tracking slowly changing values such as heart rate, respiration rate, or concentrations of chemicals in a substance. For more information on how input values are displayed, please turn to page 232.

Channel

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

Label

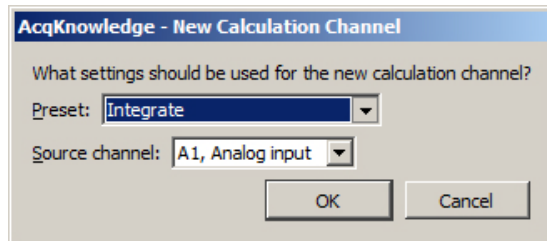
Editable labels can be attached to each channel. To change the label for any channel, position the cursor in the area to the right of the channel numbers (A1 through A16) under the label heading and enter a text label. Up to 38 characters are supported and these labels will appear next to the channel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

Calculation Channel Presets

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

To set an initial calculation channel preset:

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



4. After clicking OK, the setup dialog for the selected preset will appear. Set the desired parameters and click OK. (For detailed information about setting Calculation channel parameters, see Chapter 6 on page 126.)

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

- a) Calculation channel type
- b) Parameters for that calculation
- c) Channel name.

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

The Channel Setup dialog contains a “Preset” pop-up menu by each channel that lists the current Preset or, if no Preset has been selected for that channel, the Calculation type (Integrate, Difference, etc.). When 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. Just click the Presets head and scroll to select the desired preset.

Preset	Preset	Preset	Preset	Preset
Integrate	FLC	EMG Integrated	EMG Root Mean Square	Lung Volume
Integrate	FLC	WFLC	CWFLC	Large Animal Systolic BP
Smoothing	WFLC	CWFLC	Adaptive Filter	Large Animal Diastolic BP
Difference	CWFLC	Adaptive Filter	Comb Band Stop Filter	Large Animal Mean BP
Rate	Adaptive Filter	Comb Band Stop Filter	Metachannel	Large Animal Heart Rate
Math	Comb Band Stop Filter	Metachannel	Rescale	Pulse Rate
Function	Metachannel	Rescale	dp/dt	Respiration Rate
Filter	Rescale	dp/dt	dp/dt Max.	Small Animal Systolic BP
Expression	dp/dt	dp/dt Max.	dp/dt Min.	Small Animal Diastolic BP
Delay	dp/dt Max.	dp/dt Min.	EMG Integrated	Small Animal Mean BP
Control	dp/dt Min.	EMG Integrated	EMG Root Mean Square	Small Animal Heart Rate

Calculation Presets

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.
- Create a new Preset from existing Calculation channels. Click “Setup” to display the Calculation Setup dialog and click the “New Preset” button. The settings will be applied to the current channel, and a prompt will appear to enter a name for the new Preset. Preset names cannot be duplicated, nor can the default name of a Calculation channel type be used (Integrate, Difference, etc.). The new Preset will be included in the pop-up menus and saved with the file.
- To reorder channel Presets (by type, use, etc.), choose Hardware > Organize Channel Presets and then use the up/down buttons as appropriate (see page 245).
- Presets are not applicable to and therefore not selectable on Analog or Digital channels.

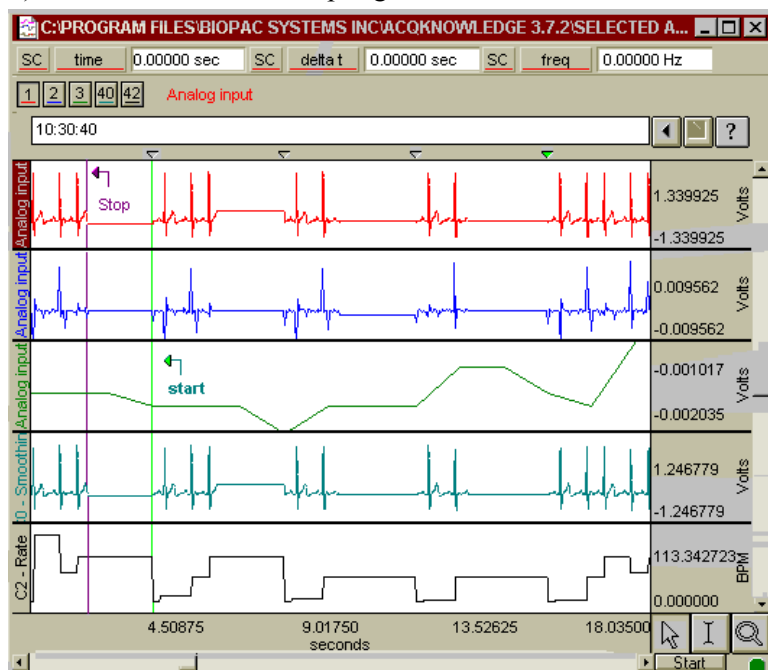
Channel Sampling Rate

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

- Offline operations that involve multiple channels must use the same sampling rate for all Source and Destination channels. These operations include waveform editing, Waveform math, Expression calculations and Template functions; notable exceptions are “Off-line Averaging” under Find Cycle/Peak and “Reset via a Control Channel” under Integrate.
- When wave data is copied to the clipboard or journal, data values will be inserted at the highest sampling rate.
- There is no restriction on the acquisition length when using Variable Sampling Rates.
- When Variable Sampling Rates are used in conjunction with the Append mode, and the mode is started and stopped manually, it is statistically possible that, prior to the next pass of the Append, extra data points may be inserted in various data channels to “line up” the data (see sample on page 113). These extra data points simply replicate the last sample in any affected channel.

To minimize the impact of the extra data points:

- a) Make sure the lowest sampling rate is on the order of 10 Hz or higher, or
- b) Don’t use Variable Sampling Rates.



Set Up Channels—Advanced

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

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

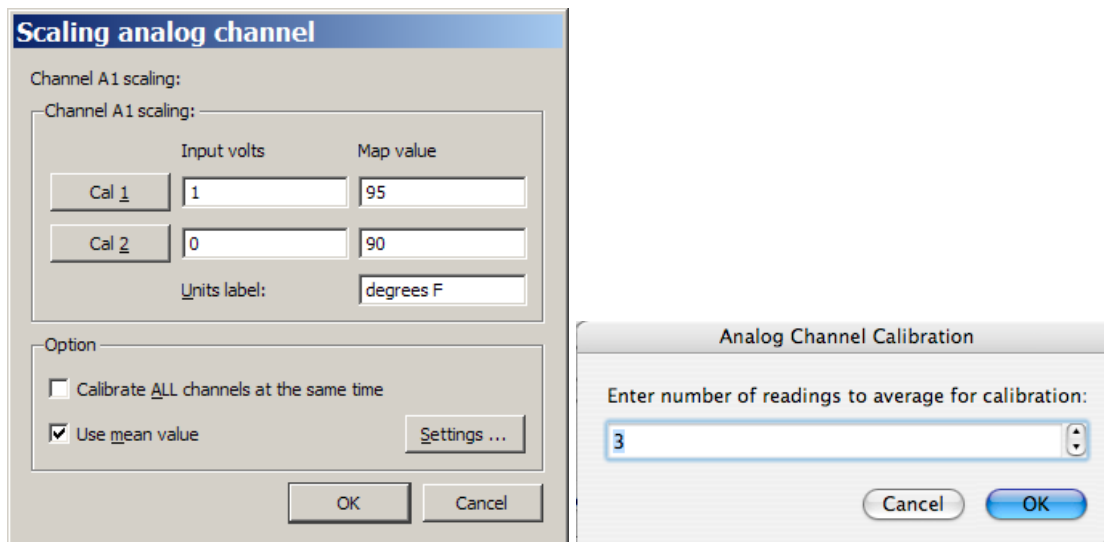
In the upper left corner of the Channels dialog, there are three tabs titled Analog, Digital, and Calculation. These refer to the three respective channel types available in AcqKnowledge. The general features (acquiring, plotting, and the like) are the same for each type of channel, although there are considerable differences between the type of data each channel is designed to handle. Up to 16 channels each of analog, digital, and Calculation channels are supported in MP150 hardware, and 4 channels of analog, 8 channels of digital and 16 Calculation channels are supported in MP36R hardware. Analog and digital channels may be acquired in any combination, and the only requirement for Calculation channels is that 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 supports the rescaling of Analog channel signals to more meaningful numbers. As an example, imagine a temperature transducer is connected to an SKT100C amplifier with a gain setting of 5°/Volt, and output set to channel 1. Ordinarily, the values from the amplifier would be read in as Volts or milliVolts. For this acquisition, the signal from the transducer would need to be expressed in terms of degrees Fahrenheit. To calibrate the transducer, bring it to two known temperatures. At the first temperature, take a voltage reading by selecting “Show Input Values” from the Hardware menu. (See page 232 for a description of the Show Input Values options). At 90° F, a reading of 0 Volts will be displayed. The transducer is then brought to a temperature of 95° F, resulting in a reading of +1 Volts.

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



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

The Input Volts and Map (Scale) Value boxes reflect the value of the incoming signal and how it will be plotted on the screen, respectively. Thus, an incoming signal of +1 Volts would be plotted as 95° F, whereas a signal of 0 Volts would be plotted as 90° F. 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 scaling dialog, type in “degrees F” for Units, and click OK.

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

Next, the transducer could be brought to another known temperature that is considerably higher or lower than the first. Click Cal 2 and the new known temperature could then be entered in the Map (Scale) value box for Cal 2. *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 data acquisition unit, power up the Hardware, 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:

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

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

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

Increased Channel Count Support (*AcqKnowledge* 4.3 and above)

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

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

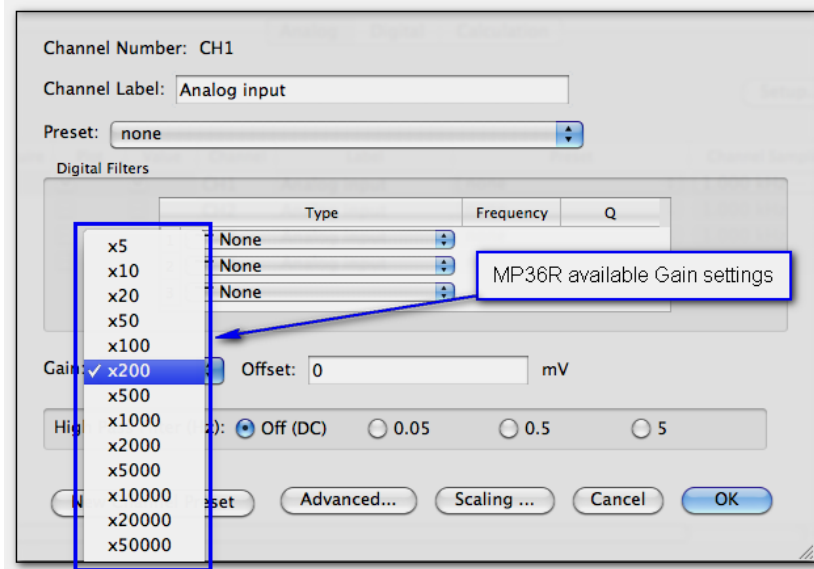
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107													

Left Cardiac Work

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

Analog channels MP36R

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



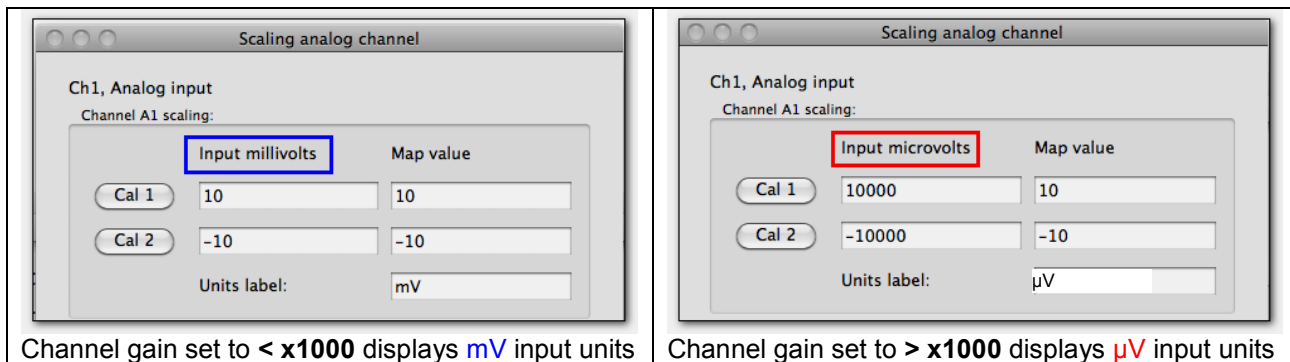
Offset

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

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

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

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



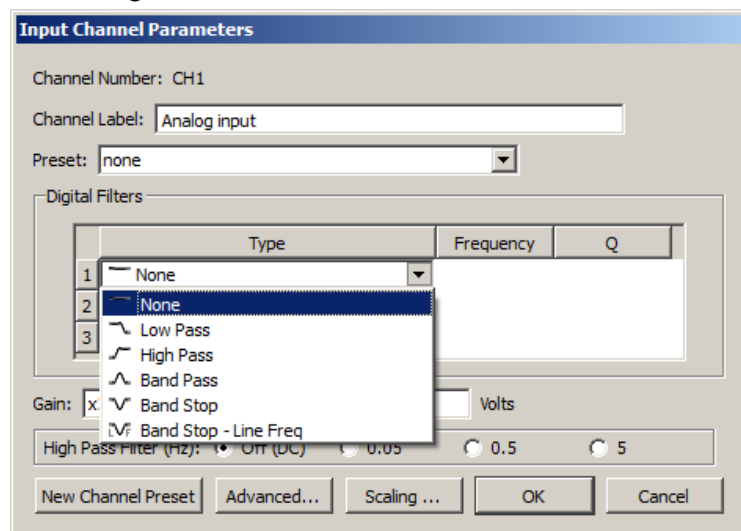
Channel gain set to < x1000 displays mV input units

Channel gain set to > x1000 displays μ V input units

Adjustable, user defined, digital IIR filters for MP36R

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

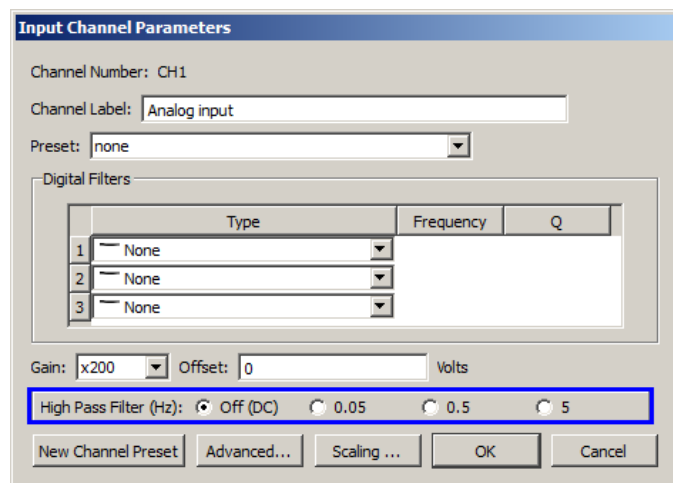
In the “Digital Filters” section, select Filter 1, 2, and/or 3 and then adjust the *Type*, *Freq*, and *Q*.



The default setting is no filters applied.

High Pass Filters MP36R

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



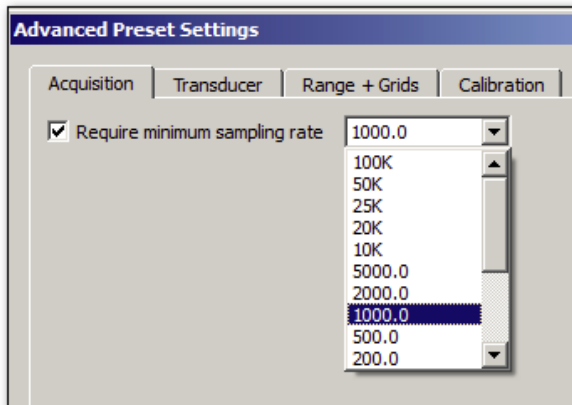
High Pass Filter	Appropriate use
0.05 Hz HP	ECG Respiration data
0.5 Hz HP	ECG when there is a lot of motion artifact causing a shifting baseline EEG Pulse plethysmograph Most other types of AC Coupled data
5 Hz HP	EMG Heart Sounds

Additional controls in MP36R Input Channel Parameters

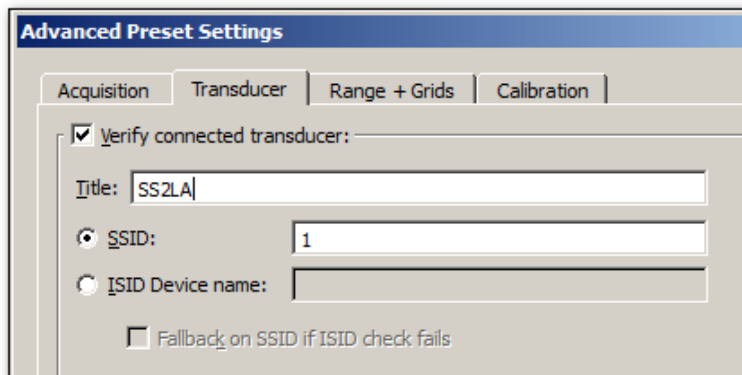
Button	Explanation
New Channel Preset	Allows a custom Preset to be saved under a unique name
Advanced	Opens Advanced dialog. The Advanced dialog may be used to specify additional settings, requirements, and dependencies for the preset. See below for complete explanation of all Advanced options.
Scaling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

MP36R Advanced Preset Settings

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



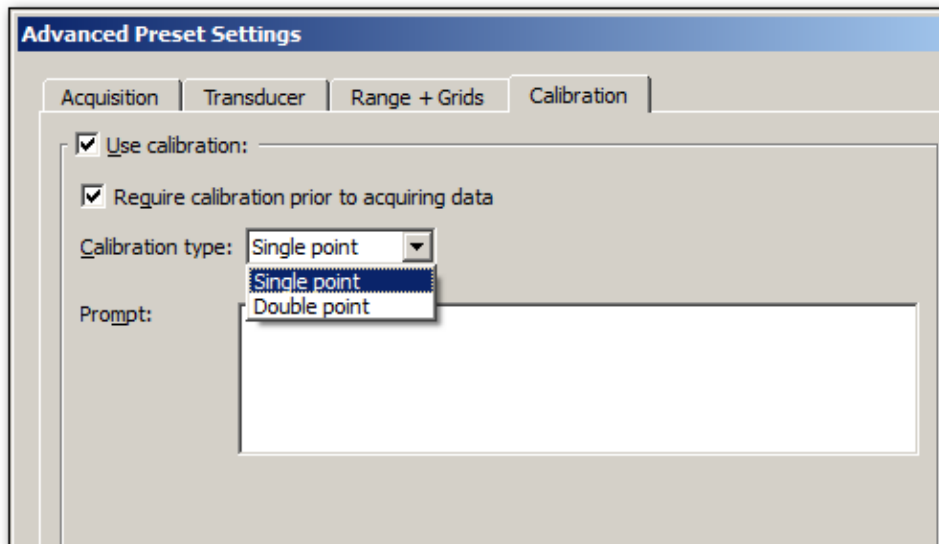
Acquisition Tab	Explanation
Require minimum sampling rate	When enabled, specifies that a minimum sampling rate must be selected in order for acquisition to continue.



Transducer Tab	Explanation
Verify connected transducer	When enabled, the software will check for a specific transducer according to the settings in this group box prior to the start of each appended segment
Title	Editable text field used to identify transducer name.
SSID	If checked, indicates which SmartSensor resistor ID should be validated for this channel prior to each acquisition. The ID must be an integer between 1 and 23. See SSID table on page 121.
ISID Device Name	If checked, indicates that the internal transducer description should be validated for this channel prior to each acquisition.
Fallback on SSID if ISID check fails	If the ISID device name check is unsuccessful for a connected transducer, fall back and check the SmartSensor resistor ID. See SSID table on page 121

Acquisition	Transducer	Range + Grids	Calibration
<input checked="" type="checkbox"/> Apply initial visual range:			
Top: <input type="text" value="10"/> Volts Bottom: <input type="text" value="-10"/> Volts			
<input checked="" type="checkbox"/> Apply locked vertical grid:			
First grid line: <input type="text" value="0"/> Volts Grid spacing: <input type="text" value="5"/> Volts / div			
<input checked="" type="checkbox"/> Apply locked horizontal grid:			
First grid line: <input type="text" value="0"/> seconds Grid spacing: <input type="text" value="2"/> seconds / div			
<input checked="" type="checkbox"/> Apply grid appearance:			
Major line color: <input type="color" value="#808080"/>		Minor line color: <input type="color" value="#D3D3D3"/>	
<input checked="" type="checkbox"/> Show minor grid		Num minor divisions: <input type="text" value="5"/>	
Vertical precision: <input type="text" value="2"/> ▾			

Range + Grids Tab	Explanation
Apply initial visual range	The initial vertical axis range of plotted data will be set as indicated at acquisition start of the first data segment.
Top	Indicates the maximum vertical visual range in destination channel units.
Bottom	Indicates the minimum vertical visual range in destination channel units.
Apply locked vertical grid	Locked vertical grid settings are applied for the channel. For more details on grid setups, see Grid Details on page 78.
First grid line	Provides the fixed location of the origin of the vertical grid.
Grid spacing	Sets the spacing interval between major vertical grid divisions.
Apply locked horizontal grid	A channel-specific independent horizontal grid will be applied when the channel is added to a graph.
First grid line	Sets the origin location of the horizontal grids.
Grid spacing	Sets spacing between major horizontal grid lines based on the time domain.
Apply grid appearance	Enables options for setting grid color/appearance of major and minor grid lines.
Major line color	Allows customization of major grid line color.
Minor line color	Allows customization of minor grid line color.
Show minor grid	Shows/hides minor gridlines
Vertical precision	Indicates number of digits displayed on vertical axis.
Num minor divisions	Sets the number of minor grid divisions for the channel.



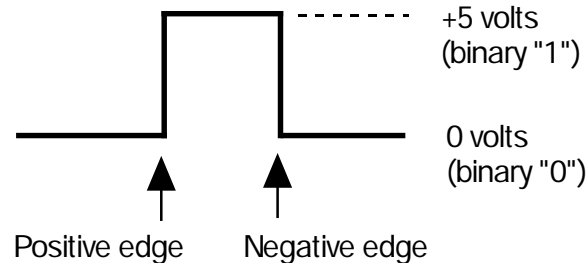
Calibration Tab	Explanation
Use Calibration	Additional calibration procedures will be applied to adjust the channel scaling based on values read from a physical transducer.
Require calibration prior to acquiring data	When checked, calibration will always be required for this channel prior to acquiring the first segment of data.
Calibration Type	Specifies calibration option to be performed on the channel. Two types are available: <ul style="list-style-type: none"> • Single point – records a single input voltage and adds it to the Input Volts value of both Cal1 and Cal2 • Double point – records two independent voltages in a sequence of two dialog steps and records the first in the input volts for Cal1 and the second for the input volts in Cal2
Prompt	One prompt for “Single point” calibration. Two prompts for “Double point” calibration. Field(s) for inputting dialog text to be displayed to the user for acquiring the single voltage input to apply to the scaling input voltage values.

MP36R Transducer SSID Table

Device Part #	Description	SSID	ISID Name
BSLCBL3A, BSLCBL4B	Recording cable	1	
BSLCBL5	3.5mm phone plug adapter	6	
BSLCBL8, BSLCBL9	High-impedance recording cable	1	
BSLCBL14A	3.5mm phone plug adapter to MP35 Input.	6	
BSLSTMB/A	10 V setting	18	
BSLSTMB/A	100 V setting	19	
BSL-TCI13	Piezo interface cable	1	
BSL-TCI21	pH probe interface	12	
SS1L, SS2L, SS2LA	Electrode lead set	1	
SS2LB	Electrode lead set	N/A	SS2LB
SS3LA	EDA (GSR) finger electrodes	2	
SS4LA	Pulse Plethysmograph finger transducer	3	
SS5L, SS5LA, SS5LB	Respiration Belt (for Chest)	4	
SS6L, SS7L, SS8L	Temperature transducer	5	
SS9L, SS9LA	BNC Adapter	6	
SS10L	Pushbutton switch	7	
SS11LA	Airflow transducer	8	
SS12LA	Variable range force transducer	9	
SS13L	Blood Pressure (Arterial)	10	
SS14L	Displacement transducer	11	
SS17L	Piezo microphone	14	
SS19L	Blood Pressure cuff (with Gauge)	10	
SS19LA	Blood Pressure cuff	N/A	SS19LA
SS19LB	Blood Pressure Cuff	N/A	SS19LB
SS20L, SS21L, SS22L, SS23L, SS24L	Goniometer	16	
SS25L, SS25LA	Hand Dynamometer	9	
SS25LB	Hand Dynamometer	N/A	SS25LB
SS26L, SS26LB, SS27L	Accelerometer	17	
SS28L	Heel Toe Strike assembly	9	
SS29L	Multilead ECG cable	1	
SS30L	Stethoscope, electronic	14	
SS31L	Non-Invasive Cardiac Output Module	15	
SS32L	Dissolved Oxygen probe	20	
SS33L	GAS – O ₂ (Used on GAS-System2)	21	
SS34L	GAS – CO ₂ (Used on GAS-System2)	22	
SS35L	Flow transducer	18	
SS36L	Reflex Hammer	9	
SS39LA	MP3X Circuit Probe and Power Cable for Breadboard	6	
SS40L, SS41L, SS42L	Diff. Pressure transducer	10	
SS43L	Psychological response indicator	11	
SS56L	Clench Force (Bulb) transducer	N/A	SS56L
SS57L	EDA (GSR) with electrode pinch leads	2	
SS57LA	EDA (GSR)	N/A	SS57LA
SS59L	Superlab Interface cable for MP35	6	
SS61L	Finger Twitch transducer	16	
SS62L	Microphone	14	
SS63L, SS64L, SS65L, SS66L	Fixed Range Force Transducer	9	
SS67L	Pneumogram transducer	10	
SS68L	Ph Probe	12	
SS70L	BNC Adapter (for MP35), Isolated version	6	

Digital Channels


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

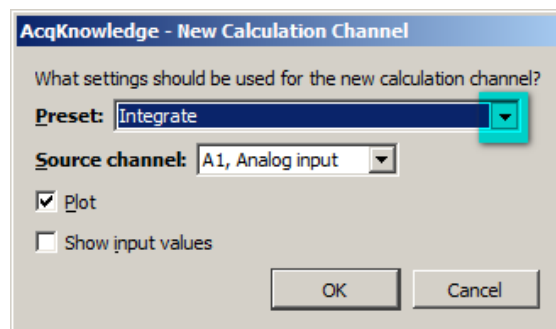


Calculation Channels

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

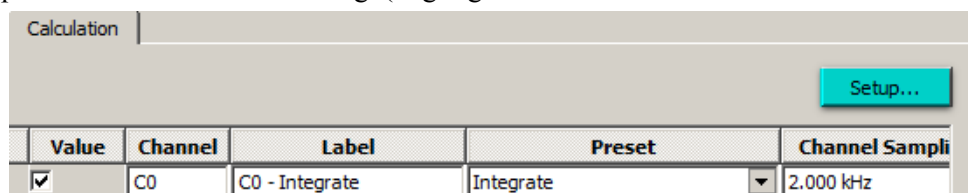
Calculation channels can be used to compute a host of new variables by using transformations (including BPM, integration calculations, and math functions). The channels are Set Up in much the same way (using Acquire/Plot/Values boxes) as analog or digital channels, with the exception of the pull-down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

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



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

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



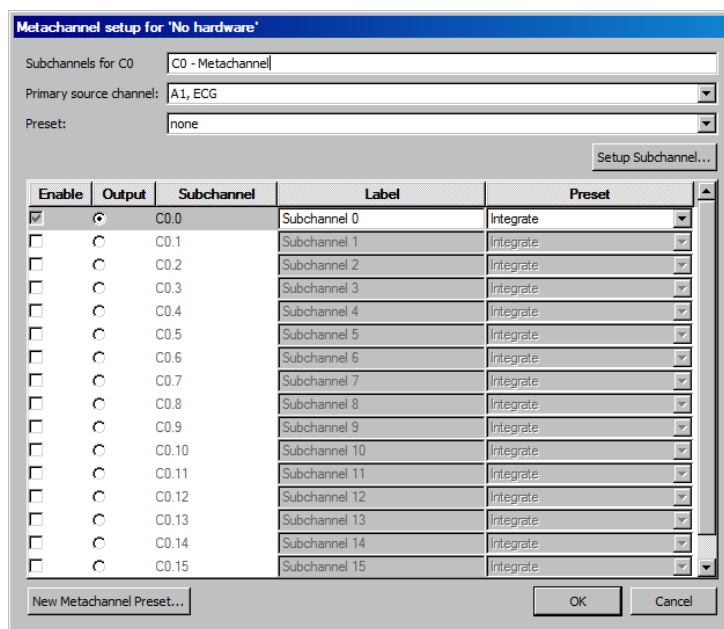
Up to 16 Calculation channels can be acquired, and you may use the output of one Calculation channel as the input for another channel, as long as the output channel has a higher channel number than the input channel. In other words, it's possible for Calculation channel 3 to include the result of Calculation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

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

Metachannel

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

- *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#.#

To have *AcqKnowledge* perform a Metachannel calculation:

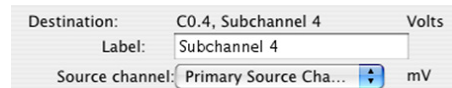
1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Metachannel.
5. Click the Setup button in the Input Channels dialog to generate the Metachannel dialog.

Primary Source

The primary source for a metachannel can be set to any analog or digital enabled channel, or an enabled calculation channel with a lower number.

Set Up Subchannel

Click this button to display the calculation setup dialog for the selected subchannel and then set the calculation parameters and the source channel.



The screenshot shows a dialog box with three fields: 'Destination' set to 'C0.4, Subchannel 4' with 'Volts' to its right; 'Label' set to 'Subchannel 4'; and 'Source channel' set to 'Primary Source Cha...' with a dropdown arrow and 'mV' to its right.

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

Limitations on Subchannels

Subchannels are allowed to take on any of the main calculation channel types. All calculation types are available, with some restrictions.

- Output of reset events is not supported for Integrate and Rate subchannels.
- For Expression subchannels, the expression language will be enhanced to allow for "PSC" to be typed into the expression to refer to the data of the primary source channel.
- Unlike regular calculation channels, the actual data for subchannels is not retained in memory. Subchannels are only used as temporary data and the results discarded after the value of the output subchannel has been computed.

AcqKnowledge QUICK STARTS

Quick Start templates (.gtl graph template files) are installed to the Sample Data folder. Use **Quick Start** files to establish the settings required for a particular application or as a good starting point for customized applications. See Open As Graph Template on page 252 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
45	Vibromyography	Muscle Activity
46	Pressure Volume Loop	Blood Pressure & Flow
47	Heart Rate Alarm	Monitor heart rate with audible alarm

✓ Integrate	Sine Wave
Smoothing	Small Animal dp/dt Minimum
Difference	Small Animal dp/dt Maximum
Rate	Small Animal Systolic BP
Math	Small Animal Diastolic BP
Function	Small Animal Mean BP
Filter - IIR	Small Animal Heart Rate
Expression	Square Wave
Delay	Ramp Plateau Ramp
Control	Vibromyography
FLC	
WFLC	Electrocardiogram (ECG), .5 - 35 Hz
CWFLC	Electrocardiogram (ECG), .05 - 35 Hz
Adaptive Filter	Electrocardiogram (ECG), .05 - 100 Hz, AHA
Comb Band Stop Filter	Electrocardiogram (ECG), 0.5 - 150 Hz
Metachannel	Electroencephalogram (EEG), .5 - 35 Hz
Rescale	Electroencephalogram (EEG), .5 - 100 Hz w/notch
Run Macro	Electrogastrogram (EGG)
Slew Rate Limiter	Electromyogram (EMG), 5 - 250 Hz w/notch
Filter - FIR	Electromyogram (EMG), 5 - 500 Hz
	Electromyogram (EMG), 5 - 1000 Hz
Blackman-Windowed Tone	Electromyogram (EMG), 30 - 250 Hz w/notch
dp/dt @ 200 samples/sec.	Electromyogram (EMG), 30 - 500 Hz
dp/dt @ 500 samples/sec.	Electromyogram (EMG), 30 - 1000 Hz
dp/dt @ 1000 samples/sec.	Electrooculogram (EOG), .05 - 35 Hz
ECG R-R Interval	Evoked response (ERS), 1 - 500 Hz
ECG R Wave Amplitude	Evoked response (ERS), 20 - 500 Hz
EEG Alpha (8 - 13 Hz)	
EEG Beta (13 - 30 Hz)	
EEG Theta (4 - 8 Hz)	
EEG Delta (0.5 - 4 Hz)	
EEG Gamma (30 - 90 Hz)	
EGG (.02 - .125 Hz)	
EMG Integrated	
EMG Root Mean Square	
Heart Rate (from ECG)	
Large Animal dp/dt Minimum	
Large Animal dp/dt Maximum	
Large Animal Systolic BP	
Large Animal Diastolic BP	
Large Animal Mean BP	
Large Animal Heart Rate	
Lung Volume	
Pulse Rate	
Random Pulses	
Respiration Rate	
Segment Timer	

Chapter 6 Calculation Channel Presets

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

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

The Setup dialog has a “Presets” pop-up menu that contains all of the Presets for the Calculation type being configured. To enable the Preset pop-up menu, set at least one analog channel to “Acquire” (calculation channels require a source channel). For example, if a Difference Calculation channel is being configured; all Presets for the Difference Calculation will be listed. Just click the Presets head and scroll to select the desired preset.

After selecting a Preset, the Setup dialog is updated with the corresponding information.

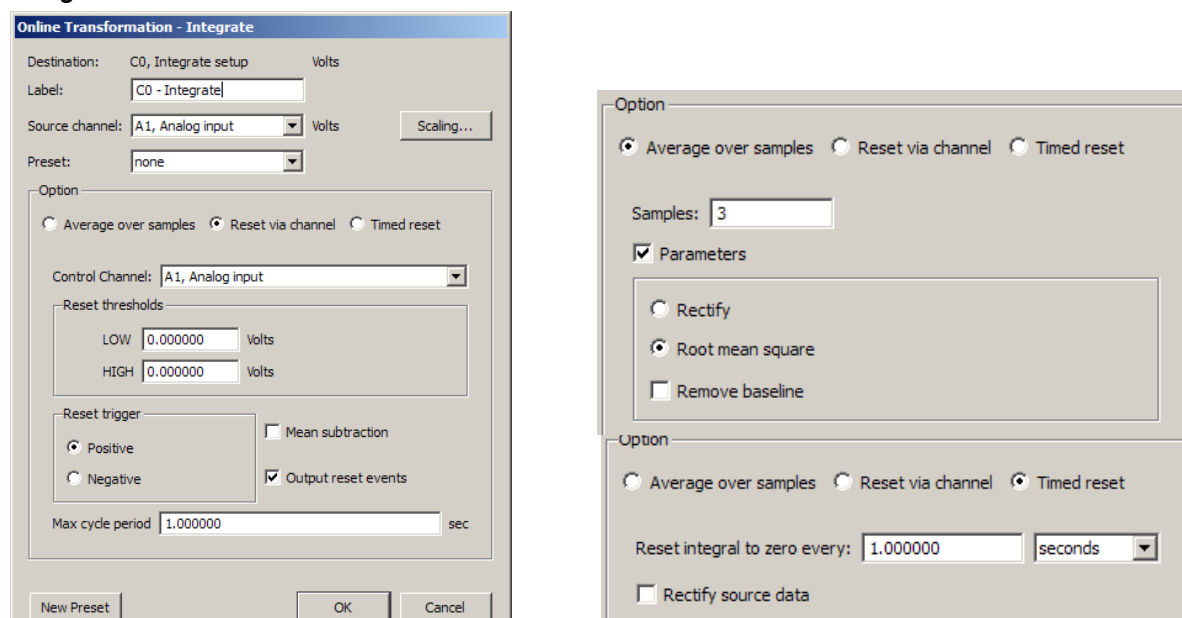
- The Setup dialog reads “none” if the channel configuration doesn’t match any Preset. The menu will flip to “none” when the settings for a channel are changed such that they no longer match a Preset.
- To create a new Preset from existing Calculation channels: Click “Setup” to display the Calculation Setup dialog and

click the “New Preset” button. The settings will be applied to the current channel, and you will be prompted to enter a name for the new Preset. Preset names cannot be duplicated, nor can the default name of a Calculation channel type (Integrate, Difference, etc.). Newly-created Presets will be included in the pop-up menus and saved with the file.

- To reorder channel Presets (by type, use, etc.), choose Hardware > Organize Channel Presets and then use the up/down buttons as appropriate (see page 245).
- **MP150 hardware:** Presets are not applicable to and therefore not selectable on Analog or Digital channels.
- **MP36R hardware:** Presets are available on Analog channels but not Digital channels.

 Watch the [AcqKnowledge Preset Option video tutorial](#) for a detailed demonstration of this feature.

Integrate Calculation



The online Integrate Calculation offers three basic options:

Reset via channel. Perform a real-time integration of input data over a variable number of sample points. This option is extremely useful for converting flow signals into volumetric equivalents. The integral of flow is volume. For example, when recording airflow with a pneumotach, volume can be precisely calculated as the flow varies in a cyclic fashion:

- Real-time conversion of flow signals into volume signals (i.e., Blood flow → Blood volume; Air flow → Air volume)
- Any processing involving a need for a cyclic, continuous integral calculated in real time. For example: Acceleration → Velocity; Velocity → Distance; Frequency → Number of cycles; Power → Energy

Average over samples. Perform a moving average (mean) and associated processing (Rectify; Root mean square) over the specified number of sample points. This option is useful to process EMG signals to:

- Smooth noisy data
- Display the real-time “integration” (rectified, then sample averaged) of the raw EMG data
- Display the real-time “root mean square” calculation of the raw EMG data
- Return real-time windowed standard deviation

Timed reset. This option is available in AcqKnowledge 4.1 and above in the Integrate calculation channel and transformation. This mode computes a straight sum of the source data points and resets this sum after a fixed amount of time has elapsed. This periodic integral is used in several types of analysis, such as EMG analysis where it can generate an EMG signal or estimate the power in fixed time intervals. The time interval at which the integral resets to zero may be specified in seconds or in samples. The timed integrate reset functionality may also be used in calculation channel presets and by the Mac OS X Integrate automator action.

To have AcqKnowledge perform an Integrate calculation in real time:

- Choose Hardware > Set Up Data Acquisition > Channels (click “View by Channels”).
- Click the Calculation tab.
- Check an Acquire box for the Calculation channel you want to contain the modified data. You may also check the Plot and Values boxes as appropriate for each channel.
- Click the Preset pull-down menu and select Integrate.
- Click the Setup button in the Input Channels dialog to generate the Integrate dialog.

(Off-line Integrate is available under Transform > Integrate.)

Destination

Determined by the calculation channel selected. (C0, C1, C2, etc.)

Acquire	Plot	Value	Channel	Label
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	C0	C0 - Integrate
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	C1	C1 - Smoothing

Source

Any Analog or Digital channel being acquired as well as any enabled Calculation channels with a lower number.

Reset via channel (Integrate option)

This feature is used to integrate data over a data-dependent interval. Either the source channel or a different channel can control the integration process.

Control channel

Allows user to select any active channel as the integration control channel. (Calculation channels must have a lower number.)

Reset Thresholds

The threshold is to be set at points surrounding the flow level. Typical values are:

LOW: a negative value close to 0.00

HIGH: a positive value close to 0.00

For airflow to volume conversion, the flow signal will vary positively and negatively around zero flow.

Reset trigger

The Reset trigger polarity determines on which slope (Positive ↑ or Negative ↓) the integration process will begin

and end.

Mean Subtraction

This option will subtract the mean from the data evaluated during the integration period. If this option is selected, the integration will only proceed after all the data in the integration period has been collected. When collected, the mean value of all the data is subtracted from each data point in the integration period. In this fashion, the integral of the corrected data points will result in the integral returning to exactly zero at the end of the integration interval. Although this option will result in “well-behaved” integrations, the integrated data will be delayed by a fixed amount of time, as specified by the max cycle period.

Online Enabling mean subtraction delays the signal by the mean cycle length. It waits for that period of time to pass so it can determine a mean value for the initial cycle, and it then tries to re-compute this mean for each cycle. If the resets are too short or too long, the window expires and the processing halts again until a new mean can be recomputed. Online processing may reset from threshold crossing in the control channel or window expiration when it loses mean tracking.

Offline Transformation version of this operation. Since all the data is available, the mean is computed from the data in the channel and the signal is not delayed. Also, since it isn't doing windowed means, there are no window expiration events inserted. Offline processing may reset from threshold crossing in the control channel.

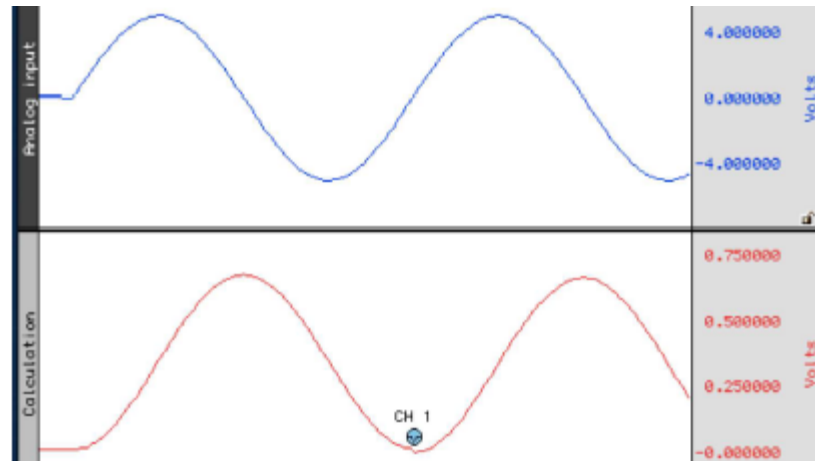
Max cycle period

The Max cycle period should be longer than the maximum time expected from trigger event to trigger event in the Control Channel. Typically, the default scale settings for cyclic integrated data will be fine.

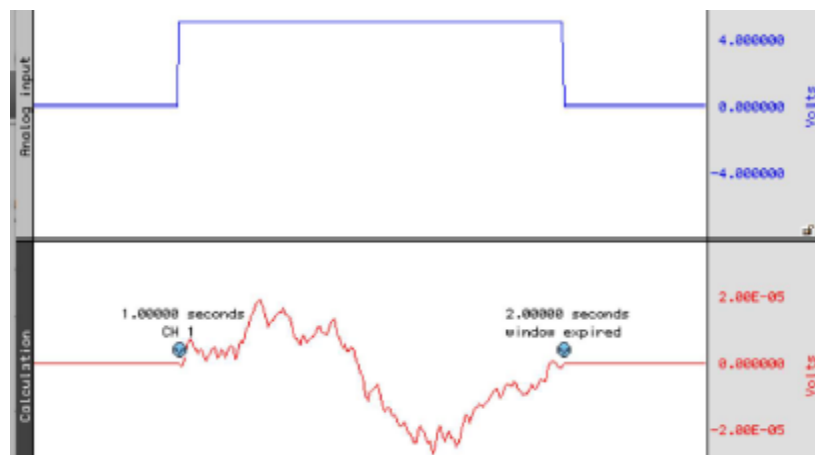
Output reset events—not available for metachannels

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

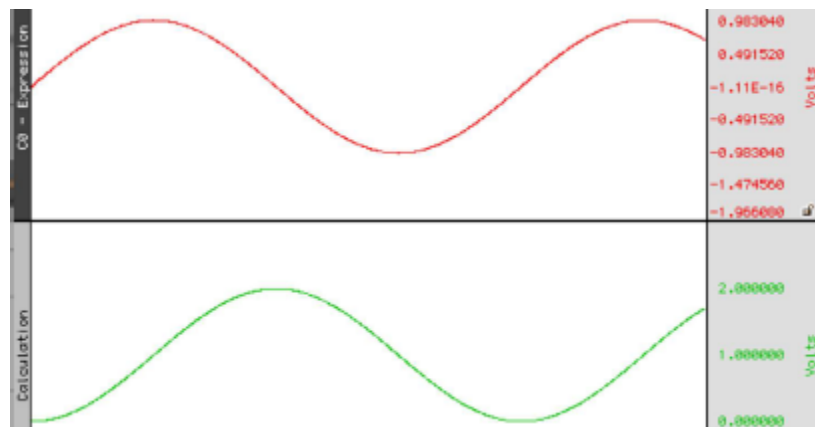
- Threshold crossing on the control channel
For example: Calculation channel resetting on positive crossings of 0V on CH 1.



- Window expiry when mean removal is enabled
For example: No threshold crossing within “mean cycle width” as specified in calc channel setup. Settings of calc channel: threshold crossings positive, 3V, Mean cycle subtraction, 1 second period width. First reset is due to threshold crossing; second reset is due to window expiry.

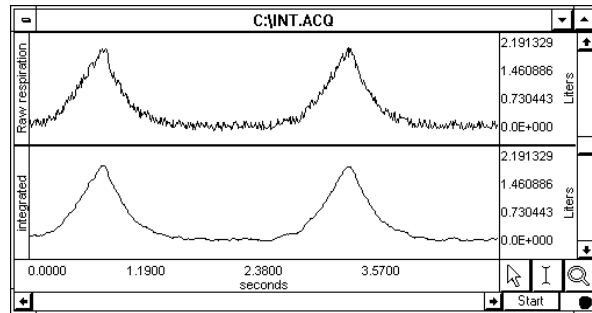


- Zero value due to “true” zero being achieved due to mathematical results
For example: Mathematical Source is sine wave, integral is cosine. Input (10V) never crosses threshold levels. Signal reaches zero mathematically; no reset events appear on output.



Average over samples (Integrate operation)

Online sample averaging can be useful when there is a high degree of noise present in the data. At least some of this noise can be “averaged out” by pooling some number of adjacent data points together, taking the average of these points, and replacing the original values with the new averaged values. This process creates a “window” of moving averages that moves across the waveform smoothing the data.



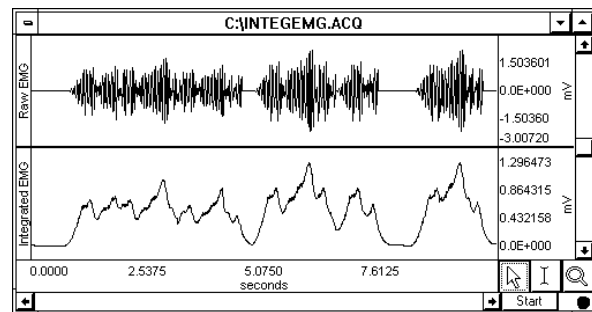
Integration used to smooth noisy data

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.



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

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

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

Remove baseline—provides the exact standard deviation of the input data (typically EMG) over the specified number of samples. When the mean of the input data equals 0-0, the standard deviation and the RMS will be equivalent.

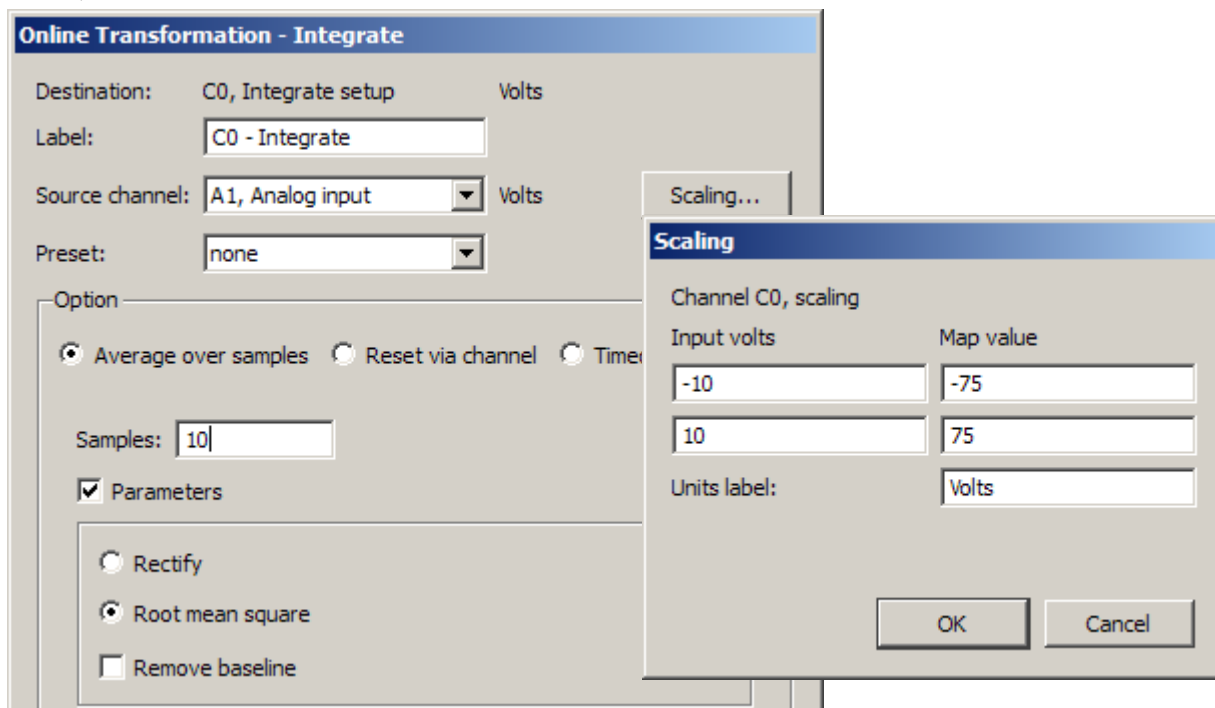
Scaling... button—Since the integration values are going to be on a different scale than the original units, you need to change the scale of the integration channel to reflect the new units. Click the Scaling... button, to generate the Change Scaling Parameters dialog.

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

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

As an example, if data was being acquired at 75 samples per second, and 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 Map (Scale) value of 75 and a Map (Scale) value entry of -75 reflected an Input value of -10 Volts.

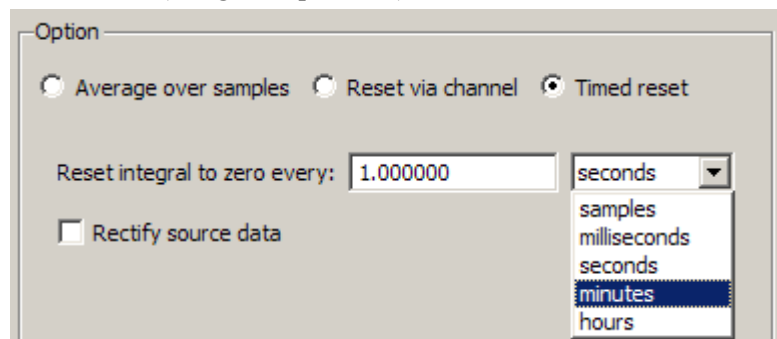
- It is important to note that this rescaling should be performed independent of any rescaling performed on analog channels themselves. Even if an analog channel is being rescaled to some other units, the input values in the integration scaling should be set to +10 Volts (next to Cal 1) and –10 Volts (next to Cal 2).



Integrate Calculation and Scaling dialogs for 10 point averaging

When data is averaged in this way, a portion of the data at the beginning of the record (equivalent to the number of samples being integrated) should be ignored, as they will reflect a number of zero values being averaged in with the first few samples of data.

Timed Reset (Integrate operation)



Timed Reset operation computes a straight sum of the source data points and resets this sum after a fixed amount of time has elapsed. This periodic integral is used in several types of analysis, such as EMG analysis where it can estimate the power in fixed time intervals.

The time interval at which the integral resets to zero may be specified in samples, milliseconds, seconds, minutes or hours.

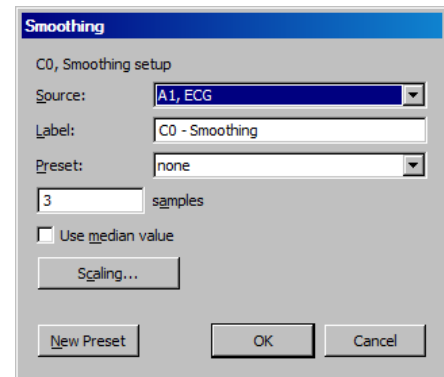
Timed reset functionality may also be used in calculation channel presets and by the Mac OS X Integrate automator action.

Smoothing Calculation

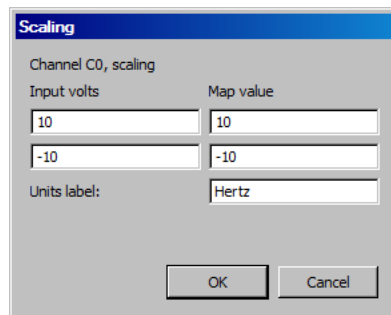
The Smoothing Calculation is useful for removing noise of varying types from a data set.

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the modified data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Smoothing.
5. Click the Setup button in the Input Channels dialog to generate the Smoothing dialog.

(Off-line Smoothing is available under Transform > Smoothing.)



Source	Source is a pull-down menu of the available channels.
Smoothing factor	enter the number of samples to use as a smoothing factor.
Smoothing method	This calculation channel provides real-time Mean (default) or Median smoothing.
<i>Mean value</i>	The default is mean value smoothing. Use Mean value smoothing when noise appears in a Gaussian distribution around the mean of the signal.
<i>Use Median value</i>	Click in the box to activate Median value smoothing if some data points appear completely aberrant and seem to be “wild flyers” in the data set. For a given sequence of wave data, $x = \{x_1, x_2, \dots, x_n\}$, Median value smoothing will sort the sequence and extract the median equivalent to the recommended NIST (National Institute of Standards and Technology) formula: <ul style="list-style-type: none"> • n is odd: median is the center element of the sorted list of n items. • n is even: median is the mean of the center pair of elements of the sorted list of n items. The smoothing calculation channel is the primary method of computing real-time median values using the definition of median as given above. The smoothing output at a sample position is the median of the window of source channel samples including the current sample and the previous samples in the window. The size of the window is 1 at the start of acquisition and increases incrementally until the final window size is reached. The median extraction method shifts between even and odd definitions as the window size is incremented.
Scaling	Click the Scaling button for access to options that allow you to modify the units or linearly scale the output.



Watch the [AcqKnowledge Smoothing video tutorial](#) for a detailed demonstration of this feature.

Difference Calculation

The Difference calculation returns the difference between two data samples over a specified number of intervals and divides the Difference by the time interval spanned by the data values. The Difference Calculation is useful for calculating an approximation of the derivative of a data set in real time.

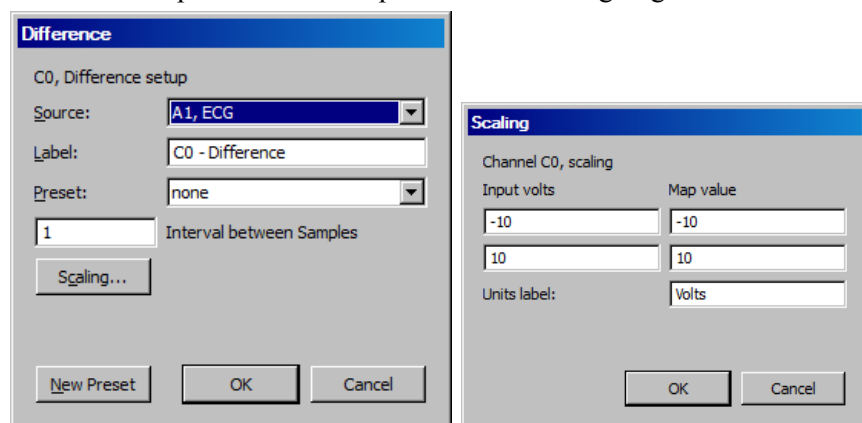
To have AcqKnowledge perform a Difference calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the modified data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Difference.
5. Click the Setup button in the Input Channels dialog to generate the Difference dialog.

(Off-line Difference is available under Transform > Difference.)

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 the Setup button in the Input Channels dialog to generate the Difference dialog:



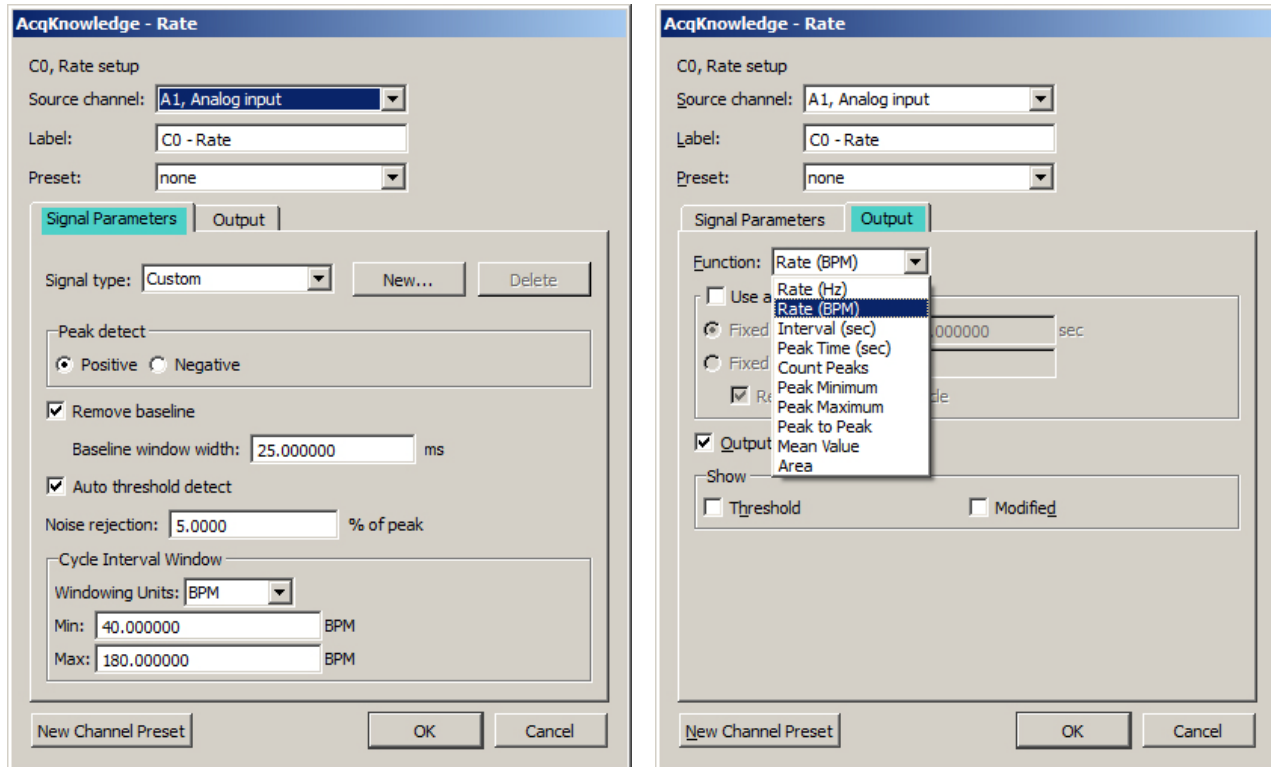
- Source** When the Source channel contains relatively high frequency data, the Difference Calculation may result in a very noisy response, so it's best to use Difference on relatively smooth data.
- Intervals** Difference is calculated with respect to the number of intervals between points (rather than the number of sample points). For instance, two sample intervals span three sample points:

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

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

✓ See page 307 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 default threshold value. This section describes the basic parameter settings for typical online Rate Calculations.

NOTE: Parallel functions can be performed after data has been acquired. A detailed description of the Rate Calculation options can be found in the Find Rate section on page 341.

To perform a Rate Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the modified data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Rate.
5. Click the Setup button in the Input Channels dialog to generate the Rate dialog.

(Off-line Rate calculation is available under Analysis > Find Rate.)

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

Label—Use to create a label for the Rate channel

Preset—Use to select from 17 pre-defined calculation channel presets. New presets affecting source channel, label and output settings can be created and saved by clicking “New Channel Preset.”

Signal Parameters Tab

Signal Type—Contains parameters for specific human and animal waveform morphologies. Choose from six pre-defined heart rate and respiration signal types, or click “New” to create and save custom setups. Unlike channel presets, all pre-defined and custom signal types appear in both calculation channel Rate (online) and analysis Rate (offline) dialogs. Signal type modifications affect settings in the Signal Parameters tab only. For more details on Rate signal types, see page 344.

Peak Detect—Choose whether to look for positive or negative peaks in the signal.

Remove baseline—provides the exact standard deviation of the input data (typically EMG) over the specified number of samples. When the mean of the input data equals 0-0, the standard deviation and the RMS will be equivalent.

Baseline window width—Width of the window for the difference operation applied prior to peak detection. (E.g. the value of the source x ms previously is subtracted from the current value to generate the signal that is analyzed with the peak detection.)

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

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.

Cycle Interval Window—When “automatic” Rate Calculations are set, specify a minimum rate and a maximum rate. These parameters define the range of expected values for the Rate Calculation. By default, these are set to 40 BPM on the low end and 180 BPM on the high end.

The Rate Calculation will use these values to find and track the signal of interest, assuming the input BPM range is reasonably well bracketed by these values. Depending on the shape of the input cycle waveform, the Rate window settings may be closer or further from the expected rates.

- For ECG-type data (where the waveform peak is narrow with respect to the waveform period), the Rate window values will closely bracket the expected values.
- For more sinusoidal data, with the waveform energy distributed over the waveform period (as with blood pressure or respiration), the Rate window will closely bracket the expected rate on the high-end, but can be up to twice the actual measured rate at the low-end.

One of the most frequent applications of the Rate Calculation is to compute BPM online for ECG, pulse, or respiration data. For more information on optimizing ECG amplifiers for online calculation of heart rate, see the ECG100C section of the *Hardware Guide*.

Windowing Units—Use to select the unit type to be used in the rate detection. The options are Hz, BPM and seconds.

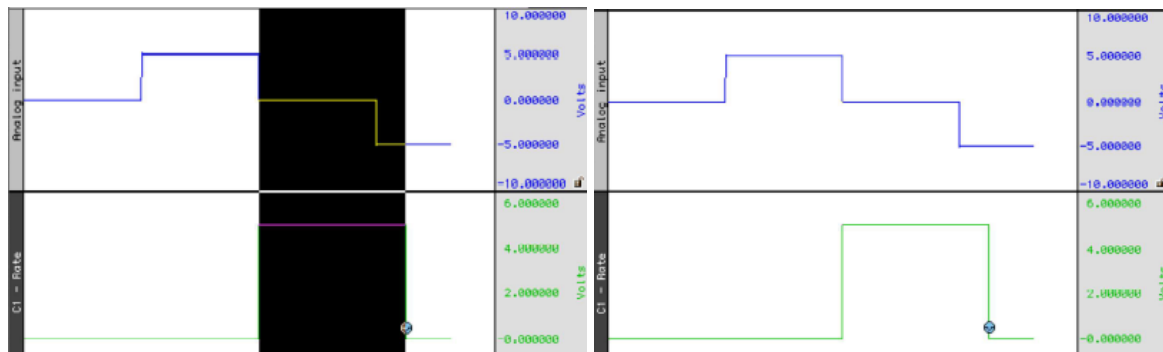
Output Tab

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

- For more information on each of these functions, see the Calculation Channels section beginning on page 122.
- Calculate systolic using the peak maximum Function, diastolic using the peak minimum Function, and mean blood pressure using the mean value Function.
- NOTE: All of these Function options are available in the post-acquisition mode through the Analysis > Find Rate function.

Use Averaging mode—Use to average the output of the selected function. Averages can be based upon a fixed time window or a fixed number of cycles. The ‘Recompute on every cycle’ option will start the averaging output after N numbers of cycles are detected and then remain fixed until the next N cycles are detected.

Output reset events (not available for metachannels)—When auto threshold detection is being used, the minimum and maximum rates of the signal are specified in the Windowing controls. If the input signal falls out of this range, the value of the rate function and automatic threshold level will be reset. By enabling “Output reset events” a reset event will be placed on the output at the location of these window expirations. Rate detector is set to “Peak function, default window of 40 BPM to 180 BPM, auto threshold detect for positive peaks. The reset event occurs after the window expiration, approximately a full 40 BPM interval after the “peak” transition from 0 to 5 volts in the source signal.



Show Threshold—Plots the threshold used by the Rate calculation function.

Show Modified—Plots the modified data as processed by the Rate Detector. Typically, the modified data is a differential version of the original input data. The data will be modified if the “remove baseline” feature is checked.

Math Calculation

The Math Calculation performs standard arithmetic calculations using two waveforms or one waveform and a constant. Calculation channels with lower channel numbers may be also used as a waveform.

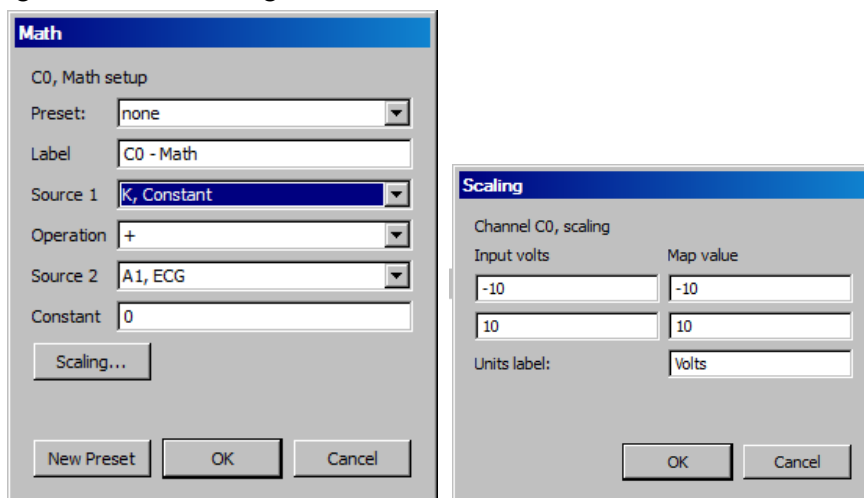
1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the modified data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Math.
5. Click the Setup button in the Input Channels dialog to generate the Math dialog.

(Off-line Math calculation is available under Transform > Waveform Math.)

Use the pull-down Source menus to select the source channels (Source 1 and Source 2).

The Sample rate line provides the sample rate for the channel selected as Source; the channel sample rate may be different than the acquisition sample rate.

Use the pull-down Operation menu to select a function. In the example below, analog channel 1 (Source: A1) is added to analog channel 2 (Source: A2). To use this summed waveform as an input for another Math Calculation channel. One useful application would be to divide this waveform (C0) by K, where $K=2$, thus producing an arithmetic average of source channels A1 and A2.



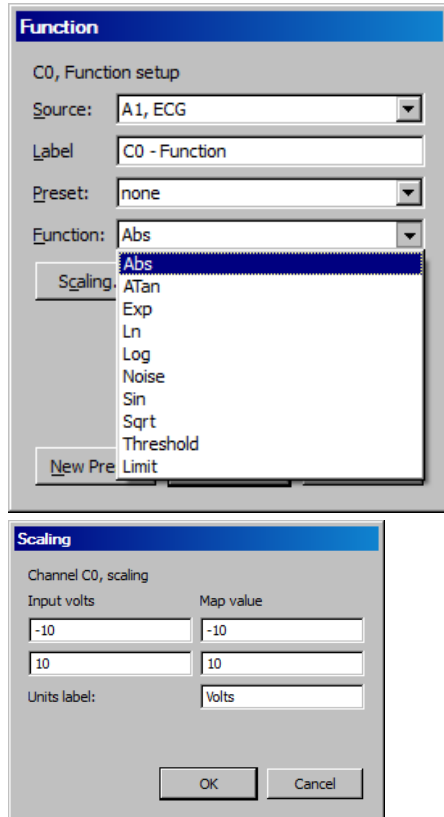
The “Constant” entry is activated when “K” is selected as a Source.

As an alternative to creating an additional Calculation channel for dividing the summed waveform, you can use the scaling function to perform the same task. To do this, click Scaling... button and then set the Map (Scale) value for the summed waveform equal to +5 and –5 (to correspond to Input Volts values of +10 and –10 respectively). This will effectively plot the sum of channels A1 and A2 as the arithmetic mean of the two waveforms.

For additional information, see the sections on Function Calculation channels (page 138) and online Expression, page 141).

For complex calculations (such as squaring a waveform then adding it to the average of two other waveforms,) Expression is a more efficient solution. These calculation channels allow more complex operations. Metachannels (page 123) allow the user to chain multiple calculation channels together.

Function Calculation



The Function calculation can be used to perform a variety of mathematical functions to a single waveform. Like math Calculation channels, function Calculations can be chained together to produce complex functions (such as taking the absolute value of a waveform on one channel and Calculating the square root of the transformed waveform on another channel). These same functions are also available under the transform menu in *AcqKnowledge* for *post-hoc* operations. Many of these functions can also found in the online Expression, see page 141 for details).

To have *AcqKnowledge* perform a Function Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the modified data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Filter.
5. Click the Setup button in the Input Channels dialog to generate the Function dialog.

(Off-line Function calculation is available under Transform > Math Functions.)

Other mathematical Functions are available in the online Expression (see page 141). Function Calculations can be chained together to produce more complex Calculations, although it is more efficient to program complex functions using the Expression calculation.

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

Function

Abs	Returns the absolute value of each data point
Atan	Computes the arc tangent of each data point
Exp	Takes the e^x power of each data point
Limit	Limits or "clips" data values that fall outside specified boundaries
Ln	Computes the base e logarithm for each data point
Log	Returns the base 10 logarithm of each value
Noise	Creates a channel of random noise with a range of ± 1 Volt
Sin	Calculates the sine (in radians) of each data point
Sqrt	Takes the square root of each data point.
Threshold	Converts above an upper threshold to +1 while converting data below a lower threshold to 0.

Thresholding Algorithm Assume a domain variable $t \in \{t_{start}, t_{start} + 1, t_{start} + 2, \dots\}$

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 $y_{low} \leq y_{high}$.

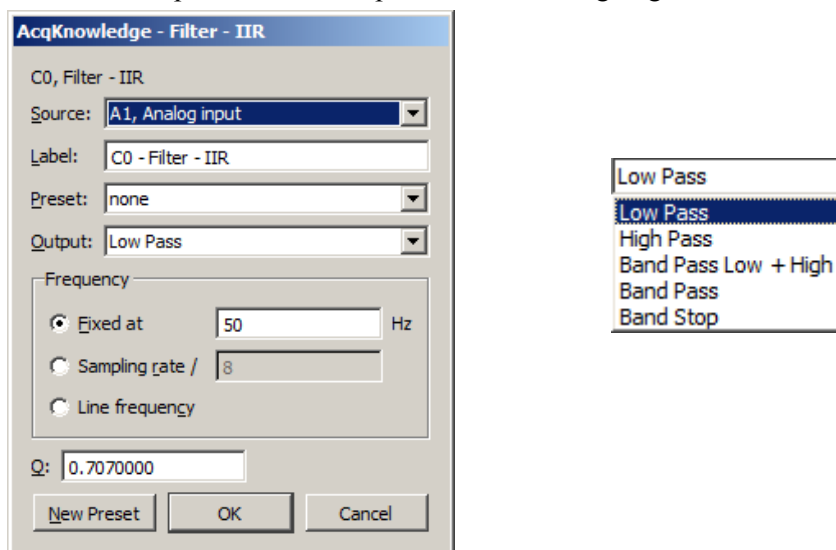
Define the Threshold function $thresh(t)$ function such that:

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

Filter IIR Calculation

The Filter IIR Calculation channel allows you to perform real time digital filtering on analog, digital, or calculation channels. To have AcqKnowledge apply a digital Filter IIR Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Filter.
5. Click the Setup button in the Input Channels dialog to generate the Filter dialog.



Filter Setup & Output Options

In the dialog above, the signal on analog channel one (A1) is run through a low-pass filter that attenuates data above 50 Hz. The “Q” for this filter is 0.707, which is the default.

One possible application of the online filtering option is in conjunction with the Show Input Values option (see page 232). Raw EEG data, for instance, can be filtered into distinct bandwidths (alpha, theta, and so forth) using one source channel and multiple filter Calculation channels. The filtered data can then be displayed in a bar chart format during the acquisition using the Show Input Values option.

Source	Set the source channel.
Sampling rate	Select this to compute the frequency at the start of acquisition as a fraction of the channel sample rate. (Unselected by default.)
Type (Output)	Lists the filter options: low pass, high pass, band pass, band pass (low + high), band stop, and comb band stop. See <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—Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified. Line frequency—Uses the line frequency at which the data was recorded.
Q coefficient	The online IIR have a variable Q coefficient. The Q value entered in the filter setup box determines the frequency response patterns of the filter. This value ranges from zero to infinity, and the “optimal” (critically damped) value is 0.707 for the Low pass and High pass filters, and 5.000 for the Band pass and Band stop filters. If you wish, you may change the Q. A more detailed explanation of this parameter and digital filters in general, can be found in Appendix B.

About Filters

While the technical aspects of digital filtering can be quite complex, the principle behind these types of filters is relatively simple. Each of these filters allows 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 50 Hz (with the default $Q=5$) would be 10 Hz. This type of filter, although functionally equivalent to the band pass (low + high) filter, is most effective when passing a single frequency or narrow band of data, and to attenuate data around this center frequency.

- The Band Stop performs the opposite function of a band pass. A Band stop filter defines a range (or band) of data and attenuates data within that band. In this case, the Band stop filter is implemented in much the same way as the standard Band pass, whereby a center frequency is defined and the Q value determines the width of the band of frequencies that will be attenuated.
- The Comb Band Stop removes interfering harmonics; resonance, aliasing, and other effects may generate interference at multiples of a base frequency. It combines all the required filters instead of requiring a separate filter for each interfering overharmonic. For setup details, see page 289.

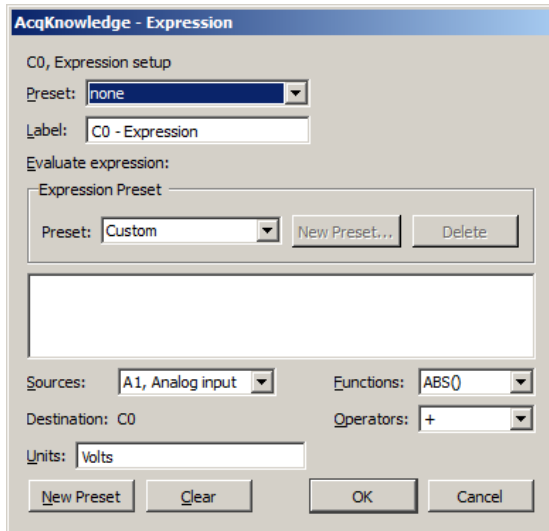
Off-line filtering

Apart from these online filter options, similar filters can be applied after an acquisition is terminated via the Transform > Digital Filters menu. Many of the biopotential amplifiers available from BIOPAC have selectable filters, which allow you to filter certain frequencies (including 50 Hz or 60 Hz electrical noise) and possibly reduce the need for online filters.

Digital filtering can also be performed after an acquisition using the same types of filters. 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 283 or Appendix B.

Expression



The online Expression calculation channel is available for performing computations more complex than possible in the Math and Function calculations, and is additionally available as an offline transformation and a measurement. (Different attributes may apply to each available Expression type.) The Expression calculation will symbolically evaluate complex equations involving multiple channels and multiple operations. *AcqKnowledge* can perform conditional evaluation, data extraction, logical operations, expressions requiring a range of samples or the results of the previous expression, and evaluation of generic formulas that can be expressed in a closed, recursive form.

Unlike the Math and Function calculations—which can only operate on one or two channels at a time—the Expression calculation can combine data from multiple analog channels, and allows you to specify other Calculation channels as input channels for Equation channels. Also, computations performed by the Expression calculation eliminate the need for “chaining” multiple channels together to produce a single output channel.

While the Expression calculation is more powerful than other Calculation channels, each Expression calculation requires more system resources than other Calculations. This essentially means that acquisitions that utilize Equation calculations are limited to a lower maximum sampling rate than acquisitions without online Expression functions. When an expression is evaluated, it is actually evaluated multiple times. The expression is computed starting at the first sample acquired, and is then evaluated once for each successive acquired sample.

AcqKnowledge can accept the notations **SC**, **MC**, and **CH n** to reference the sample at the current evaluation position or **SC(x)**, **MC(x)**, and **CH n (x)** for values at locations prior to the present evaluation location using an offset expressed in sample intervals. For example, CH1(-1) will give the previous sample of Channel 1.

The same features that are available in online Calculation channels are also available under the Transform menu for evaluation of complex equations after acquisition. Thus, simple Calculations such as summing two channels or finding the absolute value of a channel (and so forth) are best performed in either the Math calculation channels or the Function calculation channels.

On the other hand, for complex Calculation channels, such as squaring one channel, multiplying it by the sum of two other channels, and dividing the product by the absolute value of another waveform, a single Expression calculation channel is more efficient than chaining five Math and Function calculation channels.

Save to Calculation Channel

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

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the modified data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Expression.

5. Click the Setup button in the Input Channels dialog. This will produce a dialog, where you can enter the expression to be evaluated.

(Off-line Expression is available under Transform > Expression.)

The different components of each expression can be entered either by double-clicking buttons from the button rows (sources, functions, and operators) in the setup expression dialog, or by typing commands directly into the Equation box. The Expression calculation uses standard mathematical notation.

For each expression, 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 Expression calculation channel, it is important to keep in mind that while different channels, functions, and operators can be referenced, the Calculation cannot reference future sample points. 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 309) for ways around this limitation.

Functions	The arguments to each function are represented in the Functions table in italics and may be replaced by any valid expression. Each argument is separated from its next argument by a comma. Expressions can only contain commas within balanced parenthesis pairs. An ellipsis (“.”) at the end of a function description indicates that any number of arguments may be present provided they are in a comma separated list. When a function is added to an Expression, the cursor is placed between the parentheses.
Conditionals	Change output based upon a condition test. All of the conditionals treat the value zero as false and any non-zero value as true. Expressions can only contain commas within balanced parenthesis pairs.
Offset Notation	<p>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 Expression calculation channel will result in an error.</p> <p>CH<i>n</i>(<i>x</i>) Returns the value of channel with index <i>n</i> <i>x</i> samples away from the current evaluation position.</p> <p>SC(<i>x</i>) Returns the value of the selected channel <i>x</i> samples away from the current evaluation position. Only allowed for Transformations and Measurements; not allowed for Calculations.</p> <p>MC(<i>x</i>) When <i>x</i> is zero or positive, returns the value of the measurement channel <i>x</i> samples away from the current evaluation position. When <i>x</i> is negative, returns the result of the expression evaluation that occurred <i>x</i> steps previous to the current evaluation position. Only allowed for Measurement Expressions (see below); not allowed for Calculations or Transformations.</p>

Recursive notation Since transformations and calculation channels replace the source data of the channel with the result of the expression evaluation in sequence, negative offsets are equivalent to returning the final result of the expression that was evaluated a certain number of steps in the past. The channel where the expression results are stored can be thought of as a storage record of the previous evaluation steps. Negative sample offsets, therefore, can be used to compute any formula that can be expressed in closed recursive form. For example, the recursive definition of the Fibonacci sequence is:

$$F_n = F_{n-1} + F_{n-2}$$

To evaluate this as an expression transformation, use the expression:

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

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

**Expression
Measurement**

Measurements are powerful tools for quick manual analysis and also for advanced automated analysis when combined with the Cycle/Peak detector. Expression measurements extend measurements to evaluate simple formulas or complex data reduction. Each Expression measurement has an expression associated with it and the measurement result is derived from computing the Expression(s) on the selected data.

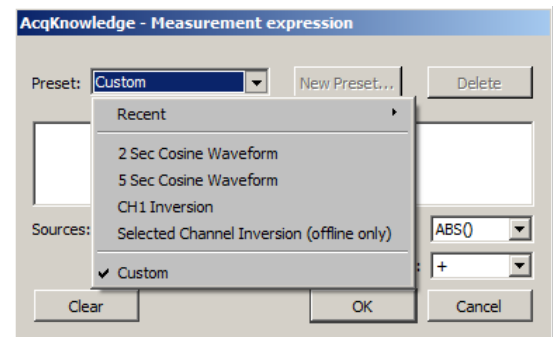
Measurement expression dialog is generated the first time a measurement is set to Expression or when the measurement preset button is clicked.

Preset menu allows access to pre-loaded commonly used expressions and displays user-defined custom presets, along with a list of recently-used expressions.

OK invokes a syntax check. If there is an error, the user will be prompted to correct the error and the error will be selected (highlighted) in the Expression edit field.

Cancel discards any changes to the Expression measurement and reverts back to the previous Expression.

Clear erases the current contents of the expression edit field.



Measurement Channel

Expression measurements can reference the “measurement channel” (MC), which refers to either the selected channel or a specific channel as set in the measurement channel selection box within the graph window.

Negative sample offsets to MC are interpreted as returning the result of the Expression from a prior step. Transformations and calculation channels achieve this as they replace the contents of their destination channels sequentially. Measurements, however, do not actually replace the data of their source channels. Expression measurements are actually executed on a temporary copy of the channel data in memory. This implies that negative 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

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 Expression and Waveform Math functions will constrain operations between waves of different rates as follows:

If an equation is operating on two or more waves of different sample rates, the result of the operation will always be output at the lowest sampling rate from the waves (Flow). If the destination channel for the result has an assigned rate other than (Flow), the operation will not be permitted. If the destination channel is set to a new channel, the operation will always be permitted.

In *AcqKnowledge* 4 and higher, all sources for Expressions and Waveform Math operations must be sampled at the same waveform sampling rate.

VSR data padding—If the channels are of unequal length (as a result of variable sampling rate or waveform editing), they will be padded for Append acquisition. Digital and Analog channels are stored as short integers by default; a waveform paste into a digital or analog channel, however, will result in its underlying data being converted to floating point. This will generate the “Abort/Replace” warning for pastes to Digital or Analog channels since the data format has changed since the last acquisition.

Additionally, if an Analog or Digital channel is used as the source waveform for a Copy, it will also be converted to floating point and will result in the “Abort/Replace” warning being generated.

Since Calculation channels are already floating point, pasting into them or copying from them will not change their data format. The channels will be padded with their last value and the append will commence.

Waveform Cut operations do not change the underlying data format for Analog, Calculation, or Digital channels. If only Waveform Cut is used, no data format conversion will occur and channels will be padded with their last value and subsequent appends are allowed.

Source	Description
ACQLENGTH	<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>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
Segment Timer	Used as a source for the onscreen Stopwatch gauge view.
Random	Generates random white noise.
Gaussian Random*	Generates Gaussian white noise for startle responses. Returns a random value from a Gaussian distribution.

*Standard Gaussian model; useful for peak fitting.

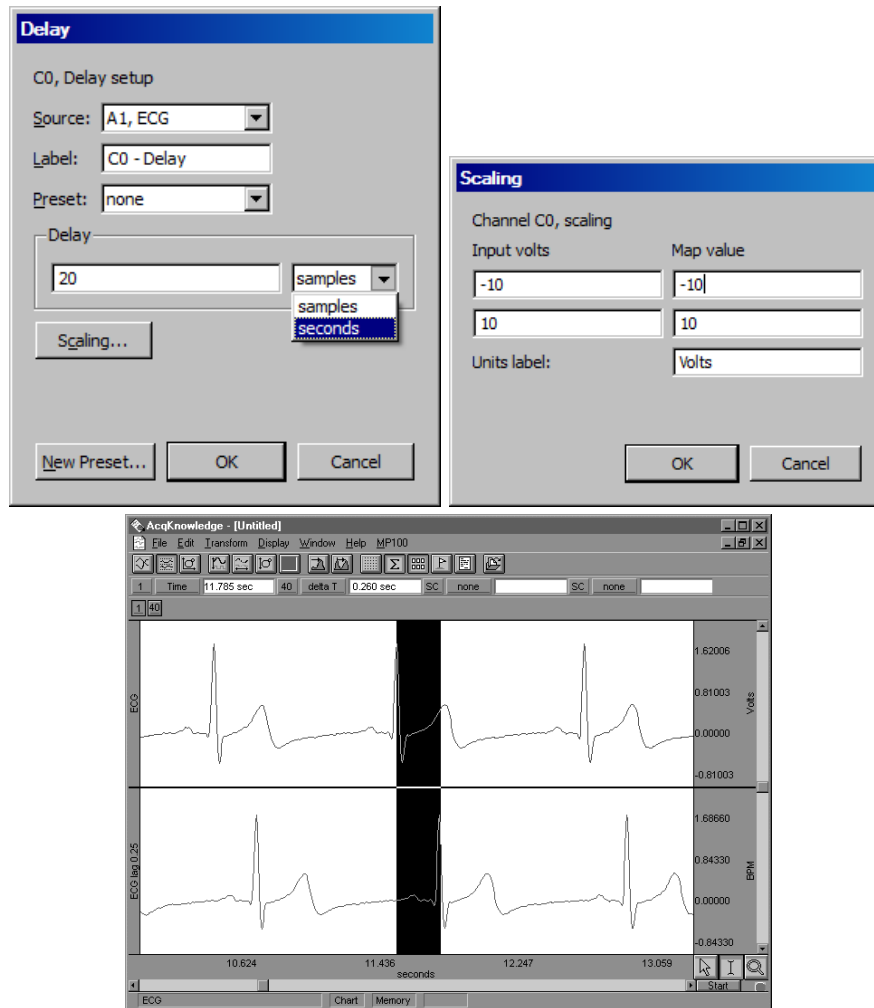
$\text{param}(0) * \text{EXP}(-((\text{TIME} - \text{param}(1)) / \text{param}(2))^2)$

Operator	Operation
+	Addition
-	Subtraction
*	Multiplication
/	Division
^	Power
(Open parentheses
)	Close parentheses

FUNCTION	RESULT
ABS	Returns the absolute value of each data point.
ACOS	Computes the arc cosine of each data point in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
AND(x, y, ...)	Computes a logical "and" operation for its arguments. Accepts up to eight (8) arguments and evaluates to 1 if all of its arguments are non-zero values. 0 if one of its arguments is zero.
ASIN	Calculates the arc sine of each value in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
ATAN	Computes the arc tangent of each sample point in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
CEIL(x)	Computes the ceiling function (the closest integer larger than the value x).
COND(T, A, B, C)	Three-way conditional takes four arguments: COND(<i>test_expr</i> , <i>neg_test_value</i> , <i>zero_test_value</i> , <i>pos_test_value</i>) Evaluates test_expr and if < 0, returns neg_test_value = 0, returns zero_test_value > 0, returns pos_test_value
COS	Returns the cosine of each data point in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
COSH	Computes the hyperbolic cosine of each selected value
EQUAL(x, y, ...)	Performs a Logical equal (numerical comparison) of its arguments. Accepts up to eight (8) arguments and evaluates to 1 if all of its arguments are equal. 0 if one of its arguments is not equal to the others.
EXP	Takes the e^x power of each data point..
FLOOR(x)	Computes the floor function (the closest integer less than the value x).
IF(T, A, B)	Two-way conditional takes three arguments: IF(<i>test_expr</i> , <i>true_value_expr</i> , <i>false_value_expr</i>) 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.

LOG	Computes the natural logarithm of each value
LOG10	Returns the base 10 logarithm of each value
FUNCTION	RESULT
MAXIMUM	Returns the maximum value of all input arguments.
MINIMUM	Returns the minimum value of all input arguments.
NOT(x)	Computes a logical negation of its argument. Evaluates to 1 if x is zero. 0 if x is non-zero.
OR(x, y, ...)	Evaluates multiple variables; true if any are true. Computes a logical “or” operation for its arguments. Accepts up to eight (8) arguments and evaluates to 1 if any one of its arguments is non-zero. 0 if all of its arguments are zero.
ROUND(x)	Returns an integer closest in value to the argument. For example: round (2.4) = 2 round(2.5) = 3 round(-1.5) = -1 round(-1.6) = -2
SIN	Calculates the sine (in radians) of each data point. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
SINH	Computes the hyperbolic sine for each sample point.
SGN	Performs the ‘sgn’ sign extraction function. Evaluates 1 if $x > 0$, -1 if $x < 0$, and 0 if $x = 0$.
SQR	Squares each data point.
SQRT	Takes the square root of each data point.
TAN	Computes the tangent of each sample point in radians. (All trigonometric functions use 'radians' as the unit of angle for input or output as appropriate.)
TANH	Calculates the hyperbolic tangent of each sample point.
TRUNC(x)	Removes the fractional part of the number and returns an integer. For example: TRUNC(2.4)= 2 TRUNC(2.5)= 2 TRUNC(-1.5)= -1 TRUNC(-1.6)= -1 <i>Note</i> When used with scientific notation, TRUNC(x) applies only to the fractional portion after the exponential factor is taken into account: TRUNC(2.93E+4) = TRUNC(29300) = “29300.” Since 2.93e+4 (29,300) has no fractional portion, the number is returned unchanged. Similarly, TRUNC(2.931245E+4) = TRUNC(29312.45) = “29312.”
XOR(x, y, ...)	Logical exclusive OR; true if an odd number is true. Computes a logical “exclusive or” for its arguments (e.g. “one or the other, but not both”). Accepts up to eight (8) arguments and evaluates to 1 if an odd number of its arguments are non-zero. 0 if an even number of its arguments are non-zero or if none of its arguments are non-zero.

Delay Calculation



Delay setup dialog and resulting graph showing a 20 sample delay

This option allows you to use a Calculation channel to plot another channel lagged (delayed) by an arbitrary interval. To have AcqKnowledge apply a Delay Calculation in real time:

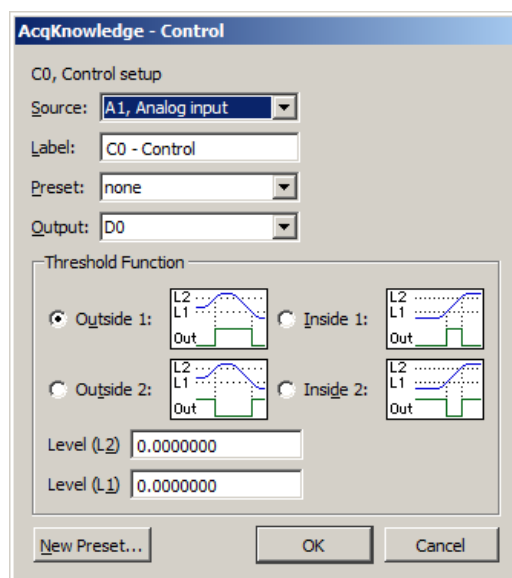
1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the modified data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Delay.
5. Click the Setup button in the Input Channels dialog to generate the Delay dialog.

(Off-line Delay is available under Transform > Delay.)

The delay interval can be specified either in terms of samples or seconds. These types of plots are useful for producing non-linear (“chaos”) plots in AcqKnowledge’s X/Y display mode (see page 38 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 above, the delay channel contains a 0.25-second interval of zeros at the beginning of data file.

Control Calculation



The Control function is used to output a digital pulse when the value for a specified input channel exceeds a certain level, falls inside a given range, or falls outside a given range. This feature is unique in that the output is on a digital channel (which ranges from I/O 0 through I/O 15) rather than a Calculation channel. Also, unlike other Calculation channels, this Control Calculation can only be performed in real time (i.e., while data is being acquired) and cannot be performed in post acquisition mode.

In addition to outputting a signal on a digital channel, the Control Calculation will also plot an analog version of the digital signal on the 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 Hardware unit and acquired as well as being connected to any external devices. The calculation channel values are not guaranteed to precisely match the actual digital output.

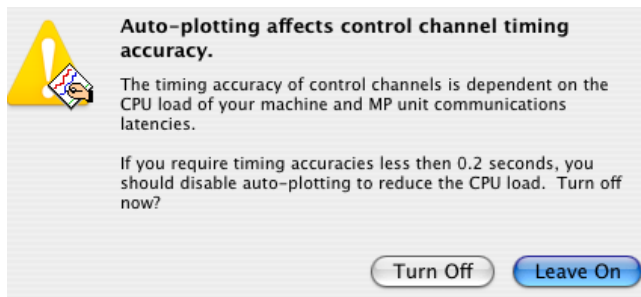
To have AcqKnowledge apply a Control Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the modified data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Control.
5. Click the Setup button in the Input Channels dialog to generate the Control dialog.

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

- | | |
|-------------------|-------------------------------|
| a) Source channel | 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.



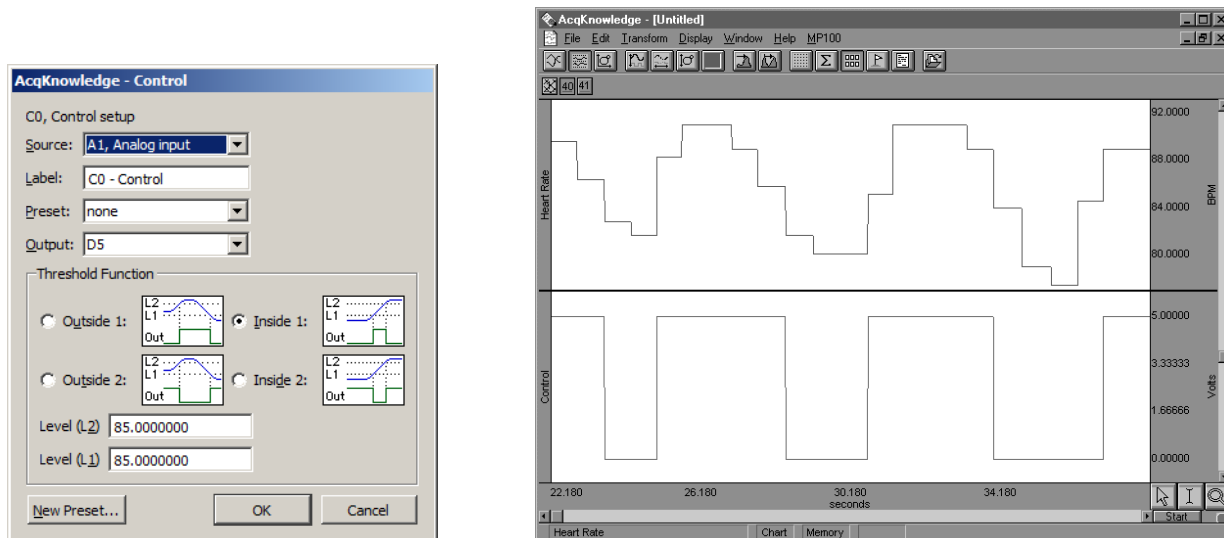
The channel selected in the Output Channel section determines which digital channel the pulse will be sent to. The digital channels range from 0 to 15 (D0 through D15) and external devices can be connected as described in the section on UIM100C connections in the *Hardware Guide*. In the sample dialog shown, the digital pulse is sent over I/O line D0.

Digital channels have two levels, 0 Volts and +5 Volts. When the signal transits from 0 Volts to 5 Volts, an “edge” is created and since the signal is going from low to high, this is referred to as a positive edge. Similarly, as the signal transits back from 5 Volts to 0, a negative edge is created. These transitions or edges can be used to trigger external devices when an analog signal level meets certain threshold criteria.

The Threshold Function option sets the criteria for the Control channel. 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 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.

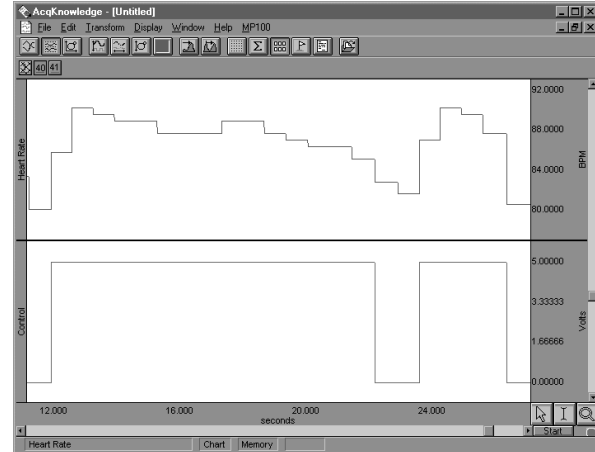
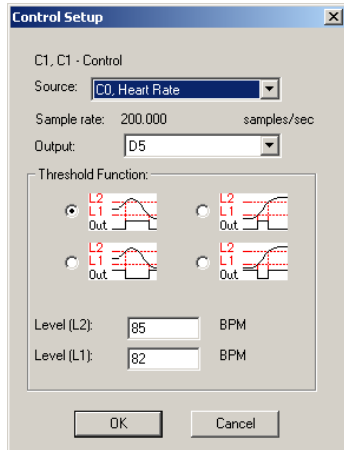
For example, suppose you want to set a Control channel to switch digital line 5 from low to high whenever the signal for Calculation channel one (C0) exceeds 85 BPM. Set the source channel to C0 and the output to D5. Select the upper right graph in the control dialog and set L2 and L1 to 85, as shown:



Control dialog and graph showing result of BPM control example

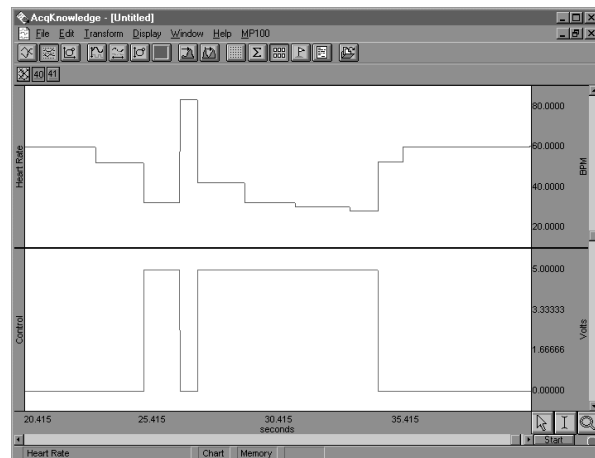
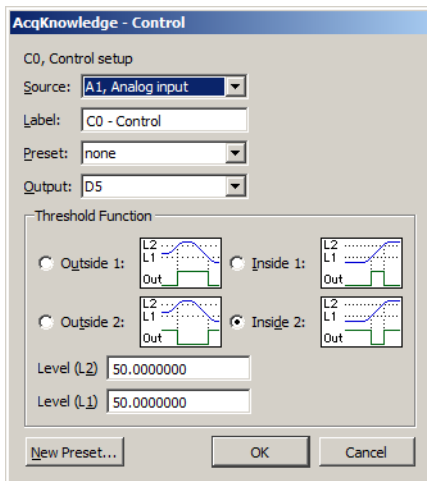
As you can tell from the preceding graph, there are a number of instances where C0 (heart rate) exceeds 85, usually for a short period of time. When it does drop below 85, it appears to return to a value greater than 85 within a second or two. In instances such as this, it might be useful to “widen”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

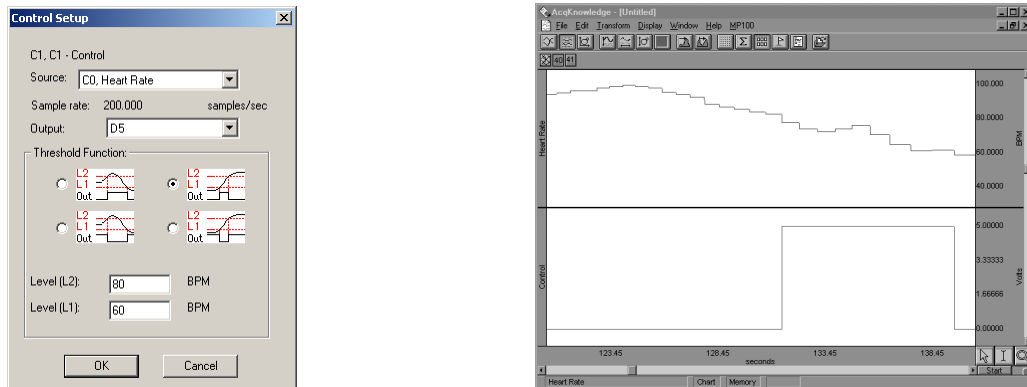


Control dialog and graph showing control channel detecting source channel levels less than 50 BPM

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.

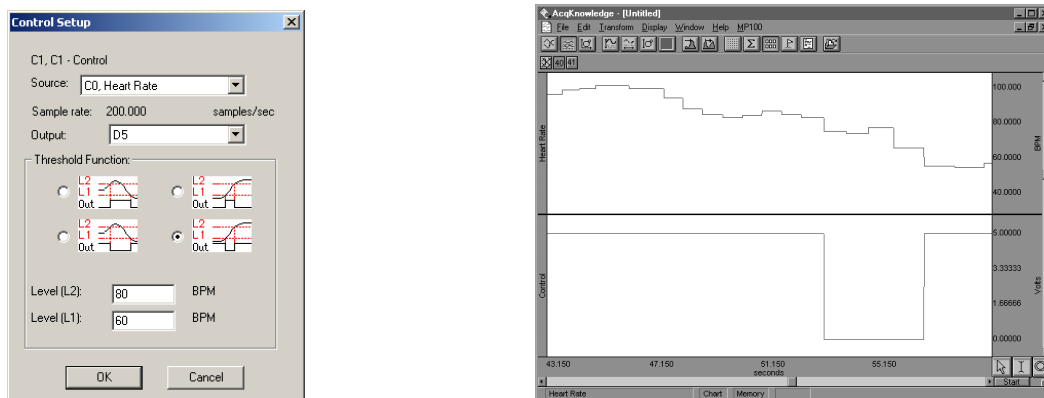
(For a description of how to connect various digital devices, see the section on UIM100C connections in the *MP Hardware Guide*.)

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).



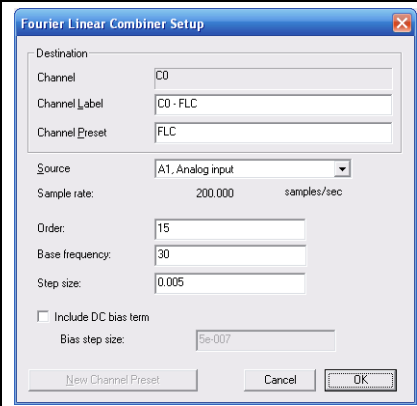
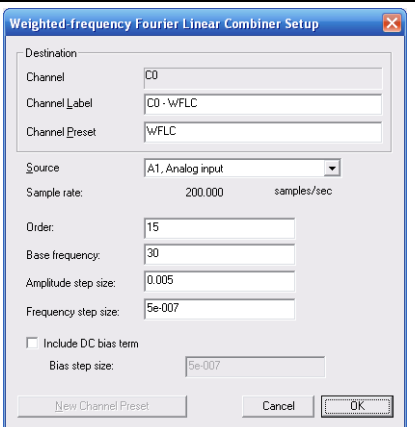
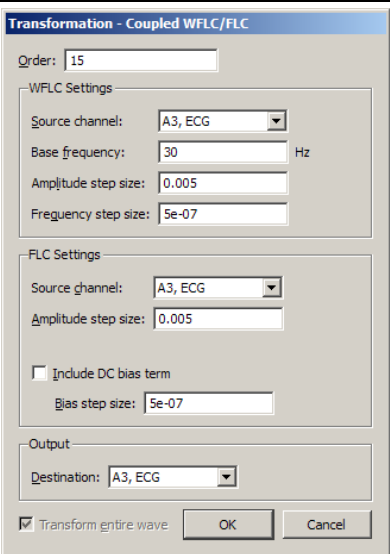
Control dialog and graph showing control channel switching from high to low when source channel is between 60 BPM and 80 BPM

Fourier Linear Combiners: FLC, WFLC, CWFLC Calculations

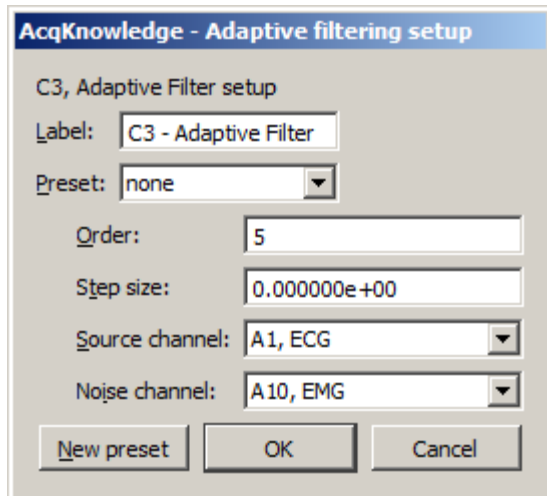
Fourier Linear Combiners are linear combinations of adaptable sinusoidal functions that are particularly well suited to processing cyclic data. Sine and cosine are harmonics that are multiples of a *base frequency* that are summed together, and the *order* is the fixed number of harmonics used in the 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.

To have AcqKnowledge apply an FLC Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
 2. Click the Calculation tab.
 3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
 4. Click the Preset pull-down menu and select FLC, WFLC, or CWFLC.
 5. Click the Setup button in the Input Channels dialog to generate the appropriate dialog.
- For offline calculation, see FLC Transform options, including *Scaled FLC*, on page 292.

		
<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



Adaptive filtering is a signal processing technique that processes two different signals in relation to one another and can be used for noise estimation, noise reduction, general-purpose filtering, and signal separation. Adaptive filtering creates efficient high-quality filters with a minimal number of terms, which can be very useful in blocking mains interferences or other known periodic disturbances.

- Useful for noise filtering where it is possible to acquire a signal that is correlated to the noise (similar to the way noise-cancelling headphones detect and remove outside noise). Applications include removing EMG from ECG or EOG from EEG.

➔ See the Adaptive Filtering transform on page 289.

To have *AcqKnowledge* apply an Adaptive Filtering Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Adaptive Filtering.
5. Click the Setup button in the Input Channels dialog to generate the Adaptive Filtering dialog.

The weights within an adaptive filter are modified on a step-by-step basis. *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 <i>mu</i> , the rate of adaptation of the coefficients within the FIR filter.
Source channel	The source channel will be replaced by the adaptive filter results.
Noise channel	The noise channel is the signal that is correlated with the noise to be eliminated from the Source; it is not modified by adaptive filtering.

Source and Noise channels must have the same channel sampling rate (under Channel Set Up).

Comb Band Stop Filter Calculation

To have *AcqKnowledge* apply a Control Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Comb Band Stop.
5. Click the Setup button in the Input Channels dialog to generate the Comb Band Stop dialog.

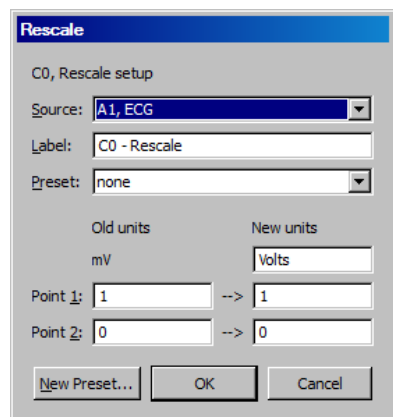
See page 139 for details.

(Off-line Comb Band Stop filter is available under Transform > Digital Filters > Comb Band Stop. See page 289.)

Metachannel

See Metachannel details on page 123.

Rescale Calculation



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

To have *AcqKnowledge* apply a Rescale Calculation in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull-down menu and select Rescale.
5. Click the Setup button in the Input Channels dialog to generate the Rescale dialog.

(Off-line Rescale is available under Transform > Rescale.)

- Use the Rescale transformation (after acquisition) to adjust forgotten calibration of analog channels or reverse incorrect calibrations.
- A "Rescale" Automator action has been added to allow rescaling to be performed in workflows. The Automator function is accessed from the Workflow menu in the Mac version of *AcqKnowledge*. (Not applicable to Windows.)

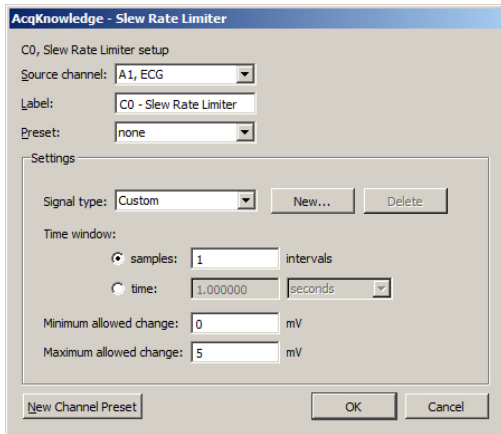
The rescale formula is:

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

Rescale Source	Displays the label and number of the selected channel.
Old Units	Displays the values of the current vertical units of the channel
New Units	Allows for manual entry of the new units to be used. The new units will be displayed in the vertical units of the channel

Note Transform > Rescale: The units cannot be modified when transforming from the selected area because it is not possible to display different vertical units for different time ranges in the same channel.

Slew Rate Limiter



Slew Rate Limiter is an effective tool for signal separating, denoising and removing motion artifact during and after recording. The algorithm restricts the rate of change of a signal to a specific time window or sample width window. The allowable amount of motion artifact over a given time/sample window can be precisely adjusted from a minimum allowable change to a maximum allowable change, thereby eliminating artifacts that exceed the selected amplitude range within a given time period.

The slew rate limiter algorithm restricts the rate of change of a signal to a specific window. If two different types of signals with significantly differing rates of change are mixed together, limiting the allowable rate of change of the mixed signal allows for signal separation by reducing the impact of a fast moving signal on a slow one (and vice versa). The slew rate limiter formula is:

Assume a mixed signal y . Define a time window width w . Define the minimum allowable change in amplitude over the time window w as $K_{max} \geq 0$ and a maximum allowable change in amplitude as $K_{max} \geq 0$ where $K_{max} \geq K_{min}$. The slew rate limiter function is then defined as:

$$slf(y, t) = \begin{cases} t < w & y(t) \\ t \geq w \wedge |y(t) - slf(y, t-w)| < K_{min} \wedge y(t) = slf(y, t-w) & slf(y, t-w) + K_{min} \cdot sgn(random) \\ t \geq w \wedge |y(t) - slf(y, t-w)| < K_{min} \wedge y(t) \neq slf(y, t-w) & slf(y, t-w) + K_{min} \cdot sgn(y(t) - slf(y, t-w)) \\ t \geq w \wedge |y(t) - slf(y, t-w)| > K_{max} & slf(y, t-w) + K_{max} \cdot sgn(y(t) - slf(y, t-w)) \\ t \geq w \wedge K_{min} < |y(t) - slf(y, t-w)| < K_{max} & y(t) \end{cases}$$

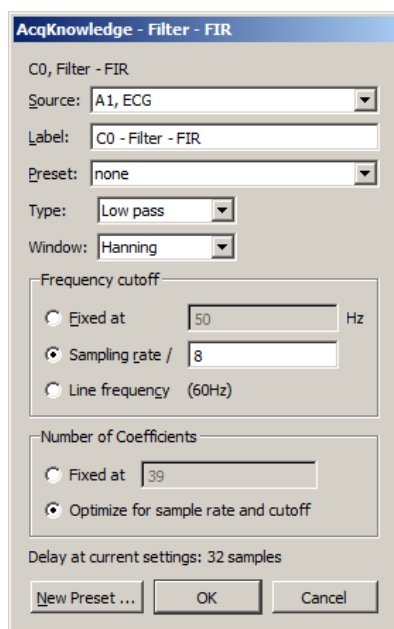
where sgn is the standard mathematical sign function and is used to preserve the relative direction of the change in the signal and $random$ is a pseudorandom non-zero number used to avoid the singularity where sgn is zero, enforcing that the rate of change will not drop below K_{min} .

The slew rate limiter may be applied in real time as an online calculation channel, or in post-processing via the Transform menu (see page 311). As with all online and offline transformations, signal type settings can be saved as custom presets by clicking the “New...” button and naming the new preset.

To have AcqKnowledge apply the Slew Rate Limiter in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check an Acquire box for the Calculation channel you want to contain the filtered data. You may also check the Plot and Values boxes as appropriate for each channel.
4. Click the Preset pull down menu and select Slew Rate Limiter.
5. Click the Setup button in the Input Channels dialog to generate the Slew Rate Limiter setup dialog.
6. Set the desired time window to apply the slew rate limiter algorithm based on seconds or samples.
7. Set the minimum and maximum allowed change to adjust the sensitivity to motion artifact.
8. Click OK and run the acquisition. Any artifact that falls outside the boundaries of the maximum/minimum allowed change setting will be eliminated from the recorded data.

 Watch the [AcqKnowledge Slew Rate Limiter video tutorial](#) for a detailed demonstration of this feature.



Filter - FIR

In *AcqKnowledge* 4.4 and higher, FIR Filters are available as an online calculation channel. Until recently, real-time FIR filtering during acquisition wasn't feasible due to processing power limitations, but these constraints are no longer an issue for modern dual-core and quad-core processors.

Online FIR filters are similar to their offline transformation menu counterparts with the exception of the following convention.

Delay at current settings: For FIR filtering in general, a delay is imposed on the output signal, and this parameter shows the number of delay samples the current settings will introduce. If the number of coefficients is fixed, the delay value will equal the number in the "Fixed" editable field. If the number of coefficients is set to be optimized for sample rate and cutoff, the delay value will vary. The filter algorithm compensates for this delay in order to assure proper alignment of filter output with the acquired signal.

When modifying the fixed number of coefficients or the frequency, the delay value is updated accordingly. However, it should be noted that a close comparison between online and offline FIR filters will reveal that they are not perfectly in phase, but out of phase by half of the imposed FIR calculation channel delay.

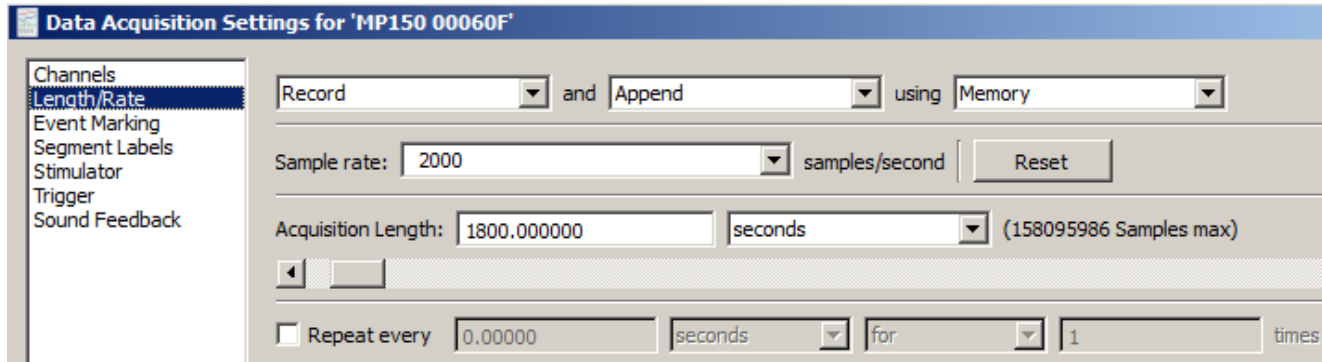
As in other *AcqKnowledge* calculation channel presets, any modified Filter – FIR setup can be saved as a custom preset by selecting "New Preset."

To have *AcqKnowledge* apply the Filter – FIR in real time:

1. Choose Hardware > Set Up Data Acquisition > Channels.
2. Click the Calculation tab.
3. Check the Acquire, Plot, and Values box for the Calculation channel to contain the filtered data.
4. Click the Preset pull down menu and select Filter – FIR.
5. Click the Setup button to generate the Filter – FIR settings dialog.
6. After starting acquisition, real time FIR filtering will appear in a dedicated calculation channel for the duration of the recording.

For specific details on the various FIR filter types, windowing, and recommended settings, see the offline Filter – FIR Transform option on page 286.

Chapter 7 Data Acquisition



Data Acquisition—The Basics

Once you have selected channels to be acquired (see **Chapter 5 Channel Setup** on page 109), the next step is to set up the acquisition parameters. These options control the data collection rate, where data will be stored during an acquisition, and the duration of each acquisition. Choose Hardware > Set Up Data Acquisition > Length/Rate to generate the following options.

Storage Mode

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

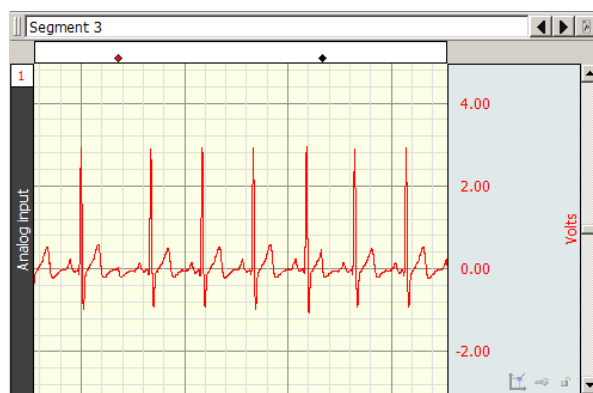
Record/Record last allows you to control whether the software saves all the data or only the most recent segment of the data.

- **Record**—the hardware will store data for the amount of time that is specified in the acquisition length box. This is the default and is appropriate for almost all types of acquisitions.
- **Record last**—only available when acquisitions are set to “Save Once” using “Memory”—the hardware will acquire data continuously, but will only store the most recent segment of data equivalent to the duration in the acquisition length dialog. That is, if the value in the acquisition length box is 30 seconds and record last is selected, the hardware will acquire data ad infinitum, but will only store the most recent 30 seconds of the data.

Save once/Autosave file/Append sets how the data is saved to a file. **Append** mode is the default setting..

- **Save once**—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** —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. Click File to generate a standard Save dialog to enter the root file name for the data from each acquisition. After you click Save in this dialog, another dialog is generated with options to append an incrementing number, time (system clock), or date (system clock) to the filename: Media functionality does not support the *Autosave file* acquisition mode.
- **Append** —similar to ‘Save Once’, except that Append allows 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, an append event is inserted into the recording. Append events can be configured to include user-defined labels and time/date stamps via the Segment Labels setup (see page 238). Although you can pause for any period of time, the Hardware will only acquire data for the amount of time indicated in the Acquisition Length box. Data can be acquired in Append mode while being saved to memory, disk, or the MP hardware unit (but not in Averaging mode).



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

Appended segments can be stored to disk, memory, or MP150. (MP36R, BioHarness, Mobita, or B-Alert does not support data storage to the hardware unit.)

- **Append to Disk:** In this mode, it is usually best to record all channels at the same rate. If the user stops the acquisition, the length will be the same for all channels—so the next segment of appended data will neatly link onto the end of the existing record.
 - Any existing AcqKnowledge 4 can be appended. Change the acquisition mode to Append; any of the storage options are applicable
 - Append to disk requires AcqKnowledge 4 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 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).



The **Rewind** button to the right of the Start/Stop button will delete the last recorded segment. Ctrl-Rewind (Windows) or Option-Rewind (Mac OS X) will delete all recorded segments (similar to the Reset button).

Append plus external trigger

Appended segments can be started with an external or internal trigger. The experiment can be tailored to start at points of interest by applying a trigger. See Triggering details on page 173.

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 113). These extra data points simply replicate the last sample in any affected channel. To minimize the impact of the extra data points, make sure the lowest sampling rate is on the order of 10 Hz or higher, or don’t use VSR.

Disk/Memory/MP/Averaging determines where to store data during an acquisition. Once data has been acquired and is stored in a file, it is stored on a hard disk or other similar device. There are a number of options for storing data *during* an acquisition. The best choice as to where data should be stored during an acquisition depends in large part on the nature of the acquisition itself, and the type of computer being used.

- Memory stores data in computer memory during an acquisition. After the acquisition is 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. A final advantage of saving data directly to Disk is that if there is a system failure (including power outage), all the data collected up to that point is saved on disk and can normally be recovered, whereas the data is deleted if it is being saved to computer memory.

IMPORTANT—When saving files to Disk, always be sure to save your files under a different name **BEFORE** you start each acquisition. Otherwise, any previous data in that file will be overwritten. In Memory mode, simply save the file after the acquisition.

- MP150 stores a small amount of data on the hardware itself. The MP150 is limited only by internal memory, with storage estimated at 4 MB and 400 kHz aggregate sampling rate. Obviously, data cannot be sampled this fast for a very long period of time if it is to be stored in the hardware. Also, as more and more channels are acquired, the duration of acquisition to the hardware unit will shorten. Data stored to the hardware is not plotted on the screen as it is being acquired, but will automatically be plotted on the screen as soon as the acquisition is terminated.
- Averaging is used exclusively for acquisitions involving repeated trials; see page 162.

Acquisition Sample Rate

The value in the box labeled “Sample rate” indicates how many samples the hardware should take per channel during each second of data acquisition. The sample rate can be changed by clicking on the pull-down menu. Individual channels can be down-sampled (variable sample rates), on the channel pane of the Data Acquisition Settings dialog. The down-sampled or channel sample rates are limited to specific power of 2 less than the acquisition sample rate; for example, If the acquisition sample rate is 100 samples/seconds, then the available channel samples rate are 100, 50, 25, 12.5, etc.

Depending on the nature of the data being acquired, the “best” choice in terms of sampling rate will vary. Technically speaking, the minimum sampling rate should be at least twice the highest frequency component of interest. This means that if the phenomenon you are interested in observing has frequency components (which are of interest) of 100 Hz, 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 318 for a more detailed description of the FFT function).

TIP: A good rule of thumb is to set the sampling rate to at least three to four times the highest frequency component of interest.

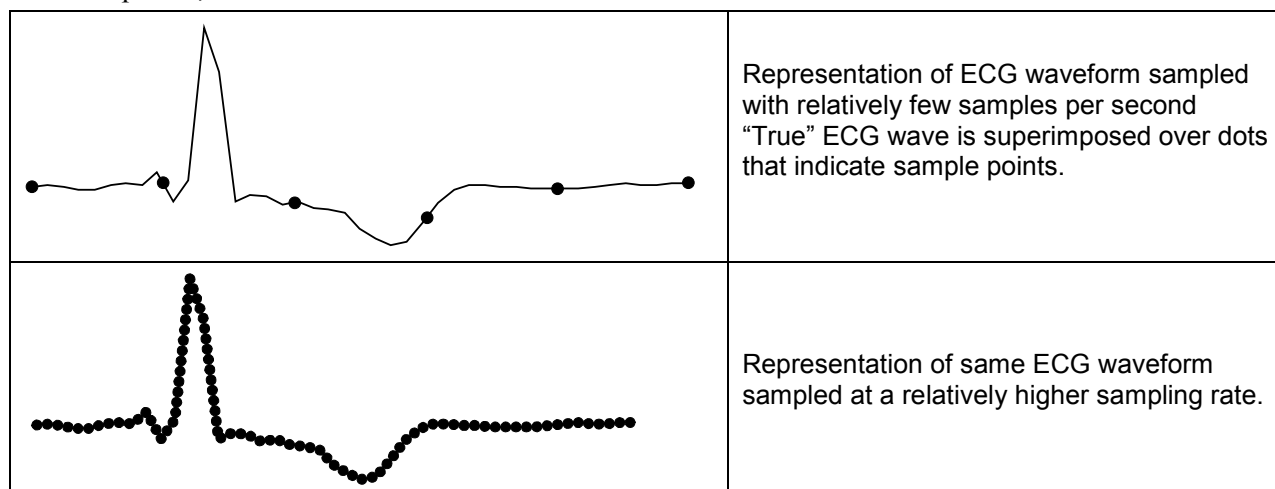
In less technical terms, lower sampling rates can be used for data with slowly changing values (e.g. respiration, EDA, GSR), whereas higher sampling rates should be set for data where values change markedly in magnitude or direction (e.g. ECG, EEG, evoked response).

The maximum allowable sampling rate will automatically adjust itself according to the storage mode, how many channels are being acquired in the channel setup window and the type of computer being used.

If data is being stored to disk or computer memory (RAM) during an acquisition set to a sample rate that is too high, the acquisition will begin normally, but 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 acquisition or channel settings should be adjusted; lower sampling rate; shorter length or fewer channels

The sample ECG waveforms below illustrate the effect of different sampling rates on quality of data. Each black dot corresponds to a sample point.

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



As shown, under-sampling completely misses the QRS complex of this waveform, although it might detect components of the QRS in subsequent beats. Although this is an extreme example of how under-sampling can affect digitally processed data, it is important to note that the rate at which data is sampled has important implications for the interpretation and analysis of data.

Acquisition length

To set the duration of an acquisition, enter a number in the acquisition length box. By default, 3600 seconds of data will be recorded. Select the length units from the popup menu to the right of the length box. The units are milliseconds, seconds, minutes, hours, or samples. Changing this option will not change the length of the acquisition, only the units used to describe it. Thus 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 units you use to determine the length of acquisition, *AcqKnowledge* will end an acquisition when the value in the total length box is reached. The acquisition can be halted at any time by clicking the “Stop” button.

Multiple Hardware

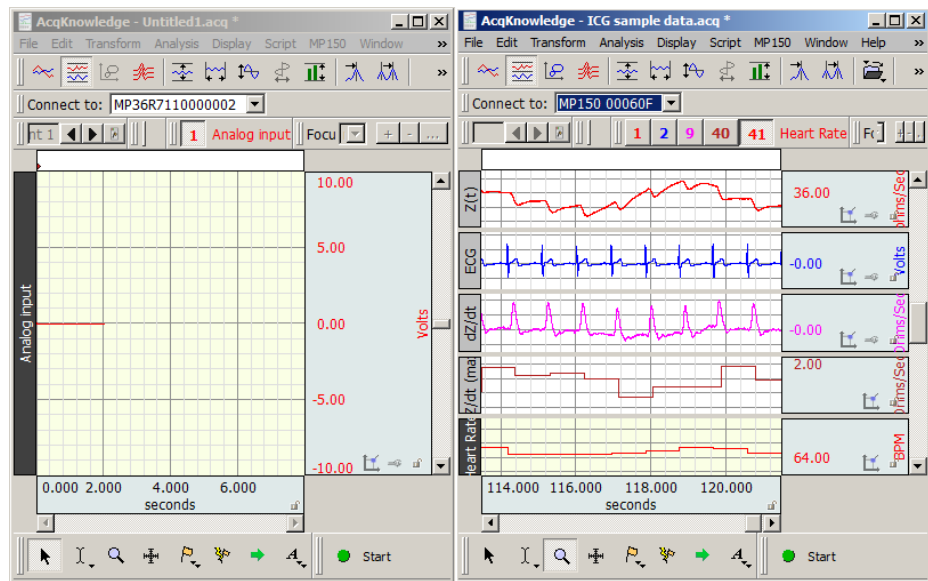
AcqKnowledge can be used with multiple data acquisition units to:

- Control multiple, independent experiments on one computer
- Increase the total number of channels used for a single experiment (e.g., 32-channel EEG)

To synchronize the Start of multiple units, use the External Trigger function.

To combine nearly unlimited channels of data into one file, use the Merge Graphs feature (see page 276).

Each graph window can support a different Hardware unit. To open a graph for a separate hardware unit, select File > New > Graph.

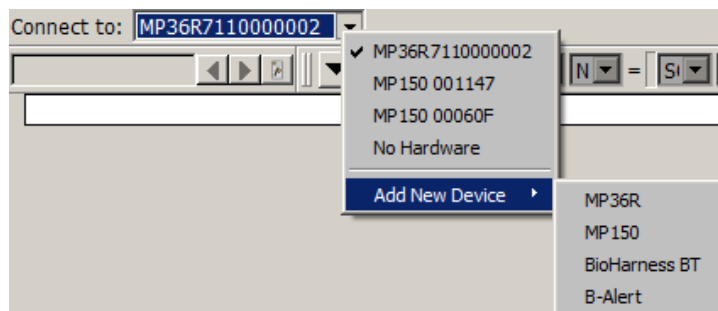


To show/hide the “Connect to:” information, go to Display > Show > and toggle the “Hardware” option, or select this item from the “Show/Hide” popup menu .

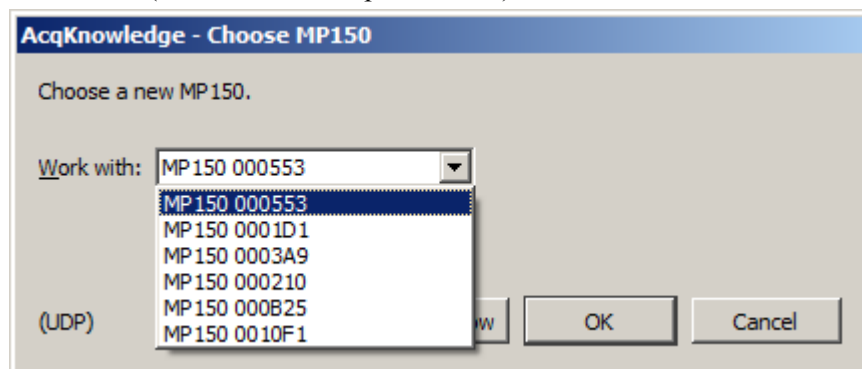
To switch the hardware unit associated with a graph window, click the “Connect to” box and select an available unit or choose Add New Device. Different hardware types may be added and consolidated in the list by selecting ‘Add New Device.’

The ‘Choose MP150’ dialog shows the MP150 units residing on a local network. (Network functionality is limited to MP150 hardware only.)

Click the **Help...** button to open a troubleshooting guide for communication problems.



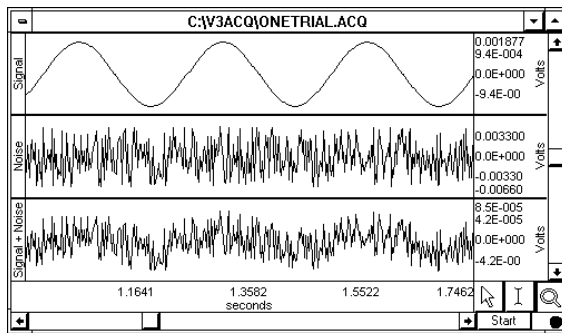
NOTE: When switching to a BioHarness BT device from another hardware type, a new graph must be launched in order for the BioHarness settings to take effect. (File > New > Graph Window)



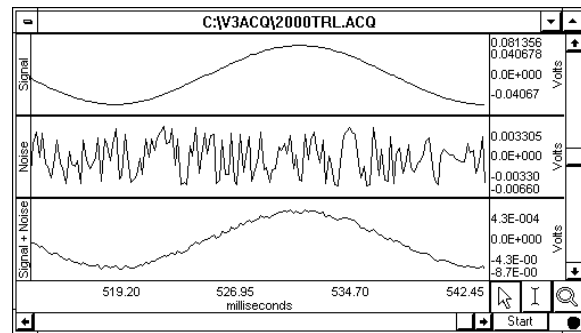
Averaging (MP150 Hardware only)

Overview

In some instances, the signal of interest does not stand out against the background or ambient noise (the level of ambient noise exceeds the signal produced by the object of interest), and the only way to detect the signal of interest is to perform repeated trials as part of one acquisition, and average the trials together. Since the “noise” associated with the signal is assumed to be random, and the “signal” is assumed to be systematic, the noise should approach zero as the individual trials are averaged together.



Signal (top) measured in the presence of noise (middle), which results in the bottom waveform when measured in standard Acquisition mode

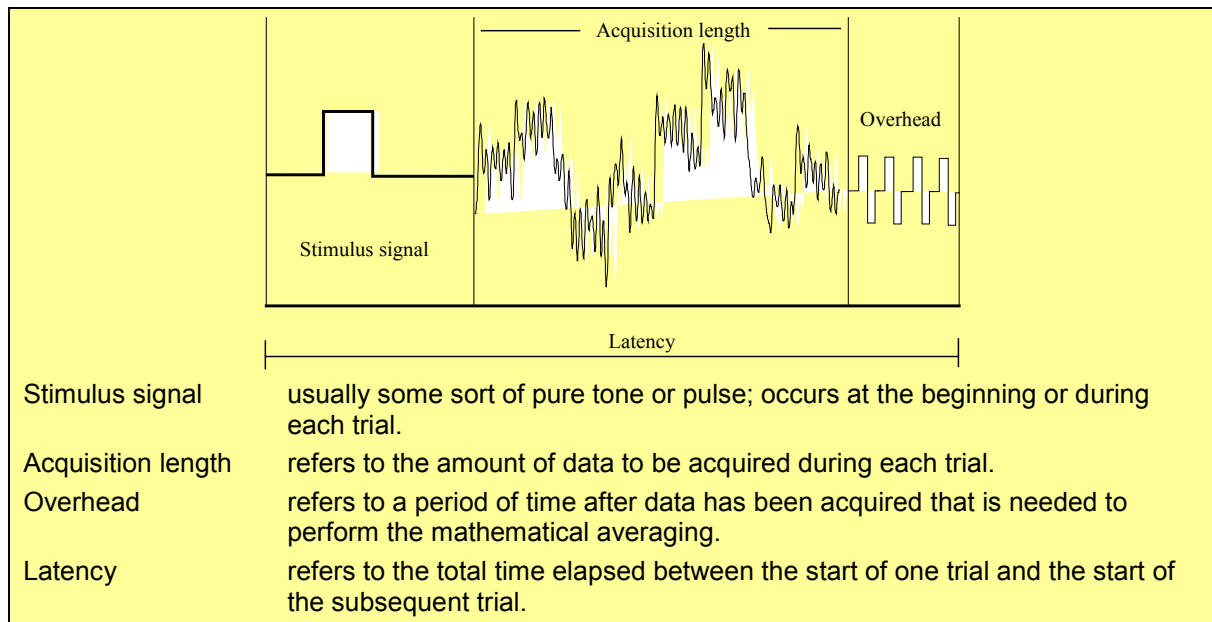


Same signal averaged in the presence of noise over 2,000 trials to produce the lower waveform.

Typically, any averaging acquisition consists of three general components:

- 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.



Important usage notes

- The maximum length of a single averaging pass is restricted to 2 seconds;** if longer averaging passes are required, use regular data acquisition and use the Ensemble Average offline analysis option to generate averages in post-processing.
- The preferred hardware setup for on-line averaging mode is direct connection to the MP150** via cross-over cable. To improve stability, avoid interruptions during acquisition:
 - Do not access top-level menus (File, Edit, Transform, etc.) or generate popup dialogs (Setup...).
 - Avoid running other programs—helps ensure that required system resources (processor time, memory, and network throughput) remain available.
 - If the MP150 is connected over a network, avoid running applications that consume network traffic (Internet Explorer, mail client, media player)—these may interrupt/delay communication to the MP150.

Averaging Setup

For Advanced Averaging, see page 165

To set up Averaging:

1. Choose MP150 > Set Up Data Acquisition > Length/Rate and select “using Averaging” option.
2. Click the Setup button to generate the Averaging options dialog.
3. Set the Averaging options as detailed below.
4. Click OK to close out of the dialog.
5. Set the Stimulus (see page 176).
6. Use the buttons in the graph window to Start or Stop the averaging acquisition.

Online averaging progress bar

An online status bar is added to graph windows in *AcqKnowledge 4* when online averaging acquisitions are in progress. The status bar displays the number of averaging passes that have been completed and the number of passes that have been rejected by the MP150 firmware. This is similar to the text displayed in the status area of Windows *AcqKnowledge 3.9.1* and earlier.

Averaging Options

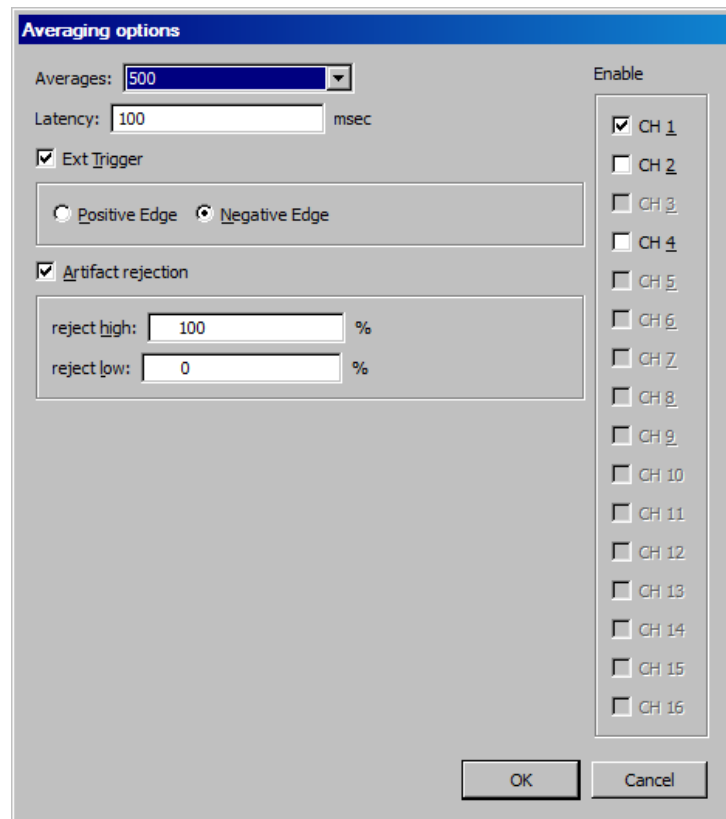
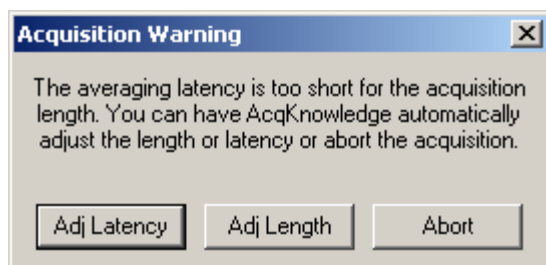
Averages

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

Latency

Latency is the total time from the start of one trial/average to the next; it includes the time for stimulus signal, acquisition and overhead. As general rule, set latency to three times acquisition length plus any experimental delays, for example allowing the subject's signal to return to the baseline. The default setting for latency is 100 msec.

If the latency is set to a value too short to allow for averaging to take place, an Acquisition Warning will be generated:



- Adj Latency: automatically adjust the latency to the shortest possible value that still allows for data to be acquired and processed.
- Adj Length: reduce the amount of data acquired without changing the latency.
- Abort: return to the graph window without any data being collected.

External trigger

To initiate a trial from an External Trigger signal enable the Ext Trigger in the Averaging options dialog as well as the Positive or Negative Edge. The trigger can be set up in the Trigger pane of the Data Acquisition Setting dialog. See page 173.

Artifact rejection

Occasionally during an acquisition, extreme levels of unwanted signal artifact may be present. 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 a user 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 Map (Scale) values to something other than ± 10 Volts, the artifact rejection formula for symmetrical limits is: $y = ((2 \cdot PV)/100) \cdot x - PV$

where y = voltage threshold
 PV = Peak Value
 x = percent threshold (whole number)

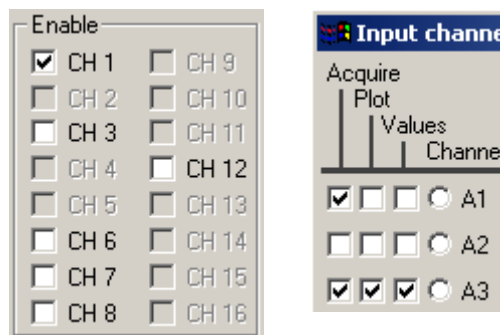
If non-symmetrical limits are used, the following equation is used: $y = ((V1 - V2)/100) \cdot x + V2$

where y = voltage threshold
 $V1$ = Higher Peak Value
 $V2$ = Lower Peak Value
 x = percent threshold (whole number)

Enable Channels

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

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



Stimulus Signal

Although 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 MP150 menu > Stimulator Setup to set all of the stimulus output functions (see page 176).

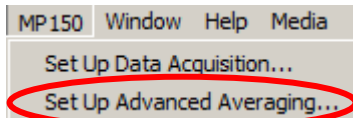
When you start Averaging, the Start button turns to Averaging status and the green dot turns to “A” to indicate that Averaging is in process.

Advanced Averaging—P300

Advanced averaging can be used to set up P300 protocols. A sample P300 setup is included in the Samples folder.

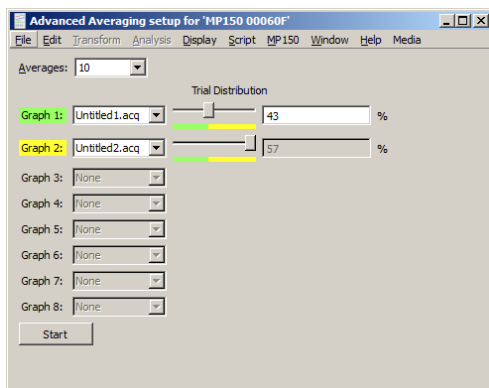
To set up Advanced Averaging:

1. Open two or more graph files.
2. Use Set up Acquisition to set each graph file for Averaging (see page 162).
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 176).
 - 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.

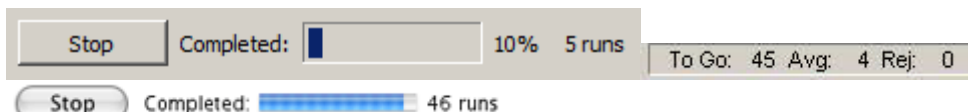
7. Set the Advanced Averaging options:



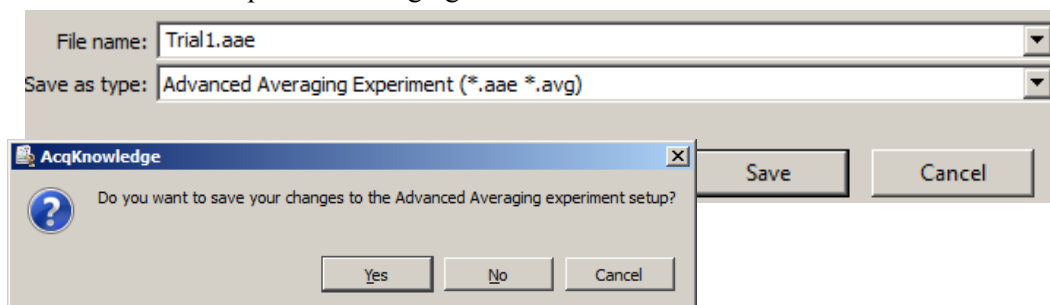
- a. Averages: Select the number of averages from the pull-down menu (max 10,000).
- b. Graph: Assign a Graph from the pull-down menu of open graph files. Up to eight graph files can be used in Advanced Averaging.
- c. Trial distribution: Use the slider to assign a percentage for each graph; the total 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 click “Yes” save the setup as an Averaging file.



Repeating

Use the Repeat mode to acquire data from repeated trials using the same parameters for each trial. Checking the Repeat every box at the bottom of the acquisition setup dialog enables two additional popup menus at the bottom of the dialog. These allow for control of how many times an acquisition will repeat as well as the interval between trials. When this is unchecked, the acquisitions will repeat as soon as possible (usually instantaneously, but slightly longer if data must be saved to a file between trials).



Interval The entry to the right of the “Repeat every” checkbox tells *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 first popup menu.

It is important to note that this value measures the interval between the start of two adjacent trials, rather than the interval between the end of one trial and the start of the subsequent trial. If the repeat interval is set for 15 minutes and the acquisition length is set to 60 seconds, then there will be a 14-minute pause between the end of the one trial and the beginning of the next.



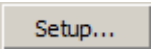
Trials Set how many trials to acquire:

- for perform a finite number of trials; enter the number of trials to acquire in the “times” field.
- forever perform an infinite number of trials. Trials will be repeated at the specified interval until the acquisition is stopped either by clicking on the stop button in the graph window or if there is not enough free memory on the target storage device.

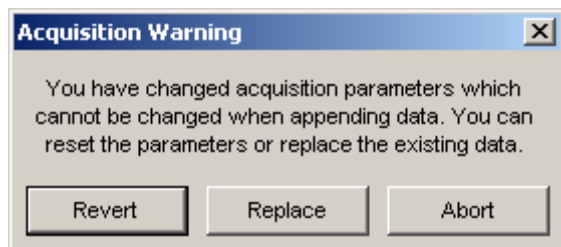
Regardless of which options are checked, data for each trial is acquired according to the acquisition parameters specified in the dialog. In the above example, each trial of data will be sampled at 50 Hz and will last 1 minute; the trials will be repeated every 15 minutes for a total of 8 trials.

Selecting the option to Record and Save Once to Disk/Memory will overwrite the previous collected data. However a warning will appear unless the “Warn on Overwrite” option is disabled. Another option is to select Autosave file from the Save once/Autosave file/Append option. When the repeating option is checked and Autosave is selected, *AcqKnowledge* will save the data from each trial using the file name and extension indicated by the autosave feature. See page 158 for a more detailed description of Autosave.

Setup Channel Options

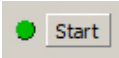
Channel	<p>The Channel column contains the alpha-numeric channel numbers. “Analog” (or continuous) input channels begin with “CH” and run from CH1-CH4 for MP36R and A1-A16 for MP150. “Digital” input channels begin with “D” and run from D1-D8. “Calculation” channels begin with “C” and run from C0-C15.</p> <p>Use the scroll button  to set up additional Digital or Calculation channels.</p>
Acquire	When the Acquire Data box is checked for a given channel, data will be collected on that channel.
Plot	If Plot on Screen is also checked, data will be plotted on screen in real-time during the acquisition. If the plot box is unchecked, data will still be recorded for that channel, but the waveform display will be disabled. To display the waveform plot during or after acquisition, show the channel. (Alt+click the channel box above the graph.)
Value	Checking the Value box means that you can choose to display (numerically and/or graphically) the values for each channel in real time. To display the values, you must also select Show Input Values (via the Hardware menu). Input values are displayed in a separate window from the main graph window.
Default	For MP36R, the default is to collect one channel of data on analog channel 1 (CH1), and to plot and enable value display for this channel. For MP150, a channel must be enabled by choosing “acquire” prior to recording, if “View by Channels” mode is used.
TIP	Usually, you will want to check all three boxes for each channel you acquire data on.
Label	The Label entry for each channel allows you to type in up to 49 characters to identify the channel.
Presets 	<p>Clicking on the Presets button will generate a menu of available presets for the channel. Presets for common applications configure the hardware gain, filters, etc.</p> <p>➤ For a detailed summary of Analog Input channel, Digital Input channel, and Calculation channel options see the Presets section beginning on page 122.</p>
Setup 	To Change Parameters for a Preset, click the Setup... button. If you change the parameters, you have the option of creating a New Channel Preset to make the established parameters available to other channels.

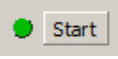
If you make a change to a preset and start recording in the Append mode, you will be prompted as follows. Choose Abort, save your data, and then change the presets to acquire as a new data file.



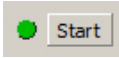
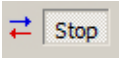
Starting an acquisition

After setting up the channels and defining the acquisition parameters, you are ready to start the acquisition. If a file window is not already open, choose **File > New** to generate a graph window.

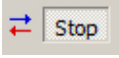
In the lower corner of the screen, next to the  button, you should see a button with a circle to the left of it. The circle indicates the status of the communication link between your computer and the hardware. If the unit is properly connected to the computer and is turned on, the circle should be solid and green. If the unit is not properly connected, a solid gray circle will appear.

Start the acquisition by clicking the  button or by selecting “**Ctrl + Spacebar**.” If there are no input devices (e.g., electrodes or transducers) connected to the hardware, 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 MP36R, see the *BSL Hardware Guide*.
- You may also start an acquisition using a variety of “triggers,” which are discussed on page 173.


Once acquisition starts, the  button in the acquisition window changes to . The two opposing arrows to the right of the button indicate that data is being collected. Also, the “Busy” status indicator light on the front of the MP150/MP36R will illuminate, showing that data is being collected.

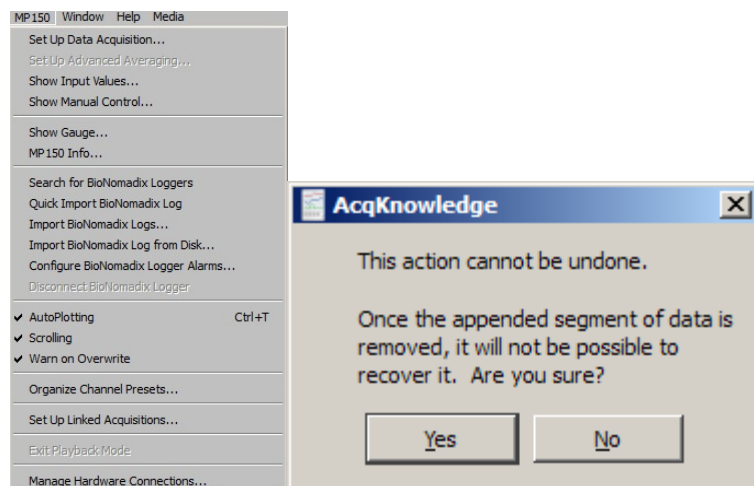
Stopping an Acquisition

To stop an acquisition at any time, click the  button in the lower right corner of the screen or select “**Ctrl + Spacebar**.” An acquisition will stop automatically when it has recorded an amount of data equal to the **Acquisition Length** entry.

Rewind



The Rewind button to the right of the Start/Stop button allows you to erase the last recorded data segment and continue to append data to the existing data file. This function will erase the last segment along with the Append Event  for that segment; the application will keep track of Append Event labels, so that the label always matches the segment number.



If the “Warn on Overwrite” option is active, a warning dialog will be generated before the segment is deleted.

Saving acquisition data

To save a data file, pull-down the File menu and choose the Save command.

Timers (Stop watches and Elapsed timers)

The Timers function allows for easy visualization and measurement of elapsed time within the AcqKnowledge user interface, and consists of a simple toolbar display. Timers can be helpful when actions need to be performed at specific intervals prior to and during an experiment. The Timers function provides an easy-to-read digital display in the toolbar region, and supports the creation of multiple timers, which can be added or removed as needed.

Timer Types

There are two main types of timers, acquisition controlled (“elapsed” timers”) and independent timers (“stop watches”). Manual “stop watch” timers can be used at any point for tracking time independently of acquisition, while elapsed timers are tied to a recording in progress and unavailable unless an acquisition is running.


Independent Timers (Stop watches)

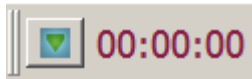
Independent timers are manually started and stopped, and have a countdown feature with an audible alarm and flasher. Multiple timers can be added to the toolbar region, and can be started and stopped independently. Pause mode is not supported. Although the timer can be stopped at any time, restarting it resets the timer back to 0:00:00.

Elapsed Timers (Acquisition controlled)

Elapsed timers start when the acquisition “Start” button is clicked and continue counting for the set duration of the recording, or until the acquisition “Stop” button is clicked. When acquiring in Append mode, the elapsed timer is reset at the beginning of each new segment. Any trigger or delay time applied between segments is not included in the elapsed time. Multiple elapsed timers can be added to the toolbar region. This mode does not support the countdown or alarm feature.

To set up a timer:

1. Display > Show > Timers or click the Show/Hide toolbar button  and choose “Timers,”
2. The timer toolbar will appear as shown below:

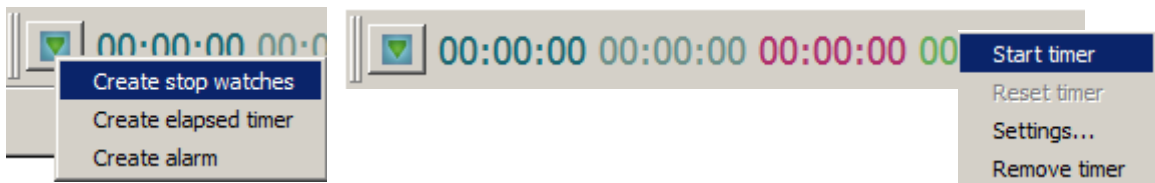


3. The **elapsed timer** option is enabled by default. If only a single elapsed timer (acquisition controlled) is desired, simply start the acquisition and the timer will start automatically.
4. If an **independent timer** (stop watch) is desired, right click on the numbers portion of the timer toolbar and choose “Settings.” In the Timer Settings, choose “Independent start” and click OK.

To start/stop independent timers: Click on the toolbar number display to toggle start/stop, or right click on the toolbar number display and choose “Start timer” or “Stop timer” (see figure below).

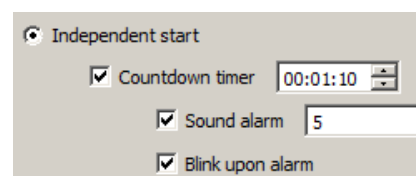
To set up multiple timers:

Click the Timers toolbar icon and choose the desired timer type. Repeated clicking on a timer option will create additional timers of that type, which will appear in the timer toolbar region.



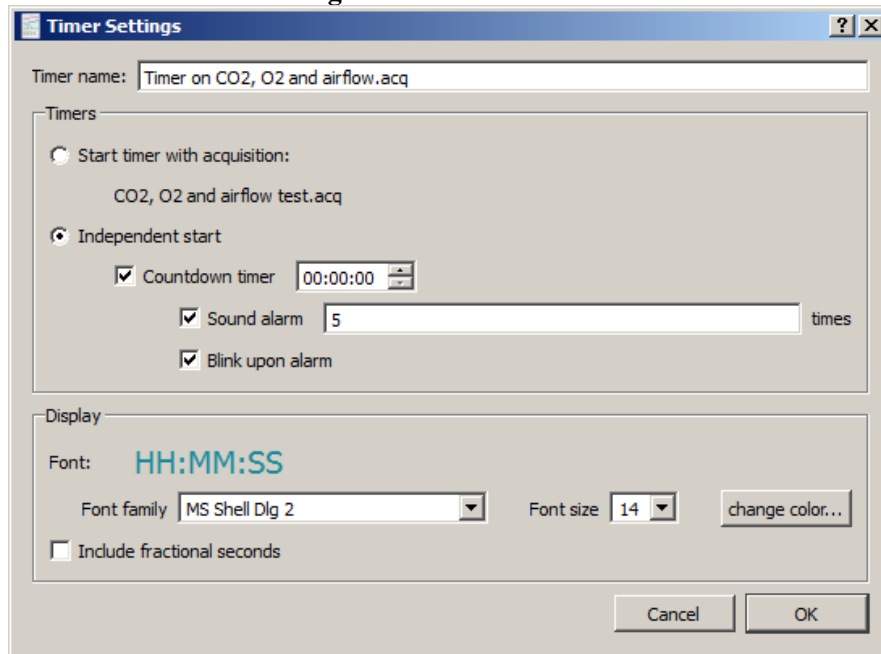
To set an alarm:

1. Click the Timers toolbar icon and choose “Create alarm.”
2. Right click on the numbers display portion of the new alarm and choose “Settings.”
3. Set the desired time in the “Countdown timer” field.
4. Check “Sound alarm” and “Blink upon alarm.”



NOTE: These settings will remain the default for subsequent alarms until the settings are changed.

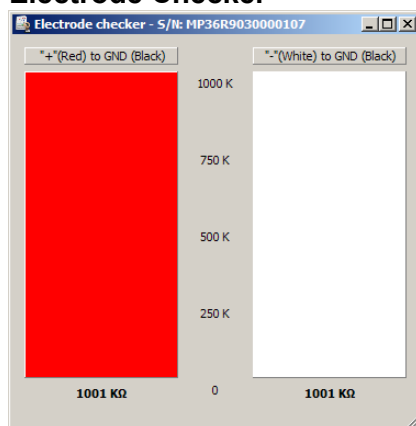
Overview of Timer Settings



CONTROL	DESCRIPTION
Timer name:	Field for assigning name to timer.
Start timer with acquisition:	Timer will start and stop with data recording only.
Independent start	Timer is started and stopped manually, independent of acquisition status.
Countdown timer	Sets the countdown time duration.
Sound alarm	Selects the audible alarm option and specifies the number of times the alarm will sound.
Blink upon alarm	Enables the timer numbers to flash on and off when the countdown is complete.
Display > Font family: > Font size > change color	Selects timer font style, size and color.
Include fractional seconds	Sets option to display 1/100ths of a second in timer display.

All parameters established in the Timer Settings are retained in saved graphs and graph templates.

Electrode Checker



The **Electrode Checker**, in conjunction with the MP36R unit, measures how well electrodes are making contact with the surface of the skin. To use this feature:

- 1) Attach the electrodes as you normally would.

- 2) Connect the electrodes to an electrode lead set (such as the SS2LB).
- 3) Instead of connecting the electrodes to one of the four analog inputs, connect the Simple Sensor end of the electrode lead to the **Electrode Check** port on the front of the MP36R acquisition unit.
- 4) Click the **MP36** menu and scroll down to select **Electrode Checker**.

This will generate a small “thermometer-like” display. At the bottom of the display you should see a number with k Ω (Kohms) symbol after it. This value describes the impedance of the electrode/skin contact, with lower numbers being associated with better conductivity. The better the conductivity, the “cleaner” the signal displayed on the screen. If the MP36R is off or no nothing is connected to the “Electrode Checker” on the MP36R unit, the Electrode Checker display will say “OFF.”



Poor contact



Good contact



Off

TIP While there are few absolutes as to what constitutes “good” contact, one rule of thumb is that this number should be below 10 k Ω , and the lower the better.

TIP To decrease the impedance of an electrode connection, you may want to “abrade” the surface of the skin with an abrasive pad (such as ELPAD). This removes a thin layer of dead skin cells and should result in a signal that has relatively little noise.

Chapter 8 Set Up Triggering

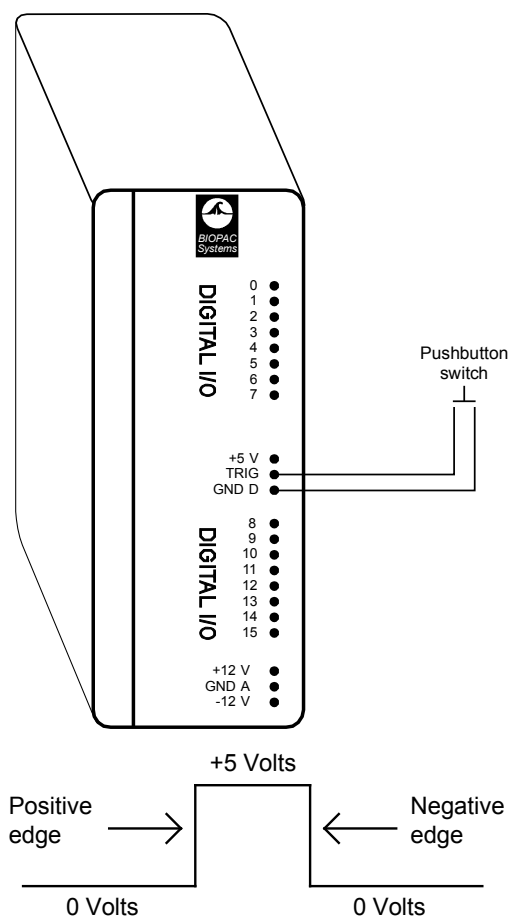
During a normal acquisition, the hardware will begin collecting data as soon as the Start button is clicked. It is also possible to begin an acquisition in a delayed fashion using a trigger. Using this feature enables an acquisition to start “on cue” from a variety of different trigger sources. All trigger options are configured in the Set Up Triggering dialog, which is accessed via **MP menu > Set Up Data Acquisition > Trigger**. By default, the trigger is Off. Other options can be selected from the popup menu in the Trigger Setup dialog. To begin an acquisition with a trigger, first choose the trigger options most appropriate for the experiment and 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 (MP150 only)

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 pushbutton 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.”

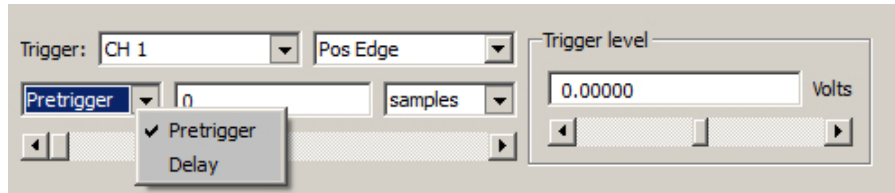
If the trigger is set to external, and the edge is set to positive, the acquisition will begin as soon as the pushbutton is pressed anytime after the start button in the graph window is pressed. Once the button is pressed, the acquisition will proceed according to the acquisition parameters you have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



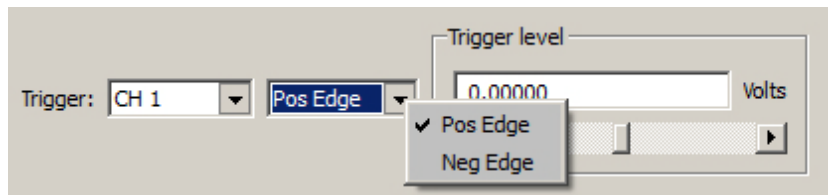
Analog Triggers

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

Select Hardware > Set Up Data Acquisition > Trigger to generate the Trigger dialog:



MP150 Triggering options



MP36R Triggering options

External: Select for Digital Trigger.

CH #: Select for Analog Trigger; must be acquiring to Memory or Disk. Specify the analog channel that contains the trigger data and then specify a voltage Level to initiate the trigger. Acquisition will begin when the data on the specified channel reaches the specified Level.

- To trigger an acquisition when an ECG wave on analog channel 1 reaches a certain voltage or value, you would set “Source” to CH 1 and then set the Level when the entry box is enabled.
- Triggering from an analog channel requires oversampling by a factor of 4, which ensures that the trigger signal will not be missed. The sampling rate can be adjusted in the Set Up Data Acquisition > Length/Rate dialog.
 - For example, an initial sampling rate of 1,000 samples/second should be increased to 4,000.

Level The Level option is activated when a Source CH is selected. Set a level to initiate the trigger (e.g., if the ECG wave peaks at 2 mV, set the trigger level just under 2 mV).

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

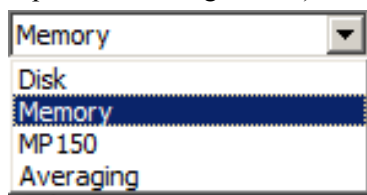
Edge	Digital	Analog
Pos	Signal changes from 0 to 1	Signal changes direction from downward to upward. Once the trigger level is crossed, the acquisition will start.
Neg	Signal changes from 1 to 0	Signal changes direction from upward to downward. Once the trigger level is crossed, the acquisition will start.

- For ECG data (and other types of data with peaks of relatively short duration) there will be only minor time differences between one edge and the next, although the positive and negative edges can be widely separated in time for data with slowly changing values (such as EDA or skin temperature data).

- Mode** Once the trigger channel and level have been specified, the final parameter is the delay. Delay can be measured in terms of samples, milliseconds, seconds, or minutes, and may be set to zero if desired. The delay option instructs the hardware to wait a specified period after the trigger level is reached before beginning the acquisition.
- Delay** When using a trigger, the default setting is for the acquisition to begin immediately after the trigger pulse or level occurs. You can modify this default by using the Delay option in the Trigger Setup dialog. This feature allows an acquisition to begin a specified period after the trigger level is reached. To start an acquisition one second after a switch closes, set the trigger to external and enter 1.00 in the box next to Delay. The default scale for Delay is seconds, meaning that the acquisition will begin a specified number of seconds after the trigger has been initiated. The scale of the delay can be changed from seconds to samples, milliseconds, or minutes.
- 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.

NOTE: Delay option not available in MP36R hardware.

Pretrigger functionality is not supported in all acquisition modes (MP150 > Set Up Data Acquisition > Length/Rate): **NOTE:** Pretrigger option is not available in MP36R hardware.



Mode	Source: EXTERNAL	Source: CH #
Disk	Pretrigger supported	Pretrigger supported
Memory	Pretrigger supported	Pretrigger supported
MP150	Pretrigger supported	not available
Averaging	not available	not available

When the Pretrigger function is enabled, start an acquisition by clicking the Start button. When the internal memory in the data acquisition hardware is full, the hardware will start replacing the oldest data with the newest data (similar to the record last feature). This process continues until the trigger event occurs. Following the trigger, the hardware will collect data until the total length is reached. The acquisition now contains data from both before and after the trigger.

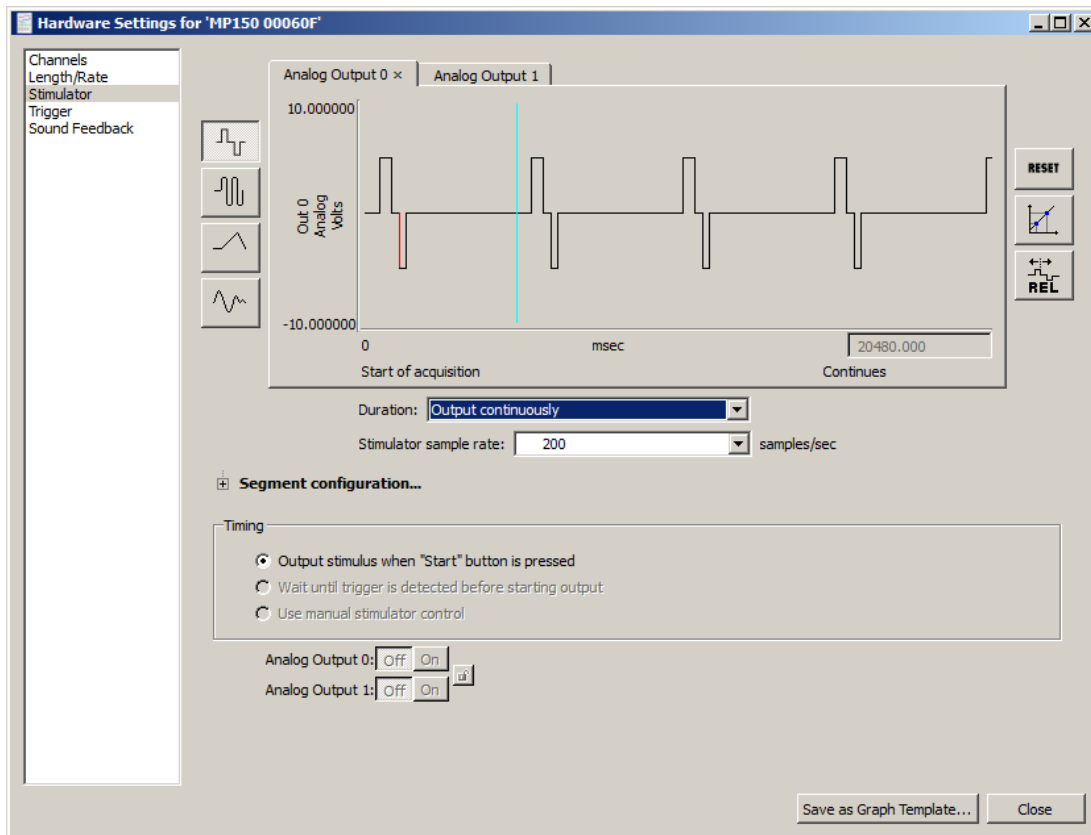
The amount of data collected before the trigger event is determined by the value in the box next to the Pretrigger popup menu. As with Delay, scaling can be set in terms of samples, milliseconds, seconds, or minutes. The duration of the Pretrigger may also be adjusted using the scroll box to the right of the Pretrigger dialog.

When Pretrigger is selected, it is important to note...

- The total length of the acquisition includes the duration of the Pretrigger. If the acquisition length is set to 120 seconds and the Pretrigger is set to 20 seconds, only 100 seconds of data will be collected after the trigger event occurs.
- Since the total length of the acquisition includes the duration of the Pretrigger, the duration of the Pretrigger may not exceed the length of the acquisition.

Chapter 9 Set Up Stimulator

Note This chapter refers to stimulator setup for MP150 hardware only. For MP36R, see the next chapter, 'Output Control.'



Although data acquisition is the primary function of the MP System, AcqKnowledge supports output of a signal through one or two analog channels while data is being acquired. This type of signal output is configured in the Stimulator setup window.

Four types of signals can be output:

Square waveforms—page 182

Ramp waveforms—183

Tone waveforms—183

Arbitrary waveforms—184

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 MP150 > Set Up Data Acquisition > Stimulator. Like the standard graph window, the Stimulator setup window plots time on the horizontal axis and amplitude on the vertical axis.

Use the Stimulator window to create and shape waveforms for output. Adjust the Stimulator Sample Rate (described below) to further control the parameters of the Stimulator Output design.

For any waveform (or stimulus) to be output, the following parameters must be specified; the type of stimulus, the “shape” of the signal, the output channel to be used, and how many times the stimulus should be output.

All the above parameters are set up from within the Stimulator Setup dialog. Regardless of the type of waveform selected, stimulus signals will normally be output when an acquisition is initiated, either as a result of clicking the “Start” button, using the “manual stimulator control” or via a trigger being activated.

Stimulator Sample Rate

A 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. For a full explanation of MP150 Stimulator sample rates, see page 185.

Use the “Stimulation sample rate” pull-down menu to select a unique sample rate for the stimulator.

➡ *See also:* Application Note [AH162](#) - Using the Stimulation Features of the MP System.

Stimulator Parameters

The Stimulator parameters are set by using the buttons in the right pane of the setup window.

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

Scaling



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

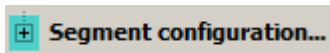
This type of rescaling does not change the amplification of the signal, it is useful for recalibrating the output signal to more meaningful units. In the example shown here, an output signal of +10 Volts is rescaled to +128 dB, while an output signal of −10 Volts is rescaled to reflect 0 dB.

Relative



Set the duration of each segment of the output waveform in Seg # Width. In the sample dialog shown below left, a 5000 msec output is created by entering individual segment widths: 500 + 400 + 250 + 200 + 3650 = 5000 msec.

Note In AcqKnowledge 4.4 and higher, the segment level fields are hidden by default and must be expanded by clicking the Segment Configuration “+” button (below).



For details about stimulator segment and width configuration, see page 182.

Segment	Level (Volts)	Width (msec)
Seg #1	0.000000	500.000000
Seg #2	5.000000	400.000000
Seg #3	0.000000	250.000000
Seg #4	-5.000000	200.000000
Seg #5	0.000000	3650.000000

Output

Analog Output 0/Analog Output 1: Signals can be output on one or two analog output channels. The output channels are listed as A0 and A1 and correspond to Analog Output 0 and Analog Output 1 on the UIM100C module.

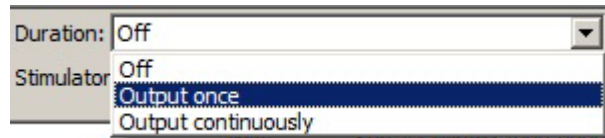
- For dual stimulation and independent control, connect an output device to A0 and A1.

- See *Analog Output for MP150 Users* notes on page 180.

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 μ sec in duration.

Duration

Set independently for A0 and A1.

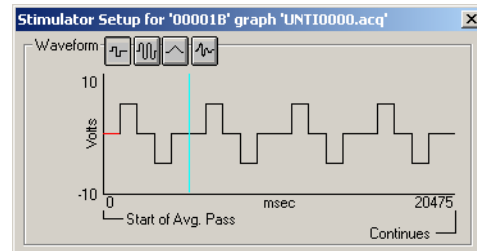


Off: Turn Output OFF (no stimulus signal output).

Output once: Output the stimulus signal once.

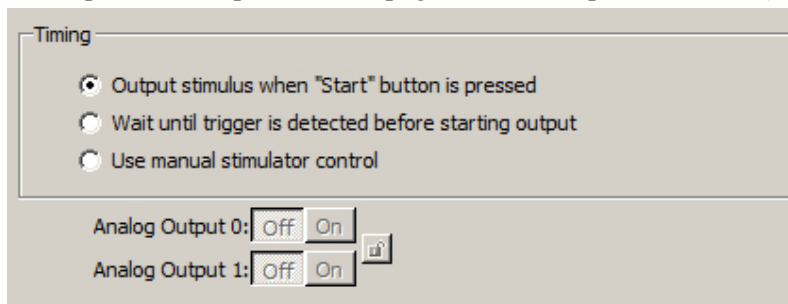
Output continuously: Output the stimulus signal for the duration of the acquisition (forever).


When Output continuously is selected, a vertical line is generated at the end of the first section of the waveform in the stimulator window to indicate where the first output signal ends and the second begins. The line can be dragged left or right like a vertical segment in a stimulus waveform to control the duration of the waveform as it is continuously output. Maximum continuous waveform output is 20 kHz.



Stimulator sample rate: 1000 samples/sec

Use to choose the Stimulator sample rate for the generated signal. (The Stimulator sample rate is independent of the acquisition sample rate. See page 185 for sample rate details.)



Control timing of output by aligning it with the Start button, waiting until a trigger is initiated before generating the signal, or manually toggle the selected stimulator on or off. Click the “lock” button  to synchronize both stimulator outputs to the On/Off buttons.

Note “Wait until trigger” option is only active if Triggering is enabled in the “MP150 > Set Up Data Acquisition > Trigger” menu.

Trigger

When a trigger option is selected (in the Trigger Setup window), AcqKnowledge allows selection of additional options with respect to when the signal is output. By default, the stimulus signal will be output when you click 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 173).

Manual Stimulator Control

- Only available when a stimulator is connected and 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 cannot be used if the MP150 is set to acquire in averaging mode.

- The stimulator output will start simultaneously with the acquisition.
- The On/Off buttons will start and stop the stimulator output.


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


A “lock” between the two sets of controls can be used to turn both stimulators on or off at the same time. This lock is useful for two-channel stimuli delivery, such as stereo sound.

UNLOCKED

☐ Wait until trigger is detected before starting output


☒ Use manual stimulator controls:


Analog Output 0: 

Analog Output 1: 

LOCKED—Both channels Start/Stop together

☒ Use manual stimulator controls:

Analog Output 0: 

Analog Output 1: 

Stimulator Output Type

Output type: ☒ Analog ☐ Digital

Timing

☒ Finish all output, then start averaging pass

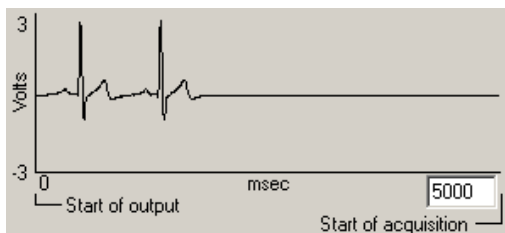
Output length: ms

☐ Include output in averaging pass

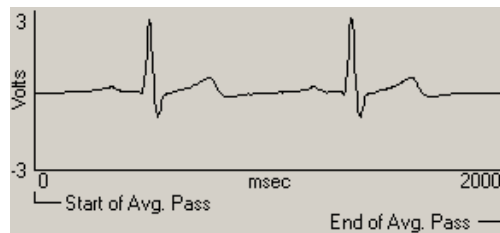
If an averaging acquisition is selected in the MP hardware setup, the timing can be set to delay the averaging pass until after the signal is generated, or to include the signal output in the averaging pass. Note that the signals cannot exceed the duration of the averaging pass.

The “Digital” setting will generate a true digital pulse (0 Volts and +5 Volts) prior to the averaging pass on digital I/O Channel 15.

- For Averaging details, see page 162.



Finish all output, then start averaging pass



Include output in averaging pass

Analog Output for MP150 Users

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

- Static output: Use “Manual Control” (page 233) to set the output level for each channel in the range -10V to +10V.
- Dynamic output: Use “Stimulator Setup” (page 176) 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:

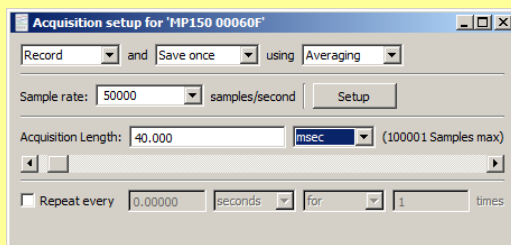
- Acquisition is in progress (or before Averaging pass) AND
- Stimulator is enabled via the “Stimulator Setup” dialog.

When the stimulator is in use:

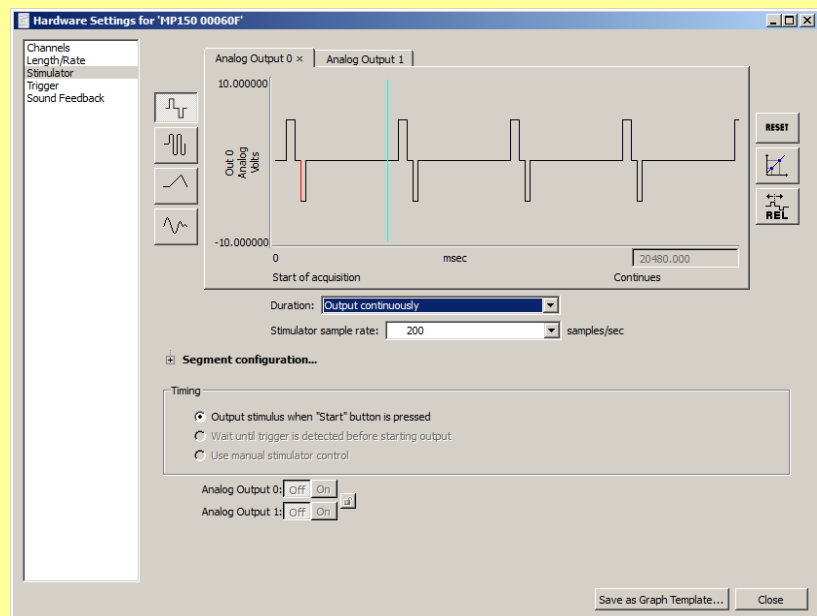
1. Any Stimulator Output starts (from before Time = 0) with the value established for “Manual Control.”
2. If Segment # Width = 0 the stimulator ignores the associated Segment # Level.
3. If the stimulator is in 1x mode, after the output waveform is sent, the value of the last segment is fixed until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

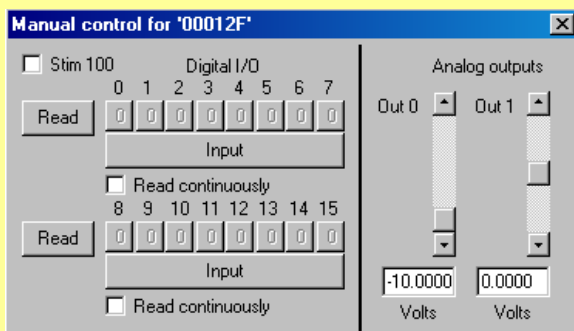
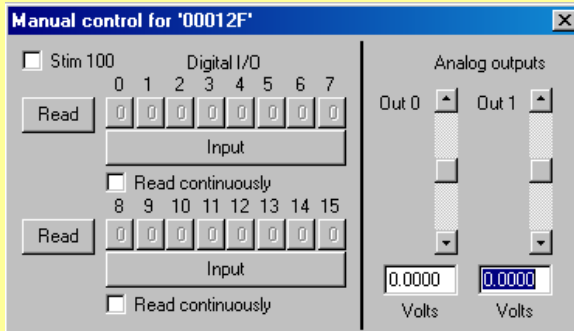
Acquisition parameters:



Stimulator parameters:

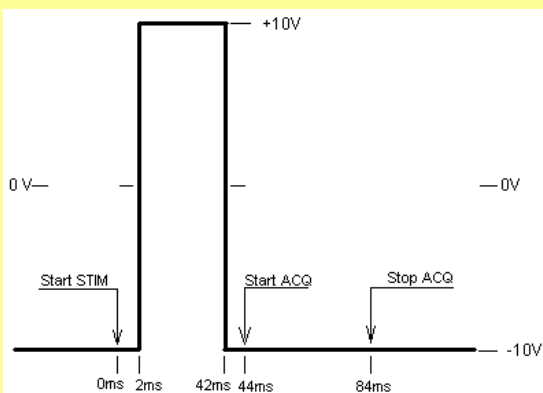
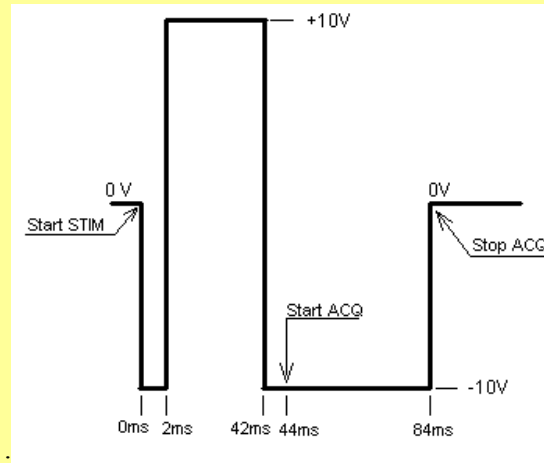


Manual Control list box:



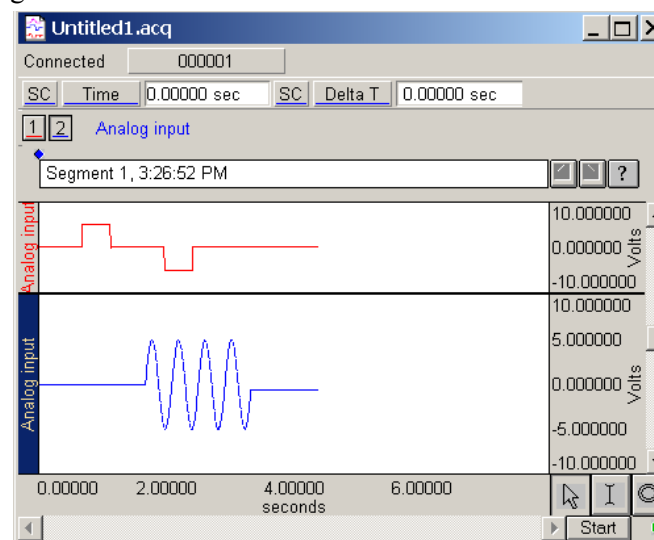
For details on Manual Control, see page 233.

Stimulator Output pattern (using MP150)



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. Click the tab for each output at the top of the Stimulator Setup dialog and complete independent settings.



- For additional stimulus paradigms, add MP150 units (see Multiple Hardware, page 161).

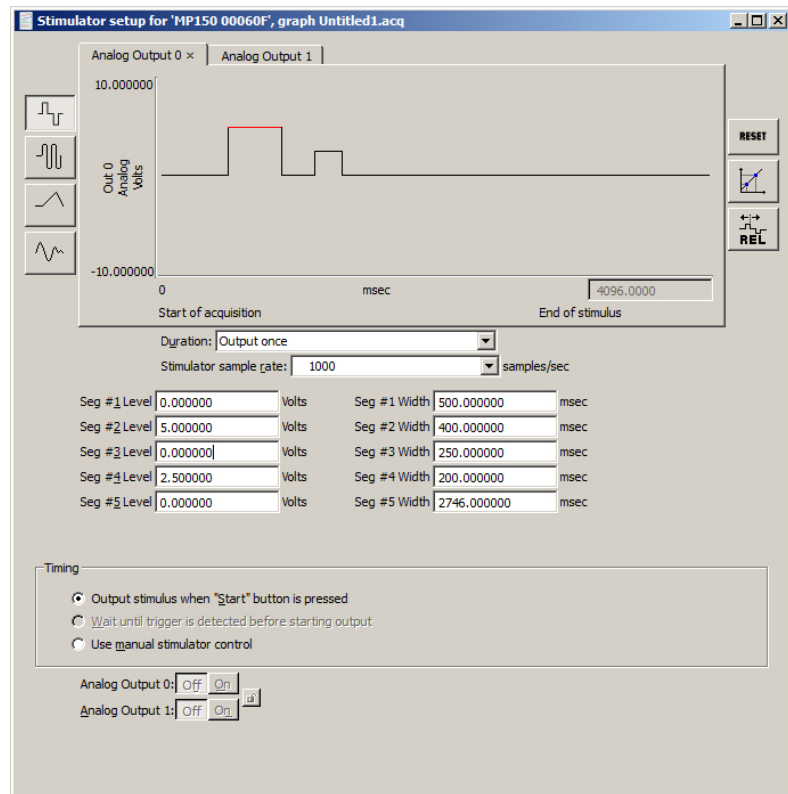
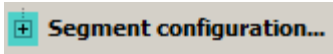
Square waves



Square waveforms are useful for generating pulse waveforms, which can be used as stimuli or to trigger a stimulus-generating device (such as a flash device or a tone generator).

To output a square wave, choose the “Output Once” in the “Duration” section. You should see a rectangular wave appear in 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.

NOTE: in AcqKnowledge 4.4 and higher, the segment level fields are hidden by default and must be expanded by clicking the Segment Configuration “+” button (below).



In a square wave, each of the editable segments is oriented horizontally, with vertical segments connecting the adjacent sections of the wave. The first segment of a pulse waveform is the segment that appears at the far left of the waveform section. By positioning the cursor on this segment of the waveform, 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 wave can be “edited” in this way.

Tone Stimuli



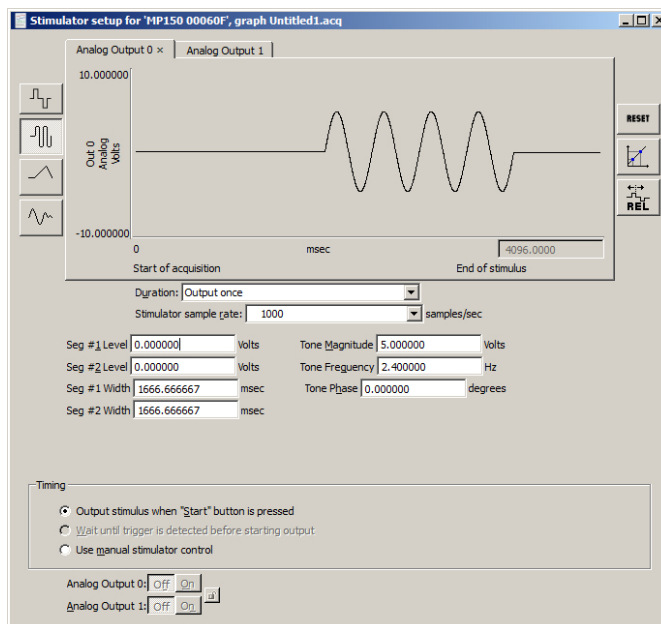
Tone waveforms allow for the creation of pure tone signals of any duration, magnitude, and frequency. This option outputs a pure sine wave, which is useful for audiological and stimulus response testing.

A tone waveform is comprised of two segments, with only the second segment being the actual tone itself. This allows 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 any value, although the most common settings are between 20 Hz and 20,000 Hz.
- Magnitude refers to the peak-to-peak range of the signal, which can range from ± 0 to ± 10 Volts.
- Phase of the stimulus signal can be any value equal to or greater than 0 degrees. Phase settings of more than 359 degrees will be rescaled to fit the 0°-359° range. In other words, setting the phase to 360° or 720° has the same effect as setting the phase to zero degrees.

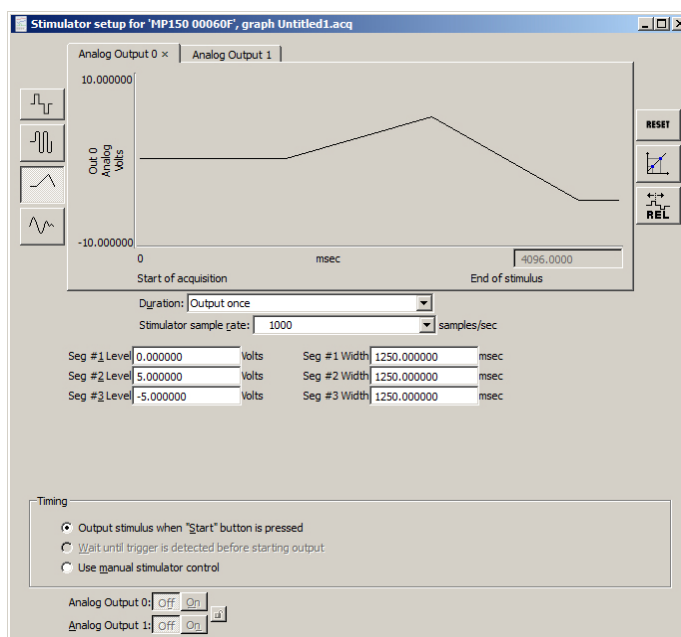


Ramp Waves



Ramp waveforms are useful for constructing a monotonically increasing or decreasing stimulus signal.

Ramp waves are comprised of three segments and the amplitude and duration can be set discretely for all three sections.



Arbitrary Waveform



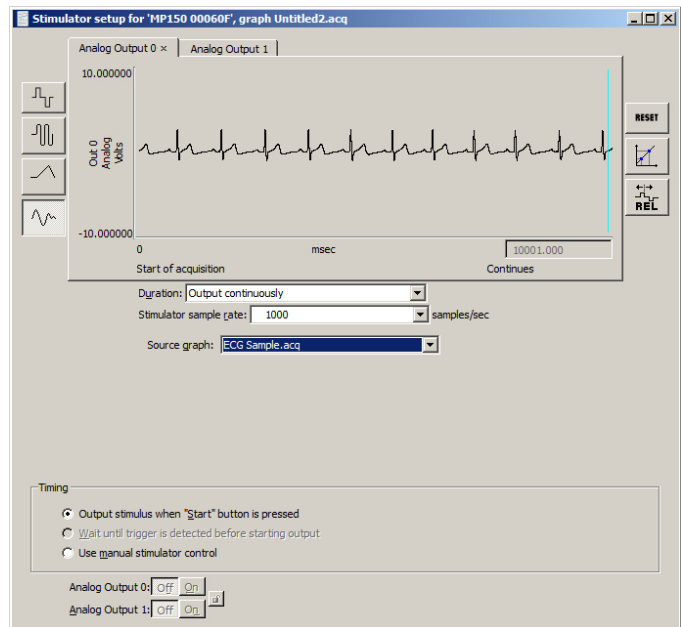
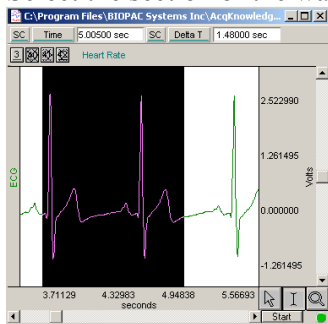
The Arbitrary waveform option is used to set a waveform's shape and length using standard AcqKnowledge editing functions.

- The length of an arbitrary waveform is only limited by the available memory.
- Unlike the other types of waveforms, Arbitrary waveforms have no segments, so the “shape” of the waveform is determined by selecting an existing waveform and the only parameters that can be set are Scaling, Repeats, and Trigger.
- Maximum continuous output is 20 kHz.

To create an arbitrary waveform:

A. Copy waveform segment

1. Open a waveform in a standard graph window.
2. Select the section of the waveform to be outputted.



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

Stimulator Icons

<i>Waveforms:</i>		Square wave
		Tone (sine) wave
		Ramp wave
		Arbitrary wave
<i>Parameters:</i>		Reset the display (use after adjusting the time scale)
		Scaling (rescale Stimulus signals to different units)
		Set time base to relative
<i>Output:</i>	Analog Output 0	Tab to output to Analog Output channel 0 (default)
	Analog Output 1	Tab to output to Analog Output channel 1
	Analog Output 0: Analog Output 1:	Manually start and stop stimulator output by clicking the On/Off buttons. When the padlock is engaged, both stimulator outputs can be controlled simultaneously.

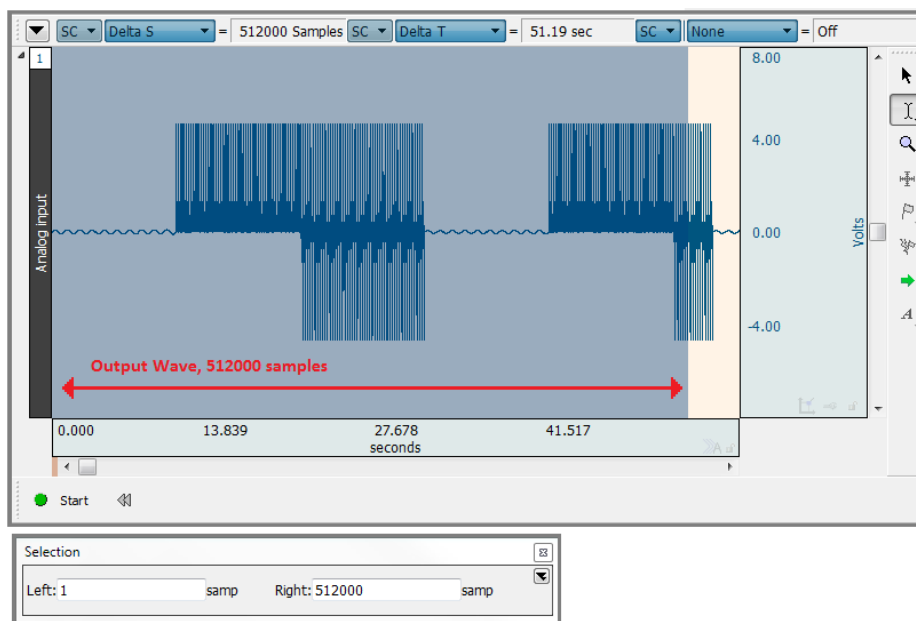
MP150 Stimulator Sample Rates

The MP150 is the most common data acquisition device used with *AcqKnowledge*, and when combined with the UIM100C and STM100C modules, capable of outputting various waves at different rates, durations and types. As explained earlier in this chapter, there are four basic Stimulator signal types: **Square**, **Sine**, **Triangle** and **Arbitrary** waves. Square, Sine, and Triangle waves are limited to 4096 samples, which may be outputted once or continuously. 4096 samples also define the upper limit of a short burst wave. Arbitrary waves, like the other types, can be outputted once or continuously, but are not subject to the 4096 sample upper limit.

The Stimulator output sample rate is configured in *AcqKnowledge* by choosing MP150 > Data Acquisition Set up > Stimulator > Stimulator sample rate. The stimulator sample rate may be the same, lower, or higher than the acquisition sample rate. The output signal can be redirected to an analog input channel. In this case, the number of samples displayed in the graph is determined by the acquisition sample rate. If the source wave can be uploaded entirely to the MP150 memory ($\leq 512\text{K}$ samples), then the number of samples displayed in a reference analog input channel may be estimated with this formula:

$$\text{Displayed Samples} = \text{AcqRate} / \text{StimRate} * \# \text{Sample}_{(\text{source wave})}$$

Arbitrary wave sources are derived from any waveform within a saved data file or from a newly created waveform. Calculation channels, Transform and Edit operations may also be used to create unique waveforms.



Example source wave

The Expression calculation channel, Absolute value transformation and Edit Copy/Paste operations were used to create the example waveform shown above. The highlighted portion was used as the *source wave*.

The MP150 supports an aggregate (combined channel) sample rate of 400 K samples and has an internal memory of 512 K samples.

$$\text{Aggregate Sample Rate} = \# \text{analog channels} * \text{Acquisition Sample Rate}$$

Any down sampling of channels is applied in *AcqKnowledge*, and does not affect the sampling rate generated in the MP150.

Up to 512,000 samples can be uploaded into the MP150 memory and then outputted as a stimulator signal. Longer source waves will upload the first 512,000 samples, and the remaining waveform data as memory becomes available.

The following components affect the limits for the stimulus output:

- Acquisition setup
 - o mode
 - MP150 Memory
 - Save to disk or memory

- sampling rate
- Stimulator setup
 - Duration
 - Output Once
 - Output Continuously
 - Stimulator sample rate
 - Analog Output: one or two analog output enabled
- Source graph/wave length
 - Short burst wave ≤ 4096
 - Long waves > 4096 and ≤ 512 K samples
 - Within the limits of the MP150 internal memory
 - Longer waves > 512 K samples

There are two basic AcqKnowledge acquisition modes, “Save to MP150 Memory” and “Save to Memory/Disk.” On-line Averaging also uses the MP150 memory.

Save to MP150 Memory: This acquisition mode was designed for short burst signals at high acquisition sample rates with short duration. While longer acquisition can be acquired in this mode, the system may be slow to respond. Depending on the computer resources, it may take several seconds for the screen to update. Should this become an issue, adjust the CPU allocation in the AcqKnowledge Preferences. In the Preferences, select “Performance” and move the slider to the right toward Better data transfer for high speed acquisition.

AcqKnowledge Preferences are accessed from the Main Toolbar  or via Display > Preferences.

Analog Output Upper Limits Summary

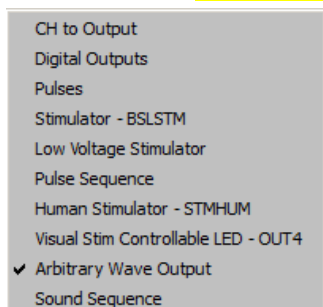
The upper limits for short burst, long, and longer waves are provided below.

Note: At high or maximum aggregate acquisition sample rates, the display may become sluggish and data may take several seconds to be displayed. Additional user actions may overwhelm the system.

	Short Burst Wave (≤ 4096 samples)	Long Wave (> 4096 samples but ≤ 512 K samples)	Longer Waves (≤ 512 K samples)
Stimulator Sample Rate:	100 K max (sample rate not adjustable for averaging)	100 K max	20 K max
Acquisition Modes:	Save to MP150 Memory Save to Averaging	Save to MP150 Memory Save to Memory or Disk	
Source Output Maximum per Analog Output:	4096 samples	512 K samples (256 K if dual stimulators are used via outputs A0 and A1)	
Maximum Aggregate Acquisition Sample Rate:	400 K		

Chapter 10 Output Control

Note Output Control chapter refers to MP36R hardware only.
For MP150, see the previous chapter, 'Set Up Stimulator.'



The MP36R hardware can output pulses or analog voltages via the **Analog Out** port; this port is also used to connect to BIOPAC's external stimulators. The MP36R has an additional **I/O Port** which is used to output digital (TTL Level) signals.

Parameters for output signals are set via **Output Control**. Access to a specific Output Control is via the **MP36R > Output Control** submenu.

There are three basic Output Control categories:

- Pulse – Pulses, Stimulator-BSLSTM, Low Voltage Stimulator and Human Stimulator-STMHUM
- Pulse trains – Pulse Sequence, Sound Sequence and Visual Stim Controllable LED-OUT4
- Other – CH to Output, Digital Outputs, Arbitrary Wave Output

There are a total of ten Output Controls for the MP36R:

<u>Output Control</u>	<u>See...</u>	<u>MP36R Functionality</u>
CH# to Output	page 189	Direct analog CH1-4 to output listen to signals
Digital Outputs	page 191	Control 8 digital outputs
Pulses	page 186	Use with third-party devices; software can control pulse width and repetition.
Stimulator - BSLSTM	page 192	Use with BSL Stimulator
Low Voltage Stimulator	page 192	MP36R: Use OUT3 adapter for MP36R built-in low voltage stimulator. Software can control pulse amplitude, width and repetition (-10 to +10 V)
Pulse Sequence	page 188	Direct analog CH1-4 or digital D1-8 output. Allows for output of customized pulse trains.
Human Stimulator – STMHUM	page 193	Hand-held stimulator, allowing the subject to control the stimulus delivery. Configurable from 1-100 V.
Visual Controllable LED – OUT4	page 198	Direct analog CH1-4 or digital D1-8 output. Allows for output of customized pulse trains to an LED transducer for visual stimulus studies (OUT4).
Arbitrary Wave Output	page 199	Arbitrary wave output is very similar to the stimulator in the MP150, allowing for generation of square, sine or ramp signals, or arbitrary signals from another open graph window.
Sound Sequence	page 198	Outputs customized sounds assignable to a user configurable pulse train.

To open an Output Control, select it from the **MP 36R > Output Control** submenu. A checkmark appears next to the submenu selection and an **Output Control** panel is displayed, bordered in red in the active data window. To close an Output Control, select from the menu again (toggles between display and hide) or right-click in the open control panel and choose **Close**.

Only one Output Control panel per graph may be open at any time. Switching between different data files may display different output control panels, which operate differently.

Because some output devices can be used for stimulation on humans and can achieve voltages up to 100 Volts, built-in software logic makes output control as safe as possible. See page 213 for safety notes regarding human subjects. The following applies to all Output Controls.

The output will not operate unless its software control panel is open.

When an Output Control panel is closed, or the AcqKnowledge application is closed, MP36R output goes to 0 Volts, preventing the output device from sending pulses.

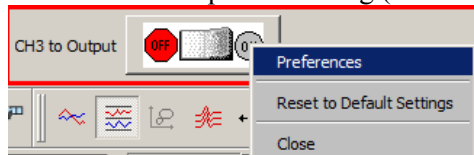
When an Output Control panel is opened, output is always OFF until activated by a click of the ON/OFF switch in the control panel or, if parameters allow, a click of the Start button in the data acquisition window. (Exceptions are the Digital Outputs Control when set to the preference “Set each output immediately.”)

If desired, custom Output preference parameters can be saved as a preset for a current graph (file preset) or for all graphs (global preset) by using the “Save Settings” button in the Output Preferences window. A saved Output preference can be selected from the Output Settings pop-up menu in the Output Control’s panel.

Output Control **Preferences** dialogs establish the parameters for output. Preferences dialogs are only available when the corresponding Output Control panel is open and active.

To generate the **Preferences** dialog:

Open an Output Control panel and then right-click over it to generate a pop-up menu. Choose **Preferences** to open the dialog (**Close** will close the control panel).



If a control panel entry box is grayed, its values may be already be established or limited by settings in the Preferences dialog. If **Preferences** parameters allow, enter values directly in the **Output Control** panel.



Key into the entry boxes and then enter the value by pressing the **Enter** key.

Use the **Tab** key or mouse to move to another entry box.

Click the **OK** button if in the preference dialog.

Values entered into a control panel or its Preferences dialog that are outside the specifications of the output device, or outside the limits defined by the Preferences dialog, may change automatically to reflect either the closest value to that requested that the hardware can achieve, or the closest increment defined by the limits in Preferences. (The system will not check while you type, it checks and may make changes after the value is entered.)

For example, if a Pulse width of 5 ms is entered into the Pulses Output Control panel entry box, but Preferences defines a range limit of .5 to 2 ms for Pulse width, the system will automatically change the new entry to 2 ms.

Saving Panel settings:

Output Control panel settings will be retained until a file is closed or saved. If a file is closed but not saved, settings will be lost (defaults established); if a file is saved, panel settings will be saved.

CH# to Output



The CH# to Output Output Control redirects an analog input signal to the **Analog Out** port on the back of the MP36R UNIT. The signal from the assigned channel will continue to be record and plot data.

This Output Control is used commonly when attaching headphones to the MP36R unit to listen to signals coming in on an analog input channel; for example listening to the Electromyogram.

To display this control panel:

Choose MP 36R > Output Control > CH# to Output to open the control panel.

MP36R users may use analog input CH1-CH4. Channel 3 is the default setting. If another channel N has been designated, the menu will read "CH<N>."

Use the control panel **ON/OFF Switch** to start and stop output. OFF grounds the output so no signal (or sound) should be present.

Set **Preferences** to designate which channel to redirect to output.

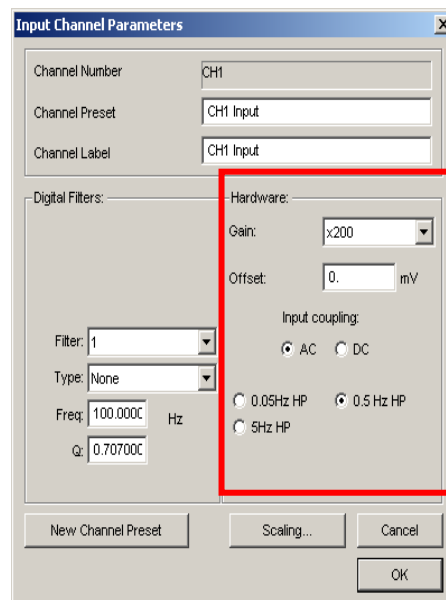
Open the Preferences dialog by right-clicking the control panel.

Use the pull-down menu to select the desired channel CH 1-4 to use for the output.

Click OK to set the output channel and return to the control panel.

Note Only the Hardware settings (Gain, Offset, Input Coupling) from the Input Channel Parameters dialog (MP36R > Set Up Data Acquisition > Channels > Setup) will be applied since output is established prior to the processing of Digital Filters.

See **MP36R Input > Output Scaling** values on the next page.



MP36R Input > Output Scaling

The MP36R hardware can pipe signals from any channel input to the output using the “CHX to Output” control panel in the AcqKnowledge software—due to the difference between the input and output range, there will be a change in signal level (scaling). The output range depends on the output pin used as shown in the following table.

Output Pin (Analog Out port)	Pin Description	Output Range (Volts)
Pin 1	Headphones, A.C. Coupled	-2.048 to +2.048
Pin 2	Low Voltage Stimulator, D.C. Coupled	-10 to +10

The input range is gain-dependent. The table below shows the scaling (multiplying) factors to use for each gain setting.

Gain	Input Range +- millivolts	Output Scale**— <i>accurate to ±10%</i>	
		<i>Factor 1</i> Pin 1 (Headphone out)	<i>Factor 2</i> Pin 2 (Low Voltage Stimulator)
x5	± 2 V	1.024	5
x10	± 1 V	2.048	10
x20	± 500 mV	4.095	20
x50	± 200 mV	10.238	50
x100	± 100 mV	20.475	100
x200	± 50 mV	40.950	200
x500	± 20 mV	102.375	500
x1,000	± 10 mV	204.750	1,000
x2,000	± 5 mV	409.500	2,000
x5,000	± 2 mV	1023.750	5,000
x10,000	± 1 mV	2047.500	10,000
x20,000	± 0.5 mV	4095.000	20,000
x50,000	± 0.2 mV	10238.000	50,000

Notes

- * 1: To properly measure the output signal you need at least a 2K Ohm load.
- ** 2. Input to Output scaling is accurate to within 10%.

Digital Outputs Control



The Digital Output Control manages the signal output for each of the eight digital lines via the **I/O Port** located on the back of the MP36R. Digital lines are used to control external devices.

The digital output uses standard TTL levels which correspond to the control panel setting as follows:

Control Panel setting	Output Voltage level (Volts)
0	0
1	+5

To display this control panel:

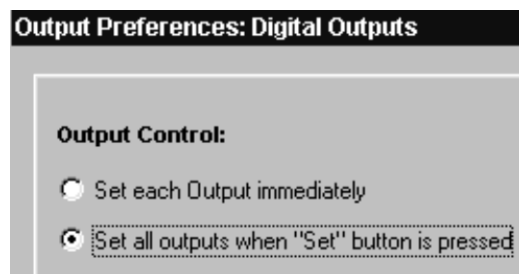
Choose **MP36R > Output Control > Digital Outputs** to open the Digital Outputs Control panel

Click each digital output line to set its digital state to 0 (off) or 1 (on).

To set **Preferences** for Digital Outputs, open the Preferences dialog by right-clicking the control panel.

Select from the following two options:

Set each output immediately (default) allows you to toggle the state of each digital output line between 0 and 1, and change the state **immediately**. In this mode, no **Set** button is available in the control panel. Output for each line is set upon clicking its toggle button.



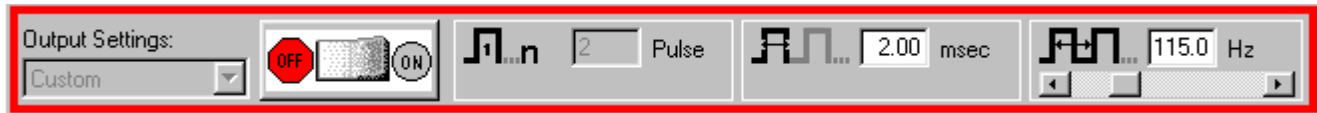
Set all outputs when Set button is pressed allows you to toggle the state of each digital output line, but the states will not physically be changed until the **Set** button is clicked on the control panel. In this mode, a **Set** button is available in the control panel. When the **Set** button is clicked, all eight digital lines will update simultaneously.

Pulses Output Control

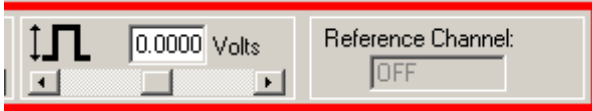
Stimulator – BSLSTM Output Control

Stimulator – Low Voltage Output Control

Stimulator Human Stimulator (STMHUM) Output Control



Control panel options for Pulses, Stimulator – BSLSTM and Stimulator – Low Voltage



Additional control panel options for Low Voltage Stimulator

A variety of pulse output options are available. Exercise caution when using any of the options with human subjects—see the **Safety Note** on page 213.

Pulses Output Control

Select this Output Control for general pulse output, or when synchronizing to 3rd-party devices.

Use for reaction time measurements, where a subject listens with headphones for a series of “clicks” (pulses) and responds as quickly as possible with a button press. Determine reaction times by calculating the time between the start of the pulses and the responses.

Use with the **BIOPAC STP30W** Stimulus Presentation System (SuperLab) to measure responses to visual or auditory stimuli. To perform sophisticated evoked response averaging tests (e.g. P300), pair triggers with different visual or auditory stimuli.

Use to trigger another device (automatically send a pulse from the MP36R UNIT when acquisition starts).

Use to control a 3rd-party stimulator. BIOPAC recommends use of the BIOPAC BSLSTM Stimulator with the MP UNIT and BIOPAC software. If using the BSLSTM Stimulator, use the **Stimulator - BSLSTM Output Control** instead of this Pulses Output Control.

Stimulator – BSLSTM



Select this Output Control when using the Biopac Student Lab stimulator (BSLSTM)

Use with stimulation electrode HSTM01 for safe stimulation of human subjects (0 – 100 Volts), as well as lower voltage (0 - +10 Volt) general-purpose stimulation, such is used with amphibian muscle or nerve preparations.

Set up note Placing the BSLSTMA/B unit too close to MP36R hardware can result in data distortion of the BSLSTMA/B pulse width signal; distortion is more apparent at higher sampling rates.

- NEVER set the BSLSTMA/B atop MP36R hardware
- Position the BSLSTMA/B away from the MP36R hardware to reduce the signal distortion



Low Voltage Stimulator

Select this Output Control for low-voltage (-10 - +10 Volt), direct drive stimulation via MP36R Analog Out port (with or without OUT3 BNC adapter).

Use with stimulator electrode HSTM01 for safe, stimulation of human subjects (0 – 100 Volts), as well as lower voltage (0 - +10 Volt) general-purpose stimulation, such is used with amphibian muscle or nerve preparations.

Outputs through a BNC connector so it can be used with most stimulation cables (such as those that terminate in a needle probe).

Stimulator Human Stimulator – STMHUM

Select this Output Control to conduct stimulation studies that enable subjects to control the stimulus delivery.

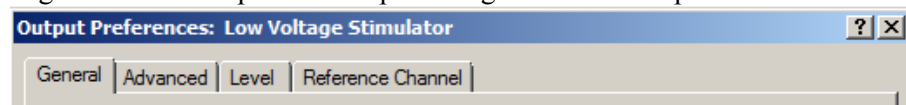


This hand-held stimulator connects directly to the MP36 Analog Out port and has a red button for delivering the stimulus signal. The electrodes on the bottom of the unit are placed directly onto the subject. The STMHUM functions much like the BSLSTM but with no additional hardware required. The voltage range is 0 – 100 volts and can be limited or locked to a user defined level in the STMHUM Output Control panel, which resembles that of the Low Voltage Stimulator.

To use one of these control panels:

Choose MP 36R > Output Control and then select Pulses, Stimulator – BSLSTM, Low Voltage Stimulator, or Human Stimulator (STMHUM).

Right-click the Output Control panel to generate the Output Preferences dialog.



Set the Preferences.

General: ON/OFF, Number of pulses, Event options — see page 205

Advanced: Pulse width, Pulse repetition (rate) and Verify Transducer (STMHUM) — see page 209

Level (Low Voltage Stimulator and STMHUM only): Pulse level — see page 211

Reference Channel (Low Voltage Stimulator, Pulse Sequence and STMHUM only): The Reference Channel is the channel on which the pulse is outputted, and configurable as Analog channels CH1-CH4, or Digital channels D1-D8.

Once configured, Preferences may be saved using the **Save Settings** command, activated by pressing the saved settings from the pop-up menu in the control panel (see page 205).

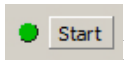
Confirm the settings in the control panel. Adjust as desired within the parameters established in Preferences.

Entry limits: Settings entered into the Preferences dialog may establish, or limit, the values in the Output Control panel entry boxes. Enter pulse settings directly into the control panel only if the Preference settings are not locked to a specified value. A grayed or disabled entry box indicates that the values are locked.

Initiate the pulse sequence as defined in Preferences (see page 205).



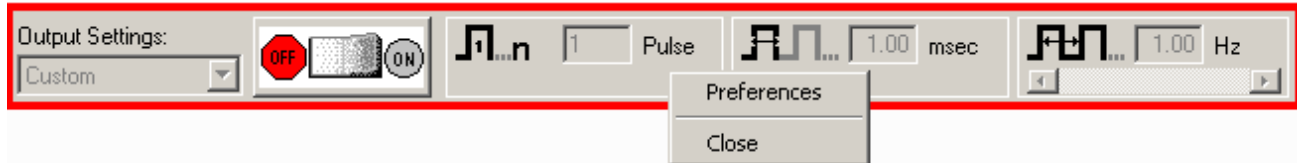
ON/OFF Button in Output Control Panel uses the switch in the Control panel.



Recording uses the **Start /Stop** button in the data acquisition window.

To close an Output Control panel:

Right-click anywhere in the Output Control panel to generate a pop-up menu and then choose **Close**, or select it (or another output control) from the MP36R > Output Control submenu.



Pulse Sequence Output Control

In AcqKnowledge 4.2 and higher, this Output Control allows sequences of pulse configurations and delays to be sent to the MP36R unit, making it possible to create more complex stimulus setups.

Enabling the pulse sequence output control option will display the following control panel at the top of the graph window:



Pulse sequence configuration is performed in the Preferences dialog of this output control panel. (Accessible via right-click on panel shown above.) When a pulse train element is selected in the configuration, the controls will become visible in the right hand portion of the preferences dialog. The configuration makes use of three basic building blocks:

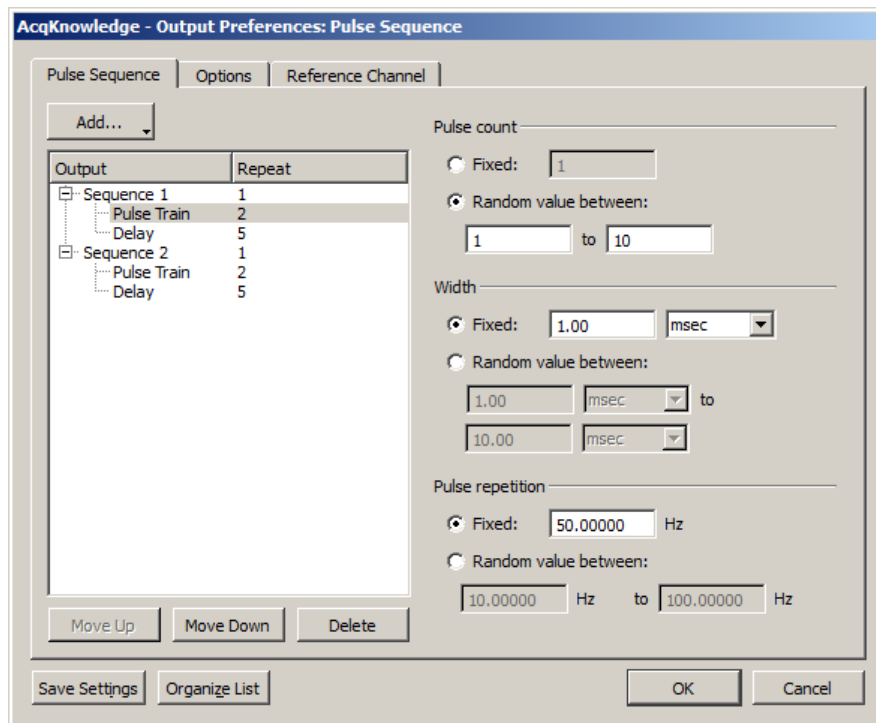
A *sequence* consisting of a number of delay and pulse train elements. The final configuration consists of one or more sequences that are outputted in order. Normally the entire configuration is outputted. There is a special operational mode on 'Start with Recording' that will take only the indexed sequence matching the current recording segment.

A *pulse train element* consists of Pulse count, Width and Pulse repetition, These elements can be fixed or randomly generated.

A *delay element* that allows for the introduction of time during which no pulses will be generated.

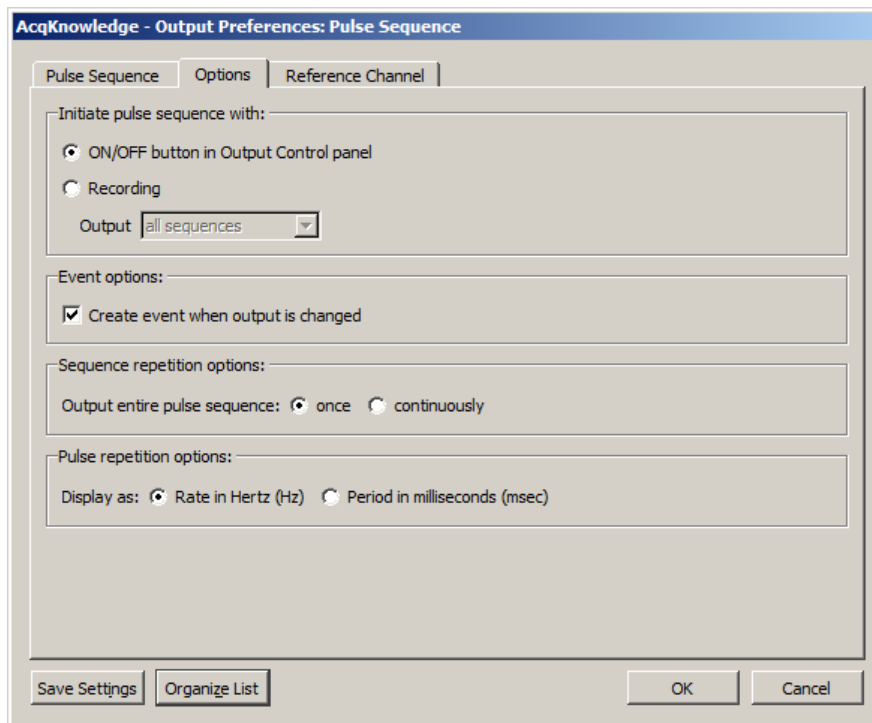
Each one of these building blocks also has a “repeat” count associated with it that will perform the action a set number of times. (Adjust by selecting the desired ‘Repeat’ and inputting a new value) Individual sequences, pulse trains and delays can be added, deleted, repeated and reordered as desired. In the right pane of the Preference dialog (shown below), fixed or random pulse counts, widths and repetitions can be configured and combined. As in other Output Controls, custom settings can be saved and organized in a list view. (See below for additional setup dialogs)

For a full explanation of preferences and tabs common to all Output Control panels, see the “Pulse Definition” section on page 203 and the “Output Control” section on page 204.

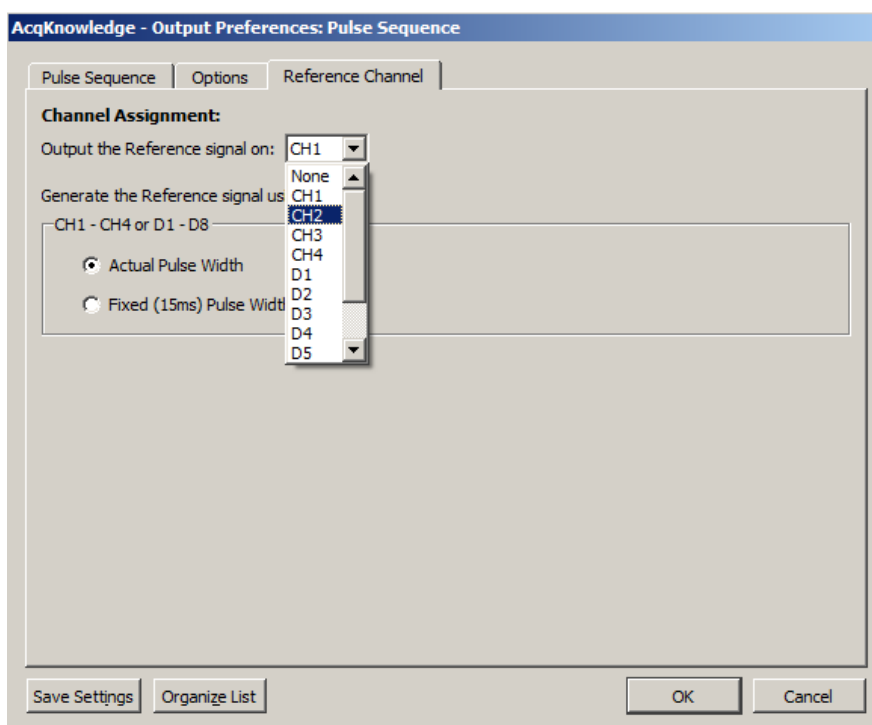


Preferences available in Pulse Sequence tab

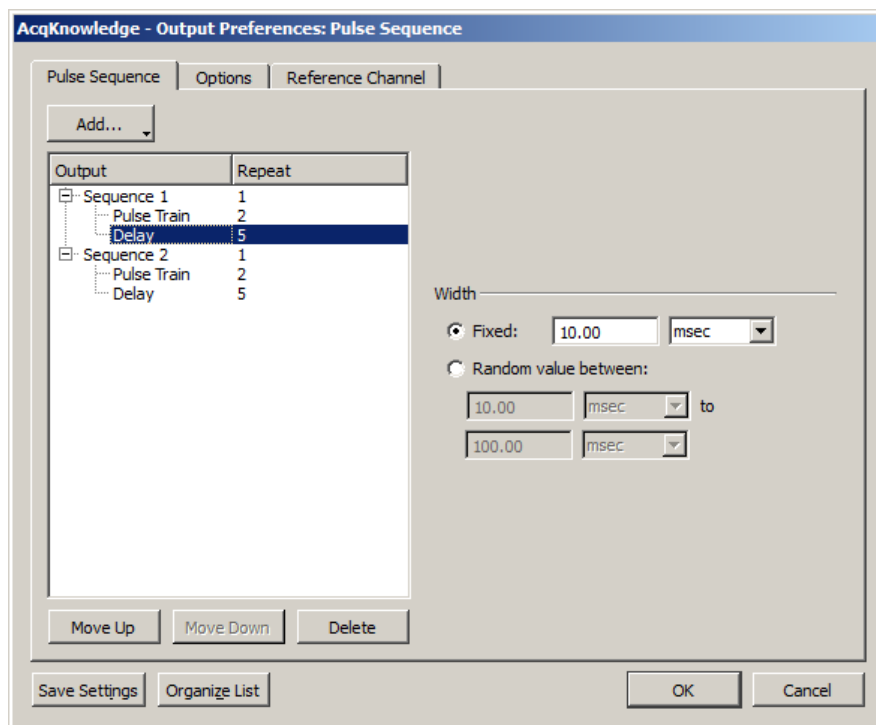
- Add:** Displays pop-up menu for adding Sequences, Pulse Trains or Delays.
- Output:** Displays the configured sequences and sequence elements for the current or saved session.
- Repeat:** Editable field for setting the number of times the pulse train or pulse train element is repeated
- Pulse count:** Fixed – a set number of pulses is generated per sequence.
 Random – set a random number of pulses to be generated per sequence.
- Width:** Fixed – each pulse width will be of a set duration, in units of microseconds, milliseconds, or seconds.
 Random – sets the pulse width duration to fall between two set time ranges.
- Pulse repetition:** Fixed – sets a fixed interval between the start of one pulse to the start of the next pulse
 Random – sets a random interval between two set values for the start of one pulse to the start of the next pulse.
- Move Up/Down Delete:** Selectively reorders or deletes the various pulse train elements.
- Save Settings:** Saves modified settings as a custom preset for the current graph, or for all graphs.
- Organize List:** Orders custom presets into a list and categorizes the custom presets for the current file or globally across the application.



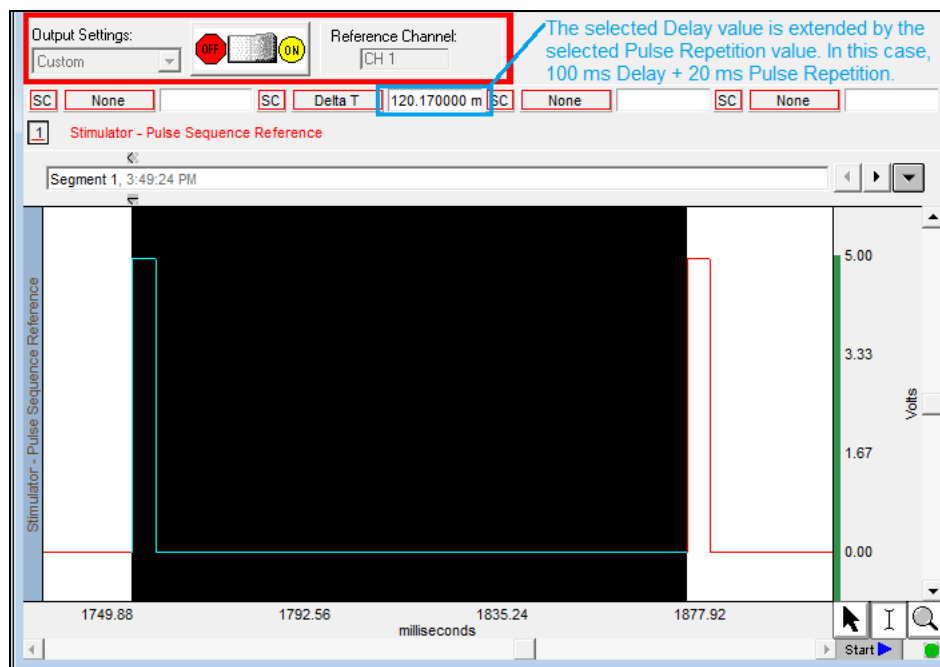
Preferences available in Options tab



Preferences available in Reference Channel tab

*Delay Preferences***About Delay between Pulse Trains:**

The amount of actual Delay between pulse trains will vary from the set value depending upon the pulse repetition value that is used. In the example sequence below, a Delay of 100 milliseconds between pulse trains has been set up, combined with a pulse repetition rate of 20 milliseconds. Because the pulse repetition rate is applied before the Delay occurs, the actual Delay between pulse trains in this case will be 120 milliseconds. If it is critical that a Delay reflect an exact value, it is advisable to subtract the selected pulse repetition value when setting up the Delay parameters.

*Delay between pulse trains*

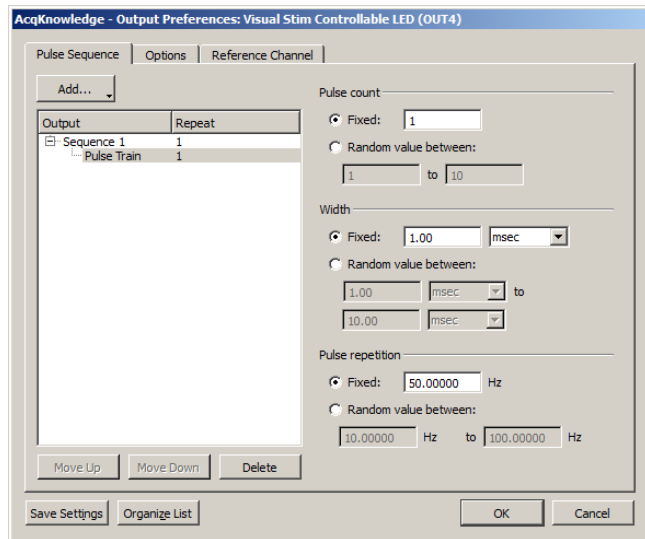
Visual Stim Controllable LED – OUT4 Output Control

This Output Control is used to set up parameters for the OUT4 LED transducer used for conducting visual stimulus studies, in which flashes of light of varying intensities and intervals are presented to a subject. The OUT4 LED transducer is connected directly to the MP36 Analog Out port.

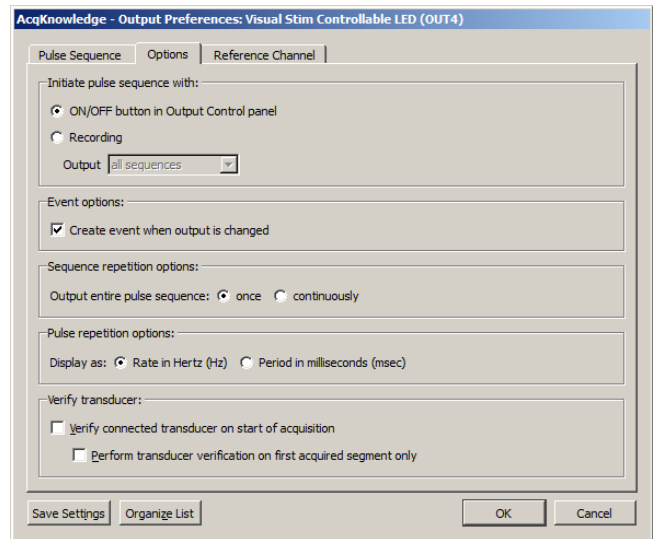
To use this Output Control choose **MP Unit > Output Control > Visual Stim Controllable LED**.



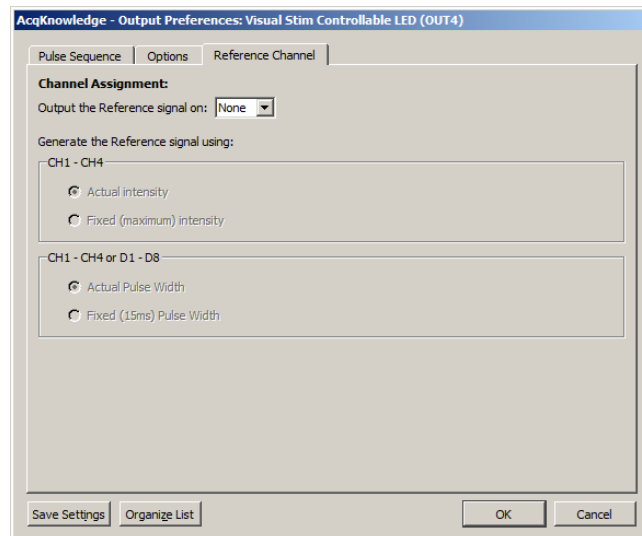
The Visual Stim Controllable LED Output Control panel is identical to the Pulse Sequence control panel, but with the addition of an intensity control for controlling the LED brightness level. The preferences operate identically to those of the Pulse Sequence Output Control covered in the previous section.



Pulse Sequence Tab for Visual Stim Controllable LED



Options Tab for Visual Stim Controllable LED



Reference Channel Tab for Visual Stim Controllable LED

For specifics on the Visual Stim LED preferences set up, see the Pulse Sequence Output Control section on page 194.

Arbitrary Wave Output

AcqKnowledge with MP36R supports signal output through one analog channel while data is being acquired. This is configured by using the Arbitrary Wave Output option.

Four types of signals can be output:

Square waveforms—page 182

Ramp waveforms—183

Tone waveforms—183

Arbitrary waveforms—184

Each of these waveform types can be set to repeat signal output either Once or Continuously, and parameters can be set to either Relative or Absolute time scales. Like the standard graph window, the Stimulator setup window plots time on the horizontal axis and amplitude on the vertical axis.

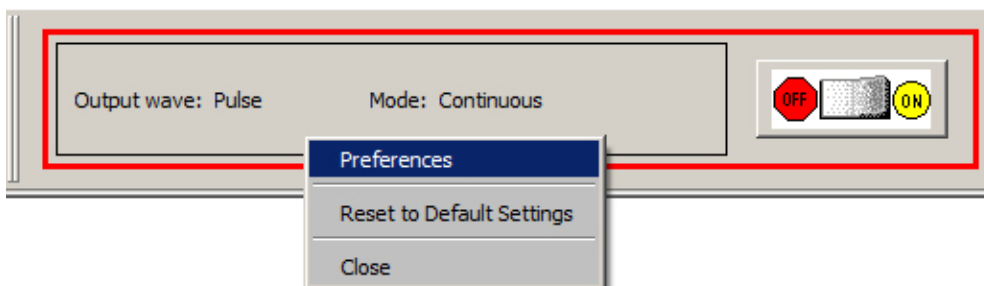
Use the Stimulator window (see following page) to create and shape waveforms for output. Adjust the Stimulator Sample Rate to further control the parameters of the Stimulator Output design.

For any waveform (or stimulus) to be output, the following parameters must be specified; the type of stimulus, the “shape” of the signal, the output channel to be used, and how many times the stimulus should be output.

The above parameters are set up from within the Stimulator Setup dialog. Regardless of the type of waveform selected, stimulus signals will normally be by clicking the AcqKnowledge graph’s “Start” button or by using the On/Off Output Control panel button.

To set up the Arbitrary Wave Output:

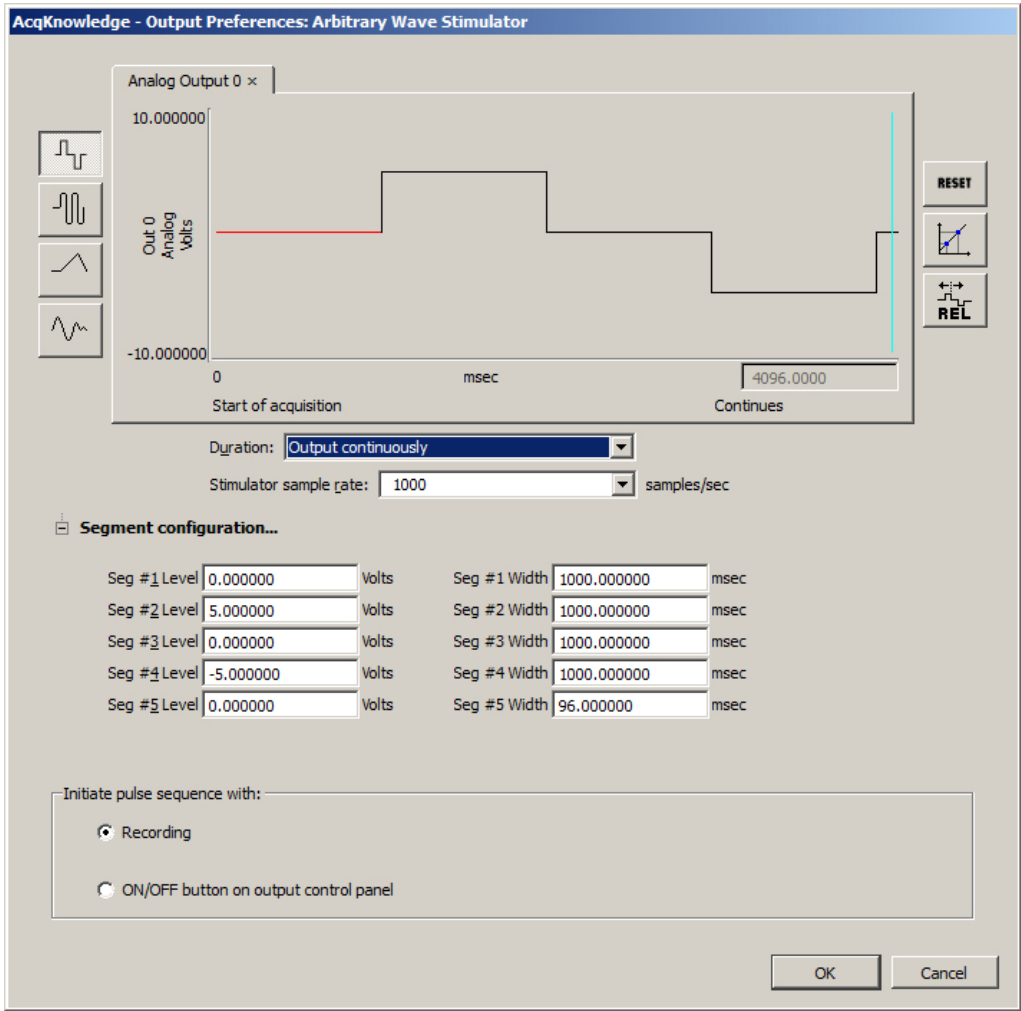
1. Select MP36R > Output Control > Arbitrary Wave Output.
2. Right click the Arbitrary Wave Output Control panel and choose “Preferences” to launch the Stimulator setup window.










3. Set the desired waveform type and stimulator options in the Stimulator window.

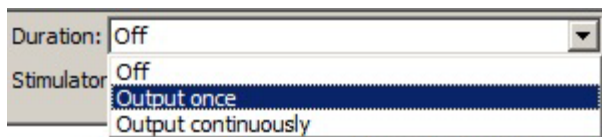
The MP36R Stimulator setup window (see following page) is nearly identical to the MP150 setup window detailed in the previous Stimulator chapter, with the following exceptions:

- The signal output is limited to one analog channel (vs. two in MP150 hardware).
- The pulse sequence is initiated by starting the acquisition or by toggling the On/Off button on the Output Control panel (vs. the Timing or Trigger controls in MP150 hardware).
- Stimulator averaging output is not supported in MP36R hardware.



Stimulator Icons		
Waveforms:		Square wave
		Tone (sine) wave
		Ramp wave
		Arbitrary wave
Parameters:		Reset the display (use after adjusting the time scale)
		Scaling (rescale Stimulus signals to different units)
		Set time base to relative
Output:	<div><p>Initiate pulse sequence with:</p><p><input checked="" type="radio"/> Recording</p><p><input type="radio"/> ON/OFF button on output control panel</p></div>	Sets Stimulator to be active when “Start” button is clicked OR when toggled via the ON/OFF button on the Arbitrary Wave Output control panel.

Duration



Off: Turn Output OFF (no stimulus signal output).

Output once: Output the stimulus signal once.

Output continuously: Output the stimulus signal for the duration of the acquisition (forever).

When Output continuously is selected, a vertical line is generated at the end of the first section of the waveform in the stimulator window to indicate where the first output signal ends and the second begins. The line can be dragged left or right like a vertical segment in a stimulus waveform to control the duration of the waveform as it is continuously output. Maximum continuous waveform output is 20 kHz.

Stimulator Sample Rate



Use to select the Stimulator sample rate for the generated signal. (The Stimulator sample rate is independent of the acquisition sample rate. See page 185 for sample rate details.)

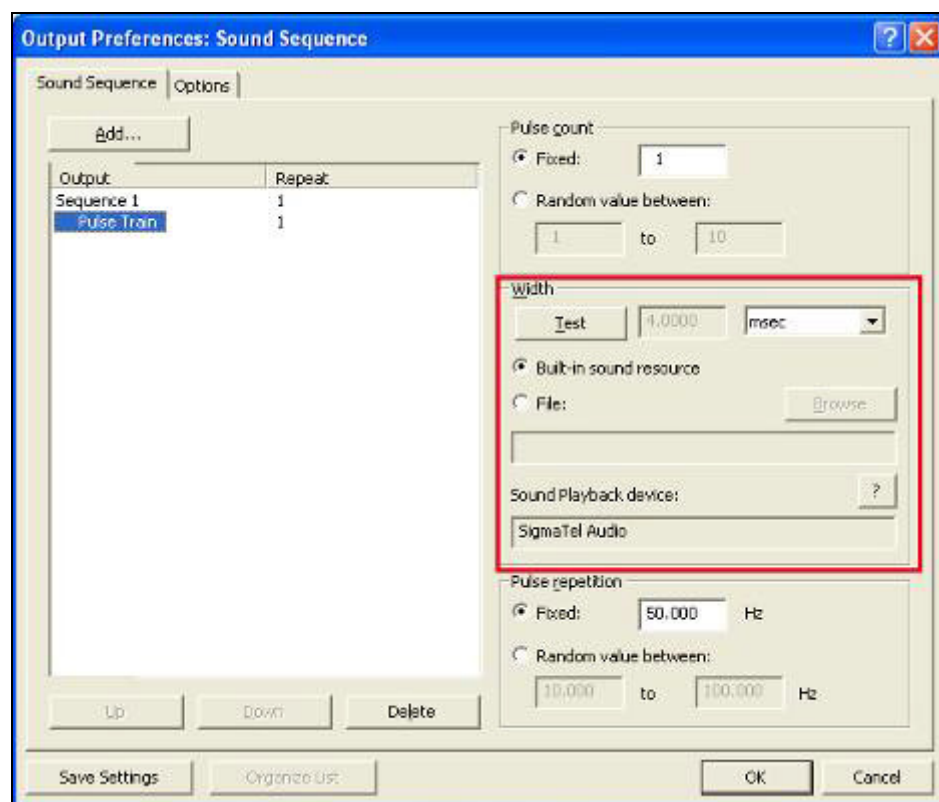
For more details on all other MP36R Stimulator parameters and functionality, see the previous MP150

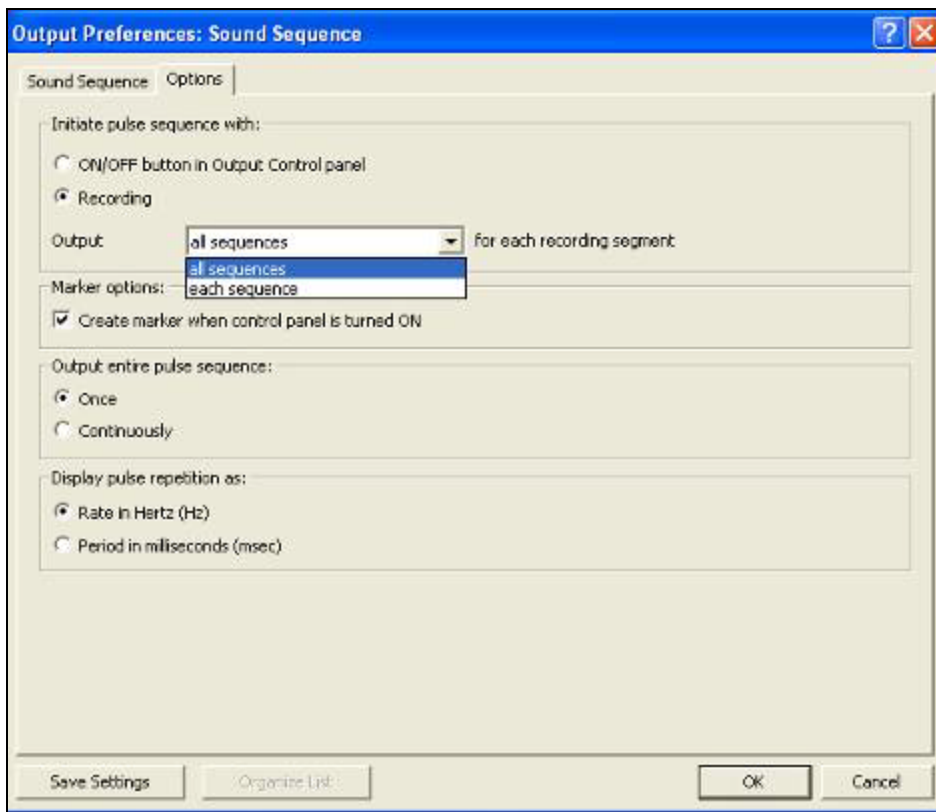
Stimulator chapter on page 176.

➔ See also: Application Note [AH162](#) - Using the Stimulation Features of the MP System.

Sound Sequence Output Control

In *AcqKnowledge* 4.2 and higher, Sound Sequence Output Control offers users the option of configuring and customizing sounds to be outputted for aural stimulus experiments. The control panel and Preferences dialogs used for Sound Sequence closely resemble that of Pulse Sequence. The built-in sound resource (a default “click”) may be used or any other file in *.WAV format can be substituted via the “File” and “Browse” button. The “Width” and “Pulse Repetition” values are dependent upon the duration of the sound file selected for output. The “Test” button will output an audio sample of the selected sound resource.



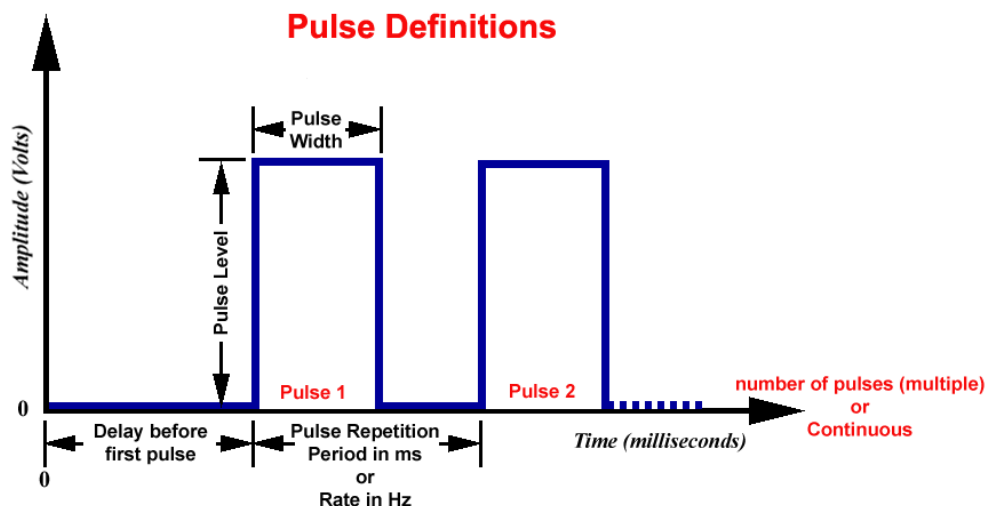


The option *all sequences* means that each configured sound sequence (regardless of number) will be outputted within the same segment. If "Once" is selected in the "Output entire pulse sequence" option, a configured sequence will be heard one time only. If "Continuously" is selected, the first Sound Sequence will be repeated after the last one has completed, looping the pattern repeatedly until the recording is stopped.

The option *each sequence* means that each sound sequence will be outputted on a segment-by segment-basis only. For example, if one Sound Sequence is configured, it will only be heard during the first recording segment, but not during the second recording segment). If two Sound Sequences are set up, the first one will be heard during the first segment and the second one during the following segment. If no additional Sound Sequences have been configured, nothing will be heard during the third segments and beyond. (Exception: If "Save Once" acquisition mode is used, the Sound Sequence will be repeated when the recording is overwritten during subsequent passes).

Pulse Definitions

The following terms are used in the Output Control panels, Preferences, and guidelines for Pulses, Stimulator – BSLSTM, Low Voltage Stimulator and Human Stimulator-STMHUM.



Delay before first Pulse	Initial delay from start of acquisition to start of first pulse.
Number of pulses	Number of successive pulses that will be sent out at the specified Pulse Width, Repetition and Level. Set for Single (1), Multiple, or Continuous (Cont).
Pulse Level	Amplitude of the pulse, expressed in Volts. <i>Note:</i> The output of the BSLSTM is 0 Volts when the pulse is not active.
Pulse Repetition <i>Also called —</i> Events per second Pulse frequency Pulse sequence Pulse train Repetition rate Sample train	Can be expressed as Period (ms) or Rate (Hz). <i>Period:</i> Time between pulses; measured in milliseconds from the start of one pulse to the start of the next pulse. <i>Rate:</i> Number of pulses that occur in a one-second interval; measured in Hertz. Rate relates to Period as: $\text{Rate (Hz)} = 1000 / \text{Period (ms)}$
Pulse Width	Time that the pulse is in the non-zero or active state.

Output Control Panel Descriptions

The Output Control panels for Pulses, Stimulator – BSLSTM, Low Voltage Stimulator and Human Stimulator-STMHUM work in conjunction with Preferences to control pulse output. Control panel functions are detailed here:

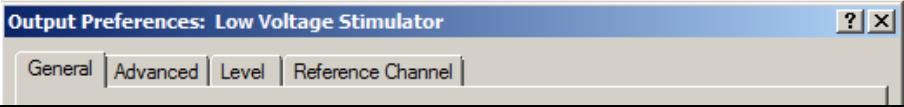
OUTPUT CONTROL PANELS

General Notes

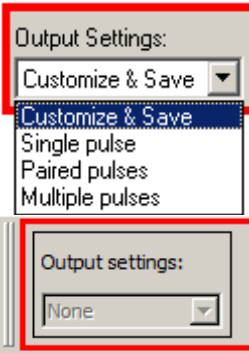
Pulse parameters can interact with each other.
For example, the pulse repetition period cannot be set to a value less than the pulse width.
In order to simplify the interaction, the Pulse width entry overrides other entries as required; it is the priority parameter.
For example, if the pulse width is changed such that it exceeds the pulse repetition period, the pulse repetition period will be automatically adjusted to accommodate the new pulse width entry. If, however, the pulse repetition period is changed such that it is less than the pulse width, the repetition period will be changed, upon attempted entry, to the closest value that can be achieved without changing the pulse width.
Entries are checked and rounded (not truncated) as necessary to meet limitations of the hardware or the Preferences.
When a file is opened, the output device will not turn ON automatically. A user must manually press either the “Record” button or the “Start” button.
The exceptions are the “Voltage Output” control panel and the “Digital Outputs” control panel if “Set each Output immediately” is selected; these settings will output values immediately.
Output control settings are “local,” which means that they are stored at the data file level, not the program level. Use the save as graph template (File > Save As) option to use existing Preferences in new data files.
If a file is saved with an Output Control panel visible and then closed, the panel will be visible when that file is re-opened.

Preferences

Right-click a control panel to generate the Preferences dialog, and then select a tab for the settings you want to adjust.



Output Settings



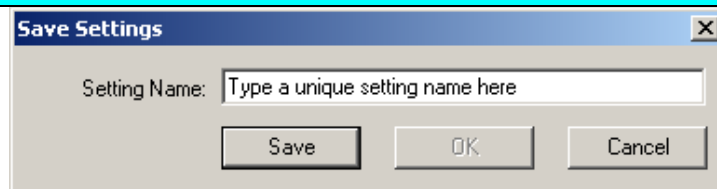
Displays the name of the current Preferences setting. The pull-down menu lists the names of all output Preferences saved using the **Save Settings** button (see page 205). The pull-down menu is not accessible when an output pulse train is in progress. If no settings configurations have yet been saved when the Output Control panel is first opened and no parameters are changed, the Output Settings box displays “Default.”

When output settings are saved, the Output Settings box displays the name of the last selected setting. Use **Organize List** to change the display order of the menu, rename, or delete items (see page 205).

When a saved setting is selected from the pull-down menu, the Output Control panel and all Preferences dialog options will be updated.

For Reference Channel—Low Voltage Stimulator; Human Stimulator; Visual Stim Controllable LED (OUT4) and Pulse Sequence only. All Output Settings must use the same reference channel assignment; other parameters can be unique for each setting.

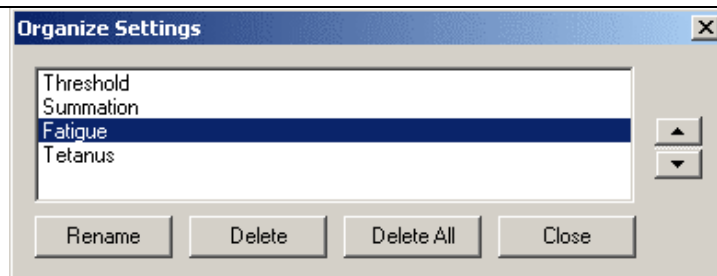
OUTPUT CONTROL PANELS



Once configured, Preferences may be saved using the **Save Settings** button at the bottom of the Preferences dialog. **Save Settings** generates a dialog to name and save a defined configuration of Stimulator output settings. Saved configurations are accessible via the Output Settings pull-down menu in the Output Control panel. When a setting is selected from the menu, all current output parameters are updated to reflect the saved settings.

Multiple configurations can be saved as long as each has a unique name; the Save button will be inactive if the name you enter is not unique.

Settings can be saved locally (to a specific file) or globally. The data file or template file holds the output parameters as established when the file was saved plus any other named configurations of Output Settings.

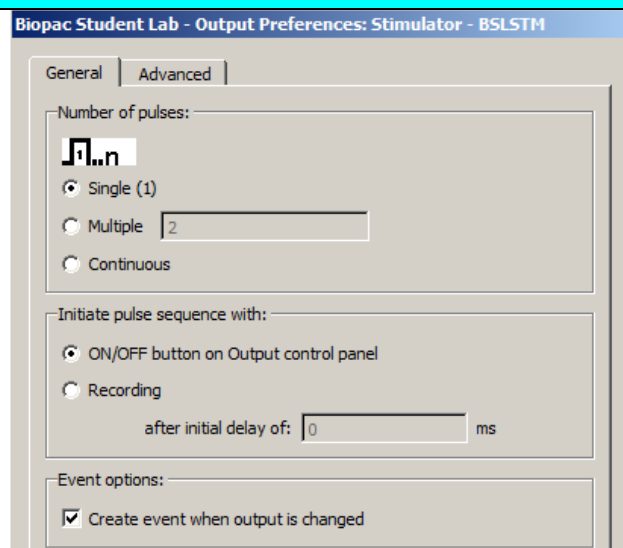


Use the **Organize List** button at the bottom of the Preferences dialog to order, rename or delete saved Preferences settings. The up or down arrows are only available if two or more settings have been saved. Select a setting and then click the up and down arrows to set the position, or choose rename or delete. Selecting “Delete All,” removes all saved settings will be deleted and the default options will be reactivated.

GENERAL TAB (OUTPUT PREFERENCES)

General Tab

The General tab is available when using Pulses, Low Voltage Stimulator, Stimulator-BSLSTM and Human Stimulator-STMHUM.



GENERAL TAB (OUTPUT PREFERENCES)

Number of Pulses



Indicates the number of pulses to be output. When the Output Control panel is closed, the pulse output will be immediately stopped.

Single will establish a single pulse for outputting. All pulse repetition options, entry boxes and scroll bars in both the control panel and preferences windows will be disabled (grayed).

Multiple will establish a specific number of pulses for outputting. The selection will activate an entry box where you can enter 1-254 pulses. When this option is selected, the Pulse Repetition scroll bar is activated in the Output Control panel.

Continuous will establish a continuous pulse train for outputting. When this option is selected, the Pulse Repetition scroll bar is activated in the Output Control panel.

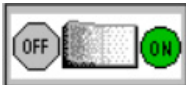
If “Initiate pulse sequence with ON/OFF button in Output control panel” is set, the pulse sequence will be stopped prior to acquisition and will have to be manually turned back on after the recording.

Initiate pulse sequence with...

ON/OFF Button



OFF (red)



ON (green)



AUTOMATIC
START (yellow)

Controls the start and stop of pulses. Changes to Pulse Width and Repetition Rate can be made in the Output Control panel entry boxes during a pulse sequence, and during a recording, if all other Preferences parameters allow it. Any change in the pulse output will occur immediately. ***This lets you change the stimulator output “on the fly.”***

When “Initiate pulse sequence with **ON/OFF button**” is selected:

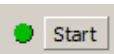
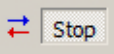
The ON/OFF button controls pulse output independent of the acquisition status.

OFF is always available.

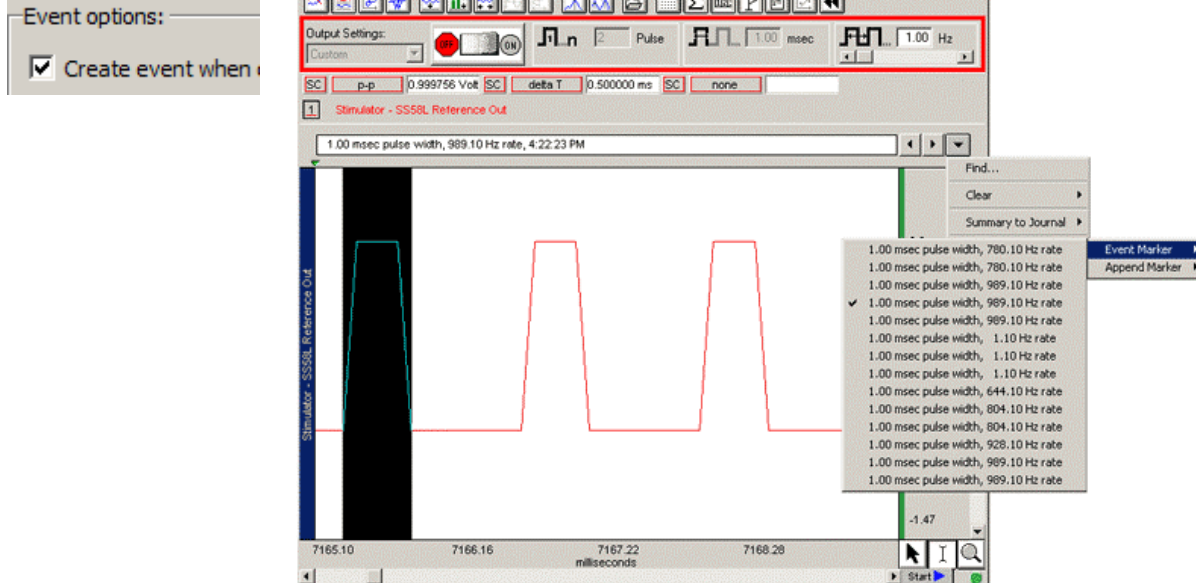
The ON/OFF button reflects the current output state, with one exception: if the pulse sequence lasts less than 0.5 seconds, the button will remain in the “ON” state for at least 0.5 seconds to indicate that the ON state occurred.

When the Number of Pulses selected is Multiple, ON/OFF acts as a momentary switch. Press the ON (green) button to start pulses; it will automatically turn OFF (red) at the end of the specified pulse train.

The switch defaults to OFF. Saving a data file or saving as a Graph Template will save all stimulator preferences except the status of the pulse switch, which will always be saved in the OFF position.

Recording	When “Initiate pulse sequence with Recording ” is selected:		
	If the preference setting “Initiate pulse sequence with: ON/OFF button” is active, the control panel changes will take effect immediately. If settings are changed during a pulse train, changes do not take effect until the next time the stimulator starts. Pulse output turns ON and OFF corresponding to the Start and Stop of the recording.		
Start button			
	When in this mode, and not recording, the ON button will display as yellow, indicating that pulse output will automatically begin at the “Start” of the recording.		
Stop button			
Pulse outputting can be turned OFF during a recording, but it cannot be turned back ON until the end of the recording.			
When a Repeat sequence is running, pressing the OFF button will turn OFF the output <u>for the entire recording sequence</u> and the button will display as OFF until after the last sequence, when the switch will display as yellow ON (automatic start) indicating that pulse output will begin again at the “Start” of the next recording sequence. You cannot turn pulse outputting back ON during a repeated recording sequence.			
When the acquisition stops, all stimulator pulses will cease, regardless of the Output Control panel settings.			
The pulse output will stop concurrent with the end of the acquisition, even if the specified pulse output is not completed before the acquisition ends. When a new acquisition is started, the pulse output will start from the beginning.			
In this mode, no changes can be made in the Output Control panel until the recording stops. Changes made after recording stops will take effect when a new recording is started.			
When a pulse is sent out, the event label and indicator arrow will be generated (if the event preference is turned ON and events are displayed).			
<hr/>			
After initial delay	After initial delay of ... is enabled only when “Initiate pulse sequence with Recording ” is chosen. Specify a delay interval from the start of recording to the start of the first pulse. This is useful for viewing data prior to the stimulus pulse. The BIOPAC output device determines the delay range.		
(Applicable to Pulses, Stimulator - BSLSTM, Low Voltage Stimulator and Human Stimulator-STMHUM only)	INITIAL PULSE DELAY <u>MP36R or BSLSTM</u>		
	Range	0 - 100 milliseconds	0 or .5 - 100 milliseconds*
	Resolution	10 microseconds	1.953 microseconds
	*Entries greater than 0 milliseconds must be at least 0.5 milliseconds.		

Pulse Events

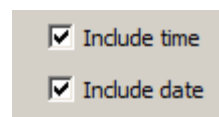


An advantage of using the AcqKnowledge software for output signals is that information regarding the pulse is automatically recorded along with the data. The amplitude reflects the output pulse level.

- Events can be automatically inserted and labeled for each Reference pulse or change in pulse train. The label will contain the Pulse width and Pulse rate (and system time stamp if selected).
- Events reflect setting changes made during an acquisition.
- All output pulse information is automatically recorded and archived with the saved data.

Set the event option by clicking in the box to “Create event when output is changed.”

Set the “Include time/date” option in the global Preferences (MP36R > Set Up Data Acquisition > Event Marking)



The event label accurately captures pulse data, but the event arrow may not always line up exactly with the leading edge of the pulse; this typically is not a problem because the recording will include the actual stimulus pulse which can be used for timing measurements. Depending on the acquisition Sample Rate, the leading edge of the pulse in the recording may not correspond to the exact time the pulse was sent—it may be off by as much as one sample period. If the event precision is critical for your recording, increase the Sample Rate.

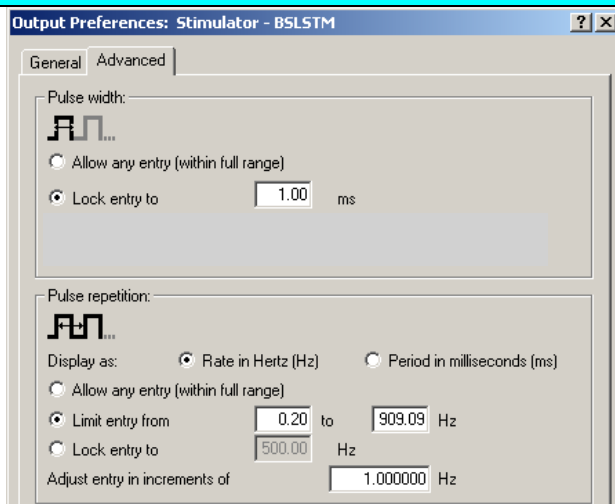
To display events, use the toolbar icon or Display > Show > Events.

The **Range** switch on the front of the **BSLSTM** stimulator should be set to 10 V or 100 V prior to recording and should not be changed during recording; if using a Preset, the corresponding Preset should also be selected prior to recording. The pulse level can then be determined by moving the decimal to the right or left depending on how the range was switched.

ADVANCED TAB (OUTPUT PREFERENCES)

Advanced Tab

(Applicable only to Pulses, Stimulator - BSLSTM, Low Voltage Stimulator and Human Stimulator-STMHUM)



Pulse Width



Indicates the Pulse Width setting, which determines the maximum Pulse Rate frequency. The Pulse Width value is limited by the Preference setting.

The entry is activated when the value is changed and the Tab or Enter key is pressed; it does not require a stimulator restart to take effect.

The Pulse width entry overrides other entries as required.

An entry may be automatically changed if any of the following conditions apply, in which case the closest possible value will be selected:

It falls outside the allowable range.

It is rounded to .01 millisecond increments (MP36R resolution).

Width has been limited by the **Pulse Width: Limit Entry** settings of Preferences.

Allow any entry

Pulse width is limited to the output capabilities of the BIOPAC MP36R unit. This option allows any entry within the allowable range specified below:

PULSE WIDTH RANGE MP36R hardware

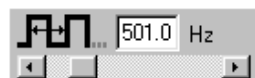
Range .050 – 100 milliseconds

Resolution 10 microseconds

Lock entry to

This entry locks the width to a single, specified value (within the allowable range). No other value can be entered.

Pulse Repetition



Indicates the Pulse Repetition period (Hz or ms).

The **Pulse period** must be greater than the **Pulse width**. See “TBPMIN” in the Output Preference > Advanced Tab Limits table on the next page.

The full range of acceptable Pulse Rate values is from **.2 to 6,667 Hz (MP36R)**.

The maximum Pulse rate (PRPMAX) depends on the Pulse width setting:

Pulse width 100 ms → maximum Pulse rate = **9 Hz**

Pulse width .020 ms → maximum Pulse rate = **3333 Hz**

The formula for pulse width vs. pulse repetition is $PRPMIN = PW + TBPMIN$

Where: $PRPMIN$ = the MINimum Pulse Repetition Period allowed.

PW = Pulse Width setting

$TBPMIN$ = MINimum Time (in ms) between successive pulses for the output device (see device specifications)

If “Limit changes from ___ to ___” is selected in Advanced preferences, then PRPMAX will be determined by the formula above or the specified limit, whichever is greater.

An entry may be automatically changed:

- If it falls outside the allowable range.
- To round it to .01 Hz increments (resolution of system).
- To make it at least 0.1 millisecond greater than the Pulse width.
- By the Pulse Repetition Rate: Limit entry Preference.
- By the Pulse Repetition: Adjust entry increments Preference.

You may manually enter any value for pulse width, but when using the scroll bar or arrows, entries will be constrained by the “Adjust entry increments” Preference setting.

Pulse Repetition Scroll Bar	<p>The Pulse Repetition Scroll Bar adjusts rate or period by the increment of change and limits established in Preferences. With each click of the scroll bar arrows, the rate will be increase by the specified increment.</p> <p>When “Initiate pulse sequence with ON/OFF button in Control Panel” is selected, changes take effect upon release of the scroll box as long as the stimulator is running.</p> <p>The scroll bar is disabled when Number of Pulses is set to “Single” or Pulse Repetition is set to Lock Entry to...”</p>
Display as	<p>Pulse repetition can be displayed as Pulse Rate (expressed in Hz), or Pulse Period (inverse of Pulse Rate, expressed in milliseconds).</p> <p>Pulse Repetition Rate relates to the Pulse Repetition Period as: $\text{Pulse Rate (Hz)} = 1000 / \text{Pulse Period (milliseconds)}$</p> <p>The “Display as” units selection is also used for: Pulse repetition entries in the control panel. Scroll bar increments. The Pulse Repetition Rate: Limit entry Preference. The Pulse Repetition: Lock entry Preference. The Pulse Repetition: Adjust entry increments Preference.</p> <p>When units are changed from Rate in Hertz (Hz) or Period in milliseconds (ms), the limits of the Pulse Repetition range will be converted by the formula: $\text{Period increment in ms} = \text{Round to nearest whole number} [\text{Period Range} * (\text{Rate increment in Hz} / \text{Rate Range in Hz})]$</p> <p>For example, if the Range was 1Hz to 10 Hz with an adjustment increment of 1Hz, the proportional calculation would be Period increment = 900 ms (1Hz / 9 Hz) = 100 ms</p>
Allow any entry	Pulse width is limited to support the output capabilities of the BIOPAC output device. See Output Preference > Advanced Tab Limits table for allowable range.
Limit entry	Establishes minimum and maximum values that can be manually entered or changed with the scroll bar.
Lock entry	Locks the Repetition to a single, specified value (within the allowable range). No other value can be entered in the control panel.
Adjust entry	Controls the scroll bar or scroll arrow increment; does not apply to manual entry.

Advanced Tab Limits	Pulses		BSLSTM	
Pulse width				
Range (ms):	.050 – 100	.049 – 100	.050 – 100	.049 – 100
Resolution (ms):	.010	.001953	.010	.001953
Pulse Repetition				
Rate range (Hz):	.2 – 16,667	.2 – 10,204	.2 - 2,000	.2 – 2,004
Period range (ms):	.060 – 5,000	.098 - 5,000	.500 – 5,000	.499 – 5,000
TBPMIN Minimum time between Pulses (ms):	.010	.049	.450	.450
Resolution (ms):	.010	.001953	.010	.001953
Initial Pulse Delay				
Time range (ms):	0 – 100	0 or .5 - 100	0 – 100	0 or .5 - 100
Resolution (ms):	.010	.001953	.010	.001953

LEVEL TAB (OUTPUT PREFERENCES)

About Level Low Voltage Stimulator and Human Stimulator-STMHUM allows the software to specify the pulse amplitude. The amplitude can be set to any value within the limits of the stimulator; the range is -10 to +10 Volts for the Low Voltage Stimulator and 0-+100 V for the Human Stimulator-STMHUM

Pulse Level

Low Voltage only



The **Level entry box** allows the user to manually enter any value within the limits of the system or within the limits of the Preference settings from the Level tab.

The Level entry box will be inactive (grayed) if:

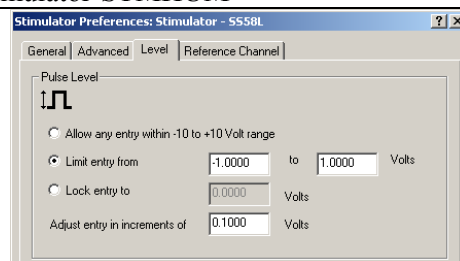
The Level preference “Lock entry to” is active.

If “Initiate pulse sequence with Recording” is active (from the General tab) and a pulse sequence is in progress or “wait for trigger” is in progress.

Use the entry box or the scroll bar to set the Pulse level. When a value is entered which is out of range, the value will be rounded to the closest value obtainable after the “Enter” or “Tab” key is pressed.

If “Initiate pulse sequence with ON/OFF button in control panel” is active (from the General tab), then values entered during a pulse sequence will take place immediately.

If “Initiate pulse sequence with Recording” is active (from the General tab), any entry made between acquisitions will take place on the next “Start” of acquisition.



Allow any entry The level is limited to the output capabilities of the stimulator. This option allows any entry within that range.

Limit entry This entry reduces the range within the limits of the stimulator’s output capabilities.

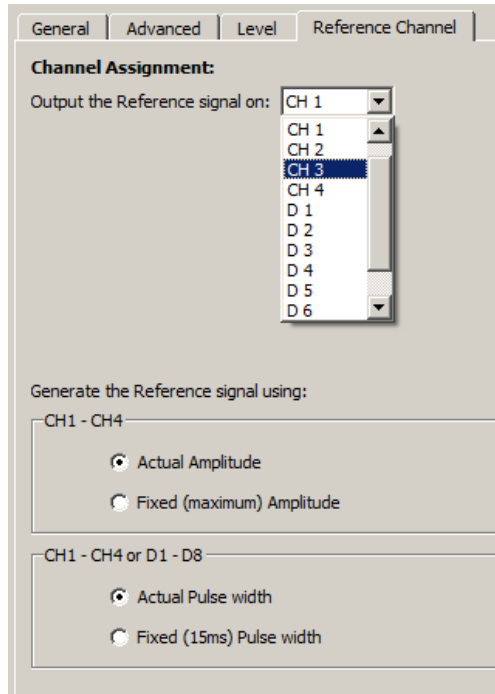
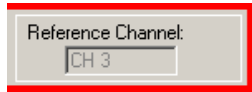
Lock entry This entry locks the level to a single specified value.

Adjust entry This setting affects the scroll bar or scroll arrow increment only; it does not apply to manual entry.

The smallest increment is 5 mV, as limited by the MP36R. The specified increment is used to round manual entries to the closest obtainable value.

REFERENCE CHANNEL TAB (OUTPUT PREFERENCES)

Reference Channel



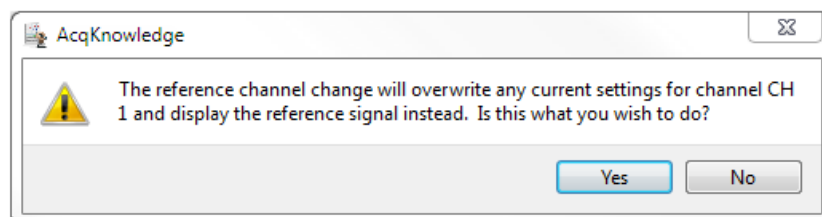
This option allows monitoring of the output signal on one of the analog or digital input channels without making any physical connections. This is an internal, hardware/firmware, feature that recreates the output signal and allows recording in “real time.” The assigned reference channel will override any “real” input signal.

The reference signal is not the real signal, but is a very accurate “estimate” of the real signal. The pulse timing accuracy will be within 100 microseconds. If an analog input channel is used as the reference channel, the pulse level will be accurate within 5%. If the stimulation encounters a load that reduces or distorts the pulse output, the reference signal will not reflect this amplitude distortion.

If a digital input channel is used as the reference channel, only a digital representation of the pulse will be generated; 0 to 5 volts.

Channel Assignment Use the pull-down menu to choose which analog or digital input channel will be used as the output reference channel.

When a new reference channel is assigned, a warning will be generated to alert you that this setting will overwrite the existing Channel Setup parameters for the selected channel.



For example, if CH1 is set up for ECG data and then selected as the Reference Channel, the ECG parameters will be replaced. If another channel is then selected, CH1 will be reestablished with the default analog input parameters, and the ECG settings would need to be recreated via presets or manual entry.

The reference Channel label should read: “(Selected Output) - Reference Out.”

When an Analog Input Channel is assigned as the Reference channel, that channel (as viewed from MP36R > Set Up Data Acquisition > Channels) will be in a locked mode and the Preset pull-down menu will be disabled. The assigned reference channel will be inactive for “real” inputs until the Reference Channel Preference is changed to “None” or another channel.

Once the control panel with an assigned Reference channel is closed, the data Acquisition Settings > Channels will automatically update to the default settings.

Generate using

You can specify how the Reference signal should be shown.

If using **analog** input from CH1 - CH4, you may select actual or fixed (max) amplitude and actual pulse or fixed pulse width. Fixed pulse widths are useful when the pulse width is much smaller than the sample interval (1/sample rate) is used.

For example, Frog muscle stimulation uses a 1 ms pulse width and a sample rate of 2000 samples/second to capture the muscle response. At this sample rate, the stimulus pulse cannot be reliably recorded. By using the fixed width of 15 ms, the pulse should be recorded.

If using **digital** input from D1 - D8, select actual or fixed (15ms) pulse width.

Usage Guidelines & Setup Summary for BSLSTM Output Control

HUMAN SUBJECT SAFETY

- Before using the stimulator on human subjects, it is very important to limit the energy the stimulator outputs. For optimal safety:
- Before powering on the BSLSTM stimulator, set the voltage level to zero by rotating the LEVEL knob on the front of the BSLSTM fully counterclockwise.
- Use BIOPAC HSTM Series Probes. You **MUST** use these probes in order to limit the energy the stimulator can output.
- Never create an electrical path across the heart.
- Never use on subjects with pacemakers.
- Read this manual and the BSL Hardware Guide to become familiar with Stimulator operation.

1. Connect the BSLSTM Stimulator to the MP36R and power on both units. (For instructions on how to connect the BSLSTM to the MP36R Acquisition Unit, refer to the *BSL or MP Hardware Guides*.)
2. Connect the Stimulator Trigger cable to the Analog Out port of the back of the MP36R hardware.
3. Connect the Stimulator Reference Output cable to an Input Channel on the front of the MP36R hardware. This channel will be set up in Step 8 below as the Stimulator Reference Channel.
4. The **Reference pulse** has a fixed Pulse width of 15 milliseconds, so chosen so that the Sample Rate of the recording may be as low as 100 samples/second and still capture the Reference pulse.
5. Before powering on the BSLSTM stimulator, set the voltage level to zero by rotating the LEVEL knob on the front of the BSLSTM counterclockwise all the way to the left.
6. Open a new data acquisition graph.

7. Confirm that **Events** are activated. Events are activated by default. If not activated for a given recording, choose **Display > Show > Events**.
8. Set up the **Stimulator Reference Channel**. This is the Analog Input Channel on the front of the MP36R that receives the Stimulator Reference Output cable from the back of the BSLSTM. Remember, the reference channel is generated from the stimulator and not the software.
9. Choose MP36R > Set Up Data Acquisition > Channels. This will generate a Set up Channels dialog.
10. Select the **Acquire**, **Plot** and **Enable** options for the analog channel to use as the Stimulator Reference Channel.
11. Click **Presets** and scroll to select “Stimulator (0-10V)” or “Stimulator (0-100V)” to match the Range switch setting on front of the BSLSTM.
12. Click **Setup** to view or change the analog channel parameters. Review the BSLSTM Stimulator section (page 192) and Analog Channel Setup section (page 116) before modifying channel/preset parameters.
13. You may set the Gain and other input parameters as desired.
14. Click OK to accept the parameters.
15. Close the Set up Channels window.
16. Adjust the voltage output of the stimulator by using the **Level** control on the front of the BSLSTM.
17. Rotate the **Level** knob clockwise to increase and counterclockwise to decrease, reading the voltage in the BSLSTM’s digital display.

Stimulator Safety Features

The stimulator cannot operate unless its Output Control panel is open.

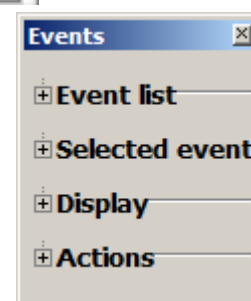
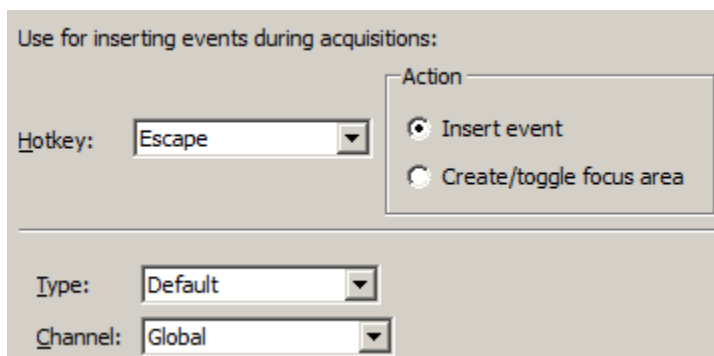
The Pulse ON/OFF Switch on the Stimulator Output Control panel must be OFF in order to open and configure Stimulator Preferences.

If the Stimulator Output Control panel (or the AcqKnowledge application) is closed in the middle of a pulse train while the stimulator is running, the stimulator will shut down and the pulses will stop.

If another data acquisition window is activated, the stimulator will stop and remain OFF unless restarted using the parameters associated with the new data window. The only exception is that if the stimulator is ON and the data window corresponding to current stimulator parameters is acquiring data, then the stimulator will continue to run until the end of the acquisition.

Chapter 11 Set Up Event Marking

Events (Markers)



Event Toolbar

Event Insertion

Event Control

Event (Marker) Overview

For detailed analysis, it can be useful for waveforms to have extra information associated with them. This information might include waveform boundaries from ECG analyzers, spike classifications from a spike sorter, heartbeat classifications, or even detailed user notes. *AcqKnowledge 4* uses “event” functionality to store and manage this information.

An event is a piece of information associated with a specific time in a waveform. An event can capture points of interest within a file (i.e. subject moved, dose added) or on a particular channel (i.e. T-wave onset). Once events are marked in the file, *AcqKnowledge* can use the event information for analysis, including measurement (page 231) and cycle detection (page 325).

- An event has the following pieces of information associated with it:
 - Event type
 - Sample location: the time position in hardware samples where the event is defined.
 - Channel: the channel for which the event is relevant.
 - Some events, such as the time of the start of an appended segment, may be relevant to all of the channels of a graph—these are “Global” events.
 - Label: a string of text that can be entered either automatically or by the user to provide more information about an event. Labels can be fixed or sequential in *AcqKnowledge 4.2* and up.
- Different event types can be entered automatically or manually. These different event types allow events to be filtered and also support analysis routines that key off of these events.
 - Event insertion tool
 - Set up Event Marking (see page 218) 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 216)
 - Cycle Detector Output Events option (see page 325)
 - Contextual menu in Event region
 - Specialized Analysis (see page 348) to automatically insert events according to complex analysis algorithms

Event Toolbar



The event toolbar displays the visible events in the graph and provides a quick editing area for event descriptions. The right button toggles visibility of the Event Palette for detailed control (see page 219). The palette will “refresh” when events change the event configuration, such as horizontal scrolling, scale changes, changes in the selected event via clicking in the graph window, editing of the event label by using the event bar, transformations that define new events for the graph, waveform editing operations, and additions of new events by clicking the event bar at the top of the graph window. The right/left arrow buttons are for navigating through events. If events are placed in the waveform, the arrow navigation will locate events in the selected channel only.

Event Tooltips

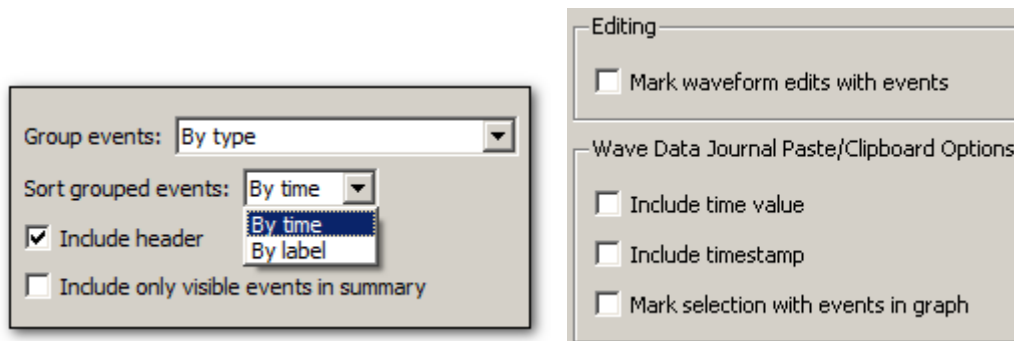
If events are being displayed within the plotting area and tooltips are enabled, a tooltip will be associated with every event in the plotting area. The tooltip includes the event type description, the user-defined label (if present), the time location of the event, and the amplitude of the waveform at the event location. While this information can be drawn directly on the graph, event tooltips assist in browsing event information when the screen becomes too crowded and there is not enough room to display all of the times, amplitudes, and labels.

Event tooltips are displayed under the event icon.

- If the event is being plotted directly on the waveform, this will be the point on the waveform associated with the event.
- If there is an indicator and the event icon is at the top of the indicator, the tooltip will be anchored at the top of the indicator.
- If the events are being plotted at the top of each track, the tooltip is anchored at the top of the plotting area directly underneath the event icon.

Event tooltips will not be displayed if tooltips are disabled, if events are only being displayed in the events bar at the top of the screen, if X/Y mode is in use, or if events are not currently visible.

Preferences for Events



Preferences > Event Summary and Waveform

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

- Group events

Sorted by type	sorted by event type descriptions first
Sorted by channel	grouped based upon where they are defined (Global events appear first, followed by groups for each individual channel).

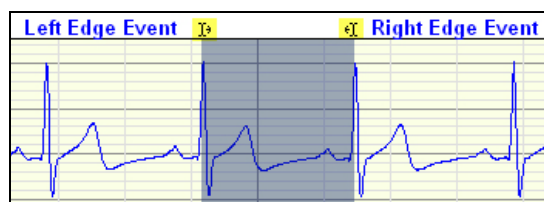
- **Sort Grouped events**
 - Sorted by time sorted in order by increasing time
 - Sorted by label sorted alphabetically by label
- **Include only events visible on the screen**

Determine if the summary is generated for all of the events that are in a graph, or only for those events that are currently visible on the screen. If there are thousands of events in a file, this feature allows the list to be pared down to those of interest.

Event summary options will be saved with the graph if the graph has a graph journal, and can be pasted into the journal using “Summary in Journal” Event Palette Actions command (see page 223).

Other event preferences are available under Preferences > Waveforms

- **Mark waveform edits with events**
- **Mark selection with events in graph**—enabling this preference automatically brackets the edges of selected data areas with “selection begin” and “selection end” events when measurements or waveform data are pasted to the Journal. (This option is also available under Preferences > Measurements.)



“Selection Begin” and “Selection End” events

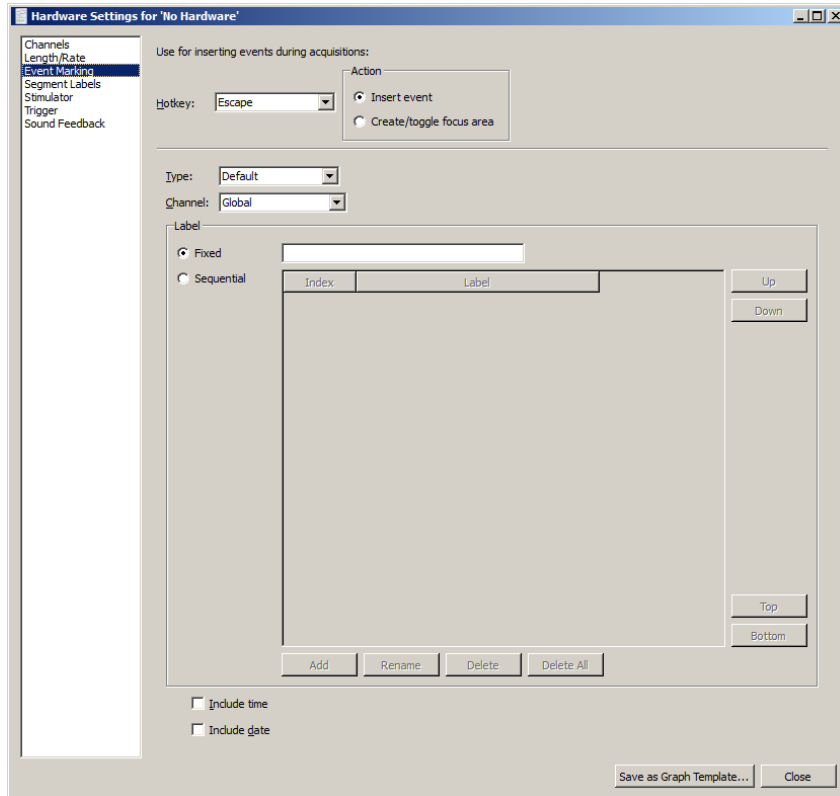
“Selection begin” and “selection end” events may also be applied manually by selecting an area of data and choosing the “Mark Selection” button in the Selection Palette.

- **Include time value**— include the time value (relative to start = 0) for the paste.
- **Include timestamp**—Include time and date stamps for when the paste occurred; this timestamp will match any timestamp pasted into the journal. When selected, any selection events added to the graph will have their labels set to match the timestamp.
- **Auto-paste results in independent journal** (Preferences > Journal)—Selection events and time stamp events can be automatically inserted to an independent Journal.

Combine these options to retain enough information to reproduce measurement results and correlate measurement results with specific areas of the graph; this helps verify the accuracy of measurement results made through manually constructed graph selections.

Any change to these settings will be retained within a saved graph file and will become the default for newly constructed graphs.

Event Marking Setup



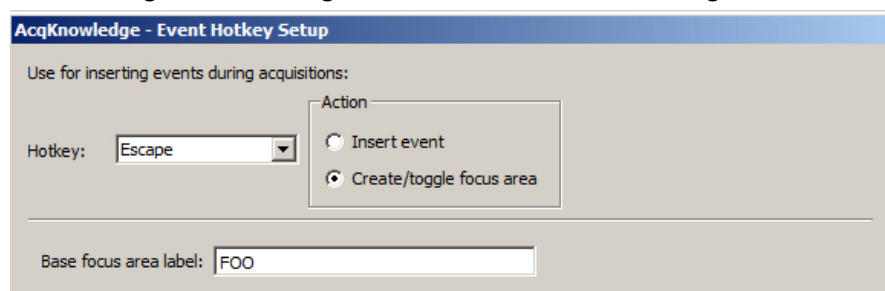
Events of different types can be inserted during acquisition, whether or not events are visible in the graph. When a *hotkey* is pressed during acquisition, an event will be inserted into the graph at the end of the most recently acquired data. Each hotkey can have a different configuration, adjustable through a dialog accessible via the “Hardware > Set Up Data Acquisition > Event Marking...” menu item.

Hotkey	Assign Escape or F1 through F9. When a different hotkey is chosen, the other controls of the dialog change to reflect the configuration of the new hotkey.
Action	Choose whether the Hotkey assignment creates an event or a focus area.
Event type	Lists the standard hierarchical menu of available event types; Types are detailed on page 225. 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.” <ul style="list-style-type: none"> Fixed - Provides a fixed label from text entered into the label field to the right. This label is used every time the assigned hotkey is pressed. (<i>AcqKnowledge</i> 4.2 and higher) Sequential - Labels for events will iterate sequentially through the entries in the table index when the assigned hotkey(s) is pressed. The area under ‘Label’ is editable for entering text.

Additional Hotkey Setup Controls	Function
Add	Adds an editable label field to the list.
Rename	Allows renaming of the existing segment label.
Delete	Deletes a selected custom label.
Delete All	Deletes all custom labels.
Up	Incrementally moves a selected label up the list.
Down	Incrementally moves a label down the list.
Top	Moves a selected label to the top of the list.
Bottom	Moves a selected label to the bottom of the list.
Include time	Adds timestamp to labels when checked
Include date	Adds current date to labels when checked

Create/Toggle Focus Area Action

Selecting the ‘Create/Toggle Focus Area’ action presents a similar setup dialog, but dictates that hotkeys setups will be assigned to defining Focus Areas instead of inserting events.



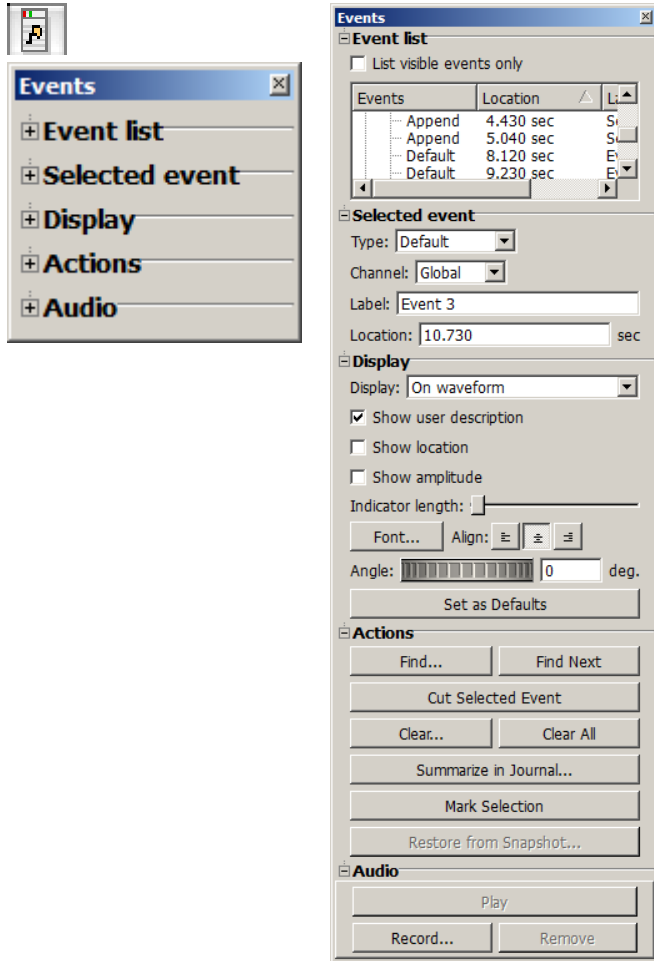
When this option is chosen, pressing an associated hotkey during a recording will initiate a focus area in the graph. Toggling the same hotkey will conclude the focus area. The focus area will appear highlighted and outlined in the graph following the second (termination) keystroke. As with events, multiple hotkeys and labels can be assigned.

Example for setting up a Focus Area Hotkey:

1. Choose the desired hotkey from the Hotkey list.
 2. Under Action, select ‘Create/toggle focus area.’
 3. Assign the focus area a label by typing it into the ‘Base focus area label’ field.
 4. If additional focus area hotkey assignments are desired, choose another hotkey from the list, and repeat steps 2 and 3.
 5. When focus area hotkey assignments are completed, click OK.
- If the same hotkey combination is repeated to create subsequent focus areas, the base focus area label will remain the same but with incrementing numbers appended to the title.
 - If a different hotkey combination is used for subsequent focus areas, unique base focus area names will be used as assigned.
 - Starting a focus area assigned to one hotkey and then starting another focus area assigned to a different hotkey will terminate the original focus area and start a new one.
 - Focus areas can be created and toggled while a recording is in progress.
 - Focus areas can be shown/hidden by choosing the the Show/Hide toolbar function (right) and checking or unchecking the “Focus Areas” option.



Event Palette

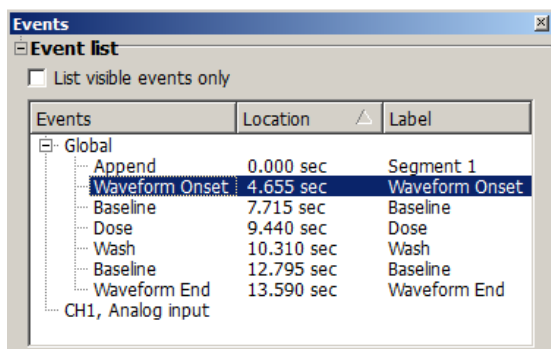


The event palette is a floating window that provides a quick summary of events for the top most graph and can be used to examine, search, and modify events. Events can be extracted in a time range for a specific event type and specific channels.

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 220.
- Selected event, see page 221.
- Display, see page 222
- Actions, see page 223.
 - See the Event Journal Summary enhancements.

Event List



The event list provides an expandable, scrollable, hierarchical view of the events in the topmost graph. Events are grouped by their channel on the top level.

The event list has three columns of information:

- Events: the readable type for each event
- Location (Time): the time location for each event
- Label: the user defined description for the event.

Sort the contents in ascending or descending order on each column by clicking the column header. Events and Description will sort in standard alphabetical order, Location will sort based on the horizontal axis location of each event.

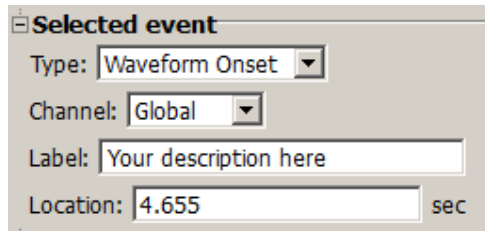
Select a single event from the event list by clicking on a single event. The event will be selected in the graph window and made visible if it is not currently displayed.

List visible events only toggles the checkbox to switch between the two display modes.

- When enabled, the event list will display only those events that are being displayed on the plotted portions of the graph. As the user navigates through the graph with the scrollbars, horizontal scale, or other means of changing the amount of visible data, the event list will continually refresh to contain the new set of visible events.

- When disabled, the event list will display all of the events for the entire graph. This can allow for easier navigation through graphs with hundreds of events, such as PhysioBank files.

Selected Event



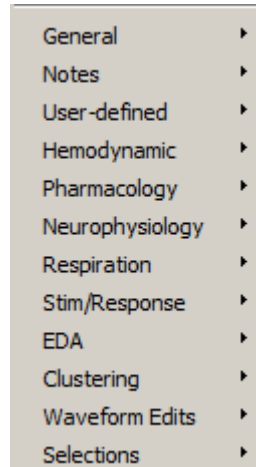
Selected event

Type:

Channel:

Label:

Location: sec



- General ▶
- Notes ▶
- User-defined ▶
- Hemodynamic ▶
- Pharmacology ▶
- Neurophysiology ▶
- Respiration ▶
- Stim/Response ▶
- EDA ▶
- Clustering ▶
- Waveform Edits ▶
- Selections ▶

Event type options are detailed on page 225.

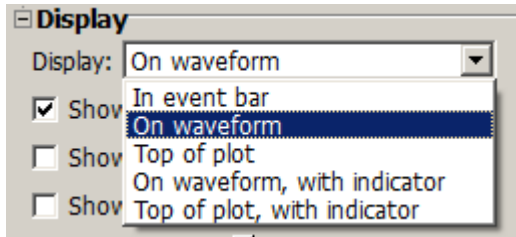
When a single event is selected, the type, channel (or “General” for global events), user-defined label, and location of the event will be filled in and can be edited. The controls can display information about only one event at a time; if no event is selected, the controls will be grayed out.

Event Location

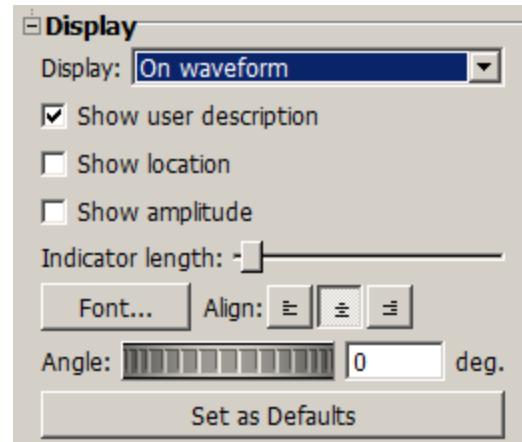
“Location defines the position where the selected event occurs, relative to the first sample in the file. To change the location of an event, change the position entered in the Location box. Precision matches the horizontal axis setting.

Events (with the exception of Append events) may be repositioned if desired. Alt-click (Windows) or Option+click (Mac) over the event icon and hold down the mouse button. Then simply drag the event to the desired location on the event bar and release the mouse button.

Display



Event display location



Event display detail

Display controls determine the location and detail of events to be drawn in the frontmost graph.

- Location—Choose one of the five display methods (described on page 222).
- Detail—the three checkboxes to establish how much information to include with events.
- Indicator length—Set the slider to shorten or lengthen the indicator line. This option is only active if the display mode is “On waveform, with indicator” or “At top, with indicator.”
- Font – Align – Selects font style and alignment of Event labels.
- Angle – Determines the angle in degrees that the Event text can be displayed in the graph. Value can be positive or negative.
- Set as Defaults – Saves any modified event palette settings as the default for newly inserted events and subsequent graphs. Applying this option has no effect on previously existing events. (*AcqKnowledge 4.4.1 and higher only.*)

Location & Display

Description

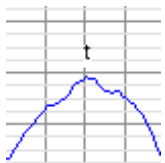
In event bar



Event icons are displayed in the global events bar located on top of the plot area in the graph window. This does not allow for distinguishing what channel a specific event belongs to.

- To select the event, click the icon in the events bar.

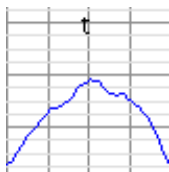
On waveform



Event icons are displayed above or below the actual sample in the source channel corresponding to the location of the event.

- To select the event, click the event icon on top of the waveform.

Top of plot



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

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

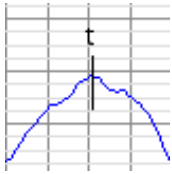
On waveform, with indicators

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

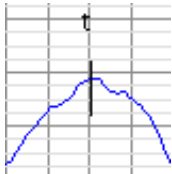
- To select the event, click the event icon or the indicator line.

Location & Display

Description



Top of plot, with indicators



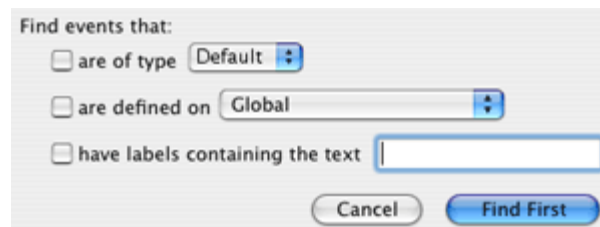
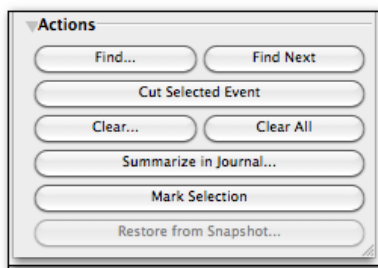
Event icons are displayed at the top of the channel track with a vertical line of configurable length running through the data sample of the source channel at the event's location.

- 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 the Find button to generate the Event search criteria dialog, and then combine or restrict information to define desired events: event type, specific channel location, or label search.

Click "Find First" to search for the first event in the graph that matches the criteria. If found, the event will be selected and made visible in the graph window.

Find Next

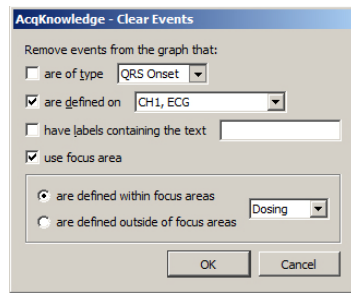
Finds the next single event that matches the established search criteria until no remaining events match the search criteria.

Cut Selected Event

Active only when an event is selected, removes the selected event from the graph.

*Clear**Clear all*

Generates a search criteria dialog (similar to the Find dialog) and removes all matching events from the graph. There is also an option to clear events defined within a focus area without affecting the remaining events, or to clear events defined outside of a focus area while leaving events within the focus area intact.



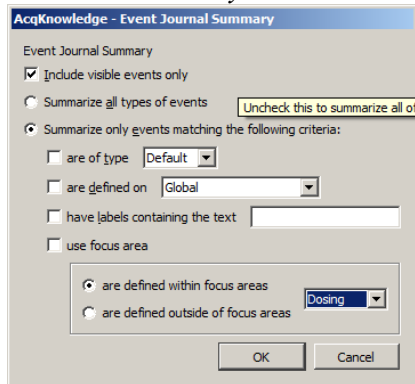
Summarize in Journal

Displays a dialog with controls that affect which events are included in the summary.

Events can be filtered by visibility on the screen. Creates a textual summary of all of the events in the journal.

- See “Event Preferences” on page 216 for more information about modifications to the traditional events summary.

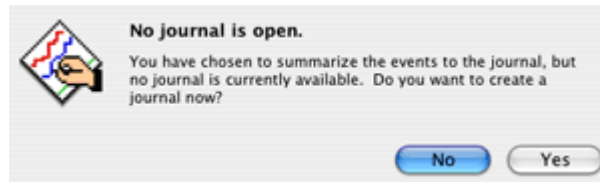
Event Journal Summary Enhancements



Events to be included in the summary can be filtered using the same criteria as Find... in the Event Palette. By adding the ability to summarize only events matching specific criteria, textual reports of arrhythmias or other infrequently occurring events of interest can be generated with ease. Events defined within or outside of focus areas can also be included or excluded from the summary.

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

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

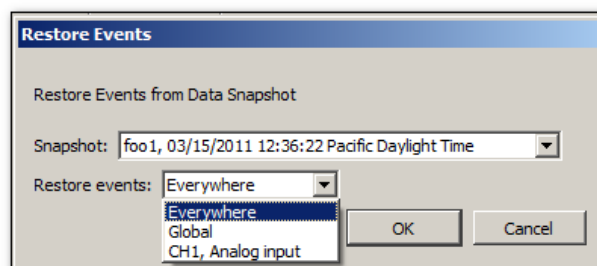
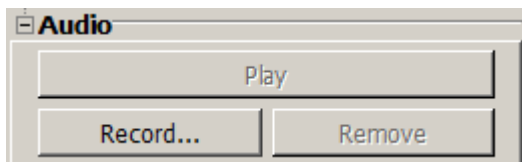


Mark Selection

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.

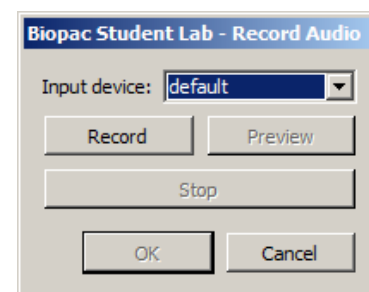
Restore from Snapshot

Enables deleted events to be restored from events present in a Data Snapshot. This option becomes active only if a Data Snapshot of the main graph is displayed. The following prompt will be displayed when Restore from Snapshot is selected. For information on Data Snapshots, see page 54.

*Audio*

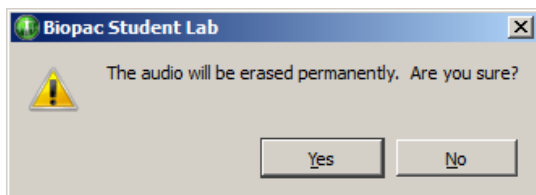
This option allows you to record audio (such as verbal observations) and link it to selected events in your event list. The controls are very simple to use, and the audio is recorded via your computer microphone or selected audio capture device.

To set up a recording, select an event in the Event list and click “Record.” This opens the “Record Audio” setup dialog (see right).



<i>Record Audio buttons</i>	<i>Description</i>
<i>Input device:</i>	Select the onboard audio capture device to be used for the recording. Use the default or select another from the list of supported devices.
<i>Record</i>	Click to start the recording.
<i>Stop</i>	Click to end the recording.
<i>Preview</i>	Listen to the recording before linking it to an event. If recording is acceptable, click OK. To repeat recording, click Record again.

Once a recording is accepted, it can be played back by clicking “Play” in the Audio controls or by selecting the audio-linked event in the Event list. Selecting the linked event in the graph’s event bar will also play the recording. Recordings can be erased by clicking the “Remove” button. Once a recording is removed, it cannot be recalled.

*Event Type Options*

Event Types are pre-defined options for assigning event information. The Event Type is for marking purposes only and does not imply any analysis has or will occur for the event (unless Specialized Analysis was performed, see page 348).

Once Event Types are defined, some analysis functions can be automated, including measurement (page 231) and cycle detection (page 325).

Event classifications:		<p><i>Event classifications</i> 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.</p> <p>For example, the “Hemodynamic” event classification includes a “Beats” sub-class with pre-ventricular contraction and escape beat event types.</p>	
<div> <div>Default</div> <div> General ▶ Notes ▶ User-defined ▶ Hemodynamic ▶ Pharmacology ▶ Neurophysiology ▶ Respiration ▶ Stim/Response ▶ EDA ▶ Clustering ▶ Waveform Edits ▶ Selections ▶ B-Alert ▶ BioHarness ▶ SMI Import ▶ Mobita ▶ Sleep Scoring ▶ </div> </div>			
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. Custom Append labels can be created in Hardware > Set Up Segment Labels. (See page 238.)	
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 contraction Unclassifiable contraction Left bundle branch block	Nodal premature Supraventricular premature Premature ventricular R-on-T premature ventricular Fusion of ventricular and

	normal Right bundle branch block Bundle branch block Atrial premature Aberrated atrial premature	Atrial escape Nodal escape Supraventricular escape Ventricular escape
Hemodynamic > Blood Pressure	Systole Diastole	End Systolic pressure End Diastolic pressure
Hemodynamic > ECG Complexes	QRS onset, peak, and end T-wave onset, peak, and end P-wave onset, peak, and end Q-wave peak S-wave peak	U-wave peak PQ junction J-point ST segment change T-wave change
Hemodynamic > Impedance	A-point B-point C-point	O-point X-point Y-point
Hemodynamic > Monophasic AP	Plateau	Upstroke
Hemodynamic > Other	Start of ventricular flutter Ventricular flutter wave End of ventricular flutter	Pacemaker artifact Isolated QRS-like artifact Non-conducted P wave
Notes	Arrow—short, medium, or long Flag	Star
Pharmacology	Baseline Dose	Wash
Neurophysiology	Spike Episode Begin	Spike Episode End
Respiration	Inspire Start Apnea Start	Inspire End
Stim/Response	Stimulus Delivery	Response
EDA	Skin Conductance Response	Specific SCR
Clustering	Cluster 1-9 End Cluster Training Set	Cluster n Outlier
User-defined	User Type 1-9	
Classification	Pre-defined Event Type Options	
Waveform Edits	Cut Paste begin	Paste end
Selections	Selection begin	Selection end
B-Alert	Start of Eye Blink Artifact Start of Excursion Artifact Start of Saturation Artifact Start of Spike Artifact Start of EMG Artifact Workload – EMG Start	End of Eye Blink Artifact End of Excursion Artifact End of Saturation Artifact End of Spike Artifact End of EMG Artifact Workload – EMG End

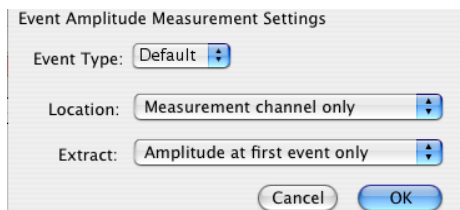
	Workload – Invalid PSD Start Dummy Data Start Misaligned Data	Workload – Invalid PSD End Dummy Data End
BioHarness	Button Pressed	
SMI Import	Left eye hit object SMI stimulus image has been presented to the subject	Right eye hit object
Mobita	Start out of range	End out of range
Sleep Scoring	Wake Onset REM Onset Sleep Stage 1 Onset Sleep Stage 2 Onset Sleep Stage 3 Onset Sleep Stage 4 Onset Unscored Onset Sleep Spindle Onset	Wake End REM End Sleep Stage 1 End Sleep Stage 2 End Sleep Stage 3 End Sleep Stage 4 Ebd Unscored End Sleep Spindle End

Event Measurements

Measurements are a quick way to extract information from a graph. Three measurements extract information from events. When combined with the Cycle/Peak Detector (page 325), they are also powerful data reduction tools. These event measurements can provide quick summaries of event information, compute mean intervals between event types, and detail other operations.

- evt_ampl Event Amplitude Measurement (see below)
- evt_count Event Count Measurement (see page 229)
- evt_loc Event Location Measurement (see page 229)

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).

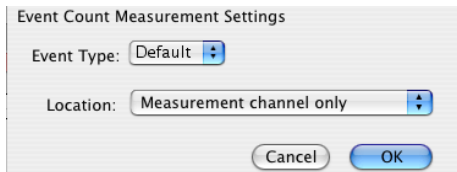
Select Event Amplitude or click the measurement info button to generate the settings dialog.

Event Type	Determines the type of events that will be processed; Types are detailed on page 225.
Location	Determines where the processed events need to be defined. The menu options are: <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 events 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	Determines what processing will be performed on the amplitude values extracted from events that match the Type and Location settings. The processing options are:

- Amplitude at first event only—The value of the measurement channel at the time of the first matching event in the selected area.
- Amplitude at last event only—The value of the measurement channel at the time of the final matching event in the selected area.
- Sum of amplitudes at all events—Computes the sum of the value of the measurement channel from each matching event within the selected area.
- Mean amplitude from all events—Computes the average amplitude value of the measurement channel from all of the event locations within the selected area.
- Minimum amplitude from all event —Computes the minimum amplitude value of the measurement channel from all of the event locations within the selected area.
- Maximum amplitude from all events—Computes the maximum amplitude value of the measurement channel from all of the event locations within the selected area.
- Median value of amplitude from all events—Computes the median of the set of measurement channel amplitudes at all events.
- Peak to peak interval of the set of amplitudes from all events—Takes the peak-to-peak difference from the set of measurement amplitudes at all events (max - min).
- Standard deviation of amplitudes from all events—Computes the standard deviation of the set of measurement channel amplitudes at all events.

If there are no matching events of the selected type in the selection, the measurement result will be zero.

Event Count Measurement



evt_count – evaluates the number of events within the selected area. The measurement result is unitless.

Select Event Count or click the measurement info button to generate the settings dialog.

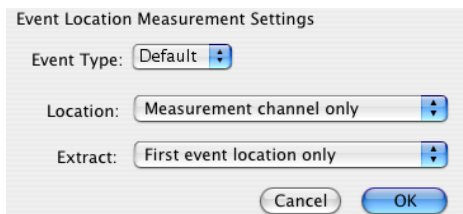
Event Type Determines the type of events that will be counted; Types are detailed on page 225.

Location Determines where the counted events need to be defined: the pull-down menu options are:

- Measurement channel only—Only includes events that are defined on the channel specified in the measurement channel pull-down menu; global events and other channel events are *not* included.
- Global events only—Only includes events that are defined as global events appearing in the events bar; channel events are *not* included. Changing the measurement channel will not affect the measurement result.
- Anywhere—Includes events defined on any channel and also global events. Changing the measurement channel will not affect the measurement result.

If there are no matching events of the selected type in the selection, the measurement result will be zero.

Event Location Measurement



evt_loc – extracts information about the times of events.

The measurement result will take on the units of the horizontal axis; if specific units were set for time or frequency via Preferences, those units will be used.

Select Event Location or click the measurement info button to generate the settings dialog.

Event Type Determines the type of events that will be processed; Types are detailed on page 225.

Location Determines where the processed events need to be defined. The menu options are:

- **Measurement channel only**—Only extracts the time of events that are defined on the channel specified in the measurement channel pull-down menu; global events and other channel events are *not* included.
- **Global events only**—Only extracts the time of events that are defined as global events appearing in the events bar; channel events are *not* included. Changing the measurement channel will not affect the measurement result.
- **Anywhere**—Extracts the time of events defined on any channel and also global events. Changing the measurement channel will not affect the measurement result.

Extract

Determines what will be extracted from events that match the Type and Location settings:

- **First event location only**—The measurement will equal the time at which the first matching event in the selected area is defined.
- **Last event location only**—The measurement will equal the time at which the final event within the selected area is defined.
- **Sum of all event locations**—The times at which all matching events are defined are added together to produce the measurement result. This sum of times can be combined with Event Count measurements to compute average intervals over the selected area.

If there are no matching events of the selected type in the selection, the measurement result will be zero.

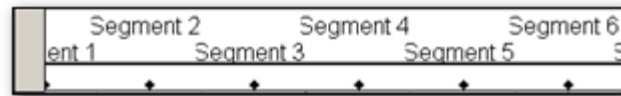
Printing Events

When a graph is printed and events are displayed onscreen for the graph, event icons will print as they are displayed. Event icons will be scaled, depending on the printer's DPI, to be proportional to the vertical scale plotted on the screen. If events are located at linearly interpolated positions, event icons will be dimmed on the printout (see the Variable Sample Rate section).

Event display setting Printed result

Global events

Global events are drawn above and outside of the data plotting rectangle in the printout. If the event labels are close together, their alignment will be staggered to show separate lines of label text. (AcqKnowledge 4.2 and higher)



In event bar

All events are drawn above the data area of the printout. Only labels may be drawn with the events.

Top of plot *or* Top of plot, with indicator

Channel-specific events are drawn at the top edge of their channel's track. No indicator lines are drawn. Depending on the display settings of the graph, the event label, amplitude of waveform at the event location, and Time of the event may be printed *below* the event icon

On waveform *or* On waveform, with indicator

Channel-specific events are drawn immediately above the position of the waveform sample at their location and will appear to be printed immediately above the data of the waveform. No indicator lines are drawn. The vertical printing position of an event icon will be identical for "On waveform" and "On waveform, with indicator" displays. Depending on the display settings of the graph, the event label, amplitude of the waveform at the event location, and time of the event may be printed *above* the event icon.

"Draw vertical divider at event locations" option in the Print Setup dialog.

- **Enabled:** draws a dashed vertical line at the precise time location of each event. Vertical divider lines for the event type will extend

Global	Through all channels of data
In event bar	Through all channels of data
Top of plot	From the top to the bottom of the relevant channel track

On waveform From the top to the bottom of the relevant channel track

- Disabled: prints only the event icon, label, amplitude, and time. No indicator lines will be printed for the event display. The vertical divider can be used in place of indicator line drawing.

Events and Waveform Editing

Waveform editing will adjust event locations for channel-specific events. Waveform editing will never alter the time values for Global events (not associated with any specific channel, such as append events).

Copy When a portion of a waveform is copied the channel events will also be copied to the clipboard.

Cut When a portion of a waveform is cut, events within that selected area will be removed and channel events to the right of the removed area will be shifted to the left.

- If waveform editing event insertion is active, a waveform edit event will be inserted at the location of the edit operation indicating a “Cut” operation in its description.

Paste When the waveform is pasted from the clipboard, the channel events will appear at their same locations and any channel events to the right of the end of the pasted segment will be shifted by the length of the pasted segment.

- If waveform event insertion is active, a waveform event marker will be inserted at the beginning and at the end of the pasted segment.

Constructing Graph Selections from Events

Graph selections can be defined from events (in addition to the I-beam tool).

1. Click the first event to select it.
2. Hold down the Control key (Windows) or Command key (Mac) and click the second event. A selected area will be created in the data between the two events.

Event Plotting and Variable Sampling Rate

Event positions are defined in terms of the hardware sampling rate. The Variable Sampling Rate feature can generate waveforms with a sampling rate lower than the hardware sampling rate. Through explicit event definition, waveform downsampling, or other operations, events on a downsampled channel may not align with an actual waveform sample, but rather occur at a hardware sample position in between the waveform samples. These events will be drawn using linear interpolation when applicable, and only if the waveform is being drawn in line plot mode. In step plot and dot plot modes, regular event drawing routines are used, with the vertical position and amplitude of the nearest waveform sample to the event’s left.

When an event is to be drawn on an intermediate position on a waveform, the linearly interpolated value is calculated for the hardware sample location. The interpolated value is derived from the closest waveform sample to the left and to the right. The vertical position on the waveform of the event and indicator line will match the vertical position of the linearly interpolated sample amplitude. This will place it immediately above the line connecting the two waveform samples on screen.

If an event is being drawn using linear interpolation

- Event icons will be dimmed, regardless of their display position (on waveform or top of the plot).
- Indicator lines will be drawn on the waveform at a linearly interpolated position and the indicator line will be a gray dashed line instead of a solid black line. (Indicator lines are never printed.)
- Amplitude labels, if included with the event, will correspond to the linearly interpolated amplitude at the event location and the linearly interpolated amplitude will be drawn in *italicized text*.

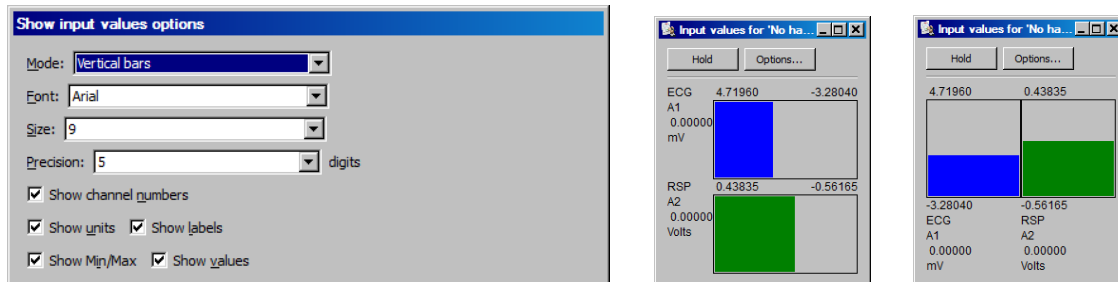
 Watch the [AcqKnowledge Event Marking tutorial video](#) for a detailed explanation of this feature.

Chapter 12 Other Hardware Menu Commands

This chapter covers the following MP hardware menu items not appearing in other chapters:

Show Input Values	Display channel data values in real time in a color bar graph format.
Show Manual Control (MP150 only)	Monitor and/or output pulses through the digital input/output.
Show Gauge	Displays onscreen blood pressure gauge or stopwatch.
MP150 Info (MP150 only)	Displays configuration and firmware information for the MP150 hardware.
BioNomadix Logger options	Only applicable when BioNomadix Logger hardware is used. Contact BIOPAC for information about the Logger.
Autoplot – Scrolling – Sweep – Warn on Overwrite options	Data display options during acquisition.
Organize Channel Presets	Rename, delete, reorder or configure channel presets.
Set Up Linked Acquisitions	Record data simultaneously from multiple hardware devices.
Manage Hardware Connections	Connect, disconnect or switch supported hardware types.

Show Input Values



The Show Input Values option of the MP (Hardware) 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.

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, 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 111 for more information).

Hold Regardless of the display options selected, the display can be “frozen” at any point in time by clicking the Hold button. Clicking this icon will hold the values at their level(s) when the icon was pressed. The window will remain frozen until the icon is clicked again. Once the values are “unfrozen,” the values will return to the standard real time display mode.

Options **Mode** controls the format of the values display.

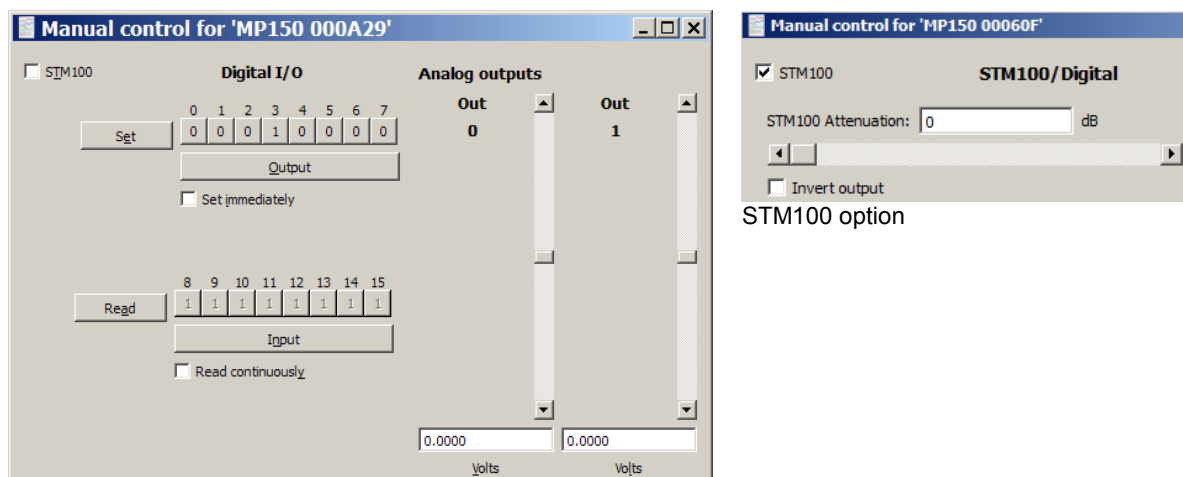
- **Numeric Values**—displays the voltages of the appropriate channels numerically.
- **Bars: Horizontal bars or Vertical bars**—the range of values of the bar graphs corresponds to the range for that channel in the graph window. To see the bar “bounce” less for a particular channel in the graph window, increase the units per division.
- **Font and Size** determine text display from fonts installed on your computer

Precision controls the total number of digits displayed.

Show controls the amount and type of information displayed regarding each channel. Click the box next to each option to activate or deactivate it.

- **Channel Numbers** will display the channel numbers (A1 for the first analog channel, for example).
- **Units** will display the units for each channel (as indicated in the main graph window).
- **Labels** will display the channel labels (ECG 1, Respiration, etc.) along with the input values. This feature is especially useful when values from multiple channels are being displayed simultaneously.
- **Min/Max** will display the range of values associated with the data. This range corresponds to the upper and lower display limits for each channel as it appears in the graph window.
- **Values** will display number values along with the horizontal or vertical bar chart.

Manual Control (MP150 only)



The Manual Control dialog 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.

See page 180 for important Analog Output details.

The 16 digital channels are sectioned off into two blocks, with the first block consisting of I/O channels 0 through 7, and the second block consists of I/O 8 through 15.

- All the channels within a given block are programmed together and can be set as either inputs or outputs.
- The two blocks can be set independently.
 - For example, one block can be set to input data and the other to output data, or one block is inactive and the other block reads or outputs data.

To read incoming values for a given block of digital channels, click the Input button below the row of channels 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 AcqKnowledge is launched, values for digital channels #0-7 always read "0" and #8-15 always read "1" to allow for compatibility with the STM100C module, which utilizes the lower eight digital lines for attenuation control.

When Read Continuously is enabled (below the Input button), the values will be read in real time. When unchecked, the displayed values correspond to the values for that block of channels as of the last time the Read button was depressed. This mode provides much the same information as the Show Input Values mode.

To output values for a given channel, the block containing that channel must first be enabled to output data. To do this, click the bar below the channel boxes so the button reads "Output." 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 would be setup as shown above.

The function buttons toggle as follows:

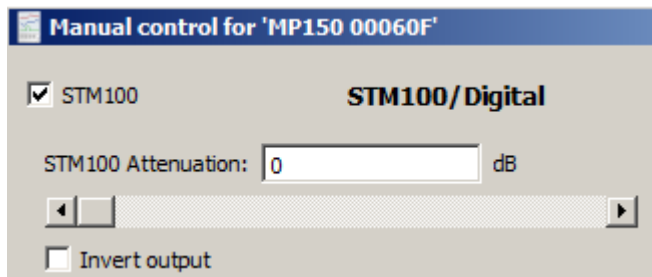
- | | |
|-------------------------|--|
| Input toggles to Output | When Input is selected, the checkbox is "Read continuously." |
| Set toggles to Read | When Output is selected, the checkbox is "Set immediately." |

To output a signal on Channel 3, click the Set button to the left of the channel box. If the Set immediately box is checked, the signal will be output when the channel button is clicked.

IMPORTANT

Potential use conflicts can arise between the parameters set in the Manual Control window and those set for digital channels in the Set Up Channels window.

STM100 option



STM100 option

When the STM100C stimulator module is connected to an MP150 System, the output level can be controlled via the STM100 option of the Manual Control dialog.

Attenuation Attenuate the output signal by a given number of decibels (dB) for controlled stimulus applications. To output a signal with no attenuation, simply set the "Stim 100 Attenuation" to 0 dB.

Manually outputting a value on a digital channel can stop an acquisition if data is being collected at very high speeds (greater than 10,000 samples per second aggregate).

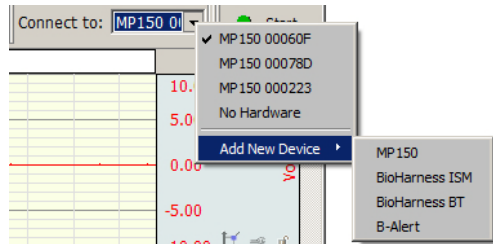
Invert output Check this box to invert the polarity of the signal output through the STM100C. This function can also be achieved by flipping the polarity switch on the STM100C from positive (POS) to negative (NEG).

For more information on the STM100C stimulator output module, see the *MP Hardware Guide.pdf*.

Set Up Linked Acquisitions

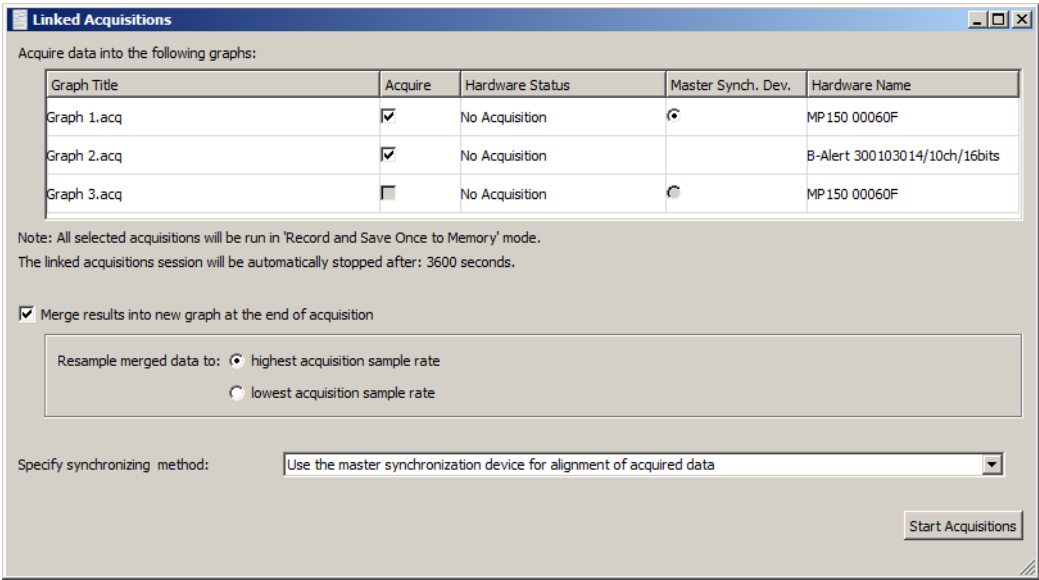
This Hardware menu option allows acquisitions to be configured and recorded simultaneously from multiple hardware devices types over separate graphs. (For example, acquisitions can be simultaneously linked to two MP150, two MP36R units or an MP150 and a B-Alert unit..) In order for Linked Acquisitions to function, each selected graph must be connected to a different hardware unit. (If two or more graphs are connected to the same hardware unit, the linked acquisition session will not start.)

To add or change the hardware device to any open graph, click the “Connect to:” toolbar button and select or add a new device from the menu. (“Connect To” toolbar button must be enabled via Display > Show > Hardware.)



The linked acquisition can output recorded data into the separate graphs, or optionally, merge the data into one graph. If the latter option is chosen, data from the separate graphs will be contained in separate labeled channels within the merged graph.

The sample rates and recording duration can vary between the linked acquisition graphs, but all recordings are limited to Save Once to Memory mode. Append or Disk modes are not supported in linked acquisitions.



Top Column	Description
Graph Title	Displays the titles of the available graphs.
Acquire	Includes or excludes graphs from linked acquisition.
Status of Hardware Device	Shows current status of hardware.
Master Synch. Dev.	Indicates the hardware providing the synchronization signal. This option is supported in MP150 hardware only.
Name of Hardware Device	Identifies hardware device linked to graph.

Functions	Description
Merge results into new graph at the end of acquisition	Outputs data collected from multiple recordings into one graph.
Resample merged data to: highest acquisition sample rate	Data in all graphs will be resampled to highest used sample rate among all graphs in the set.
Resample merged data to: lowest acquisition sample rate	Data in all graphs will be resampled to lowest used sample rate among all graphs in the set.
Specify synchronizing method	Offers various options for synchronizing the linked acquisitions.
<p>“Use the timestamp” method – Compares all timestamps, detects the one with the latest time, and then cuts the beginning section of the data in each channel.</p> <p>“Use the master synchronization” method – Used specifically for pairing and synchronizing data obtained during linked MP150 and B-Alert acquisitions. This is the only option where the Master Sync Device radio button is active. This option requires the use of a BIOPAC CBLX10 cable to link the MP150 hardware with the B-Alert X10 headset. This cable allows for the injection of signals used to align data recordings between the two independent units. (See the MP Hardware Guide for more details on the CBLX10.)</p> <p>“Use simple cutting of data” method – Searches for the shortest acquisition length and uses this parameter to calculate how much data will be removed from the beginning of longer acquisitions. This is the least precise of the three synchronization methods.</p>	
Start Acquisition	Starts the recording for all selected graphs.

Limitations on Linked Acquisitions synchronization methods

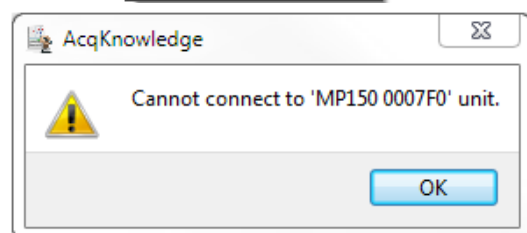
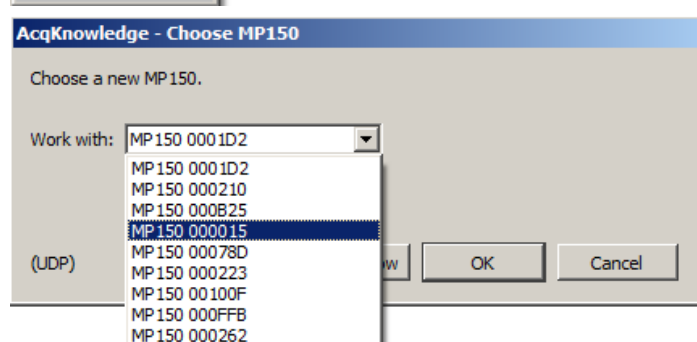
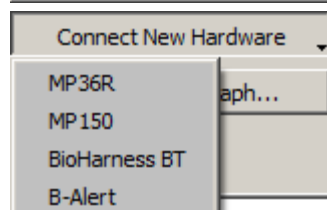
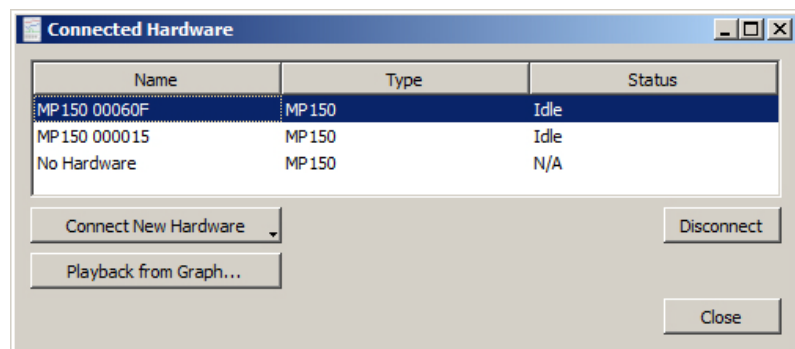
Synchronization Mode	Description	Criteria
Any method	Minimum number of selected graphs	2
	Minimum number of analog channels	1
	Minimum length of acquisition when B-Alert device is used	12 sec.
Master synchronization device method	Allowed hardware types	MP150 and B-Alert only
	Minimum sample rate on first channel of B-Alert hardware	256 s/s

Linked Acquisitions and wireless connections: In general, if the computer is trying to use multiple network cards at the same time with an MP150, the MP150 either needs to be on the primary network, or additional network cards must be disabled, or network bridging must be enabled in the Windows system settings. When self assigning IP addresses, the MP150 may also choose a new IP address each time it is power cycled, which will prompt for reconnection.



Watch the [AcqKnowledge Linked Acquisitions video tutorial](#) for a detailed explanation of this feature.

Manage Hardware Connections



The Manage Hardware Connections option enables easy connection and disconnection of new hardware, and allows switching from a particular hardware unit (or hardware type) to another. The following controls are available:

Connect New Hardware

Choosing ‘Connect New Hardware’ opens a popup menu for selecting and adding additional hardware units. Once a new hardware unit added, it will be available for use in the application, and will appear in the connected hardware list. (The example at left shows the selection of additional MP150 units on a local area network.)

The ‘Choose MP150’ pull-down menu lists all MP150 units that are powered ON and sitting on the same local area network. The software pings the selected MP150 unit and if available, the unit is added to the list. If the unit is busy or otherwise unavailable, a “Cannot connect to MP150” prompt such as the example below left is displayed.

Disconnect

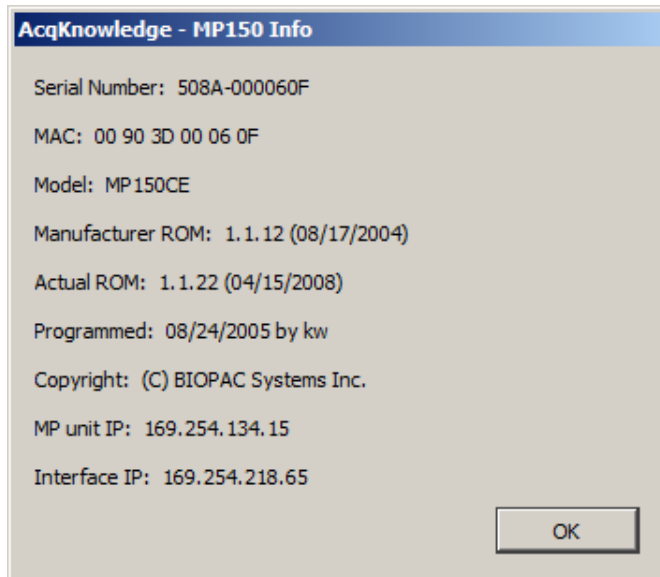
Use to disconnect from any available hardware in the list.

Playback from Graph

Launches the “Open for Playback” dialog. For more information on Playback Mode, see page 43.

MP150 Info

Select MP150 Info from the MP150 menu to generate a dialog with information about the software and firmware versions being used by AcqKnowledge:

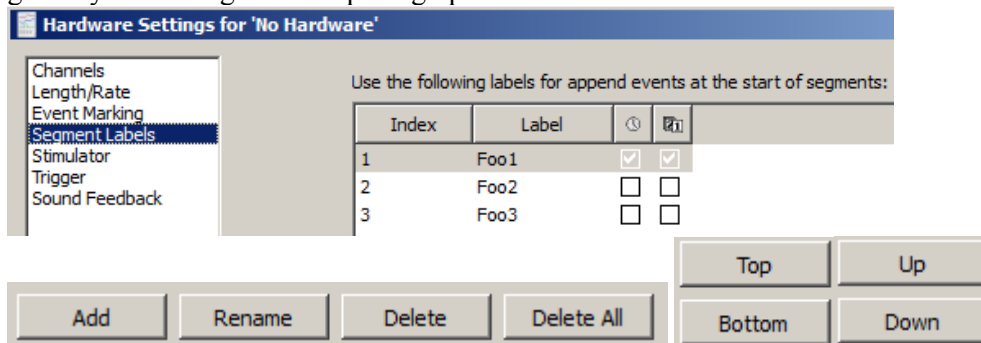


Manufacturer ROM is the factory-installed firmware version; check this before you “Reset” the MP150 unit for a Firmware Rollback (see page 567).



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

Segment Labels

Selecting Set Up Segment Labels from Hardware > SetUp Data Acquisition > Segment Labels launches a setup dialog enabling assignment of user-defined labels to append event segments. The Segment Label options are applied to the active graph only. The selected settings will be saved with the graph, but will not be applied globally to existing or subsequent graphs.

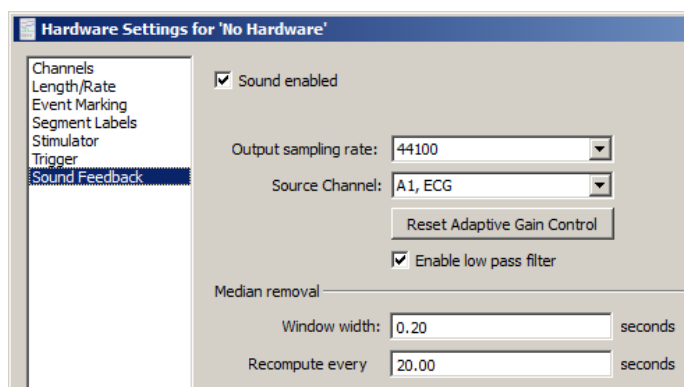


- Add Adds a segment number to index. Segment text can be edited under ‘Label.’
- Rename Used to rename an existing segment label.
- Delete Deletes a selected segment from Index.
- Delete All Deletes all segments from Index.
- Top/Bottom Moves selected segment to top or bottom of Index.
- Up/Down Incrementally moves a selected segment up or down the Index.

Enabling checkboxes below the   icons adds time/date stamps to the segment label.

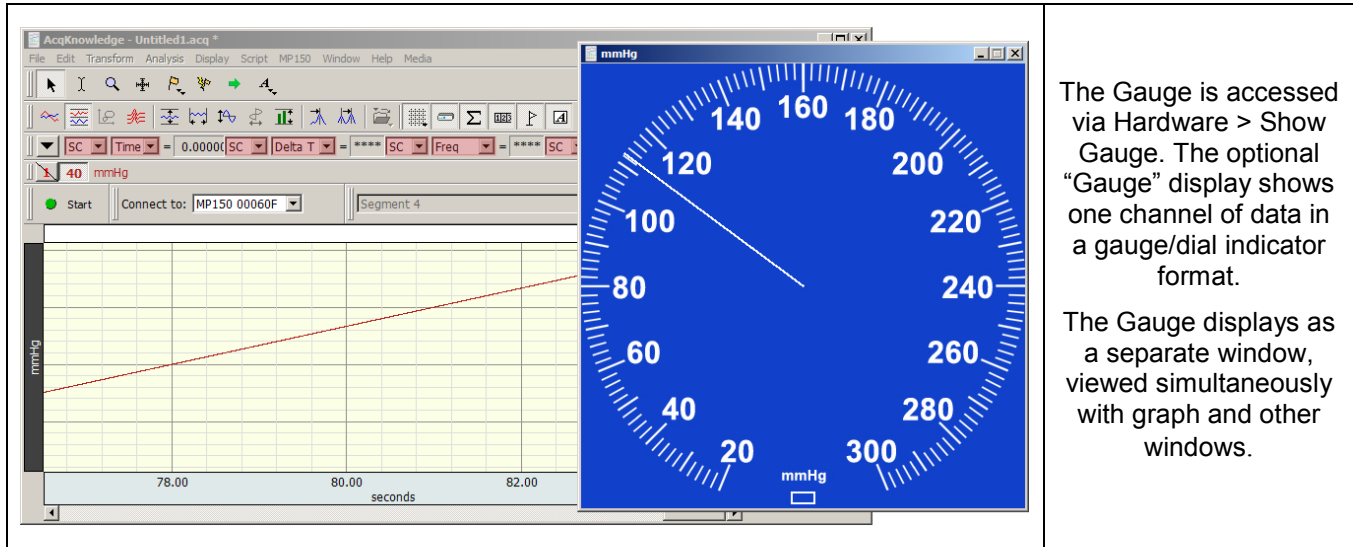
Sound Feedback

Sound Feedback enables data to be redirected to the computer's default audio output in real time. This feature can be used to monitor waveform data as sound through the computer speakers or headphones.



SOUND FEEDBACK CONTROLS	FUNCTIONS
Sound enabled	Turns sound feedback of data on and off.
Output Sampling Rate	Selects from available sampling rates of the default audio device.
Source Channel	Selects the analog, digital or calculation channel from which the audio will be acquired.
Reset Adaptive Gain Control	Resets gain control to adapt to the current level of the signal. Use after sound feedback has started to re-adjust the level after accidental spikes or large artifacts.
Enable low pass filter	Applies a low pass filter at the Nyquist frequency (50% of the acquisition sampling rate). This IIR filter can help smooth out transition artifacts due to upsampling of data to the audio sampling rate. (Enabled by default)
Median removal controls (Window width, Recomputate)	Removes baseline offset from the output signal.
Window width	Sets width of median removal window (in seconds). Must be a positive value.
Recompute every	Provides the time duration (in seconds) after which the median of the data is regenerated from the raw source data. Must be a positive value.

Gauge

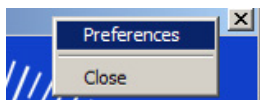


NOTE: The Gauge feature is available in AcqKnowledge 4.2 and higher only.

The Gauge window:

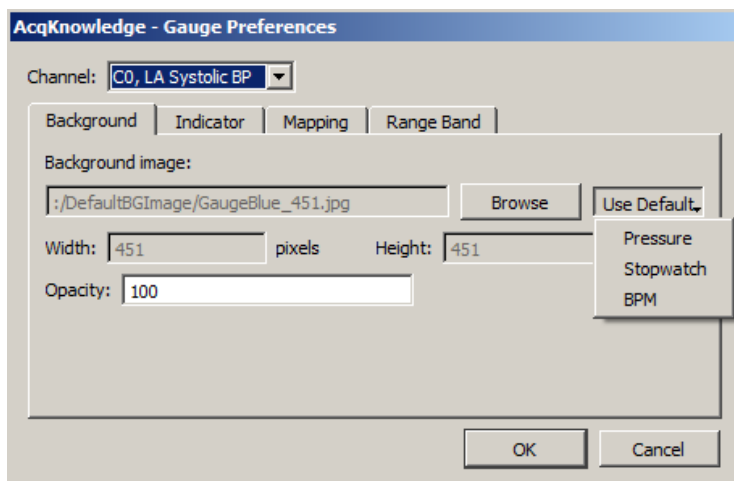
- Will display one channel of data: (analog or calculation)
- Updates and displays simultaneously with the graph window. For analog channels only, the display will update when the recording is stopped, but at a slower rate than when the recording is running.
- Can update during and in between acquisitions for all hardware devices; display may be updated at a rate slower than the sample rate and may display a value that represents the average of several samples.
- The background image (BMP, JPG or TIFF), indicator origin, range, length, thickness and color are all user-configurable. An optional range band overlay can also be enabled.
- Selectable gauge bitmaps include Blood Pressure Cuff, BPM or Stopwatch
- All window preferences as well as the window visibility, size and position will be saved with the file.
- Window sizing is "fixed" to the size of the background image, meaning it will have a 1 to 1 correspondence with the monitor pixels

Gauge Preferences



Gauge Preferences are accessed by right-clicking over the gauge and using the contextual menu. There are four tabs for setting the various Gauge parameters.

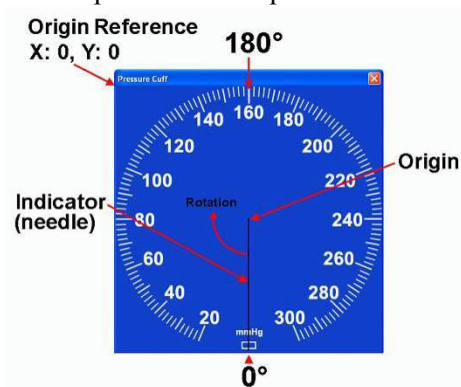
Background is the default tab presented in Gauge Preferences and contains options for setting the Background image.



<i>Channel</i>	Provides a pop-up menu for assigning any one of the ENABLED analog or calculation channels.
<i>Background Image</i>	Displays the path and file name of the current background image. The default image is a blue blood pressure gauge sized at 451 x 451 pixels.
<i>Browse</i>	Allows alternative background images in different directories to be used in place of the default gauges. The Browse location will default to the file path used by the currently selected background image. To change the background image, click the “Browse” button and locate the desired file. After the background image is specified, the pixel Width and Height will be updated. The Width and Height fields are not editable.
<i>Use Default</i>	Displays a menu of available default background images. (Pressure, Stopwatch and BPM).
<i>Opacity</i>	Changes the transparency of the gauge image.

Indicator

The “indicator” or “needle” is a simple line vector drawn from an assigned center point to an endpoint calculated according to the “Length” parameter.



Origin Center point of the indicator line referenced from the top left of the image (not the top left of the window) meaning neither the frame of window nor the title bar is included. The “X” parameter specifies the horizontal distance in pixels and the “Y” parameter the vertical distance. “X” cannot exceed the Width of the background image and “Y” cannot exceed the image Height. The *default* values are: Origin: X: Width/2, Y: Height/2. **Note that the pixel count starts at “0” so a 225 pixel square image will have its center point at 112 pixels.**

Length Specifies indicator span in pixels starting from the “Origin.” Default is the smallest of the Length or Width dimensions divided by 2.

Thickness Specifies the indicator width in pixels, with a selectable range between 1 and 10. The default is 1 pixel.

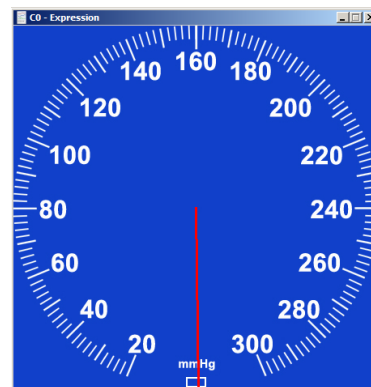
Color Specifies color of the indicator “needle” as Black (default) or White.

When recording is stopped

If the source channel is a Calculation channel, no gauge updating will occur when the recording is stopped. Under this circumstance, the “When recording is stopped” options become available. This allows the user to specify whether the indicator should not be displayed, should be reset to zero, or should retain the last value.

Mapping

For setting up two point mapping: Input to Angle.



Background | Indicator | **Mapping** | Range Band

Input

Angle

0.000000 Volts 0.000000

50.000000 Volts 359.000000

☒ Indicator is limited to specified mapping

Input Defines the input values in the scaled units. The units shown in the example are volts, but would reflect the units of the source channel (mmHg, psi, etc.). The Input mapping of the upper scale value is set to a default of 50 of the source channel unit type.

Angle Any angle can be entered, but 0, 360, 720, etc degrees means that the indicator will always be pointing straight down.

When assigning mapping angles: Because the indicator “needle” must rotate clockwise, the first value should be the lower angle. The first value also defines the indicator’s starting angle but does not need to be 0 degrees. For example, the Stopwatch Gauge’s starting angle should be 180 degrees (pointing straight up). If half-circle gauges are used, the starting angle may be 90 degrees.

Indicator is limited to specific mapping

If this option is enabled, and the indicator needle reaches its mapped upper limit, it will stop rotating and turn red. If this preference is not selected, the needle will not change color if the defined mapping limits are exceeded and the needle will just continue in a clockwise rotation.

Range Band (Default OFF)

Use the Range Band as an optional feature to highlight a specified area of the Gauge View.

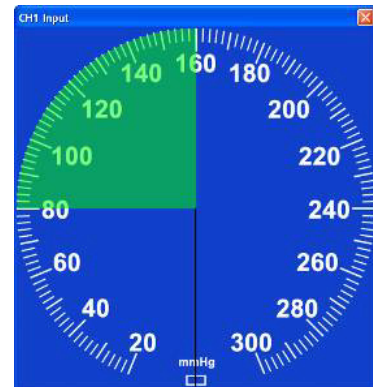
Background | Indicator | Mapping | **Range Band**

☒ Show Range Band

Start: 0.000000 Volts

End: 50.000000 Volts

Opacity: 50 %



Start/End Defines a “pie” shape (defined by Mapping values) sourced from Gauge center and superimposed over the background image.

Color Clicking on the color bar will bring up a color palette, which allows any color to be selected. The default color is green.

Opacity Used to adjust the transparency of the Range Band. 100% means the background image will be fully obscured behind the range band, and 0% means the Range Band itself will not be visible. The default setting is 50%.

Segment Timer “Stopwatch” option

(Available in AcqKnowledge 4.2 and higher only)

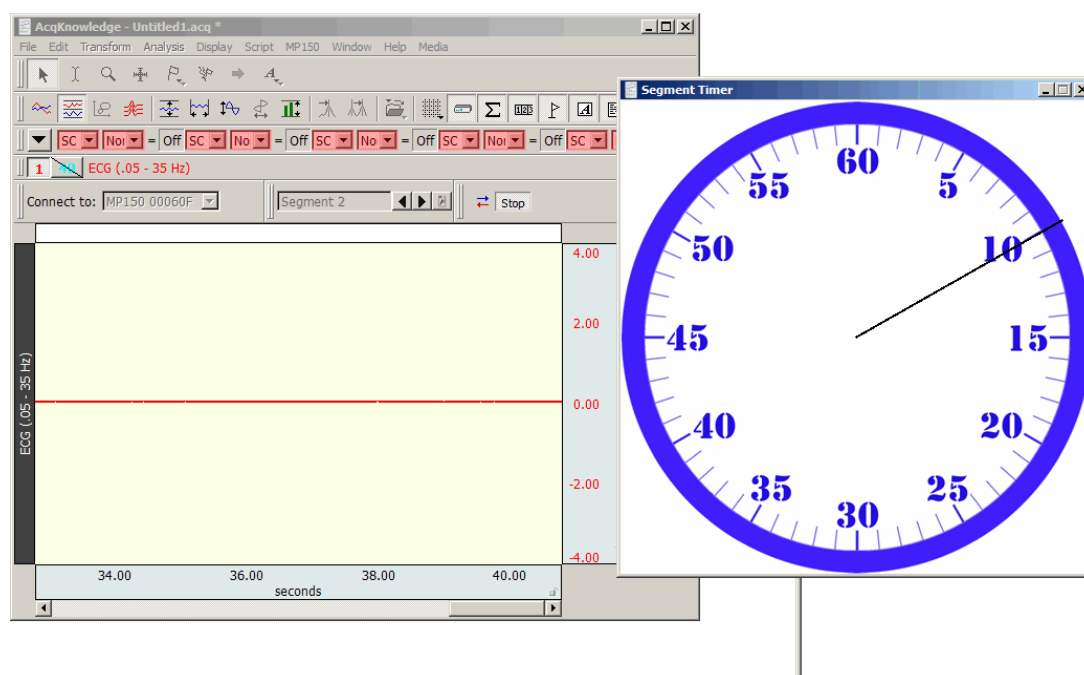
In addition to the standard Gauge described above, the Segment Timer Gauge option offers an analog “Stopwatch” view of an acquisition in progress. As the recording progresses, a circular onscreen stopwatch gauge displays the elapsed time with a sweep-second indicator. All customizable parameters shown above for the default Gauge view are applicable to the Stopwatch view. A custom mapping for the Stopwatch view can be created, or use the pre-configured “Segment Timer Gauge” graph template in the Sample Data folder.

Using the Segment Timer graph template – open the sample template in the following directory:

Main drive\Program Data\Biopac Systems, Inc\AcqKnowledge 4.4\Sample Data\Segment Timer Gauge.gtl

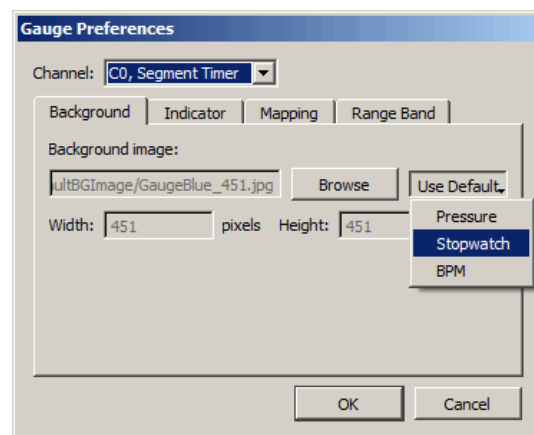
Clicking ‘Start’ will show the Stopwatch in progress. The template is setup to record ECG Lead II on CH 1 and is tied to a new Segment Timer calculation channel. However, no connections are needed to verify the segment timer and the template can be customized as desired. To change parameters, choose Preferences from right contextual menu with mouse positioned over the gauge window.

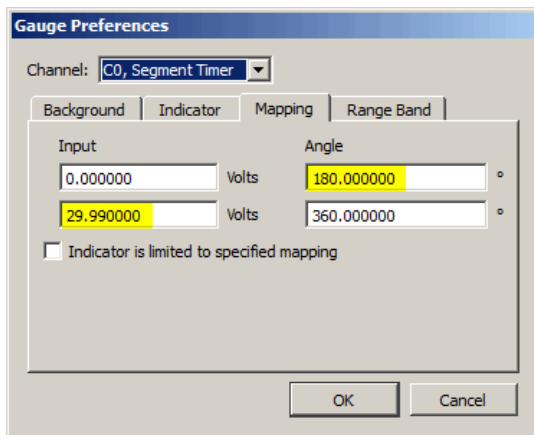
When the recording is stopped, timer indicator will also stop. When the next recording segment begins, the segment timer will reset to 0. (This default can be changed in the Gauge Preferences).



To configure a new Segment Timer Stopwatch view:

1. Set up desired acquisition parameters and channels.
2. Hardware menu > Set Up Data Acquisition > Channels > Calculation tab and choose the Segment Timer preset.
3. Hardware menu > Show Gauge and open Preferences by right-clicking the contextual menu over the Gauge window.
4. In the Gauge Preferences, choose “C0 – Segment Timer” for the Channel and “Stopwatch”, as shown on right.
5. Choose the “Mapping” tab, enter the following Input to Angle mapping values and click **OK**:





6. Start the acquisition. Note the Stopwatch view will accurately reflect the time scale of the recording in progress.

Autoplotting, Scrolling and Sweep Display Modes

Checking or unchecking the Autoplotting, Scrolling and Sweep options controls how data is displayed on the screen during an acquisition. By default, 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 Scrolling is disabled and Autoplotting is enabled, the screen will be cleared when the data reaches the right edge of the screen, and plotting is redrawn from the left.

When both Scroll and Autoplot are unchecked, the incoming data will be plotted until the screen is full. Once the screen is full, data will continue to be collected, but only the first screen is displayed. By default, the hardware will display the first eight seconds of the data record, but this can be reset manually by changing the horizontal scale. To toggle Autoplot ON or OFF in the middle of an acquisition:

- select Ctrl+T (Windows) or Command+T (Mac OS X) on the keyboard, or
- Choose the MP menu and enable or disable “Autoplotting”

Sweep display mode is similar to an oscilloscope sweep display in which data is plotted left to right, but old data remains visible on the screen while new data is incoming. This type of display is also seen in some clinical devices.




In order for Sweep display to function:

- Autoplotting must be enabled
- Scrolling must be disabled
- Sweep must be enabled

In this configuration the old data remains visible while incoming data in the form of a black vertical line “sweeping” across the old data from left to right. The old data and horizontal time scale are redrawn with once the line sweeps across its axis.

Limitations: Sweep mode when scale modifications affecting the vertical or horizontal scale are applied. This includes: autoscaling, show all data, adaptive scaling, zoom, window resizing, end of acquisition. Sweep can be toggled from the hardware menu during acquisition and is data view independent. The sweep state is saved in graph files and templates.

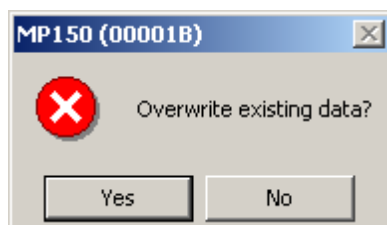
Sweep mode is applicable in Scope, Chart, Stacked Plot, and Split View modes. It is not supported in XY mode.

Manual, Autoscrolling and Sweep options can also be accessed via the , , or  button in the lower right region of the horizontal axis region. For full details on this tool, see Autoscroll Horizontal Axis Controls on page 52.



Warn on Overwrite

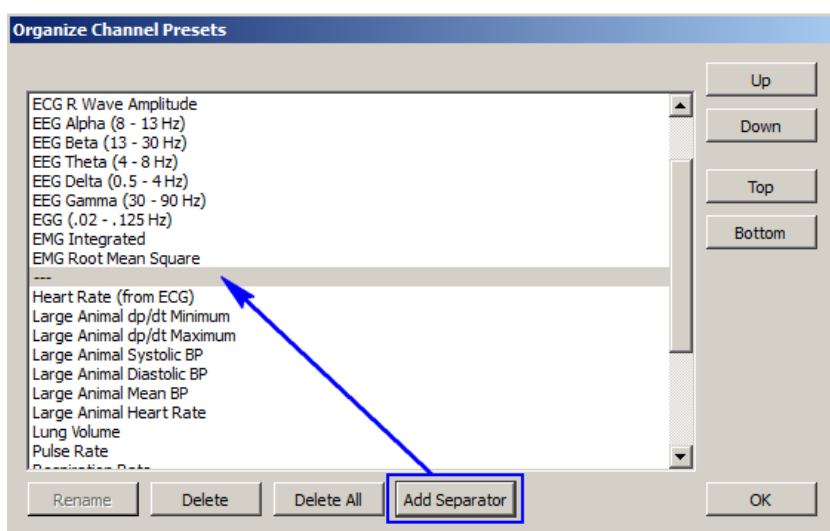
Selecting the “Warn on overwrite” option from the Hardware menu will generate a prompt each time you start a new acquisition:



If you click “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 “No” and then open up a new file to work in.

This prompt will appear at the beginning of each acquisition when the hardware is in Save Once with repeats mode. “Warn on Overwrite” can be disabled by deselecting this option under the Hardware menu.

Organize Channel Presets



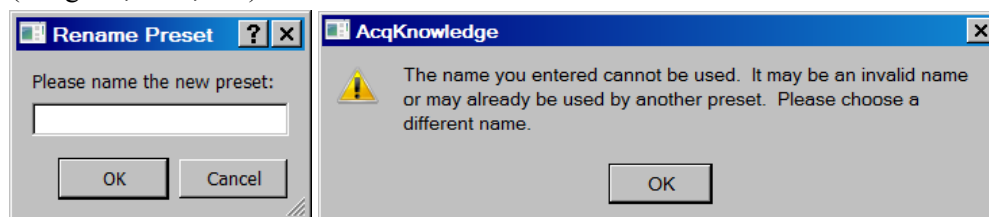
The Organize Channel Presets option controls the channel presets (established or custom) in the Hardware > Set Up Channels dialog; you can rename, rearrange or delete Presets. This option can be used to place the most frequently selected Presets at the top of the menu or group related Presets, such as established ECG Presets. Click a Preset description to select it, and then use the buttons to organize the Presets.

Up and **Down** buttons move the selection one space at a time.

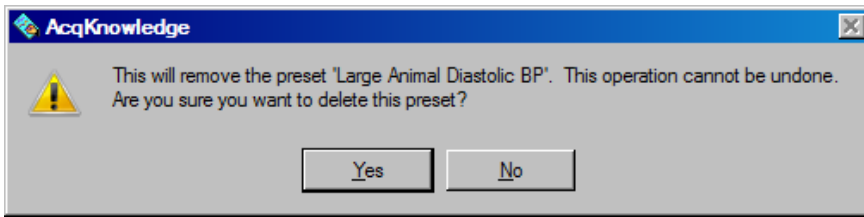
Top and **Bottom** buttons jump to the start or end of the list.

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

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.



Add Separator adds a new Separator entry to the Preset list and is useful for dividing different Preset types. If a Preset is currently selected in the list, the Separator will be added below it. (See diagram above) If no preset is selected, the separator will be added to the end of the list. Separators can be rearranged or deleted in the same manner as Presets. (AcqKnowledge 4.2 and higher only)

The default location for Preset files is Computer > Local Disk > ProgramData > BIOPAC Systems, Inc > AcqKnowledge 4.4 > Presets.

Exit Playback Mode

This option is enabled when Open File for Playback (see page 43) has been selected. Select to resume acquisition functionality (change Playback menu to Hardware menu, Replay button to Start button).

Part C—Analysis Functions


OVERVIEW

This part describes how to analyze data; in most cases, analysis is performed after the data has been collected. This involves creating, managing, and saving files, as well as editing data, performing mathematical transformations, and displaying data in various ways. Many of the functions covered here are also discussed in *Part A—Getting Started*. Features that can be computed during an acquisition (primarily transformations and calculations) are discussed in *Part B—Acquisition Functions*.

For general information about sections of the graph window, and to become familiar with the “look and feel” of *AcqKnowledge*, turn to the *Editing and Analysis Features* chapter. Descriptions of functions can be found in the chapters describing each menu. All of the commands discussed here can be found under the File, Edit, Transform, or Display menu items.

Menu	See...	Type of Commands
File	Page 248	General file management commands, including opening, saving, and closing files. Export data files.
Edit	Page 272	Cut, copy, and paste between and within files. Export data files.
Transform	Page 282	Operations that primarily modify the data in the graph.
Analysis	Page 313	Operations that primarily derive data and measurements from the graph.
Specialized Analysis	Page 348	A courtesy copy of the new <i>Specialized Analysis</i> package with automation and scoring routines is included under the Analysis menu.
Display	Page 427	Control how data appears on the screen either during or after an acquisition.
Media	Page 458	Capture and Playback controls to synchronize video/audio with data.

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. Custom toolbars can be created by clicking the Customize Toolbars icon. 

Click Display > Show > to view the toolbar options. Check a toolbar option to activate it.

See page 57 for Toolbar icon definitions.

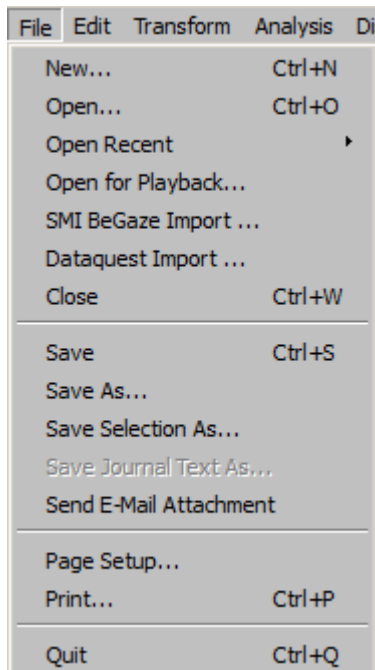
Shortcuts

Keyboard shortcuts are detailed on page 65.

Mouse shortcuts are detailed on page 69, including contextual menus.

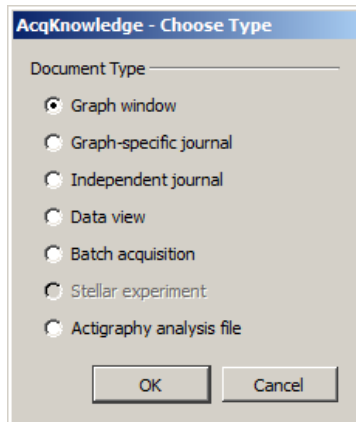
Chapter 13 File Menu Commands

Overview



Most of the items in the File menu are standard menu items and follow the standard Windows conventions or Macintosh conventions. By default, all files are created and saved in the *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.

New



Graph Window

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. When a new graph window is created, 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 > Graph-specific Journal

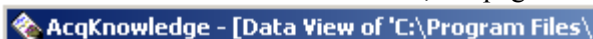
Creates a graph-specific journal; see page 53 for details.

New > Independent Journal

Creates an independent journal; see page 53 for details.

New > Data View

Creates a new Data View for the active (frontmost) graph and names the window “Data View of ‘Filename’.” For Data View details, see page 44.



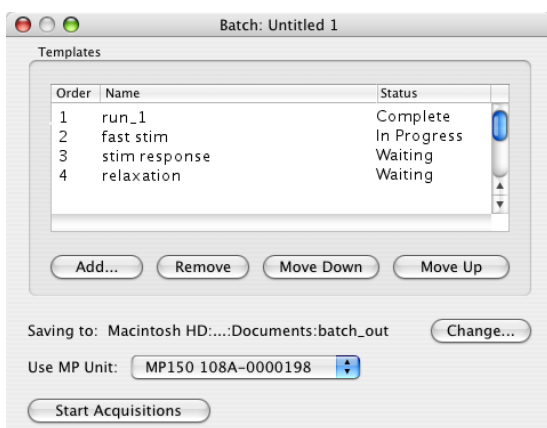
New > Batch Acquisition

Use the Batch Acquisition feature to configure advanced experimental setups and acquire data from a sequence of templates. Each template in the Batch may have different acquisition settings, channel configurations, and stimulator setups. Use a Batch for long duration experiments with hardware setting changes across segments, to automate routines, or to run multiple experiments on the same experimental setup in succession.

- For example, if an experiment has a preparatory period, a stimulus period, and a response period, three graph templates could be batched:
 - A template to acquire for the length of the preparatory period
 - A second template with a stimulator configured for the stimulus period
 - A third template to acquire the response period without stimulation

All three templates could be added in sequence to a single Batch Acquisition, which would then acquire all of the data for all three templates with a single start.

To create a new batch, choose File > New > Batch Acquisition to generate the Batch dialog.



The Templates controls at the top allow you to add, remove, or re-order the templates.

- Double click a template in the list to open the output graph from the most recent acquisition.
- Batch acquisition cannot combine acquisitions that do not end, so the acquisition storage mode for template files cannot be set to “Save last,” “Autosave” or “Repeat forever.”

Status

N/A	No status is available for the template, no batch acquisition has been performed.
In Progress	Data is currently being acquired for the template.
Waiting	A batch acquisition is in progress but has not yet reached the step where the template is used.
Complete	Data acquisition for the template has been finished successfully and has been saved to disk at the batch output location.
Error	A batch acquisition was aborted manually or due to communication errors. The data for the template may not have been saved or may be unreliable.

Batch Errors

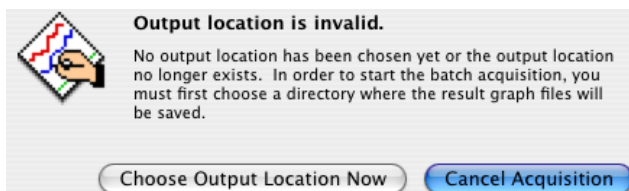
Misconfigured templates and misconfigured averaging templates may generate the Adjust Length/Adjust Latency/Abort Acq warning prior to the start of acquisition. Clicking “Abort” will halt the batch acquisition. Misconfigured templates may result in those rare cases where data was acquired into a graph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

Saving to:

Use the “Change” button to specify the directory where the acquisition output should be saved.

Use MP Unit:

Specify the MP unit that should be used for the Batch Acquisition.



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

Start/Stop Acquisitions

Start Acquisitions

Stop Acquisitions

Toggles to start 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

Start Acquisitions

Resume Acquisitions

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

Batch Acquisitions can be saved for use at a later time using File > Save Batch Acquisition As. Batch Acquisition files retain all of the settings for their individual templates and can be used even if the original templates used to configure the batch no longer exist or have been moved. Each template is acquired and saved into an output graph file that can be opened at a later point in time to examine the results.

To open a Batch Acquisition, use File > Open and select type “Batch Acquisition.”

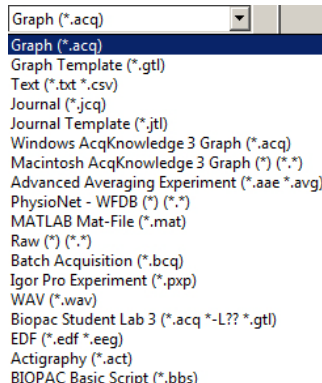
When a batch acquisition is started, the templates will acquire data in the order indicated from the specified MP unit. Files are saved before the next acquisition is started.

- If the batch acquisition completes successfully, the batch output directory will contain all of the graph files that were created during the acquisition. Each output graph is saved into a user-specified directory and is titled “Batch *n* - template name” where *n* is the order in the acquisition sequence.

File	Edit	Transform	Display
New...			⌘N
Open...			⌘O
Open File for Playback...			
Close Batch Acquisition			⌘W
Save Batch Acquisition			⌘S
Save Batch Acquisition As...			
Page Setup...			
Print Graph...			⌘P

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.



Multiple files

To open multiple files in a single dialog, hold the Control/Command key down and select multiple files. To open consecutive multiple files in a single dialog, select the first file, hold the Shift key down and select multiple files. *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.

Graph The default file formats (*.acq) is 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. Format options for the graph file include

- **Graph**—*AcqKnowledge* 4
- **Windows *AcqKnowledge* 3 Graph**—previous release format
- **Macintosh *AcqKnowledge* 3**—previous release format
- **Biopac Student Lab *PRO* Graph**—import files created using the Biopac Student Lab *PRO* software; to open BSL Lesson files (.ldd), manually add the extension “.acq” to the end of the file.

BSL File Import Notes

BIOPAC produces two different software lines, the *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 *PRO*. This allows data acquired with an MP36, MP35 or MP30 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.

Template Graph Template files (*.GTL)

This powerful feature allows for creation of a template file with predefined experiment parameters. Simply click “Start” to run the experiment.

The Graph Template option allows you to open a copy of a master file so you can maintain the master settings. Graph template files open to previously saved setup parameters (as established under the Hardware menu) primary graph window size.

This feature can be especially useful for recreating protocols in the laboratory. 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
O
T
E**

- a) The graph window will not contain any data. (Since no data is saved in the template, arbitrary waveform output setups, which require a source data file, will not function in a template.)
- b) 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 Data folder and can be used to establish the settings required for a particular application or as a good starting point for customized applications.

Text *.TXT*. Text files are a convenient way of transferring information between applications, and most spreadsheet and statistics programs are capable of importing or exporting data in a text file format. 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.

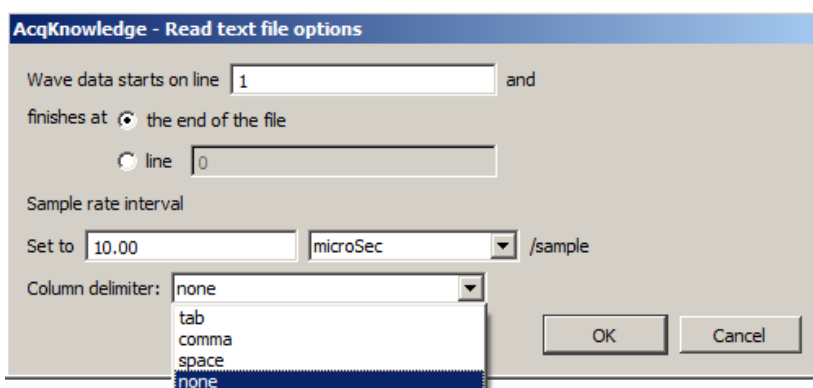
Journal *.JCQ—Opens an independent journal; see page 53 for details.

Open the journal file from the File Menu (File > Open > Journal); right-clicking or double-clicking a saved Journal file will open a blank application window.

Jrnl Temp *.JTL—Opens a journal template; see page 53 for details.

Options

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



Wave data starts on line

To control how much data is read in, enter a value in the read line box at the top of the dialog. This tells *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. The interval between samples is equal to the reciprocal of the sampling rate; $\text{Interval} = 1/(\text{Sample Rate})$. For example, if data was 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 60 Hz, 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 “none” 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.

AVG Advanced Averaging Experiment—not supported in *AcqKnowledge* 4.0.

PhysioNet PhysioBank is a public service of PhysioNet and offers downloadable archives of gigabytes of “standard” data for cardiac arrhythmias, gait analysis, and other types of physiological signals. *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.

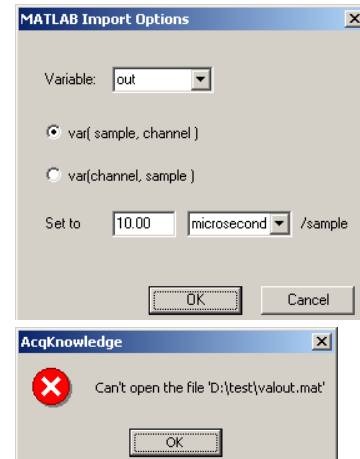
MAT MATLAB® format *AcqKnowledge* can open files created as a MATLAB work space.

- Windows™ can open MATLAB v6 compatible MAT files, including MATLAB 7 if the “v6” flag is specified in MATLAB before saving.
- 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.



Raw

This low-level data exchange option interprets all data at a single sample rate; variable sample rates are not supported. All of the data will be unscaled when opening (importing) files. That is, a value of 0 will be imported as a zero voltage. Scaling will need to be manually applied to the data. Options to open (import) raw data:

- Data type: 32-bit or 64-bit IEEE floating point format or 8-, 16-, and 32-bit integer formatted data
- # of channels: Enter the number of channels stored in the data file as a positive integer less than or equal to 60.
- Layout: *Packed sequential*: All of the data for an individual file is located in a single block of the file and multiple channels follow one another.
Interleaved: Data is grouped into a single “frame” for each sample location with one data element for each channel, so data for a particular channel is spread throughout the file (similar to Linear PCM audio file format).
- Endian: Little and big endian byte ordering, matching the data formats of x86 and PowerPC/Sparc, respectively. Set to big for Mac-Power PC generated raw files (default), or to little for Mac-Intel generated or Windows-generated raw files.
- Set to x/sample : Specify the *inter sample interval* of data in the file, which will be translated into an appropriate sampling rate. The edit field will accept an arbitrary floating point number. The units menu contains μsec , msec, sec, MHz, kHz, Hz. The edit field will be dynamically converted to match the units selection; no conversion will be used when switching between frequency and time.

Batch

Batch files (*.bcq) is the format used for a saved Batch acquisition setup. All previous configurations are saved in this file, so a Batch experiment can be rerun without having to repeat the setup. When a saved Batch file is opened, the batch setup window appears with previous graph templates intact. From here, the setup can be modified and saved under the same or a different name.

Igor Pro

Igor Pro Experiments (compatible with Igor Pro 3.1, 4.0, and 5.0).

The waves contained in an Igor Pro packed experiment can be opened (imported) in AcqKnowledge provided that the packed experiment files comply with the following:

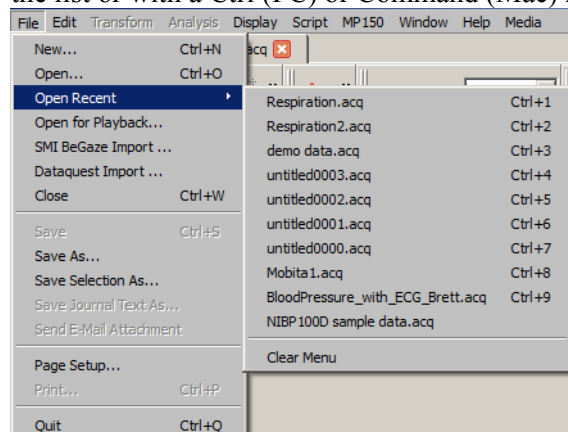
- no text waves
- all waves in Version 2 or Version 5 format (Igor defaults)
- no complex waves
- all waves one-dimensional (vectors)
- all waves multiples of the same fundamental inter sample interval

If the wave has an associated wave note, it will be used as the channel label.

WAV	<p>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.</p> <ul style="list-style-type: none"> • 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	<p>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:</p> <ul style="list-style-type: none"> • channel data • channel labels • units • sampling rate (taken from maximum sample rate of all channels) <p>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.</p>
ACT	<p>Opens actigraphy files generated from analysis of existing accelerometer data files related to sleep studies and wake/sleep activity. Actigraphy licensed functionality is required for this file format to be active. For information on Actigraphy, see page 519.</p>
BBS	<p>Opens Biopac Basic Scripting files. Biopac Basic Scripting licensed functionality is a scripting language development option for AcqKnowledge. For more details, see page 484.</p>

Open Recent

The File > Open Recent command generates a list of recently used files. These files can be opened directly from the list or with a Ctrl (PC) or Command (Mac) keystroke combination.



Maximum number of files in File > Open Recent: 10

The listed files appear in the order they were opened, with the most recently-opened file appearing at the top. Default number of files appearing in the list can be modified in the Preferences. (Display > Preferences > Other or Main Toolbar)

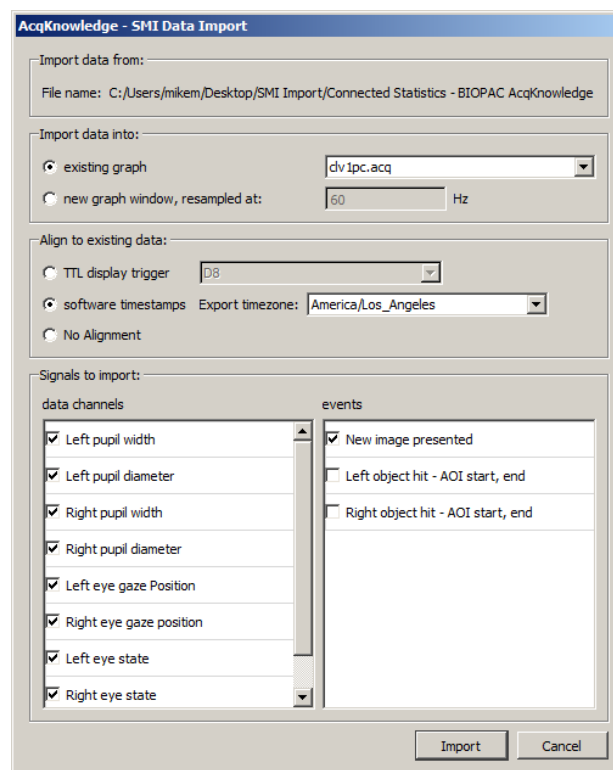
Open for Playback

The File > Open for Playback command generates a standard file open dialog; see page 43 for Playback details.

SMI BeGaze Import

This option allows for import of SensoMotoric Instruments BeGaze software's eye tracking data and aligns the data with other physiological signals recorded in *AcqKnowledge*. In order to use the SMI BeGaze Import feature in *AcqKnowledge*, the BeGaze eye tracking data must first be exported to a text file format readable by *AcqKnowledge*. (BeGaze software offers text file export of the eye position, pupil width measurements, analyzed data and eye tracking events.) BeGaze eye tracking data can then be imported into an existing *AcqKnowledge* graph, a new graph, or aligned to existing data.

To use TTL display trigger synchronization, the digital output line from the SMI hardware must be connected to the hardware unit used for recording record data, and digital channels must be enabled during data acquisition. The time of the first image presentation within the BeGaze data will be placed at the first positive peak within the digital signal. The software's timestamp alignment will extract the recording time from the BeGaze data and align it with the internal *AcqKnowledge* timestamps. For more details about timestamp alignment, see page 258.



When importing and aligning data to an existing graph, physiological data must be recorded into a single segment. Data recorded as multiple appended segments will not be properly aligned.

BeGaze exports may contain only a subset of the recorded and analyzed data. Signals not present in the export file will be removed from the 'Signals to import' checkbox options.

Importing SMI Begaze Data into AcqKnowledge

To import SMI Begaze eye tracking data into AcqKnowledge:

1. In Begaze software, export the eye tracking data to *.txt format and save the file.
2. Launch a new graph in AcqKnowledge or open an existing graph for BeGaze data import.
3. In AcqKnowledge, choose “File > SMI BeGaze Import” and navigate to the *.txt file exported in Step 1 and click “Open.” This will launch the SMI Data Import setup screen.
4. Under “Import data into:” choose the AcqKnowledge destination graph for SMI Begaze data import.
5. Choose the desired alignment option (digital trigger signal, timestamps from AcqKnowledge and SMI data, or no alignment.)
6. Select the eye tracking signals and SMI events to import and click “Import.”

The selected SMI signals and events will be placed into the AcqKnowledge graph at the appropriate locations.

Note: The SMI Begaze Import feature is available in AcqKnowledge 4.3 and higher only.

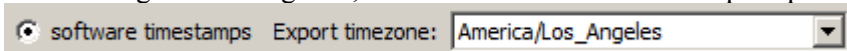
-  Watch the [AcqKnowledge SMI BeGaze import and synchronization video tutorial](#) for a detailed demonstration of this feature.

Using the Software Timestamps Option to Align Data

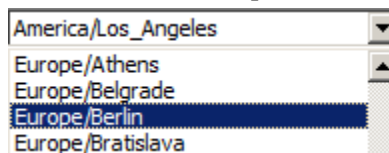
If the existing AcqKnowledge graph and SMI *.txt file selected for import were recorded in different time zones, selecting the “software timestamps” option helps compensate for the timezone disparity and aligns the data accordingly. In order for the timestamp alignments to be accurate, it is essential to know the timezone the SMI *.txt file was recorded in. (The “export timezone” default setting is determined by the clock time/date properties of the AcqKnowledge computer.) However, if the SMI eye tracking data was exported from another computer in a different timezone, changing the “export timezone” parameter to match that timezone will help properly align the imported data with the current timezone of the AcqKnowledge graph. This is best illustrated in the following example.

In this example, the exported SMI BeGaze eye tracking data selected for import into AcqKnowledge was recorded in the “Europe/Berlin” timezone, while the AcqKnowledge graph was recorded in the “America/Los Angeles” time zone. To synchronize both files timestamps to the current timezone:

1. Follow Steps 1-4 from above (“Importing SMI BeGaze Data”).
2. Under “Align to existing data,” select the “software timestamps” option.



3. Scroll down the “Export timezone” list and select “Europe/Berlin.” (Or an applicable timezone.)



4. Click “Import.”

If the AcqKnowledge graph and the SMI BeGaze file selected for import were recorded/exported in the same timezone, it is not necessary to use the “software timestamps” alignment option. In this instance, choose the “No alignment” option.

Dataquest Import

Dataquest ART is a data acquisition software package from Data Sciences International (DSI). This package is used with a variety of devices including implantable telemetry units. The File > Dataquest Import option allows data acquired from ART files to be directly extracted into AcqKnowledge. The following Dataquest file information is supported and retained in AcqKnowledge:

- Data accuracy
- Retention of animal IDs
- Import of either waveforms or parameters

- Provides choice of animal subjects to be imported

Datquest File Description

Unlike graph files, Dataquest ART saves data as multiple files in a single directory. Each file may be either a continuous recording or consist of multiple segments.

A recording may contain multiple animals/subjects. Each animal/subject is given an animal ID. This animal ID forms the basename of all of the various Dataquest data files.

Two primary types of data are recording for each animal: waveforms and parameters. Waveforms are the semi-continuous raw data recorded from transmitters during the segment. For multi-channel recordings, each channel may have an independent sampling rate and the sampling rate may vary within an individual channel for an individual experiment, but the duration and recording frequency are identical across all channels and animals.

Parameters are derived measurements such as heart rates, mean pressure, and other values derived from the raw data. The user's protocol may dictate which type of data will be useful in the analysis, but many DSI customers perform further data reduction on the parameters instead of working with the raw data.

Dataquest splits waveforms and parameters up into separate files. Specific ID parameters are stored into a sequence of files named "ID.P##" where ## is a continual incrementing sequence of alphanumerics 0-9A-Z. Each individual waveform is stored into a series of files named "ID.C##." C is a single character indicating the channel number 0-9A-F, for up to 16 channels. ## is a continual incrementing sequence of alphanumerics 0-9A-Z, similarly to parameter files.

Each individual parameter or waveform file may contain data from multiple segments. A new file is created once the size of a particular storage file reaches a user-specified limit. The total number of files, therefore, does not necessarily equal the number of segments.

The data for each specific segment in the file also contains a timestamp indicating the calendar time of the beginning of the segment.

Creating Graphs from Dataquest Data

Although related, waveforms and parameters are very different types of data. *AcqKnowledge* primarily stores and analyzes continuous signals. As parameters are not continuous signals, they are not easily combinable with waveforms in a single graph. Therefore, parameters and waveform data are imported differently.

Waveform Graphs

Waveform graphs are imported with waveform data within individual channels. Dataquest waveforms may have different sampling rates for each individual waveform and potentially varied sampling rates within an individual waveform. The imported graph's sampling rate will be set to the highest sampling rate of all segments of the file.

If a file contains multiple animal units, you can control which animals should be imported. By default all animal units are imported into a single graph.

Each data segment is separated by an append marker to allow the use of Find Cycle across discontinuous data segments. The append marker label corresponds to the segment timestamp of the in the local time zone.

For each animal with ID, the individual channels are imported with labels as "ID – label" if the DSI file contains a label for the channel. If there is no label is found, it will be labeled with its index "ID – Channel C" where C is the index from the beginning of the specific DSI file extension.

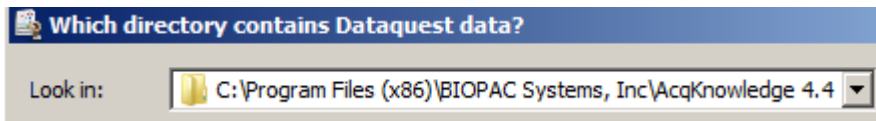
Parameter Graphs

Parameters are stored by Dataquest as one set of numbers per segment. Parameter graphs are imported using the same approach as rate detector XY output graphs. The graph will be set up as an arbitrary horizontal axis labeled "segment index." Each parameter will be imported into a single graph channel, with the channel named "ID – Param," "ID" replaced with the animal ID, and "Param" replaced with the name of the parameter as read from the Dataquest DSI file. The parameters are then imported as data points.

Only subsets of animals may be chosen; all parameters will be imported for the chosen animals. Users wanting a subset of parameters may optionally erase or hide graph channels after the data is imported.

To Import Dataquest files into AcqKnowledge:

1. Choose “File > Dataquest Import.”

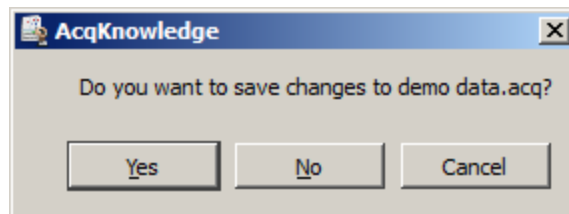


2. Navigate to the Datquest file and click “Choose.”
3. Make the desired selection in the Dataquest Import dialog and click OK.



Close

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



Close without saving

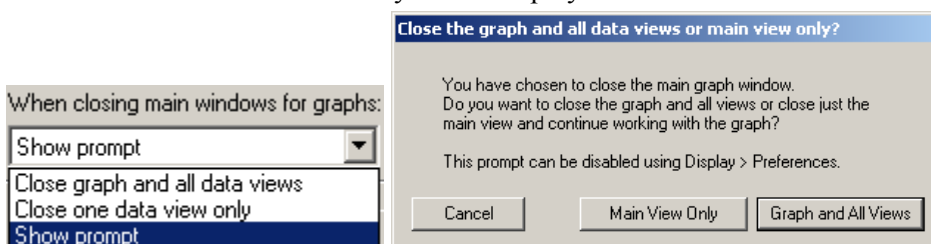
- *Windows*—click the in the upper right corner of the file window
 - *Mac OS X*—click the in the upper left corner of the file window
- Click “No” when AcqKnowledge asks you if you want to save the changes.

Close during acquisition

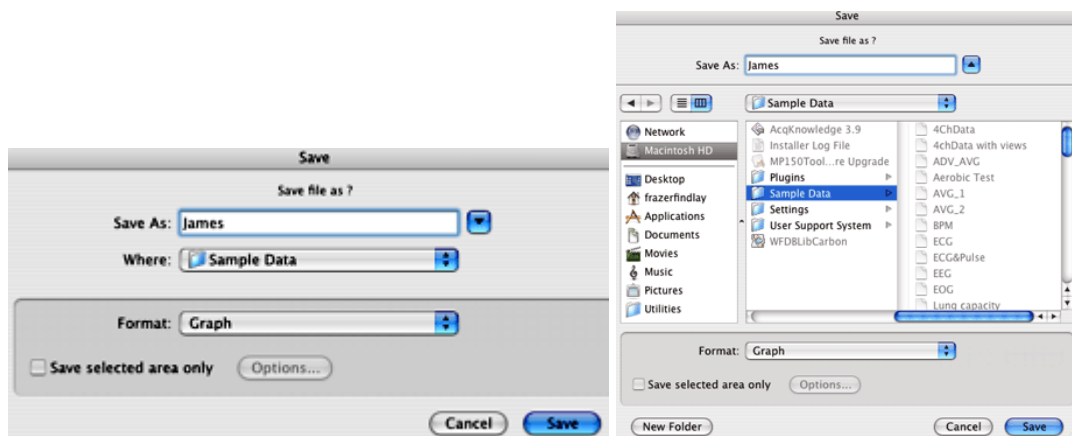


Close multiple data views

Set the level of close functionality under Display > Preferences > Other or Main Toolbar.



Save



This menu command will save any changes made to a file. If more than one file is open, this command 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.

- The Save menu is dynamic and corresponds to the type of file you are trying to save, i.e. Save Graph, Save Journal.

Files should be less than 2 GB, except AcqKnowledge 3.9 “Graph” files on the Mac, which can be larger if not compressed. Data files greater than 2 GB can be opened, but edit, transformation and analysis operation cannot be performed.

To save data in another format (such as a text file), use File > Save As.

Save As

Graph (*.acq)
Graph (*.acq)
 Graph Template (*.gtl)
 Text (*.txt)
 Windows AcqKnowledge 3 Graph (*.acq)
 PhysioNet - WFDB (*)
 MATLAB Mat-File (*.mat)
 Raw (*)
 Igor Pro Experiment (*.pxp)
 WAV (*.wav)
 EDF (*.edf *.eeg)
 JPEG (*.jpeg)
 Compressed Graph (*.acq)
 Excel Spreadsheet (*.xls)

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

Graph

AcqKnowledge format

The default file format for the File > Save as command is to save files as an AcqKnowledge 4 file, which is designed to be as compact as possible. These files can only be opened by AcqKnowledge 4, but data can be exported to other formats once it has been read in.

- To save in the previous release format, choose **Windows AcqKnowledge 3 Graph**. When a file is saved in AcqKnowledge 3 format, the following calculation channel types will revert to Integrate: Band Stop Comb Filter, Adaptive Filter, FLC, WFLC, CWFLC, Rescale and Metachannels.

File Compatibility

Windows AcqKnowledge cannot save as Macintosh AcqKnowledge files.

Macintosh AcqKnowledge 3.9 and above 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 and above can save PC-compatible Graph (*.acq) and Graph Template (*.gtl) files. Variable sampling rate information and hardware settings are retained, and Journals can be read from and written to PC files. Choose the format “Graph (Windows)” to create PC-compatible files.

The Mac version does not save PC GLP files or compressed PC files.

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 252 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 hardware menu and retains the size of the primary graph window. In general, the minimum file size for graph templates is 700 K-800 K; file size may increase as setup options are enabled.

When a file is saved as a Graph Template:

a) No graph data will be saved.

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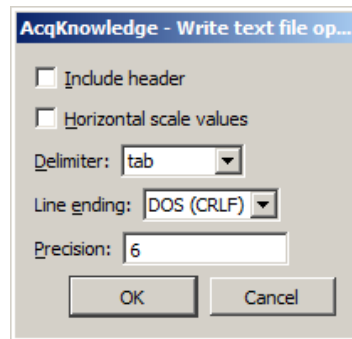
- Since no data is saved in the template, arbitrary waveform output setups, which require a source data file, will not function in a template.
- You must select Save / Save as and select “File of type .ACQ” to save the graph data.

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*.

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.

**Include header**

When the first box is checked, a “header” is included at the top of the text file that contains information about the sampling rate, number of channels, date created, and other information relating to the data. This information is frequently useful, but some programs will attempt to read in the header information as data, which could result in nonsensical results. You may wish to include the header as it can always be edited out later using a text editor or the journal.

Horizontal Scale

The second 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 308).

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 ending

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

Precision

Use to define the number of significant digits used for the horizontal scale when pasting wave data. Very high sampling rates may require more than the default value of 6 digits to accurately resolve the inter-sample interval.

PhysioNet This format requires that the WFDB library is 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.

***.MAT MATLAB**

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

- Windows™ 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.

- data** Contains the data of the graph in floating point format, for all of the channels of the array. The first dimension of this array is the amount of data in each channel, the second dimension increments with each channel. Therefore, each column contains a full channel of data that can be accessed in MATLAB via data (1:length, [channel number]).
- units** This string array contains the textual representation of the units of the samples stored in data, with one element per channel of data.
- labels** This string array contains the labels of each of the channels, with one element per channel.
- isi** This floating point array of one element gives the number of units of a single inter sample interval of the data.
- isi_units** This single string array provides a units string for a single unit of isi. Time data will always be “ms,” frequency data will always be “kHz,” and other values will be represented by an Arbitrary horizontal axis type in an ACQ graph.
- start_sample** Contains the time offset of the index 0 sample of data in isi units. This will be 0 for many graphs, but if only a selected area of a graph was exported into the MAT file, the start_sample will contain the offset from the original data corresponding to the start of the data array in the MAT file.

Raw

Options to save (export) data for low-level data exchange are:

Data type: 32-bit or 64-bit IEEE floating point

Layout: *Packed sequential:* All of the data for an individual file is located in a single block of the file and multiple channels follow one another.
Interleaved: Data is grouped into a single “frame” for each sample location with one data element for each channel, so data for a particular channel is spread throughout the file (similar to Linear PCM audio file format).

Endian: Little and big endian byte ordering match x86 and PowerPC/Sparc data formats, respectively. To exchange with Windows applications or Mac-Intel, set to little endian; to exchange with standard Mac applications, set to big endian.

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.)

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™.

WAV

This option saves the graph data into a WAV audio file for exchange with other applications. The “.wav” extension will automatically be added if the save as filename does not end with it.

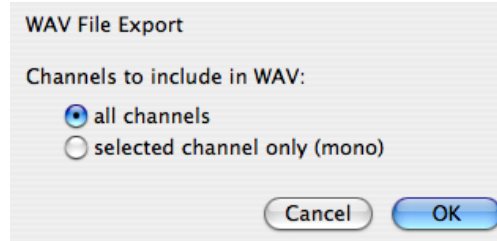
The “Selected area only” checkbox will be active for WAV export. When checked, only the highlighted area will be exported to the WAV file. The final sample of this range is not included in the export, mirroring the other file export routines of *AcqKnowledge*.

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

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:

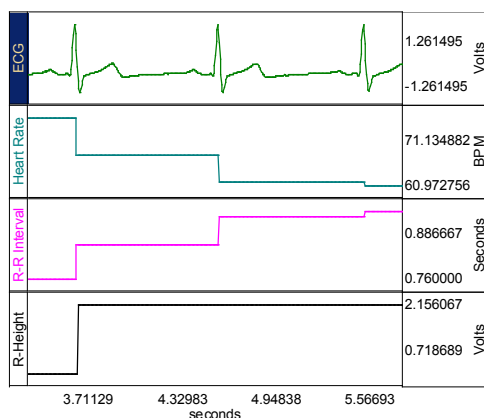
EDF Header Element	Default
subject ID	Empty*
recording ID	Empty*
recording date	Set to the modification date of the graph file on disk. If no graph file is on disk, the current date is used.
recording time	Set to the modification time of the graph file on disk. If no graph file is on disk, the current 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.

JPG

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



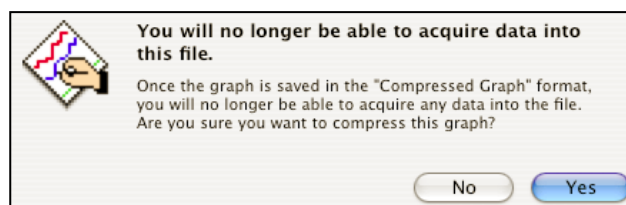
When data is saved as a graphic, only the data currently on the screen is saved. So, if you have a data file that spans eight hours but only two minutes is displayed on the screen, only two minutes of data will be converted to a graphic file. Since *AcqKnowledge* uses information about the computer screen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

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

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



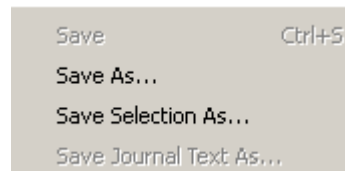
Excel Spreadsheet

Excel Spreadsheet Export—Graph data can be saved directly to an Excel spreadsheet by using the Excel Spreadsheet format in File > Save As. Each channel will be placed into its own column of the spreadsheet. Also available for File > Save Journal Text As, Find All Cycles journal, and Specialized Analysis tools.

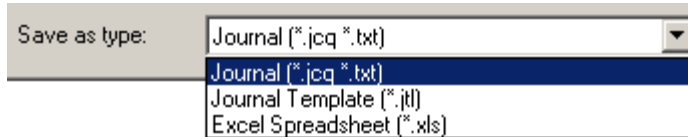
Note The Excel spreadsheet option requires Excel or a compatible spreadsheet application that can read Excel files (OOo, Symphony, etc.). If Analysis results are exported to an Excel spreadsheet, and a compatible application is not available, results will open as a text document the data and nonsense characters.

Save Selection As

To save only the data that has been selected with the I-beam tool, choose File > **Save Selection As**; this option saves the selected area to another file and does not affect the current file that you are working in. Specify file name and file type and then click Save.



Save Journal Text As



Choosing File > Save Journal generates a save dialog to save the journal text as a separate file. Specify file name and file type and then click Save.

Journal



Text (.TXT) format*—Saves an independent journal; see page 53 for details.

Jrnl Temp

.JTL format—Saves a journal template; see page 53 for details.

Excel Spread- sheet

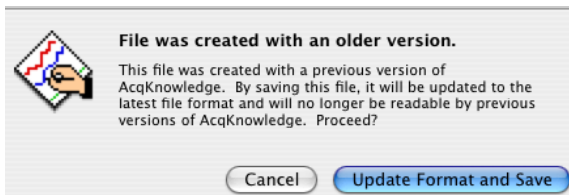
Excel Spreadsheet File (.XLS)*—Journal text can be exported directly into an Excel spreadsheet by using the File > Save Journal Text As with the Excel Spreadsheet format. Each line of text in the journal will be saved as a single row with tabs separating columns. A selected portion of a journal can also be written to a spreadsheet. This export allows for textual data reduction results to be easily exported into a spreadsheet to allow for further analysis.

- Also available for File > Save As, Find All Cycles journal, and, for Specialized Analysis tools.

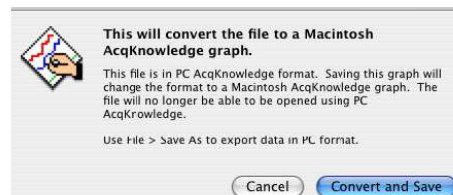
Note The Excel spreadsheet option requires Excel or a compatible spreadsheet application that can read Excel files (OOo, Symphony, etc.). If Analysis results are exported to an Excel spreadsheet, and a compatible application is not available, results will open as a text document the data and nonsense characters.

File Format prompts

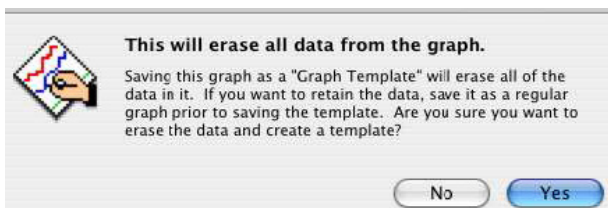
When a file open or save function requires a format change for compatibility or alters file content, a prompt will be generated to require the user to confirm the option to update format or convert and save.



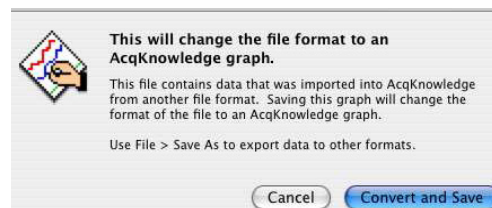
Created with a previous version of AcqKnowledge



Windows PC AcqKnowledge format



Saving as a "Graph Template" will erase all data



Imported from another file format

Send Email Attachment

Use this feature to create an email attachment containing an image of the active *AcqKnowledge* graph, along with the journal contents. (*AcqKnowledge* 4.2 and higher only).

When using this feature:

- The default email program will launch, along with a ‘compose new email’ window.
- An Open Document (*.odt) text file containing an image of the currently opened graph and associated journal text will be copied to the attachment field. The formatting and images present in the journal should be preserved.
- Further details can be typed into the body of the email prior to sending.

In order to open the attachment, the email recipient must have a word processing application compatible with *.odt file format, such as OpenOffice, NeoOffice or Microsoft Word™.

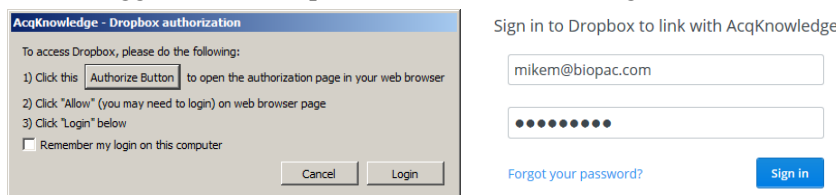
Copy to Dropbox – Open from Dropbox

The Dropbox options allow for copying or opening *AcqKnowledge* data files to or from a Dropbox account directly from within the *AcqKnowledge* application. This is useful for storing files online where they may be accessed from any computer. In order to use this feature, access to an active Dropbox account is necessary.

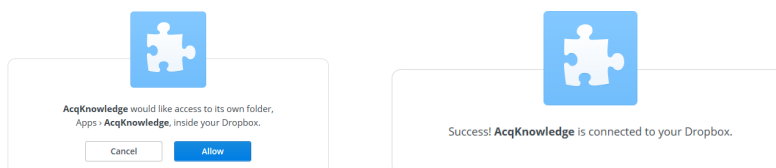
To create a Dropbox account, go to www.dropbox.com.

To set up *AcqKnowledge* to use Dropbox:

1. File > Copy to Dropbox. If Dropbox is being used for the first time in *AcqKnowledge*, or if you are not logged in to a Dropbox account, the following authorization dialog will appear.



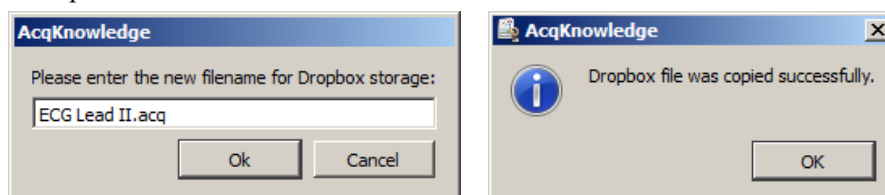
2. Click the “Authorize Button” and sign in to your Dropbox account.



3. Click “Allow” to grant *AcqKnowledge* permission to create a new Dropbox folder (above left).
4. A confirmation dialog will appear indicating *AcqKnowledge* is successfully connected to Dropbox (above right). Close or minimize your Internet browser window.
5. Dimiss the Step 1 Dropbox authorization dialog by clicking “Login.” As long as you remained logged in to your Dropbox account, this setup procedure will not need to be repeated.

To Copy files to Dropbox:

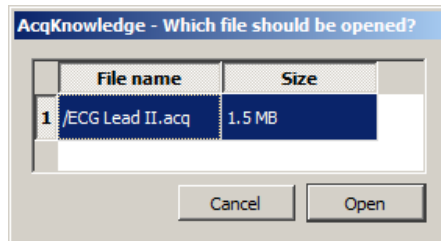
1. File > Copy to Dropbox.
2. Accept the default filename or enter a new one and click OK.



3. A confirmation dialog will appear indicating the file is stored on Dropbox.

To open files stored on Dropbox:

1. File > Open from Dropbox.
2. Select the desired file from the list of stored AcqKnowledge files and click “Open.”



NOTES:

- If Dropbox is being used for the first time in AcqKnowledge, or if you are not logged in to a Dropbox account, the authorization dialog shown on the previous page will appear before you can access a stored file.
- More than one file can be opened from the list, but they must be selected individually. Multiple selections are not supported.
- To log out of Dropbox from AcqKnowledge, choose File > Logout from Dropbox.

Page setup

Choosing File > Page Setup produces a standard printer setup dialog that allows you to setup any available printers. All the options in this dialog 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.

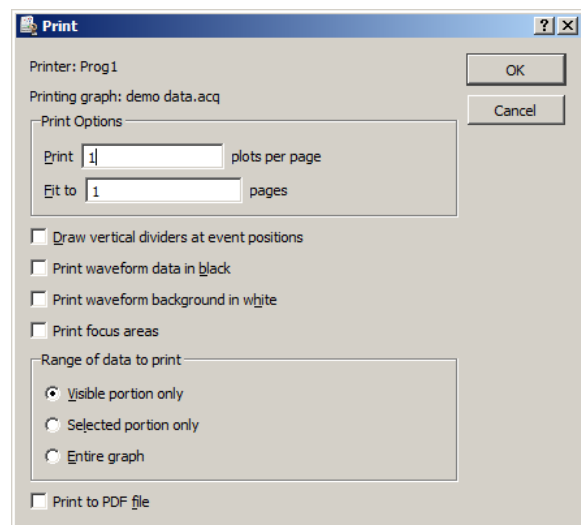
Print

The File > Print menu that AcqKnowledge uses is similar to the standard computer print dialog; however, there are additional options available

The Print menu is dynamic and corresponds to the type of file you are trying to print, i.e. Print Graph, Print Journal.

Click Print for more options.

Note: In Mac OS X, the option to create a PDF file appears in the initial Print dialog.



- **Print Options**

- **Plots per page**—Control how many plots appear per page when the file is printed. Printing more than one plot per page has the effect of “snaking” graphs on a page much the same way text appears in a newspaper. For example, if this option was selected so that two plots were printed per page, *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.
- **Fit to pages**—Print the contents of a window across multiple pages. When a record is printed over multiple pages, the amount of data on the screen (the amount of data to be printed) is divided by the number of pages entered in the dialog. The graph on the screen is then printed across the number of pages specified in the Total pages box at the bottom of the File > Print dialog. These two options apply only to graph windows, and do not apply to Journals.
- **Draw vertical dividers at event positions**—Adds visible borders at points where events occur.
- **Print waveform data in black**—Waveforms will appear black when printed, regardless of selected colors in graph channels.
- **Print waveform background in white**—Prints white background, regardless of selected background colors in graph channels.
- **Print focus areas**—Turns focus areas on or off for the printout.
- **Range Options**—determine the range of data that will be included in the printout
 - **Visible portion only** synchronizes the range of data in the printout to match the range of data that is visible on the screen.
 - **Selected portion only** prints only the data that is selected in the graph. This option is disabled if there is no selection in the graph. When working with Journals, it is easy to generate large amounts of text content in the window. Only a portion of this information may actually be of interest and this feature allows for only portions of the text to be printed. If there is no selected text, the entire journal or modification log will be printed regardless of this setting.
 - **Entire graph** prints all of the data contained in the graph from zero to the maximum length channel.
- **Print to PDF file**—generate a PDF file.

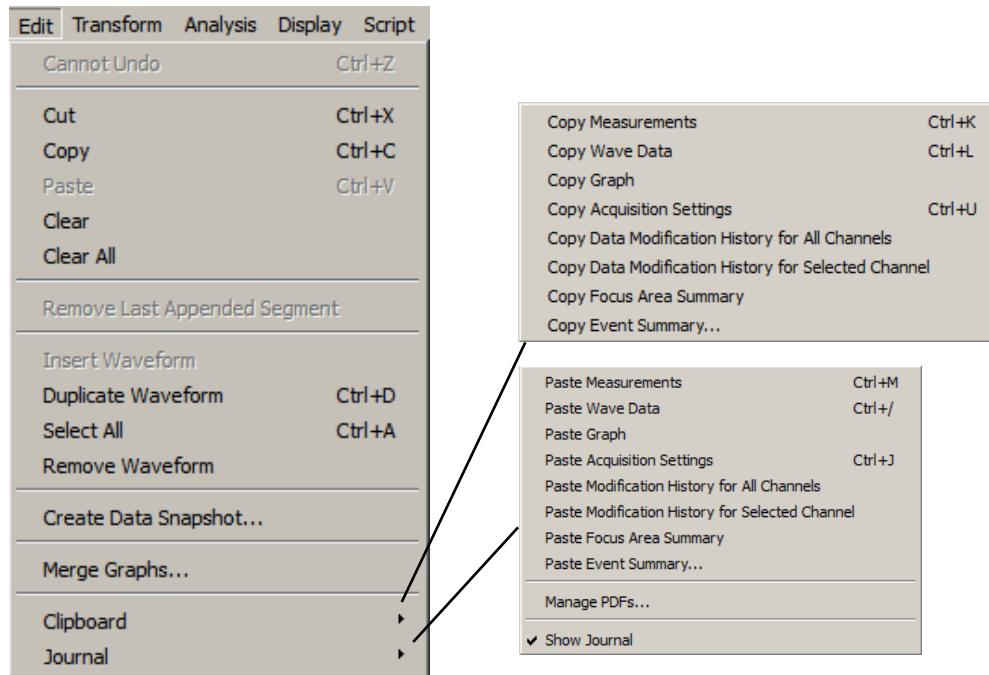
Quit


Select Quit from the File menu to exit *AcqKnowledge* software; you will be prompted to save any open graph files that have been modified since they were last saved.

Mac OS X only—Use Quit under the *AcqKnowledge* menu (page 456) to exit the software.

Chapter 14 Edit Menu Commands

Overview



One of the most useful features in *AcqKnowledge* is the ability to edit and work with data by cutting and copying sections from one window to another. In this sense, *AcqKnowledge* can manipulate data much as a word processing program handles blocks of text. To select an area of interest in the *AcqKnowledge* data for further study, use the I-beam selection tool to highlight an area.  This selection tool is used for a variety of purposes including cutting and pasting waveform data, making measurements and determining which portion of a waveform to save as text values. To select this tool, click its icon on the toolbar. Notice that the cursor changes into the familiar “I-beam” cursor when moved within the graph area. Click the mouse and drag to select a portion of the waveform.

IMPORTANT

When multiple waveforms are present, the highlighted area appears to include all of the waveforms, but most modifications and transformations apply only to the selected channel.

Once a section of a waveform has been selected, functions such as editing, transformations, saving data to the journal, saving as text, and using the measurement functions can be performed on the selected area. The cursor always selects at least one sample point; when there is no defined area, a single sample point will be selected, and the cursor will blink. Highlight a larger area by positioning the cursor over the first point of interest, hold down the mouse button, and drag the cursor either left or right to highlight an area. Modify the selected area by placing the cursor anywhere on the graph, then holding down the shift key and clicking the mouse. This feature is useful for fine-tuning the selected area. To fine tune, first coarsely select an area. After zooming in (with the zoom tool) on either edge, then use the shift key to precisely align the edges of the selected area.

AcqKnowledge also allows the selection of an area spanning 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 the button while holding down the shift key. While still depressing the mouse button, move the cursor to the exact position desired.

By using the selection tool to select areas of the waveform, the Cut, Copy, Paste and Clear functions are designed to work in much the same manner as any text editor. These functions operate only on the selected area.

Edit menu functionality during acquisition

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

Undo / Can't undo

The Undo command allows for restoration of data that was unintentionally deleted or modified. Undo applies to editing commands and transformations (such as digital filtering and mathematical operations).

There are some important exceptions to the Undo command.

First, neither Edit > Clear all nor Edit > Remove waveform can be undone. It is a good idea to make backup files before performing any editing, especially when using these commands.

Second, changes in the display options (i.e., changing the horizontal scale or changing the color of a waveform) cannot be undone, since they are easier to manipulate and less drastic than cutting data out of a waveform. If 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.

Perform multiple levels of undo on a per graph basis. The most recent operation is undone first followed by the previous operation until the maximum number of Undo operations are reached. The maximum number is set in Application Preferences (Display > Preferences > Graph > Maximum levels of undo) .



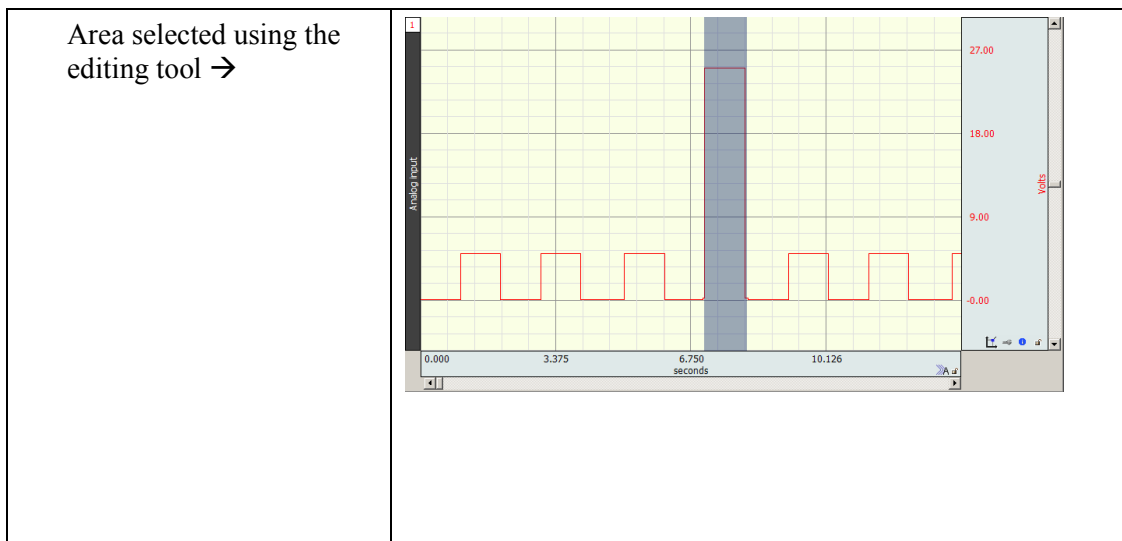
NOTE: Specialized Analysis (page 348) scripts are complex and undo may not function for all steps.

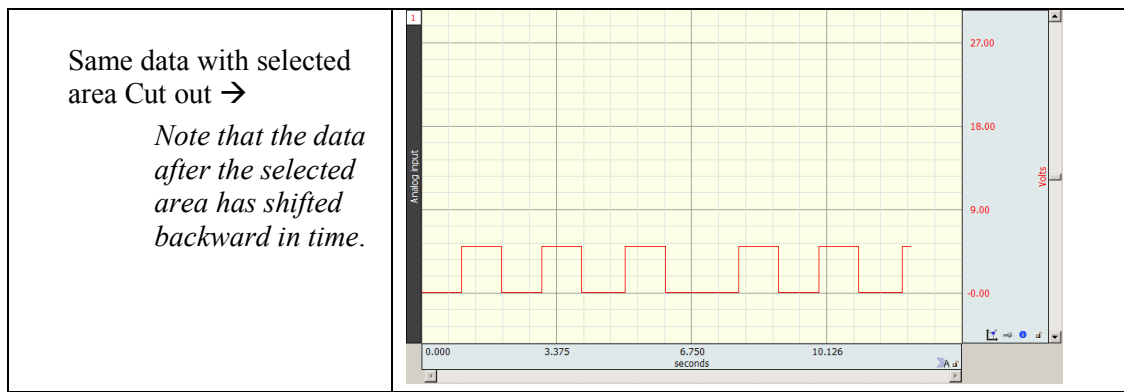
Cut

When Edit > Cut is selected, the selected portion of the active graph channel removed and copied to a clipboard, where it is available for pasting into other windows.

Cut cannot be performed during acquisition.

- When a selected area is removed from a waveform, the data will shift left to “fill in” the deleted area. So, if ten sample points are deleted, all data after the selected area will be shifted over ten sample points. Since this alters the relationship of events to the time base, 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.





Copy

Choosing Edit > Copy will copy the selected area of the active graph channel to the clipboard without modifying the text/waveform on the screen.

- Once the area has been copied, it can be inserted in another window of the same type using the Edit > Paste command or, for waveforms, the Edit > Insert waveform command.
- To copy a waveform to another channel in the same graph window, choose the Edit > Duplicate waveform command.
- Edit > Copy applies only to a selected area of graph data. To copy and entire graph, use Edit > Clipboard > Copy Graph (see page 277.)

Paste

The Edit > Paste command will take the contents of the clipboard and paste it into the currently selected area of the active window of the same type.

- If no area is selected, the data is pasted at the beginning of the waveform in a Graph window or the end of the text a Journal window.
- Paste cannot be performed during an acquisition.

Clear

The Edit > Clear command works much the same way as the Cut command, with the key difference being that data is not copied to the clipboard. This function deletes the selected area from the selected channel only. If the entire waveform is selected (as with the Edit > Select all command), the clear command will delete all the waveform data and leave an empty channel.

Clear may move or alter memory and cannot be performed during acquisition.

- As with the cut command, the clear function operates on only one channel, and when a portion of the waveform is deleted, the remaining data will shift left. If multiple channels of data are present, one channel will be “shorter” than the others.
- To remove a selected area of data from multiple channels, use the Edit > Clear all command.

Clear all

Choosing Edit > Clear all will delete the selected area from *all* channels. This is similar to the clear function in that data is removed and is not copied to the clipboard. The Clear all command, however, removes a section of data from all waveforms, whereas the clear command applies only to the selected channel.

Clear All may move or alter memory and cannot be performed during acquisition.

- When Edit > Select all is chosen prior to performing the Clear all function, all waveform data for all channels will be deleted.
- The Edit > Undo command does not work for Clear all.

Select All

When Select all is chosen from the Edit menu, the entire selected channel becomes highlighted. For almost all commands, when a waveform is selected using Select all, subsequent operations apply to the selected channel only.

- The exception is when Edit > Clear all is chosen after Edit > Select all. When this occurs, all data from all waveforms will be deleted.

Insert waveform

The Edit > Insert waveform command is useful for copying a waveform (or a section of a waveform) within the same or another graph. However, within the same graph, Duplicate waveform is simpler. To do this, first select the area to be copied using the cursor and the Edit > Copy command. Next open the graph window to insert the waveform into.

Select the new graph and choose Edit > Insert waveform. A new (empty) channel will then be created and the data copied into the empty channel.

- Insert waveform cannot be performed during acquisition.
- This command cannot be undone directly, although selecting the inserted channel and choosing Remove waveform from the Edit menu effectively undoes this operation.

Duplicate waveform

Choosing Edit > Duplicate waveform will create a new channel in a graph window and copy an entire waveform (or a selected area) to the new channel. When a portion of the waveform is selected, only the highlighted area will be duplicated.

Duplicate waveform may move or alter memory and cannot be performed during acquisition.

- To duplicate the entire waveform, choose Edit > Select all and then select Duplicate from the Edit menu or click the right mouse button and select Duplicate from the pull-down menu.

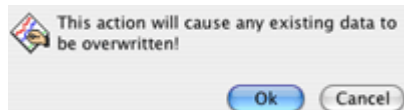
Remove waveform

Deletes the entire selected waveform, regardless of what other options are selected. Remove waveform may move or alter memory and cannot be performed during acquisition.

- The Edit > Undo command does not work for Remove waveform.

Remove last appended segment

Removes the last appended segment. Equivalent to the  Rewind toolbar icon.



- Edit > Undo does not work for Remove last appended segment.

Create Data Snapshot

The Snapshot options store “snapshots” of the original acquired data at specific stages along with the full graph file. Use snapshots for analysis or reporting to compare results to original waveforms or intermediate stages of analysis. This is essentially an embedded archive; it is not a backup tool.

IMPORTANT: Archive functions do not create a new file—they are not backup functions. Original data is copied and pasted to the end of the original file. You cannot use this feature to recover lost or damaged graph files.

See page 54 for Snapshot details.

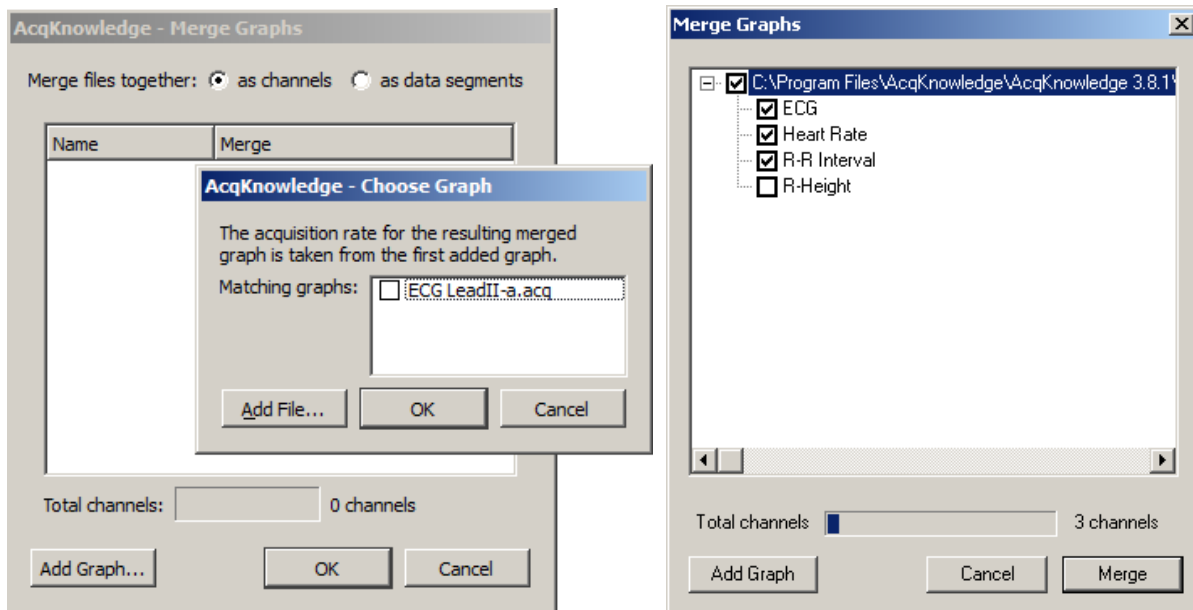
Merge Graphs

Combine multiple graph files into a single file for performing cross-file analysis and storage. Use merge with the multiple-hardware capabilities to produce single graph files containing multiple streams of data from an individual subject.

Use Merge Graphs to combine data from multiple graph files acquired with the same acquisition rate into one merged graph file.

Note Merge Graphs requires *AcqKnowledge* to allocate additional memory and then load the data into memory; when this operation is executed on large data files, the application may crash—on Windows OS, the resulting file size of a merge should be less than 2 GB; data files greater than 2 GB can be opened, but edit, transformation and analysis operation cannot be performed.

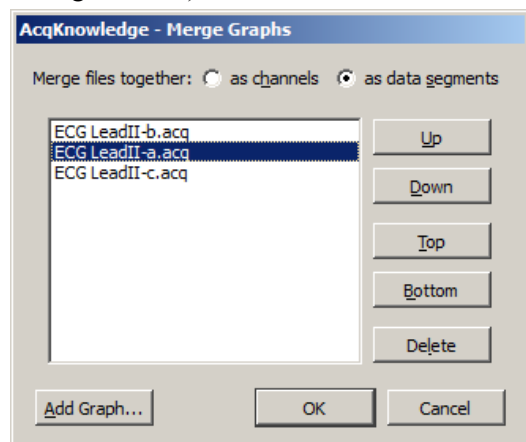
1. Select Edit > Merge Graphs to generate the Merge Graphs dialog.
2. Click Add Graph to generate the Choose Graph dialog.
3. Choose a file to add to the merge.
 - “Add” the “Matching graph” listed (this pull-down menu includes all open files with the same acquisition rate)
 - “Add File...” to browse and select a file that is not already open
4. Adjust the selection for individual channels if desired.
 - Click the “+” to list individual channels in the graph file.
 - Toggle the checkbox to add or remove the associated channel/graph file.
 - 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.



Merging graphs as data segments

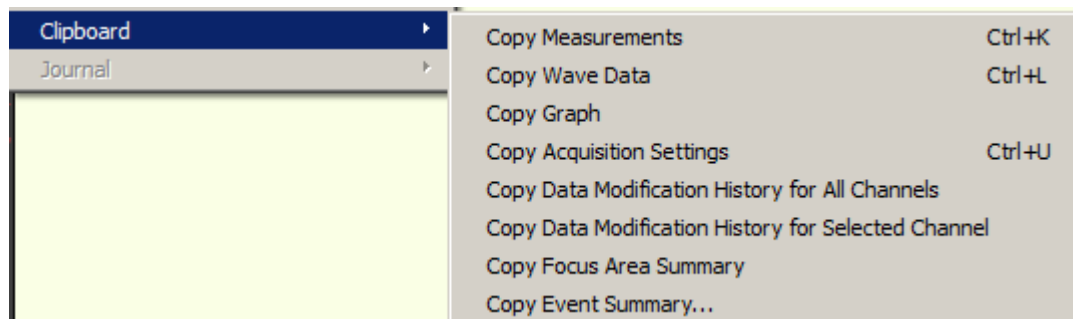
Individual graphs may also be merged into a single channel as appended segments. This can be useful for concatenating data types that don't support append mode, or when importing data from software that outputs each session as a self-contained graph file.

To merge separate files into sequential segments, check the Merge Graphs “as data segments” option and select the data files as shown in steps 1-7 above. The same limitations exist for appended graphs as do for graphs merged into individual channels. (All selected graphs must share the same sample rates and channel configurations.)



Additional navigation controls become available when merging graphs as appended segments. This allows you to reorder the data segments into the sequence desired for the merged file. By default, the first graph added to the list will be displayed as data segment 1, but this can be easily modified by selecting any appended graph and moving it up or down the list via the “Up”, “Down”, “Top”, “Bottom”, or “Delete” navigation buttons.

Clipboard



All of the clipboard commands involve copying data from *AcqKnowledge* to the standard Windows clipboard, where the contents of the clipboard are made available for other applications. Transferring data to the clipboard allows data to be copied from *AcqKnowledge* to other applications even after closing the graph window and/or quitting *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 in the window to the clipboard.

➤ Copy Measurements

Copies the contents of all visible measurement popup menus, along with the values associated with these windows. Once the measurements have been copied, they can be pasted into any application that allows paste functions, including word processors, drawing packages, and page layout programs. A sample of measurements pasted from *AcqKnowledge* into a text document follows:

BPM = 85.714 BPM delta T = 0.700 sec p-p = 0.8170 Volts

➤ Copy Wave Data

Copies the data (in numeric form) for all channels from the *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 in the File > Save as dialog. See page 252 for more detailed instructions on how to set the column delimiter. Transferring data through the clipboard performs essentially the same function as saving data as a text file (using the File > Save As command), with the obvious exception that transferring data through the clipboard does not save data to disk.

➤ Copy graph

Copies the graph window as it appears on the screen to the clipboard, where it is stored in graphic format. You can then place the graphic into a number of different types of documents, including word processors, drawing programs, and page layout programs. The JPEG graphic format are common to almost all applications, and images saved in these formats can be edited in most graphics packages and many word processors.

Using the copy graph function is similar to saving a graph window as a JPEG (using the File > Save As command), except that using the file save command writes a file to disk, whereas transferring data through the clipboard does not save a file.

➤ Copy Acquisition Settings

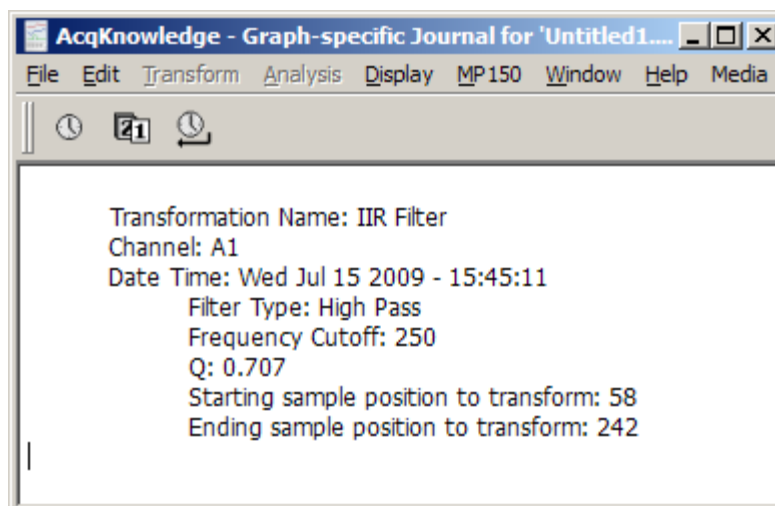
Creates a textual summary of the current acquisition settings and sends it to the clipboard, where it can be pasted into the journal via Edit > Journal > Paste Acquisition settings, or pasted to another program.

The summary includes sampling rates, channel configuration, calculation channel settings, triggering options, averaging options, and if any stimulator is active. This is useful for retaining records for acquisition parameters (and for technical support, if necessary). Use this feature to keep a textual record or printout of the configuration of your hardware unit along with your data.

➤ Copy Data Modification History...

Copies the transformation history for all channels or a selected channel to the clipboard. Modification history includes the transformation name, channel (analog, calculation, or digital), date & time, and relevant transformation parameters, including starting and ending sample position.

Use Edit > Paste to move it from the clipboard to an active Journal window or other word processing application.



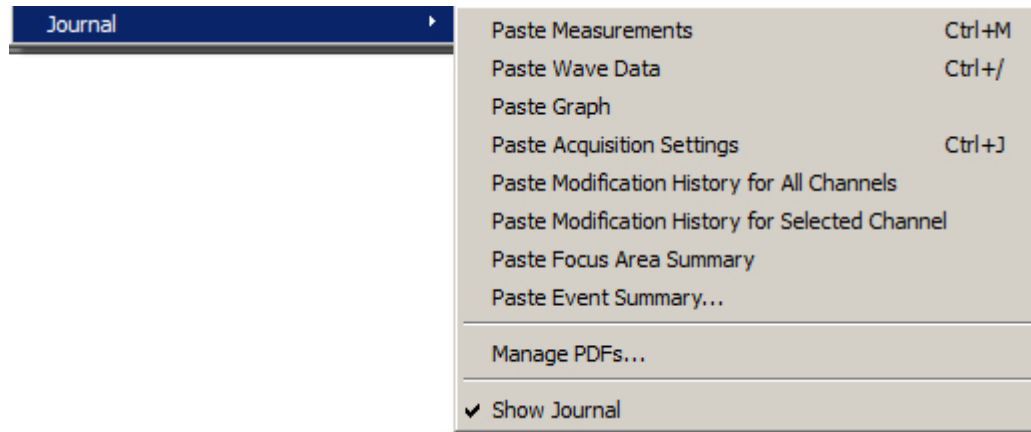
➤ Copy Focus Area Summary

Copies the starting and ending position of the focus area in horizontal axis units. Summary includes focus area label.

➤ Copy Event Summary

Copies events to the clipboard as selected in the Event Summary setup dialog.

Journal



The Edit > Journal sub-menu options are similar to those found in the Edit > Clipboard menu. The key difference is that data (whether measurements or raw data) is pasted directly into the journal rather than copied to the clipboard.

➤ Paste Measurements

Choosing Paste Measurements from the Edit > Journal menu will cause all visible measurement windows to be pasted into the journal. Each time this is selected, the measurements and values are pasted into the journal using the precision specified in the Display > Preferences dialog. You can also change the total number of measurements displayed by adding more rows of measurements. Use the Preferences menu (see page 444) 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

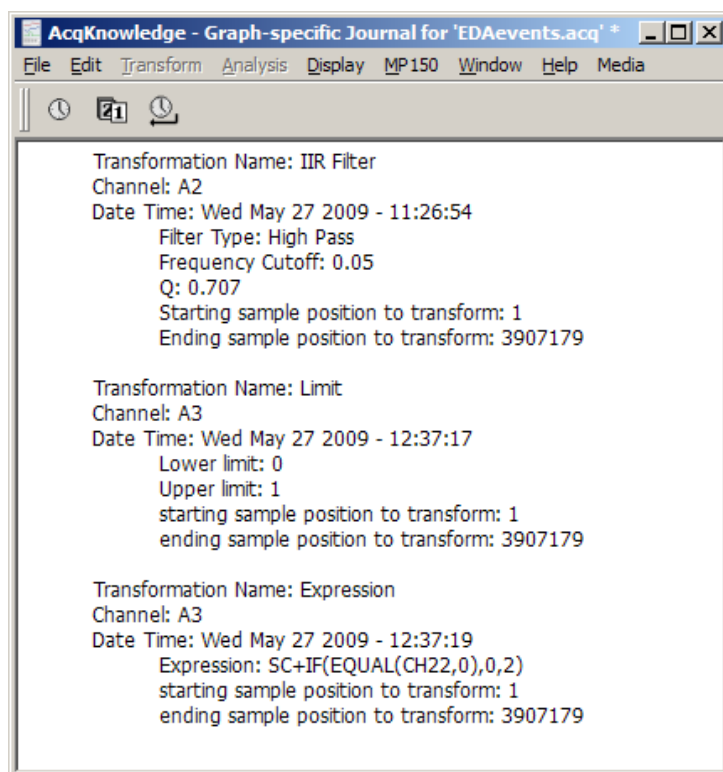
Converts the selected area of the waveform to numeric format and paste it into the journal in standard text file format. As with the copy wave data command (in the Edit > Clipboard submenu) this will paste the selected area from all channels, not just the selected channel, and will place a delimiter 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. See the Save As section on page 261 for more information on how to change the column delimiter.

➤ Paste Acquisition Settings

Pastes the acquisition settings to the journal as they were copied via Edit > Journal > Copy Acquisition settings.

➤ Paste Modification History...

Use after Copy Data Modification History... to paste the transformation history from the clipboard for all channels or for the selected channel to an active Journal window or other word processing application. Modification history includes the transformation name, channel (analog, calc, or digital), date & time, and relevant transformation parameters, including starting and ending sample position.



➤ Paste Focus Area Summary

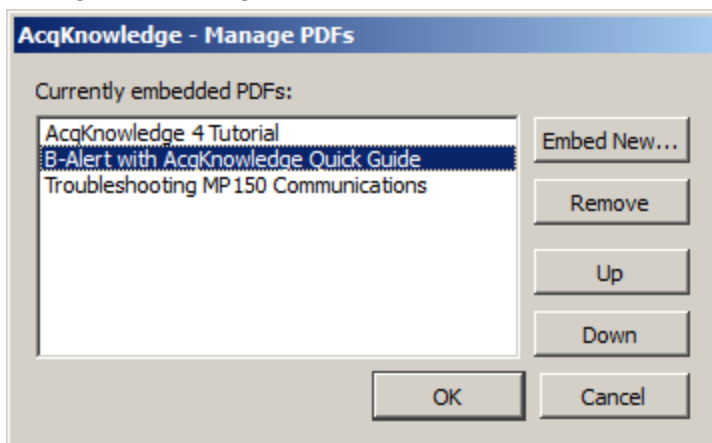
Pastes the focus area summary to the journal as copied via Edit > Journal > Copy Focus Area Summary.

➤ Paste Event Summary

Pastes the event summary to the journal as copied via Edit > Journal > Copy Event Summary.

➤ **Manage PDFs**

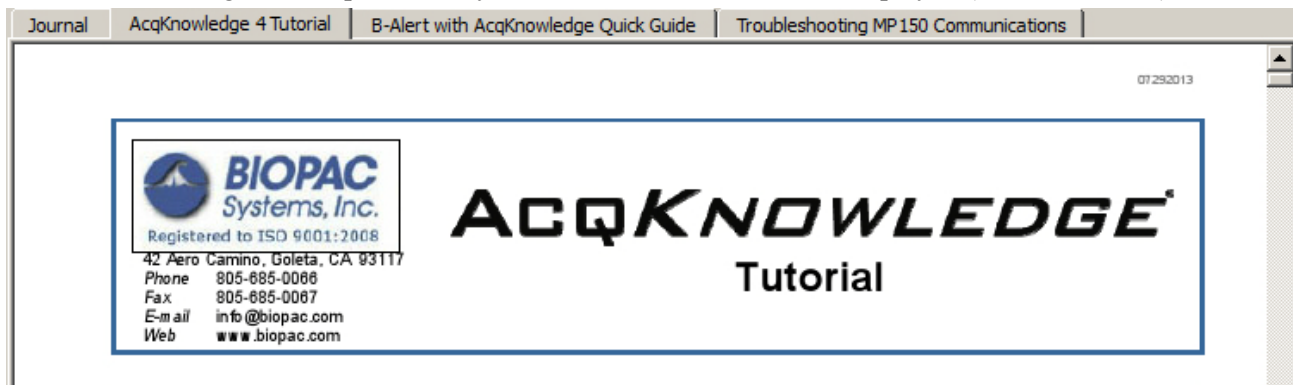
Use this option to select and import (embed) PDF files into the Journal as tabbed windows. Multiple PDFs may be imported and each PDF appears under its own tab heading. Choose **Edit > Journal > Manage PDFs**, or right-click in the Journal and choose **Manage PDFs**. The following dialog will appear:



Control	Description
Embed New	Launches a “File > Open” dialog for navigating to the directory containing the PDFs to be embedded.
Remove	Removes a PDF from the list. (The actual PDF is not deleted.)
Up	Moves the selected PDF up the list and determines its tab order in the Journal.
Down	Moves the selected PDF down the list and determines its tab order in the Journal.
OK	Imports the embedded PDFs into the Journal

After embedding PDFs into the Journal, you may toggle between them by clicking the tabs. Clicking the Journal tab will activate the Journal window. Saved Journal content is not affected by embedded PDFs.

- The Journal formatting tools are not available when a PDF is actively displayed.
- The Manage PDFs option is only available when the Journal is displayed (Show > Journal).

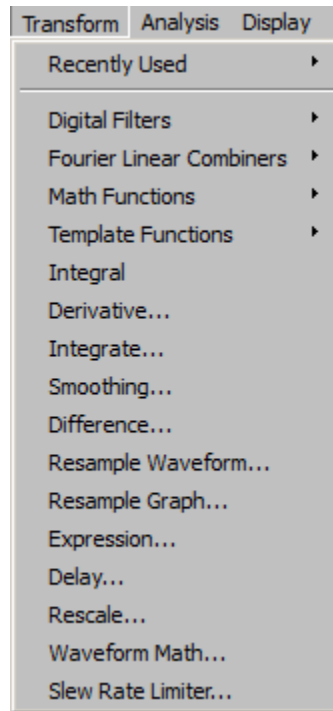


➤ **Show Journal**

Toggle to display/hide the Journal window.

Chapter 15 Transform Menu Commands

Overview

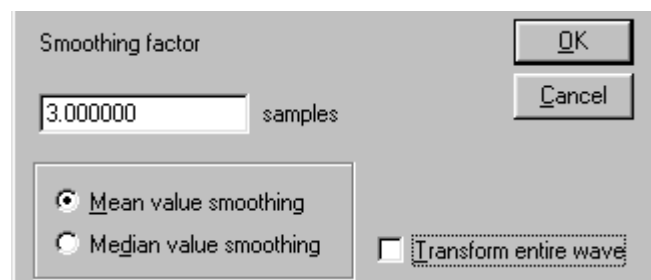


The Transform menu contains operations that primarily modify the data in the graph.

AcqKnowledge provides a number of options for post-acquisition analysis and transformations. These transformations perform a range of operations on the data, from digital filtering and Fourier analysis to math functions. All of these options can be found under the Transform menu, and are disabled while an acquisition is in progress. Unless otherwise noted, all transformations described here apply to the selected channel only. Some options (such as the expression and math functions) allow users to specify a channel (or channels) to be transformed.

It is important to remember that 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.

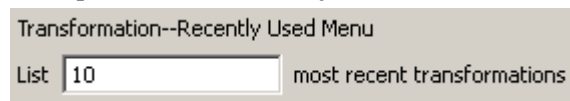


- b) For transformations that do not generate a dialog, use the Edit > Select all command prior to selecting the transformation. This will transform the entire waveform for all of the transformation functions.
- Edit > Select All is not necessary when only a single point is selected prior to selecting 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.

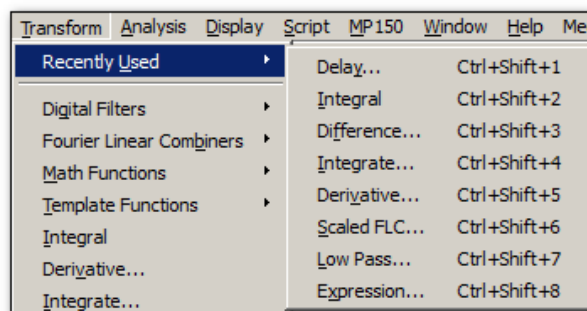
Recently Used Transformations

The Transform > Recently Used submenu allows quick access to a user's most recently used transformations and analysis commands. The Recently Used submenu also appears at the top of the Transform submenu available from the context menus of waveforms.

The submenu lists a default of five of the most recently used transformations, with the most recently executed at the top of the menu. To adjust the number of recent transformations displayed, select Display > Preferences.

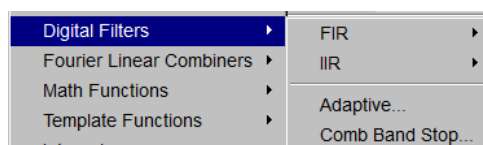


The recently used transformation listing is saved and restored across subsequent launches of *AcqKnowledge*. It also is application wide: Executing a transformation in any graph will add that transformation onto the recently used list. The recently used list is independent for each user account.



The recently used transformations can also be launched by the keystroke combinations appearing in the menu. (*AcqKnowledge* 4.2 and higher)

Digital Filters



FIR filters are linear phase filters, which mean that there is no phase distortion between the original signal and filtered waveforms.

IIR filters are not phase linear filters, but are much more efficient than FIR filters in processing data. The IIR filters are useful for approximating the results of standard biquadric filters of the form:

$$(as^2 + bs + c) / (xs^2 + ys + z)$$

These types of filters are commonly implemented in electronic analog circuitry. IIR filters are also used for online filtering (discussed on page 139).

➤ 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 289 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

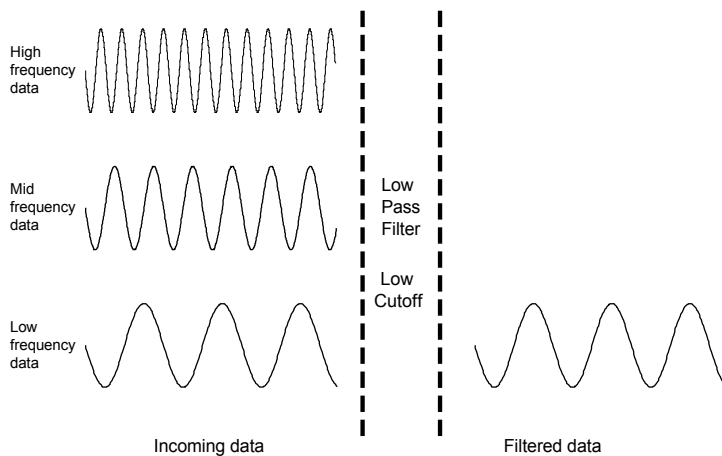
Descriptions of these four classes of filters follow, with visual examples of how these filters work. In each of the four examples, a single channel of data containing frequency components in three ranges (low frequency, mid-range, and high frequency) is acquired.

- 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.

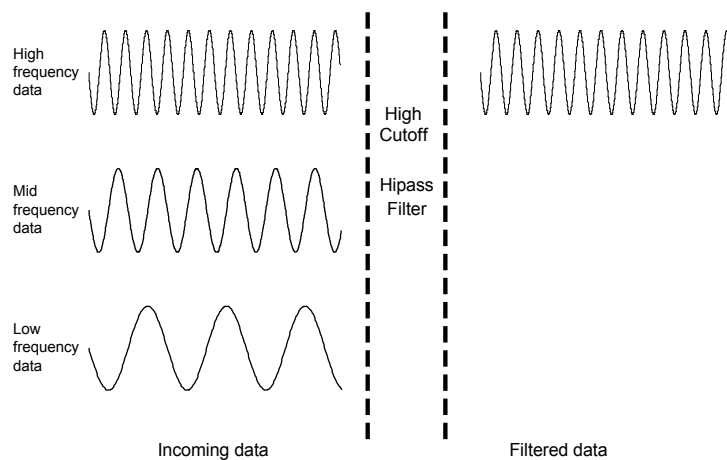
Low pass filtering

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

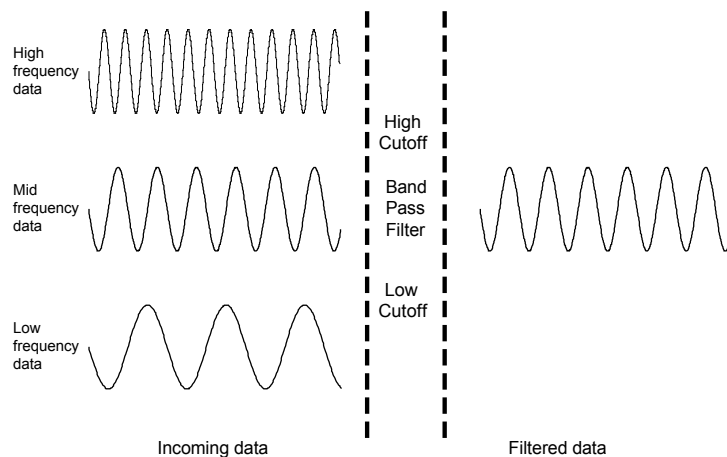
In the example below, a high pass filter removes the low and middle range data, but allows the high frequency data to pass through the filter.



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.

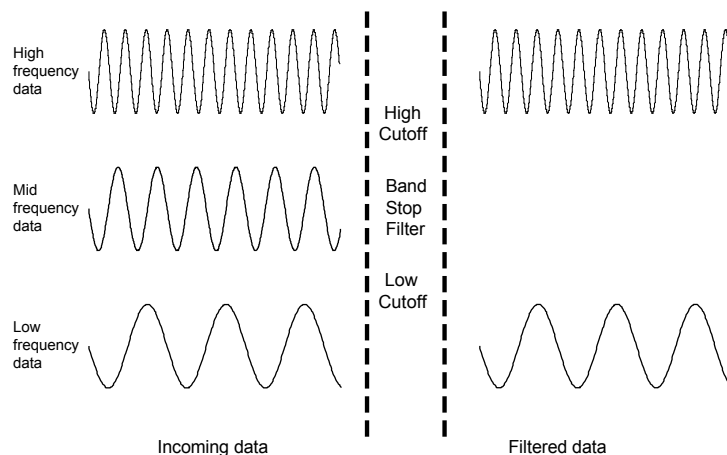
Band pass filter

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.

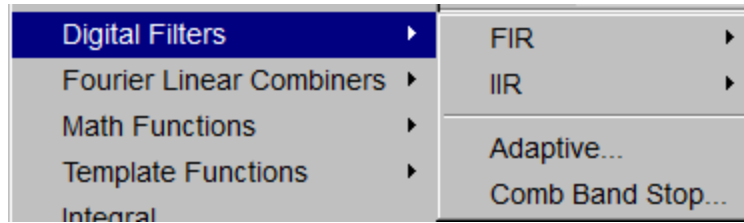


Band stop filter

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

When you select an FIR filter type, the corresponding Digital Filter dialog 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 B on page 562) allow you to “fine tune” the filter response.
2. Cutoff Frequency (Hz) (or threshold). Enter a fixed value or set to a fraction of the sampling rate or to line frequency.

Sampling rate—frequency is set to a fraction of the sampling rate and automatically updates when the sample rate is modified.

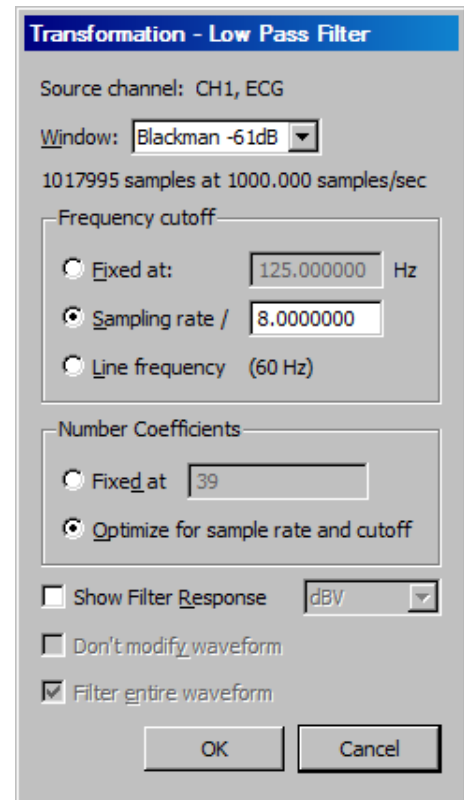
Line frequency—frequency is set to the line frequency at which the data was recorded.

Fixed at —Fixed value guidelines are as follows:

- *Low Pass Filter*—data with frequency components below the cutoff will pass through the filter, whereas frequency components above the threshold will be removed. For low pass filters, the default cutoff frequency is the waveform sampling rate divided by eight and can be set to any value between 0.000001Hz and 0.5 times the sampling rate.
 - *High Pass Filter*—data with frequency components above the cutoff will pass through the filter, whereas frequency components below the threshold will be removed. For high pass filters, the default threshold is the waveform sampling rate divided by four and can be set to any value between 0.000001Hz and 0.5 times the sampling rate.
 - *Band-type Filters*—a low threshold and a high threshold must be specified to define the band of data (the frequency range) that is either passed or stopped, depending on whether it is a Band Pass or Band Stop filter. In either case, the default for the low threshold is the waveform sampling rate divided by eight and the default for the high threshold is the waveform sampling rate divided by four. The threshold settings can take on any value from 0.000001Hz and 0.5 times the sampling rate, but the two thresholds cannot be set to the same value and the high threshold must be greater than the low threshold.
3. Number of Coefficients. Enter a fixed value or enable the optimize option.
 - Fixed at—This determines how well the filter will match the desired cutoff frequency (or range). The minimum number of coefficients is 3 and the maximum must be less than the total number of sample points in the selected area. The software will truncate the maximum number of coefficients to the highest odd number less than the total.
 - Optimize for sample rate and cutoff—the number of coefficients is set as four times the sampling rate divided by the cutoff frequency of the filter. Optimize does not necessarily produce the best quality filter, but it takes less time.

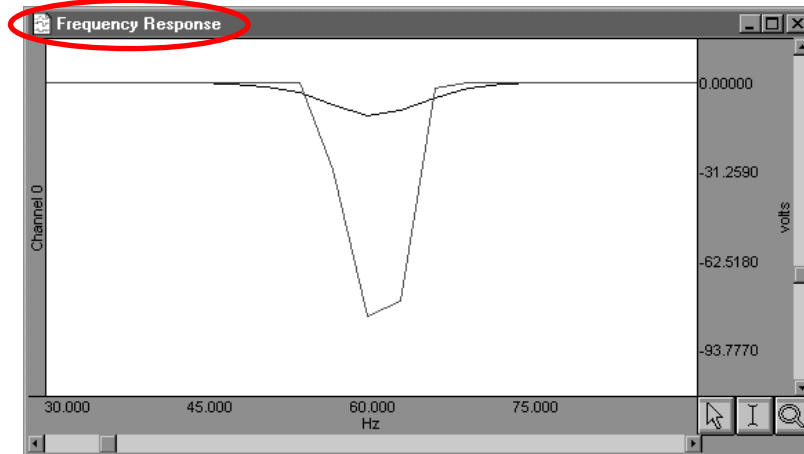
The recommended number of coefficients is

$$4 \times (\text{waveform sampling rate/lowest frequency cutoff for the filter})$$



For every filter except the band pass, the lowest frequency cutoff is equal to the specified cutoff frequency for the filter; for the band pass filter, the lowest frequency cutoff is the low frequency cutoff setting. Filters that use a small number of coefficients tend to be less accurate than filters that use a large number of coefficients. Larger coefficients increase filter accuracy, but also increase the processing time required to filter the data.

To see how changing the number of coefficients affects the way data is filtered, it can be useful to examine the filter response patterns. In the example below, data was collected at 500 Hz and the band stop filter was designed to remove 60 Hz noise using a low cutoff of 55Hz and a high cutoff of 65Hz. The same data was band stop filtered using 39 coefficients (upper waveform) and then 250 coefficients (lower waveform).



Along the horizontal axis, the units are scaled in terms of frequency, with lower frequencies at the left of the screen. The values along the vertical axis are scaled in terms of dB/V and indicate the extent to which various frequencies have been attenuated.

In both filter response waveforms, there is a downward-pointing spike that is centered on 60 Hz. The baseline of the filter response corresponds to a value of approximately 0 on the vertical axis, indicating that the signals significantly above or below 60 Hz were not attenuated to any measurable extent. 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.

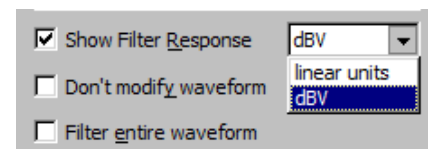
For example, the upper waveform in the filter response plot represents data that was filtered using a value of 39 coefficients. The slope is relatively shallow when compared to the lower waveform, which represents a filter response performed with 250 coefficients. Although the filter that used 250 coefficients 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).

- Units: Select linear units or dBV.

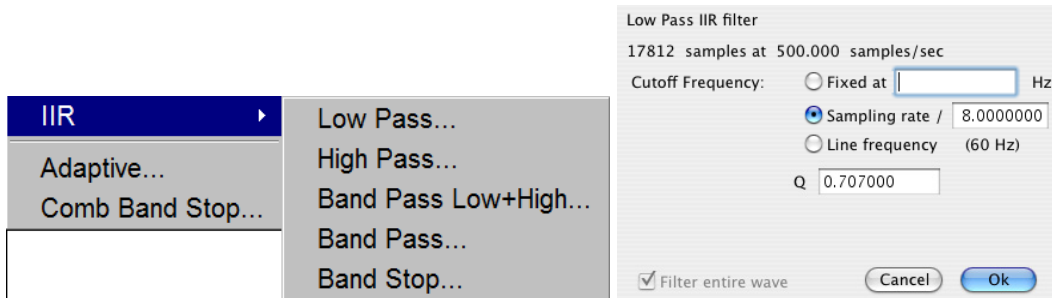
5. Don't modify waveform. This option is useful in conjunction with the “Show Filter Response” option. When both boxes are checked, AcqKnowledge will produce a plot showing the filter response, but will not modify the waveform. This allows you to repeatedly specify different filter options (without modifying 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.

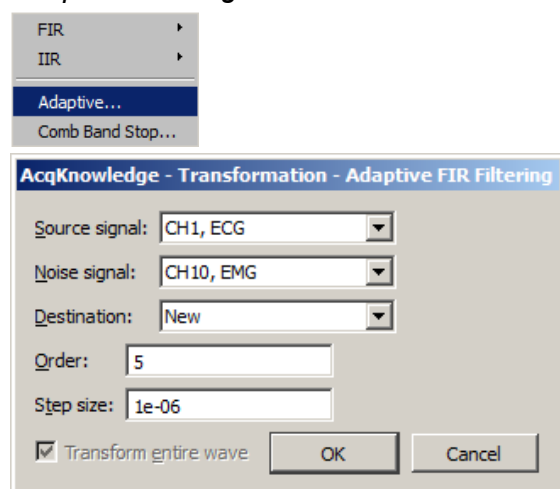
IIR Filters

To access the IIR filter dialog, click the Transform menu, scroll to select Digital Filters, drag right to IIR and drag right again for the filter options. For all filter types, the software will limit the frequency setting so it cannot exceed one-half the channel sampling rate. For real-time filter options, see page 139.



Low Pass and High pass	Pass data that falls below or above the specified standard. The Low Pass default is waveform sample rate/8; the High pass default is waveform sample rate/4.
Band Pass (low + high)	<p>Pass a variable range of data. Specify a low frequency cutoff and a high frequency cutoff to define the range or “band” of data that will pass through the filter; frequencies outside this range are attenuated. For the Band Pass Low + High filter, the low default is waveform sample rate/8 and the high default is waveform sample rate/4.</p> <ul style="list-style-type: none"> 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 50 Hz (with the default $Q=5$) would be 10 Hz. Although functionally equivalent to the Band Pass (low + high) filter, this filter is most effective when passing a single frequency or narrow band of data, and to attenuate data around this center frequency. The Band Pass (single frequency) default is waveform sample rate/8.
Band Stop (single freq)	Defines a range (or band) of data and attenuates data within that band (the opposite function of a band pass). This filter is implemented in much the same way as the standard Band Pass, whereby a center frequency is defined and the Q value determines the width of the band of frequencies that will be attenuated. The Band Stop (single frequency) default is waveform sample rate/8.
<i>Q coefficient</i>	The online filters are implemented as IIR (Infinite Impulse Response) filters, which have a variable Q coefficient. The Q value entered in the filter setup box determines, in part, the frequency response of the filter. This value ranges from zero to infinity, and the “optimal” (critically damped) value is 0.707 for the Low Pass, High pass and Band Pass filters. A Q of .707 for any of these filters will result in a second order Butterworth response. The Q is set to a default of 5.000 for the single frequency Band Pass and Band stop filters. For more details about the Q setting, see the Appendix.
Sampling rate	Sets the Frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.
Line frequency	Sets the Frequency to the line frequency at which the data was recorded.

Adaptive Filtering



➔ See the Adaptive Filtering Calculation Channel on page 154.

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.

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

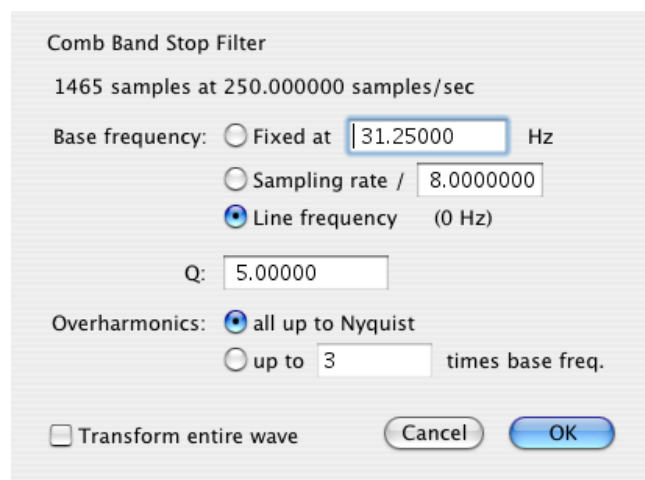
Specify a positive integer for the number of terms to be used in the internal FIR filter.

Step size

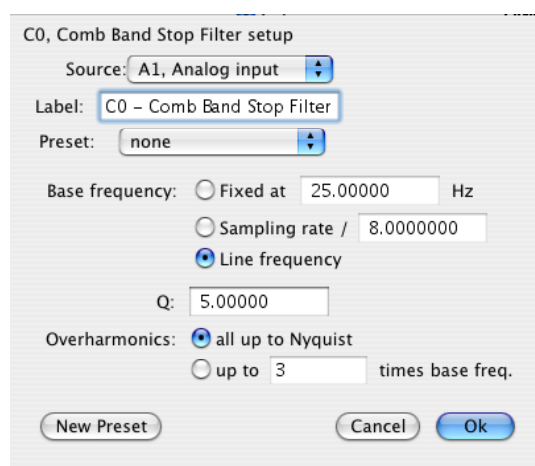
Provides μ , the rate of adaptation of the coefficients within the FIR filter.

Comb Band Stop Filter

Comb Band Stop filters out a fundamental frequency and its overharmonics (integer multiples of the base). Resonance, aliasing, and other effects may generate interference at multiples of a base frequency. The Comb Band Stop filter combines all the required filters instead of requiring a separate filter for each interfering overharmonic.



Transformation Dialog



Calculation Channel Dialog

Comb Band Stop filters remove a fundamental frequency and its overharmonics (e.g., integer multiples of the base frequency) from a signal, and are useful for removing noise. *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 OS — Use the "Comb Band Stop Filter" Automator action to integrate Comb Band Stop filters into Workflows.

For a given base frequency ω and quality factor Q , the comb filter approximation will be given by the set of following formulas:

$$y = (F_{\omega} \circ F_{2\omega} \circ F_{3\omega} \cdots \circ F_{k\omega})(x)$$

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). Sampling rate—Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified. Line frequency—Uses the line frequency at which the data was recorded.
Q	Quality factor used when computing the coefficients of the IIR notch filters. <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.

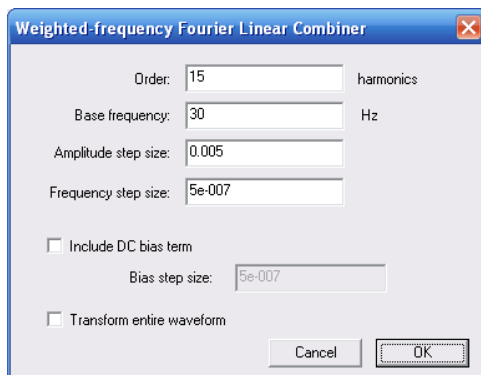
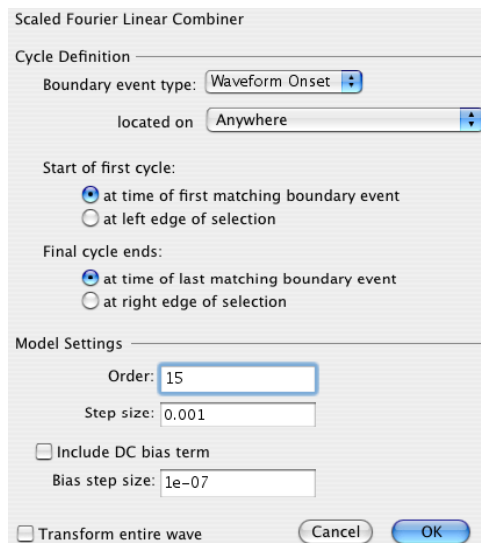
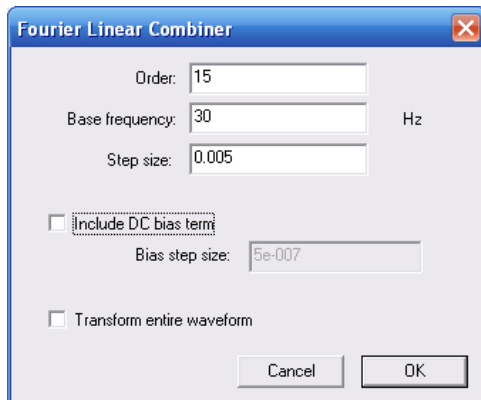
Harmonics	<p>Removes the base frequency and integer multiples of the base frequency up to and including the multiple contained in the edit field</p> <ul style="list-style-type: none"> • Must be an integer greater than 0 and must not exceed k max • The final multiple must be less than the Nyquist frequency. If it is not, the input will need to be corrected before the comb filter can be applied.
OK	<p>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> <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	Quits without modifying any data.
Source	All enabled analog, digital, and lower-index calculation channels.
Label	<p>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 n is the index of the calculation channel.</p> <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 153.
- ➔ See FLC references on page 293.



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

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.

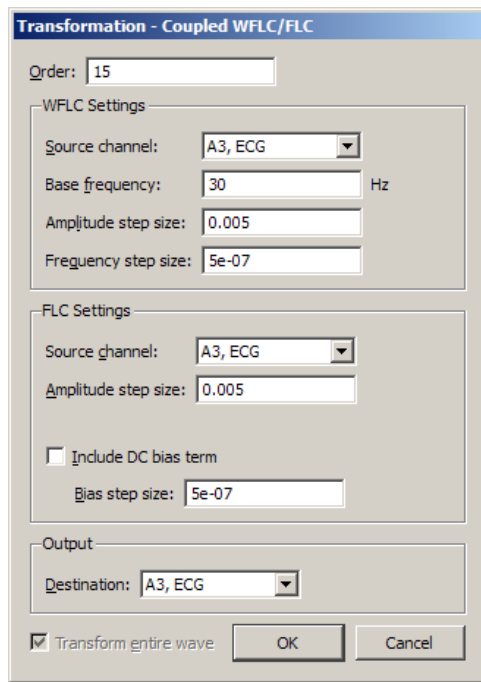
Weighted-Frequency FLC

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.



The dialog box is titled "Transformation - Coupled WFLC/FLC". It contains the following sections:

- Order:** A text field with the value "15".
- WFLC Settings:**
 - Source channel:** A dropdown menu showing "A3, ECG".
 - Base frequency:** A text field with the value "30" and a unit "Hz" to its right.
 - Amplitude step size:** A text field with the value "0.005".
 - Frequency step size:** A text field with the value "5e-07".
- FLC Settings:**
 - Source channel:** A dropdown menu showing "A3, ECG".
 - Amplitude step size:** A text field with the value "0.005".
 - Include DC bias term:** An unchecked checkbox.
 - Bias step size:** A text field with the value "5e-07".
- Output:**
 - Destination:** A dropdown menu showing "A3, ECG".
- Transform entire wave:** A checked checkbox.
- Buttons:** "OK" and "Cancel" buttons at the bottom right.

Coupled WFLC/FLC

Runs a WFLC on the signal to determine the harmonic frequency and then runs the result through an FLC using the computed harmonic. The second FLC can be run on the same or a different channel.

The transformation will occur in the channel designated as "Output."

Well suited for real-time extraction of information from one signal based upon the frequencies contained in another signal.

- Use to remove movement noise from ECG.
- Unique configurations can be established with two input signals, one for frequency and one for amplitude.

FLC References

The basic Fourier linear combiner (FLC) is described by Vaz and Thakor.

- Christopher A. Vaz, and Nitish V. Thakor, "Adaptive Fourier Estimation of Time-Varying Evoked Potentials," *IEEE Trans. Biomed. Eng.*, Vol BME-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 AcqKnowledge will transform the entire wave. If a math function attempts to divide by zero, a zero will be returned.

For complex transformations involving multiple functions, you may want to use the Expression transformation (see page 309 for details).

The following table describes the commands available in the Transform > Math functions menu:

Math functions ▾

Abs

ArcTangent

Connect endpoints

Exp

Limit...

Ln

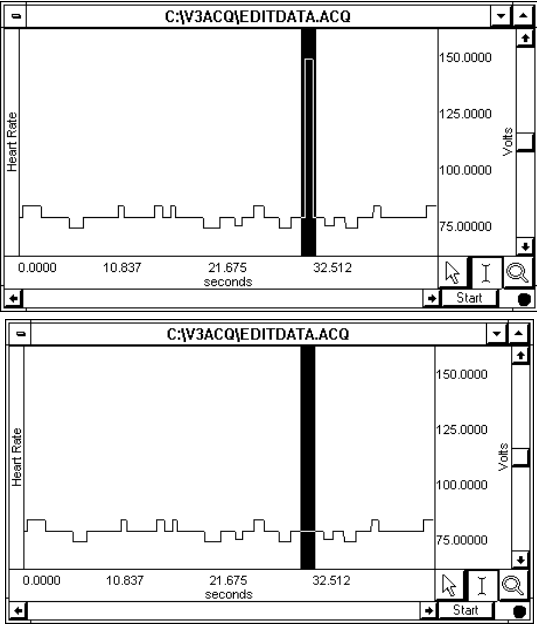
Log

Noise

Sin

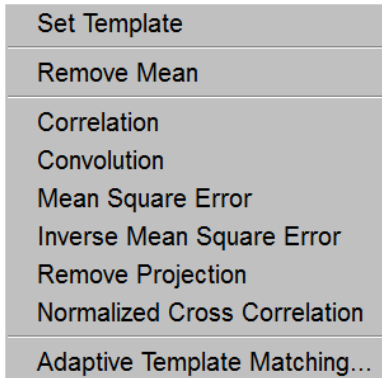
Sqrt

Threshold...

Transform > Math	Explanation of Command
Abs (Absolute Value)	Computes the absolute value of the data. All negative data values are made positive, with no change in magnitude. This function can be used to rectify data.
Atan (Arc Tangent)	Returns the arc tangent of each data point in radians. This rescales the data such that the range is from $-\pi/2$ to $\pi/2$.
Connect endpoints (Connect the endpoints)	<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 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. The Cut operation will remove data, but the subsequent data will be shifted to the left. Connect endpoint preserves the time series of data on the horizontal axis by connecting the edges of the selected area..</p> <div></div> <p>Area selected before (top) and after (bottom) connect endpoints function</p>
Exp (Exponential)	Computes the function e^x , where x is the waveform data and e is 2.718281828. This is the base of the natural logarithms.

<i>Limit (Limit data values)</i>	<p>“Clips” data outside the range specified by the set of boundaries in the limit dialog. This operation prompts the user for an upper and lower limit. Any data values outside these limits will be clipped. To limit only one boundary (high or low), set one edge to the desire level and the second boundary beyond the Max/Min value of the data within the selected area. For example to set all negative values to zero and leave the positive values unchanged: set the lower limit to zero and the upper limit to a value greater than max for the selected area.</p>
<i>Ln (Natural Logarithm)</i>	<p>Computes the natural logarithm of the selected section. The inverse of this function is the exponential function, <i>Exp</i>.</p>
<i>Log (Base 10 Logarithm)</i>	<p>Computes the base 10 logarithm of the selected section.</p> <p>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.</p>
<i>Noise</i>	<p>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.</p>
<i>Sin (Sine)</i>	<p>Calculates the sine of the selected section. The data is assumed to be in radians.</p>
<i>Sqrt (Square Root)</i>	<p>Takes the square root ($\sqrt{}$) of each data point in the selected section.</p>
<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_{max} 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



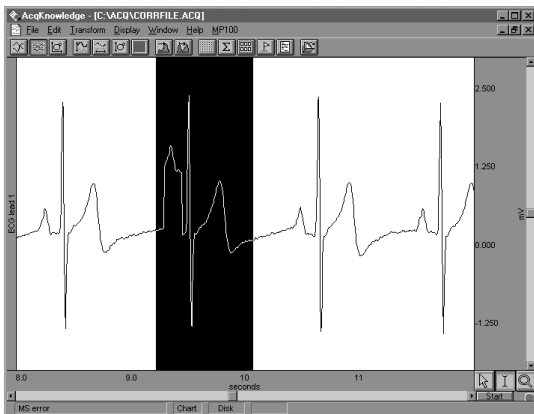
The Template Functions are useful for comparing waveforms. Technically, the template functions provide correlation, convolution, mean square error, inverse mean square error, remove projection, normalized cross correlation transformations of a template waveform against another waveform. To activate the full template menu, select an area and then select set template.

Set Template

Use the following ECG waveform as an example and contains an abnormality. After detecting an abnormality, this operation can help detect if there are other (similar) abnormalities in the recording. To do that, it's necessary to select the pattern to search for, and then compare that pattern to other data sets in the file.

Selecting a section of a wave to be used as a template:

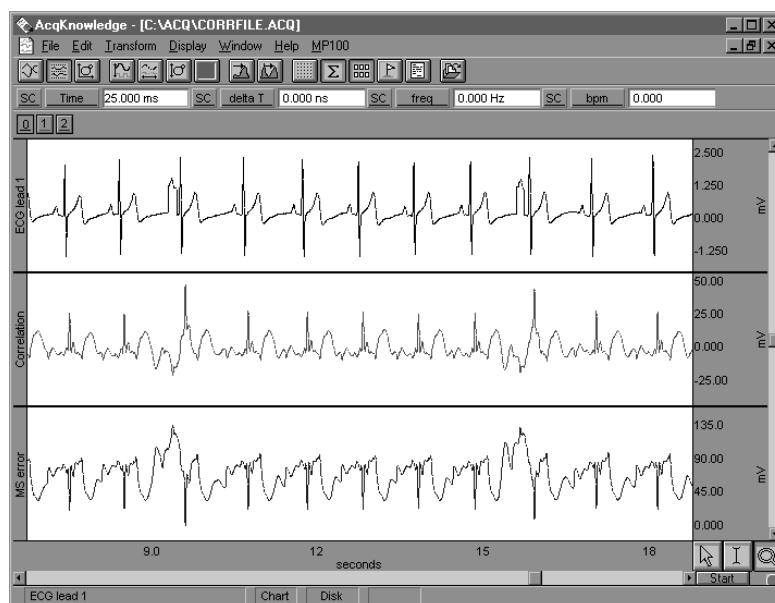
- 1) Highlight the section to be used as a pattern.



- 2) Click the Transform menu and choose Set template from the Template functions submenu. This copies the selected portion into a buffer for subsequent template functions
- 3) Select the waveform and position the cursor at the beginning of the data.
- 4) Choose Correlation from the Template functions submenu. The center waveform in the graph below shows the result of the correlation.

Note the higher amplitude peaks where the template data more closely matches the waveform. The lower waveform illustrates the mean square error function, which is similar to the correlation function.

This indicates that there are two abnormal beats in the waveform. The first one appears at about 3 seconds and is the one used as a template; the second one appears at about 11 seconds.



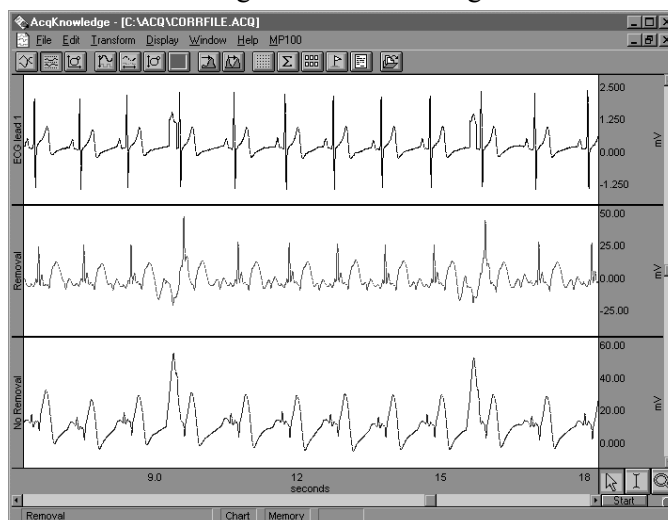
Result of correlation and mean square error functions

- 5) Use the zoom tool to inspect the abnormalities more closely.

Remove mean

A drifting baseline can be problematic when comparing waveforms. The effectiveness of a comparison of a template or waveform with a slowly drifting baseline will be increased by applying the Remove mean template function. The remove mean option causes the mean amplitude value of the template and the compared section of the waveform to be subtracted from each other before the sections are compared. This way, a large baseline offset will have very little effect on the comparison. This option is toggled every time it is selected and is enabled when a check mark is present.

For example, the following graph shows the original waveform at the top, the correlated waveform with mean removal in the middle, and the same correlation without mean removal at the bottom. Note how the mean removal effectively compensates for the drifting baseline in the original waveform.



Correlation with and without mean removal

Template algorithms

The template functions are: correlation, convolution, mean square error, inverse mean square error, normalize cross correlation, remove projection and adaptive template matching.

- a) Correlation is a simple multiplication and sum operation. The template is first positioned at the cursor position in the waveform to be correlated. Each point in the template waveform is multiplied by the corresponding point in the data waveform (the waveform to be correlated) and summed to produce the resulting data point. The template is then moved one data sample forward and the operation is repeated to produce the next resulting data point. The resulting data points replace the waveform to be correlated. The correlation function algorithm can be expressed by the following formula, where $f_{\text{output}}(n)$ 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 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) Remove Projection Template removes the projection of a reference signal from another part of a signal (whereas the other template functions revolve around the comparison of a portion of a signal against a reference signal).

Remove Projection treats the template in memory as a vector. The projection of the selected area onto the template is computed as a vector dot product. This projection is then removed from the source data.

After a remove projection transformation, the remaining data consists of the part of the signal that is the most unrelated to the template.

Remove Projection can be useful for emphasizing signal differences. For example, it may be useful for exploring differences in an arrhythmia in comparison to a normal reference beat. It may also be useful as a denoising building block by removing the projection of a signal against idealized noise in the template.

The number of samples in the template should match the number of samples in the selected area of source data.

- Dot product is undefined for vectors of mismatched dimensions.
- If the template is longer than the selected source data, the template will be shortened (for that single transformation; it will be restored afterward) so its length matches the selection width.
- If the selection is longer than the template, any data occurring after the end of the template will not be transformed.

To create a Remove Projection template:

1. Highlight the portion of data to be used as the reference signal.
2. Transform > Template > Set Template.
3. Highlight the portion of the data to be analyzed.
4. Transform > Template > Remove Projection.

- f) Normalized cross-correlation (NCC) is useful when searching for variations in the signal. Regular cross-correlation (Transform > Template > Correlation) can exhibit large amplitude spikes when the energy of a signal varies greatly or amplitudes change suddenly, causing jumps that are not necessarily indicative of a match with the template. Normalized cross-correlation is a statistical method that can help resolve these issues by applying normalization to both the template and signal being searched. This reduces the effect of amplitude variation in the result, making normalized cross-correlation useful for template matching purposes.

This transformation computes the windowed normalized cross-correlation, and results in a value between -1 to 1, which indicates the linear fit of the data set. Normalized cross correlation is defined as:

$$\gamma = \frac{\sum_{i=0}^L (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=0}^L (x_i - \bar{x})^2 \sum_{i=0}^L (y_i - \bar{y})^2}}$$

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. The same zero padding is used when computing NCC at the end of every selected area when the template is running off the end of the data. This zero padding should trend the NCC to zero at the right edge of the transformed area, in most cases.

Adaptive Template Matching

Many different types of physiological analysis involve locating repetitive features within a signal. These may occur at regular intervals or may occur sporadically. Sometimes the areas of interest may be intermingled with other results, such as occasional heartbeat arrhythmias occurring in a long-term ECG recording. Template matching is one frequently used approach for locating areas of waveforms that exhibit certain characteristics. An example selection is specified as the input template. Then, using cross correlation or related methods, the areas of an arbitrary wave that most strongly match the example can be located.

Adaptive Template Matching allows the template to vary during execution to incorporate changes to the morphology of signal attributes. The adaptation consists of a moving average of a number of the most recent matching attributes. A template match will be defined as a peak in the windowed normalized cross correlation of the adapting template with the signal.

Normalized cross correlation helps to eliminate artifact due to baseline shift and changes in overall power and amplitude. This heuristic is sensitive to waveform morphology instead of amplitude.

Template width

The number of samples in the template that will be used as the initial template for the transformation, as set using Transform > Template Functions > Set Template.

Note One template is shared globally by all graphs and data views in 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.

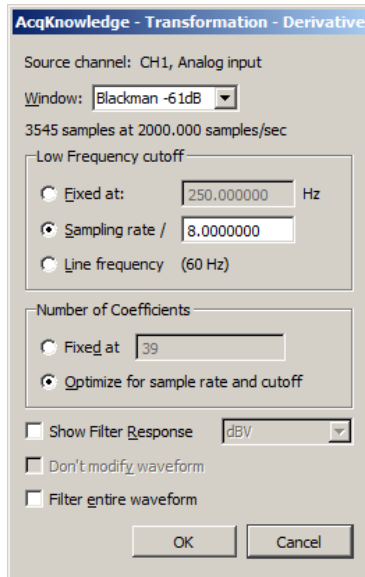
Integral

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 ΔTs is the horizontal sampling interval (reciprocal of the sample rate):

$$f_{\text{output}}(n) = \sum_{k=1}^{n-1} f_{\text{input}}(k) + [(f_{\text{input}}(n-1) + f_{\text{input}}(n)) / 2] * \Delta Ts$$

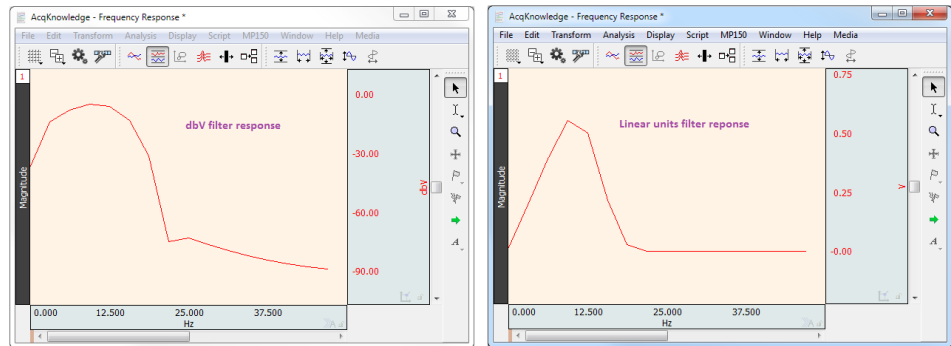
The units will be (amplitude units • horizontal units). The integral function can be used to compute the area under the curve in a continuous fashion. For instance, in data acquired by an accelerometer, the integral of the data would be the velocity, and the integral of the velocity would be the distance. As with all transformations, this function can be applied to either a selected area or to the entire waveform.

Derivative



Derivative calculates the derivative of the selected area of a waveform. Since high frequency components return nonsensical results in a derivative, a low pass filtering function is included in the Derivative function (see page 284 for more information on low pass filters). Derivative is based on an FIR filter implementation.

The Filter Response for a Derivative transformation will be displayed in linear units or in dBV. The Derivative FIR filter frequency response will appear as a linearly increasing magnitude up to the point of the specified cutoff frequency, at which point, the filter magnitude will drop off sharply.



Derivative may provide better results than Difference; if high frequency noise is present in the signal.

Cutoff Frequency The value entered in the cutoff frequency box should be roughly equivalent to the highest frequency component of interest present in the time series data. The default cutoff frequency is 0.125 times the waveform sampling rate.

Sampling rate—Sets the frequency to a fraction of the sampling rate and automatically updates when the sample rate is modified.

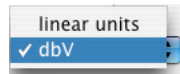
Line frequency—Uses the line frequency at which the data was recorded.

of Coefficients **Fixed**—The default number of coefficients is $(4 \times \text{waveform sampling rate}) / \text{Cutoff Frequency}$. 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—Estimate the number of coefficients as four times the sampling rate divided by the cutoff frequency of the filter. Optimize does not necessarily produce the best quality filter, but takes less time.

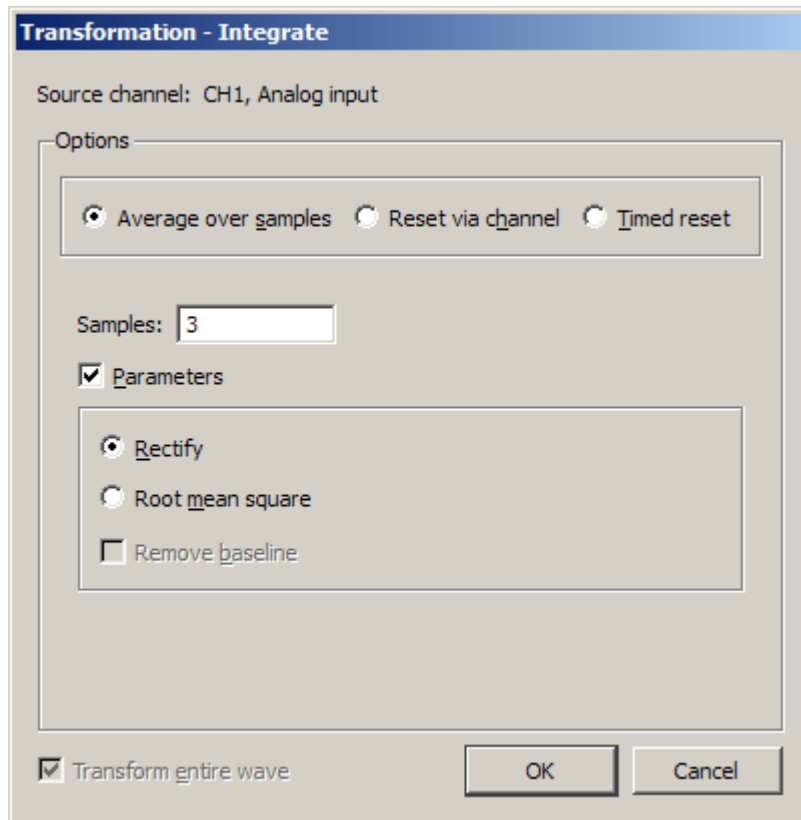
Units

Select linear units or dBV.



TIP: A good rule of thumb is to use a number of coefficients greater than or equal to two times the sampling rate divided by the lowest cutoff frequency specified. For example, if running a low pass filter at 1Hz on data sampled at 100 Hz, choose at least $(2 \times 100/1)$ 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 127, 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

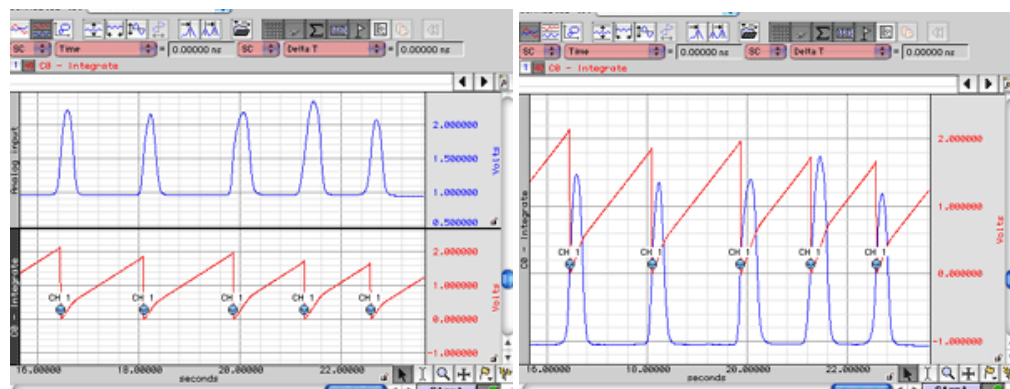
Mean subtraction causes the online version to be delayed by the mean cycle length. It waits for that period of time to pass so it can determine a mean value for the initial cycle, and it then tries to re-compute this mean for each cycle. If the resets are too short or too long, the window expires and 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

Enable the checkbox option to create an Event at each signal reset.



The Integrate formula is the same in the calculation (online, real-time) mode and the transformation (off-line, post-processing) mode; it varies only based on the parameters selected.

Notes

- For the first points, value of index “ i ” will be *less than or equal to zero*; it means that for summation 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](http://mathworld.wolfram.com/StandardDeviation.html) at <http://mathworld.wolfram.com/StandardDeviation.html>).
- The Root Mean Square formula is identical to the Standard Deviation formula, but without mean removal; this is the $n-1$ definition.
 - For an explanation of $n-1$ versus n in the formula, see notes in: <http://duramecho.com/Misc/WhyMinusOneInSd.html>
 - For a window size n , to convert from the $n-1$ definition to the n definition, use $\sqrt{(n-1)/n}$
- The formulas to calculate RMS are optimal for data with a zero mean (typical for biopotential data). Data with a non-zero mean can be rescaled with the Transform option Rescale. Choose Transform > Rescale, and then enter the following parameters:

<u>Input value</u> <u>(Scale) value</u>	<u>Map</u>
10	7.07107
-10	-7.07107

- 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 304

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)

$$F(x_j) = \sqrt{\frac{\sum_{i=j-s+1}^j (f(x_i))^2}{s - 1}}$$

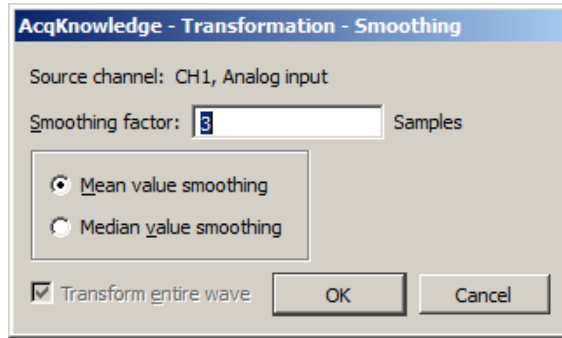
Where: i - index for source values (**the real range is 1..j); j - index for destination values (1..n); n - number of samples; x_i, x_j - values of points at horizontal axis; $f(x_i)$ - values of points of a curve; $F(x_j)$ - integrated values of points of a curve; s - number of samples to average across.

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 $j \geq s$ $k=s$

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 or median value of the moving average “window.” This has the same effect as a crude low pass filter, the advantage being that there is less change to shape and amplitude of the original waveform.

Samples *AcqKnowledge* allows the user to set the width of the moving average window (the number of sample points used to compute the mean) to any value larger than three. By default, this is set to three samples, meaning that *AcqKnowledge* will compute the average of three adjacent samples and replace the value of each sample with the mean or median before moving on to the next sample. For data acquired at relatively high sampling rates, it is recommended to set the smoothing factor to a higher value, since smoothing three sample points when data is collected at 1000 Hz will only average across three milliseconds of data, and will typically do little to filter out noise. To set the size of the window, enter a value in the Transform > Smoothing dialog.

This function is most effective on data with slowly changing values (e.g., respiration, heart rate, GSR) when there is noise apparent in the data record.

Mean value Mean value smoothing is the default and should be 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:

$$f_{\text{output}}(n) = \sum_{k=n-(m/2)}^{k=n+[m-1]/2} f_{\text{input}}(k) / m$$

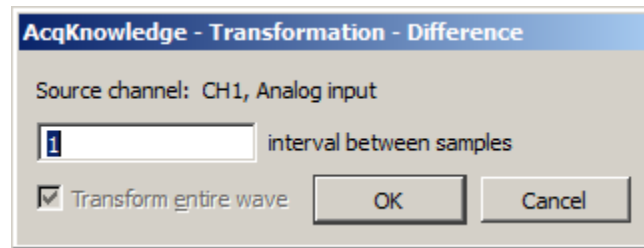
Median value Use Median value smoothing if some data points appear completely aberrant and seem to be “wild flyers” in the data set.

The Median value smoothing formula is shown below, where “m” is the number of points in the window and “n” is the sample number:

$$f_{\text{output}}(n) = \text{median}(n - [m/2]; n + [m/2])$$

 Watch the [AcqKnowledge Smoothing video tutorial](#) for a detailed demonstration of this feature.

Difference



The Difference function measures the difference (in amplitude) of two sample points separated by an arbitrary number of intervals. The difference is then divided by the total interval between the first selected sample and the last selected sample.

When the difference transformation is selected, a difference interval dialog will be generated and the number of intervals between samples can be entered (default of 1).

For data with no high frequency components, a 1-interval difference transformation approximates a differentiator.

The formula for the difference transformation is shown below, where “m” is the number of intervals difference, [] rounds the integer down, “n” is the sample number, and 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):

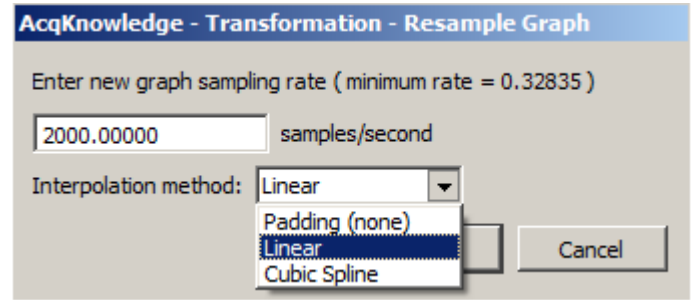
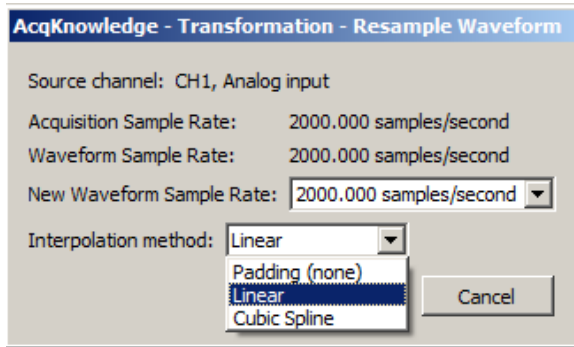
$$f_{\text{output}}(K) = (f_{\text{input}}(K+2) - f_{\text{input}}(K-2)) / (\Delta T_s * m)$$

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.

Resample



Variable sampling rate and the flexible acquisition speeds of hardware units can create data sets that are at different sampling rates. For some types of data analysis, the data must be resampled to a common sampling rate. AcqKnowledge has resampling facilities with Transform > Resample Graph; Transform > Resample Waveform, and Pasting between graph windows of different sample rates when the “Interpolate pastings between graphs” Preference is enabled (via Display > Preferences, page 450).

AcqKnowledge provides three interpolation methods for resampling data. Any changes made to the interpolated pastings between windows Preference and the interpolation method used in the Preferences dialog will be retained across launches of the software.

Padding—Padding will use the closest original value of the waveform to the left of the new sample position for the value, constructing a padded square 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—Linear interpolation is the default; previous software versions generated any missing data via linear interpolation. This method uses the sample points of the old waveform as the endpoints of a line. Missing data points are approximated from points lying on this linear segment.

Cubic spline—Cubic spline interpolation will construct a spline for the entire data set and use the values of this spline as the new waveform values. A natural fit spline is used that keeps zero second derivative at the endpoints of the fit. Cubic splines are useful when the analysis requires data with a smooth derivative.

Resample Graph

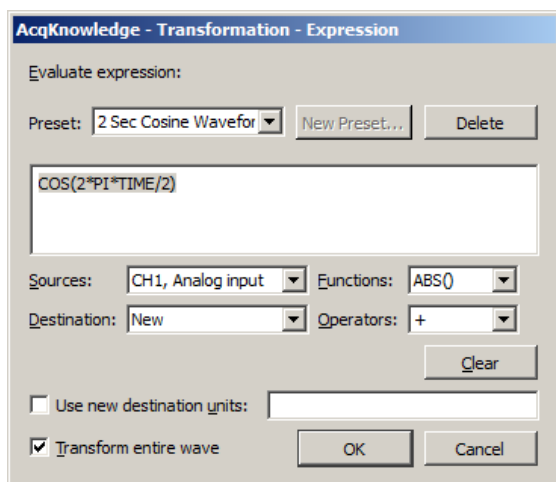
Apply an arbitrary, user-defined sample rate to all waveforms present in a file.

- This option will adjust as needed the channel sampling rate as well as the acquisition sampling rate.

Resample Waveform

- For Resample Waveform, the highest rate that can be entered is the Acquisition Sample Rate. Resamples the active channel to a different rate. Resampling data maintains the same time scale but changes the number of samples per second. This option can be used to increase the number of sample points per interval (usually samples per second). When this is applied, 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 and information will be lost.
 - For example, a 4-channel data file sampled at 250 samples per second for 15 minutes requires about 1.8 MB of disk space. If these channels are resampled to 100 samples per second, the size of the file on disk is about 720 KB, a considerable reduction.
- The highest rate a channel can be resampled to is the file acquisition rate (Hardware menu > Set Up Acquisition).
- If data is resampled to a lower rate and then resampled again at a higher rate, the waveform will maintain the resolution of the lower sampling rate, only with more data points.

Expression



See the tables on page 145 for descriptions of sources, operators and functions for the Expression dialog.

The post-acquisition Expression transformation is available for performing computations more complex than available with the Math and Function calculations. The post-acquisition version of the Expression transformation includes all the same features as the online version described on page 141. The Expression transformation will symbolically evaluate complex equations involving multiple channels and multiple operations. Unlike the Math and Function calculations, which can only operate on one or two channels at a time, the Expression transformation can combine data from analog or digital channels, as well as calculation channels with a lower channel number. Also, computations performed by the Expression transformation eliminate the need for “chaining” multiple channels together to produce a single output channel.

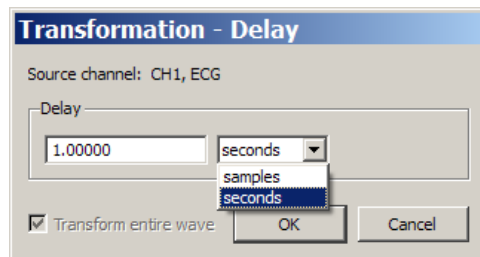
To have AcqKnowledge solve an expression and save the result to a new channel, choose Transform > Expression. For each expression, specify a source channel (or channels), the function(s) to be performed, any operators to be used, and a destination for the result. The components of each expression can be entered either by selecting them from the pop-up menus (sources, functions, destination, and operators), or by typing mathematical commands directly into the expression box.

Any expression can be assigned a specific name and saved as a custom preset. A pop-up menu of recently used expressions is also available in the Preset menu, along with a pre-loaded list of commonly used expressions.

The Expression transformation can reference past and future points.

Delay

The Delay transformation allows the addition of time delays in postprocessing (similar to the Delay calculation channel that can be used to add time delays to signals). The time delay can be added by introducing zero-valued samples at the start of the area to be delayed. The length of the waveform will remain the same; an amount of data at the beginning of the wave prior to the delay will be lost, with the length equal to the delay. To set up a delay, choose the Transform > Delay menu item.



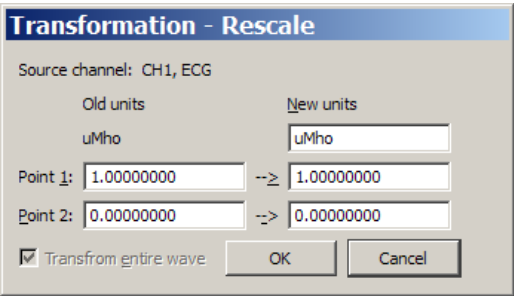
When inputting the delay amount, the units can be changed between **seconds** and **samples**.

- **Delay by samples** is applied according to the acquisition sampling rate, not the channel sampling rate.

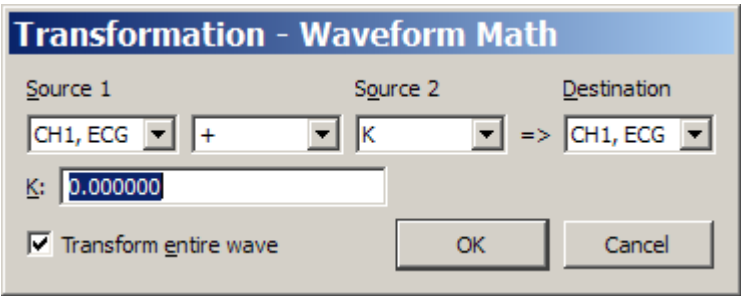
The Automator action allows Delay to be used in Automator workflows. See page 25.

Rescale

The Rescale transformation operates identically to the Rescale calculation—see page 155.



Waveform Math

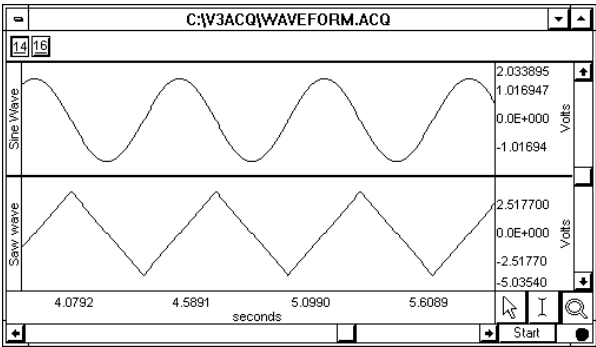


The Transform > Waveform Math operation allows arithmetic manipulation of waveforms. Waveforms can be added together, subtracted, multiplied, divided or raised to a power. These operations can be performed using either two waveforms or one waveform and an arbitrarily defined constant. Operate on the entire waveform by choosing Transform entire wave, or operate on portions of the waveform that have been selected using the cursor tool. If there is no selected area, only one sample point (the one selected by the cursor) will be transformed.

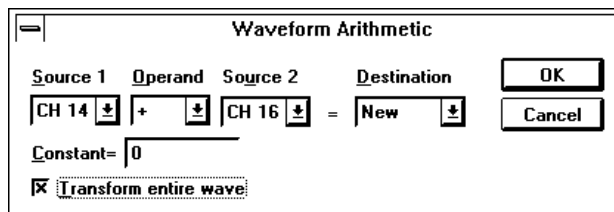
All of the main components of a waveform math calculation can be selected from pop-up menus in the Waveform Arithmetic dialog.

- Source** The channels to be used in the transformation are referred to as source channels (Source 1 and Source 2), and can be combined using any of the operators in the pop-up menu. Source channels 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** Save the results to an existing channel or create a new channel. Choose an existing channel from the pop-up menu or select the “New” option, which will create a new channel (using the next available channel).

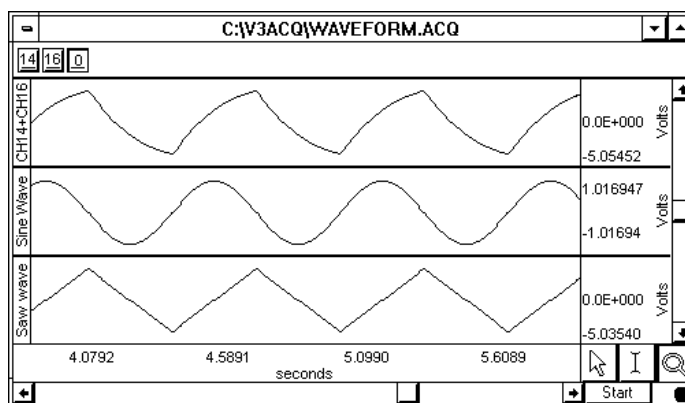
Waveform math can be used many ways. As one example, two waveforms can be added together. The following screen shows a sine wave in channel 14 and a triangle wave in channel 16.



To add these two waves, select Transform > Waveform Math and set source 1 to channel 14, the operator to addition “+”, source 2 to channel 16, and destination to New as shown here:

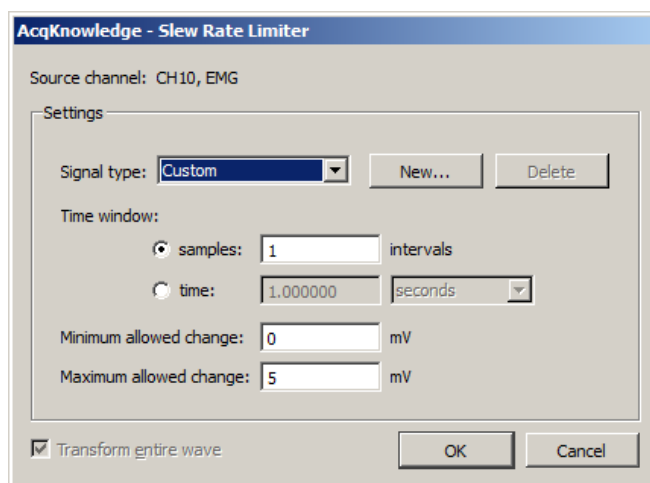


Click OK to perform the transformation. The following screen shows the sum of CH14 and CH16 on a new channel.



NOTE: If 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.

Slew Rate Limiter



The Slew Rate Limiter transformation is used for denoising and removing motion artifact during and after recording. The allowable amount of motion artifact over a given time/sample window can be precisely adjusted from a minimum allowable change to a maximum allowable change, thereby eliminating artifacts that exceed the selected amplitude range within a given time period.

Tailor the range for a given type of artifact by modifying the Time window and Minimum/Maximum allowed change parameters. Parameters for various levels of artifact detection can be permanently stored by clicking “New...” and saving the signal type as a custom preset.

To apply the slew rate limiter transformation in AcqKnowledge:

1. Select the desired source channel in the data.

2. Transform > Slew Rate Limiter.
3. Select the time window using a sample interval or a time value.
4. Set the desired minimum allowed change value.
5. Set the desired maximum allowed change value.
6. Click OK.

Any artifact that falls outside the boundaries of the maximum/minimum allowed change setting will be eliminated from the data.

See also: Slew Rate Limiter online calculation channel on page 156.

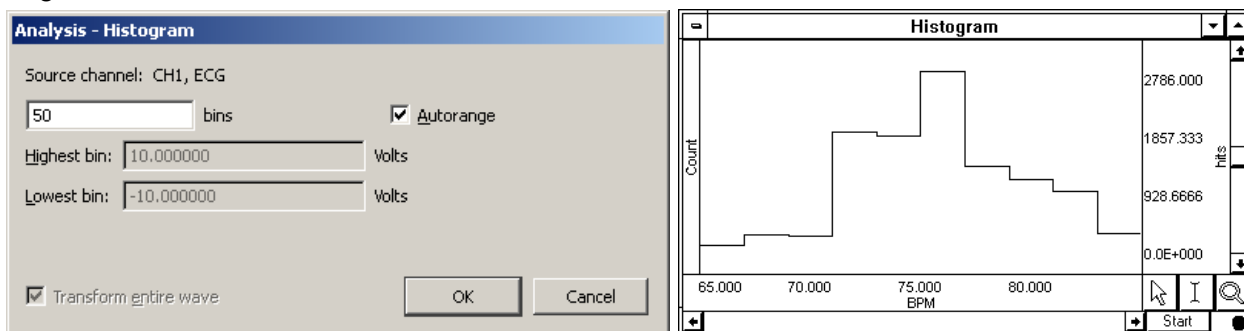
-  Watch the [AcqKnowledge Slew Rate Limiter video tutorial](#) for a detailed demonstration of this feature.

Chapter 16 Analysis Menu Commands

Overview

The Analysis menu contains operations that derive data and measurements from the graph—plus a courtesy copy of the Specialized Analysis package with classifiers and automation routines.

Histogram



The Histogram function produces a histogram plot of the selected area. When a histogram is created, the sample points are sorted into “bins” along the horizontal axis that contain ranges of amplitude values. These bins divide the range of amplitude values into equal intervals (by default, ten bins) and the individual sample points are sorted into the appropriate bin based on their amplitude value.

For instance, if a waveform had a range from 65 BPM to 85 BPM, the lowest bin would contain all data points with a value from 65 BPM to 67 BPM. The second lowest bin would hold all data points between 67 BPM and 69 BPM, and so on, until the tenth bin was created. *AcqKnowledge* then counts the number of “hits” (the number of data points) in each bin and plots this number on the vertical axis.

Analysis > Histogram Options:

- bins** Determines how many bins the data will be divided into; the default is ten bins.
- Autorange** Fits all the data selected into a bin; the bin sizes are determined by the extent of the data and the desired number of lines. Automatically sets the center of the lowest bin equal to the minimum value of the waveform (or the selected area, if a section is highlighted), and centers the highest bin on the maximum value of the waveform (or selected area, if any).
- Disable to fix the bin sizes and enter values for Highest Bin and Lowest Bin.

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.

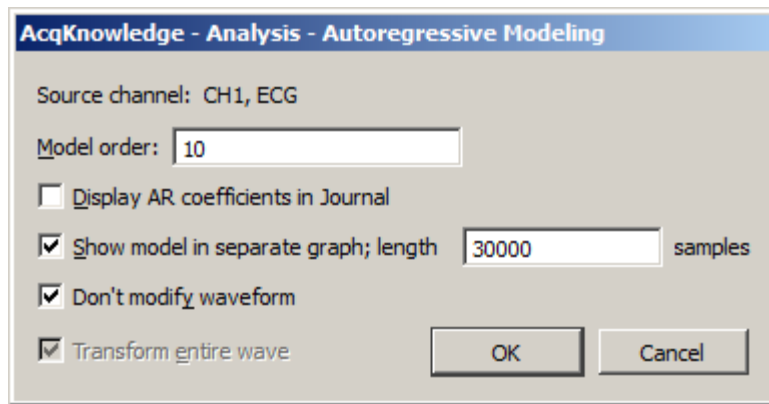
Since the histogram function sorts sample points into a relatively small number of categories, the histogram window is likely to display a large number of “hits” in each bin, especially if data was collected at a relatively fast sampling rate. If this is the case, you may want to resample the data at 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.

Autoregressive Modeling

About autoregressive modeling

Autoregressive modeling is linear mathematical modeling algorithm well suited to operation on discrete series of data. Using autoregressive models of physiological data, it is possible to perform advanced time series analysis, compression, denoising, arrhythmia detection, and waveform classification. Its ability to be used to extrapolate spectral features from waveforms at low sampling rates makes autoregressive modeling quite useful for electrogastrogram analysis.

AR modeling has a large number of applications in physiological signal analysis. These applications derive from its ability to approximate data through a more compact representation in AR coefficients. Other applications leverage AR modeling's ability to generate additional data for a signal with roughly the same characteristics. Specialized applications exist for ECG, EEG, and EGG in addition to general purpose analysis procedures.



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 317.

Output can also paste model parameters as tabular text to a journal. If “Don’t modify waveform” and “Show model in separate graph” are both enabled, a new graph window will be generated to display the specified number of samples resulting from the best-fit autoregressive model.

Nonlinear Modeling

About nonlinear modeling

Modeling is used in physiological data to assess how well data conforms to a theoretical model. This is used to express a sampled signal in a continuous form and to perform data reduction. The nonlinear modeling features in *AcqKnowledge* support more advanced physiological analysis than is possible with the linear regression measurement, which is a rudimentary single order linear model.

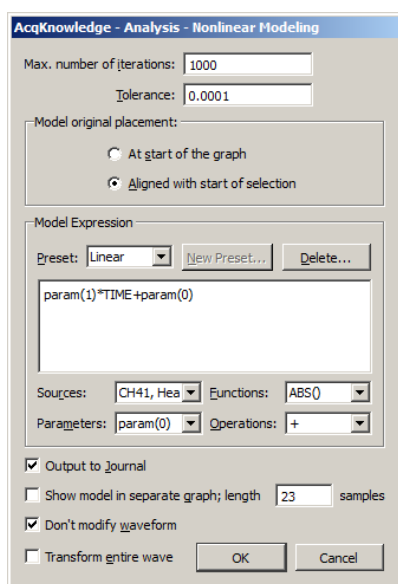
Nonlinear modeling is the process of finding the best fit of a mathematical function to an arbitrary data set. Fitting the function—or model—to the data consists of choosing a set of function parameters that minimize error between the actual data points and the values generated from the model function.

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 103

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.

Nonlinear modeling (also called “arbitrary curve fitting”) determines the “best fit” of an arbitrary function to source data; the function is called a *model*.

A model must match underlying trends in the data to produce meaningful results. Also, to properly interpret the value of the best fit coefficients and any further derived results, users must consider the limitations of the simplex search method, which include: estimation only; not guaranteed to terminate; not guaranteed to find the exact solution; may get stuck in local minima.

Model Origin Placement

Controls where the zero point of the model is placed. Selection-relative placement is useful when comparing different sections of the same channel of data by looking for variations in their best fit model parameters. If channel data is used as part of the Model Expression the location from where the channel data is extracted will not be translated; regardless of the model origin setting, the channel data will be used from the selected area only.

Model Expressions

These model expressions use the same expression format as other parts the program, such as the Expression calculation channel. See the function tables starting on page 145 for details on Sources, Functions, and Operators.

Preset

The following presets for the most common types of models are included. Users can extend presets or create custom models if these presets are too general to achieve exact fits with simplex search. Presets are stored at Computer > Local Disk > ProgramData > BIOPAC Systems, Inc > AcqKnowledge 4.x > Presets.

Preset	Description	Expression
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 active can be used as sources with the Model Expression.

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.

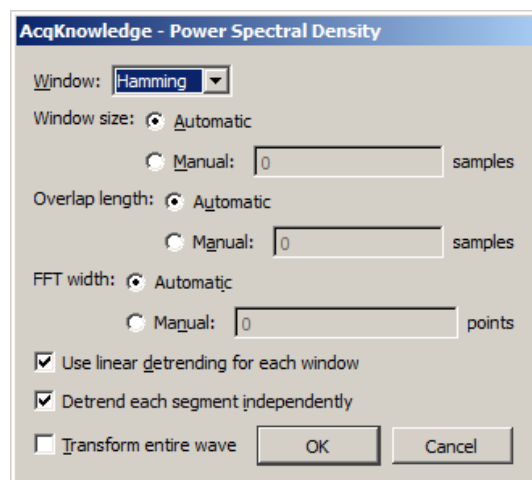
Don't modify waveform suppresses replacement of the selected source data.

- 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.

Power Spectral Density



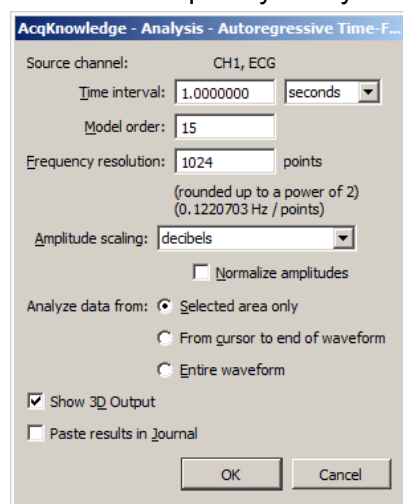
The Power Spectral Density (PSD) function extracts the power present at different frequencies within a signal and is useful for EMG analysis. The PSD transformation approximates the same result as squaring the linear FFT magnitude. PSD is not available when the horizontal units of the source graph are set to Frequency.

AcqKnowledge uses the Welch periodogram to average signal time-sliced portions of the signal and reduce noise effect, and generates a two dimensional graph displaying the wattage of a particular frequency component in a signal. Windowing options are Hanning, Hamming, or Blackman. The graph is plotted as horizontal frequency vs. vertical $(\text{units})^2/\text{Hz}$, where *units* are the vertical axis units of the source data.

Use linear detrending for each window—when enabled, linear regression detrending is applied for each individual segment prior to the FFT computation; when disabled, windowing only is applied.

Detrend each segment independently—becomes available when “Use linear detrending” is enabled. When this option is enabled, detrending is applied independently for each segment; when disabled, detrending from the previous segment will be incorporated into the next segment.

AR Time-Frequency Analysis



The AR Time-Frequency transformation can be used to examine changes in the spectral density of a signal using enhanced frequency resolution from derived AR models. Examining frequency changes over time can be a useful tool for arrhythmia detection and rough classification of waveforms.

Autoregressive spectrum time-frequency analysis divides a waveform into equal-length time segments, calculates an AR model (see page 316) 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.

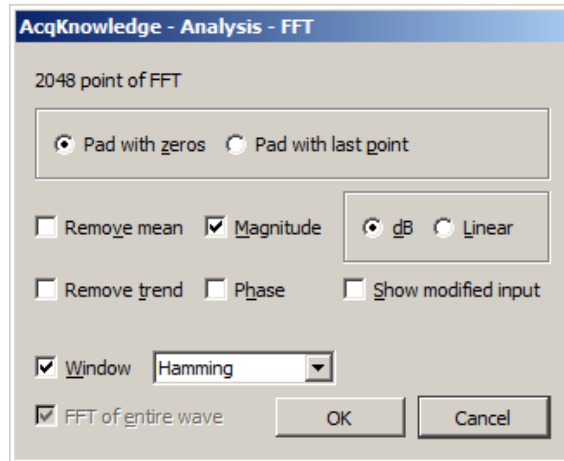
Frequency resolution—Enter a positive integer to indicate the number of points contained in the FFT of an individual time segment; it will be rounded to the closest power of 2 when analysis is performed.

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 232 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

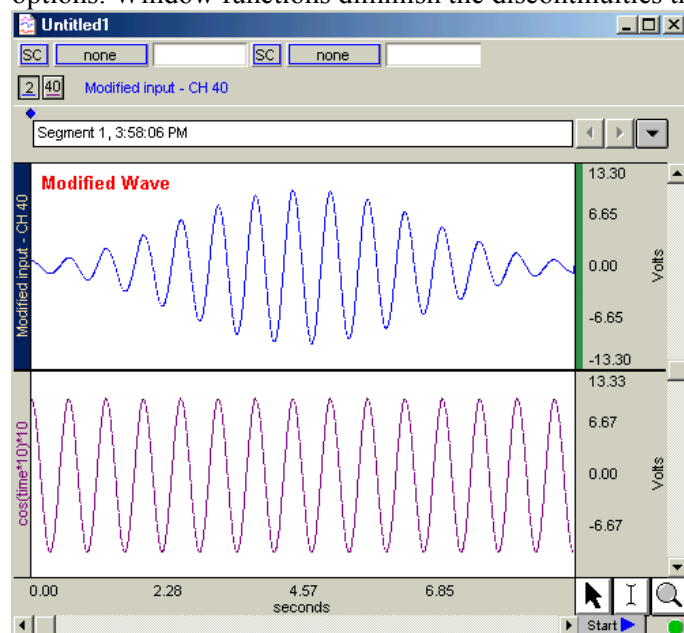
Pad with zeros: a zero

Pad with last point: 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.

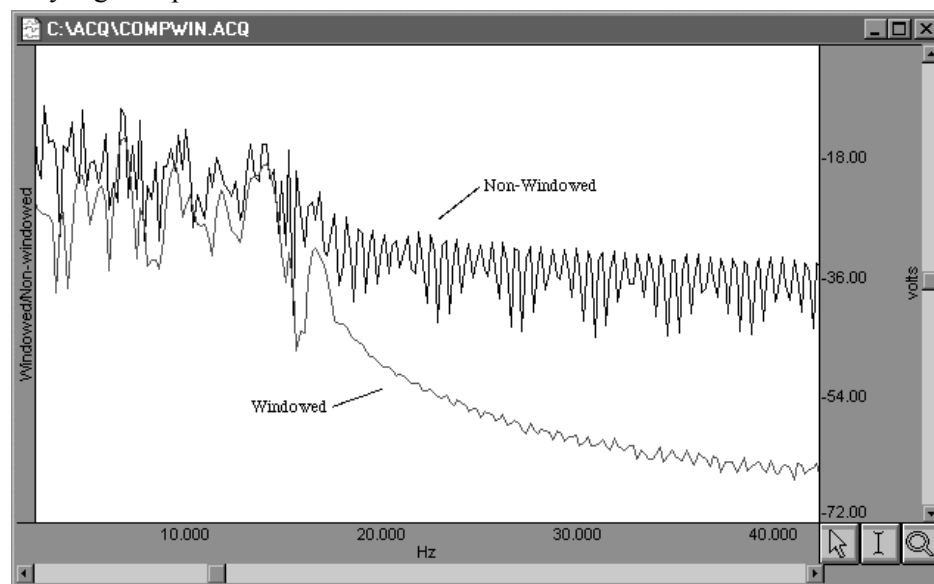
Show Mod.

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.

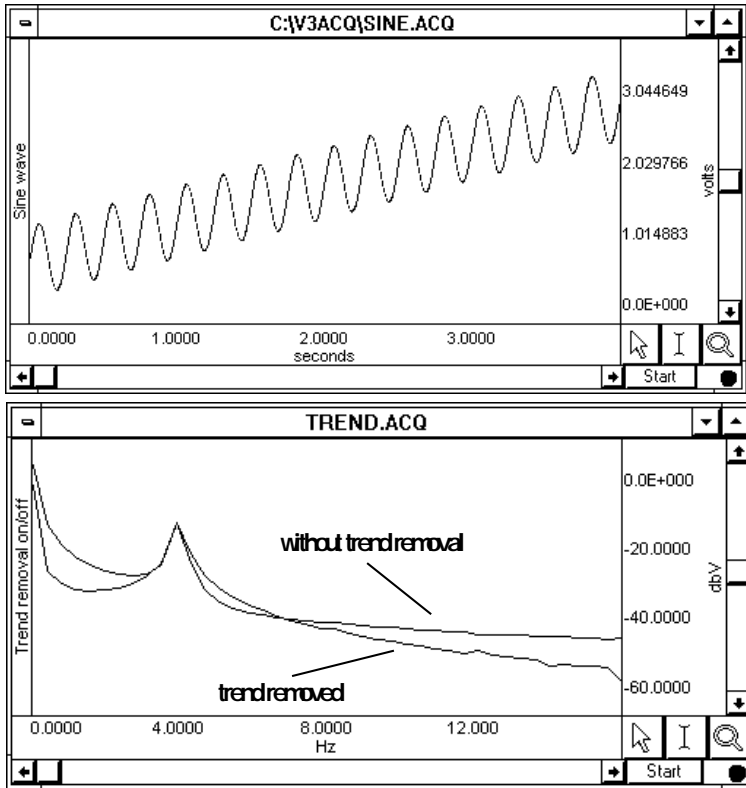


Remove Trend

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.

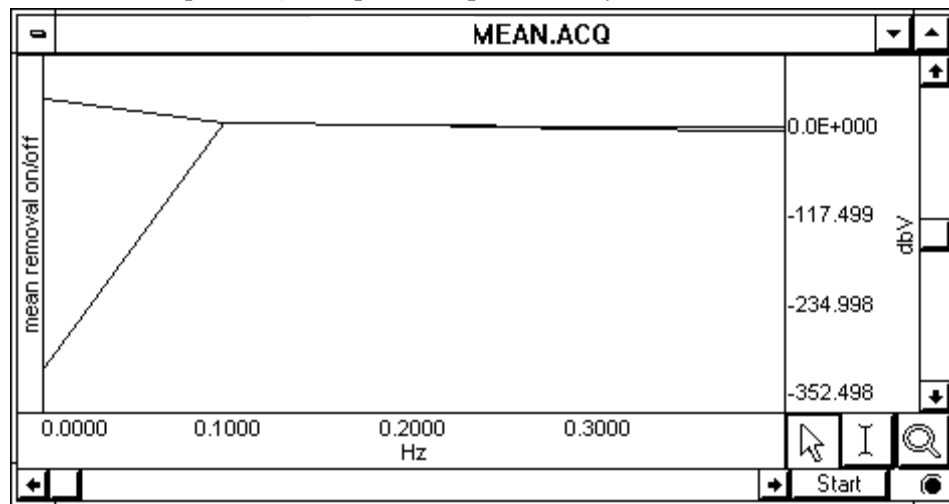
For example, the following sine wave has an upward trend through the data (positive trend component). The lower graph shows FFTs of the skewed sine wave data with and without the trend removed.

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:

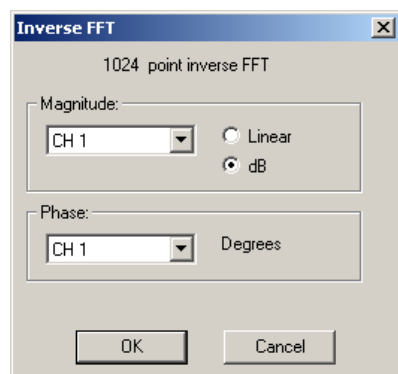


Note the large spectral components at the beginning of the top plot, without mean removal. This is due to the offset of the original data. The bottom plot is with mean removal.

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 the button next to linear and check OK. The other options in the dialog work as they normally do when the dB scaling option is selected. The relationship between log and linear units is: $\text{dBV}_{\text{out}} = 20 \log \text{VIN}$.
- 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.

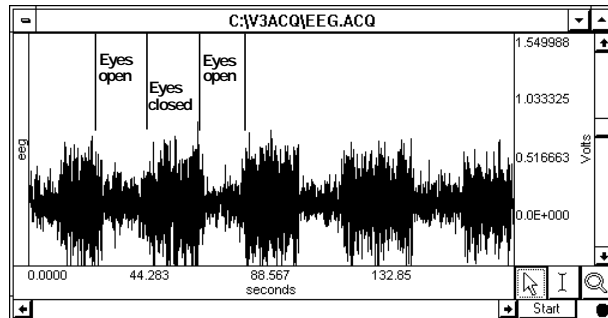
To obtain a meaningful IFFT result you must have a graph window open with at least one magnitude channel and at least one phase channel. With the window open, choose IFFT from the Transform menu to generate the Inverse FFT dialog.

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:



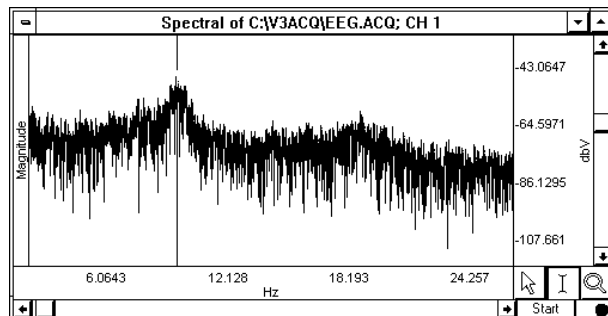
2. Select Transform > FFT from the menu.

The FFT Parameters dialog will be generated; in this example, the Window function chosen is Kaiser Bessel:

3. Click OK.

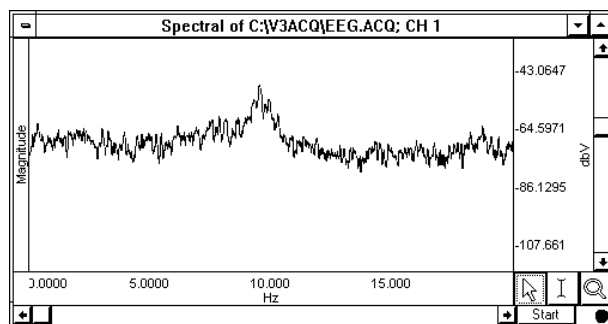
A frequency domain window (a graph window which places frequency along the horizontal axis rather than time) will be created and displayed, showing the spectrum of the input data.

The window is named “Spectral of (the original window name)” and ends with the channel number, as shown here:



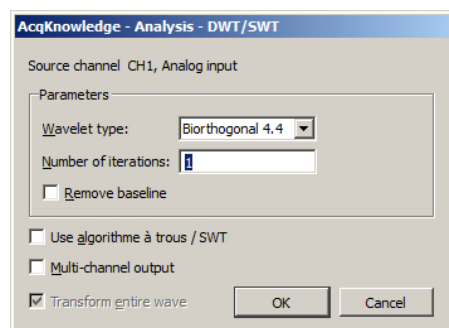
The resulting magnitude value for each component is equal to the peak value of the sine wave contributing to that component. The entire pattern of frequency components is known as the frequency spectrum of the data. The somewhat erratic appearance of the spectrum is usually due to small-scale variations 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 (0-20 Hz shown) used 20-point smoothing.



Watch the [AcqKnowledge FFT video tutorial](#) for a detailed demonstration of this feature.

DWT/SWT



About Wavelet Transformation

Wavelet transforms are similar to Fourier transforms. Instead of projecting a signal in a space of sines and cosines, wavelet transforms project a signal into a space comprised of orthogonal functions called *wavelets*. Discontinuities are more obvious in wavelet transforms than in sines and cosine analysis, making wavelet transforms a better choice for decomposing a signal to its fundamental form. Wavelet transforms can be used for noise reduction and filtering, extracting features from signals that are not apparent in time or frequency domains, and predicting signal qualities from a small number of data points.

Discrete wavelet transformations (DWT) break a source signal into high-frequency and low-frequency components. Use for ECG and EEG analysis. DWT creates a new graph with wavelet coefficients on the horizontal axis and the amplitude for each coefficient on the vertical axis, pastes acquisition settings to the graph journal, and places an event at each boundary between the high- and low-frequency components produced at each iteration.

Wavelet type Specify Biorthogonal 4.4, Symlet 4, Coiflet 6, Daubechies 8 or Spline 3.

Number of iterations Specify the number of transforms to execute.

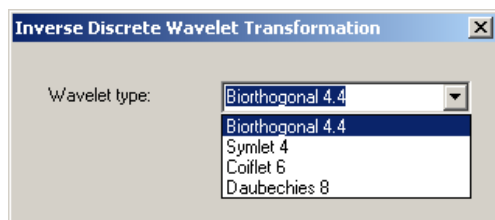
Stationary wavelet transformations (SWT) differ from DWT in that the “stationary” transformation retains all coefficients at each processing level, so each level’s output is equivalent to the length of the input signal. At each output level, the low and high pass filters are upsampled by inserting $2k-1$ zeros between each wavelet filter coefficient. This method retains information unnecessary for reconstruction of the original signal but produces output that may be more useful for identifying and enhancing specific characteristics of the original signal.

To enable the SWT option, check the “**Use algorithme à trous / SWT**” box. Like the DWT transformation, the SWT output will appear in a new graph.

Multi-channel output: This option places a copy of the original source data in the first channel of the output graph. Coefficients for each level are inserted as subsequent channels of the graph labeled “*dn*” with *n* replaced by the level of decomposition. The final channel is prefixed with an “*h*” indicating the high-pass coefficients left over from the final run.

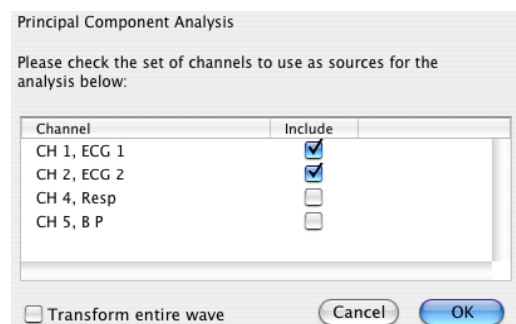
If either the multiple channel or the SWT options are used, the Inverse DWT cannot be used to reconstruct the original data. To reconstruct the original data, apply regular DWT with single channel output.

Inverse DWT



Operational on the result of a DWT. Projects data from wavelet space to time space. For correct recomposition of the source data, the wavelet type specified for the IDWT must match the wavelet type used for the DWT. Amplitudes of the wavelet coefficients may be changed, but an IDWT will fail if the horizontal units, events at DWT iteration level boundaries, or file length have been modified.

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.

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.

AcqKnowledge uses the FastICA algorithm to generate a new ICA graph with each component in a separate channel.

For more information on the FastICA algorithm, see [this link](#).

Select two or more channels—all of the selected channels must have the same sampling rate.

Specify tolerance and number of iterations.

ICA limitations to consider for application and interpretation:

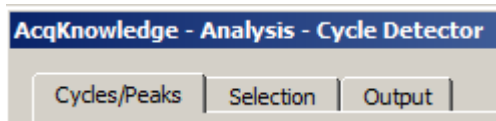
1. The number of mixed sources must be equal to the number of independent components (as in the example where two microphones captured two sound types).
2. Sources must be statistically independent; highly-correlated signals cannot be effectively separated.
3. Sources must have non-Gaussian probability distribution. It is not possible to separate out components like white noise through ICA.
4. Signal mixing must be a constant, linear process. Any type of non-linear signal propagation cannot be expressed in linear combinations of sources, the underlying assumption of ICA.
5. The component sources must be stationary (that is, point sources).

Inverse ICA

Available only for graphs produced by ICA. Reconstructs mixed signals based on the components and mixing matrix of the ICA graph. The statistical nature of the algorithm implies that it cannot perfectly reconstruct original source data—it estimates the most probable set of source signals. The graph is reconstructed in a new window, with a list of the components used pasted to the journal.

Find Cycle (Peak Detector)

 Watch the [six-part AcqKnowledge Find Cycle video tutorial](#) for a detailed demonstration of this feature.



The Find Cycle/Peak Detector setup dialog is accessed by choosing Analysis > Find Cycle, or using the Ctrl+F keystroke.

Overview

The advanced Cycle/Peak Detector combines with the powerful Event Marking System. Use it to perform amplitude, time, or event-based measurements. New output options for measurements, averaging, events, clustering (K-means), and 3D surface (cycle data, histogram, FFT, and DWT).

The Find Cycle detector uses three tabbed settings panels to define and automate cycle/peak detection:

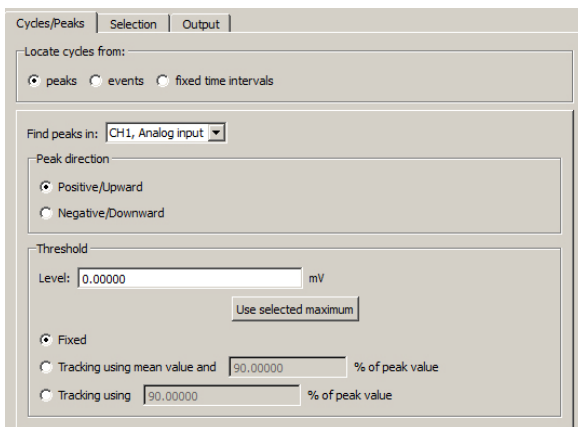
Cycles/Peaks Selection Output

Cycle detector settings are graph-independent, which means that find cycle/peak operations can be performed in multiple graphs without needing to re-enter graph-specific settings for each run. By using multiple data views, different find cycle/peak operation can be performed on the same set of data without losing settings between “Find Next Cycle/Peak” operations.

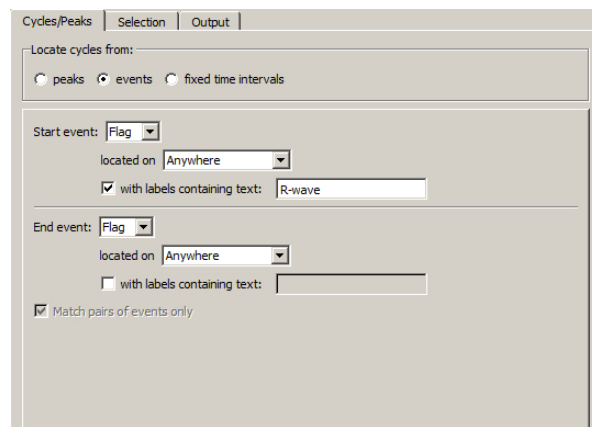
When the Cycle/Peak Detector is first opened for a graph, the dialog will be filled with the values from the last successfully executed find Cycle/Peak operation. Subsequently, changes to the settings will be applied only to that graph.

TIP When running the cycle detector multiple times and you need to put the edge back at the beginning of the waveform for the next pass, use the keyboard shortcuts Home, End, Page Up, and Page Down to quickly change edge location (see page 65).

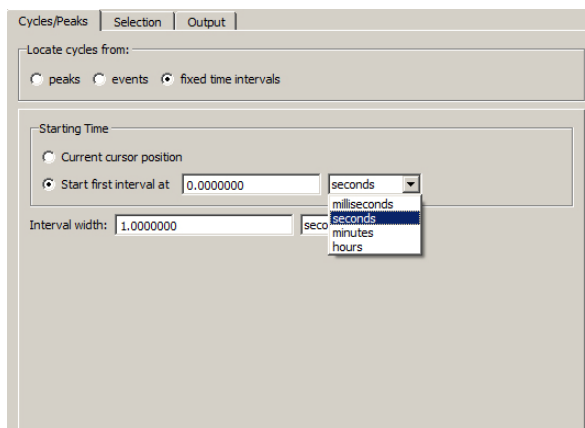
Cycles/Peaks tab



Peaks



Events



Fixed Interval



Find Cycle controls available at bottom of dialog

Find Next Cycle

When selected from the Analysis menu (or Ctrl+E), both edges will move one peak to the right while staying above the threshold.

Find All Cycles in Graph

When selected from the Analysis menu, Find Cycle setup dialog or selecting Ctrl+R, the software will find all cycles/peaks through the end of the file. If your data file is very large, it may take some time to find all the cycles since *AcqKnowledge* loads data from disk while it scans for the cycles.

Find in Selected Area

When selected from the Analysis menu or in the Find Cycle setup dialog, only cycles within a selected area will be detected, all others will be ignored.

Find All Cycles in Focus Areas

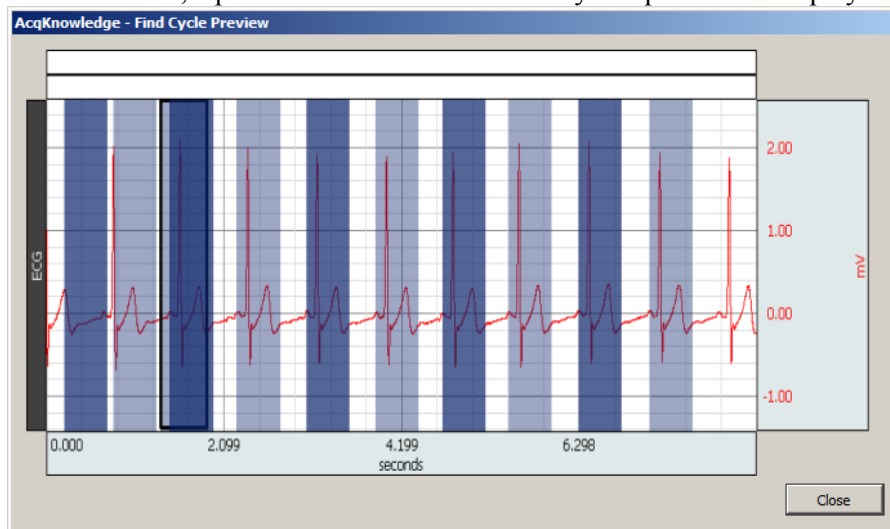
If the graph contains defined focus areas, this option will limit cycle detection to focus areas only. If no focus areas are defined, this option will not be available. This is selectable via the Analysis menu or in the Find Cycle setup dialog.

Find First Cycle

Use this option to apply changes to the Find Cycle setup and locate the first cycle. This is selectable via the Analysis menu or in the Find Cycle setup dialog.

Preview (Selection tab)

When selected, a preview of the selected Find Cycle operation is displayed prior to applying the settings.

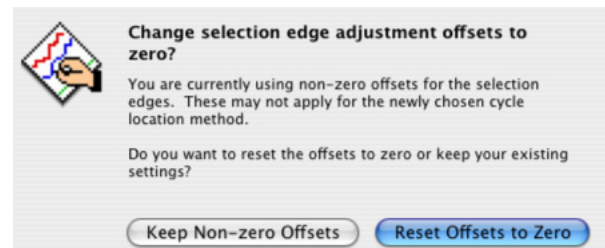


Find Cycle definitions

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 (see page 329)
- Events (see page 329)
- User-defined fixed time intervals (see page 329)

When the cycle location mode is switched on the “Cycles/Peaks” tab, the edge selection offsets will be checked. If they are non-zero, a prompt will appear, warning that that the edge adjustment offsets may not apply for the new cycle location mode. The user can reset the offsets to zero (default) or retain the (non-zero) settings used in the previous cycle location mode.



Peaks

Peak direction	Positive/Upward – searches for positive voltage spikes in the signal. Negative/Downward – searches for negative voltage spikes in the signal.
Level	<i>Important usage note</i> —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 the “Use selected maximum/minimum” button underneath the level. When changing the source channel or peak direction, also use this button to re-compute the recommended level based upon the new settings. The recommended level is “Tracking using % of peak value” (see below) using a percentage factor of 75%.
Threshold	Fixed —Keeps the threshold voltage level constant.
Tracking	The Tracking threshold mode modifies the threshold after it finds a peak, depending upon the value of the new peak, and will compensate for a slowly drifting baseline.

Hints regarding the use of Tracking Threshold Options

- If data has a very consistent cyclical nature, either Tracking Option will work.
- If data has spurious positive or negative peak values present, the Means Reference Tracking Option is a better choice.
- If data has an erratic baseline, but consistently sized, positive and negative peaks, the Peaks Reference Tracking Option is a better choice.

Tracking using mean value and % of peak value—Adjusts the threshold voltage level after each peak, based on the average of the last cycle’s data and the specified percentage of the current peak voltage. The Means reference option will determine the Mean Value of all the data, from peak to peak. This Mean Value establishes a variable reference upon which the tracking threshold operates. The software determines the new threshold (NT) as follows:

For Positive Peaks

$$NT = \text{Mean Value} + (\text{Positive Peak Value} - \text{Mean Value}) \times (\% \text{ factor})$$

For Negative Peaks

$$NT = \text{Mean Value} - (\text{Mean Value} - \text{Negative Peak Value}) \times (\% \text{ factor})$$

Tracking using % of peak value—Adjusts the threshold voltage level dynamically based on the specified percentage of the value of the most currently found peak. The Peaks reference option will determine the Positive Peak Value and Negative Peak Value of all the data, from peak to peak. The Positive and Negative Peak Values establish a variable reference upon which the tracking threshold operates. The software determines the new threshold (NT) as follows:

For Positive Peaks

$$NT = \text{Neg. Peak Value} + (\text{Pos. Peak Value} - \text{Neg. Peak Value}) \times (\% \text{ factor})$$

For Negative Peaks

$$NT = \text{Pos. Peak Value} - (\text{Pos. Peak Value} - \text{Neg. Peak Value}) \times (\% \text{ factor})$$

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 **interval start** (formerly “left edge” in AcqKnowledge versions 4.4.1 and earlier), later in time matches the **interval end** (formerly “right edge” in AcqKnowledge versions 4.4.1 and earlier). 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 produces 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 events not associated with any channel. Select “Anywhere” to search for events of specific types across channels.

With Labels optional Toggle the “With labels containing text” checkbox to set this option. When checked, the matching event’s label must contain the text in the edit box to the right of the checkbox.

- The text search is not case sensitive. The search must be non-empty for cycles to be located properly.

When unchecked, the matching event can have any label, including none.

The Cycle detector uses the following algorithm to search for cycles in the graph:

1. From the starting point, find the first event matching the criteria of the Start event. This will be defined as the *left event*. If no event matches the Start criteria, no more cycles are in the file.
2. If the Start event criteria match the Ending event criteria and zero width cycles are allowed (e.g. “Match pairs of events only” is unchecked), define the right event as identical to the left event and go to step 5.
3. From the location of the left event, find the closest event matching the criteria of the End event. This will be defined as the *right event*. If no event matches the End criteria, no more cycles are present in the graph.
4. Within the time region between the left and right events, search for any events that match the Start criteria. If such an event occurs, redefine the left event to be this matching event and repeat the step. If no event is located, then the closest pair of events has been located.
 - This step is useful for working with data that has missing portions of the sequence, as can come out of some classifiers. For example, if two event types A and B are used as the endpoints, a sequence of three events AAB will match the last two events as the cycle. This is logical in the case of physiological data where, if B should occur periodically in the signal, AA is an indicator of an abnormality or missed classification.
5. Set the selected area to the time interval whose endpoints are the left and right events.
6. Perform selection adjustment and output as indicated by the settings on the “Selection” and “Output” tabs.
7. If “Find All Cycles” is being performed, return to step 1 and use the ending event location as the new starting point to find any remaining cycles in the graph.

Fixed Interval

Fixed interval-based cycle detection is based upon cycles found in consecutive time intervals of a fixed width. The time width is user defined and the starting point of the cycle detection can be placed at the current location of the cursor, or to begin at an exact point of time in the graph.

Starting Time

☒ Current cursor position

☐ Start first interval at 0.000000 seconds

Interval width: 1.000000 seconds

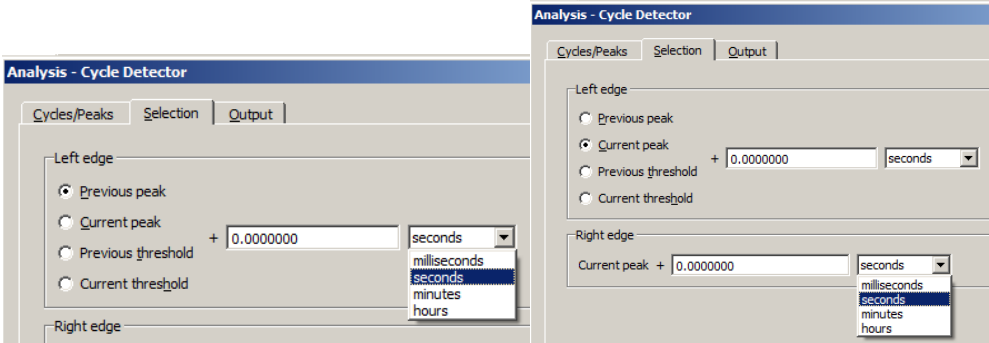
The time units for starting the first interval and setting the interval width can be selected in milliseconds, seconds, minutes or hours.

Selection tab

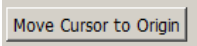
Use the Selection tab to adjust the range of data that will be analyzed to generate any output. By default, the data range is set to be the entire cycle as located by the settings on the Cycle/Peak tab, but it can be adjusted to analyze only specific portions of the cycle.

The controls on the Selection tab vary based on the settings on the Cycle/Peak tab

Peak When the Cycles/Peaks location method is “Peaks,” 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.



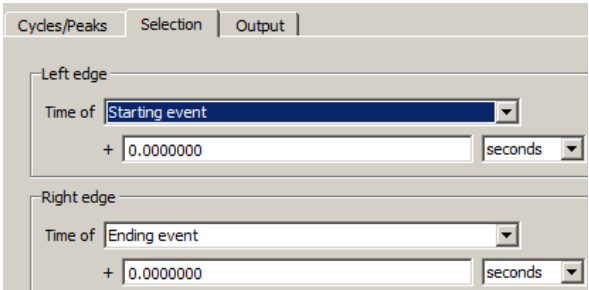
To perform analysis on the entire data within each cycle, the selection should be from the “previous peak” to the “current peak.” To examine fixed-width time windows located at each peak, use the “current peak” to “current peak” settings and adjust the two time offsets accordingly. Note that your settings must place the left edge earlier in time than the right edge for the peak detection to succeed properly.



“Move Cursor To Origin” (at bottom left of screen) sets the graph data selection back to the first sample. Use this to reset the cursor in order to find all of the data in the graph.

Event When the Cycles/Peaks location method is “Events,” 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.

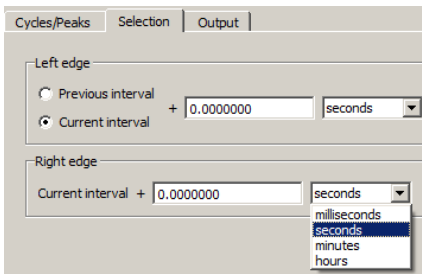


To analyze data over each entire cycle, use the “starting event” to “ending event” setting. To examine fixed-width time windows occurring within each cycle, set the left edge and the right edge to the same event (e.g. “starting event” to “starting event” for time windows at the beginning of each cycle) 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.

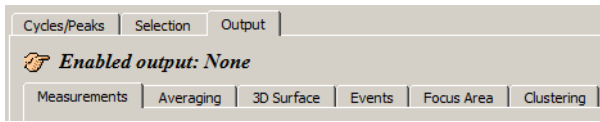
To analyze the data over each entire interval, use the “previous interval” to “current interval” setting.

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



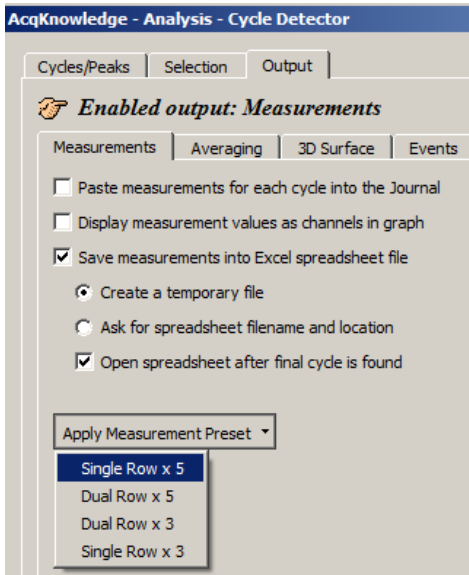
the time offsets accordingly. Note that your settings must place the left edge earlier in time than the right edge for the peak detection to succeed properly.

Output tab



The Cycle/Peak Detector includes six Output options, which can be independently enabled: Measurements, Averaging, 3D Surface, Events, Focus Area and Clustering. The selected output, if any, is listed at the top of the Output tab as Enabled output.

Output Measurements

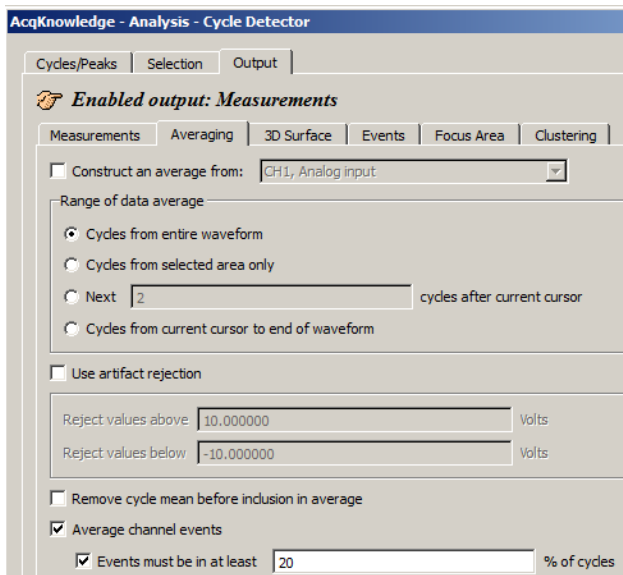


Toggle each checkbox to enable/disable the option:

- Paste measurements for each cycle to the Journal.
- Plot measurement results; display measurement values as channels in graph.
- Save measurements to Excel spreadsheet file, plus output options. In order for spreadsheet output to be generated, a “Find All Cycles” operation is required.
- Apply Measurement Preset – this option replaces the current measurement configuration with any of these selectable presets.

NOTE: If the horizontal axis is in world time (HH:MM:ss), any time measurement exported to Excel will be reported in standard time units, such as seconds or minutes.

Output: Averaging—Offline



Use “Averaging Output” to perform offline ensemble averaging of source data or ensemble averaging of event locations. Specify the channel where the cycles/peaks are to be located in the “Cycles/Peaks” tab and specify the channel whose data should be ensemble averaged in the “Average” controls on the “Output” tab.

Toggle the “Average channel events checkbox near the bottom of the tab to turn event averaging on and off.

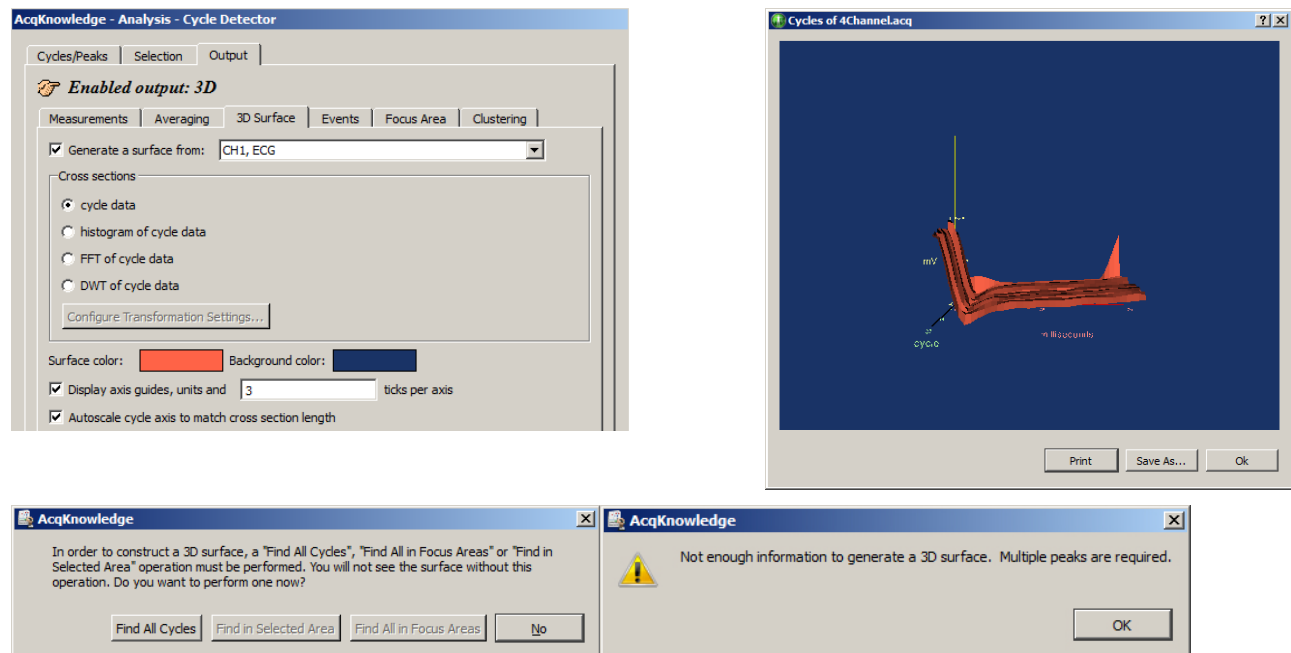
Offline averaging can produce average locations of events within the defined cycle along with the average data. When a cycle is found, any events in that cycle will be noted. Events that are on the channel of data being averaged will be examined for inclusion in the average.

Index

For each individual cycle, each event will be given an index starting at 0 and increasing to one less than the number of occurrences of that event type within the cycle. The time offset for each event from the start of its cycle will be averaged along with the offset for events with the same index from all other cycles. When the graph of the averaged data is produced, these average time offsets

- from the start of the cycle will be used to define new events for the averaged data. If the events and averaging interval were correlated with the data, the average event offset will produce a reasonable representation of the appropriate event locations for the averaged cycle.
- Average events reflect the accuracy of classifiers and the consistency of data used to locate each cycle.
- Label** Each event is labeled with the number of cycles contained in the event. Differences in the event sequence can cause spurious events to be inserted. The label helps in manual inspection for events that were only in one or two cycles.
- Rejection** Toggle the “Events must be in...” checkbox to turn rejection on and off, and specify a percentage for the relative number of cycles an event must appear in to be considered valid.
- Remove...** When mean removal is enabled, the mean value of the data within each cycle is subtracted prior to including it in the overall signal average. This mean removal option is useful for:
- Extracting signals that are “riding” on top of other signals with high DC offset (e.g., MRI artifact on top of skin temperature)
 - Compensating for baseline drift where there are not enough cycles present in the data for the baseline variation to completely cancel itself out.

Output 3D Surface



Toggle the “Generate a surface” checkbox at the top of the 3D tab to turn Surface Output on and off.

- 1) Choose a channel to generate a 3D surface from.
- 2) Confirm or establish the cycle period of interest on the channel.
 - Use the *Cycles/Peaks* tab and the *Selection* tab to adjust the threshold and edge positions for the cycle period for 3D output.
- 3) Choose a cross-section output format for the cycle data: cycle data, histogram, FFT, or DWT.
 - For histogram, FFT, or DWT, click “Configure Transformation” to change the settings.
- 4) Select surface and background colors.
- 5) Set axis options.
- 6) Click OK.

Use the 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.

- Cycles/Peaks tab: set the threshold level to identify each R-wave.
- Selection tab: set the edge to
Current Peak
Left edge -.5 seconds
Right edge .5 seconds
- On the Output tab
Enable 3D Output
Specify the channel to generate a surface from.
Choose “cycle data” for the cross-section format.
- Click Find All Cycles.

Output Events

Toggle the “Output events” checkbox at the top of the Events tab to turn Event Output on and off.

The Cycle/Peak Detector Output mode can define events at specific locations; a maximum of two events per cycle can be inserted with Event Output. After the Cycle Detector has located a cycle and adjusted the selection, the data within that cycle can be analyzed and used to create new events in the graph (data-driven or time specific).

Event definition

Insertion method & channel selection

Brief definitions follow, see the Event Location table on page 334 for details:

To place the event directly at the specified interval (start or end). See Interval Adjustment on page 333.

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 minimum of a specific channel's data within the selection.

The channel whose data should be examined is specified in the pull-down menu directly to the right of the insertion method pull-down menu:

Output type

For each insertion method, the “Output type” pull-down menu adjusts the event type of the inserted event.

Output channel

Sets the channel where the event is inserted, either “Global” for defining global events or specific channels.

- None—disables any insertion for that event and all of the other controls will be hidden except the insertion method pull-down menu.
- Interval start / Interval end—a pull-down menu is displayed to be used to change between the different offset methods
- Minimum / Maximum

Output label

Use this edit field to type in specific label text. Each event that is inserted will have its label set to this text. By default, it is empty (inserted events will not be labeled).

Interval Adjustment

When an “At location” method is used, options will be generated to fine-tune event placement relative to the Interval end or Interval start of the selection.

Offset

Underneath the insertion method pull-down menu, a set of controls will be added, allowing the user to specify the percentage, choose whether to search for an increase or decrease, and choose the channel whose signal should be examined.

The screenshot shows a dialog box titled "Event 1". It contains several controls: a pull-down menu for "Interval start" with "-2.5" selected, a pull-down menu for "Threshold crossing" with "+/-" selected, and a pull-down menu for "Output type" with "Star" selected. Below these, there is a text field for "Output channel" containing "CH1, Analog input". At the bottom, there is a text field for "Output label" containing "-2.5, Interval start, neg.".

When the offset method is “Threshold crossing,” the event will be placed when the signal on a channel crosses a threshold.

There are a number of possible ways to configure the threshold crossing:

- Fixed—The edit field may contain a specific voltage level for the threshold. In this configuration, an event will be placed if the value of the channel specified in the next pull-down menu crosses this fixed voltage value.
- + value—The edit field may specify an offset from the value of the channel at an interval start or end. The threshold voltage level is the value of the chosen source channel plus the offset from the edit field. To specify a threshold lower than the value of the channel at the interval start or end, choose the – value option. Mean and percentage of peak-to-peak + or – options are available as well.

Direction of crossing

The direction of the crossing can be specified.

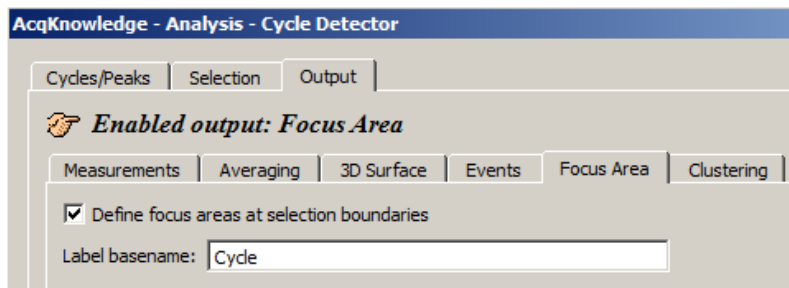
- + (positive crossing)—the signal must approach the threshold from below and cross to above the threshold before an event is inserted.
- - (negative crossing)—the signal must approach the threshold from above and cross to below the threshold before an event is inserted.
- ± (mixed threshold)—an event will be inserted at the first positive or negative crossing that is encountered.

Event Location Table

<i>Insertion Method</i>	<i>Location Process</i>
Interval, at location	Place an event at the left or right boundary of the selected area, as specified.
Interval +/- 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>Interval start + Place at the time closest to the left boundary of the selection. The percentage is calculated from the value of the signal at the left boundary of the selected area.</p> <p>Interval end - Place at the time closest to the right boundary of the selection. The distance between the event and the right edge of the selection will have an amplitude difference equal to the indicated percentage of the right edge's value.</p> <p>If the signal does not increase or decrease by that percentage within the selection, no event will be inserted.</p>
Interval +/- 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>Interval start + Place at the time closest to the left boundary of the selection. The percentage is calculated from the result of subtracting the minimum value of the signal over the selected interval from its maximum.</p> <p>Interval end - Place at the time closest to the right boundary. The distance between the event and the interval end of the selection will have an amplitude difference equal to the indicated percentage of the minimum value of the signal over the selected interval subtracted from its maximum.</p> <p>If the signal does not increase or decrease by that percentage within the selection, no event will be inserted.</p>
Interval +/- 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 interval + offset ▪ mean value in selected area + offset <p>Interval start + Search for the first location where the signal on a particular channel crosses the threshold.</p> <p>Interval end - 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 Focus Area

Use this tool to define and highlight focus areas within the graph and include them in the Find Cycle output.

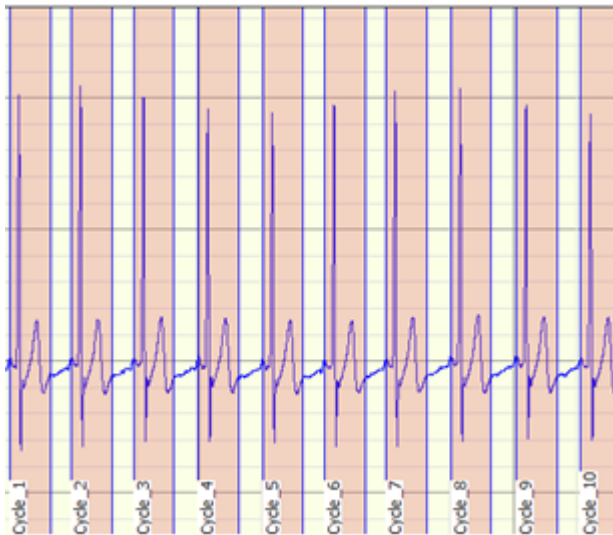


Define focus areas at selection boundaries

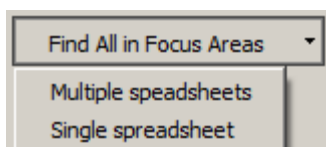
When checked, focus area output is enabled. Focus area selection boundaries will be defined as determined in the Find Cycle selection setup.

Label basename

Use to assign a name or label to the cycles located in the focus area. The defined basename will appear in the focus area section of the graph, along with incremented numbers for each subsequent cycle. (See below)



Find Cycle data derived from multiple focus areas can also be exported to either a single spreadsheet, or multiple spreadsheets. If the “Multiple” option is selected, each defined focus area will have data exported to a separate spreadsheet. (i.e., three focus areas will output three spreadsheets.)



Output: Clustering

Clustering is the process of taking a set of data points and partitioning them into a fixed number of groups called clusters. Each cluster represents data points that may share some type of commonality. This can be used to assign each data point to a class of similar points. Clustering can be used for hemodynamic analysis and is one of the basic analysis tools used for spike analysis in neurophysiology.

Algorithm Overview

K-means clustering is an iterative algorithm that begins with a data set of real-valued points in an n-dimensional space. Given this data set, one then specifies how many clusters are present. The k-means clustering algorithm attempts to find the location at the center of each of these clusters. Essentially, this

algorithm partitions the data set into k groups such that the sum of the differences between the centers of each group and its remaining members is minimized.

A basic algorithm description is:

- A. Given a total of k clusters, choose k potential cluster centers.
- B. Assign each member of the data set to a cluster according to the closest potential cluster center using a Euclidean distance function (sum-of-squares).
- C. Adjust the location of the potential center for each cluster to a more optimal value. The most basic method is to assign the new center to match the mean value of all of the members of the set.
- D. Determine if the set of clusters and centers is satisfactory. If not, go to step 2 and repeat the clustering process.

There are many different variations on what constitutes satisfactory ending conditions. The most ideal stopping criteria are when the cluster assignments no longer change with successive iterations. When there is no change in the centers, the solution perfectly minimizes the Euclidean distance sum for each cluster, unique up to variations in ordering of the dimensions. In practice, determining the perfect clustering of a data set is computationally intensive and may require some time to process. Approximations of perfect clustering are quicker to compute and usually produce sufficiently accurate results.

A waveform segment is reduced to a single data point by extracting numerical quantities known as *features*. *Feature clustering* is a very common data reduction method in use by clustering-based spike sorting software. Each feature is a single real-valued number extracted from the data. Examples of features are: maximum amplitude in waveform segment, minimum, time to maximum, time to minimum, peak to peak distance, sum of all values, maximum slope of peak.

A commonly used clustering analysis starts with two features. The features are then calculated for each waveform segment and presented on a scatter plot, allowing the user to visually determine how many clusters may be present. A k -means clustering analysis is then run on these data points to determine the center of the clusters in feature space. With the center known, each waveform segment is then assigned to a cluster depending on the values of its features.

Clustering Settings

Enabled output: None

Measurements Averaging 3D Surface Events Focus Area **Clustering**

Preset: none [New Preset] [Delete...]

Settings Criteria Output

Source channel: CH1, ECG

Number of clusters: 2

Cluster Centers

Locate: ☒ manually ☐ by learning

	Center #	Criteria 1
1	1	0.000000
2	2	0.000000

☒ Remove outliers: 2 x stddev. of cluster

[Find in Selected Area] [Find All in Focus Areas] [Find All in Graph] [Find First Cycle]

[Preview] [OK] [Cancel]

Enabled output: None

Measurements Averaging 3D Surface Events Focus Area **Clustering**

Preset: none [New Preset] [Delete...]

Settings Criteria Output

Source channel: CH1, ECG

Number of clusters: 2

Cluster Centers

Locate: ☐ manually ☒ by learning

Training set: all data

Max. iterations: 100

Tolerance: 1e-05

☒ Remove outliers: 2 x stddev. of cluster

[Find in Selected Area] [Find All in Focus Areas] [Find All in Graph] [Find First Cycle]

[Preview] [OK] [Cancel]

Number of clusters

After features have been extracted, data points constructed from the feature are split up into a number of groups. Enter the number of clusters into which the data is to be partitioned.

Locate Cluster Centers

Clustering has a good potential to form the basis for classifiers to score physiological data. The cluster centers can be located by keeping their centers fixed and manually setting the cluster centers (above left) or by automatic learning, which dynamically locates the cluster centers based upon a training set of all data, a subset of data based upon a percentage, or based upon a selected event in the data.

Manually

The manual method allows the centers of each cluster to be manually typed in and edited. Instead of running a full k-means algorithm to locate centers, the k-means algorithm will simply run through the data set and assign each element to the closest cluster center and apply any outlier detection.

This simplistic clustering will allow centers as computed from a previous run to be used in subsequent clustering. Using manually specified centers is necessary to provide consistency when clustering data that may occur in different experiments or different graph files. The use of manual centers allows for the clustering implementation to be used as a classifier to compare new data sets to clusters as determined from either ideal or previously scored data sets.

By Learning

The learning method will use the full k-means clustering algorithm as described above. This consists of choosing candidate centers, computing mean distances, adjusting the candidate center positions, and repeating until termination conditions are met.

The data set used to compute the center positions can either be the full data set, a subset of the data or an event within the data set.

Training Set Definition

The training set is the set of data that is used during the iterative portion of the clustering algorithm that learns the potential center of each cluster. Training sets are only used for learned centers. There are three ways to specify a training set for use in clustering:

- Use all 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. There are a number of reasons to perform partial clustering. One is computational efficiency. K-means clustering can be a time intensive procedure, as each iteration of the algorithm must recompute all of the distances to reclassify the entire data set. By performing partial clustering, it is possible to reduce the complexity of the k-means clustering step by limiting the amount of source data that needs to be processed in each step. This may be acceptable in situations where perfect partitions are not required.

Another use of partial clustering is to construct a *classifier*. A classifier is some method for assigning a particular data point to a specific class. To construct a classifier using k-means clustering a k-means algorithm is run on a training set that has known desirable data properties for splitting data into a number of classes. Once the centers of this training set are known, they can be used to perform another clustering analysis on a set of unknown data and determine how well that data exhibits the properties of the training set.

Max. iterations

This field is used for entering the maximum number of iterations the k-means algorithm is run. If the specified number of iterations is reached, processing will halt and no centers will be located.

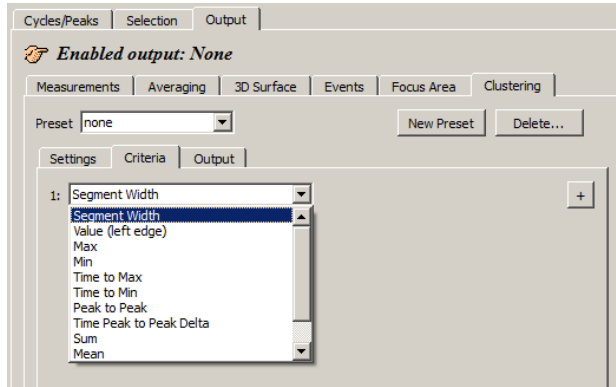
Tolerance

This value represents the minimum distance allowed for center adjustment. If the centers move by less than this value in subsequent learning steps, they will be considered stable and clustering will commence.

Remove Outliers

The clustering analysis allows for optional removal of outliers, or spurious data points. When enabled, each cluster is assigned a boundary. After each data point has been assigned to the cluster, the standard deviation of the distance of each point from the center of the cluster is computed. When outlier rejection is enabled, any data point that is farther away from the center than a specific number of standard deviations will be removed from the cluster. Enabling outlier removal retains only the points in a cluster that have the strongest association with each other.

Clustering Criteria



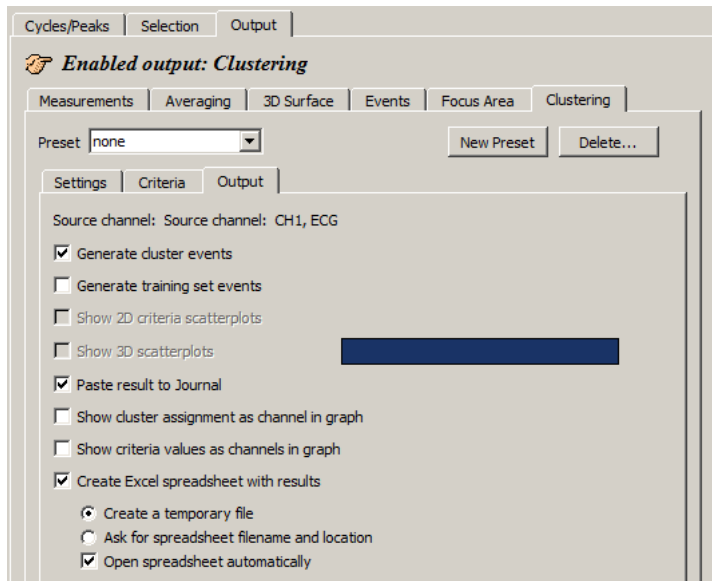
For a particular segment of a waveform, features are extracted based upon user-specified criteria.

Segment Width	Peak to Peak
Value (left edge)	Time peak to Peak Delta
Max	Sum
Min	Median
Time to Max	Mean
Time to Min	Measurement Result

Multiple segments are located using the Find Cycle/Peak functionality. After the criteria have been computed for each segment, clustering is then performed. This allows segments to be partitioned based upon their features. For example, “Segment Width” criteria can be used to partition ECG cycles into two clusters of shorter segments and longer segments.

The criteria Segment Widths are reported in milliseconds, as are the other time-based criteria (Time to Max; Time to Min; and Time Peak-to-Peak Delta). If the measurements are fixed to units of milliseconds, then K-Mean Criteria results will match measurement magnitude results. Clustering is defined with a hard left to right directionality for all measurements. Therefore, Delta T will have opposite signs than the same measurement pasted with Find Peak.

Clustering Output



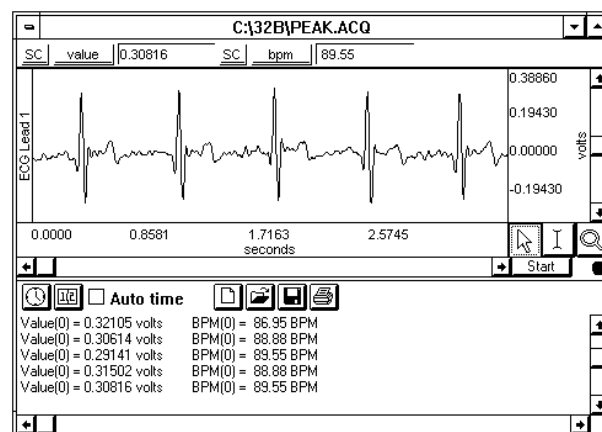
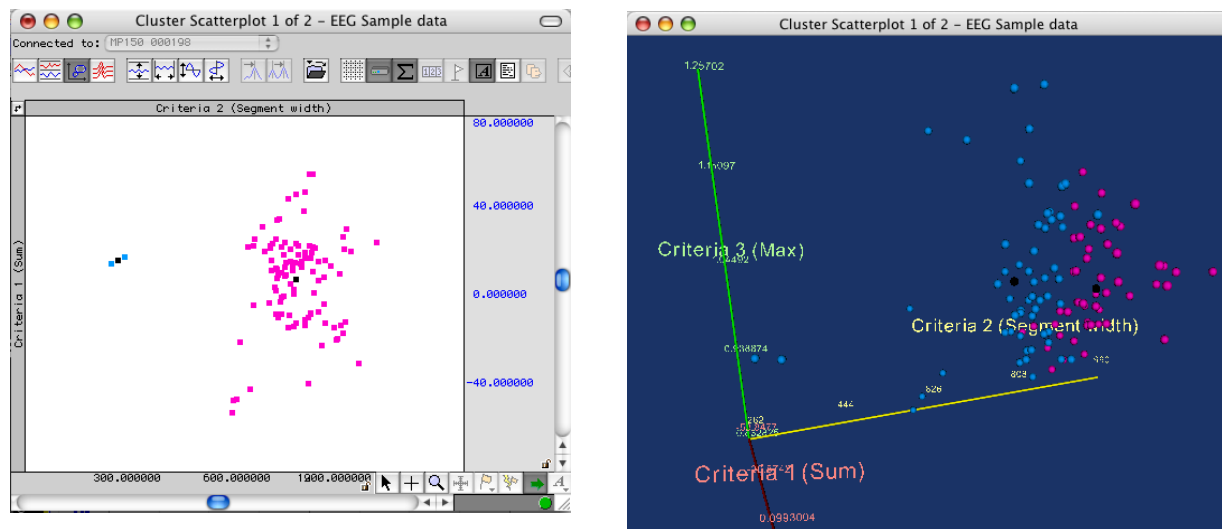
The output of a clustering analysis can be presented in multiple ways, including events, waveforms in the graph, textual tables, and visual scatterplots. These outputs allow for visual examination of the clustering results for anomalies and also provide a foundation for further data reduction using other 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.

One of the traditional methods of presenting results of a k-means analysis is through scatterplots. Scatterplots are dot plots with a

single dot per waveform segment run through the k-means clustering algorithm. They provide good visual references that can be used to estimate the potential number of clusters actually present in data and to compare the distinguishing abilities of different sets of criteria.

The scatterplot can be extended into three dimensions to provide feedback on relations between three criteria at the same time. With each criterion assigned to one of the three coordinate axes, a small sphere centered around the criteria values for a waveform segment can be constructed. Displaying the spheres for all data points would create the 3D scatterplot.

To generate 3D criteria scatterplots, select at least three criteria. There is also an option to change the 3D scatterplot background color and export results to an Excel spreadsheet. (See example scatterplots, next page).



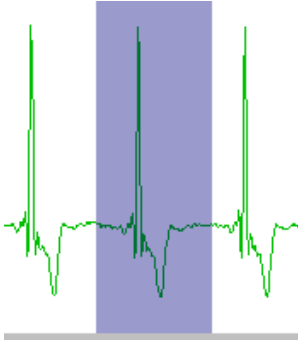
If the “Paste measurement to Journal” preference is set, measurement values will be pasted into the Journal each time a cycle is found, as shown above. Each column corresponds to a measurement value (in this case, Value and BPM).

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 Cycle (peak detection) function.

1. Select the area around a typical peak.

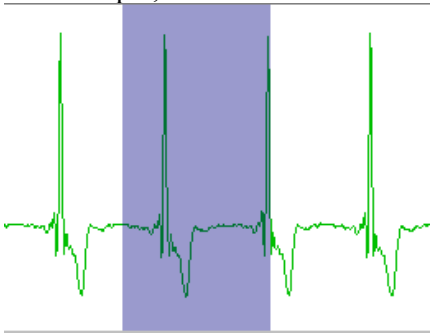


2. Select Find Cycle (Locate cycles from peaks).
3. Enable “Use selected maximum” on the Cycles/Peaks tab to automatically set an appropriate threshold value based on the amplitude of the cycle detector.
4. Click the Output tab and choose the desired option(s), such as paste measurement controls to update the journal with the measurement values from the new peak.
5. Click a Find button.
 - Find first cycle – the edge will blink at the first cycle point
 - To manually move through the file, click Find next
 - Or, select an area and choose Find all
 - Or, place the edge in the data and Find all will detect cycles from that point forward.
 - Find All Cycles will find all cycles from the beginning of the selected area to the end of the waveform.
 - Find in Selected Area will only find cycles in the selected area.
 - Find in Focus Area will only find cycles in focus areas.

To use an offset

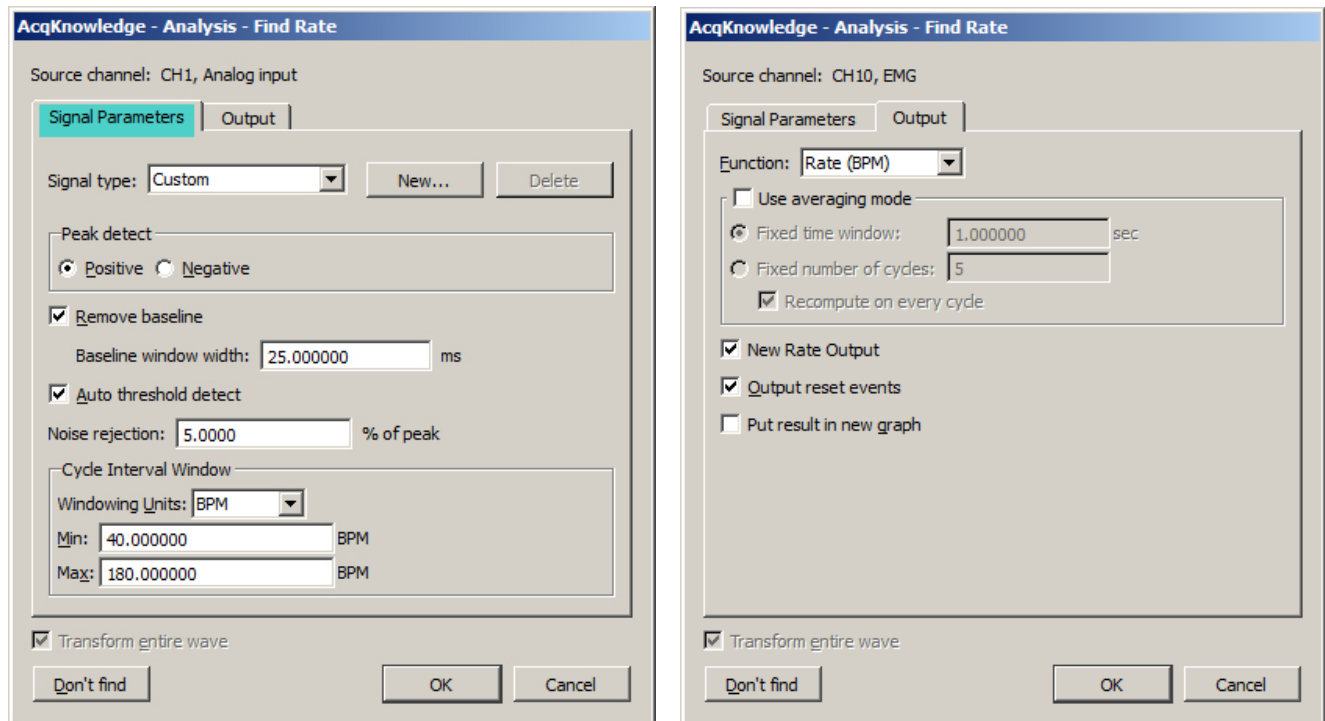
Use the Selection controls to set a time window around the selected cycle; previous peak controls the left edge, Current peak has options to control the left and right edges.

1. Use steps 1-4 above.
2. Click the Selection tab.
3. Set the desired edge values.
 - For example, to set the time window 0.5 seconds *prior* to the previous peak.



To control the left and right edges, select current peak and enter the appropriate time window to define an interval around the cycle.

Find Rate



The Rate Detector is critical to *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.

Rate detector settings are graph-independent, which means that find rate operations can be performed in multiple graphs without needing to re-enter graph-specific settings for each run. By using multiple data views, different find rate operations can be performed on the same set of data without losing settings between "Find Rate" operations. When the Rate Detector is first opened for a graph, the dialog will be filled with the values from the last successfully executed Find Rate operation. Subsequently, changes to the settings will be applied only to that graph.

Modes of Operation

The Rate Detector incorporates a significant amount of flexibility to optimize performance when extracting data from periodic physiological waveforms. There are three basic modes of operation for the Rate Detector:

- 1) Fixed threshold detect mode
- 2) Auto threshold detect mode (enables Noise rejection)
- 3) Remove baseline and Auto threshold detect mode

Generally, it's best to use the simplest Rate Detector mode 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.

1) Fixed threshold detect mode:

Fixed threshold detect mode is the simplest mode of operation for the Rate Detector. As shown here, the Threshold Level has been set to 0.00 Volts. If the waveform crosses 0 Volts, the Detector will begin to look for Positive or Negative peaks (based on the Peak detect setting).

Not available in Fixed mode:

Noise rejection

Baseline window width

Windowing options

2) Auto threshold detect mode:

Auto threshold detect mode is a more advanced and flexible mode of operation for the Rate Detector. In this case, the Rate Detector will create a variable threshold defined as:

Positive peak search

$$0.75 \cdot (\text{Old Peak Maximum} - \text{Old Peak Minimum})$$

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:

$$\text{Hysteresis} = \text{Noise rejection (\%)} \cdot (\text{Old Peak Maximum} - \text{Old Peak Minimum})$$

Signal Parameters | Output

Signal type: Custom [New...]

Peak detect
☒ Positive ☐ Negative

☒ Remove baseline
 Baseline window width: 25.000000 ms

☒ Auto threshold detect
 Noise rejection: 5.0000 % of peak

Cycle Interval Window
 Windowing Units: BPM
 Min: 40.000000 BPM
 Max: 180.000000 BPM

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:

$$\# \text{ of points} = (\text{baseline window width} / 1000) * \text{Sampling Rate}$$

This difference waveform is then passed through the variable threshold:

$$\text{Positive peak search} = 0.75 \cdot (\text{Old Peak Maximum} - \text{Old Peak Min})$$

$$\text{Negative peak search} = 0.25 \cdot (\text{Old Peak Max} - \text{Old Peak Min})$$

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

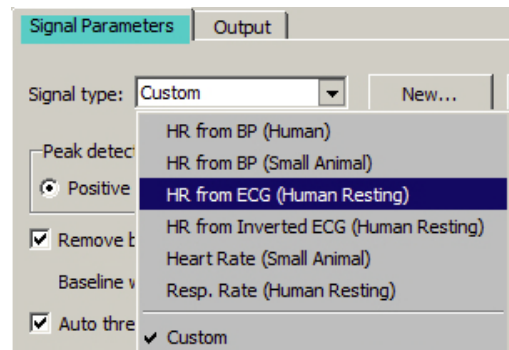
the window), the threshold is changed to the mean value of the moving file of data points. This operation permits successful recovery in the event of spurious waveform data values.

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>

Signal type

The Signal type menu contains parameters for specific human and animal waveform morphologies. All pre-defined and custom signal types are common to both calculation channel Rate (online) and analysis Rate (offline) dialogs. Signal type modifications affect settings in the Signal Parameters tab only, and do not affect the Output tab settings.

Select from six pre-configured signal types or click “New” to create, name and save custom setups. This allows quick access to frequently used Rate detection signals without the need to recreate modified settings. Custom Rate signal types may be added or deleted in the same manner that channel presets are in other areas of the AcqKnowledge application.



Peak detect

By default, the Peak Detector searches for Positive peaks (upward pointing, such as the R-wave of an ECG signal) to calculate the rate of a waveform. In some instances, however, 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 a difference operation to preprocess the signal. This option is useful when signals have a slowly fluctuating baseline.

Auto threshold detect

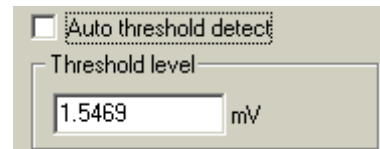
When the Auto threshold detect box is selected in the Find Rate dialog, AcqKnowledge automatically computes the threshold value using an algorithm that accentuates peaks and uses information about the previous peak to estimate when and where the next peak is likely to occur. This threshold detector is 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.

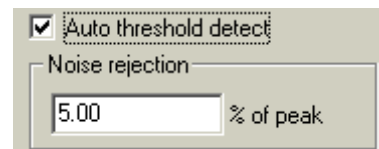
- The Auto threshold detect option is typically more accurate.



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.

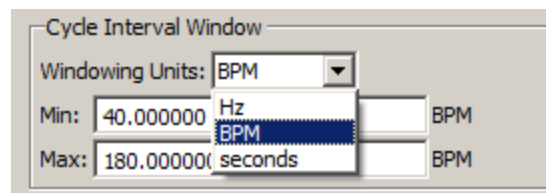
- The default is equal to 5% of the peak-to-peak range.



Cycle Interval Window

The Cycle Interval Window is used to specify an upper and lower limit for the Rate calculation. Window is activated when “Auto threshold detect” is enabled; the Windowing Units pull-down menu is only activated when the selected Function can have variable units. (Hertz, BPM or Seconds.)

Setting the upper and lower bounds for the “window” tells AcqKnowledge when to start looking for a peak.

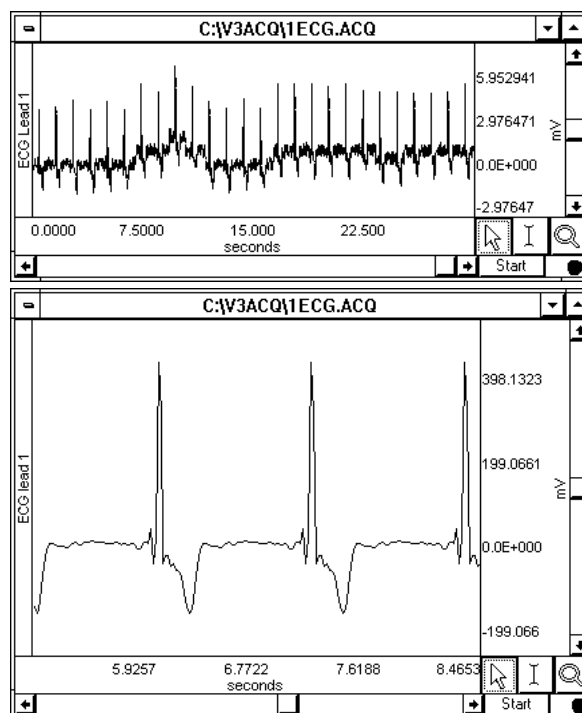


Defaults: Min 40 BPM
Max 180 BPM

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 ($60 \text{ seconds} \div 180 \text{ BPM}$), and the interval for the lower band is 1.5 seconds ($1 \text{ minute} \div 40 \text{ BPM}$). 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.

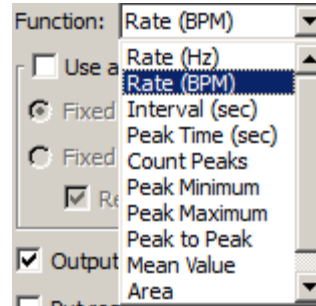
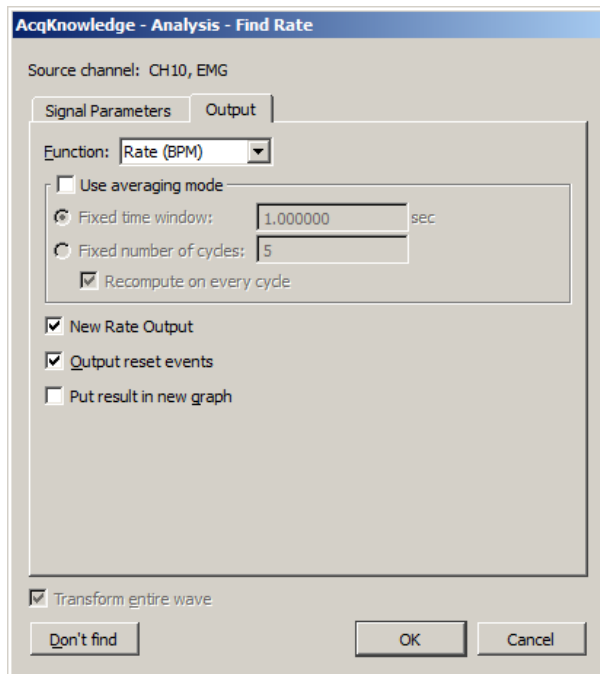


Window (Peak Interval)

A simple peak detector uses what is called a *threshold-crossing algorithm*, whereby each time the amplitude (vertical scale) value exceeds a given value, the peak detector “remembers” that point and begins searching for the next event where the channel crosses the threshold. The interval between the two occurrences is then computed and usually rescaled in terms of BPM or Hz. This is how the *AcqKnowledge* rate Calculation functions when all options are unchecked.

In the sample waveform shown here, the threshold was set to 390 mV to detect the peaks of the waveform and provide an accurate rate calculation. Since it only recognizes signals greater than 390 mV as a peak, this 390-mV threshold is referred to as an “absolute threshold.” Most waveforms are not so well behaved, however, and artifact can be introduced as a result of movement, electrical interference, and so forth. Combined with actual variability in the signal of interest, this can result in “noise” being included with the signal, as well as baseline “drift” can render absolute threshold algorithms useless.

Additional Find Rate Dialog Settings, Output Tab



Function

The Rate Detector Function menu lists a variety of calculations, which are discussed below.

Rate (Hz), Rate (BPM), Interval (sec)

The most commonly used function is the Rate (BPM) option, which calculates a rate in terms of beats per minute or BPM. Rate calculations can also be performed that return a rate value scaled in terms of frequency (Hz) or time interval (sec). When rate is reflected in terms of a time interval, the time difference (delta T) between the two peaks is returned. This is sometimes referred to as the *inter-beat interval* (IBI). The frequency calculation returns the rate in Hertz (Hz), which is computed by dividing 1 by delta T. These measurements are perfectly correlated with the BPM calculation, since BPM is equal to 60 times the frequency calculation, or 60 divided by delta T.

Peak time

Returns the time (in seconds) at which the peak occurred. Like the other Rate functions (e.g., BPM and Hz), the value of the last peak time will be plotted until a subsequent peak is detected. The resulting plot will resemble a monotonically increasing “staircase” plot.

Count peaks

Produces a plot of the number of peaks (on the vertical axis) vs. time on the horizontal axis. When used with the delta measurements (in the measurement windows), this is a convenient way to calculate how many peaks occur within a selected area.

Peak maximum/minimum

Tracks the maximum value of the peak (the ECG R-wave). This correlates to the systolic pressure in blood pressure readings. To search for minimum peak values, select negative from the Peak detect section of the dialog.

Peak-to-peak

Looks at the vertical difference between the maximum and minimum values of the waveform on a cyclical basis—useful when 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

This function computes the area of the signal between two peaks, on a cycle-by-cycle basis.

Sum (not shown)

This function extracts the sum of all amplitudes for each cycle.

Use Averaging Mode

Use this option to average the output of the selected function using values based upon a fixed time window or a fixed number of cycles. If the average is taken from a fixed number of cycles, there is an additional option to recompute on every cycle. When unchecked, the output will be reset after the selected number of cycles are detected and remain fixed until the next group cycles are detected. When checked, the output will start after the first cycle is detected and will then be refreshed on every cycle.

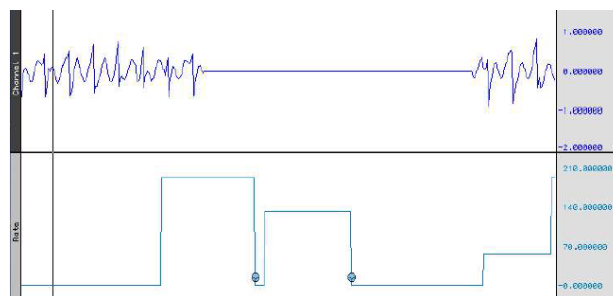
Output reset events

This option controls the definition of reset event insertion into the graph.

If no thresholds are found within the user-specified window width, the automatically detected threshold level will “reset” and tracking will start anew; the output of the rate detector function may also drop to zero. When “Output reset events” is enabled, a reset event will be added to the channel whenever the threshold is reset due to window expiration

- This helps distinguish zero-valued output due to window resetting and true zero-value output.

In the sample shown, the signal drops to zero during a period of analysis (e.g., due to lead clip falling off). Reset events indicate automatic threshold tracking was lost in this interval and the points where the search for a new level begins.



Put Result in New Graph

When this option is checked, the results from the find rate calculation are plotted in a new graph window with data displayed in X/Y format, with time on the horizontal axis. By default, this option is unchecked and the resulting transformation is placed in the lowest available channel of the current graph.

NOTE: When put into a new waveform or used as a calculation channel, the output rate function uses padding to generate a signal at a continuous sampling rate. The extracted value is used for padding until the next cycle is detected. This padding can cause unsuitable weighting for statistical analysis. For accurate statistical analysis with only one value for each cycle, use the offline rate detector "show output in new window" to produce a "value" waveform with one output point for each cycle. This output is suitable for export to Excel or other software for statistical analysis.

Find Rate of Entire Wave

When this option is checked, the rate (or other function from the Find rate command) will be calculated for the entire wave (other than the selected area, if any).

Don't Find

Saves dialog settings so 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 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.

A courtesy copy of the Specialized Analysis package is installed under the Analysis menu with AcqKnowledge™ 4.

See the next chapter for full details.

Chapter 17 Specialized Analysis

Detect and Classify Heartbeats	
Locate Human ECG Complex Boundaries	
Locate Animal ECG Complex Boundaries...	
Gastric Wave Analysis...	
Gastric Wave Coupling...	
Vibromyography Filter	
Actigraphy	▶
Chaos	▶
Correlation Coefficient	
Electrodermal Activity	▶
Electroencephalography	▶
Electromyography	▶
Ensemble Average	
Epoch Analysis	
Focus Areas	▶
Hemodynamics	▶
HRV and RSA	▶
Impedance Cardiography	▶
Magnetic Resonance Imaging	▶
Neurophysiology	▶
Noldus	▶
Pressure-Volume Loop	▶
Principal Component Denoising	
Remove Mean	
Remove Trend	
Respiration	▶
Spectral Subtraction	
Stellar	▶
Stim-Response	▶
Waterfall Plot	
Wavelet Denoising	

The Specialized Analysis package includes comprehensive analysis tools to automate analysis to save hours (or days!) of processing time and standardize interpretation of results.

- AcqKnowledge™ 4 includes a courtesy copy of the Specialized Analysis Package under the Analysis menu.

Specialized Analysis provides extensive post-acquisition analysis options similar to modules from Mindware Technologies, PONEMAH Physiology Platform, EMKA Technologies, SA and other advanced analysis applications. If 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%.

Analyze data collected on Hardware Systems with Windows OS or Mac OS X.

*See the **Analysis** menu on page 313 for other operations that derive data and measurements from the graph:*

Histogram
Autoregressive Modeling
Nonlinear Modeling
Power Spectral Density
AR Time-Freq Analysis
FFT
DWT
Principal Component Analysis
Independent Component Analysis
Find Cycle
Find Next Cycle
Find All Cycles in Focus Area
Find All Cycles
Find In Selected Area
Find Rate

The Specialized Analysis package includes the following Analysis Packages and Classifiers:

Analysis package—bundle of transformations created to assist with analysis in a specific area of research.

Classifier—special-purpose transformation that defines events at well-known points of interest on standard waveforms, such as the ECG wave boundary classifier and the QRS beat detector and arrhythmia detector.

Detect and Classify Heartbeats
 Locate Human ECG Complex Boundaries
 Locate Animal ECG Complex Boundaries
 Gastric Wave Analysis
 Gastric Wave Coupling
 Chaos Analysis
 Detrended Fluctuation Analysis
 Optimal Embedding Dimension
 Optimal Time Delay
 Plot Attractor
 Correlation Coefficient
 Electrodermal Activity
 Derive Phasic EDA from Tonic
 Event-related EDA Analysis
 Locate SCRs
 Preferences: Output Display Format; Phasic EDA
 Construction Method: Smoothing Baseline Removal or
 High Pass Filter
 Electroencephalography
 Compute Approximate Entropy
 Delta Power Analysis
 Derive Alpha-RMS
 Derive EEG Frequency Bands
 EEG Frequency Analysis
 Remove EOG Artifacts
 Seizure Analysis
 Preferences: Output Display Format
 Electromyography
 Derive Average Rectified EMG
 Derive Integrated EMG
 Derive Root Mean Square EMG
 EMG Frequency & Power Analysis
 Locate Muscle Activation
 Preferences: Output Display Format
 Ensemble Average
 Epoch Analysis
 Focus Areas
 Define Between Events
 Define for Appended Segments
 Hemodynamics
 Classifiers: ABP; LVP; MAP
 Arterial Blood Pressure
 Baroreflex Sequence Analysis (licensed feature)
 Baroreflex Slope Analysis (licensed feature)
 ECG Interval Extraction
 Estimate Cardiac Output from ABP
 Left Ventricular Blood Pressure

Monophasic Action Potential
 Preferences: Output Display Format; LVEDP Location
 Method; dP/dt pk-pk %; MAP Plateau Location Method;
 dP/dt MAP pk-pk %
 HRV and RSA
 Multi-epoch HRV – Statistical
 Multi-epoch HRV and RSA – Spectral
 R-R Poincare Plot
 RSA – Time-series
 Single-epoch HRV – Spectral
 Impedance Cardiography
 Body Surface Area
 ICG Analysis
 PEP Pre-ejection Period
 dZ/dt Derive from Raw Z
 dZ/dt Classifier: B, C, X, Y, and O Points
 dZ/dt Remove Motion Artifacts
 Preferences: Output Display Format; C-, B-, and X-Point
 Location; Stroke Volume Calculation Method; Body
 Measurement Units; Body Surface Area Method; Ideal
 Weight Estimation Method; dZ/dt Max Method
 Magnetic Resonance Imaging
 Artifact Frequency Removal
 Artifact Projection Removal
 Median Filter Artifact Removal
 Neurophysiology
 Amplitude Histograms
 Average Action Potentials
 Histograms
 Generate Spike Trains
 Episodes
 Find Overlapping Spike Episodes
 Set Episode Width and Offset
 Preferences: Detect Spike; Default Episode Width; Default
 Episode Offset; Default # of Spike Classes
 Noldus
 Principal Component Denoising
 Remove Mean
 Remove Trend
 Respiration
 Compliance and Resistance
 Penh Analysis
 Pulmonary Airflow
 Spectral Subtraction
 Stim-Response
 Digital Input to Stim Events Stim-Response Analysis
 Waterfall Plot
 Wavelet Denoising

AcqKnowledge File Portability

Use Specialized Analysis to analyze AcqKnowledge data files collected on Hardware Systems running on Windows/PC or Mac OS X. Open/save the following file formats:

Opening files for Specialized Analysis

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.

Graph (*.acq)
 Graph Template (*.gtl)
 Text (*.txt *.csv)
 Journal (*.jq *.bt)
 Journal Template (*.jtl)
 Windows AcqKnowledge 3 Graph (*.acq)
 Macintosh AcqKnowledge 3 Graph (*.acq)
 Advanced Averaging Experiment (*.aae *.avg)
 PhysioNet - WFDB (*.wfdb)
 MATLAB Mat-File (*.mat)
 Raw (*.raw)
 Batch Acquisition (*.bcq)
 Igor Pro Experiment (*.pxp)
 WAV (*.wav)
 Biopac Student Lab PRO Graph (*.acq)
 EDF (*.edf *.eeg)

File Compatibility

- Mac AcqKnowledge 3.9 and above can open and create PC-compatible Graph (*.acq) and Graph Template (*.gtl) files. Variable sampling rate information and hardware settings are retained, and Journals can be read from and written to PC files. Files must end on a multiple of the lowest channel sampling rate to be fully PC compatible.

Saving files after Specialized Analysis

Graph (*.acq)
 Graph Template (*.gtl)
 Text (*.txt *.csv)
 Windows AcqKnowledge 3 Graph (*.acq)
 PhysioNet - WFDB (*.*)
 MATLAB Mat-File (*.mat)
 Raw (*.*)
 Igor Pro Experiment (*.pxp)
 WAV (*.wav)
 EDF (*.edf *.eeg)
 JPEG (*.jpeg)
 Compressed Graph (*.acq)
 Excel Spreadsheet (*.xls)

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 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.

File > Save Selection As allows you to save only a portion of your file. When this 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.

Saving Files AcqKnowledge 4

File Compatibility

Windows AcqKnowledge 3.9 and above files can be opened with Mac AcqKnowledge 3.9 and above, but some advanced features may not transfer.

Mac AcqKnowledge 3.9 and above 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 and above can save PC-compatible Graph (*.acq) and Graph Template (*.gtl) files. Variable sampling rate information and hardware settings are retained, and Journals can be read from and written to PC files. Choose the format “Graph (Windows)” to create PC-compatible files.

The Mac version does not save 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—The Specialized Analysis tools have been updated to automatically export their results to an Excel spreadsheet if desired. The spreadsheet contents mirror the tabular Journal text output. All the spreadsheets are saved as temporary files, so they need to be re-saved in order to be saved permanently.

- Also available for File > Save As, File > Save Journal Text As, and Find All Cycles journal.

Note Specialized Analysis scripts are complex and undo may not function for all steps.

Some of the specialized algorithms are very complex and processor intensive, so they may take a long (even very long) time to return a result.

Most specialized analysis operations create additional channels in the graph, thus changing the underlying data in the source channel. In this instance, attempting to acquire appended data into the source channel of a graph that has had an analysis operation applied will result in a standard message: “You have modified or edited data in a way that prevents appending acquisition. You can replace the existing data or abort.” This is normal for analysis operations that have modified the underlying graph data. Under this circumstance, all analysis operations will generate this message with the exception of the following:

- DWT/IDWT
- HRV
- ICA/IICA
- PCA/IPCA
- Detect and Classify Heartbeats
- Power Spectral Density
- Nonlinear Modeling

In AcqKnowledge 4.3 and later, an option to perform analysis on the entire graph or on the focus areas only is presented in setup dialogs for most Specialized Analysis tools. (This option not present in earlier AcqKnowledge versions.)

Analyze: ☒ entire graph
☐ focus areas only

Detect and Classify Heartbeats



This robust QRS detector is tuned for human ECG Lead II signals. It locates QRS complexes and places an event near the center of each QRS complex to identify the type of heartbeat event:

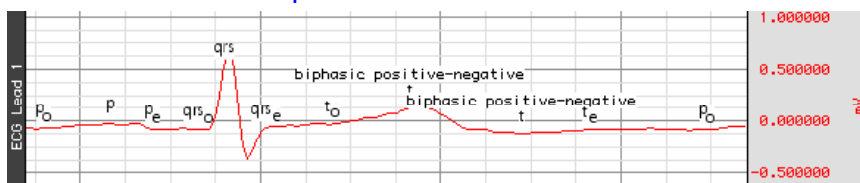
- Normal: The beat was recognizable as a valid heartbeat falling in a human heartbeat rate.
- PVC: The beat was shorter than the beats around it and may be a pre-ventricular contraction. These events can be found in the “Hemodynamic > Beats” submenu of the event type listing.
- Unknown: The beat wasn’t recognizable as a valid heartbeat. This may occur on the first beat prior to the QRS detector locking onto the signal. It may also occur if tracking is lost due to changes in signal quality.

The Cycle/Peak detector may be used with these events to perform further cardiac analysis.

For information on the algorithm used in Detect and Classify Heartbeats, see page 426.

▶ Watch the [AcqKnowledge Detect and Classify Heartbeats video tutorial](#) for a detailed demonstration of this feature.

Locate Human ECG Complex Boundaries



Locate Human ECG Complex Boundaries performs ECG waveform boundary detection for human ECG Lead II signals; ECG signals must be sampled at 5 kHz or below to be analyzed with this classifier. It will attempt to locate the boundaries of the QRS, T, and P wave and will define events for each individual complex. It will attempt to insert the following events; all of these complex boundaries can be found in the “Hemodynamic > ECG Complexes” submenu of the Event Type listing.

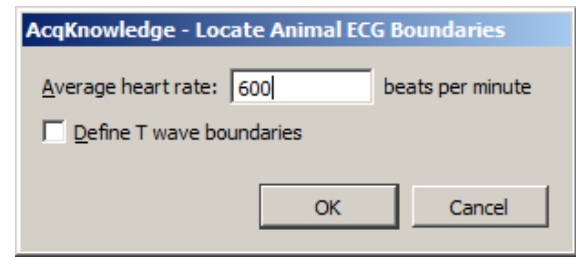
Wave	Type	Event Placement & Description
QRS	Onset	Before the beginning of the Q wave
	Peak	At the top of the R wave
	End	After the end of the S wave
T-wave	Onset	At the onset of T
	Peak	At the peak of the T wave <i>Note:</i> This may not be a positive peak if the T-wave is inverted. If the T-wave seems 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.

For information about the algorithm used in Locate Human ECG Complex Boundaries, see page 426.

Locate Animal ECG Complex Boundaries

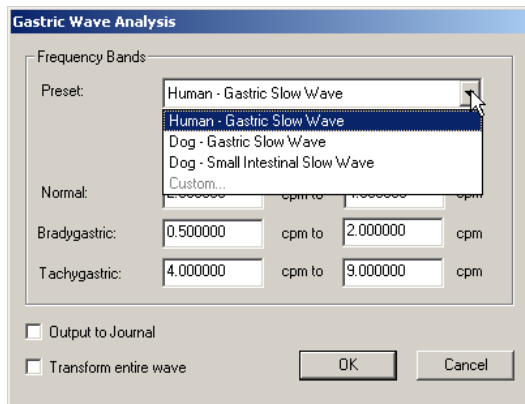
Locate Animal ECG Complex Boundaries optimizes the ECG waveform boundary detection for animal input. Smaller animals such as mice often lack a detectable T wave, so in the setup dialog the T wave boundaries are disabled by default. If appropriate to the experiment, T wave detection can be applied by enabling the “Define T wave boundaries” checkbox. The average heart rate can also be customized to reflect the normal range of a particular animal subject. (The default rate is 600 BPM.)



For information about the algorithm used in Locate Animal ECG Complex Boundaries, see page 425.

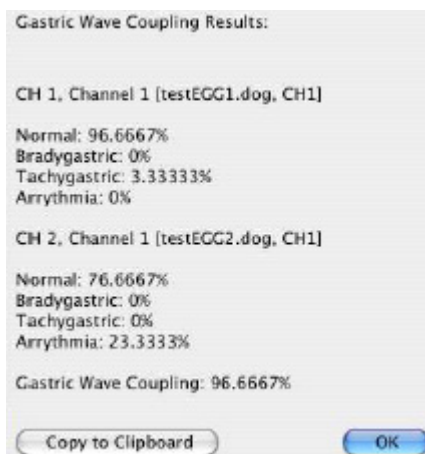
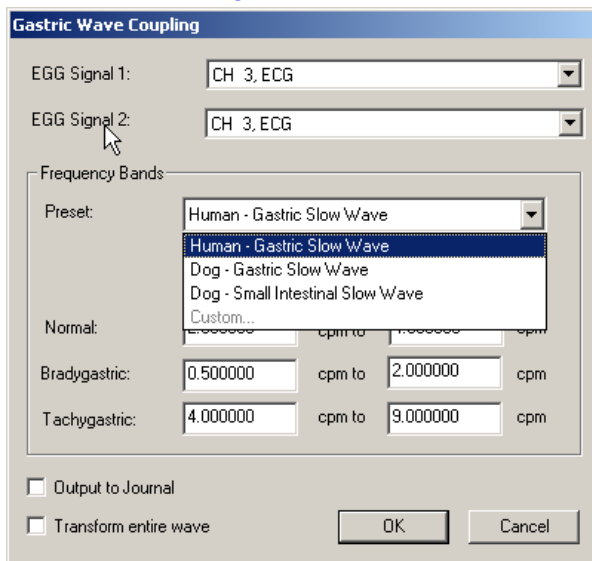
- ▶ See the [AcqKnowledge Locate Animal ECG Complex Boundaries video tutorial](#) for a detailed explanation of this feature.

Gastric Wave Analysis



Gastric Wave Analysis uses autoregressive time-frequency analysis to determine the classifications of gastric waves present in an EGG signal. The single wave analysis determines the percentage of gastric waves that fall within the frequency bands corresponding to normal, bradygastric, and tachygastric waves. The analysis also indicates the percentage of waves that fall outside of these boundaries and are arrhythmias. The frequency bands are expressed in units of “contractions per minute” and may be adjusted by the user. Presets for commonly used subject and wave types are predefined; 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.

- See the [AcqKnowledge Gastric Wave Analysis and Gastric Wave Coupling video tutorial](#) for a detailed explanation of this feature.

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.

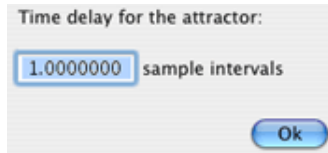
Optimal Time Delay

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.

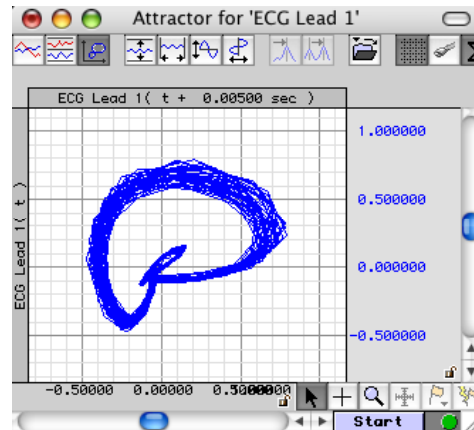
Optimizing the time delay in this fashion picks the shortest delay where the signal exhibits the most independence with respect to its time-delayed version.

The fractal dimension and other chaos-related measurements operate on a single channel of data. In the process of extracting these measures, a signal is compared with a time-delayed version of itself to examine the patterns in dynamics of the data. These measures take a fixed time delay setting. The Optimal Time Delay transformation can be used to choose the best value for the parameter.

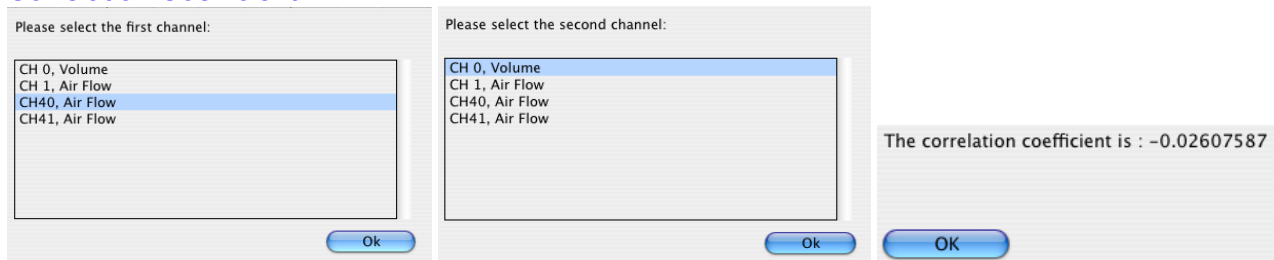
Plot Attractor



Assists in constructing X/Y plots for the attractors of time delayed data. By visually examining the shape of the attractor at a given time delay, To develop an intuitive sense for the underlying nature of the data and the dynamics of the system. Plot Attractor functions on the active channel of the graph. It prompts the user for a time delay and then constructs a new graph window with an X/Y plot of the attractor of the original signal against the time delayed version of the signal. It does not perform any additional computation aside from assisting in the setup and configuration of the attractor plot.



Correlation Coefficient



The *correlation coefficient* is a statistical measure related to the degree of variance or covariance between two data series. Given two data series x and y of length n , the correlation coefficient r is given by the formula:

$$r = \frac{n \sum x y - \sum x \sum y}{\sqrt{[n \sum x^2 - (\sum x)^2][n \sum y^2 - (\sum y)^2]}} \quad (\text{see } \text{http://mathworld.wolfram.com/CorrelationCoefficient.html})$$

The square of the correlation coefficient can be used to determine the proportion of variance in common between the two signals. As the square gets closer to 1, the signals are a better statistical match for each other.

To derive the correlation coefficient, two channels of data are compared against each other.

- the channels must have the same length
- the channels must have the same waveform sampling rate
- all of the data of the entire graph for the two channels will be used to compute the correlation coefficient.

Electrodermal Activity



Overview

The **Electrodermal Activity** analysis routines are separated into three menu options that transform the tonic EDA signal to create a phasic waveform, locate and score skin conductance responses, or perform a detailed event-related EDA analysis by combining event information from the Stim-Response: Digital Input to Stim Events routine (see page 420) to the event-related EDA Analysis routine. The Event-related routine will automatically derive the phasic waveform and locate SCRs.

The routines employ a scoring system that marks the waveform and the point of stimulus delivery. It's easy to manually adjust the automated scoring by relocating the event onset/peak/end before rerunning the analysis. The event-related analysis provides a variety of measures from the SCR data, including classification of specific and non-specific responses. The results are pasted into the journal file or Excel for further analysis.

Preferences must be established for each routine and can be adjusted at any time via the Preferences option (page 363). The time to complete the analysis routine will vary based on the number of SCR responses and the sample rate of the data.

Definitions

The prompts and results of the Electrodermal Activity analysis package use the following terminology and units:

μmho—the unit abbreviation for micromhos, used in channel labels and analysis results; micromho is equivalent to microsiemens.

EDA (Electrodermal Activity)—the general area of skin conductance signals. Sometimes referred to by the older term “galvanic skin response.”

Tonic EDA—continuous data acquired from an EDA electrode that includes all baseline offset. Sometimes referred to as “skin conductance level.” Averaging the tonic EDA over a specific period of time results in the average skin conductance level over an interval. Tonic EDA is recorded using BIOPAC equipment with the high pass filtering set to off (DC mode).

Phasic EDA—a continuous signal indicative of localized changes in the tonic EDA signal. Sometimes referred to as “continuous skin conductance response.” Phasic EDA can be thought of as AC coupled tonic EDA. The EDA analysis package offers multiple ways of constructing phasic EDA including smoothing and high pass filtering. The EDA analysis package performs the majority of its analysis on tonic EDA signals, so if phasic EDA is being recorded directly it is recommended that a second channel be used to record tonic EDA.

Skin Conductance Response (SCR)—an individual localized change in the tonic EDA signal. An SCR may occur in response to a stimulus or may occur spontaneously. In general, there are multiple SCRs present in a tonic EDA signal and they can be detected as deflections from the localized baseline.

Reference

The Electrodermal Activity analysis package was developed to support the parameters established in:

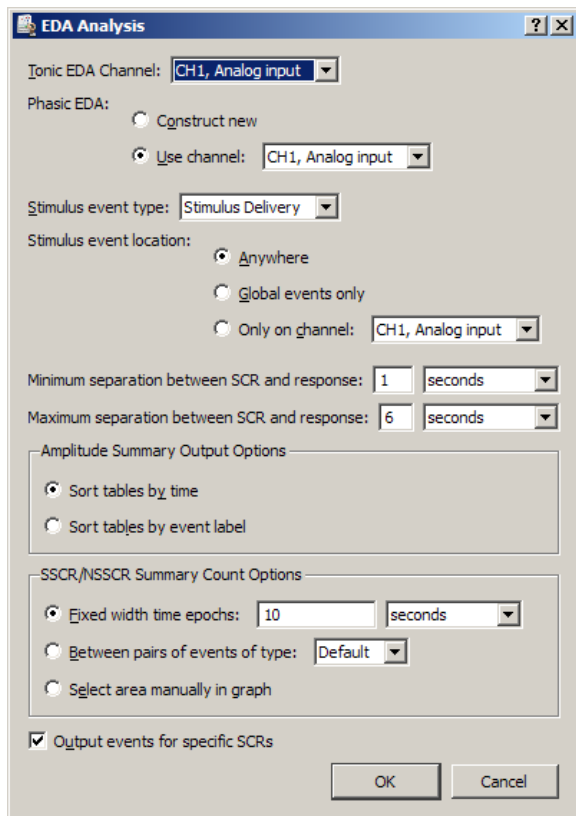
M. E. Dawson, A. M. Schell, and D. L. Fillion. The electrodermal system. In J. T. Cacioppo, L. G. Tassinary, and G.B. Bernston, editors, *Handbook of Psychophysiology*: second edition, pages 200–223. Cambridge Press, Cambridge, 2000.

Derive Phasic EDA from Tonic

Given a tonic EDA signal, this transformation uses baseline smoothing or high pass filtering (the method currently set in Preferences) to construct a new Phasic EDA channel in the graph containing the estimate of the phasic EDA. This routine is automatically included in both the locate SCR and Event-related EDA routines.

Phasic EDA refers to a continuous signal indicative of localized changes in the tonic EDA signal. This data is sometimes referred to as “continuous skin conductance response.” Phasic EDA can be thought of as AC coupled tonic EDA. The EDA Analysis Package offers multiple ways of constructing phasic EDA including smoothing and high pass filtering. The EDA Analysis Package performs the majority of its analysis on tonic EDA signals, so if phasic EDA is being recorded directly it is recommended that a second channel be used to record tonic EDA.

Event-related EDA Analysis



The Event-related EDA Analysis transformation routine assists in the extraction of EDA measures that are linked to specific stimuli. The stimulus event marks must be included in the file BEFORE using this analysis.

This analysis routine requires four elements:

1. Tonic and Phasic waveforms.

Tonic EDA Channel: A Tonic EDA signal must be present in the graph.

Phasic EDA:

Construct new: Given a tonic EDA signal, a phasic EDA will be automatically constructed using baseline smoothing or high pass filtering (the method currently set in Preferences).

Use Channel: If the graph contains a phasic waveform, select the appropriate channel.

2. Stimulus delivery events.

Digital events with a common event type must be located BEFORE using this analysis.

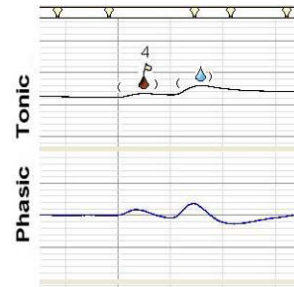
The Event-related EDA Analysis requires that an event be defined in the graph at the location of the delivery of each stimulus. This event may be defined using the Event Tool, hotkey insertion during acquisition, or any other method of defining events. All of the stimulus delivery locations to be extracted must have the same event type (e.g. "Flag"). To analyze multiple different event types, the transformation script must be executed multiple times.

- If you are using E-Prime, SuperLab, or some other stimulus delivery system and have the digital events captured in the AcqKnowledge file, we recommend that you use the Stim-Response: Digital Input to Stim Events routine (see page 420). This routine will automatically classify and label the digital events for use by the Event-related EDA analysis.

Stimulus event type: If using the Digital Input to Stim Events, select Stim/Response > Stimulus Delivery. Stimulus delivery events are located by event type or by specific channel of the graph.

Stimulus event location: Specify the location as anywhere, global only, or on a specified channel. See the Events section for details.

3. Skin conductance responses.



Sample EDA Analysis Output

All SCR events are marked on the tonic waveform as follows:

(open paren.

The point at which the phasic signal crosses the SCR threshold level established in EDA Preferences; see page 363



blue waterdrop

blue marks the peak response of a nonspecific, event-related SCR



red waterdrop

marks a specific SCR "SRR" with a flag numbered with the stimulus event type

) close paren.

The point at which the phasic signal crosses the zero threshold level

If the tonic EDA signal does not already have SCR events defined on it, SCR events will be automatically constructed on the channel using the Locate SCRs transformation routine.

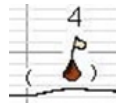
4. Specified time window between the stimulus event and the skin conductance response.

The transformation takes a maximum allowable separation window between the stimulus event and SCR response. Each stimulus delivery event is paired with the closest SCR event. SCRs that correspond to a stimulus delivery are known as specific SCRs (abbreviated “SRR”). SCRs generally occur within a certain timeframe after stimuli. The time window allows responses too close to stimuli to be rejected and classified as non-specific.

Minimum separation: specify in relation to the stimulus event (includes time unit options).

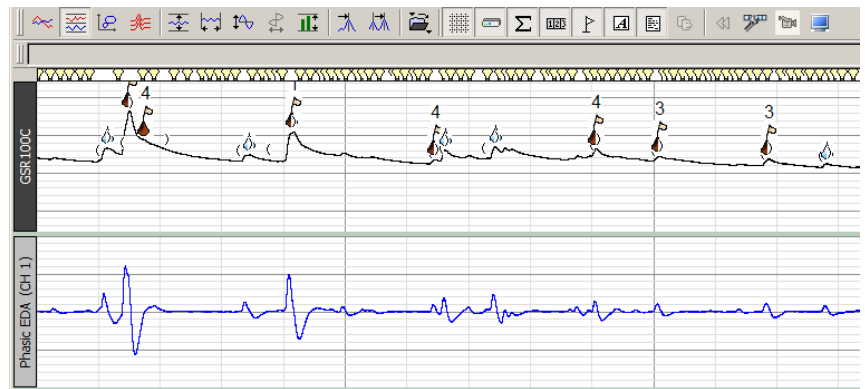
Maximum separation: specify in relation to the stimulus event (includes time unit options).

Given a response time window $[res_{min}, res_{max}]$, for each stimulus delivery event at a time t , SCR onset events that are not presently matched as SRRs will be searched for in the window $[t + res_{min}, t + res_{max}]$. The SCR onset event within this window closest in time to $[t + res_{min}]$ will be paired with the stimulus event and considered a SRR.



SRR are marked as a red waterdrop icon with a flag numbered with the corresponding stimulus event type when “Output events for specific SCRs” is enabled.

Each SRR will be matched to only one stimulus delivery event. If the closest SCR to a stimulus is farther away than this time interval, it is not assumed to be a response to the stimulus. It may be a response to a later stimulus or it may be a non-specific SCR that occurred spontaneously.



Output Events for Specific SCR

Enable this option to mark specific skin conductance events as a red waterdrop icon with a flag numbered with the corresponding stimulus event type.

Event-related EDA Analysis Output Options

Enhancements provide more options for multiple stimulus event types and unmatched events, including:

- Labels and additional measures are available in the specific stimulus and SCR analysis table
- Text and Excel tables may be optionally sorted either by time or grouped by stimulus label
- A new table has been added listing stimulus events that were not paired with an SCR
- The SRR/NS.SSR Rate analysis, which counts frequencies of SCRs in specific time periods, may now be driven by time periods defined using pairs of events or a selection in the graph
- A table has been added listing amplitude/frequency percentage statistics for all matched and unmatched stimuli events (e.g. total stimulus count, percentage of stimuli that were paired with an SCR, etc.)
- Additional optional Specific-SCR events may be defined on the tonic EDA waveform at the positions of specific SCRs with labels matching the stimulus to which they were responses. This allows for further peak-detector based runs to perform additional data reduction.

Event Related EDA Event Types:

- Waveform Onset
- Waveform End
- Skin Conductance Response
- Specific SCR

Waveform Onset and Waveform End events are also available for other Specialized Analysis operations.

Amplitude Summary Output Options

For each specific SCR that is paired with a stimulus delivery event, the following measures are extracted in table format and can be sorted by **Time** or by **Event label**. If text output is enabled in EDA Preferences, the average value of SCL, Latency, SCR Amplitude, and SCR Rise Time will be included as the final row of the table.

<i>Name</i>	<i>Abbrev.</i>	<i>Description</i>	<i>Units</i>
Stimulus Delivery Time	Stim Time	The time within the recording where the stimulus delivery event was located.	seconds
Skin Conductance Level	SCL	Amplitude of the tonic EDA signal at the time when the stimulus was delivered.	μmho
Response Latency	Latency	Time separating the stimulus delivery from the onset time of the corresponding SCR. This latency will always be less than the maximum allowable latency specified as a parameter for the analysis.	seconds
SCR Amplitude	SCR Amplitude	Height of the corresponding SCR as determined by the change in the tonic EDA amplitude from the time of SCR onset to the maximum tonic EDA amplitude achieved during the SCR: $[EDA(t_{\max}) - EDA(t_{\text{onset}})]$	μmho
SCR Rise Time	SCR Rise Time	Time taken for the tonic EDA to reach its maximum value within the SCR: $[t_{\max} - t_{\text{onset}}]$	seconds
Absolute SCR Size	SCR Size	Contains the SCR Size, which is the absolute amplitude of the paired SCR event. This is the amplitude of the “SCR” event in the triplet. Formula: $EDA[t_{\max}]$	μmho
SCR Onset Threshold	SCR Onset	Contains the absolute amplitude of the waveform onset event of the specific SCR. Formula: $EDA[t_{\text{onset}}]$	μmho
Stimulus event label	StimLabel	Contains the label of the stimulus delivery event.	N/A

The SCR Size and Onset Threshold values will be included for the textual table, graphical channel output, and in the Excel spreadsheet. The stimulus event label will be included only in the textual and Excel spreadsheet output; it is not possible to represent textual information in graph channels.

Sorting Options

The output table rows may appear in one of two orderings.

- “Sort tables by time” - Consecutive rows will be arranged in order of increasing time.
- “Sort tables by event label” - Case-sensitive lexicographical sort based on the StimLabel column; “AAAA” will be considered as unique from “aaaa” / “AaAa”, etc.

SSCR/NSSCR Summary Count Options

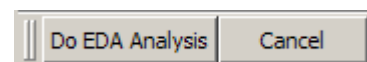
In addition to the above measures extracted for each specific SCR, the analysis performs rate extractions for specific and non-specific SCRs. By examining how the rate of SCR occurrences changes, long-term experimental trends can be investigated. This analysis is placed into a second set of waveforms (or a second table for text and Excel output).

Fixed width: fixed width window is specified as the “SCR count interval width” when performing the analysis. The entire recording is split up into fixed-width epochs of this granularity with the first epoch aligned at the start of the recording. For each fixed-width epoch, the following are extracted:

<i>Name</i>	<i>Abbrev.</i>	<i>Description</i>	<i>Units</i>
Epoch Start Time	Start Time	Time location in the recording of the start of the epoch being examined.	seconds
Specific SCR Rate	SRR	Frequency of the occurrences of specific SCRs within the epoch. Specific SCRs are those SCRs that were successfully matched to a corresponding stimulus delivery event.	Hz
Non-specific SCR Rate	NS.SRR	Frequency of the occurrences of non-specific SCRs within the epoch. These are SCRs that occur spontaneously and are not paired with any known stimulus.	Hz

Between event pairs: Select an event type from the pull-down menu. The software will locate the event markers at the beginning and end of the region of interest and perform the analysis between the two points. This option is useful if the recording is broken into defined periods—such as baseline, event, and response—using the event hotkeys.

Manually selected area: Highlight the area where NSSCR/SSCR rates should be computed and then click “Do EDA Analysis” in the graph window.



Amplitude/Frequency Percent Summary

The “Stimulus Matching Summary” table for Textual and Spreadsheet output provides overall summaries for each unique event label for Stimulus Delivery events. The table has one line for each unique event label; the labels are numbers starting with 1.

This table provides an overall average for amplitude, magnitude and % Frequency for the specific SCR associated with Stimulus Delivery events. In this case, frequency is referring to the ratio of Stimulus Delivery events to the occurrence of specific SCRs.

Assume we have a set S of all Stimulus Delivery events of an identical label.

This will be split into two subsets: S_{matched} consisting of all Stimulus Delivery events that have an associated SCR with them, and S_{ns} consisting of the non-specific stimulus events that do not have an associated SCR with them. Given these sets, the following definition holds:

$$S_{\text{matched}} \cup S_{\text{ns}} = S$$

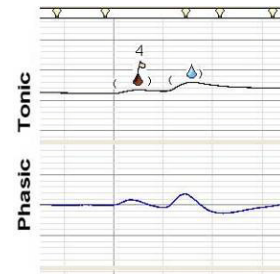
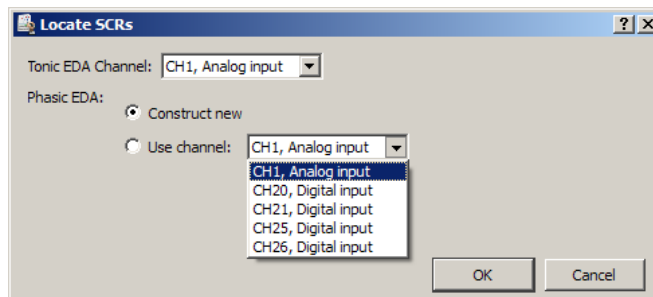
For an individual event, define the SCR Amplitude function:

$$a(s) = |EDA(t_{\text{max}}) - EDA(t_{\text{onset}})|$$

The following are the definitions of measures that will be included in the table:

Name	Abbrev.	Description	Units
Amplitude	Amplitude	Average value of the SCR amplitude of the specific SCR events. Defined by the following formula: $\text{Amplitude} = \frac{\sum_{s \in S_{\text{matched}}} a(s_i)}{ S_{\text{matched}} }$	umho
Magnitude	Magnitude	Weighted average of the SCR amplitude of the specific SCR events over the entire set of specific and non-specific events. Defined by the following formula: $\text{Magnitude} = \frac{\sum_{s \in S_{\text{matched}}} a(s_i)}{ S }$	umho
Matched	Matched	Total number of specific SCRs associated with a Stimulus Delivery event. Defined by the following formula: $\text{Matched} = S_{\text{matched}} $	
Non-matched	Non-matched	Defined by the following formula: Non-matched = Stimulus Delivery _{Total count} – Specific SCR _{Total count}	
Total	Total	Total count of Stimulus Delivery events. Defined by the following formula: $\text{Total} = S $	
Frequency (%)	Freq%	Percentage of stimulus events that were paired with an SCR. Defined by the following formula: $\text{Freq} = \frac{ S_{\text{matched}} }{ S } * 100$	
Label	Label	Textual label of the events that are included in S .	

Locate SCRs



The Locate SCRs routine will identify skin conductance response and score the waveform. This analysis is useful for analyzing spontaneously occurring skin conductance responses. The routine is automatically included in the Event-related EDA routine. All SCR events are marked on the tonic waveform as follows:

(*open paren.* The point at which the phasic signal crosses the SCR threshold level established in EDA Preferences; see page 363



blue waterdrop The peak response point of a nonspecific, event-related SCR

) *close paren.* The point at which the phasic signal crosses the zero threshold level

This transformation requires a tonic EDA signal. If a phasic EDA has already been constructed for this tonic EDA, it may be used; otherwise, the transformation will create a phasic EDA automatically according to the settings in the Preferences.

Given a tonic EDA, the Locate SCRs transformation defines an event for each skin conductive response in the tonic EDA. SCR location is a two stage process. First, all potential SCR occurrences are located on the signal. Second, all potential SCR occurrences that are not large enough are rejected.

Potential SCR occurrences are detected by performing thresholding positive peak detection on the phasic EDA signal (using H and P as set via Preferences):

1. Given a detection threshold H (expressed in μmho), search for a positive threshold crossing in the phasic EDA signal. This position is recorded as the start of the potential SCR.
2. Continue examining the phasic EDA until the first negative threshold crossing of 0 μmho occurs. This position is recorded as the end of the potential SCR.
3. Return to step 1 to continue searching for more potential SCRs.

After all of the potential SCRs have been located, the set of valid SCRs is constructed as follows:

1. Determine the overall maximum amplitude of the phasic EDA signal within all potential SCRs.
2. Given a percentage P, construct a threshold level T of P percent of the overall maximum phasic EDA signal value located in step 1.
3. Examine each potential SCR. Find the maximum phasic EDA. If $m < t$, discard the potential SCR. Mark the potential SCR as a valid SCR.

If the tonic EDA channel chosen for analysis already has SCR events defined on it, the SCR events will be replaced with the newly detected SCR events. No existing SCR events will be erased without a confirmation.

Once SCR events have been defined, they can be used in conjunction with the Cycle Detector for performing further data reduction. The “event count” measurement can be used to estimate SCR frequency during individual time ranges of the experiment.

Events on Tonic EDA

After valid SCRs are located using the algorithm above, events are inserted into the graph that can allow for further data analysis around the SCR positions. Three events are defined on the tonic EDA waveform for each individual valid SCR:

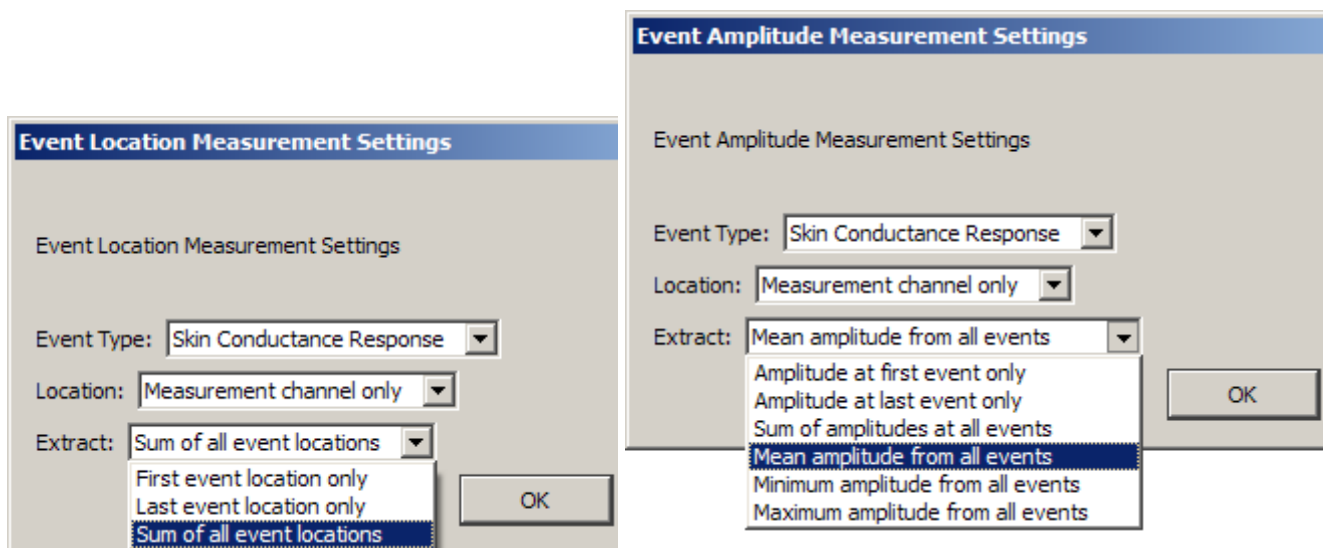
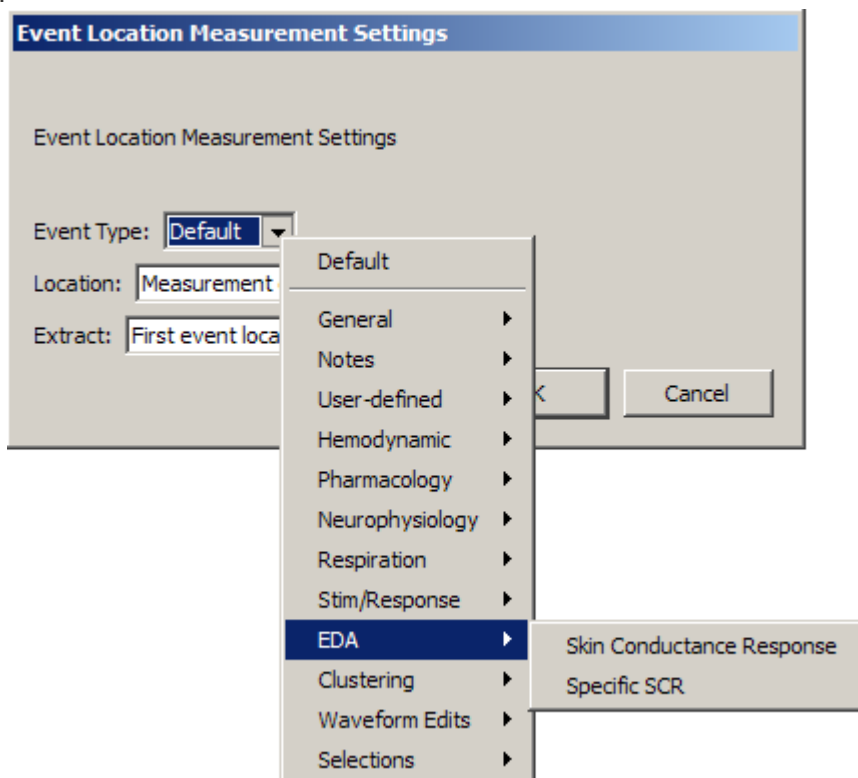
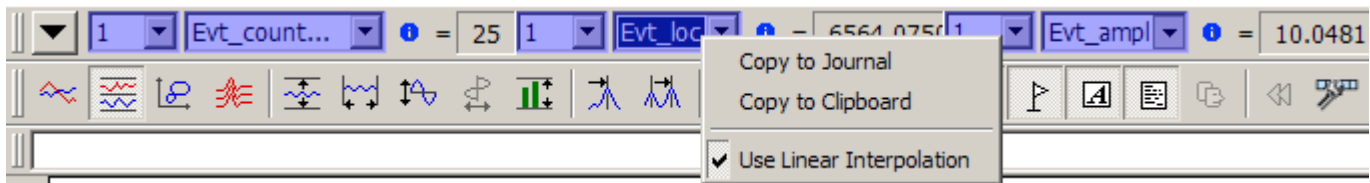
1. “General > Waveform onset” event at the SCR onset time. This is the point where the threshold H was crossed in the phasic EDA.
2. “EDA > Skin conductance response” event at the time where the tonic EDA reaches its maximum value within the SCR (max in time range).
3. “General > Waveform end” event at the ending SCR time. This is the point where the zero threshold was crossed in the phasic EDA.

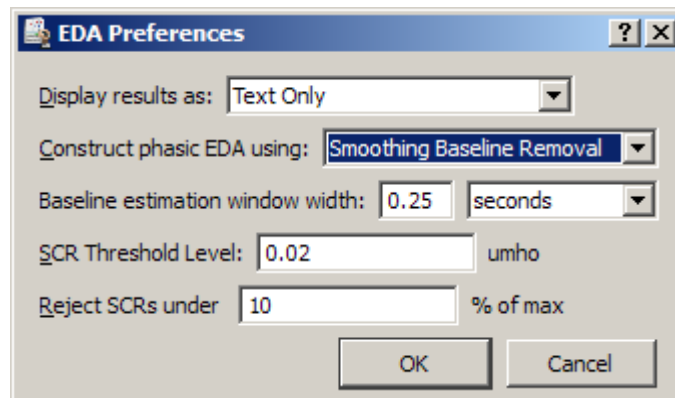
Events for SCRs will always occur as described above, in the order shown.

EDA Measurements

To perform Event-related EDA analysis, choose Analysis > Electrodermal Activity > Event-related EDA Analysis.

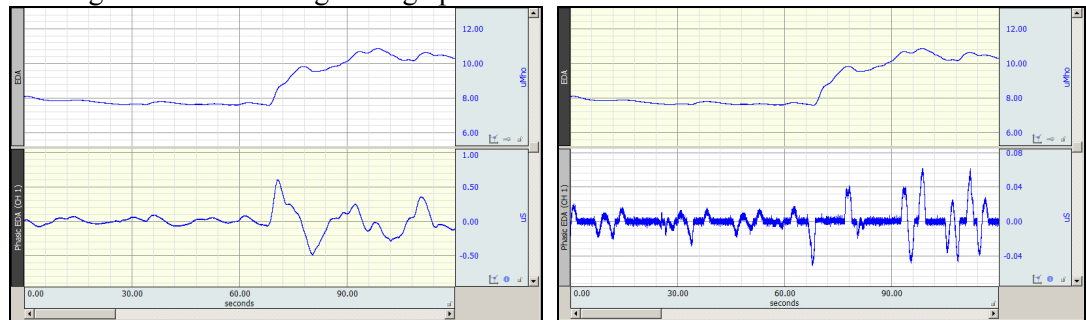
To take measurements from the skin conductance response analysis, set measurements for event count, event location and/or event frequency. Set the source channel as the Tonic EDA channel and select the location (measurement channel only, global events only, anywhere) and measurement parameters as desired. This method is useful for spontaneously occurring skin conductance response analyses. Take measurements over a manually selected area or use Find Cycle analysis to take automatically measurements over a user-defined time interval.





The following EDA Preferences can be configured and will be applied to all options in the analysis package:

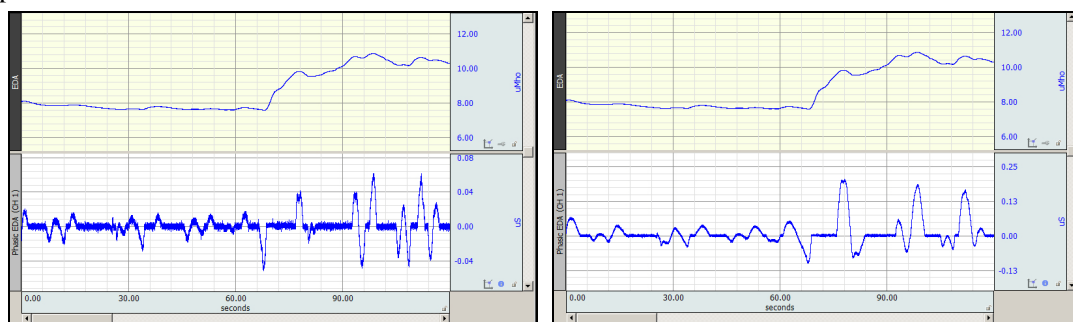
- **Display results** as text, graph channels, or Excel
- **Construct Phasic EDA using** High pass Filtering or Smoothing Baseline Removal
 - High pass Filtering—High pass filtering constructs phasic EDA by applying a digital IIR high pass filter ($f = 0.05$ Hz, $Q = 0.707$) to the tonic EDA signal. This high pass filter essentially AC couples the tonic EDA signal similar to using the high pass hardware filter available on the GSR100C module.



0.05 Hz High Pass Filter

Smoothing Baseline Removal

- Smoothing Baseline Removal—Smoothing baseline removal constructs phasic EDA by subtracting an estimate of the baseline conductance from the tonic EDA. Set the baseline estimation
- **Baseline estimation:** The estimate of the baseline is generated using median value smoothing. This is more computationally intensive than high pass filtering. Increasing the window will increase sensitivity and return more responses.

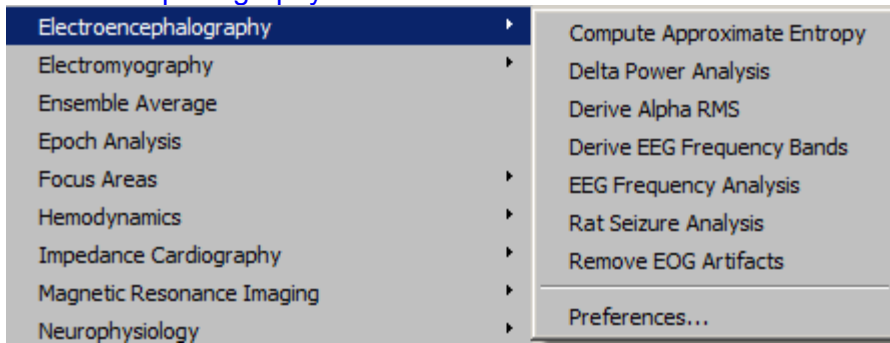


Baseline window set to 4 seconds

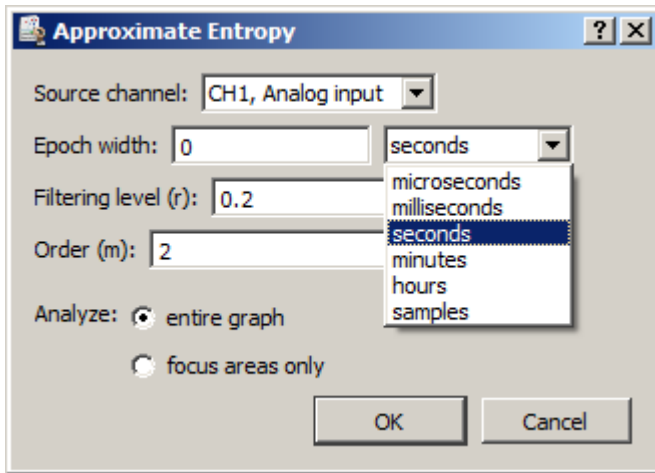
Baseline window set to 8 seconds

- **SCR detection parameters:** threshold detection level H and percentage P, see page 361.
 - The default values are $H = 0.02$ μ mho, $P = 10$, where H is detection threshold and P is percentage
 - Setting H to 0 and P to 10% will approximate the SCR detection algorithm referenced in K. H. Kim, S. W. Bang and S. R. Kim, “Emotion recognition system using short-term monitoring of physiological signals,” Medical & Biological Engineering & Computing, vol. 42, pp. 419-427, 2004.
 - Setting P to 0% will retain all potential SCRs (none will be rejected in the second phase).

Electroencephalography



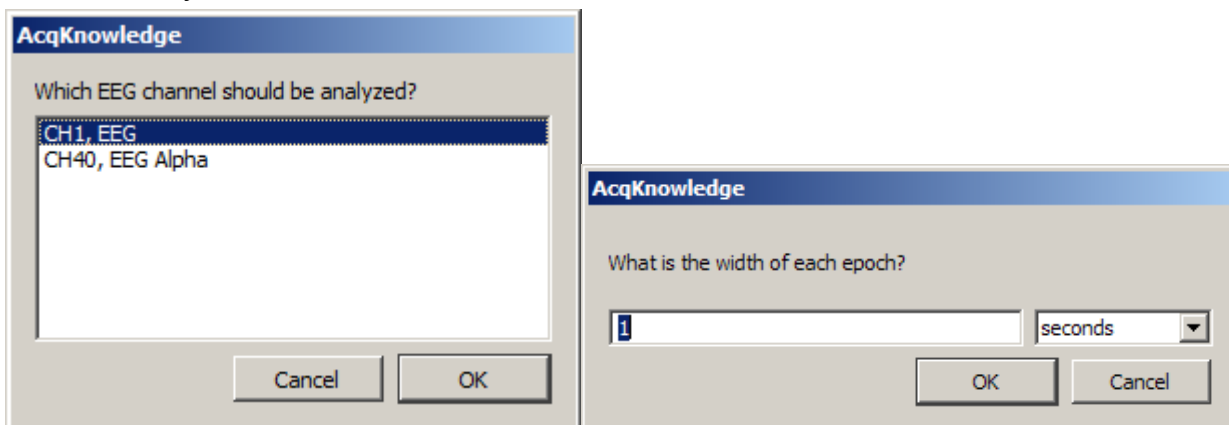
Compute Approximate Entropy



Approximate entropy is a statistical measure that attempts to quantify the predictability of a data sequence. A perfectly predictable data series (such as a pure sine wave) has approximate entropy of zero. Several studies are beginning to examine approximate entropy of EEG data and its relationship to external factors such as drugs and sleep states.

The Compute Approximate Entropy script divides an EEG signal into fixed-width epochs and computes the approximate entropy for each epoch. Derivation of the approximate entropy is a computationally intensive process and may take several minutes or hours to complete. To obtain only the sub-ranges of the EEG data, use the “focus areas only” option to restrict the approximate entropy computations to that data range only.

Delta Power Analysis

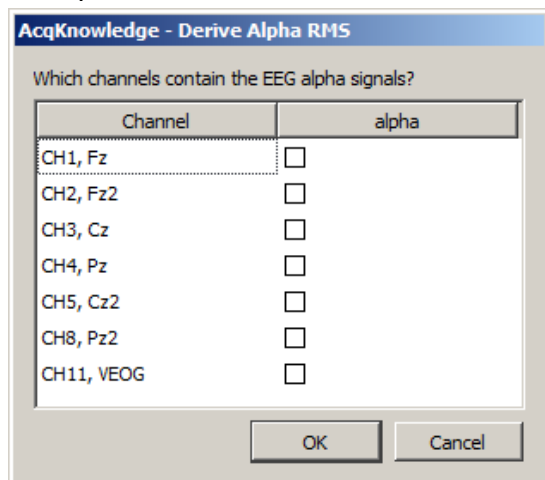


Delta power is the total power of the EEG signal that occurs within the delta frequency band as configured in the Preferences. Delta power has been examined in a number of various EEG studies as an indicator of sleep/wakefulness and other conditions. By examining changes in the delta power, it may be possible to correlate delta power with effects of external factors.

The Delta Power Analysis script divides an EEG channel into fixed-width epochs. For each epoch, the power spectral density is computed and the total power within the delta frequency band is derived from the PSD. This delta power value is then placed into the graph or into the journal as specified by the output preferences.

Delta power can be measured from either a filtered or unfiltered EEG channel. To compute delta power for individual frequency bands, they must be derived prior to running the Delta Power Analysis script.

Derive Alpha RMS



AcqKnowledge - Derive Alpha RMS

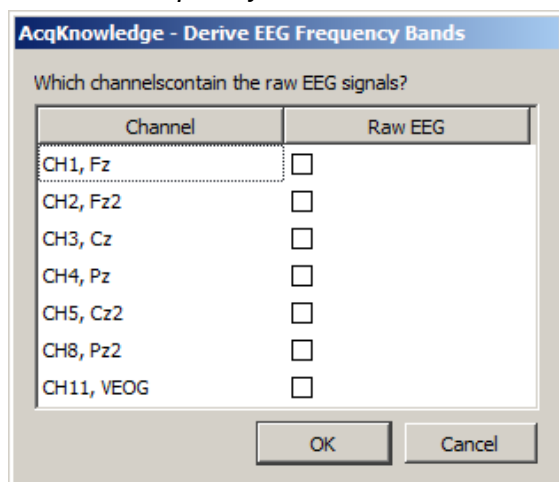
Which channels contain the EEG alpha signals?

Channel	alpha
CH1, Fz	<input type="checkbox"/>
CH2, Fz2	<input type="checkbox"/>
CH3, Cz	<input type="checkbox"/>
CH4, Pz	<input type="checkbox"/>
CH5, Cz2	<input type="checkbox"/>
CH8, Pz2	<input type="checkbox"/>
CH11, VEOG	<input type="checkbox"/>

OK Cancel

The Derive Alpha RMS script constructs an integrated RMS waveform from an alpha EEG signal (the alpha EEG signal can be constructed with Derive EEG Frequency Bands). Alpha RMS is the windowed root mean square value of the signal using a window width of 0.25 seconds. Individual channels are selectable for analysis.

Derive EEG Frequency Bands



AcqKnowledge - Derive EEG Frequency Bands

Which channels contain the raw EEG signals?

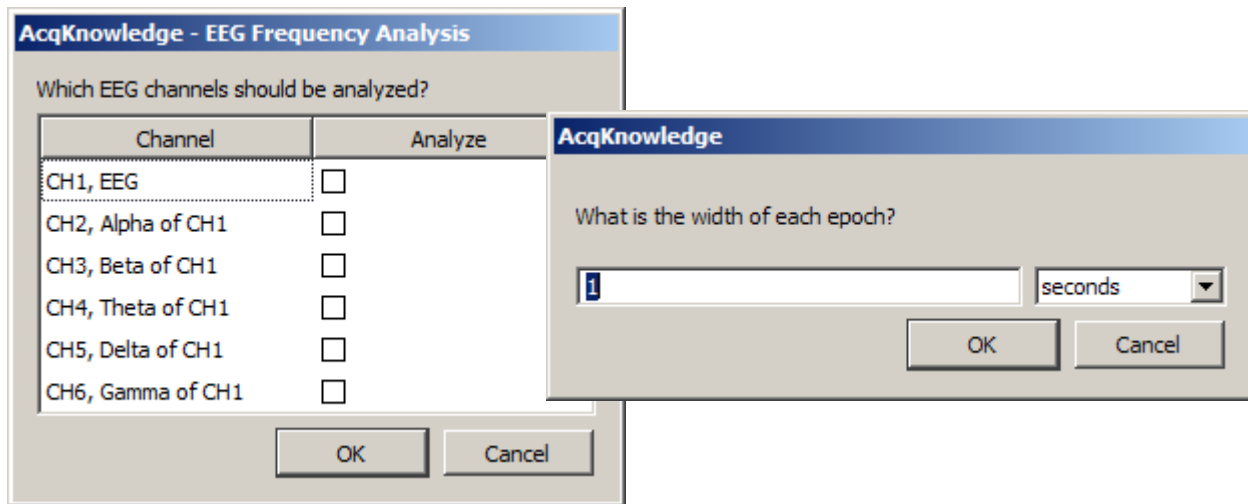
Channel	Raw EEG
CH1, Fz	<input type="checkbox"/>
CH2, Fz2	<input type="checkbox"/>
CH3, Cz	<input type="checkbox"/>
CH4, Pz	<input type="checkbox"/>
CH5, Cz2	<input type="checkbox"/>
CH8, Pz2	<input type="checkbox"/>
CH11, VEOG	<input type="checkbox"/>

OK Cancel

The Derive EEG Frequency Bands script applies filtering to an unfiltered EEG lead signal to generate the following five standard EEG bands: Alpha, Beta, Theta, Delta, and Gamma.

The frequencies for each band are specified in the analysis package preferences. Filtering is performed using the digital filter, IIR Band Pass Low+High.

EEG Frequency Analysis



EEG may be characterized in terms of frequency and the power within specific frequency bands. The EEG Frequency Analysis script performs various feature extractions from EEG signals using FFT and other techniques to examine the power within the EEG signals. This analysis may be performed for multiple EEG leads simultaneously, allowing for either analysis of multiple leads or analysis of multiple EEG alpha, beta, theta, or delta bands from a single raw lead.

The EEG Frequency Analysis script divides the EEG signals into fixed-width time epochs. For each individual time epoch, 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

 Watch the [AcqKnowledge EEG Frequency Analysis video tutorial](#) for a detailed demonstration of this feature.

Seizure Analysis

Seizure Analysis is designed to enhance functionality of the Epoch wireless EEG system commonly used for acquiring small animal signals. Long term EEG recording is often used for studying seizure activity. Unlike human EEG, EEG for non-anesthetized animals may contain a variety of superimposed artifacts resulting from random motion and scratching. Seizure Analysis offers a reliable means of differentiating actual seizure activity from other types of motion artifact.

The Seizure Analysis tool consists of a configurable difference interval, slope threshold, time epoch width and spike detector. Using the default values found in the figure above, seizure activity is defined as follows:

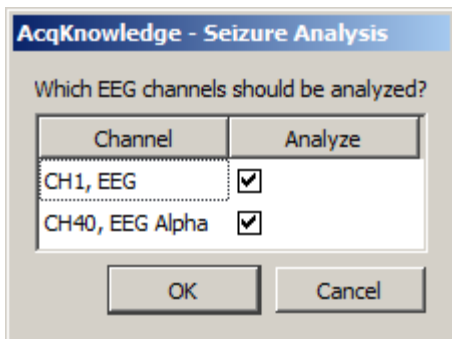
1. Perform a difference on the EEG data with a 16 ms window width. At this window width, normal EEG spikes in the signal have a roughly logarithmic distribution.
2. Identify maximum threshold for normal spike distribution, chosen at 270 microvolts on the difference signal.
3. Perform peak detection on the difference signal with the fixed chosen threshold. Spikes above this threshold are considered candidate epileptic spikes and marked with a check mark on the waveform.

After spikes are located seizures will be located using a spike frequency method:

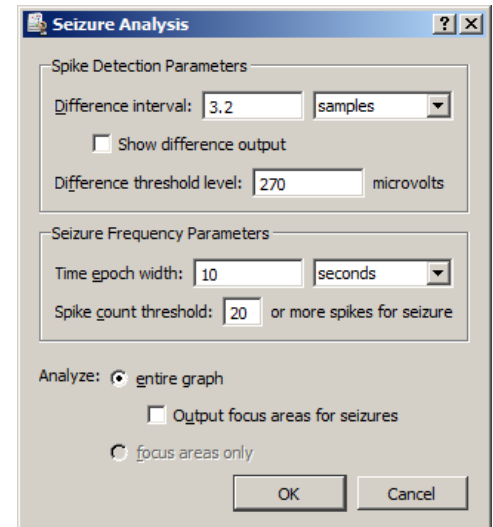
1. Split data up into 10 second periods.
2. Count the number of spikes in each period. If more than 20 spikes occur within the period, the period is marked as a seizure.

Using Seizure Analysis

1. Analysis > Electroencephalography > Seizure Analysis and set the EEG data results preferences if necessary. (See page 370)
2. If more than one EEG channel is to be analyzed, as is often the case with the Epoch EEG system, the following selection screen will appear. If there is only one channel of EEG data in the file, this screen will not be displayed and the seizure analysis screen depicted above will appear.

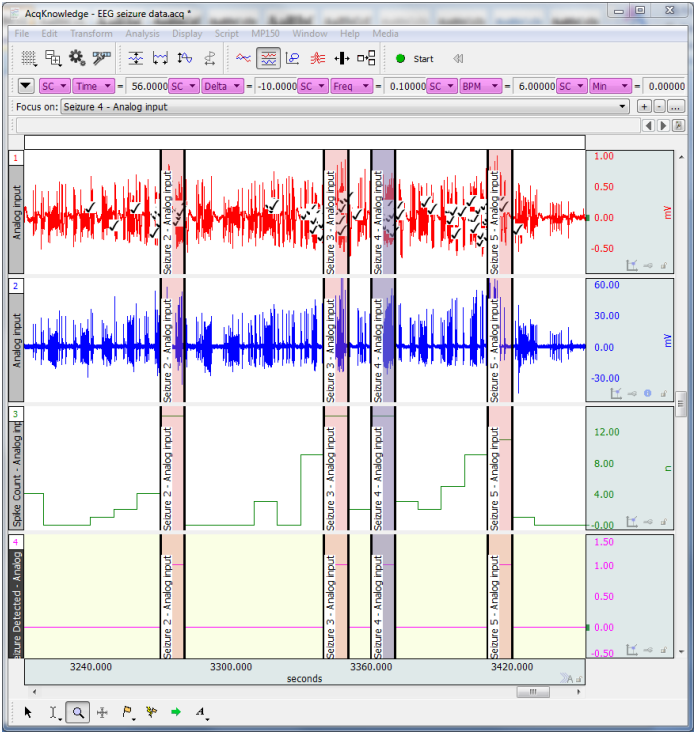


3. Set the desired parameters for seizure detection and click OK.



If the EEG Analysis Preferences are set to display results as graph channels, two new channels of data will be created. The first channel shows a tachogram of the number of epileptic spikes identified within the Time epoch. The second channel displays a square wave that runs from 0 to 1; a 1 indicates that an epoch matches the seizure threshold. In the default setting, 20 seizure spikes have to be identified within a 10 second epoch for the epoch to be classified as containing a seizure.

If the “Output focus areas for seizures” option is checked, a focus area is created for each epoch that contains a seizure. This option is useful for running additional analysis routines and taking measurements over just the areas of data that contain seizures.

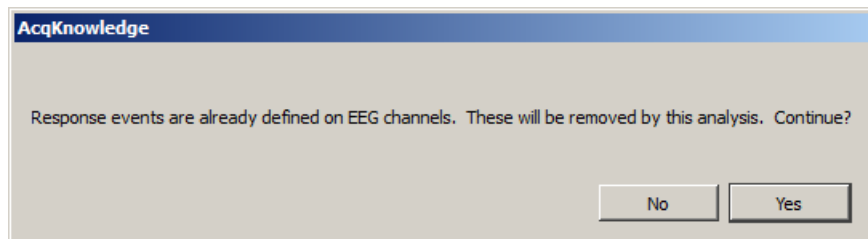


Seizure Analysis Parameters

CONTROL	DESCRIPTION
Difference Interval	Alters the time window used to compute the difference for slope detection. Default value is 3.2 samples.
Show difference output	The difference interval used for spike detection will be displayed in the graph.
Difference threshold level	Adjusts the fixed threshold level used to locate peaks in the difference signal corresponding to EEG spikes associated with seizures. Default value is 270 microvolts.
Time epoch width	Adjusts the time width used for seizure detection. Default value is 10 seconds.
Spike count threshold	Sets the number of spikes that must be present in the specified time window (epoch) in order to be indentified as seizure activity.
Analyze: entire graph	The entire graph is scrutinized for potential seizure activity.
Output focus areas for seizures	In addition to normal output, the analysis will create focus areas in the graph at each identified seizure period.
Analyze: focus areas only	Only focus areas will be scrutinized for potential seizure activity.
Output events for seizure intervals	A pair of “waveform onset” and “Fwaveform end” events will be created at boundaries of identified seizure areas.

Spike Event Output

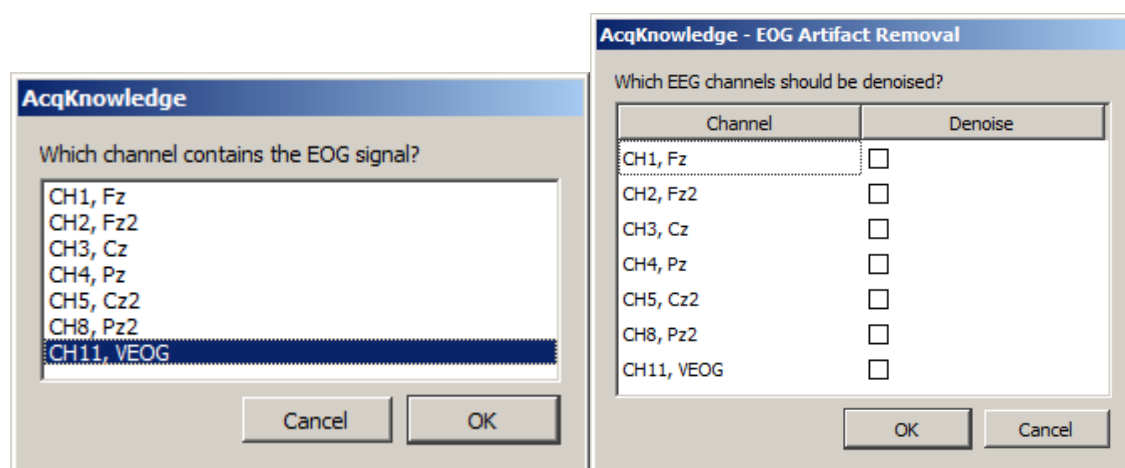
For all types of seizure analysis output, this analysis will leave Stim-Response ✓ events on the EEG channel wherever spikes are detected according to the analysis parameters. These events allow for visual verification of spike detector functionality. If any Response events are found on the EEG channels at the start of the analysis, then following dialog will be presented:



Clicking “Yes” removes the existing events. Only Response type events will be removed from the EEG channels; other types of events, or events on other channels will not be affected.

▶ Watch the [AcqKnowledge Seizure Analysis video tutorial](#) for a detailed demonstration of this feature.

Remove EOG Artifacts



Some EEG recordings involve subjects performing various visual tasks such as reading or watching video. Under these conditions, EEG may be susceptible to interference from the much stronger EOG signal arising from eye motion, particularly if EEG is recorded from near the front of the skull. Remove EOG Artifacts helps remove EOG interference from the EEG signals, recovering the EEG data for use in further analysis.

EOG removal is performed using a blind signal separation technique known as Independent Component Analysis. ICA is used to split up statistically independent signals that have been mixed together during recording. Since EOG is independent of EEG, ICA can be used to remove it.

In order to use Remove EOG Artifacts, a distinct EOG signal must be acquired in addition to the EEG signals. The EOG signal is required to identify the components correlated to eye motion.

EOG artifact removal functions better when it is performed on multiple EEG leads simultaneously. Better results may be obtained by including EEG leads that do not exhibit EOG interference since the increased number of leads allows for more fine-grained signal separation. Good results can be seen with as few as two EEG leads and one EOG lead. While this technique can be performed with a single EEG lead, the results will not be as dramatic.

Note ICA is a non-deterministic technique, so it may not be possible to automatically separate the signals for every EOG/EEG data set. For ICA to be successful, it may be necessary to fine-tune the parameters of the ICA search procedure to match the data, use a different electrode configuration, or use fewer or more leads.

Preferences...

EEG Analysis Preferences

Display results as: Text Only

Spectral edge: 90 %

EOG ICA removal tolerance: 0.0001

EOG ICA maximum iterations: 1000

Frequency Bands

Delta:	0.5	Hz to	4	Hz
Theta:	4	Hz to	8	Hz
Alpha:	8	Hz to	13	Hz
Beta:	13	Hz to	30	Hz
Gamma:	36	Hz to	44	Hz

OK 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.

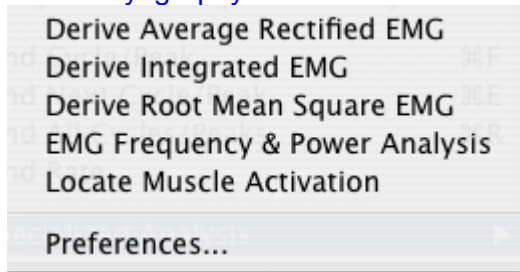
Because ICA is a statistical technique, any filtered data produced with Remove EOG Artifacts should be carefully verified against other information to ensure that the approximations produced via ICA represent information that is truly correlated to the expected ECG.

The spectral edge percentage indicates the cutoff percentage of the total power at which spectral edges will be placed. The default value is 90%.

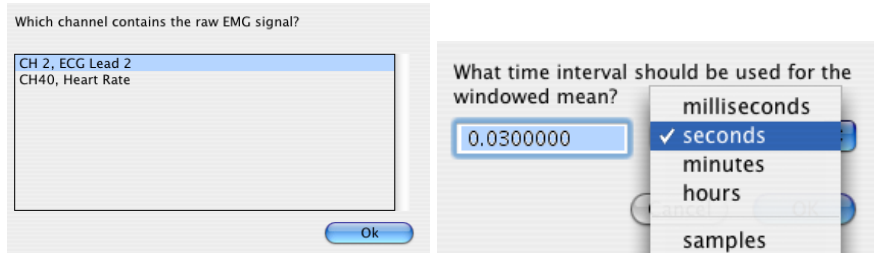
The frequency bands of alpha, beta, delta, and theta may be modified to match different analysis protocols. The default frequency ranges are:

- 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

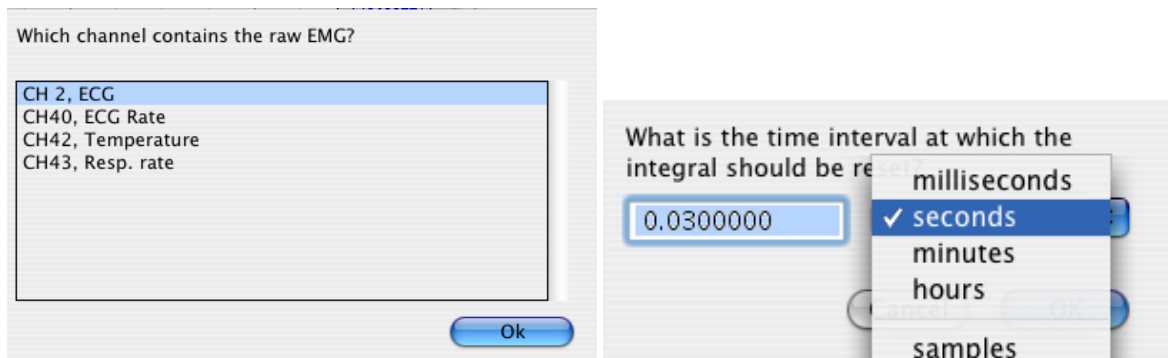


Average rectified value (ARV) is defined as a time windowed mean of the absolute value of the signal. ARV is one of the various processing methods used to construct derived signals from raw EMG data that can be useful for further analysis.

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.

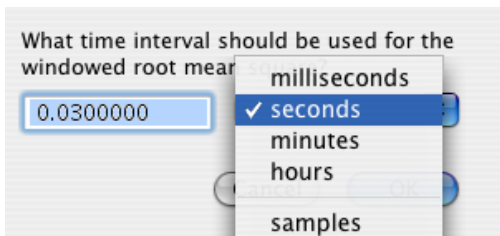
Derive Integrated EMG



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.

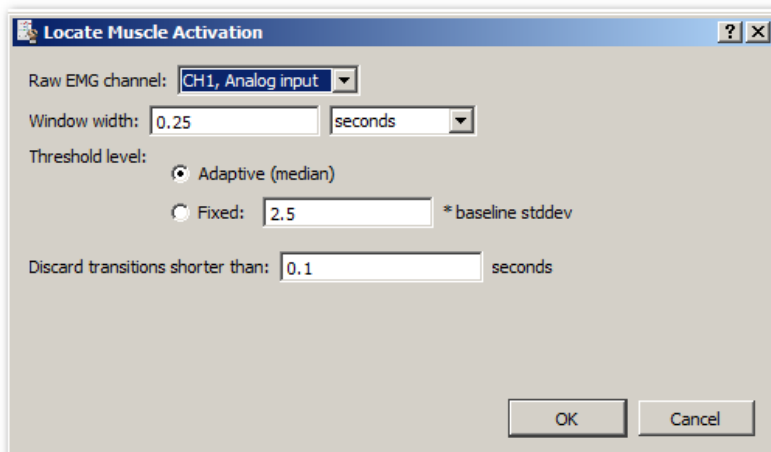
RMS EMG is computed using the Integrate transformation in a Root Mean Square Average over Samples configuration.

EMG Frequency and Power Analysis

Several frequency domain techniques may be used for data reduction of EMG signals. The EMG Frequency & Power Analysis script extracts several measures derived from the power spectrum of an EMG signal. The EMG signal is split up into a fixed number of time periods; within each window, the power spectrum is computed using the Power Spectral Density transformation. For each time period, the following measures are extracted:

Name	Abbrev.	Description	Units
Median Frequency	MedianF	Frequency at which 50% of the total power within the epoch is reached.	Hz
Mean Frequency	MeanF	Frequency at which the average power within the epoch is reached.	Hz
Peak Frequency	PeakF	Frequency at which the maximum power occurs during the epoch.	Hz
Mean Power	MeanP	The average power of the power spectrum within the epoch. (Units Note: V will be replaced with the voltage units in which the EMG was recorded)	$\frac{V^2}{Hz}$
Total Power	TotalP	The sum of the power at all frequencies of the power spectrum within the epoch. (Units Note: V will be replaced with the voltage units in which the EMG was recorded)	$\frac{V^2}{Hz}$

Locate Muscle Activation



When performing gait analysis, exercise physiology, or other research, identification of periods where the muscle is active can allow for correlation of external factors to muscle activity.

Locate Muscle Activation attempts to identify various periods of muscle activity using statistical methods. The transformation requires a raw, unfiltered surface EMG channel. It takes a window width of w seconds, by default 0.25 seconds. It is important that the first w seconds of the EMG signal be “background noise”, that is, that the muscle being examined is relaxed for the first quarter second. This quarter-second period is used to estimate baseline parameters that affect the entire process.

Note The LMA analysis expects EMG to be an AC-coupled signal centered around zero without baseline offset. If the signal is centered below zero, then no muscle activations are located. The Remove Mean function from the Analysis menu can be used to center the signal around zero for most waveforms.

This transformation implements a variation of the Hodges and Bui detection algorithm as described in:

P. W. Hodges and B. H. Bui, “A comparison of computer-based methods for determination of onset of muscle contraction using electromyography,” *Electroenceph. Clin. Neurophysiol.*, vol. 101, pp. 511-519, 1996.

The variation implemented is a threshold-based algorithm roughly consisting of the following steps:

1. Determine mean value μ_0 and resting standard deviation σ_0 of the first w seconds of the signal.
2. Construct a filtered ARV EMG signal, z . The window width w is used when constructing the ARV signal.
3. Extract the variance of the signal with respect to the noise with the formula

$$g = \frac{z - \mu_0}{\sigma_0}$$

4. Using a threshold h , determine when the signal g lies below and above the threshold. Portions of time above the threshold are periods of muscle activity.
5. Discard any transitions across the threshold if they are shorter in duration than a user-specified time, t .

There are two methods of specifying the threshold h . An adaptive method examines the signal g and chooses the threshold to be the median of g over the entire waveform. Alternatively, the threshold can be specified manually. Using a manual threshold can be useful in adjusting the detection to better match specific EMG data. A suggested threshold is 2.5. By lowering the threshold, a larger quantity of data will be considered as muscle activity. By raising the threshold, a larger quantity of data will be considered to be noise.

The transition discard time t is specified in seconds. The default value of t is 0.1 seconds. If muscle activity is being inaccurately identified as inactivity for short periods within active times, try increasing the value of t . Do not set t to be greater than the smaller of either the shortest duration of a single muscle contraction or the shortest rest interval between consecutive muscle contractions.

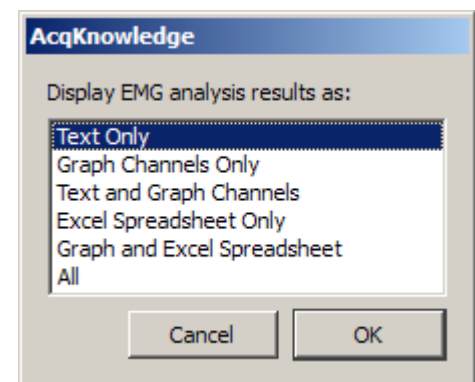
There are two outputs from the Locate Muscle Activation script.

- A new waveform, Muscle Active, will be added to the graph. The value of this wave will be zero when the muscle is at rest and one when the muscle is active. This wave can be used to quickly visually examine the record for periods of activity.
- Events are also generated on the raw EMG waveform. A Waveform Onset event is placed at each transition from inactive to active, and a corresponding Waveform End event is placed at each active-to-inactive transition. You can use these events in conjunction with the Cycle Detector to perform further data reduction based on muscle activity.

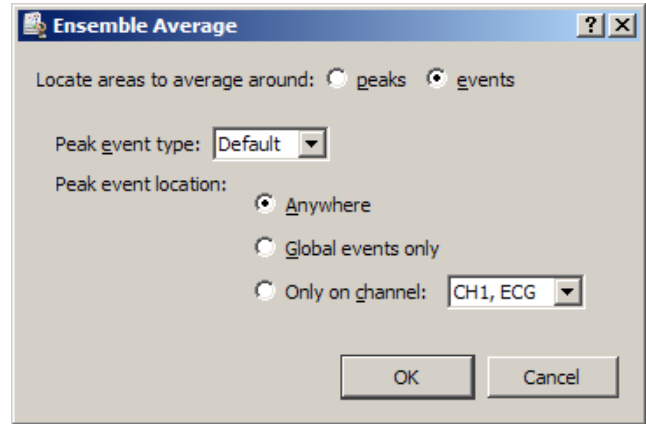
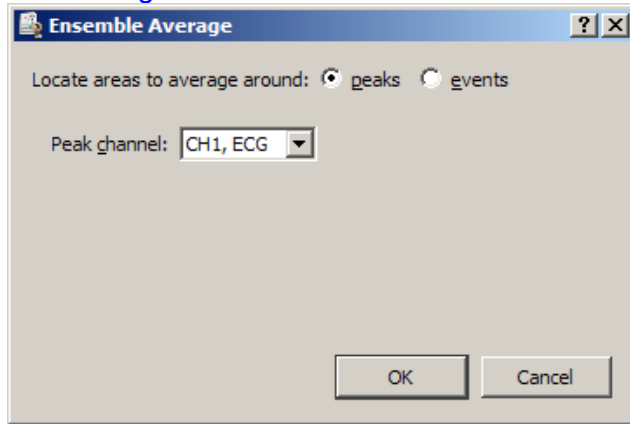
The detection of muscle activation onset and end from surface electrode EMG is an imprecise process. The output of this location should be visually examined for misidentification of activation periods that are too short, too long, overlapping, or missed.

Preferences...

The Preferences allow the type of output to be chosen for displaying results: text, graph channels, or Excel.



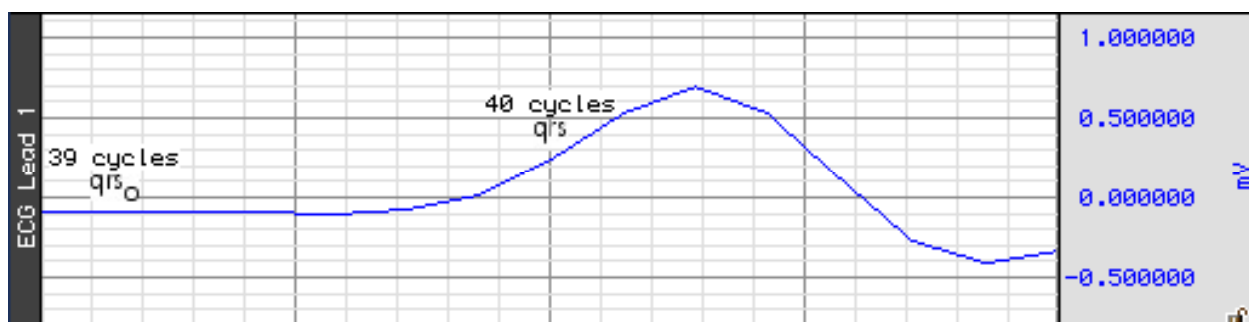
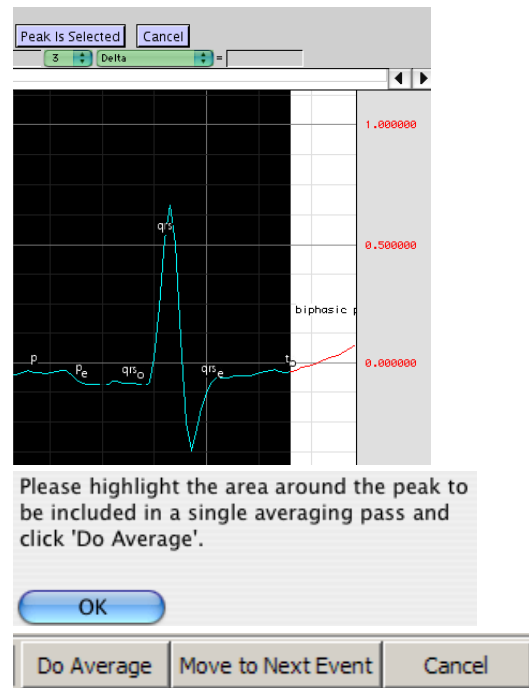
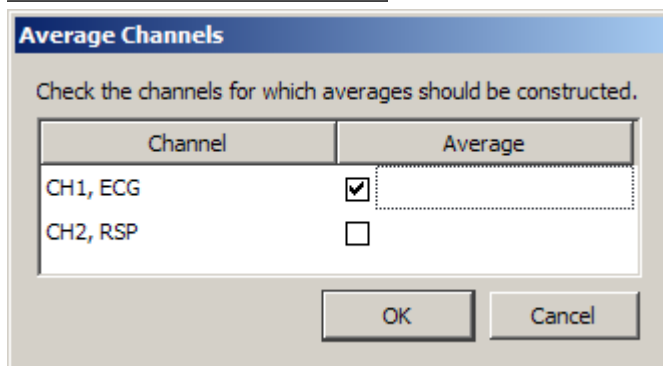
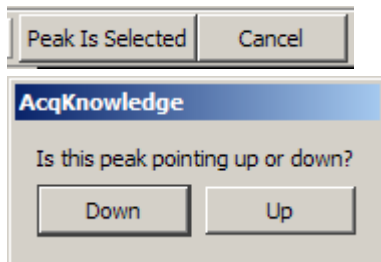
Ensemble Average



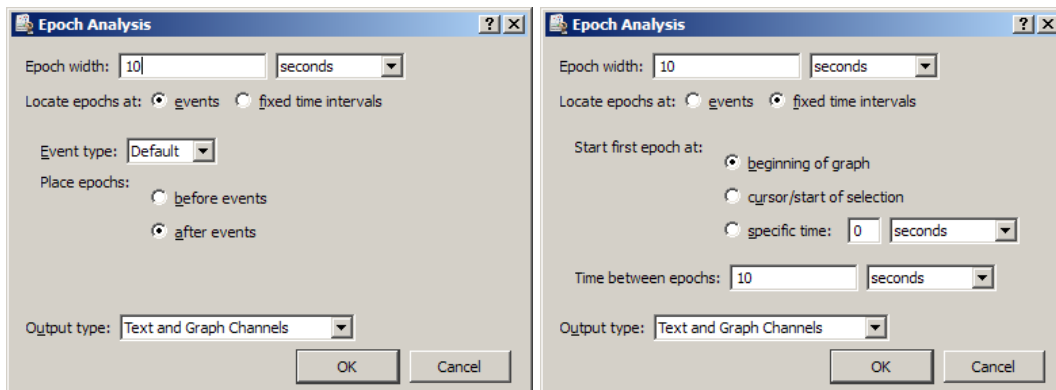
Ensemble Average assists in performing offline averaging. Offline averaging produces an average waveform from a number of cycles, also known as an *ensemble average*. Averages of multiple channels can be extracted simultaneously and be consolidated into a single graph window showing the results. Offline averaging is also available as a function within the Find Cycle feature.

This option provides two methods for locating individual members of the ensemble.

- **Peaks:** Data-driven peak detection with positive or negative peaks in the data. This method automatically derives appropriate threshold levels from a user-selected peak and is useful for constructing averages keyed to periodic signals with strong spikes, such as ECG.
- **Events:** Place members of the ensemble surrounding events in the waveform. Events must be previously defined by the user, either manually or through another automated process. This method is useful for constructing averages keyed to any types of events in a graph.



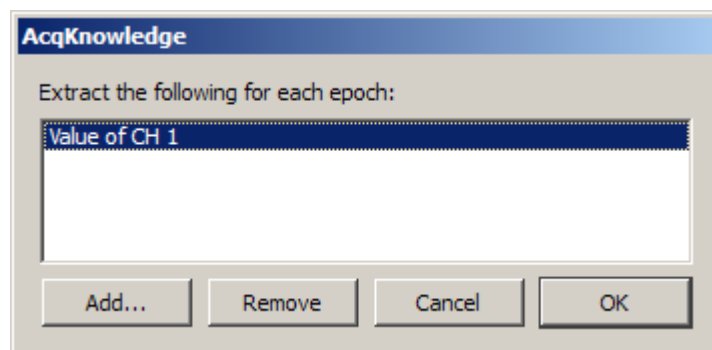
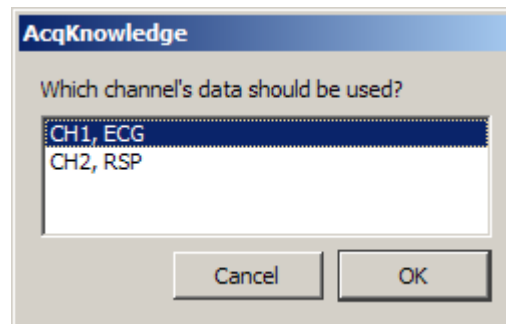
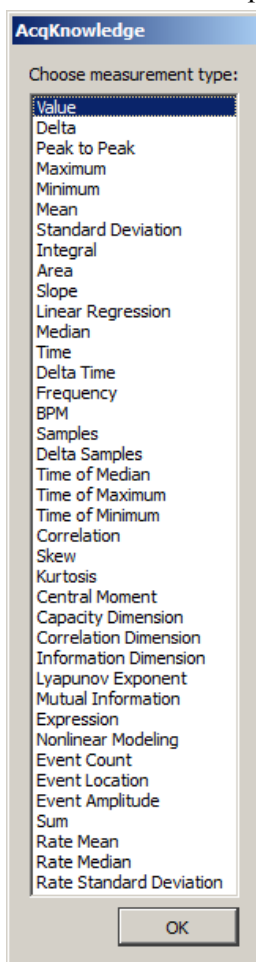
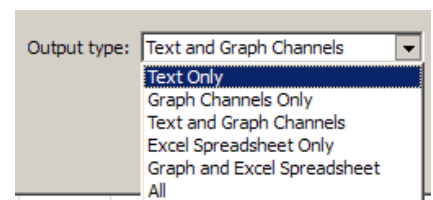
Epoch Analysis



Extracts basic measures from fixed-width time segments of data. A fixed-width time segment of data is known as an *epoch*. The location of these fixed-width intervals can either be keyed off of locations of events in the graph or tied to regular time intervals (e.g. occurring at a constant frequency). All of the standard *AcqKnowledge* measurements can be extracted on an epoch-by-epoch basis with the exception of Calculate.

Epoch-by-epoch measurement results can be viewed either as channels of data in the graph, a textual summary, or on an Excel spreadsheet; textual summaries include a final row with an overall average of each extracted measurement.

Times output by Epoch Analysis are always expressed in seconds; all other units correspond to the current preferred measurement unit settings accessible under Display > Preferences.



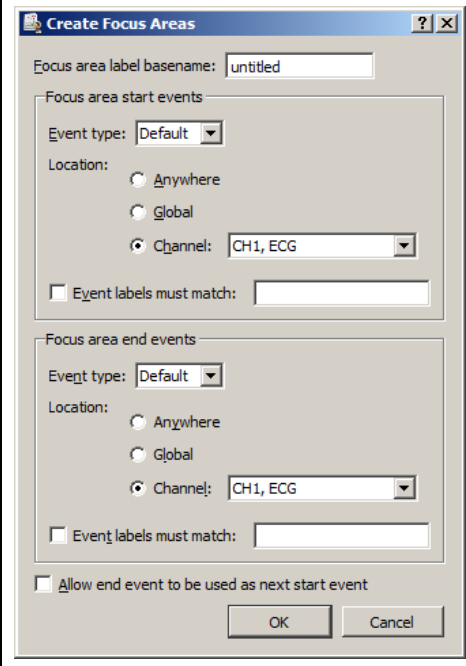
NOTE: The Expression measurement function MMT() is available in Epoch Analysis, but the results may not be reliable.

Focus Areas between Events and Segments

In addition to the standard focus area functionalities discussed on page 89, focus areas can also be used as an analysis tool to define areas of interest between certain event types or between appended segments.

Define Between Events

The parameters for defining focus areas using this method are highly customizable, and can be based upon specific event types or titles as well as various event locations in the graph. The following table explains the various focus area start and end event options.

	<p>Focus area label basename: Use to assign a title for the focus areas. Successive focus areas will use the same title with the addition of incrementing numbers.</p> <p>Event type: Use to select the type of event for defining the focus area.</p> <p>Location:</p> <ul style="list-style-type: none"> • Anywhere—all channel and global events are included in the event matching criteria. • Global—when selected; only global events are included. • Channel—when selected; only events in an individual channel are included. Select the desired channel from the combo box menu. <p>Event labels must match: When checked, only events with labels matching the edit field text will be defined. When unchecked, all events of the selected type are matched, regardless of label.</p>
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Define for Appended Segments

This method simply defines the time range between appended segments as focus areas. No configurable options exist for this feature within the Analysis menu.

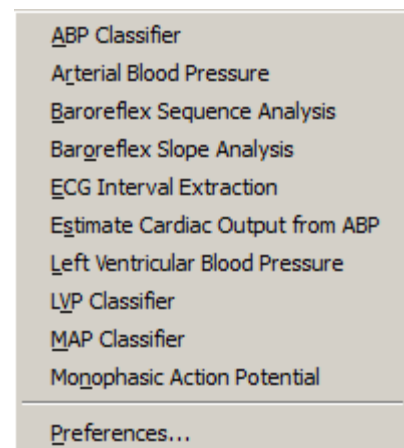
Hemodynamic Analysis

Hemodynamics is the study of blood and circulation related data. This analysis package concerns itself with interpretation of ECG, blood pressure, and monophasic action potential data; ECG signals must be sampled at 5 kHz or below to be analyzed with this package.

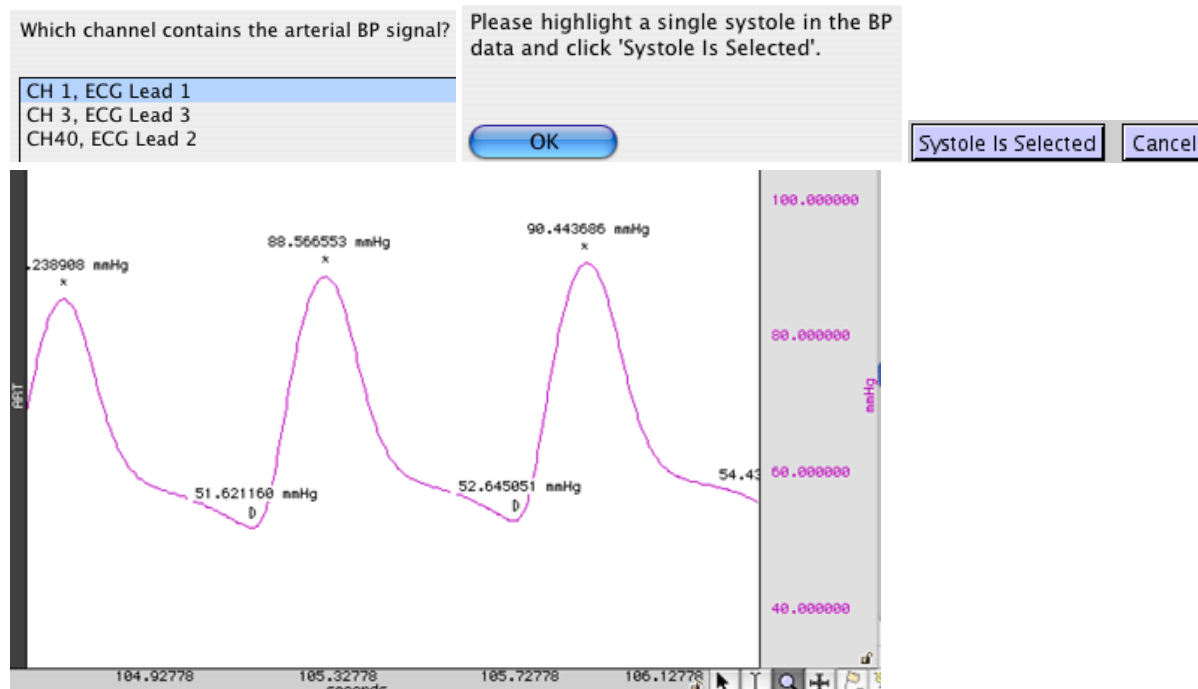
IMPORTANT: These routines are designed specifically for human subjects and may not function well, or at all, on animal subjects, particularly small animals.

The Hemodynamic analysis package consists of:

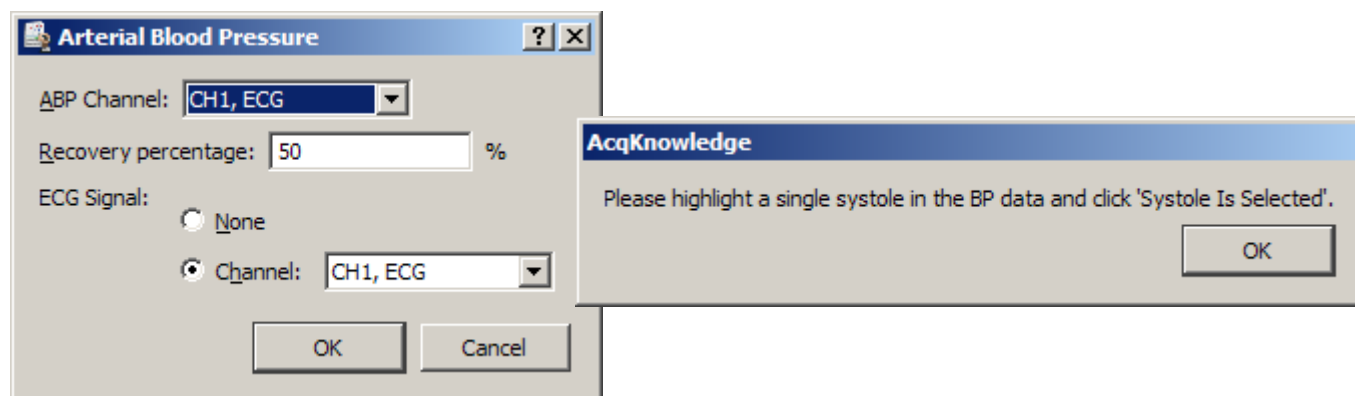
- ABP Classifier
- Arterial Blood Pressure
- Baroreflex Sequence Analysis (licensed feature, see page 515)
- Baroreflex Slope Analysis (licensed feature, see page 515)
- ECG Interval Extraction
- Estimate Cardiac Output from ABP
- Left Ventricular Blood Pressure
- LVP Classifier
- MAP Classifier
- Monophasic Action Potential
- 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.
- Adding smoothing or a low pass filter to the signal may improve Arterial Blood Pressure results.

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:

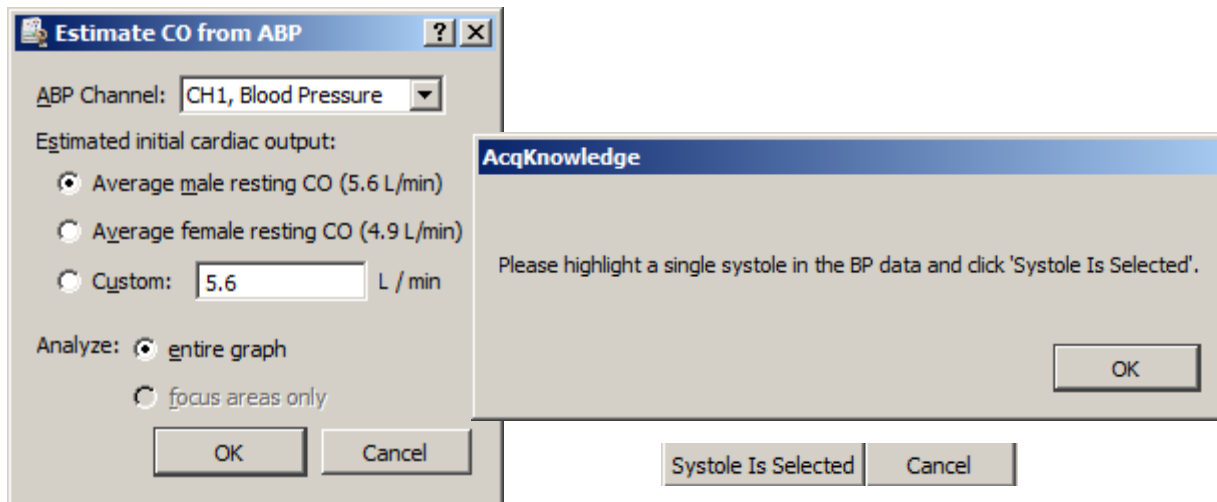
Name	Abbrev.	Description
Corrected QT interval	QTC	QT time interval divided by the square root of the RR interval
Heart rate	HR	RR time interval expressed in BPM
P height	P-H	Amplitude at the peak of the P wave in a cycle
PRQ interval	PRQ	Time between the onset of the P wave to the Q wave
QRS width	QRS	Time between onset of the QRS complex and the end of the QRS complex. Equivalent to the time between onset of Q and end of S
QT interval	QT	Time between the beginning of the Q wave and the end of the T wave
R height	R-H	Amplitude of the R wave in a cycle
RR interval	RR-I	Time between consecutive R peaks in the waveform
ST interval	ST	Time between the S wave to the end of the T wave

At the end of the text table output, the average of all of the cycles will be displayed. Additionally, both text and Excel output will indicate the number of cycles that did not have all three of the QRS, P, and T waves defined. These are cycles where the classifier missed a boundary and are listed as “Bad cycles,” which may happen due to noise or other artifacts in the signal.

Estimate Cardiac Output from ABP

This analysis algorithm, based on the universally recognized Liljestrand non-linear compliance formula, derives an estimate of cardiac output (CO) from an existing arterial blood pressure (ABP) signal. Using this method, it is possible to obtain an accurate measure of this data in a noninvasive fashion. For optimal results, the analysis must first be calibrated through the Estimate Cardiac Output from ABP setup dialog in which an initial resting cardiac output is selected. Adding smoothing or a low pass filter to the signal may further improve results.

1. Select the desired Hemodynamics > Preferences settings. (See page 383 for details.)
2. Hemodynamics > Estimate Cardiac Output from ABP.
3. Select the channel containing the blood pressure signal.
4. Choose an estimated calibration cardiac output level based upon typical male, female, or custom parameters.
5. Select the entire graph or desired focus areas for analysis and click OK.
6. Follow the “Highlight a systole in the BP data” prompt and click OK.
7. Click “Systole Is Selected” to begin the analysis.



If no systolic/diastolic events exist in the selected BP channel, they'll automatically be scored and added using the ABP classifier analysis script. Cardiac output results are presented in graph, text or spreadsheet format, depending on the desired extraction method set up in the Hemodynamics preferences.

For text and spreadsheet output, the following measures are extracted.

Name	Abbrev.	Units	Description
Start Time	--		The time at the beginning of each cycle.
Heart Rate	HR	BPM	Heart rate as extracted from blood pressure signal in BPM.
Estimated Cardiac Output	CO	L/m	Estimated cardiac output as computed using the estimated calibration constant and Liljestrand formula.
Estimated Stroke Volume	SV	L	CO/HR

For graph channel output, the following channels are added to the graph:

Channel Label	Units	Description
Heart Rate - ch	bpm	Heart rate as extracted from blood pressure signal in BPM (e.g., time duration of the cycle in seconds / 60).
Estimated CO - ch	L/m	Estimated cardiac output as computed using the estimated calibration constant and Liljestrand formula.
Estimated SV - ch	L	Estimated stroke volume. Equal to: CO / HR.

If focus areas only are being analyzed, a new set of three channels will be defined for each focus area.

- ▶ Watch the [AcqKnowledge Cardiac Output from ABP video tutorial](#) for a detailed demonstration of this feature.

Left Ventricular Blood Pressure

Extracts various cycle-by-cycle cardiac measures of left ventricular blood pressure data, optionally in conjunction with an ECG Lead II signal. Examines the LVP signal, ECG, and derivative of the LVP signal.

- If the LVP and ECG signals have not been classified before this analysis is executed, they will be classified automatically.
- Derivatives of the LVP signal can be pre-existing or can be constructed automatically.
- If an ECG signal is not included, only pressure related measures will be extracted.

The analysis outputs the following information on a cycle-by-cycle basis and the textual output cites the average of all of these cycle-by-cycle measurements:

Name	Abbrev.	Description
Contractility index	CI	maximum value of dP/dt during the cycle divided by the pressure at that time location
Developed pressure	DP	Amplitude interval between end diastolic pressure and systolic pressure
dP/dt Max	-	Maximum change in pressure over the cycle
dP/dt Min	-	Minimum change in pressure over the cycle
End diastolic pressure	LVEDP	End diastolic pressure for the cycle. This is not necessarily the minimum pressure during the entire cycle. LVEDP is located on the LVP signal using the method set in the preferences.
Minimum pressure	MIN	Absolute minimum pressure occurring during the entire cycle. This is not necessarily equivalent to the end diastolic pressure
QA Interval	QA	Time interval between the Q wave of the ECG and the end diastolic pressure
Rate	-	heart rate in BPM as extracted from the time interval between consecutive end diastolic pressure locations
Recovery time	%REC	Time it takes for dP/dt to increase from the minimum dP/dt location to a user specified percentage of that minimum value
Systolic pressure	SYS	Maximum pressure occurring during the entire cycle
Tau	-	Monoexponential time relaxation constant tau computed on a cycle by cycle basis. <i>See "Computation of Tau" on page 381 for specifics.</i>
Tension time index	TTI	Integral of the pressure between end diastolic and the time of minimum dP/dt

Computation of Tau

There are many different methodologies used to extract the time constant from LVP data. The time constant is extracted from a best fit parameter of a model to the trailing edge of LVP data on a cycle by cycle basis. This analysis uses a monoexponential model of zero asymptote for computing tau.

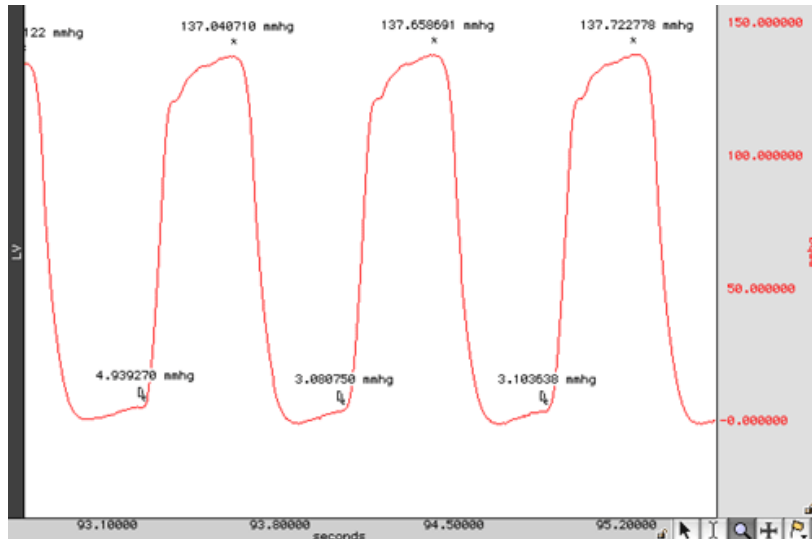
The relaxation period is defined as the range of data between the time of minimum dP/dt in the cycle to the point where the LVP pressure signal drops below the previous LVEDP level. Within this range, the following model is fitted to the data using the simplex search method:

$$P_0 e^{\frac{t}{\tau}}$$

where P_0 is the value of the LVP signal at the time of dP/dt minimum and t is the time coordinate shifted such that t is 0 at the time of dP/dt minimum. The best fit value from this model is used as the value of the relaxation time constant.

LVP Classifier

Operates on left ventricular blood pressure (LVP) data to define events at the systolic pressure and the left ventricular end diastolic pressure for each cycle.

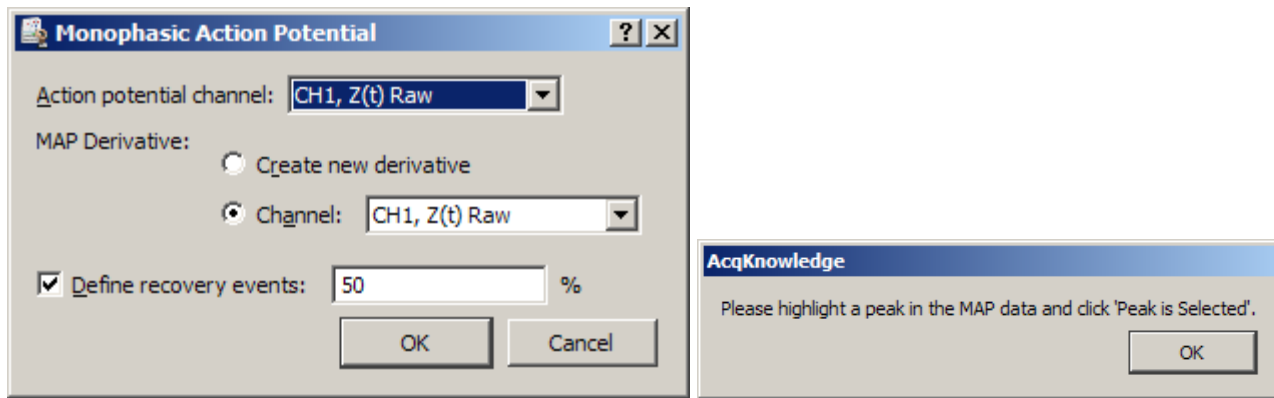


The location of these points is performed using filtered derivatives of the original LVP signal. Pre-filtering the signal (low pass of 50 Hz or less) or smoothing the signal before running the classifier may improve accuracy. The LVP classifier locates LVEDP (left-ventricular end diastolic pressure) by examining the derivative of the pressure signal based upon the location method specified in Preferences:

- Adaptive threshold of 0 plus a percentage of the peak to peak change in pressure. The percentage is user-specified; the default is 1%. If the LVP signals do not have “flat” valleys, this percentage may need to be increased to fine-tune positioning of LVEDP.
- First zero crossings before contraction.

Watch the [AcqKnowledge LVP classifier video tutorial](#) for a detailed demonstration of this feature.

Monophasic Action Potential



Performs classification of MAP data acquired from a human or animal subject and extracts various cycle by cycle intervals. Locates upstroke, maximum, 100% recovery, and user-specified recovery points on the action potential.

- Classification is performed using the action potential with its smoothed derivative; pre-filtering noise with low pass filters may improve classification.
- If upstroke, maximum, and plateau events are already defined on the MAP signal, the classifier is not invoked and only recovery events are defined.

Plateau position

To better handle animal subjects and different potential morphologies, there are two methods for locating the plateau position in monophasic action potential data; use Preferences to set the method. Each method defines recovery percentage time locations depending on the signal between its maximum and the beginning of the plateau. The plateau is located by examining the derivative of the MAP immediately following its maximum value after an upstroke.

- The first method uses an adaptive threshold of zero plus a percentage of the peak to peak change in the derivative between the maximum and the first zero crossing after the maximum. If the signal remains above the upstroke voltage in this interval, a quick algorithm is used to locate 100% recovery and user-specified percentage levels.
- The default percentage is 0.1%, which will place the plateau position very close to the second zero crossing. This slight window around zero helps place plateau start events better for MAP data that has plateaus that continue increasing after their starting position.
- Searches for the second zero crossing after the maximum. If the signal drops below the voltage level of the upstroke in this interval, a different (slower) algorithm is used to ensure the recovery percentage is relative to the upstroke voltage and not the minimum occurring between the maximum and plateau.

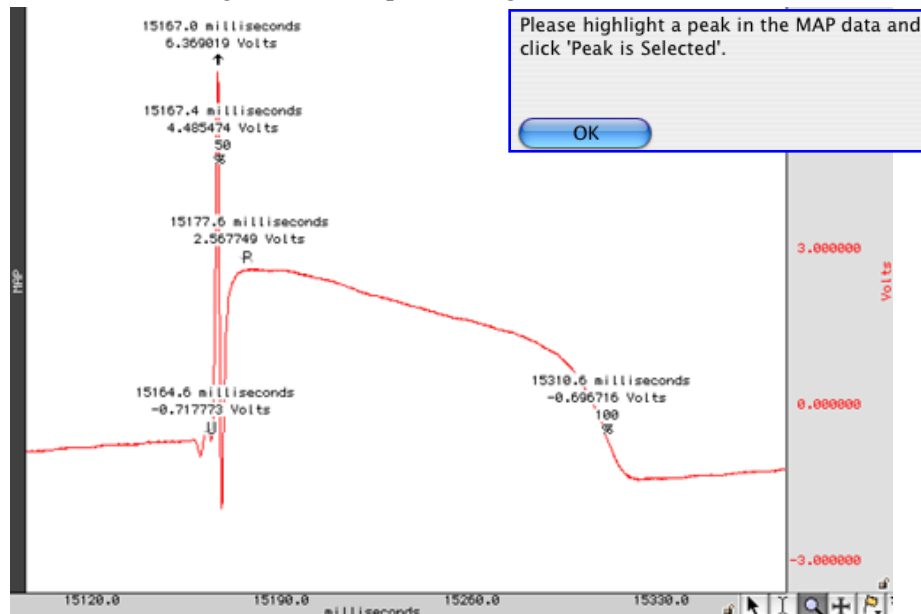
The analysis outputs the following information on a cycle-by-cycle basis and the textual output cites the average of all of the cycle-by-cycle values:

Name	Abbrev	Description
100% recovery period	100% REC	Time interval from the upstroke for the signal to recover back to the upstroke voltage level
dV/dt maximum	dV Max	Maximum change in voltage over the cycle
dV/dt minimum	dV Min	Minimum change in voltage over the cycle
End diastolic voltage	EDV	The value of the signal at the beginning of the upstroke
Max voltage	MAX	The maximum value of the signal over a single cycle
Minimum voltage	MIN	The minimum value of the signal over a single cycle. This may be less than the upstroke voltage depending on the morphology of the action potential
Plateau voltage	PLAT	The value of the signal at the start of the plateau after the completion of the upstroke
Rate	-	This is the heart rate in BPM as extracted from the time interval between consecutive upstrokes
Stroke amplitude	AMP	Voltage interval between the plateau and the upstroke voltage
User recovery period	%REC	Time interval from the upstroke for the signal to recover a specific percentage of the interval between the upstroke and the maximum voltage between the upstroke and the plateau

- ▶ Watch the [AcqKnowledge Monophasic Action Potential video tutorial](#) for a detailed demonstration for this feature.

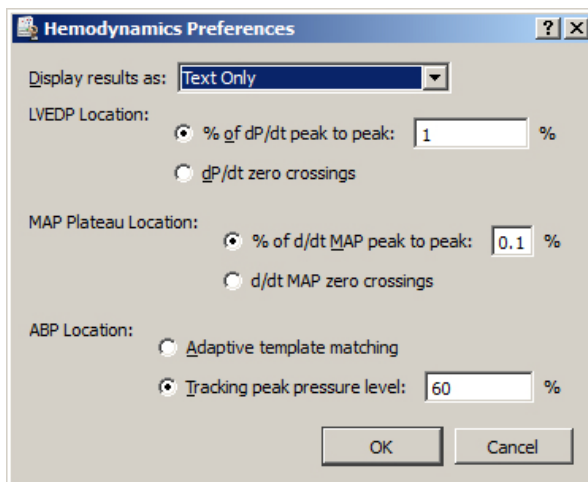
MAP Classifier

The classifier portion of Monophasic Action Potential only – defines upstroke, plateau, and percentage recovery events on MAP signals without performing the additional MAP data extraction.



The start of the plateau is located using either the second zero crossing of the derivative or a percentage of the cyclic peak-to-peak distance of the derivative. The plateau location method can be configured in Preferences.

Preferences



Display results as

Several of these transformations produce large amounts of cycle-by-cycle derived measures. Results can be displayed as a tab delimited table in the journal, as waveforms in the graph, as an Excel spreadsheet or various combinations. Results are displayed as text-only by default.

LVEDP location method – see page 381

- 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 382

- adaptive threshold of 0 plus a % of pk-pk change in the derivative between the max and the first 0 crossing after the max
- second zero crossing after the maximum

ABP Location method (Arterial Blood Pressure)

Adaptive template matching

This arterial blood pressure cycle location method uses adaptive template matching (see page 300). A single cycle is selected, systolic to systolic, which sets an example template. Subsequent blood pressure cycles are located by correlation to this template with the template adapting to the signal. This may function better if there is artifact in the pressure signal, however may not be as suitable for signals that have significant changes in heart rate. Location may also improve if a different cycle is chosen as the initial template. Adding smoothing or a low pass filter to the signal may improve results for Estimated Cardiac Output, ABP Classifier and Arterial Blood Pressure.

Tracking peak pressure level

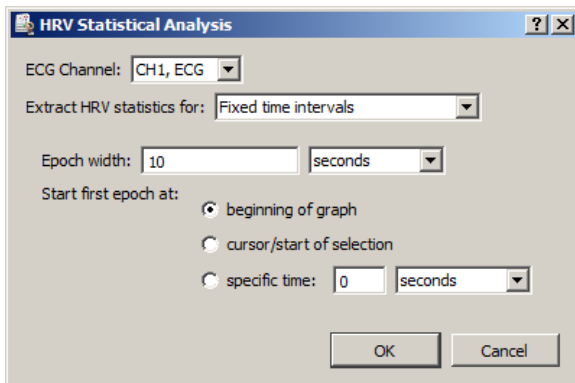
The Tracking peak pressure level ABP location method is similar to the cycle detector's peak location method. This method sets a detection threshold from a selected systole and adjusts the threshold based on a customizable tracking percentage. The default tracking percentage is 60%. If the blood pressure signal is highly variable, this tracking percentage may need to be lowered. If the tracking percentage is set too high, blood pressure cycles may be missed.

HRV and RSA Analysis

AcqKnowledge includes flexible options for extracting a wide range of heart rate variability (HRV) and respiratory sinus arrhythmia (RSA) measures. This analysis feature allows you to:

- Extract HRV measures over user-defined areas of data, such as fixed time trials (“epochs,”) events and focus areas.
- Obtain RSA measures using frequency-based HRV.
- Automatically compute HRV using geometrical and statistical methods.

Multi-epoch HRV – Statistical



This analysis computes statistical measures of heart rate variability in user-specified time intervals. These measures (RMSSD, SDDSD, and pNN50) can be extracted by fixed time intervals, time between event boundaries or focus areas. Output from the script is a spreadsheet containing these statistics and the time intervals over which they are computed. ECG complex events are also scored in the source graph. See [Application Note 129](#) for a detailed explanation of HRV statistical analysis measures.

The following table describes options in the Multi-epoch HRV Statistical Analysis setup:

Control	Description
ECG Channel:	Selects the channel to extract the statistics from. The ECG channel should be selected.
Extract HRV statistics for:	Select how the time ranges used for extracting statistics are applied. The options are Fixed time trials, Time between event boundaries and Focus areas.
Epoch width:	Indicates time duration and time units for each epoch.
Start first epoch at:	Chooses location for starting first epoch. (Beginning of graph, current cursor location or a specific time point in the graph.)

Multi-epoch HRV and RSA – Spectral

This routine performs RSA and HRV analyses on specified time slices along an ECG waveform, whether by markers, fixed time intervals or focus areas. Then the HRV parameters of VLF, LF, are teased out of the journal, formed into a table, and written back into the journal or to an Excel spreadsheet. The following table describes the HRV and RSA Spectral Analysis options:

Control	Description
HRV Preset	Selects the heart rate variability preset to be used in the analysis. (This must first be pre-defined in the main HRV analysis dialog for conveying PSD, frequency bands, etc.) For more information, see <i>Single-epoch HRV – Spectral</i> .)
ECG Channel:	Selects the channel to extract the statistics from. The ECG Lead II channel should be selected here.
Extract HRV and RSA by:	<p>Selects how the segments to be analyzed should be located. Available options are by:</p> <ul style="list-style-type: none"> Periodic time intervals – this option segments the data into fixed width epochs that occur at regular frequency intervals. It is equivalent to the “fixed time interval” option of epoch analysis. Fixed-width intervals around events – “Fixed width intervals around events” is akin to the “at events” option of Epoch Analysis. It searches for individual events and then analyzes a fixed interval of time with that event either as the beginning point or the endpoint of the time window. Time between event boundaries – allows the segments to be located between two different individual events. The boundaries should ideally be two different types of events. If set to the same type, you will be prompted for whether the ending event of a pair should be immediately reused as the start of the next time interval. Focus areas – this method extracts the HRV for each focus area defined within the graph. <p>See page 385 for specific setup descriptions for the above options.</p>
Output type:	Select the analysis output format – Text, Excel, or both.
Output events at analysis boundaries:	Defines new markers at the time boundaries of each analyzed data segment. This is useful when performing validation of the analysis.

If **Periodic time intervals** are chosen, the following setup criteria are available:

- Epoch width: – sets the duration and time units for each epoch
- Start first epoch at: – choose location for starting first epoch. (Beginning of graph, current cursor location or a specific time point in the graph.)
- Time between epochs: – indicates the time separating one epoch to the start of to the next.

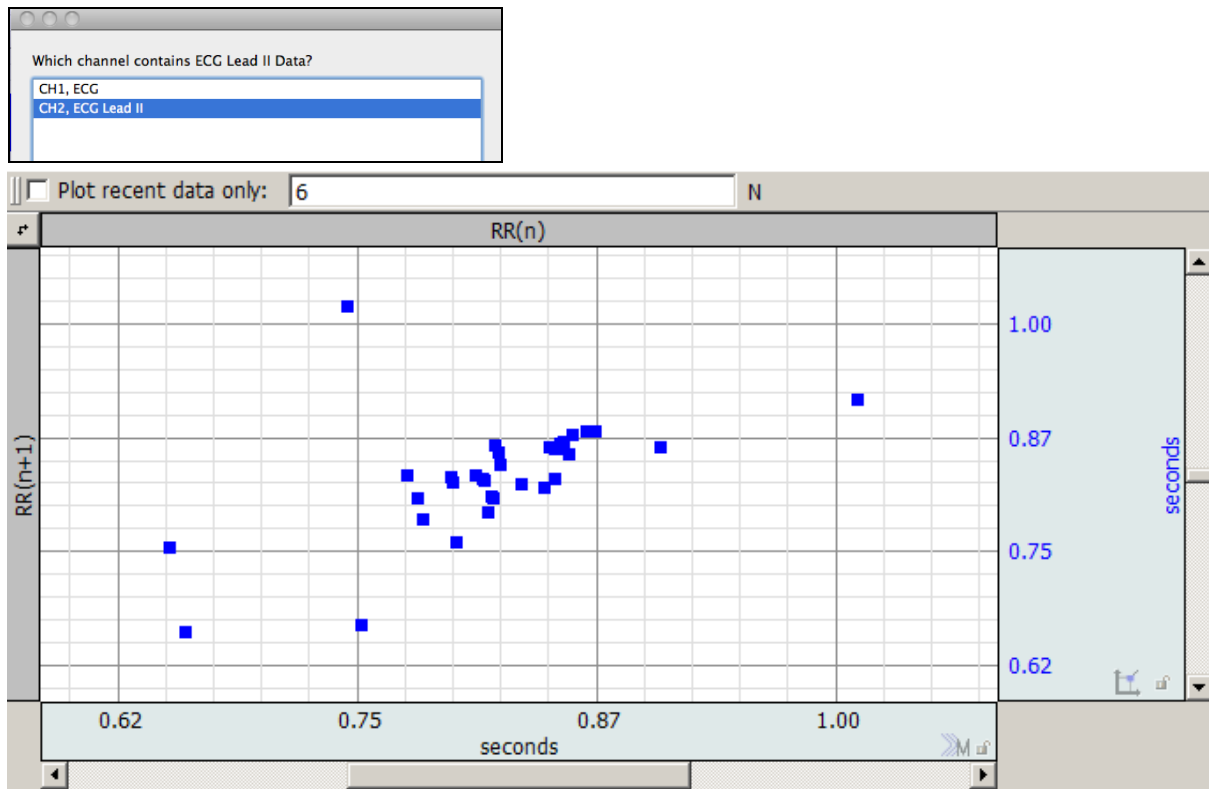
If **Fixed width intervals around events** is chosen, the following setup criteria are available:

- Event type: – choose the specific type of event to be used in the analysis.
- Before events: – when selected, the event marks the end of the analysis time interval.
- After events: – when selected, the event marks the beginning of the analysis time interval.
- Epoch width: – sets the duration and time units for each epoch.


If **Time between event boundaries** is chosen, the following setup criteria are available:

- Start event: – select the starting event type at the beginning of each time segment.
- End event: – select the ending event type at the end of each time segment.

R-R Poincare Plot

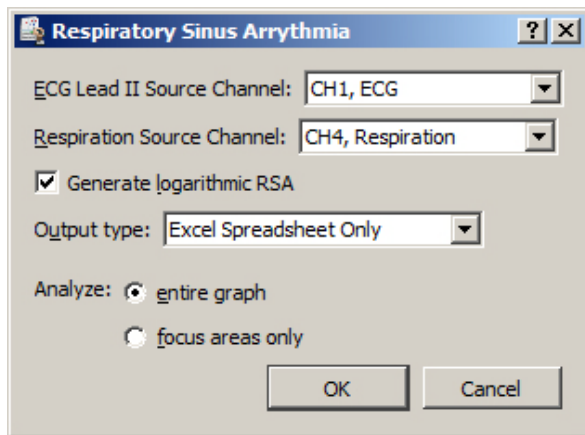


Poincare plots are constructed from ECG Lead II data. A Poincare plot is an XY plot with RR intervals in seconds on one axis and on the other axis the sequence delayed by one beat (RR vs. RR+1). This plot may be used to visually inspect for patterns in the sequence similar to an attractor plot. The RR intervals are measured in seconds.

This generates a new dot plot graph window in XY mode, no textual output is generated. Click the  button to exchange the X and Y axis (flip the plot diagonally.) Use "Plot recent data only" to isolate a subset of the most recent data points. Enter the desired number of data points to be displayed and check the "Plot" box. Or, with the box checked, enter the desired value and hit the Enter (Return) key.

Applying the R-R Poincare plot option also scores the ECG source graph with QRS events.

Respiratory Sinus Arrhythmia (RSA Time-series)



IMPORTANT—Respiration analysis assumes a bidirectional airflow signal that records both inhale and exhale. Unidirectional respiration signals cannot be analyzed at this time.

Respiratory Sinus Arrhythmia is used to explore the connection between respiration and changes to heart rate. Variations in the heart rate can be directly correlated with vagal tone. The RSA index can be used to investigate changes in this connection during recording.

This RSA index is computed using the peak-valley method as outlined in:

Grossman, P., van Beek, J., & Wientjes, C. (1990). A comparison of three quantification methods for estimation of respiratory sinus arrhythmia. *Psychophysiology*, 27, 702-714.

This method uses both a recorded ECG Lead II signal and a respiration signal. By using respiration information, this analysis method can provide breath-to-breath analysis that does not require parameter tweaking for individual subjects.

While designed for use with the RSP100C/TSD201 respiration module and transducer combination, it should be possible to use other estimates of respiration. The respiration signal is used to locate periods of inhalation and exhalation. Inhalation begins at valleys in the signal while expiration at peaks. Any respiration estimate that exhibits this morphology should be sufficient.

The RSA index outputted by this analysis is linearly scaled as per the recommendations in Grossman et. al. For comparison to other methods or studies using logarithmic scaling, Transform > Math Functions > Ln transformation can be used after analysis to convert results to logarithmic scaling.

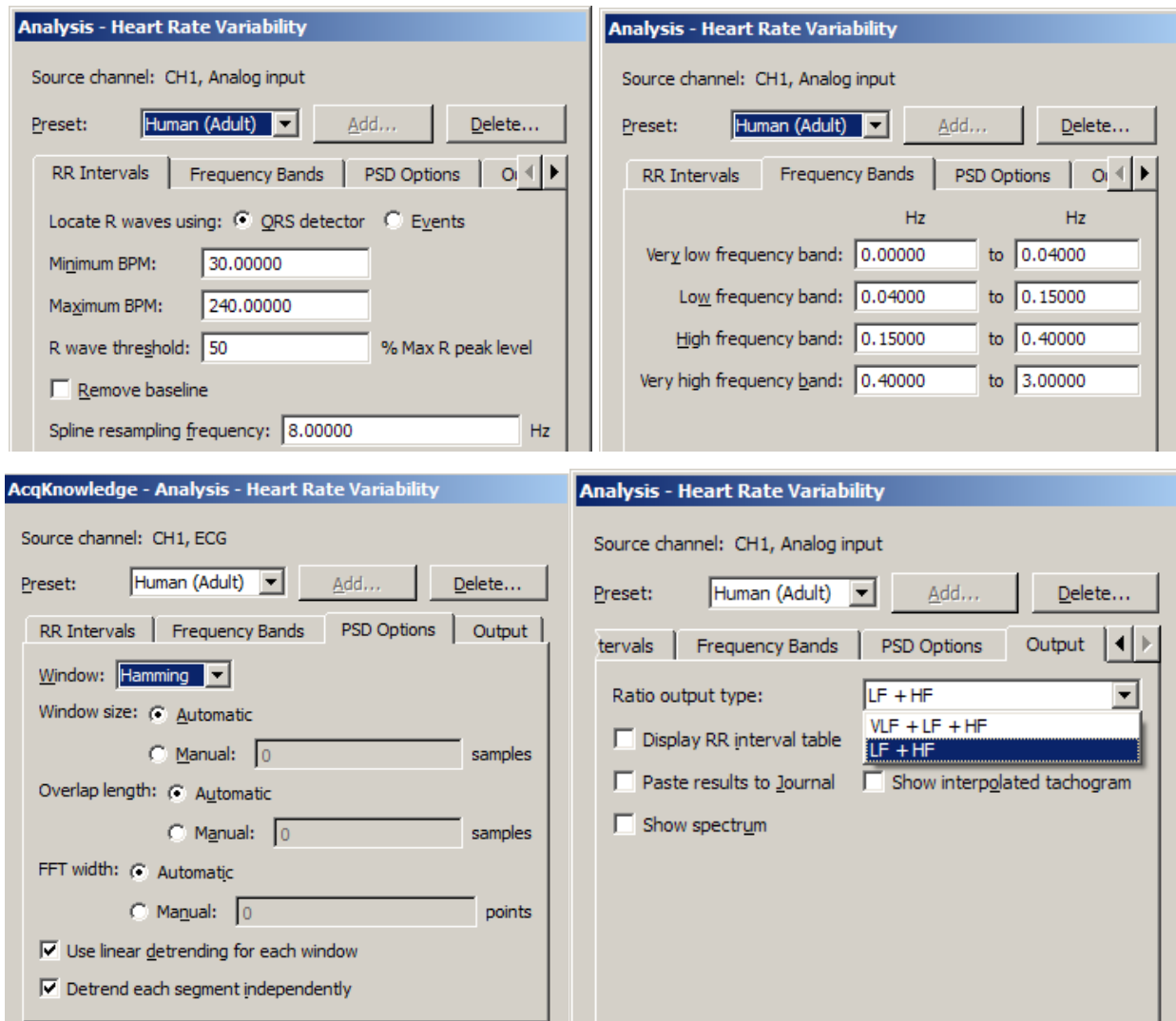
In AcqKnowledge versions 4.4.1 and higher, selecting the “Generate logarithmic RSA” checkbox will automatically output the logarithmic result.

RSA results are triggered from the respiration cycle. The RSA analysis outputs the following measures:

- | | |
|-----------------|---|
| <i>Cycle</i> | Index of the respiration cycle in the analysis. |
| <i>Time</i> | Location of the start of the respiration cycle on the time axis. |
| <i>Min Rate</i> | Minimum heart rate occurring during the inspiration window of the respiration cycle, expressed in milliseconds (IBI). <ul style="list-style-type: none"> • If a respiration cycle is invalid, this measure will be set to 0. |
| <i>Max rate</i> | Maximum heart rate occurring during the expiration window of the respiration cycle, expressed in milliseconds (IBI). <ul style="list-style-type: none"> • If a respiration cycle is invalid, this measure will be set to 0. |
| <i>RSA</i> | RSA index for the respiratory cycle, expressed in milliseconds. This is the max rate minus the min rate. This is output in linear scaling. <p>If a respiration cycle is invalid, this measure will be set to 0.</p> |

Single-epoch HRV – Spectral

Single-epoch HRV – Spectral (formerly referred to as Heart Rate Variability in AcqKnowledge versions 4.3.1 and earlier), is the examination of physiological rhythms that exist in the beat-to-beat interval of a cardiac signal. Single-epoch HRV assists in performing frequency domain analysis of human ECG Lead II data to extract standard HRV measures. The HRV algorithm in AcqKnowledge 3.9 and above conforms to the frequency domain algorithm guidelines as published by the European Heart Journal (1996) 17, 354-381.



Single-epoch HRV processing in 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).

The initial implementation of the HRV algorithm was primarily for use with long duration recordings. HRV algorithm improvements allow for further customizations to the algorithm:

- Windowing type for FFTs used to construct the PSD may be changed between Hamming, Hanning, and Blackman.
- Overall window length for segmenting source data for individual FFTs to include in PSD average may be modified.

- Length of the individual FFTs in the average can be manually specified.
- Scaling has been changed for PSDs, which are now scaled relative to the sampling frequency.
- Summary of power in individual frequency bands has been changed .
- Instead of a straight sum, an average power value is now reported .
- Power at endpoints is halved (e.g. divided by 2).
- Sympathetic/Vagal ratios may optionally include the very low frequency band in the total power estimate
- The modifications to the HRV algorithms that affect its power spectrum estimation have also been applied to the PSD transformation.

After selecting Analysis > HRV and RSA > Single-epoch HRV – Spectral, choose the appropriate tab(s) and establish settings.

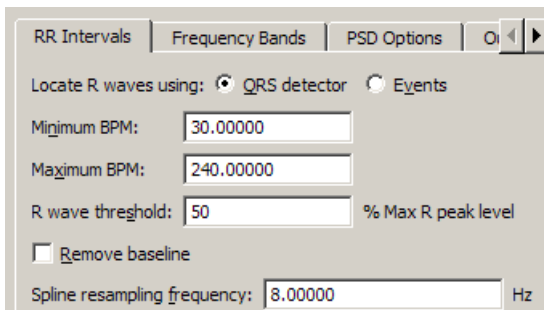
Preset controls, Transform entire wave checkbox, and OK/Cancel buttons apply across all of the tabs.

Preset—The preset menu can be used to save a variety of HRV settings, including: beat detection parameters, spline resampling frequency, and frequency band ranges. Choose a preset from the popup menu to apply its settings. To construct a new preset with the currently displayed settings, choose Add New Preset. A default preset for adult human subjects is supplied.

RR intervals

Select a method to locate R waves: QRS Detector or Events.

QRS detector



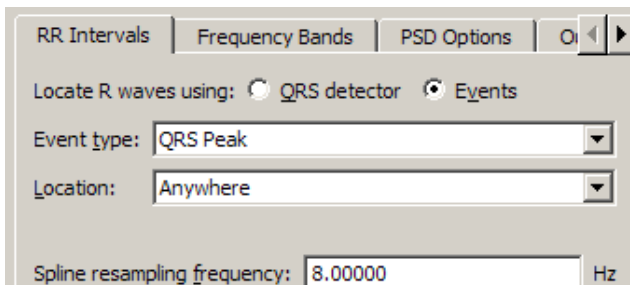
The screenshot shows the 'RR Intervals' dialog box with the 'QRS detector' tab selected. The 'Locate R waves using:' section has 'QRS detector' selected with a radio button. Below this, there are input fields for 'Minimum BPM:' (30.00000), 'Maximum BPM:' (240.00000), and 'R wave threshold:' (50) with a label '% Max R peak level'. There is an unchecked checkbox for 'Remove baseline'. At the bottom, there is a 'Spline resampling frequency:' field set to 8.00000 Hz.

The heart rate variability implementation has a built-in QRS detector. The detector does not run on raw source data; it uses a modified Pan-Tompkins algorithm to normalize the ECG data to 1, whereby the peak amplitude of the highest R-wave represents 1. Use the tachogram output to examine the output of the QRS detector.

- *R wave threshold*—The detection threshold must be specified in terms of percentage of maximum R peak level; this helps to clarify the units in which this threshold is expressed. The default threshold level of .5 should place the threshold in the middle of the R-wave, which should function on a wide range of data sets. If the R-wave amplitude varies a lot, it might be necessary to adjust the threshold level.
 - R wave threshold is expressed in normalized units, which are in the range (-1, 1): positive for positive R wave peaks. The maximum voltage in the signal maps to 1.0 and the minimum voltage in the signal maps to -1.0.

Pan J and Tompkins WJ. A Real-Time QRS Detection Algorithm. *IEEE Transactions on Biomedical Engineering* 32(3):230-236, 1985.

Events



The screenshot shows the 'RR Intervals' dialog box with the 'Events' tab selected. The 'Locate R waves using:' section has 'Events' selected with a radio button. Below this, there are dropdown menus for 'Event type:' (set to 'QRS Peak') and 'Location:' (set to 'Anywhere'). At the bottom, there is a 'Spline resampling frequency:' field set to 8.00000 Hz.

R-wave peaks will be located using events already in the graph of the channel of data to be analyzed. This assumes a single event is placed at each R-wave peak and that all of the R-peak events are of the same event type.

When using events, the built-in QRS detector is not used; the exact positioning between the events on the channel is used to extract the RR intervals.

By using events, it is possible to use other QRS detectors within *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.

Spline resampling frequency

For highest accuracy, set to no less than twice the topmost frequency of the very high frequency band.

Frequency Bands

Band	Start (Hz)	End (Hz)
Very low frequency band	0.00000	0.04000
Low frequency band	0.04000	0.15000
High frequency band	0.15000	0.40000
Very high frequency band	0.40000	3.00000

Enter the start and end of each specified frequency band to adjust the boundaries of the frequency analysis. They are preset to the frequency ranges recommended by the European Heart Journal (1996) 17, 354-381. Output of derived parameters is presented in a dialog and may also be pasted as text to the Journal.

- Very high frequency band, usually used in rat studies, is disabled if the spline resampling frequency is less than the upper bound of the very high frequency range.

PSD Options

Window: **Hamming**

Window size: ☒ Automatic ☐ Manual: 0 samples

Overlap length: ☒ Automatic ☐ Manual: 0 samples

FFT width: ☒ Automatic ☐ Manual: 0 points

☒ Use linear detrending for each window

☒ Detrend each segment independently

PSD Options establish parameters for the power spectral density transformation used to compute the spectrum from the interpolated tachogram; the options contained in this tab mirror the controls of the Analysis > Power Spectral Density transformation.

The use of linear detrending in each individual segment of source data prior to the windowed periodogram analysis can be enabled or disabled. When disabled, the algorithm may be tuned to correspond to implementations that do not apply linear trending, such as MATLAB, which uses windowing only. The same PSD options are available via Analysis > Power Spectral Density so users can regenerate the spectrum from either the raw or interpolated tachogram output as necessary.

After the user modifies the parameters for the PSD transformation, those parameters will become the new default values each time the dialog is displayed. When the application is relaunched, the default settings will be used (user changes are not persistent).

Window	Used to change the window that is applied to each segment of the source data prior to computing the PSD to be included in the average. Includes the following options:		
	Hamming	Hanning	Blackman
Window size	<p>The specified number of samples must be a power of two. Note that the window function is applied to the entire window width of the data; using a subset of the windowed data will not include the final portion of the windowed data.</p> <ul style="list-style-type: none"> If the FFT size is less than the window size, only a subset of the windowed sample data will be used. <p>Automatic If selected, the window size is selected automatically depending on the size of the source data. For a data length of n samples, choosing this radio button will use the window size:</p> $L = \frac{n}{4.5}$ <p>Manual If selected, the window size will be input manually by the user in the associated edit field. The window size must be greater than three and must be less than the length of the data selection. Users will be warned on invalid window sizes when attempting to click OK.</p>		
Overlap length	<p>After each individual FFT, the window of source samples is shifted over by a certain amount to compute the next FFT, so there is an overlap of source samples in successive windows of source for the next FFT in the average.</p> <p>Automatic If selected, the number of samples to overlap successive windows will be computed automatically. Given a window length L computed according to the window width choices, choosing this radio button will use an overlap number of samples:</p> $\frac{L}{2}$ <p>Manual If selected, the number of samples to overlap successive windows of source data. Overlapping reduces windowing artifacts. The overlap length must be positive and must be less than the window size. Users will be warned on invalid overlap lengths when attempting to click OK.</p>		
FFT width	<p>Automatic If selected, the number of points to use for each individual FFT will be computed automatically. Given a window length L computing according to the window width choices, the number of points in the FFT will be set to:</p> $N_{fft} = \begin{cases} 256, & L < 256 \\ 2^{\lceil \frac{\log(L)}{\log(2)} \rceil}, & L \geq 256 \end{cases}$ <ul style="list-style-type: none"> The number of points in the FFT is set to 256 if the window width is less than 256. Otherwise the length is set to the next power of two higher than the window width. <p>Manual If selected, the number of points in the FFT will be specified manually in the edit box to the right of the radio. The number of points in the FFT will be required to be a positive power of two. It is recommended that the FFT length be set larger than the window size. If longer than the window size, zero point padding is used. Users will be warned on invalid FFT number of points when attempting to click OK. If the user inputs a number of points for the FFT that is shorter than the window width, a confirmation dialog will be displayed to the user warning that the windowing is shorter than the requested FFT width and asked if they want to continue.</p>		

Use linear detrending for each window

When enabled, linear regression detrending is applied for each individual segment prior to the FFT computation. When disabled, windowing only is applied.

Detrend each segment independently

This option is only available when "Use linear detrending" is enabled. When this option is enabled, detrending is applied independently for each segment; when disabled, detrending from the previous segment will be incorporated into the next segment.

Transform entire wave

When enabled, the entire waveform is delayed. When unchecked, only the selected area is delayed.

- If there is no selection in the graph, the checkbox is enabled and dimmed.
- As the selection changes in the graph with the selection palette, the state of this checkbox is updated.

Improvements to PSD Options (AcqKnowledge 4.3 and higher)

- The PSD output is now scaled so power values are scaled by the sampling rate. That is: $PSD_{new} = \frac{PSD_{old}}{f_s}$
- Reporting a sum for a frequency range when computing the power in an individual band has been changed.

Given a frequency range f_{low}, f_{high} define the set S of all samples of the PSD where $S = \{PSD(f_{low}), \dots, PSD(f_{high})\}$. Define the sum of the power within the frequency range as:

$$s(f_{low}, f_{high}) = \left(\frac{S_1}{2} + \sum_{i=2}^{|S|-1} S_i + \frac{S_{|S|}}{2} \right) \times \frac{(f_{high} - f_{low})}{|S| - 1}. \text{ This applies the scaling factor to a sum of the}$$

frequencies in the frequency range, with the magnitudes at the endpoints divided by 2. Previous versions would perform a direct sum of all amplitudes within the frequency band.

- Result reporting has been changed for the overall ratios. The VLF section is now included in the ratios. A new VLF ratio has been introduced. Define $s_{vlf} = s(vlf_{low}, vlf_{high})$, $s_{lf} = s(lf_{low}, lf_{high})$, and

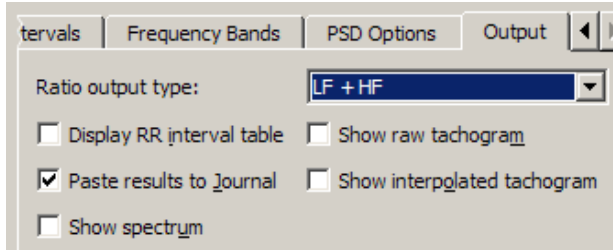
$$s_{hf} = s(hf_{low}, hf_{high}). \text{ The new VLF ratio is: } ratio_{vlf} = \frac{s_{vlf}}{s_{vlf} + s_{lf} + s_{hf}}. \text{ The new sympathetic ratio is}$$

$$\text{defined as: } ratio_{lf} = \frac{s_{lf}}{s_{vlf} + s_{lf} + s_{hf}}. \text{ The new vagal ratio is defined as: } ratio_{hf} = \frac{s_{hf}}{s_{vlf} + s_{lf} + s_{hf}}. \text{ The}$$

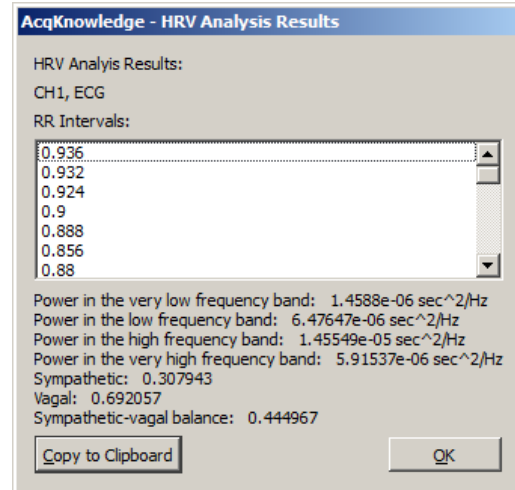
$$\text{previous algorithm defines the sympathetic ratio as: } ratio_{lf_{old}} = \frac{s_{lf}}{s_{lf} + s_{hf}}. \text{ The previous algorithm defines}$$

$$\text{the vagal ratio as: } ratio_{hf_{old}} = \frac{s_{hf}}{s_{lf} + s_{hf}}.$$

Output



Create standard result presentation graphs or assess performance of the HRV algorithm. Output options allow access to intermediate computation data for algorithm validation and/or measurements.



RR Interval table

- If the combined output formula is selected, the analysis output will contain an additional line of text: “VLF Ratio” with the corresponding percentage.

Spectrum

Displays the power spectrum density (PSD) estimation from which the PSD summations and 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.

IMPORTANT—Recording good data is essential for performing HRV analysis. The protocol for data acquisition, filtering, artifact detection and correction in Application Note 233 results in great improvements in HRV analysis.

“Results reveal that even a single heart period artifact, occurring within a 2-min recording epoch, can lead to errors of estimate heart period variability that are considerably larger than typical effect sizes in psychophysiological studies.” —Berntson & Stowell, 199

- See **Application Note 233 Heart Rate Variability—Preparing Data for Analysis Using AcqKnowledge** (online at www.biopac.com)

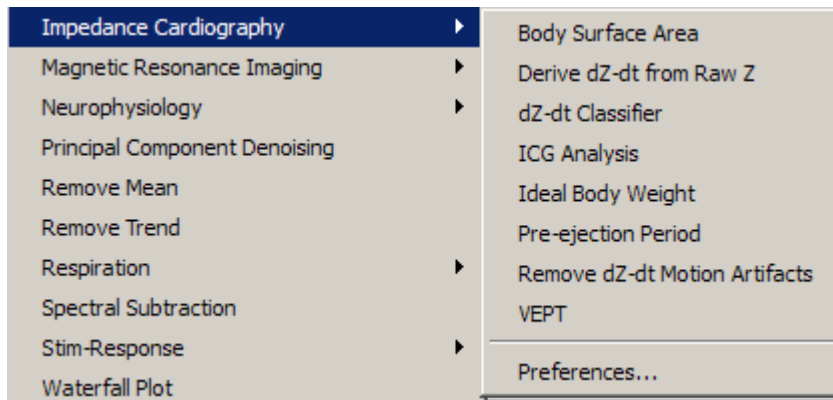
▶ Watch the [AcqKnowledge HRV Analysis video tutorial](#) for a detailed demonstration of this feature.

The note explains how to optimize ECG R-R interval data for Heart Rate Variability studies by using a template matching approach. It also explains how to identify erroneous R-R interval values caused by signal artifact and shows methods for correcting the errors by using the tools in the 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

Impedance Cardiography Analysis

The Impedance Cardiography analysis package assists in the analysis of cardiac output and other hemodynamic parameters using noninvasive bioimpedance monitoring techniques; signals must be sampled at 5 kHz or below to be analyzed with this package. This analysis offers a variety of approaches for estimation of cardiac measures.



Body Surface Area

Determines the body surface area estimation in square meters for a subject of a given height and weight, using the formula set in Preferences. It can be used to calculate body surface area independent of any of the other analysis routines, which may be useful for validation purposes or other derived calculations.

Body Surface Area equation

Use the Preferences option to select an algorithm for estimating body surface area of a subject and deriving stroke volumes from impedance data.

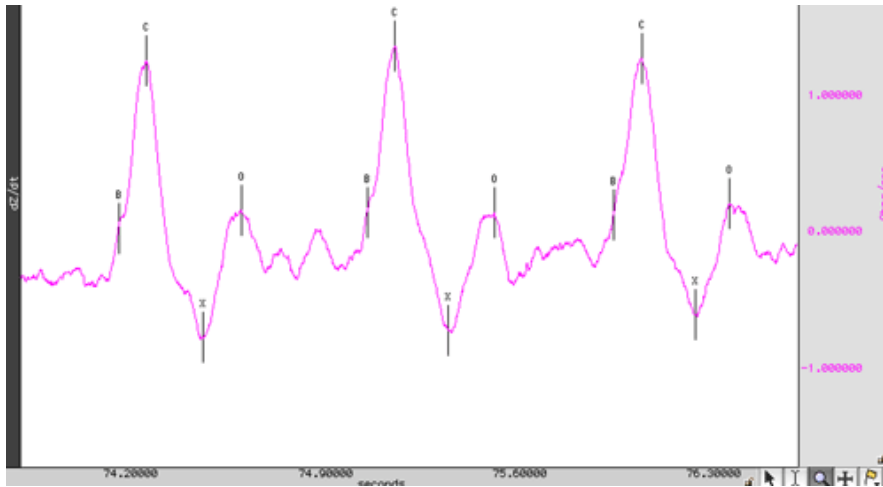
Method	Formula
Boyd	$BSA = 0.0003207 \times Height(cm)^{0.3} \times Weight(g)^{0.7285 - 0.0188 \log(Weight(g))}$
DuBois and DuBois	$BSA = 0.20247 \times Height(m)^{0.725} \times Weight(kg)^{0.425}$
Gehan and George	$BSA = 0.0235 \times Height(cm)^{0.42246} \times Weight(kg)^{0.51456}$
Haycock	$BSA = 0.024265 \times Height(cm)^{0.3964} \times Weight(kg)^{0.5378}$
Mosteller	$BSA = \sqrt{\frac{Height(cm) \times Weight(kg)}{3600}}$

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 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 ventricle 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.

- Pre-filtering 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 five methods will produce similar results for clean data. ICG Preferences has five options for B-point location:

- Second derivative classification – Given a C peak, it searches within a 150ms to 100ms time window before the C peak for the maximum of the second derivative of impedance (\ddot{Z}). The B point is placed at this maximum.
- Third derivative classification – Given a C peak, it searches for the maximum value of the third derivative of impedance (\dddot{Z}) within 300ms before the C peak. The B point is placed at this maximum.
- Cycle-by-cycle ‘Isoelectric’ crossings – Given a cycle defined by two C peaks, the mean of the dZ/dt signal is computed over the cycle. The B point is then placed at the closest time to the right C peak that is still underneath this baseline zero level.
- R to C polynomial model - Location of B point based on locations of R and C points according to polynomial equation found in Lozano et al. (2007). *Psychophysiology*, 44:113-119.
- Min derivative in C-QRS interval – Start at C, move backwards in time 35 ms, start looking for minimum of derivative of dZ/dt , stop at peak of QRS + 25 ms. Minimum dZ/dt derivative in window (35-(R+25)) ms is B.

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 the A-wave complex 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.
- Start at C, move forward in time 150 ms, start looking for minimum of dZ/dt, stop at 275 ms. Minimum in window is X.

ICG Analysis

ICG Analysis Parameters

Subject gender: ☒ Male ☐ Female

Subject frame size:

Subject height: feet inches

Subject weight: lbs

ECG Channel:

Raw Z: ☐ None, use baseline impedance: Ohms
☒ Channel:

dZ/dt: ☒ Construct new derivative
☐ Channel:

d²Z/dt²: ☒ Construct new second derivative
☐ Channel:

ABP Channel: ☐ None, mean pressure: mmHg
☒ Channel:

CVP Channel: ☒ None, estimated CVP: mmHg
☐ Channel:

PAP Channel: ☒ None, estimated PAP: mmHg
☐ Channel:

Analyze: ☒ entire graph
☐ focus areas only

The ICG Analysis routines include 20 derived impedance and hemodynamic measures that correspond to various values that are generated by other industry-standard impedance cardiography analysis tools. Many users tend to be interested only in a subset of the various measures produced by the analysis (e.g. only heart rate and cardiac output); the extra measures can “clutter” the output and frustrate users who have to delete them manually.

The ICG Analysis output options feature adds a new step to the ICG Analysis where the user may toggle the output of individual measures on and off. This allows users to suppress generation of all output for a measure including the graph channels, column in the Excel spreadsheet, and column in the text output.

ICG Analysis performs a full impedance cardiography analysis on data, extracting intervals and derived cardiac measures. The minimal set of signals required to run this analysis is an ECG Lead II signal and either a raw impedance signal or a dZ/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 402).
- ICG Preferences must first be selected in order to generate the main ICG Analysis setup window.

In addition to the minimal set of signals, it is also possible to use arterial blood pressure, central venous pressure, and pulmonary arterial pressure signals to improve the quality of the algorithm results. If any of these signals are not present, default fixed estimated values can be substituted for the mean pressures instead of deriving pressures on a cycle-by-cycle basis.

ICG Analysis may potentially perform classification of both the dZ/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	$\frac{d^2 Z}{dt^2_{\max}} \frac{CO}{BSA}$
Cardiac index	CI	Normalized cardiac output	m ³ / 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	Time 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>

Name	Abb.	Description	Units	Formula
Pre-ejection period	PEP	Time interval between the Q wave of the ECG and the B point of the ICG. Time interval between systole and aortic valve open.	sec	<i>Not applicable</i>
RR interval	RR-i	Time interval between R peaks in the waveform.	sec	<i>Not applicable</i>
Stroke index	SI	Normalized stroke volume	(ml / beat) / m ²	$\frac{SV}{BSA}$
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>Note $\frac{dZ}{dt}_{\max}$ 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	$80 \times \frac{MAP - CVP}{CO}$

<i>Name</i>	<i>Abbv.</i>	<i>Description</i>	<i>Units</i>	<i>Formula</i>
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	$\frac{1}{TFI}$
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	$\frac{dZ}{dt_{max}}$ <div style="display: inline-block; vertical-align: middle; margin-left: 10px;"> Note $\frac{dZ}{dt_{max}}$ may be either the absolute maximum or the BC delta in amplitude, as set in Preferences. </div>

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

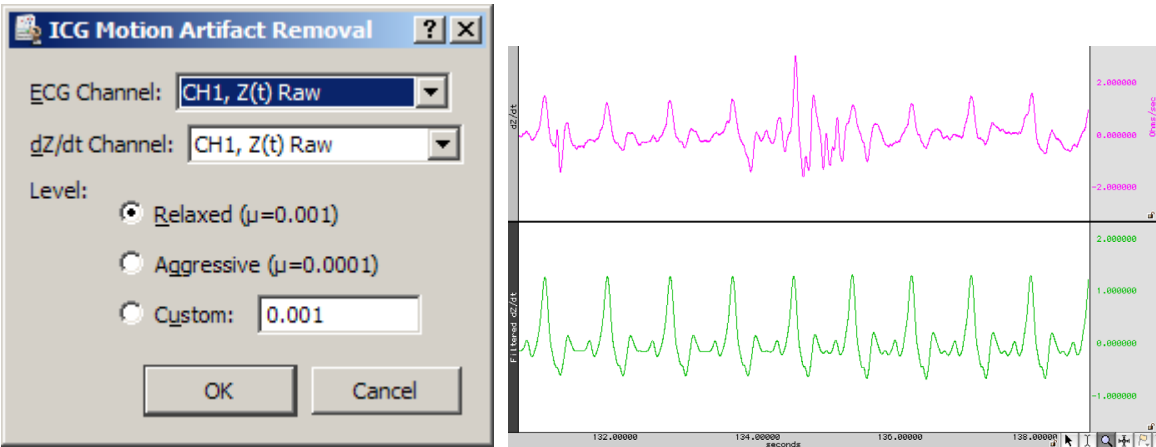
The pre-ejection period is the time interval between the electromechanical systole and the onset of ejection of blood from the left ventricle of the heart. This can be derived from standard ECG data and ICG data as the interval between the Q point on the ECG and the B point on the ICG. The Pre-ejection 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 397.

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 402).

PEP analysis will output the following information on a cycle-by-cycle basis and the final line of the textual output will be the average of all of the cycle measurements. All time unit output is in seconds unless otherwise noted.

Name	Abbrev.	Description
Heart rate	BPM	The heart rate for the cycle as indicated in BPM. Derived from the RR interval.
Pre-ejection period	PEP	Time interval between the Q wave of the ECG and the B point on the ICG for the cardiac cycle. If the PEP cannot be computed for a particular cycle, it will have the value "----" in the textual output or 0 in the graphical output.
RR interval	RR-i	Time interval between R peaks of a single cycle of cardiac data.

dZ/dt Remove Motion Artifacts



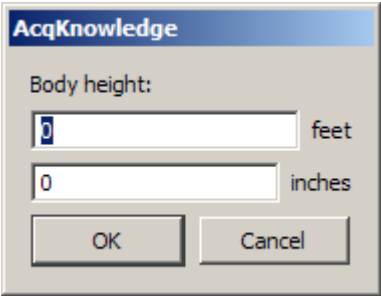
Applies SFLC motion artifact removal to a dZ/dt signal. Uses cycle information from an ECG signal to construct a sinusoidal model of the ICG signal containing only components that are correlated to the heart rate.

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.

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 units set under Preferences. 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

Motion Artifact Removal

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 Level – relaxed, aggressive, and custom.

- “Relaxed” uses a SFLC step size of .001. This allows the filter to adapt moderately quickly to changes in the dZ/dt signal.
- “Aggressive” uses a SFLC setting of .0001. The filter will adapt less quickly to changes in the ICG signal, allowing better filtering out of motion artifacts at the expense of a lessened response to changes in underlying ICG morphology.
- “Custom” allows for an arbitrary SFLC step size. The step size must be greater than zero and much less than 1 for the filter to converge.

Display results as

- Textual tables in the journal
- Channels of data inserted into the graph.

C-point location – see page 396

B-point location – see page 395

X-point location – see page 396

Stroke volume equation – see page 399

- Kubicek, or Sramek, or Sramek-Bernstein

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.

Body Measurement Units system for inputting

- English system: body height in feet and inches, distance between measuring electrodes in inches, and body weight in pounds
- Metric system: body height in meters and centimeters, distance between measuring electrodes in centimeters, and body weight in kilograms.

Body Surface Area equation – see page 394

- Boyd; DuBois and DuBois; Gehan and George; Haycock; or Mosteller

Ideal Body Weight method– see page 400

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 hardware unit along with the physiological data.

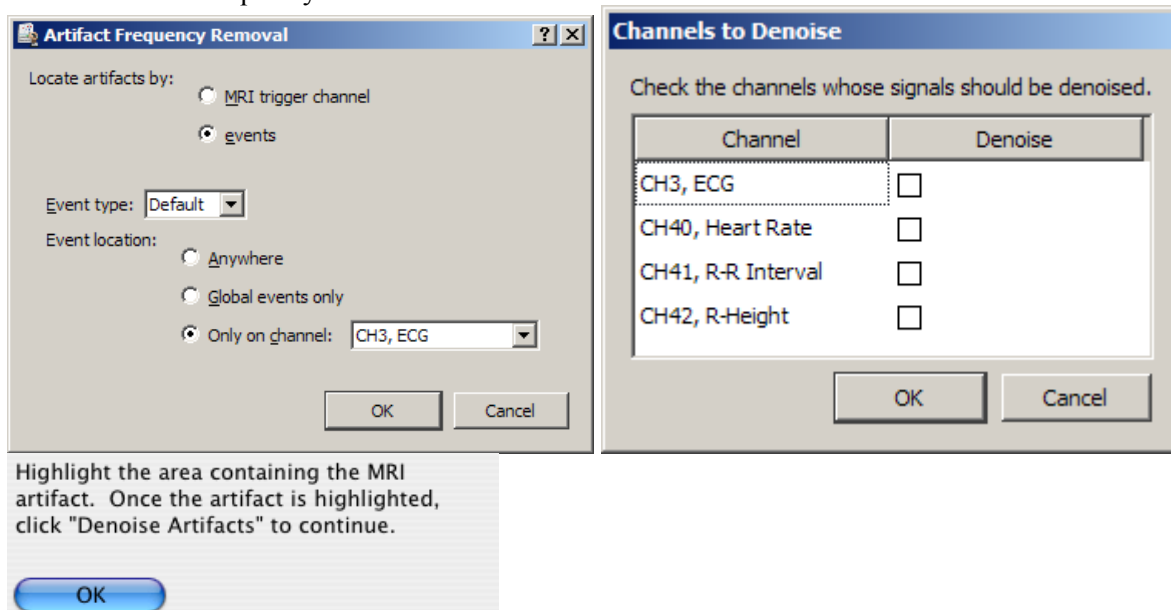
Trigger detection off of an MRI trigger signal waveform is performed using fixed level thresholding on the waveform data. The threshold level is set to be the minimum value of the entire trigger signal plus $1/10^{\text{th}}$ of the peak-to-peak distance of the trigger signal. The threshold is kept data 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.

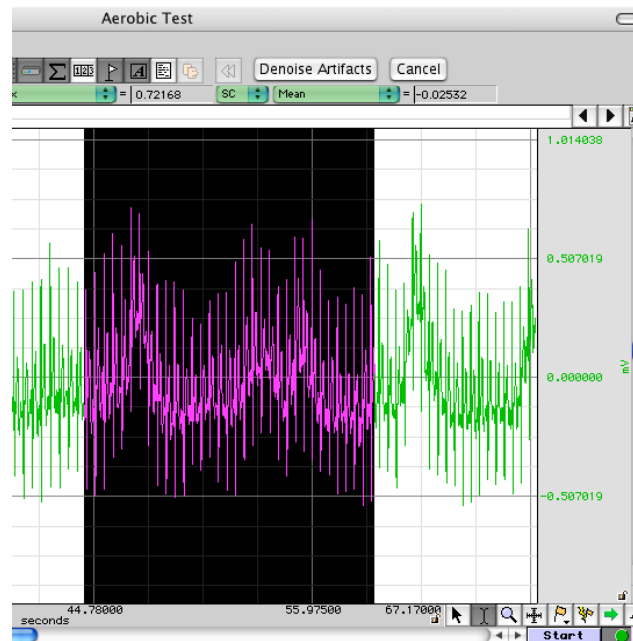
Event driven artifact location can be useful when trigger signals are not available from the MRI or are not recorded. A cycle detector analysis can be used to place events at the onset of each artifact, or these events may be placed manually. Event based detection is also useful for applying the procedures 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.

For more information on cycle detector analysis, see the Find Cycle section on page 325.

Artifact Frequency Removal

MRI > Artifact Frequency Removal





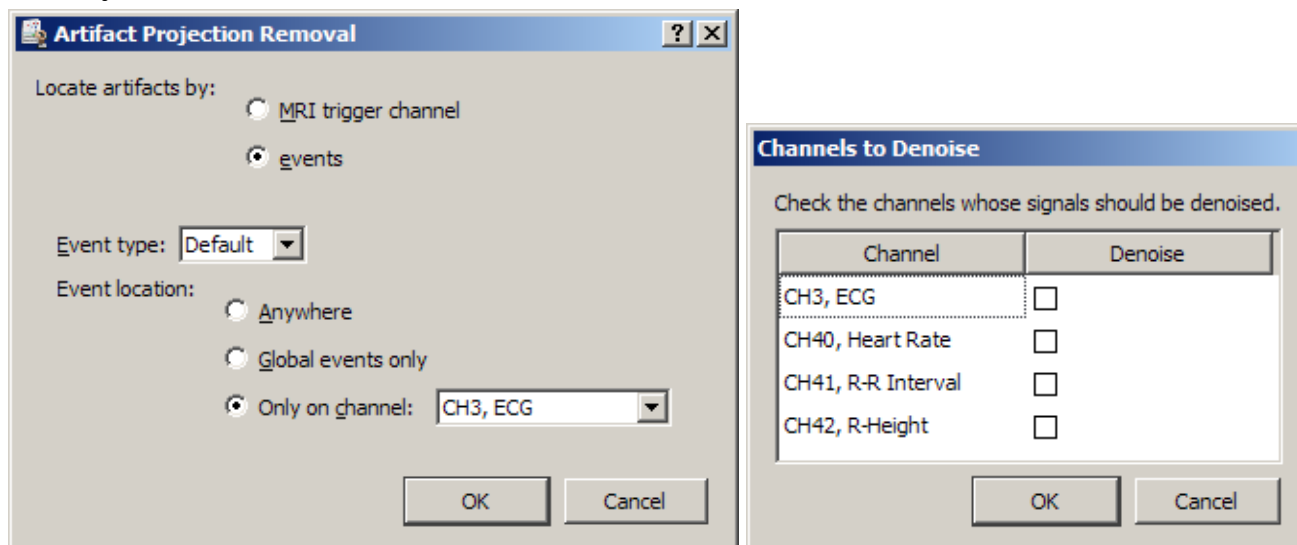
Two large sources of interference in MRI recordings are the current induced by the MRI magnetic field and the RF pulses used for triggering molecule alignment. While the overlap of this interference may be difficult to separate in the time domain, the MRI interference may have a distinctive signature in the frequency domain. Artifact Frequency Removal is a frequency domain adaptation of the ensemble projection removal of the Artifact Projection Removal transformation. It attempts to cancel out MRI artifact by removing the frequencies most strongly associated with the MRI signal.

For each channel of data to be denoised, either the MRI trigger signal or event positions are used to locate periods of MRI activity for constructing an ensemble average. The FFT of this ensemble average is computed, and the magnitude of the average FFT is set as the reference. Cyclic mean removal is applied to each period of artifact to compensate for baseline drift or signals with expected DC offset. A second pass is then made through the data. For each individual artifact, the FFT of that artifact is computed and the projection of that FFT onto the average FFT is removed. After projection removal, negative Fourier components are discarded and a time-domain signal is reconstructed using the inverse Fourier transform. This reconstructed, filtered signal is used to replace the MRI artifact in the original data.

Application of projection removal in the frequency domain has similar limitations to applying it in the time domain, that is, it assumes that the MRI interference is stationary (which is not necessarily the case). Variations in the MRI interference may cause this method to fail.

IMPORTANT Artifact Frequency Removal requires an MRI triggering signal or artifact onset events to locate artifact positions.

Artifact Projection Removal



Artifact Projection Removal attempts to remove the noise components from the artifacts within a signal. An ensemble average is made for each period of MRI artifact in a channel. Cyclic mean removal is applied to each period of artifact to compensate for baseline drift or signals with expected DC offset. As the artifacts are averaged together, the actual interference with the physiological signal caused by the MRI should become the dominant feature if a sufficient number of artifacts are present. A second pass is made through the artifacts to remove this average MRI artifact from each individual period.

The average artifact is removed using the Remove Projection transformation. This performs a vector projection of the signal onto the averaged artifact estimation and subtracts this projection. This is an improvement over straight subtraction of the average artifact as vector projection can compensate for changes to amplitude that may occur over time.

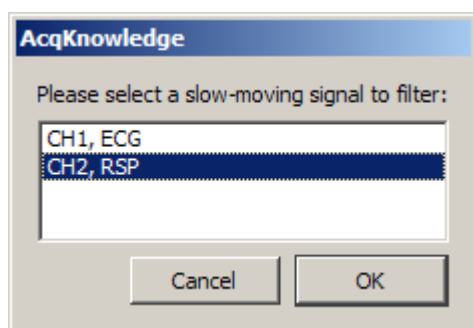
Artifact projection removal cannot compensate for MRI interference that varies in frequency due to changes in orientation of electrode leads within the MRI or other factors that may alter the MRI artifact.

Artifact projection removal is an adaptation of a denoising technique described in:

M. Samonas, M. Petrou and A. Ioannides, "Identification and Elimination of Cardiac Contribution in Single-Trial Magnetoencephalographic Signals," *IEEE Trans. Biomed. Eng.*, vol. 44, no. 5, pp. 386-393, 1997.

IMPORTANT Artifact Projection Removal requires an MRI triggering signal or artifact onset events to locate artifact positions.

Median Filter Artifact Removal

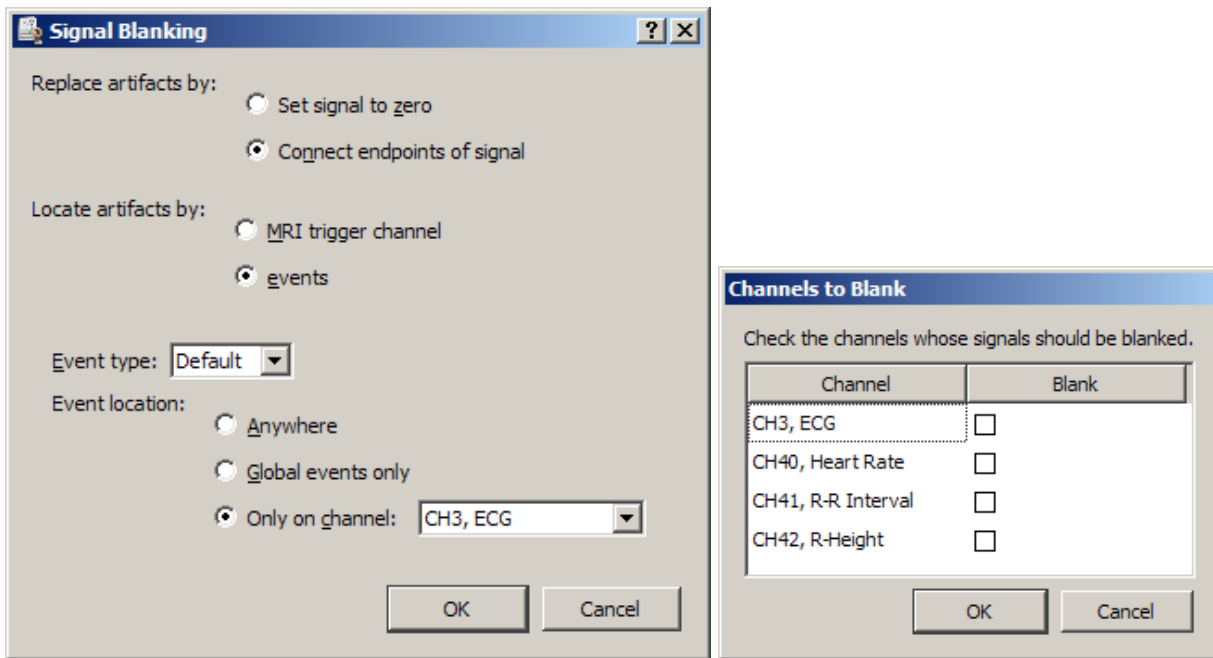


Median Filter Artifact Removal provides a basic artifact removal suitable for slow moving signals such as respiration, GSR, or temperature. It performs a windowed median transformation on the source channel with a window width of $1/10^{\text{th}}$ of the acquisition sampling rate.

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 “blanking” can be performed:

- Set value to zero – The waveform is set to zero during each artifact.
 - For integrated measures, zeroing the signal may be preferable as it will have no effect on the running sum.
- Connect endpoints – For each artifact, a selection is made and the values within the interval are replaced with a line connecting the signal value before the MRI artifact to the signal value at the end of the interval.
 - For statistical measures or DC coupled signals, connect endpoint (linear interpolation within the interval) may be preferable to avoid causing the output to trend towards zero.

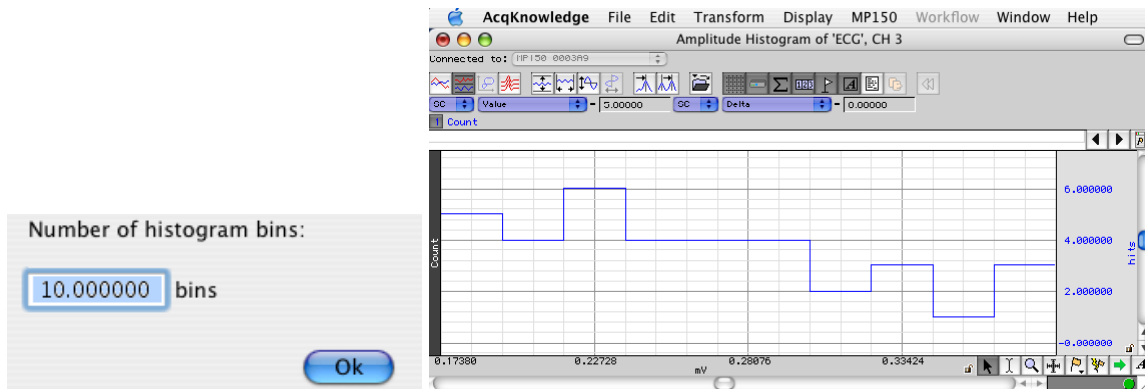
IMPORTANT Signal Blanking requires an MRI triggering signal or artifact onset events to locate artifact positions.

Neurophysiology

The Neurophysiology analysis package assists in the analysis of spikes within extracellular microelectrode recordings, such as those recorded using an MCE100C module. All of these analysis options require a continuous recorded single channel of microelectrode data.

- A *spike* is a deviation from the baseline caused by a neuron action potential. Frequently extracellular spikes will resemble exponentials. The point of maximum value of the spike will be used to locate neuron firing.
- A spike *episode* consists of a fixed time window around a spike that aims to capture the underlying neuron firing time. The episode consists both of the rise time (the time taken to reach maximum) and the relaxation period around the spike.

Amplitude Histograms

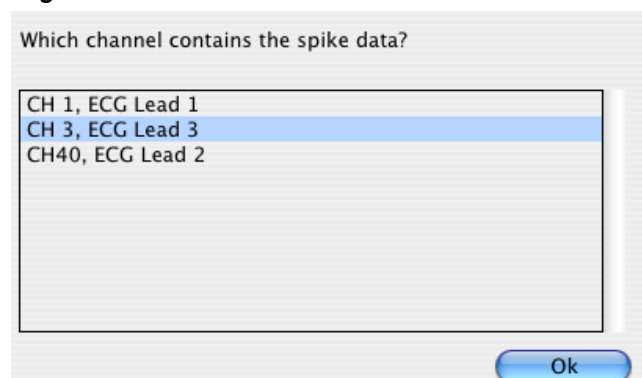


IMPORTANT To run this analysis option, the signal must first be transformed by the Classify Spike Episodes option or the Locate Spikes option. (See pages 408 and 409.)

Amplitude histograms show the population density of the maximum amplitude of neuron firing events. They may be used to interpret changes in neuron firing due to drug response or as rough indicators of the approximate number of classes of action potentials in a signal. Amplitude histograms can be generated on classified or unclassified signals.

- On classified signals, an overall amplitude histogram will be created for all of the spikes in addition to a single amplitude histogram per class (reflecting only the episodes of that class).
- On unclassified signals, a single amplitude histogram will be created from the maximum voltage within all of the spike episodes.

Average Action Potentials

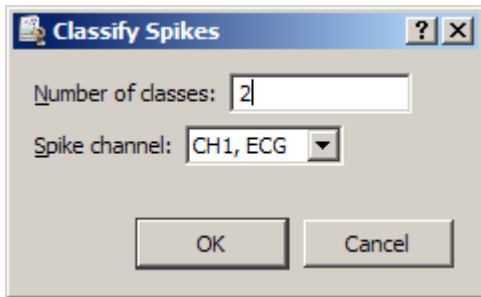


IMPORTANT To run this analysis option, the signal must first be transformed by the Classify Spike Episodes option or the Locate Spikes option. (See pages 408 and 409.)

After a classification has been completed for a spike signal, to assign spike episodes to different groups, users may wish to view the average shape of the waveforms of each class. Examining the shape of the different classes provides visual feedback as to the efficiency of the clustering, can allow for identification of certain classes as noise or artifacts, and helps to determine if the identified classes are indeed unique. Average Action Potentials can be generated on classified or unclassified signals.

- On classified signals, the resulting ensemble averages will have multiple channels.
 - The first channel will be the overall average of all of the spike episodes.
 - The remaining channels show the average of the members of each individual spike class.
- On unclassified signals, a graph will be produced with a single channel showing the average of all of the spike episodes.

Classify Spikes



IMPORTANT If cluster events from a previous spike classification are already defined on the recorded waveform, this option will erase them and replace them with the new classification of the potentials.

This analysis option will automatically classify action potentials in microelectrode data and divide them into different spike classes.

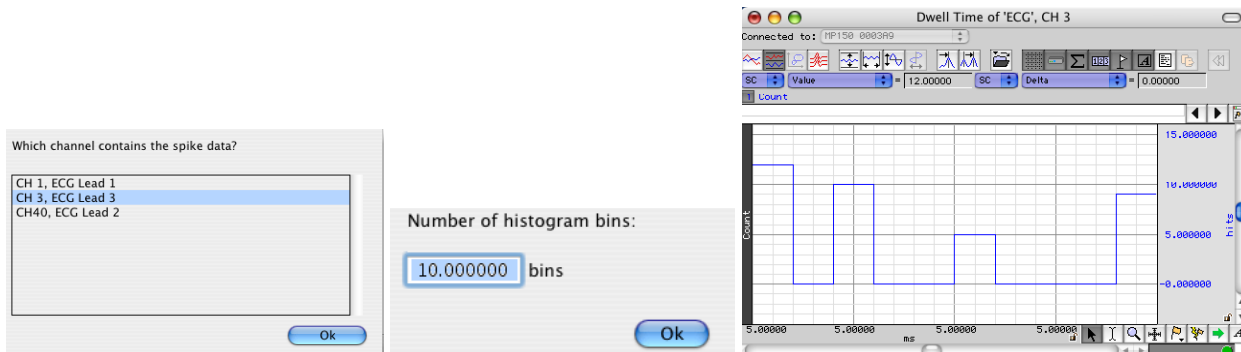
If the Locate Spike Episodes option wasn't used to find spikes before this option was selected, the Locate Spike Episodes option will be automatically performed prior to the clustering.

A single-feature k-means clustering classifier is used, and the entire data set is used for the clustering portion of the algorithm. The determining feature is the Sum criteria—that is, the sum of all of the data points within the waveform segment; this was one of the first features used in early action potential classifiers.

The clustering may not produce meaningful classes, so results should be examined for accuracy.

This style of classifier is for rudimentary spike analysis. For more advanced classification techniques, use the clustering algorithm in the Find Cycle detector. (See page 335.)

Dwell Time Histograms



IMPORTANT To run this analysis option, the signal must first be transformed by the Classify Spike Episodes option or the Locate Spikes option. (See pages 408 and 409.)

A dwell time histogram shows the population density of the duration of a neuron firing event. Dwell times can be approximated for an action potential by measuring the absolute value of the time interval between their maximum and minimum voltage levels reached during the firing of the neuron. After the minimum value in the firing recording has occurred, the neuron will be returning to its resting state, so the time difference is a good approximation for the firing duration. The dwell time histogram plots this time difference versus number of action potentials that have similar time differences. Examining varieties in dwell times can help to illustrate drug responses or to perform rudimentary classification of action potentials.

Dwell times will be defined as the time difference between the positions of the maximum signal value and minimum signal value within a spike episode. Since dwell time histograms can be used for classification purposes, they can be run on classified or unclassified microelectrode signals.

- On classified signals, an overall dwell time histogram will be constructed for all of the spikes in addition to a single histogram per class, showing times of only the spikes in that class.

- On unclassified signals, a single dwell time histogram will be created for all of the spikes. When run on a classified signal.

Find Overlapping Spike Episodes

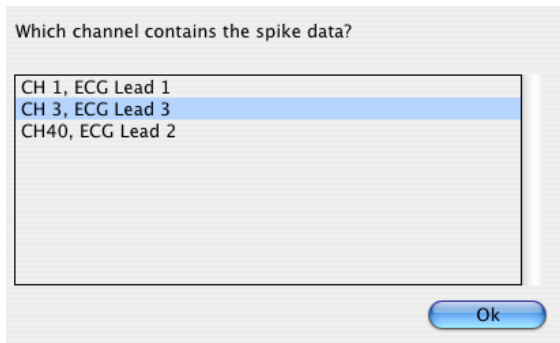
IMPORTANT To run this analysis option, the signal must first be transformed by the Classify Spike Episodes option or the Locate Spikes option. (See pages 408 and 409.)

In many extracellular recordings, it is frequent for there to be more than one neuron firing in response to the same stimulus. This can result in overlapping spike episodes when both neurons fire in close succession. Some types of analysis and spike classification are not able to produce meaningful results if too many overlapping episodes occur. “Find Overlapping Spike Episodes” can be used to locate overlapping episodes. After the spikes have been located in a signal, this option can be used to iterate only to those that are overlapping.

“Next Overlap” and “Cancel” buttons are available in the toolbar of the graph window to allow for iteration through the episodes.

Note This option is “view only.” Overlapping episodes are not affected by the analysis and will need to be manually removed manually to delete them from the file.

Generate Spike Trains



IMPORTANT To run this analysis option, the signal must first be transformed by the Classify Spike Episodes option or the Locate Spikes option. (See pages 408 and 409.)

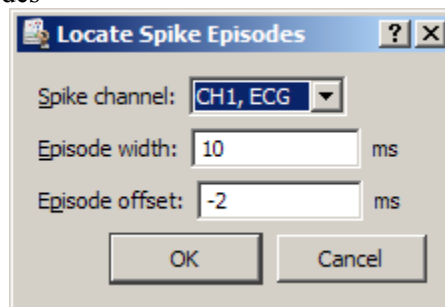
Spike trains are good visual indicators of when action potentials are firing and are good synchronization waves for further analysis and data reduction. A spike train is a channel in a graph whose value is 0 when there is no spike and 1 when there is a spike.

Spike train generation will operate only on signals whose action potentials have already been classified.

- A single spike train will be generated as a channel in the graph for each class of action potential in the signal. Be sure to choose “Graph Channels only” or “Text and Graph Channels” in the Neurophysiology Preferences. (See page 410.)
- If text output is enabled, the spike trains will be pasted as tables in the journal with one table per spike class.
- If spreadsheet output is enabled, the tables will be placed side by side so index 1 of the tables lines up for each action potential.

Locate Spike Episodes

Neurophysiology > Locate Spike Episodes

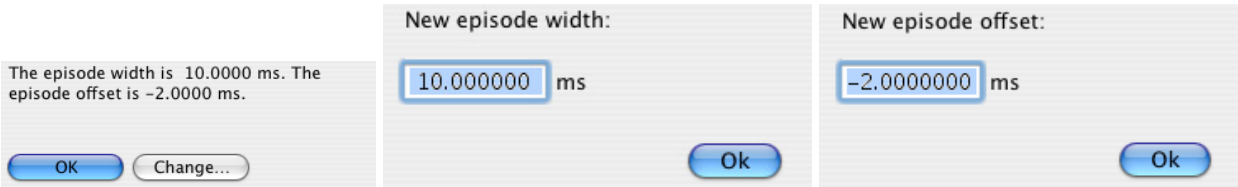


This option provides the basic spike detection for a microelectrode signal. Spike detection is performed using the following steps:

1. Obtain mean value of the entire signal.
 2. Obtain standard deviation of the entire signal.
OR: Obtain an Amplitude/Half Width Discriminator of the entire signal. See Neurophysiology Preferences for more information (page 410).
 3. Detect spikes where the signal rises above a fixed threshold determined by adding a multiple of the standard deviation to the mean.
 4. Position the episode around the threshold crossings according to the width and offset entered previously.
- A “Spike Episode Begin” event will be placed at the start of each spike episode and will be located offset milliseconds away from the threshold crossing. A “Spike Episode End” event will be placed at the end of each episode.
- If text output is enabled, a table of the start time of each episode will be placed in the graph’s journal.
 - If spreadsheet output is enabled, a new spreadsheet will be created with the start time of each episode.

Spike episodes may also be located manually by using the Cycle Detector to define “spike episode begin” and “spike episode end” events in the graph.

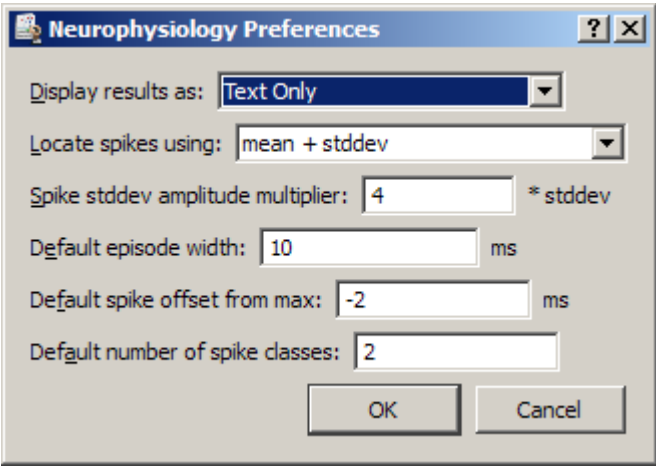
Set Episode Width and Offset



The first time spike detection is performed on a graph, the episode width and offset need to be entered. This width and offset is remembered and is used for all future spike detections in the graph performed by “Locate Spike Episodes” and other transformations. The width and offset that are entered are retained even if the file is saved and reopened.

Use this option to view or change the current width and offset.

Preferences



Preference	Description	Default Setting
Display results as:	Determines whether analysis results will be displayed as graph channels, textual tables in the journal, or Excel spreadsheets. Not all of the output types are applicable for each Neurophysiology analysis option.	Text output to journal only.

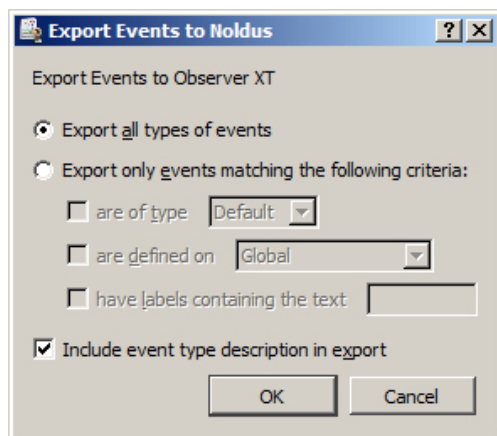
Preference	Description	Default Setting
Locate spikes using:	<p>Choose how spikes are searched for in the signal.</p> <p>Mean + Stddev—uses fixed level peak detection with a level that is computed from the mean value plus a configurable number of standard deviations of the data.</p> <p>Amplitude/Half-width 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>Half-width For a given spike, the discriminator searches from the maximum value of the spike to both the left and right of the maximum for the sample positions where the value has dropped below 50% of the maximum. The time interval between these sample positions is defined as the estimate of the half width. The acquisition sampling rate can be increased to improve accuracy of the spike half width estimates as neuron firing events involve high frequency components.</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. For each potential spike location p, computes the half-width time interval. $t_{half}(p) = t_{50r}(p) - t_{50l}(p)$ <p>where t_{50r} is the first time $> p$ such that $x(t_{50r}) \leq 0.5 x(p)$ t_{50l} is the first time $< p$ such that $x(t_{50l}) \leq 0.5 x(p)$</p> <p>Accepts the spike for each potential spike location p as a valid spike s if, where a is amplitude and t is time window:</p> $a_{low} \leq x(p) \leq a_{high} \wedge t_{low} \leq t_{half}(p) \leq t_{high}$ <p>For each valid spike location s, positions the spike episode</p> <p style="margin-left: 40px;">start output at $s + \text{offset}$ end output at $s + \text{offset} + \text{width}$</p> <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>	Mean + Stddev
Spike stddev amplitude multiplier:	Spikes are located in the signal by looking for locations where the signal deviates from its baseline by a certain number of standard deviations. This multiplier is set in this preference.	4 standard deviations

<i>Preference</i>	<i>Description</i>	<i>Default Setting</i>
Default Episode Width	The first time that any of the spike detection is run on a graph, the time width of each fixed width episode must be specified. This preference provides the default value that is seeded in the dialog. The episode width for an individual graph does not need to match this default.	10 milliseconds
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

Noldus Format

Supports import and export of files in Noldus Observer format. Noldus is a popular Human Behavioral analysis software package and the AcqKnowledge Noldus feature allows behavioral markers to be imported from Noldus into AcqKnowledge and AcqKnowledge marker information to be exported into Noldus. The following options are available:

Export Events to Noldus XT



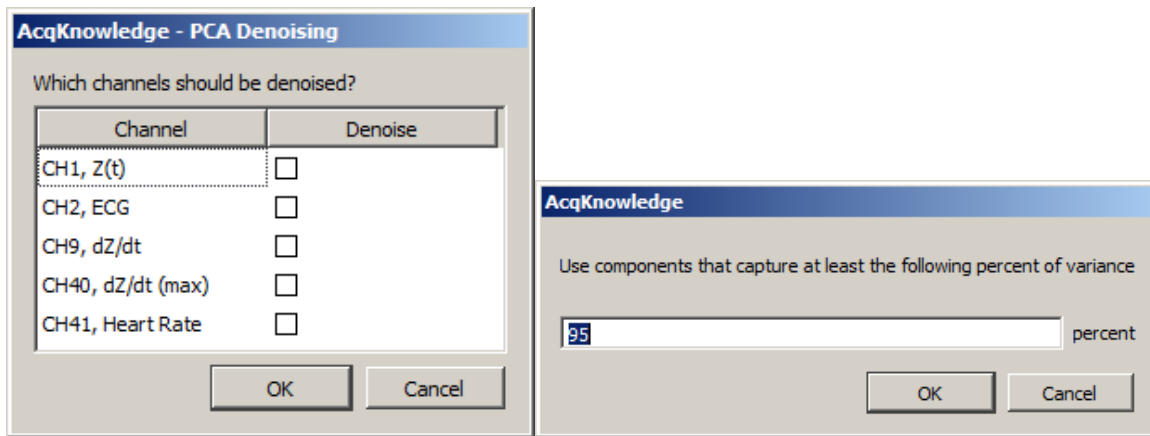
AcqKnowledge events can be exported to Noldus by “all types” or based upon selective criteria.

Import Markers from Noldus XT

The Import markers feature will read the Noldus file data and define the events in the active AcqKnowledge graph. For each range of behavior, a pair of global markers will be added with labels correlating to the behavior type as well as the start of and end of the behavior.

 Watch the [AcqKnowledge Noldus Observer import and export video tutorial](#) for a detailed demonstration of this feature.

Principal Component Denoising



Removes noise from certain types of signals. For principal component denoising to be effective, more than two signals should be used as sources and all source channels must have identical waveform sampling rates. PCA denoising is most effective on signals that are known to contain a high degree of similarity, such as multiple ECG leads or multiple EEG leads. PCA denoising should not be used on signals of different types or units as all of the principal components may be needed to fully capture the differences in the signals.

- To determine if PCA denoising will be effective on a particular set of data or to compute an appropriate variance percentage for denoising, examine the principal components directly with “Transform > Principal Component Analysis” before selecting this option.

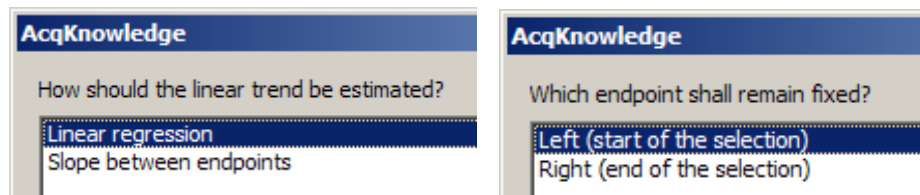
Given a set of signals, a principal component analysis is performed. The strengths of the components are then analyzed, and the original signals are reconstructed from a subset of the principal components that capture a certain percentage of the total variance of the signals. This essentially eliminates 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 Mean

Available in AcqKnowledge 4.1 and above—Remove Mean allows for mean subtraction to be performed for the selected area (or entire wave if no data is selected). It will result in the mean value being the new zero value for the waveform.

Remove Trend



Available in AcqKnowledge 4.1 (and 4.0 Windows or 3.9 Mac)—Remove Trend helps to remove baseline drift or other linear trends from data. This tool makes it easier to apply trend removal to only specific segments of a waveform. Given a selected segment of data, or an entire waveform, it computes the trend between the two endpoints (similar to the Slope measurement) and then removes this trend from the selected area such that the endpoints of the selection lie at the same voltage.

Linear Regression

Use linear regression to estimate the trend to be removed from the waveform.

Slope between endpoints

- **Left** keeps the starting point of the selection fixed at the same voltage. The software adjusts the data from left to right such that the right endpoint is aligned with the initial starting voltage.
- **Right** keeps the ending point of the selection fixed at the same voltage. The software adjusts the data from right to left such that the left endpoint is aligned with the initial ending voltage.

Respiration



IMPORTANT—Respiration analysis assumes a bidirectional airflow signal that records both inhale and exhale. Unidirectional respiration signals cannot be analyzed at this time.

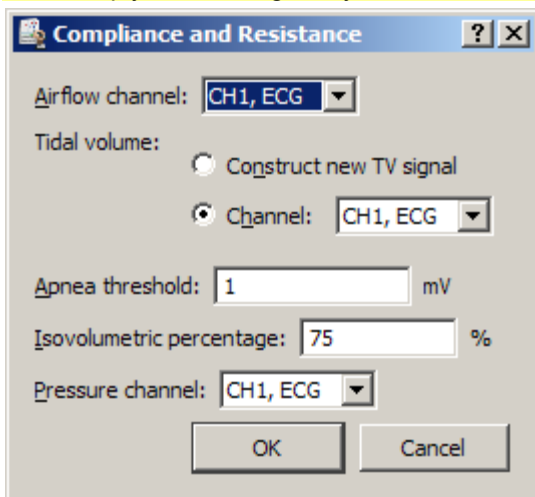
The respiration analysis package helps to analyze respiration- and airflow-related data. Other tools exist for respiration related analysis including AcqKnowledge transformations and the Respiratory Sinus Arrhythmia analysis in the Hemodynamics analysis package.

Compliance and Resistance

Compliance and Resistance analysis can be used to extract pulmonary resistance and pulmonary compliance in addition to basic airflow measures. This analysis requires an airflow signal and a pressure signal. The analysis will extract all of the measures of the Pulmonary Airflow analysis for the airflow signal. It also will locate apnea periods after exhalation using the same user-configurable threshold method as the Pulmonary Airflow analysis.

IMPORTANT— The flow signal must be recorded correctly for Compliance and Resistance analysis to work. Compliance and Resistance analysis assumes positive flow indicates inhalation and negative flow indicates exhalation (the flow conventions of the recommended connections for a BIOPAC TSD107 pneumotach or a TSD117 airflow transducer).

- If the flow signal was recorded with exhalation positive instead of inhalation positive, multiply the flow signal by -1 to invert the signal.



Pulmonary resistance is computed using the isovolumetric method. On both sides of the tidal volume peak for a breath, the position where the volume reaches a user-specified percentage of the tidal volume is located. The pulmonary resistance is defined as the difference in pressure divided by the difference in flow at these two isovolumetric positions. Due to the discrete nature of sampled data, these points may not be exactly equal in volume. To improve the accuracy of the isovolumetric method, increase the sampling rate used to acquire data.

Dynamic pulmonary compliance is extracted on a breath-by-breath basis by dividing the tidal volume by the change in pressure between the exhale start and inhale start locations of the breath.

Individual breaths are defined as the period between consecutive Inhale Start events. Airflow units are assumed to be the standard liters/sec and pressure units mmHg. For each breath period, the analysis will define the following events:

- Inhale Start event on flow signal at start of inhale
- Exhale Start event on flow signal at start of exhale
- Apnea Start event on flow signal at beginning of apnea period (if present)
- Recovery events on volume signal at isovolumetric positions to left and right of tidal volume peak

If Inhale Start and Exhale Start events are already present on the flow signal at the start of analysis, those events will be used to define the breath periods. Apnea Start and Recovery events will always be regenerated by the analysis.

The analysis will extract the following measures from the data:

<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
Pulmonary resistance	RES	Change in pressure divided by change in flow at the isometric volume locations: $\frac{\Delta p}{\Delta f}$	mmHg/ (liters/ sec)
Pulmonary compliance	Cdyn	Tidal volume divided by the change in pressure between exhale and inhale locations in the breath: $\frac{TV}{\Delta p}$	liters/ mmHg

If text output is being generated, an additional row will be added containing the average values of the measures. Time and count are not output as waveforms in the graph since they can be found in the horizontal axis.

Penh Analysis

Penh Analysis script assumes standard recording methodology for a full body plethysmograph. Positive flow is treated as exhalation and negative flow is treated as inhalation.

Penh Analysis extracts measures from data recorded in a full body plethysmograph. It operates on a single channel of data recorded from an airflow transducer connected to the plethysmograph. The analysis takes a single parameter: the Rt percentage. This percentage is used to locate the plateau, or “pause,” in the airflow signal. The pause begins at the time when the Rt percentage of the exhalation volume has been reached. The Rt percentage may be adjusted by the user and is set to a default of 65%. This analysis will place Inhale Start and Exhale Start events on the airflow signal. If these events are already present when the analysis starts, the user-defined inhale and exhale events will be used instead. This allows for the analysis to be repeated after manual inspection and correction of inhale and exhale locations and allows for different methods to be used to define the breathing boundaries.

AcqKnowledge 4.4.1 and higher also includes the following Penh Analysis options for enhancing data accuracy:

Flow threshold – Using this setting allows breath detection to occur only when a subject’s inspiratory flow exceeds a user-defined setting in units of liters per second. For example, if the threshold is set to 1.5 L/sec, the inspiratory flow must exceed 1.5 L/sec for each valid breath. If the setting is left at 0, all breath activity will be included in the output.

Breathing rate artifact rejection – Using this option will discard any respiration cycles that fall outside the boundaries of a user-defined minimum and maximum respiration rate. This is useful for eliminating unwanted signals resulting from small zero crossing spikes or other high frequency noise in the breath signal. This option is enabled by default and set to the average range of a mouse breathing rate.

Show analyzed area waveform – this option adds a new waveform to the graph indicating the time areas included in the analysis output. This analysis waveform can be useful for visually assessing the effectiveness of modifying the artifact rejection settings.

Penh analysis will place Recovery events on the airflow channel at the time positions where the corresponding percentage of the volume has been exhaled. The percentage used for the analysis is displayed in the label of the Recovery events.

For each exhalation period, the Penh Analysis will extract the following:

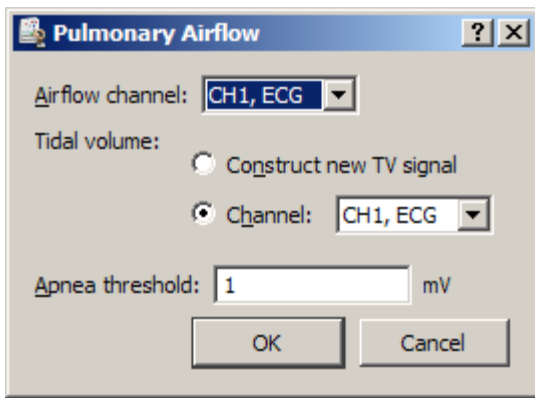
<i>Name</i>	<i>Abbrev.</i>	<i>Description</i>	<i>Units</i>
Cycle		Index of the exhalation cycle in the data, beginning at 1.	
Time		Starting time of the exhale for the cycle. This is the location of the Exhale Start event.	Seconds
Peak inspiratory flow	PIF	Maximum absolute airflow occurring in the inspiration 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
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).
- Cycles that fall outside the boundaries of the selected flow threshold and artifact rejection parameters. (AcqKnowledge 4.4.1 and higher)

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.

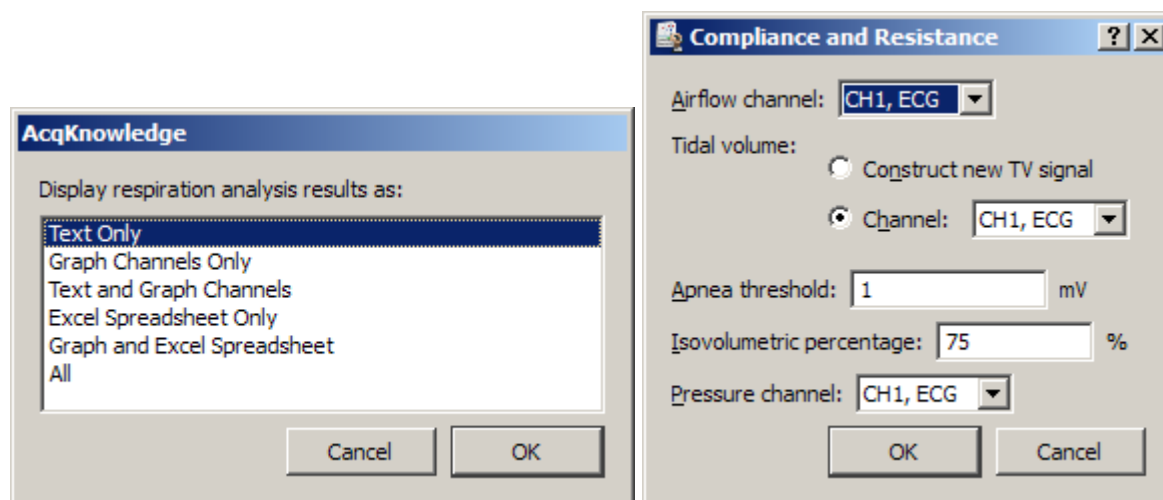
For each breath period, the analysis will extract the following:

<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.	liters / minute
		$TV * BPM$	
Breaths per minute	BPM	Breathing rate for the breath.	BPM
		$\frac{60}{TT}$	

<i>Name</i>	<i>Abbrev</i>	<i>Description</i>	<i>Units</i>
Inspiration time	IT	Time interval between the start of inhale and the start of exhale in the breath.	seconds
Exhalation time	ET	Time interval between the start of exhale and either: ⌚ start of apnea (if apnea present) ⌚ start of subsequent breath (if no apnea present)	seconds
Total breath time	TT	Time interval between the start of inhale and the start of inhale of the following breath. This is the sum of the inhalation time, exhalation time, and apnea time.	seconds
Apnea time	AT	Time after end of exhalation where the airflow signal remained within the apnea threshold defined at the start of the analysis.	seconds

If text output is being generated, an additional row will be added containing the average values of the measures. Time and count are not output as waveforms in the graph as they can be found from the horizontal axis.

Preferences



Spectral Subtraction

Spectral subtraction is a denoising technique that operates on data projected into the frequency domain. It is frequently used in speech analysis denoising applications. Spectral subtraction examines a reference noise signal and performs a Fourier transform to get the noise frequency distribution. To denoise a signal, the Fourier transform of the signal is performed. The noise estimate frequency distribution is then subtracted from the source signal. The resulting processed spectrum with the noise frequencies removed is then reconstructed into a time domain signal using the inverse Fourier transform.

Spectral subtraction performs noise removal on the entire channel in a single Fourier transformation, which allows for denoising where the noise is stationary; there is no provision for sliding window spectral subtraction at this time.

The spectral subtraction is performed using a formula with two adjustable parameters. Given a frequency spectrum F_{noise} and a mixed signal F_{mix} , the denoised frequency spectrum is computed using the following formula:

$$F_{denoise} = \left[F_{mix}^{\gamma} - \alpha F_{noise}^{\gamma} \right]^{\frac{1}{\gamma}}$$

where

Alpha is the “scaling factor” and can be used to adjust the strength of the noise estimate.

Gamma (γ) is the “power factor” and can be used to vary how the noise is removed.

$\gamma = 1$ allows for pure subtraction

$\gamma = 2$ allows for Euclidean distance formulas

and so on

$F_{denoise}$ that is less than zero is discarded and replaced by zero to maintain a valid set of Fourier coefficients for the reconstruction.

When spectral subtraction is being used in practice, the noise signal may not always match the length of the signals to be denoised. To define the subtraction formula, the spectrum of the noise must have the same number of points as the spectrum to be denoised. If there is a length mismatch, the noise spectrum is resampled automatically to match the length of the spectrum to be denoised. Cubic spline interpolation is used during the resampling to provide a better estimate of the overall noise spectrum.

Stim-Response



The Stim-Response analysis package can aid in analysis of stimulus-response studies. It allows for measurements to be extracted in tabular format for multiple stimulus classes. Stim-response configuration enhancements in AcqKnowledge 4.1 add the following functionality:

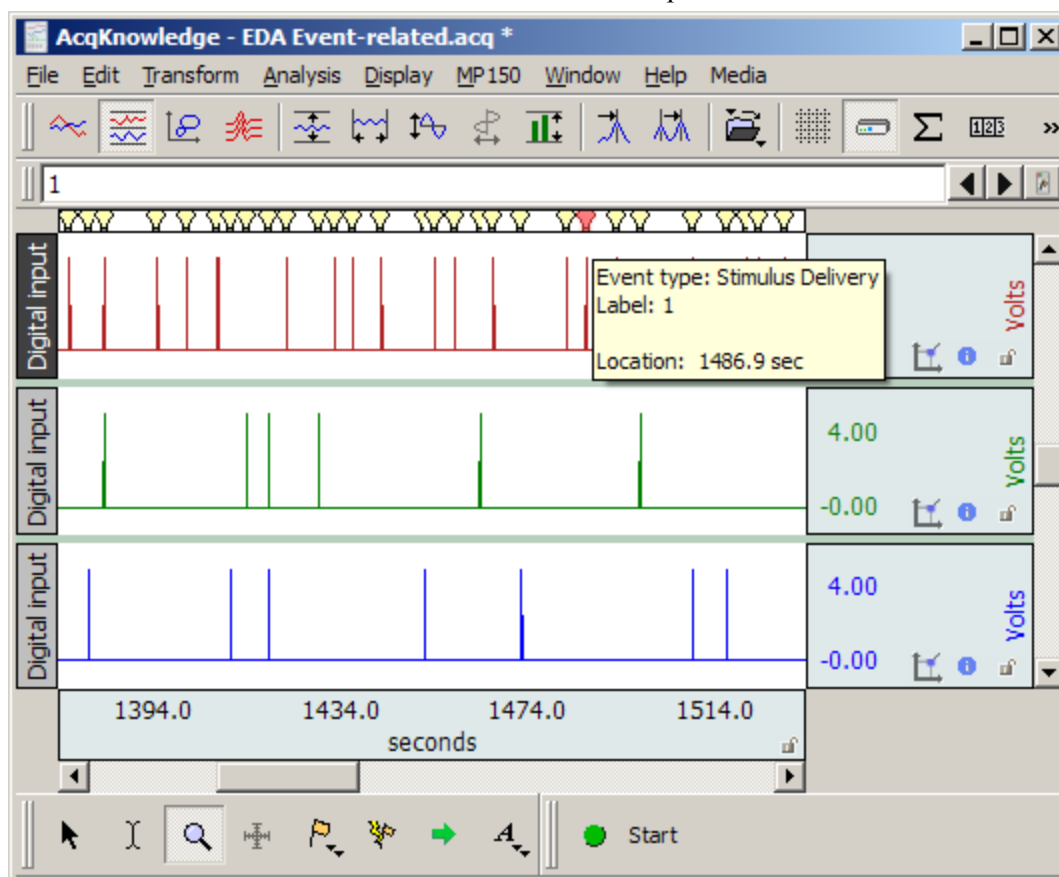
- Measurement configuration is preserved across launches of the application.
- Measurement presets may be accessed directly from the specialized analysis routine.
- Additional checking for invalid channels and measurement expressions that cannot be applied to the source data

The Event-related EDA Analysis routine uses the stimulus events to categorize specific and non specific responses. Responses are matched to the appropriate stimulus events using a user defined time window. See the Electrodermal Activity EDA Event-related analysis section for further information.

Note: Excel spreadsheet generation is supported in AcqKnowledge 4.0 Windows or AcqKnowledge 3.9.1 Mac and higher.

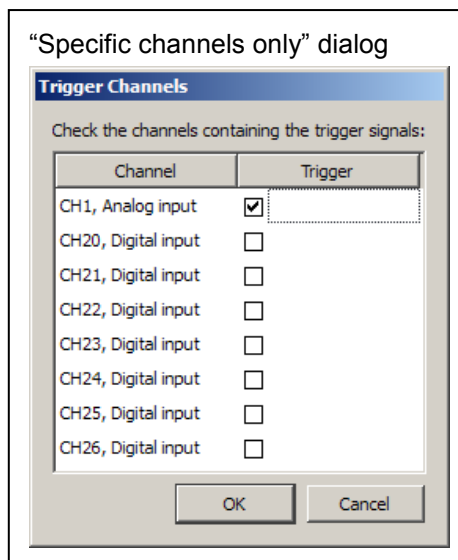
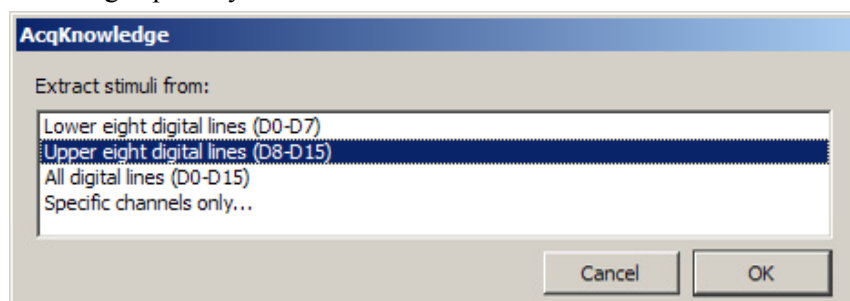
Digital Input to Stim Events

Digital Input to stim events identifies and labels stimulus events corresponding to any combination of digital inputs. A light bulb icon is placed in the global events bar, the event is labeled with the stimulus event type, and the mouse-over tag includes the event time. All event information is accessible and exportable from the Event Palette.



The Digital input to stim events function works with TTL trigger information coming from applications such as E-Prime®, SuperLab®, DirectRT®, MediaLab®, Inquisit®, and Presentation. It converts TTL data acquired on the digital channels of a hardware device into stimulus events. The system also works with analog and calculation channel signals coming from switch transducers. Unlike TTL signals, a voltage threshold level is used to determine the transition from low to high.

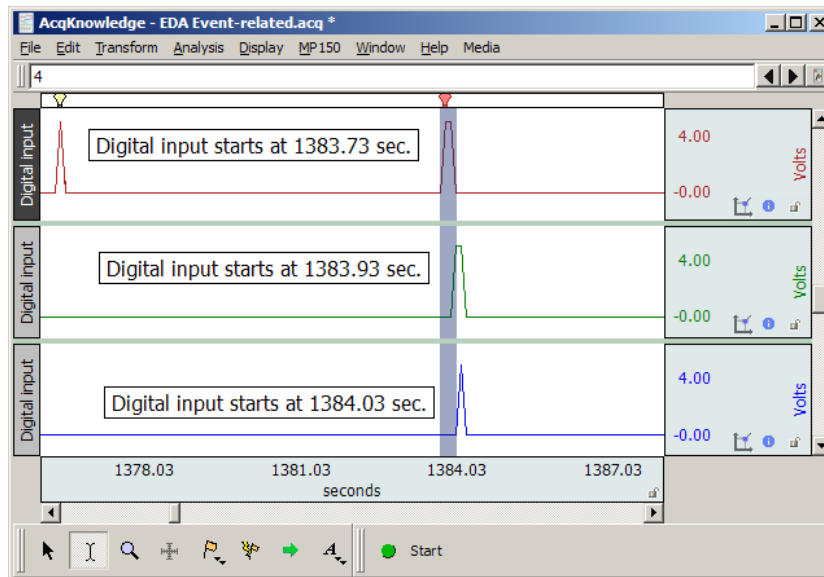
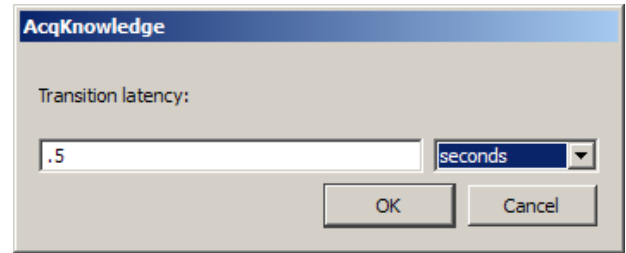
This analysis option converts TTL or switch data acquired on hardware into stimulus events. Stimulus delivery events are defined in the graph for each low to high transition of the digital data, the indications of stimulus delivery. The digital channels are interpreted as a binary number. Each stimulus event placed into the graph has the corresponding number included with its label. This allows further analysis to distinguish between different types of stimulus events by using the Cycle Detector's label matching capability.



Digital line decoding can be two byte (using all 16 digital lines) or single byte (on either the low eight or high eight digital lines). Big endian bit and byte ordering are used, with digital line 0 representing the least significant bit.

When the stimulus labels are constructed, all numbers are zero-prefixed. All stimulus events will have the same number of base-10 digits with leading zeros, regardless of magnitude. This provides each stimulus event type with a unique label that can be used with the Cycle Detector (which uses substring matching).

Some systems that trigger digital lines such as parallel ports may not be able to do so instantaneously; they may require a time window before the transition from one state to another is fully complete. A **“transition latency”** time window can be given to the analysis, specified in microseconds, milliseconds, seconds, minutes, hours, or samples. If non zero, any transitions that are separated by less than this latency are treated as a single transition and only one stimulus event is inserted. The decoded value used for the transition is the maximum value observed during the transition latency window. In the following example graph, the three digital TTL inputs correspond to one event, as marked by the red icon in the global events bar. A transition latency of .5 seconds will consider all three as part of the same event since the transitions occur within .5 seconds of each other.



Watch the [AcqKnowledge Digital Input to Stim Events video tutorial](#) for a detailed demonstration of this feature.

Stim-Response Analysis

Stim-Response Analysis allows for extraction of measurements within fixed width intervals occurring at Stimulus Delivery events. Stimulus events must be present to perform this analysis. The Stimulus Delivery events may be defined either manually, with the Cycle Detector, or using the Digital Input to Stim Events analysis option. The information that can be extracted includes the majority of the measurements available from the graph window measurement toolbar, matching the Epoch Analysis options.

Unlike Epoch Analysis, the Stim-Response Analysis splits the analysis based upon the event labels. Stimulus Delivery events with different labels are interpreted as different stimulus types. Analysis results for each individual stimulus type are summarized in separate tables. Each independent text table has its own average of the measurements over that stimulus type.

Additional options are available for positioning the fixed width interval where measurements should be made:

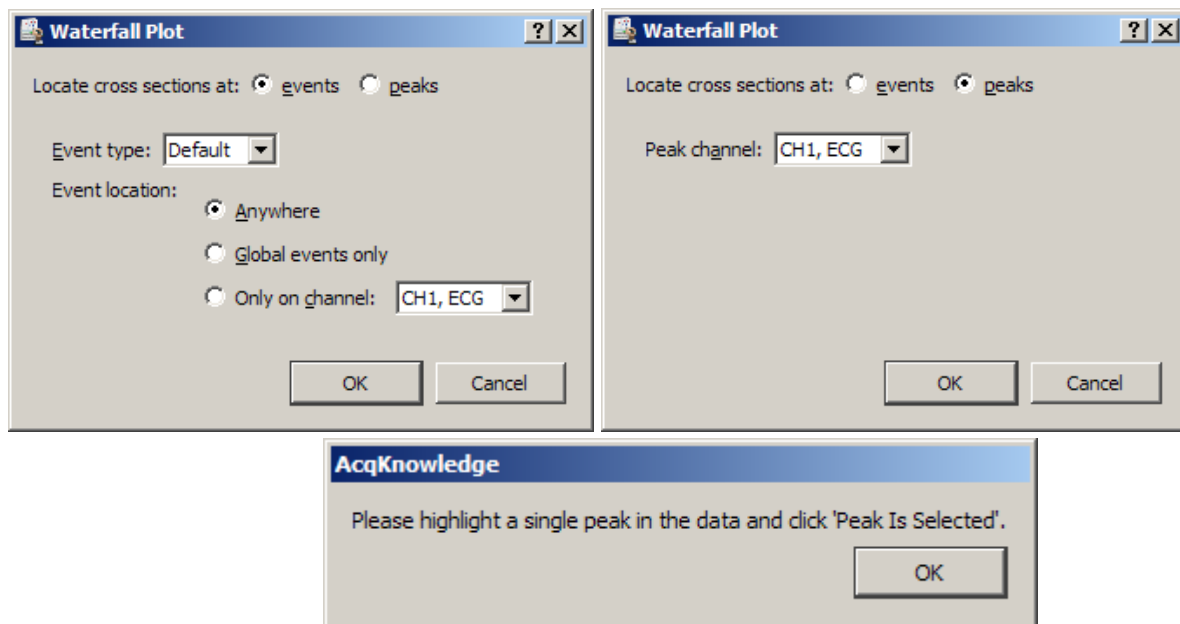
- At each stimulus event – The measurement interval is aligned so the start of the measurement matches the time of the Stimulus Delivery event.
- At fixed interval offset before or after stimulus – The measurement interval begins a fixed amount of time either before (for pre-stim studies) or after the time of the Stimulus Delivery event. This allows measurements to be made at a time relative to each stimulus onset and may be useful for measurements focusing on a specific time range (e.g. P300).

- At matching response event – This option assumes that a second set of Response events have been defined for each stimulus either manually or using the Cycle Detector. Each Stimulus Delivery event is paired with the closest Response event occurring after it. The fixed width measurement interval is aligned so the start of the measurement window is the time of this matching Response event.
 - To use the “at matching response event” window positioning option, Response events must be defined in the graph. Response events are in the “Stimulus/Response” event submenu. These events are *not* defined automatically.
 - Response events can be inserted manually into the graph using the Event tool.
 - Response events can be inserted using the event output of a data-driven Cycle Detector analysis.

Note If EDA/SCR signals are being analyzed in response to stimulus delivery, also examine the “Event-related EDA Analysis” transformation located under Analysis > Electrodermal Activity.

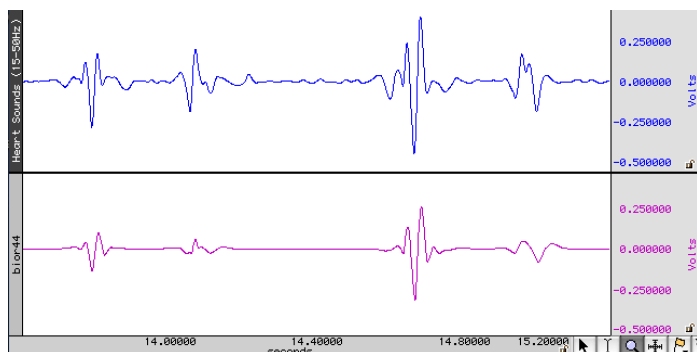
▶ Watch the [AcqKnowledge Stim-Response Analysis video tutorial](#) for a detailed demonstration of this feature.

Waterfall Plot



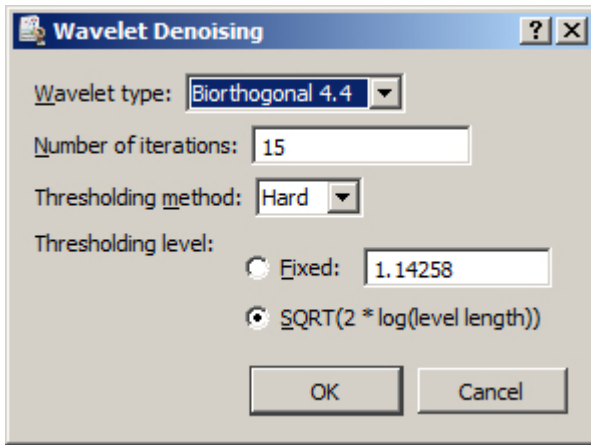
Assists in configuring the Peak Detector for 3D surface generation. These surfaces showing cycle-by-cycle data of the graph are commonly known as *waterfall plots*. Cycles are located in the graph using the same sequence of steps as the Ensemble Average transformation script. Instead of generating the 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 analysis operations to project source data into the wavelet domain, modify the wavelet coefficients (called “shrinking” the coefficients), and then reconstruct the data from the modified coefficients. Wavelet Denoising allows for noise to be removed from a signal while minimizing effects on portions of the signal that strongly adhere to a wavelet’s shape.

To perform wavelet denoising:

1. Choose the wavelet type to use for the denoising (Biorthogonal 4.4, Symlet 4, Coiflet 6, or Daubechies 8).
Certain signals may work best with different wavelet types.
2. Enter the number of iterations to use in the wavelet decomposition.
Different numbers of iterations will have different effects on the results.
3. Choose which type of thresholding should be used to shrink the wavelet coefficients.
 - Hard thresholding replaces coefficients below the threshold with zero while leaving all other coefficients unmodified.
 - Soft thresholding zeroes out coefficients below the threshold and subtracts the threshold for coefficients that are above it.

Soft thresholding may be useful for reducing edge effects, but hard thresholding will affect amplitudes less.
4. Choose the threshold level to use for shrinkage.
 - Fixed threshold for all levels. If 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 4 software implements the open source ecgpuwave ECG boundary location software and the open source OSEA QRS detector and beat classification library for ECG analysis.

Automated ECG Waveform Boundary Location

➤ ecgpuwave ECG boundary location software

AcqKnowledge 4 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*, select the ECG channel as the active channel and then choose “Analysis > Locate Human 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.

*To apply the proper algorithm for animal subjects, choose “Analysis > Locate Animal ECG Complex Boundaries.”

OSEA QRS Detector

➤ OSEA QRS detector and beat classification library

Since the release of software version 3.9, *AcqKnowledge* incorporates the open source OSEA QRS detector and beat classification library.

The OSEA library is a set of routines provided by EP Limited (<http://www.eplimited.com>). This C++ based software library provides robust QRS complex detection and rudimentary beat classification. This library is well documented and tested. The QRS detector uses a standard Tompkins-based filtering and derivative detection algorithm and has been in development since about 1985; the beat classifier development began in 1997. This algorithm development is sponsored by the NIH.

This algorithm is fairly robust against arrhythmias, baseline drifts, discontinuities, and other artifacts in the ECG signal. It achieves a 90% success rate on identifying QRS complexes on sample arrhythmia databases. The algorithm is tuned to human ECGs.

The QRS detector is optimized for 200 Hz sampled data. If the sampling rate is lower or higher, data will be internally resampled to 200 Hz before processing. The sampling rate difference may result in slightly different placement of beat events for different sampling rates.

QRS detection can be performed by selecting the desired channel of ECG data and choosing Transform > Specialized Analysis > Detect and classify beats. *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.

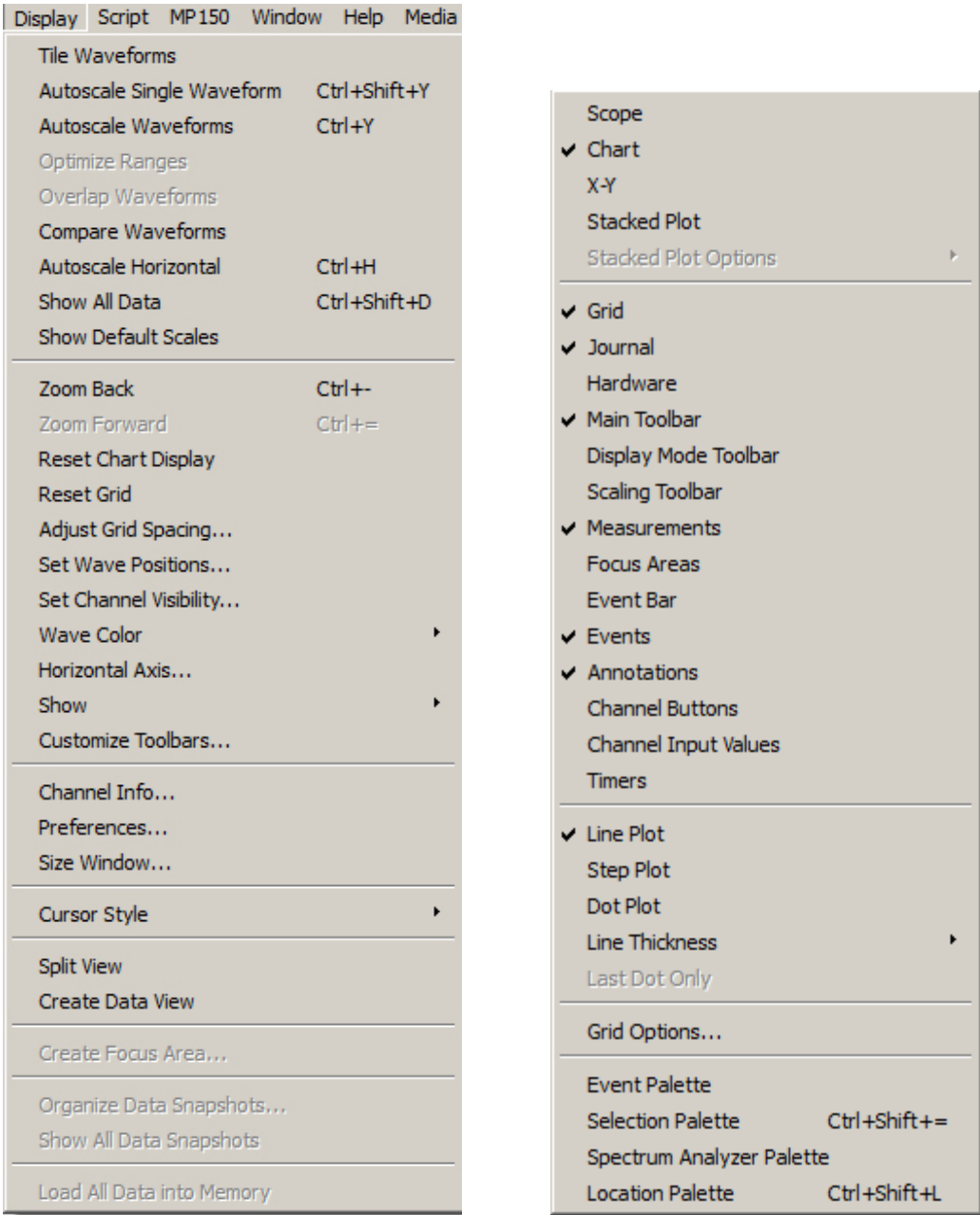
- ecgpuwave is under the GPL license
- OSEA is under the LGPL license

For the full text of both licenses, visit the Free Software Foundation (<http://www.fsf.org>).

Chapter 18 Display Menu Commands

Overview

The Display menu includes a number of features that control how the waveforms appear on the screen and how much data is displayed at a time.



Display menu and Show sub-menu

Although most of these these options change the appearance of the data, they do not modify the data itself. See the following shortcut options for Display menu commands:

- Toolbar shortcuts, page 57
- Context-sensitive shortcuts—page 69

Tile Waveforms

Tiling is an operation performed on all waveforms to visually separate them on the screen. Tile Waveforms adjusts the vertical offset to center waveforms in the display; if there are multiple waveforms displayed in chart mode, the waveforms will be centered in their “tracks.” Tiling does not adjust the scale of the waveforms; it only affects the midpoints of the visible portion of the waveform. Tiling does not affect the vertical scale factor previously set for each channel (whereas Autoscale may affect the vertical scale factor as well as the offset).

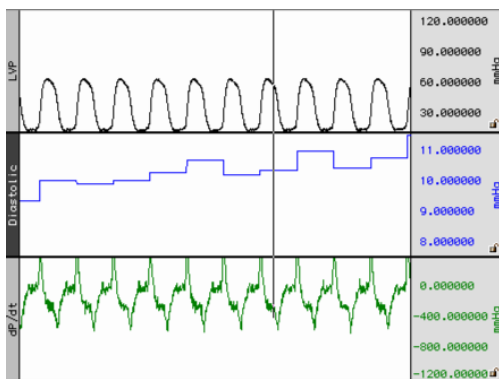
In Scope mode:

- Tiling staggers the midpoint of the channels to visually separate them on the screen while maintaining their scales.
- Waveforms are spaced evenly along the vertical axis of the screen, and each waveform is centered vertically in its division.

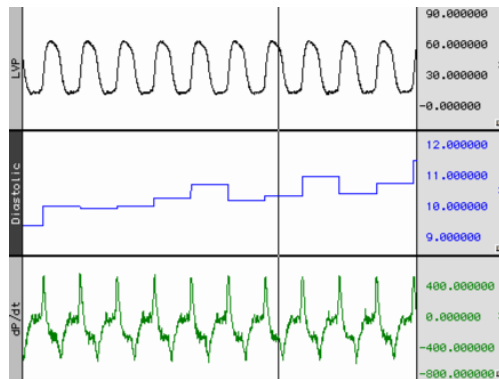
To apply tiling only to the selected waveform, hold down the CTRL key on Windows or the Option key on Mac OS X before selecting Tile Waveforms.

When grids are locked, tiling will retain the appropriate heights and percentages.

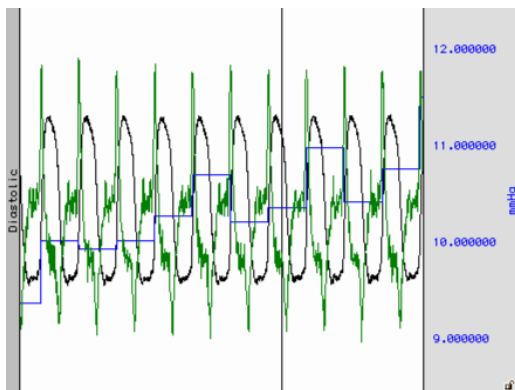
When grids are unlocked, the scale may be slightly larger in order to optimize the tick marks displayed on the vertical axis.



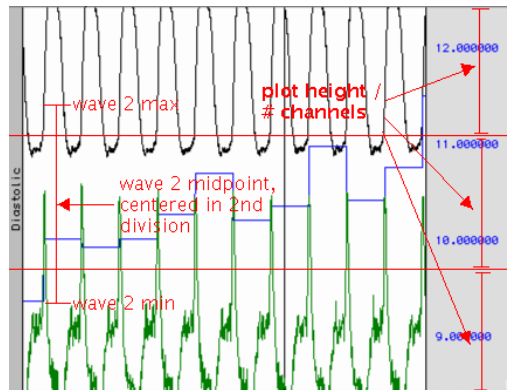
Before Chart mode tiling



After Chart mode Tiling



Before Scope mode tiling



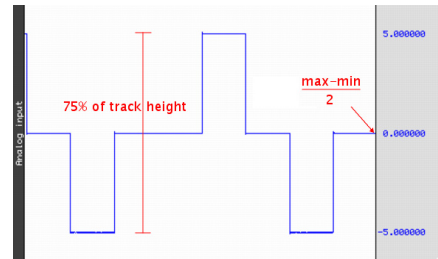
After Scope mode Tiling (red lines for illustration only)

Note that the waveforms are centered relative to the horizontal divisions of the plotting area; the range and midpoint of the second waveform (blue square wave) are indicated in the figure above.

Autoscale Waveforms

The primary use of Autoscale is to make all of the data of the channel within the current time range visible on the screen.

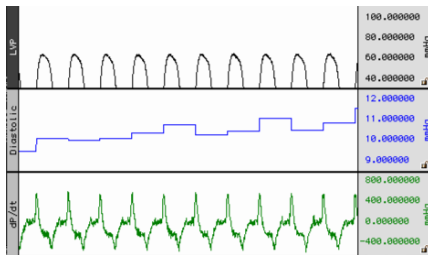
When Autoscale Waveforms is selected, AcqKnowledge determines what the “best fit” is for each displayed waveform. The percentages and midpoints are identical whether grids are locked or unlocked.



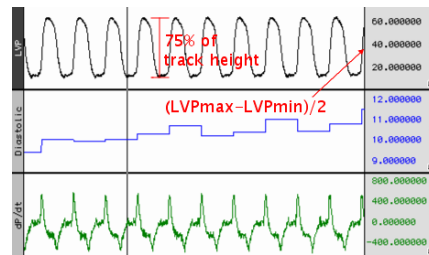
The software adjusts the vertical offset so that each channel is centered in the window (or within the channel track in chart mode) and adjusts the units per division on the vertical axis so that the waveform fills approximately two-thirds of the available area. In chart mode, the waveforms are autoscaled 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. If grids are locked, adjust scale such that *max-min* occupies 75% of the channel's track in Chart mode, or 75% of the entire plotting area X/Y mode.
4. Adjust the midpoint so $(max-min)/2$ is at the vertical center of the channel's track in Chart mode, or vertical center of the entire plotting area in Scope and X/Y modes.



Before autoscaling LVP channel



After autoscaling LVP (red lines for illustration only)

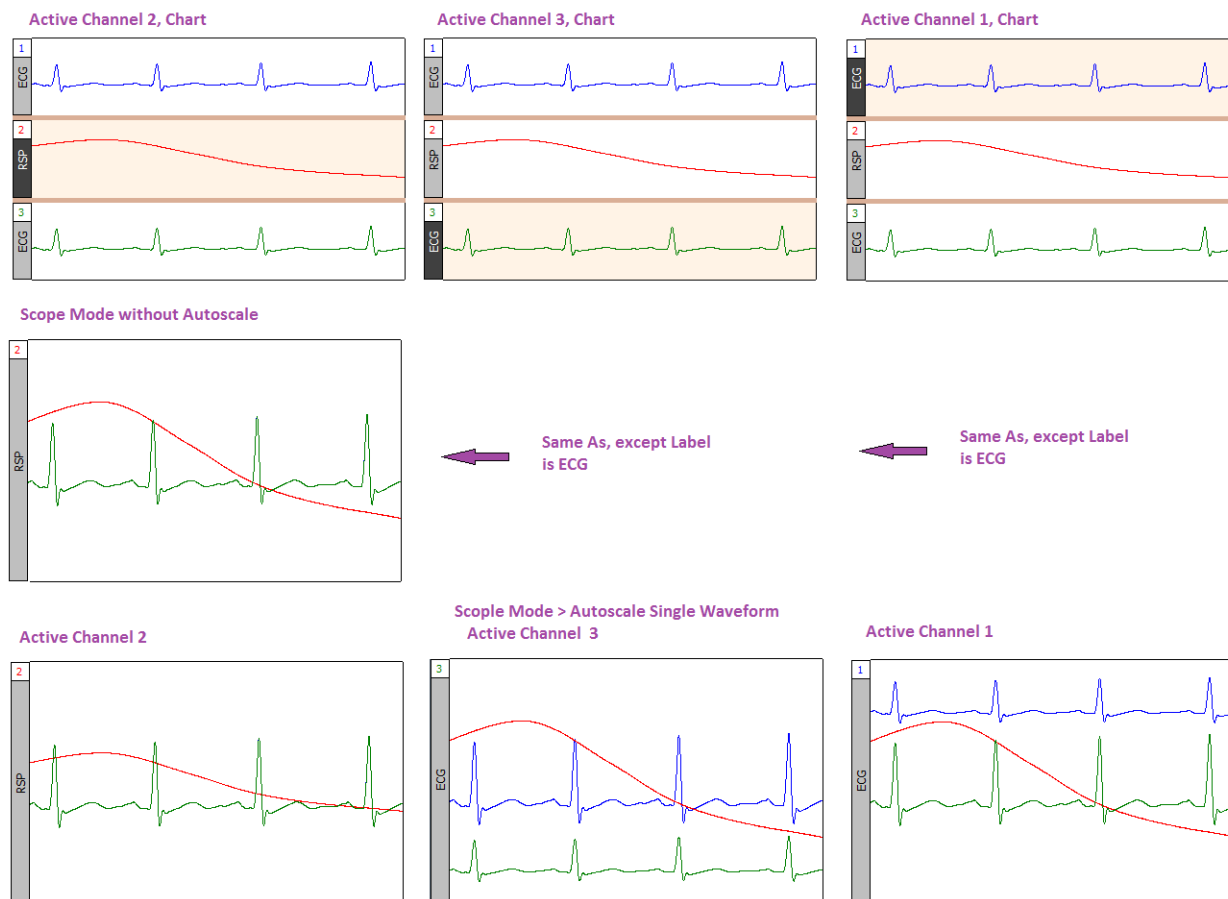
➤ The autoscaling algorithm for Scope mode is:

1. Divide the plot height into *m* equal sections of height *h* each.
2. Assign each visible channel to one of these plot sections.
3. If grids are locked, Scale the waveform such that the range between the max and min values will occupy 75% of *h*.
4. Place the midpoint between the max and min at the center of the waveform's section.

In scope mode, the screen is evenly divided into horizontal “bands” and each waveform is scaled to fit the division without overlapping.

Note: Autoscaling a single channel in Scope mode results in that channel occupying $1 / (\text{num_visible_channels})$ of the overall waveform plotting area. It will be placed in the region of the graph that corresponds to its position in Chart mode.

See following page for examples of autoscaling in Chart and Scope modes.



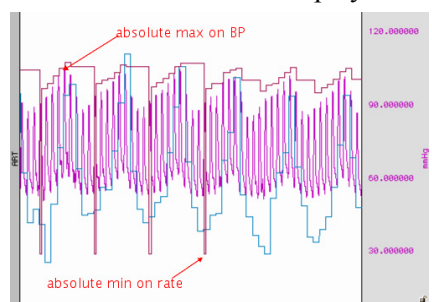
Autoscale Single Waveform

Use this option to perform the above autoscaling operations on a single selected channel rather than on the entire graph.

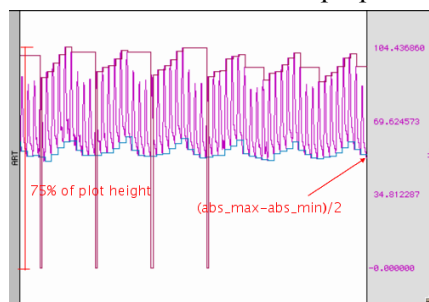
Overlap Waveforms

Overlapping waveforms places all of the waveforms at the same scale and midpoint so that the plotting location of a specific voltage on screen is at the same spot for every channel. Overlapping is useful for examining closely associated waveforms, such as the calculated diastolic, systolic and mean calculation channels “overlapped” with the raw blood pressure waveform from a continuous blood pressure signal.

In scope mode, when Overlap Waveforms is selected, the waveforms are “overlapped” into one screen. All of the currently displayed waveforms are arranged in the graph window with the same vertical scale and offset so all the displayed waveforms will fit on the graph; their magnitude reflects their size relative to the other waveforms. The overall chosen scale for all the displayed waveforms will be a function of the pk-pk value of the combined waves.



Before Overlapping in Scope mode

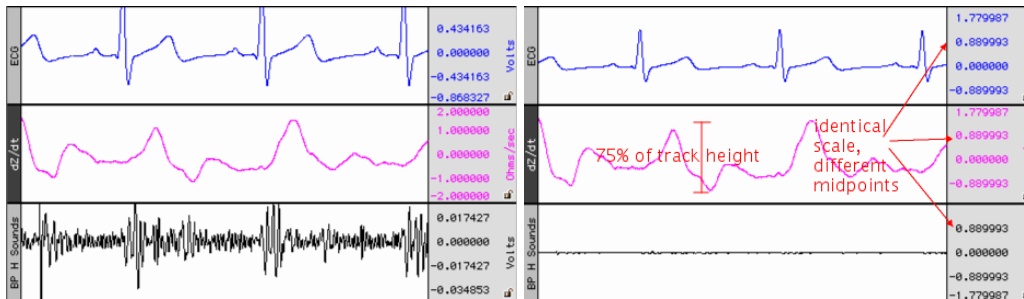


After Overlapping in Scope (red lines for illustration only)

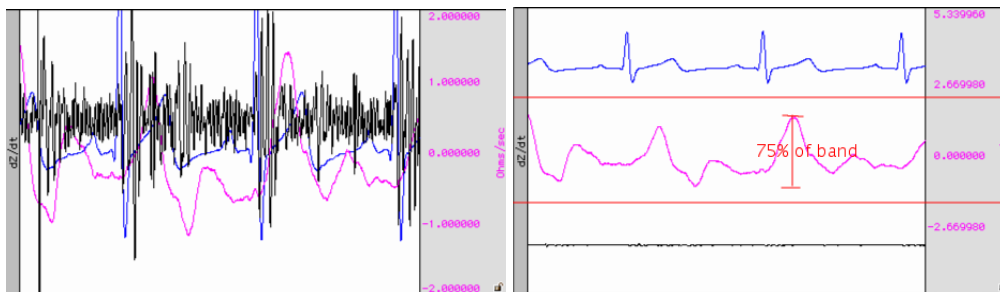
Compare Waveforms

Compare Waveforms displays all of the channels with the same amplitude scale. Compare Waveforms automatically sets the vertical scale to be the same for all channels and adjusts each channel offset so that all displayed waves are centered in the display. The scale for all the displayed channels is determined by the channel with the largest pk-pk range in the display interval. Compare Waveforms is useful for gauging the relative amplitudes of a number of channels by placing them all on the same amplitude scale and discounting the effect of waveform offset (or baseline).

- In Chart mode, Compare Waveforms functions on each channel in its track.



- In Scope mode, the channel scaling is similar but disperses the channels through the plot area similar to tiling. For a graph with m channels being plotted:



Autoscale Horizontal

The Autoscale Horizontal command is a convenient way to display the entire data file (in terms of duration) on the screen. When this is selected, the display will be adjusted so that the duration of the entire waveform fits in the graph window. For long waveforms, this can take some time to redraw.

An Autoscale Horizontal function cannot be reversed with Edit > Undo. To revert to the previous display settings, use the Display > Zoom back command.

Show All Data

The Show All Data command enhances the view by autoscaling first horizontally, then applies an “autoscale all waveforms” operation. This enables all data vertical and horizontal data in the entire graph to be displayed for easy viewing.

Show Default Scales

This option will reset a graph’s vertical and horizontal scaling parameters to the default settings used when the graph was first opened.

Zoom Back / Forward

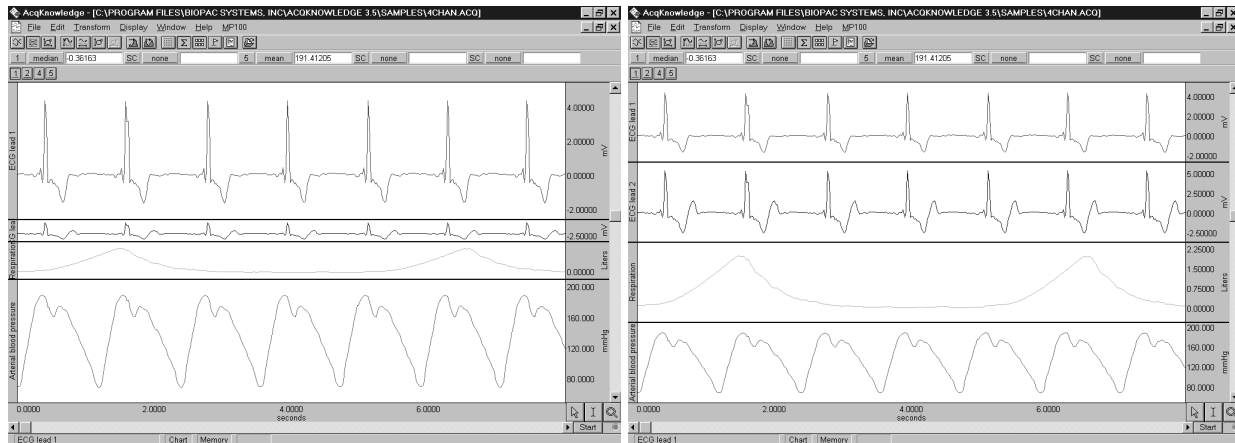
Zoom functions can affect the horizontal scale, the vertical scale, or both. Zoom restoration is functional for the Zoom tool, Autoscaling, and the Tile, Overlap, and Compare Waveform options. Zoom scales are stored until another zoom function is performed. Multiple levels of Zoom are supported.

- Zoom Back will restore settings one level at a time; This selection can be used to restore the original zoom scales. Essentially, Zoom back acts as an “undo” command for the zoom forward command and any other function that changes the amount of data displayed (either in terms of time or amplitude)
- Zoom Forward will redo a zoom function after it has been undone; you can repeat this selection to restore the latest zoom scales.

Zoom functions will work without limitation, until another Zoom is performed.

Reset Chart Display

The Reset Chart Display option redistributes the chart displays evenly after the boundaries have been changed so that each channel's vertical size is the same. This function, which only works in *Chart Mode*, can be useful for expanding a display region for analysis and then returning to the original display.



Before Reset Chart Display

...and after

Reset Grid

To return to the original grid, choose “Display > Reset Grid.” This will reconstruct the default, unlocked grid of four divisions per screen with solid light gray grid lines.

Adjust Grid Spacing

To modify the horizontal and/or vertical grid spacing, choose “Display > Adjust Grid Spacing.” This will generate a dialog for you to modify the locked axes of the selected waveform. *See page 79 for details.*

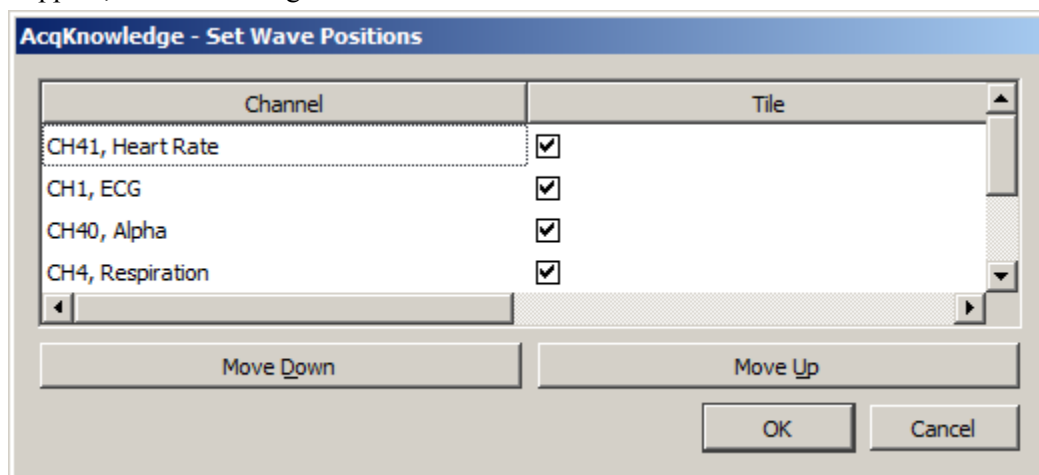
Set Wave Positions...

By default, channels are arranged on the screen based on their channel numbers, with the lower number channels being displayed at the top of the screen. The Set Wave Positions option allows waveforms to be placed in a user defined order.

- In chart mode this will result in vertical ordering of the individual waveforms.
- In scope mode this will result in vertical ordering of the individual waveforms after a tiling or autoscaling operation.

It's also possible to set any waveform to ignore the autoscaling and tiling functions. This is useful for selectively applying autoscaling to certain graph channels of interest while omitting others.

The waveform positioning function is selected through the Set Wave Position in the Display menu. The following dialog will then appear, with a scrolling list of all stored channels:



If more channels are present than those displayed, scroll through the list by clicking on the vertical scroll bar at the right. The list will scroll when moving past the top or bottom 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 the checkbox to toggle the enable.

The on-screen position of the waveforms is the same as the ordering shown in the above dialog (from top to bottom). The waveforms can be repositioned by reordering the channel labels as they appear in this dialog. To change the order of any waveform, select the channel label (e.g., CH1, ECG) and then click the Move Down or Move Up button. Repeat this operation until the waveforms are in the desired order.

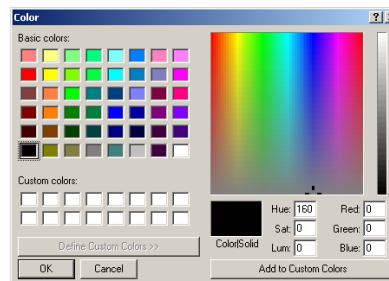
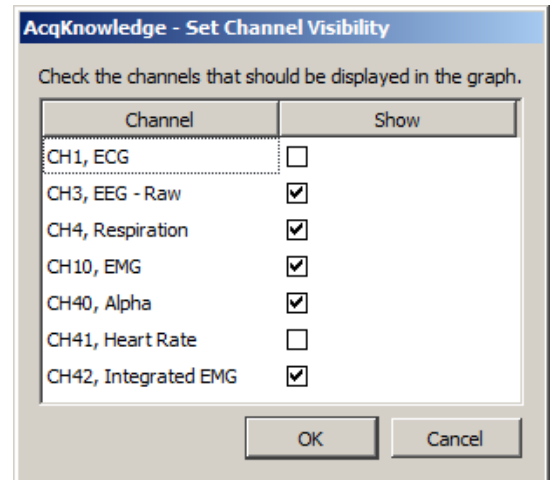
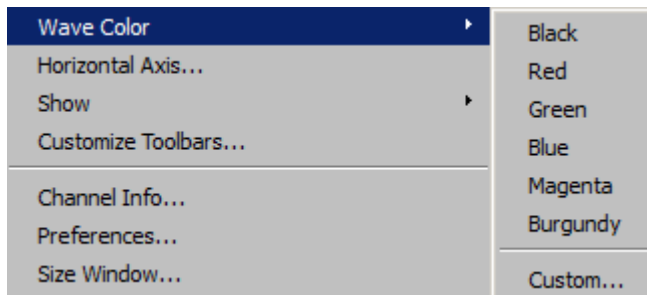
- Click OK to apply the selected order to the display screen.
- Click Cancel to revert all waveform positions to those set before the dialog was opened.

Set Channel Visibility

Set Channel Visibility offers an alternate means of showing and hiding channels. Simply check or uncheck the channel “Show” checkboxes to show or hide them. All channels can be shown or hidden simultaneously by holding down the Alt key while clicking the left mouse button. See also: Show/Hide Channels on page 89.

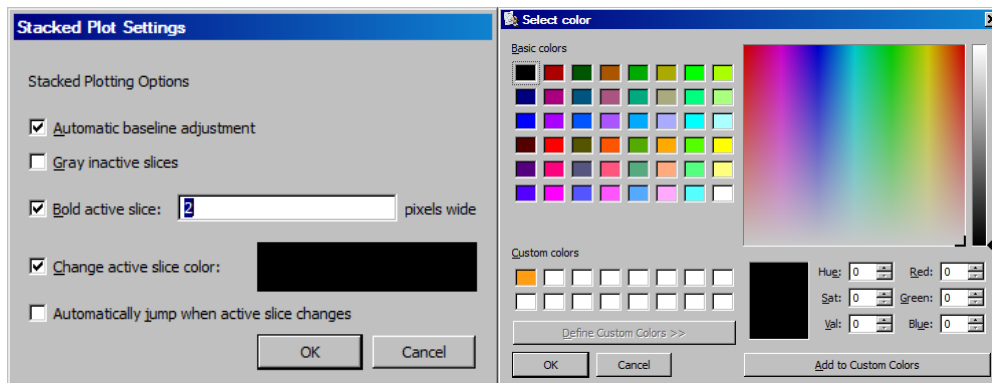
Wave Color

Select Display > Wave Color and then set the desired color of any waveform. In scope mode, the vertical scale, channel text, channel units and measurement popup menus take on the same color as the selected waveform. When adding new waveforms, AcqKnowledge assigns waveform colors in the following order: black, red, green, blue, magenta, burgundy, and custom.



Or, click the right mouse button to bring up a menu, select Color, and then select the desired waveform color from the color palette menu.

Active Slice Color



To change the Active Slice Color in Stacked Plot mode (see page 40), use Display > Show > Active Slice and then select Drawing options.

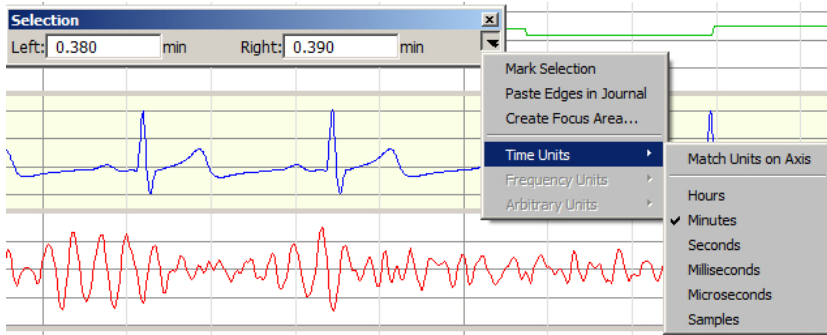
Horizontal Axis

Horizontal Axis generates the Horizontal Scaling dialog. Set the axis in terms of time, frequency, or arbitrary units, and set the horizontal sample interval (the amount of time between two sample points) and the first sample (sample offset).

Time domain scaling has two options to store and display data:

- **(ss.sss)** —absolute seconds; the time scale for an event occurring 30 seconds into the record would be 30.00 seconds
- **(HH:MM:SS)** —hours:minutes:seconds; the time scale for the same event would be 00:00:30.

Set the Time Unit precision via Display > Show > Selection palette, then press Enter (return) to accept changes.



The **Frequency Units** option plots data from a Fourier analysis or other data with a frequency base (rather than a time base). This option is only available when frequency units are present in the graph. As with the time options, this feature is typically used for importing text files from other applications. For instance, when importing a text file with 1,000 sample points that covered a frequency range from 0 Hz to 100 Hz, set the interval to 1000 Hz/100 samples, or 0.1 Hz per sample in the box to the left of the interval text box. Similarly, if the frequency range was 20 Hz to 100 Hz, set the offset to 20 Hz. Arbitrary base units can also be attached to the data (rather than a time or frequency base). When the horizontal axis corresponds to wavelength, and the data consists of 100 samples covering a range from 1 to 10 Angstroms, the interval should be 0.1 units per sample.

Arbitrary units are generally useful for changing the time base (or other horizontal scale) of data that has been imported into AcqKnowledge as a text file. For instance, to analyze data imported from a text file that contains 30 seconds of data that was collected at 100 samples per second (100 Hz), the first step would be to open the file (following the directions on page 251).

When arbitrary units are selected, two additional text boxes appear at the bottom of the dialog. The upper Units text box is used to provide a name for the horizontal scale units and the lower Units text box is used to provide an abbreviated label for the horizontal units.



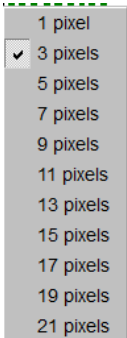

By default, AcqKnowledge assumes that the data was collected at 50 Hz, and would therefore plot the data so that a 60 second record was displayed that appeared to be collected at 50 samples per second. To change this to reflect the rate at which data was actually collected, change the sample interval box in the horizontal scaling dialog. When data are displayed on a 50 Hz time base, the sample interval will read 0.02 seconds per sample. This means that there is a 0.02-second “gap” between sample points in the record. To display data at 100 samples per second, change the interval to 0.01 seconds per sample.


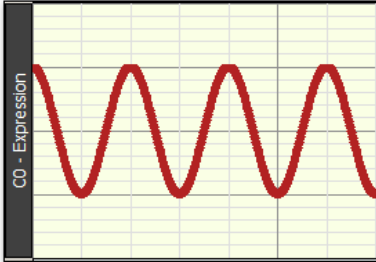


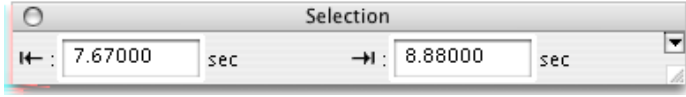
To determine the sample interval for other sampling intervals, divide 1 by the rate at which data was sampled (in terms of samples per second). Thus, a sampling rate of 0.5 Hz would translate into a sample interval of 2.00 seconds between samples, and data collected at 100,000 Hz (100 kHz) would have an interval between sample points of 0.00001000 seconds.

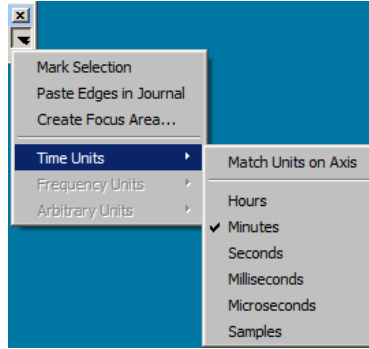
TIP: To confirm that AcqKnowledge is storing data in the same time base it was collected in, choose Channel Info from the Display menu. This will generate a dialog that describes (among other things) the sampling rate AcqKnowledge uses in analyzing the data. Once data has been saved as an AcqKnowledge file, X-axis base information is automatically saved along with the data. AcqKnowledge also saves X-axis in Frequency (FFT) or Arbitrary (Histogram).

Show

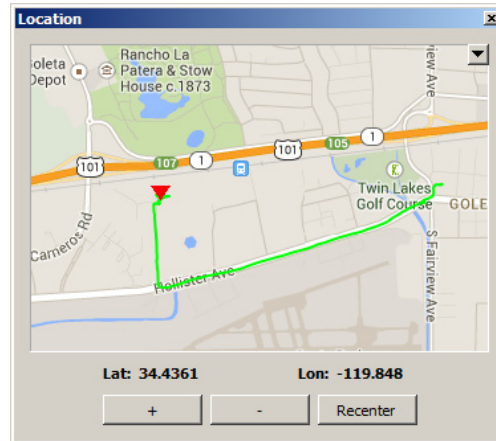
Selecting Display> Show generates a submenu controlling the data display options and other additional information appearing in the graph window. To enable an option, select it in the submenu. A checkmark appears next to the enabled menu items. The three display modes and the two plotting modes are mutually exclusive, but the remaining items can be enabled independently.

Show Option	Shortcut	Explanation
Annotations		Toggle show/hide of text annotations.
Channel Buttons		<p>When the Channel Buttons option is selected, the channel boxes appear just above and below the graph area.</p>  Channel Buttons with Channel 1 selected <p>These buttons are useful for selecting channels and “hiding” channels by positioning the cursor over the channel box, holding the ALT key on the Windows or the Option key on the Mac, and clicking the mouse button.</p>
Channel Input Values		When enabled, adds real-time display of channel amplitude values above the graph. (“Show textual value display” must be enabled in the Vertical Axis settings.)
Chart		Activates the Chart display mode (see page 38).
Display Mode Toolbar		Activates toolbar shortcuts for Chart, Scope, X/Y, Stacked Plot, Horizontal Split View and Data View.
Dot plot		Dot Plot allows viewing of data in a “dot” format. This is useful for demonstrating the concept of discrete digital sampling by dividing the waveform up into data points or “dots.”
Dot size		<p>Dot size is enabled after Dot Plot is selected.</p> <p>Dot size specifies how large each dot will be. Each dot is measured by the number of monitor pixels it occupies.</p> <p>Each “dot” corresponds to a sample point. (For example, data collected at 100 samples per second would display 100 dots per second.)</p>
Events		Displays the event marker region at the top of the graph window. See page 216 for Events.
Event Bar		Enables Event Bar display on toolbar.
Event Palette		Displays the Event Palette (see page 219 for Event Palette details.)
Focus Areas		Enables Focus Area display. See page 89 for Focus Areas.
Focus Areas Bar		Enables Focus Area Bar display on toolbar.
Grid		Superimposes a Grid on the graph window (see page 51). To change grid precision, use the axis scaling dialog of the horizontal or vertical axis.
Grid Options		Activates the Grid Options dialog (see page 81)
Hardware		Show/Hide Hardware “Connected to:” dialog in the graph display; includes network access.
Journal		Activates the Journal (see page 53).
Last Dot Only		Plots only the most recently acquired data point. Only available in X/Y mode.

Show Option	Shortcut	Explanation
Line Plot	Right-click menu	Connects each sample point with a line to create the waveform. Waveforms that are displayed in line plot mode match a true analog plot (as closely as possible). This is the default display mode for most waveforms, except histogram plots, which are displayed in Step Plot mode (see 313). The line options can be changed by clicking the right mouse button, which will generate a menu displaying several commonly used features.
Line Thickness	Right-click menu	<div>  <p>Line thickness is enabled when Line or Step plot are enabled. Use to specify the plot thickness in pixels. (AcqKnowledge 4.2 and higher)</p>  <p>Sine wave set to thickness of 5 pixels</p> </div>
Main Toolbar		Controls visibility of Main Toolbar buttons (Grid, Show/Hide, Preferences and Customize Toolbar).
Measurements		Displays the measurement popup menus and windows above the graph window (see pages 50 and 91).
Scaling Toolbar		Controls visibility of Scaling Toolbar shortcut buttons (Autoscale Vertical, Autoscale Horizontal, Show All Data, Center Data Vertically, Center Data Horizontally).
Scope		Activates the scope display mode (see page 38).
Selection Palette		 <p>Many tools within the AcqKnowledge 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 dialogs are being displayed for the graph. The selection palette offers a way to change the selected area without having to cancel the transformation setup and lose any parameters typed in the dialog. <p>To display the Selection Palette, choose Display > Show > Selection Palette. This dialog contains two edit fields that display the location of the left and right edges of the selection using the measurement units currently displayed in the horizontal axis. As the selection is changed, the new selection boundaries are shown.</p> <p>The Selection Palette also can be used to manually type in the edges of the selection. Double-click the edges and type in the new horizontal position of the edge of the selection. Press “Return” to adjust the selection to that time location and update measurements and the visible display on the screen.</p> <p>For graphs displayed in X/Y mode, the Selection Palette can be used to adjust the</p>

		<p>X-axis range of data plotted on the screen. Limiting the time range can be useful for generating X/Y plots for different intervals of the graph for comparison, such as examining PV loops from different time periods of a recorded signal.</p> <p>Click the small arrow in the top right of the selection palette for the following additional options:</p>  <ul style="list-style-type: none"> • Mark Selection—Use this option to bracket a selected area with event markers. • Paste edges in Journal—This option pastes a line of text into the Journal that includes the left and right edge measurements of the selection. • Create Focus Area—This option turns data highlighted by the selection palette into a labeled Focus Area. • Time units—Use this submenu to change the time units used in the selection palette. The following time units are available: Match units on axis; Hours; Minutes; Seconds, Milliseconds, Microseconds and Samples. The Time units submenu will be dimmed unless the graph displays time/arbitrary measures). • Frequency units— Use this submenu to change the frequency units used in the selection palette. The following frequency units are available: Match horizontal axis, Kilohertz, Hertz, Millihertz and Samples. The frequency submenu will be dimmed unless the graph displays frequency-based measures. <p>Note Changing time/frequency units in the selection palette can be helpful during zoom operations when the units displayed in the horizontal axis may not be the most convenient for inputting new selection boundaries.</p> <ul style="list-style-type: none"> • Arbitrary Units—Use this submenu to change the arbitrary units used in the Selection Palette display (Units or Samples).
Spectrum Analyzer Palette		Provides a dynamic display of the frequency decomposition of data, in real time or post-acquisition. See page 441 for details.
Timers		Enables display of stopwatch and elapsed timer toolbar.
Location Palette		<p><i>AcqKnowledge</i> 4.4 and higher supports import of GPS location data into <i>AcqKnowledge</i> graphs. This is useful for correlating a subject's geographic location with physiological data acquired during extended exercise studies where a subject might wear a long-range wireless device, such as BIOPAC's Mobita and BioHarness loggers. The Location palette, like the Selection and Spectrum Analyzer palettes, is a floating dialog that can be dragged, resized or repositioned as desired. In order for the Location palette to be operational, the subject must first log data with a compatible GPS tracking device, such as the BIOPAC GPSTRACK. The resulting GPS data can be imported from the tracking device into the <i>AcqKnowledge</i> exercise study graph, which populates the Location palette in a navigable map format. The resulting map shows the physical location of the subject throughout the exercise.</p> <p>After Import:</p>

- Browsing GPS graph data with the I-beam selection tool will relocate the red navigation arrow to the map location occupied by the subject at that exact point of the experiment.
- The map view is zoomable, and any of three different map servers can be selected in the preferences.



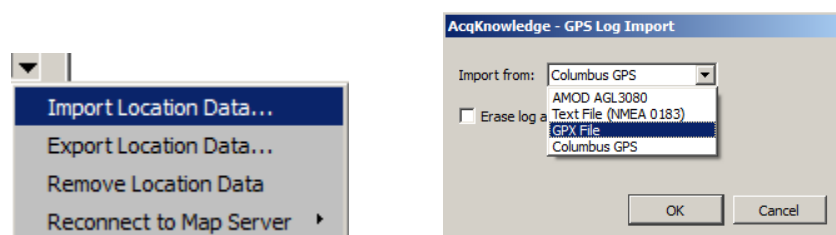
Location palette showing coordinates, zoom and recenter tools

To log GPS data:

1. Attach the GPSTRACK device to the subject and turn on the power.
2. Run the experiment. (For example, subject walks, runs, or bicycles an assigned geographical route during an exercise study where data is being acquired into AcqKnowledge via a wireless logger.)
3. At the conclusion of the experiment, turn off the GPSTRACK and remove it from the subject.

To import GPS data into AcqKnowledge:


1. With the exercise study graph open in AcqKnowledge, launch the Location palette (Display > Show > Location Palette).
2. Connect the GPSTRACK to the computer's USB port.
3. Click the arrow in the upper right corner of the Location palette and choose "Import Location Data." The GPSTRACK used will appear in the "Import from:" menu.



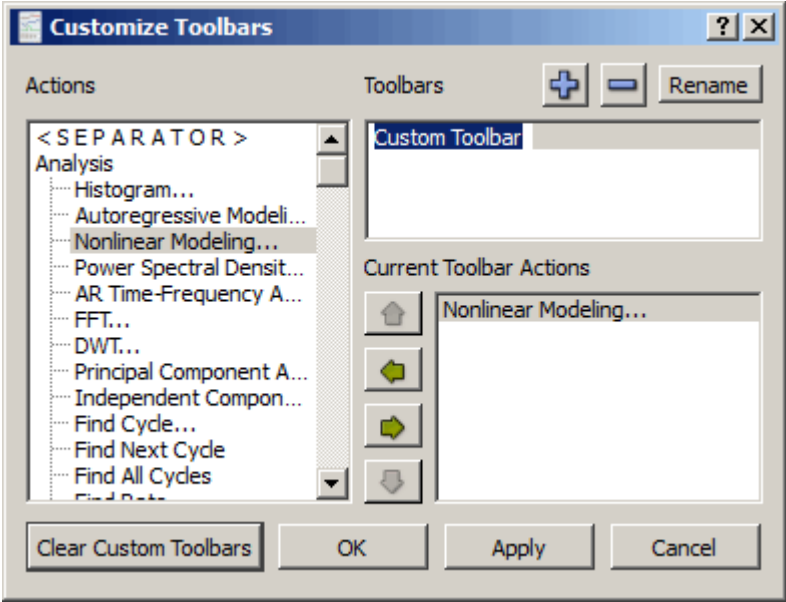
4. Click OK to import location data into the graph. The imported location data will be saved with the graph. Be sure to select the correct GPS device or file format. (AMCO AGL 3080, Columbus GPS, *.txt or *.gpx format.)

Explanation of Options:

- **Import Location Data** – Use this option to import logged GPS data into AcqKnowledge graph.
- **Erase log after data is imported** – If selected, the log file on the GPS device will be deleted following import.
- **Export Location Data** – Use to export GPS data in graph to a text file format.
- **Remove Location Data** – Removes all location data from graph.

		<ul style="list-style-type: none"> • Reconnect to Map Server – Use to connect/reconnect to any of three supported map servers (Nokia Ovi Maps, Google Maps, Open Street Map) <p>The default Map Server may also be selected in the Location Preferences (Display > Preferences > Location).</p> <p>Limitations:</p> <p>When using Edit > Merge to merge graph files from multiple hardware units: If only one graph file contains embedded GPS data, the GPS data will be copied into the merge output graph. If more than one graph has GPS data, no GPS information will be present in the merge output graph.</p> <p>Data snapshots will archive any GPS data present in the graph and retain it in the snapshot. When the snapshot is restored, the archived GPS data will be extracted into the newly created graph window, showing the data from the snapshot.</p> <p>GPS data in a graph file is read-only and cannot be modified directly within the software. To modify the GPS information, the data must first be exported, edited externally, and then re-imported.</p>
Stacked Plot Options		<p>Displays options that can help visually distinguish the active slice from other slices being drawn in Stacked Plot mode. See page 41 for details.</p> <div> <p>Jump to Start of Active Slice</p> <p>Activate Previous Slice</p> <p>Activate Next Slice</p> <p>Activate Specific Slice...</p> <p>Vertical Separation...</p> <p>Slicing Event...</p> <p>Drawing Settings...</p> </div>
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 and other hardware units), 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 57).
X/Y		Activates the X/Y display mode (see page 38).

Customize Toolbars

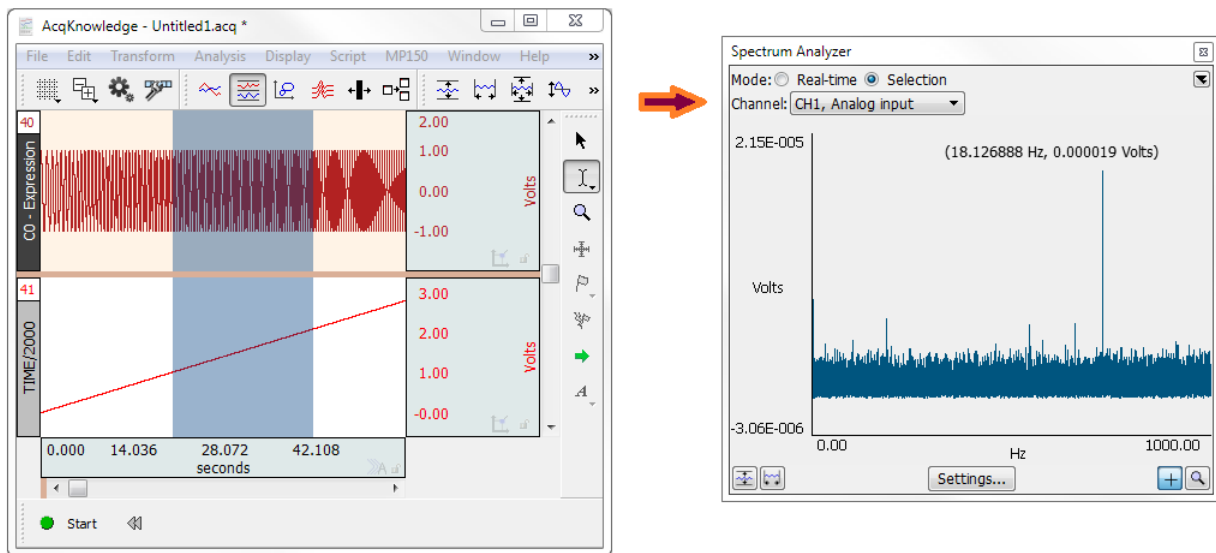


Use the Customize toolbar feature to create custom toolbars for easy access to post-processing Analysis and Transform actions. Toolbars are dockable and custom toolbar placeholders can be named independently of toolbar actions.

- **Actions** – Menu list of available Analysis and Transform functions
- **Toolbars** – List view of custom toolbar placeholders
- **Current Toolbar Actions** – List view of available actions from Analysis and Transform menu

Button	Function	Explanation
	Add toolbar button	Adds placeholder for new toolbar. (More than one toolbar action can be grouped under one placeholder).
	Remove toolbar button	Removes placeholder for toolbar.
	Rename toolbar button	Allows existing custom toolbar name to be edited.
	Up arrow	Moves a toolbar action up the list.
	Left arrow	Removes a toolbar action from the list.
	Right arrow	Adds a toolbar action to the list.
	Down arrow	Moves a toolbar action down the list.
	Clear button	Removes all toolbars from Toolbars and Current Toolbar actions list.
	OK button	Enforces addition or removal of toolbars from list or application toolbar region.
	Apply button	Applies changes without closing Customize Toolbar window.
	Cancel button	Dismisses any toolbar changes without applying.

Spectrum Analyzer Palette Details



Spectrum Analyzer breaks time domain signals into their respective frequency components to provide a dynamic display of the frequency decomposition of data, in real time or post-acquisition. Spectra can be generated in real time based on the most recently acquired data or post-acquisition based on the selected area of a saved data file.

- Spectrum analyzers can be useful for locating and correcting noise sources in a system as well as other frequency domain analysis.
- The Spectrum Analyzer displays the FFT of a portion of data of a single channel.

The spectrum analyzer applies to all graph windows displaying data in the time domain. Viewing the underlying time domain data at the same time as the spectral information also provides useful visual feedback with regards to signal quality. The palette allows for continuous availability of the spectrum analyzer across multiple graphs and for positioning alongside original data. The channel is always indicated by the popup menu within the spectrum analyzer itself. The graph whose data is analyzed will always be the topmost graph; this is the graph whose window is highest in the Z ordering.

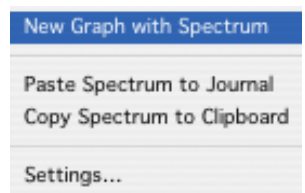
Mode:

Real-time Analyzes the most recently acquired data in a graph. The analyzer generates full FFT output so, in linear units, it is the regular FFT multiplied by two. The analyzer extracts the spectrum based on a sliding window of samples at the tail end of the signal and periodically refreshes the spectrum plot during acquisition. The analyzer uses a fixed width window size. The first spectrum will be generated after the number of samples needed to fill the initial window has been acquired. If no data is being acquired, the analyzer will not display any frequency information and will appear to be off.

Selection Analyzes the highlighted section of the active channel of a saved graph (post-acquisition). Select the channel to be analyzed from the channel popup menu.

Palette popup (upper right) Displays the spectrum analyzer palette popup menu for performing other operations on the spectrum including extracting the spectrum to a new graph window and copying spectrum data to the clipboard or journal. Options are dimmed if there is no spectrum available.

- New ...** New Graph with Spectrum constructs a new graph window with the contents of the spectrum. This allows for more detailed examination of the spectrum than is possible with the tools in the spectrum analyzer palette.
- Paste...** Paste Spectrum to Journal makes a textual representation using the current Journal preferences and copies the text into the graph journal of the graph whose data is being analyzed. This will prompt to create a journal if none exists.
- Copy...** Copy Spectrum to Clipboard makes a textual representation using the current Journal preferences and copies the text to the Clipboard.



Settings... Displays the spectrum analyzer settings dialog. Equivalent to using the Settings button at the bottom of the palette; see Settings below for details.

Channel Indicates which channel of the hardware setup or graph is being analyzed. The “Channel” popup menu contents vary with the analyzer mode:

Real-time Channel popup menu lists active channels whose “Acquire” checkboxes are checked in Hardware > Set Up Channels. The channels will be listed as “{A,D,C} {0-16}, *chan_title*” where *chan_title* is replaced with the manually entered title in the channel setup window.

Selected The channel popup menu matches the channel menu of measurements in the topmost graph window. The menu starts with “SC, Selected Channel” which, when chosen, uses the data of the active channel of the graph. The remainder of the menu lists the channel numbers and labels of the channels within the topmost graph.

Plot display Plot of the spectrum of the corresponding data.

- Vertical axis units match the source channel (displays either “dBV” or linear)
- Horizontal axis displays frequency and is always displayed in “Hz.”

If there is a valid data selection that can be used to compute a spectrum, the spectrum will be displayed in this area. If there is no valid data selection, no axes will be displayed and the plot will be replaced with the text “Not Available.” The following conditions cause spectra to be unavailable:

- graphs that contain no data (either no channels or only empty channels)
- graph is being displayed in XY mode
- graph uses either frequency or arbitrary units for its horizontal axis

When operating in selected area mode, the following additional conditions also cause spectra to be unavailable:

- selection contains no data on the active waveform
- selection is a single-point selection (not enough data to compute FFT)

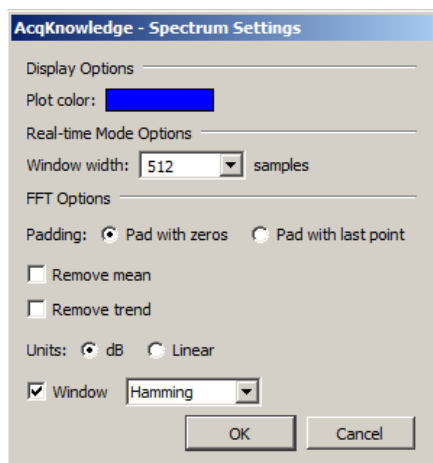
When operating in real-time mode, the following additional conditions also cause spectra to be unavailable:

- no data acquisition is in progress

Auto Vert Click to autoscale the spectrum to fit all amplitudes within the visible spectrum plotting area.

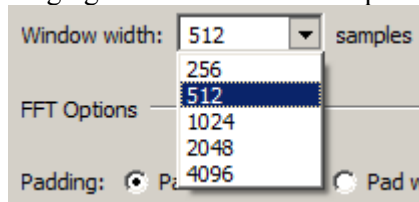
Auto Horiz Click to autoscale the spectrum to fit all frequencies within the visible spectrum plotting area.

Settings



Plot color Colorwell that changes the color used to draw the spectrum in the palette. Click to display a standard color picker.

Window Width specifies the window size used when performing analyses in real-time mode. The spectrum will always reflect the frequency characteristics of the most recently acquired data of the graph, using this window size as the number of sample points to use. This popup will list various powers of two, ranging from 256 to 4096 samples.



FFT Options

Padding—used whenever the number of input points is not an exact power of two. Data can be padded either with zero or with the amplitude of the last data point.


Remove mean—Subtracts the mean value of the data 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* FFT windowing options, to adjust the data to remove effects resulting from the discontinuities of data at the two edges. See page 318 for details about FFT.

Value

Click the crosshair icon  to display the frequency and amplitude values of the spectrum when moved within the spectrum display. The mouse cursor will change to a crosshair when inside the spectrum plot. The frequency and amplitude values corresponding to the mouse position are displayed above the spectral plot. Hold the mouse button down to display the amplitude of the spectrum at the horizontal mouse position, along with a crosshair cursor highlighting the exact location shown on the spectrum. If the active spectrum is compressed (that is, if multiple samples exist for a particular horizontal position), the value extracted will be the maximum value displayed at that pixel position.

Zoom

Click the magnifying glass  to perform zoom operations. Click and drag the mouse cursor (which will change to a magnifying glass) in the plot display to select the area to zoom in on. Alternately, click either of the axes of the spectrum palette to display a dialog used to enter display ranges manually. Enter the start and end points of the desired range for each axis. There are no grids in the spectrum analyzer palette, so the axis scaling dialogs of graphs are not applicable. Note: adaptive scaling will be disabled for the spectrum display when either the zoom tool or the axis endpoint entry dialogs are used.

TIP: To zoom out, hold the Alt key (PC) or Option key (Mac) while clicking mouse over zoomed area.

Channel Information

The Display > Channel Info... command generates an information dialog for the selected channel.

Channel Information may also be displayed by right-clicking in the channel and selecting “Channel Info...” from the contextual menu.

Channel Information

Line frequency: Unknown

Channel: **A3, ECG** Min: -1.0674 Volts

Interval: 200 samples/sec Max: 2.69094 Volts

Length: 5455 samples, 27.275 sec Mean: 0.0212502 Volts

	Transformation	Date	Time	Parameter	Value
1	Smoothing	Wed, April 6, 11	14:56:20.760	Smoothing factor	3
				Smoothing value	mean
				starting sample position to transform	1
				ending sample position to transform	5455

Paste Selected Channel to Journal Paste All Channels to Journal Close

Line Freq Files created with AcqKnowledge 4 include the line frequency (50 Hz or 60 Hz); files created in earlier versions will list “Unknown.”

Channel Use this popup menu to select the desired channel for displaying information.

Interval The time between sample points, which is the reciprocal of the sampling rate. The sampling rate can be modified by using the resample function (described on page 308), by changing the interval horizontal scale (see page 434), or by pasting data collected at one sample rate into a graph containing data sampled at a different rate.

Length Indicates the overall length of the channel in samples and in time. The waveform length is generally the same for all channels but there are exceptions:

- Downsampling a channel during acquisition
- Transform > Resample Waveform/Graph
- Edit operations – Cut, Copy, Paste, Clear

Min Provides the minimum value for the waveform data.

Max Provides the maximum value for the waveform data.

Mean Provides the mean value for the waveform data.

The fields below the statistical information contain transformation histories, time/date stamps, parameters, and values for selected channels.

Paste Selected Channel to Journal Pastes transformation modification history for selected channel to Journal.

Paste All Channels to Journal Pastes transformation modification history for all channels to Journal.

Preferences...

To generate the **Preferences** dialog, select Display > Preferences on Windows or AcqKnowledge > Preferences on Mac. Use Preferences to control measurement options, how waveforms are displayed, and other AcqKnowledge features. Select an option in the list on the left of the Preferences dialog and then set the respective preferences displayed on the right.

See page...

448

AcqKnowledge - Preferences

Measurements
Waveforms
Event Summary
Graph
Journal
Hardware
Performance
Networking
Script Editor
Other
Window
Focus Areas
Location

Number of measurement rows: 1
Number of measurement columns: 5
Digits of precision: 5
☒ Use linear interpolation
Time units: Best Match for Value
Freq units: Best Match for Value

Journal Paste/Clipboard Options

- ☐ Include measurement name
- ☐ Include measurement units
- ☐ Include measurement parameters
- ☐ Include channel numbers
- ☐ Separate line for each measurement
- ☐ Include timestamp
- ☐ Mark selection with events in graph

Journal Table Export Options

When exporting multiple rows of measurements to a table:

- ☐ put all values in a single table row
- ☒ use one table row for each measurement row

449

AcqKnowledge - Preferences

Measurements
Waveforms
Event Summary
Graph
Journal
Hardware
Performance
Networking
Script Editor
Other
Window
Focus Areas
Location
Stellar Telemetry

Drawing

- ☐ Gray non-selected waves
- ☐ Draft mode for compressed waves

Scaling/Transformations

- ☐ Duplicate before transformations
- ☐ Autoscale after transformation
- ☐ Tile after transformation

Editing

- ☐ Mark waveform edits with events

Wave Data Journal Paste/Clipboard Options

- ☐ Include time value
- ☐ Include timestamp
- ☐ Mark selection with events in graph

450

Preferences

Measurements
Waveforms
Event Summary
Graph
Journal
Hardware
Performance
Networking

Group events: By type
Sort grouped events: By time
☒ Include header
☐ Include only visible events in summary

450

AcqKnowledge - Preferences

Measurements
Waveforms
Event Summary
Graph
Journal
Hardware
Performance
Networking
Script Editor
Other
Window
Focus Areas
Location
Stellar Telemetry

Display Style
☒ Tabbed (all in single window) ☐ Windowed (one window per graph/data view)

Editing
☒ Interpolate pasting between graphs Method: Linear

Maximum levels of undo
☐ Unlimited ☒ Limit to 4 prior operations

☐ Link selections between data views for new graphs

☒ Enable cursor tools during acquisitions

☒ Show append boundary dividers

Axis controls: Transparent ————— Opaque

Chart Track Divider Appearance
☒ Default ☐ Custom:

Plotting Background Colors
 Selected channel: Reset Normal: Reset

When closing main windows for a graph with Data Views:
Show prompt

Transformation--Recently Used Menu
 List 10 most recent transformations

OK Cancel

451

AcqKnowledge - Preferences

Measurements
Waveforms
Event Summary
Graph
Journal
Hardware
Performance
Networking
Script Editor
Other
Window
Focus Areas
Location

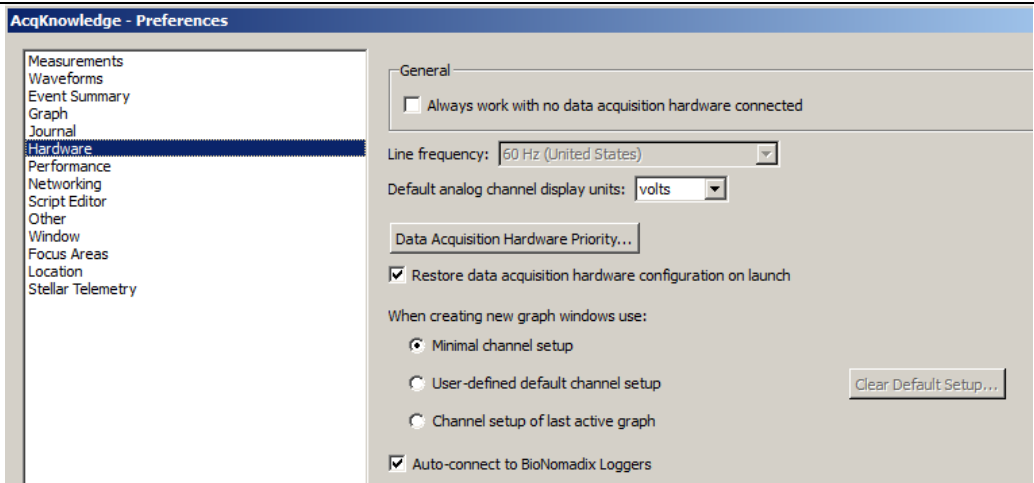
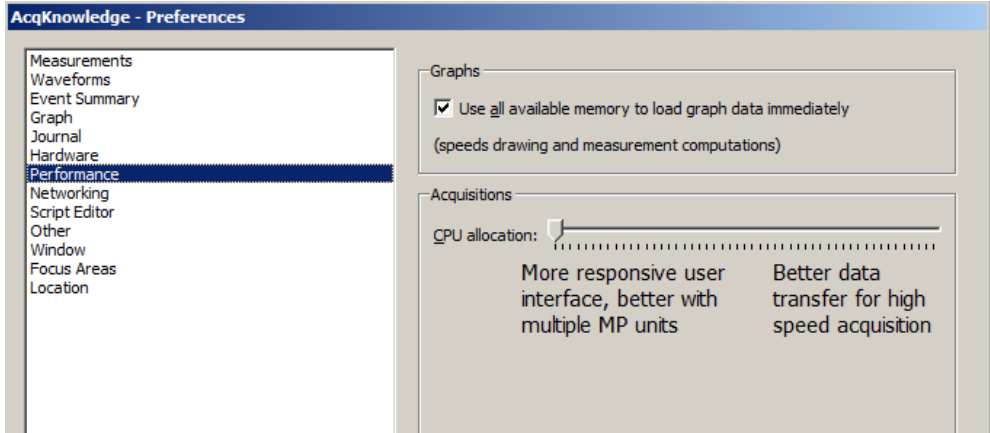
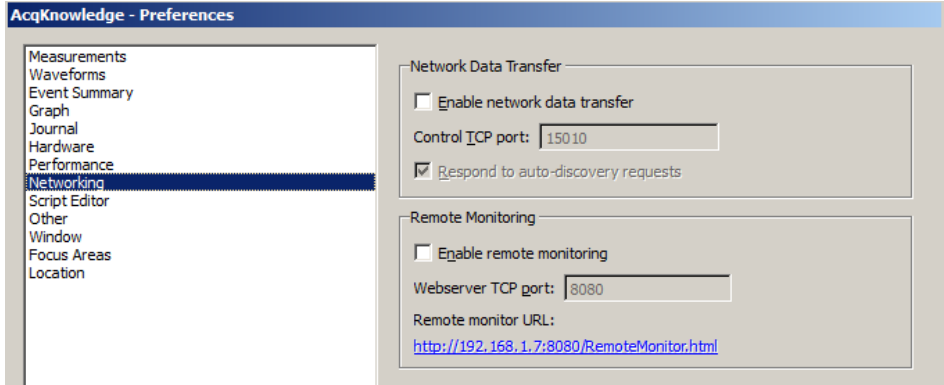
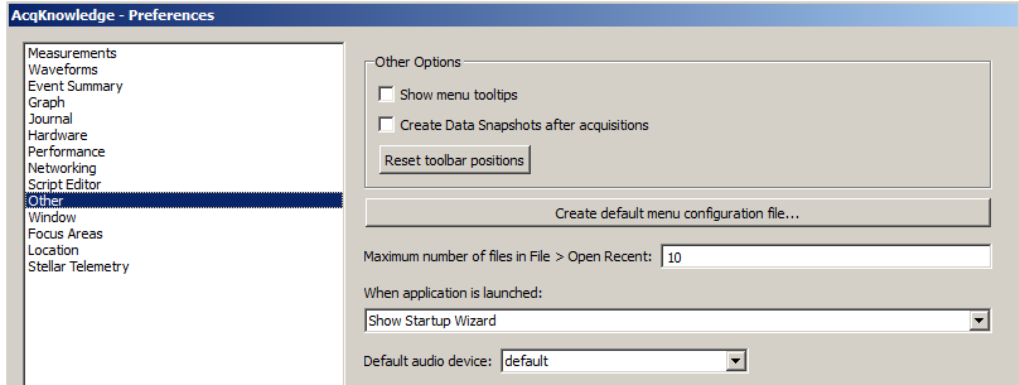
Default Font for Journals
 Font: MS Shell Dlg 2
 Size: 9

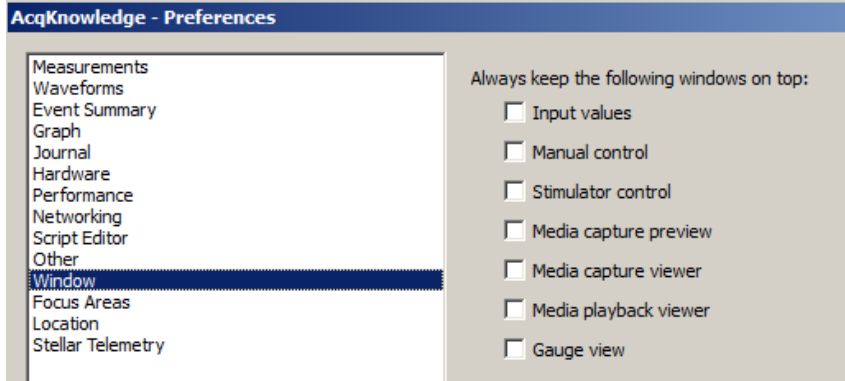
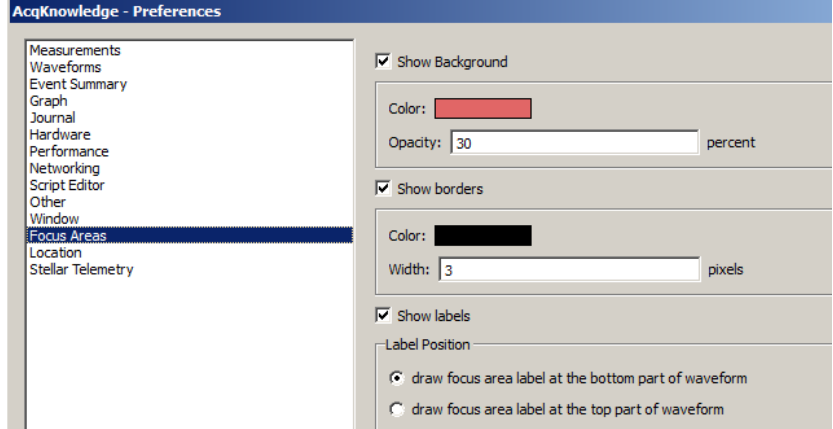
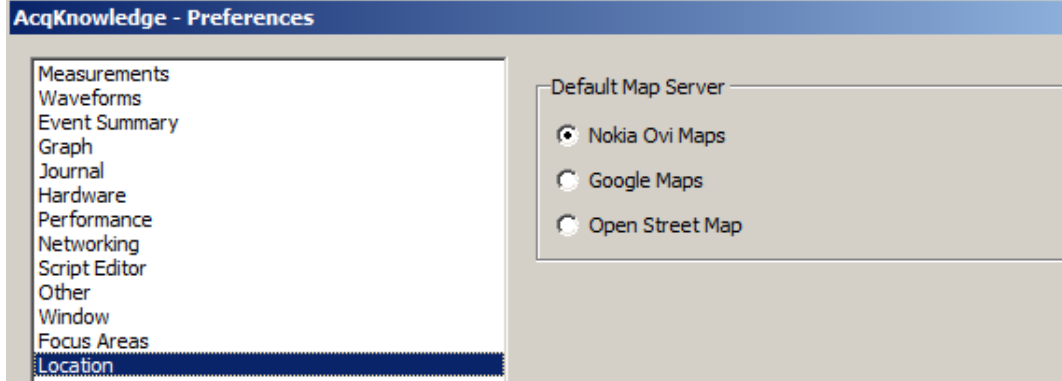
Display
☐ Wrap long lines of text to Journal window width
 Tab width: 10 spaces

☒ Auto-paste results in independent journals

Display Style
☐ Docked at bottom of graph window
☒ Dockable on any edge of graph window
☐ Floating window

451

	
451	
452	
452	
453	

	
453	
453	

Measurements Preferences

- **Measurement rows**—determines how many measurement rows will be displayed in the graph window.
 - Use Display > Show > Measurements to hide the measurements; see page 435 for details.
- **Measurement columns**—determines how many measurement columns will be displayed in the graph window.
- **Precision**—controls the accuracy of digits displayed right of the decimal (1-8) for all measurement results. For example, with the precision set to 3, a measurement result might be 125.187.
- **Use linear interpolation**—toggle to enable/disable measurement interpolation.
- **Time/Frequency units**—sets the measurement unit to use for time and frequency pop-up measurements. This locks the units for the measurement result display (i.e., if seconds is selected, a result of 70 seconds will display as “70 seconds” rather than “1.16667 minutes”).
 - Best match—Scales units to best match the interval for time and frequency based on the total file. For example, won’t set a 3 hour file to display in msec.
- **Include for Journal/Clipboard options**
 - measurement name (i.e., BPM, Delta T, Freq, etc.) with the values.
 - measurement units (i.e., volts, mmHg, and so forth) after the numeric values.

- measurement parameters used to compute the measurement function result, such as the location and operator used for Calculate measurements.
- channel numbers at the top of each column of data.
- timestamp—Automatically insert the time of day and the date when pasting measurements or wave data. This timestamp can be correlated with selection events to reconstruct the selected area.—useful for GLP auditing.
- **Use a separate line** for each measurement in the journal/clipboard
- **Mark selection with events in graph**—Automatically insert a pair of Global Selection Begin and Selection End events at the selection boundaries when pasting measurements or wave data. These events will be timestamped with the time of day and the date when the paste occurred. This timestamp can be matched to the result of “Include timestamp” to recreate selected areas for reconstructing measurement results or re-executing wave data exporting—useful for GLP auditing.
- **Journal Table Export Options** – Sets the options for how multiple measurement rows are displayed in a Journal table.
 - Put all values in a single table row – Extends multiple measurement rows horizontally into one table row.
 - Use one table row for each measurement row – Divides the measurements into multiple table rows in the same manner shown in the measurement toolbar.

Waveforms Preferences

In the center of the dialog are two options that control how waveforms are displayed on the screen.

- **Gray non-selected waves**—When enabled, the active wave will be drawn in a solid color and any non-selected waveforms will be drawn using lighter, dotted lines (or with lighter colored dots if dot plot is in use). This can help emphasize the selected waveform when viewing data in Scope mode.
- **Draft mode for compressed waves**—allows for some (“compressed”) waveforms to be plotted in “draft” mode, which results in faster plotting time, although the display is not exact. A waveform is considered compressed when more than three sample points are plotted per pixel on the screen. For example, on a VGA display that is 640 pixels wide, a compressed waveform would be any type of waveform displaying more than 2000 samples (approximately) on the screen at any one time. Using the default horizontal scale (which plots eight seconds of data on the screen), any data sampled at more than 250 samples per second would be considered “compressed.”
- **Scaling/Transformations**—the following options determine how data will appear on the screen after it has been transformed (e.g., filtered or mathematically operated on). Neither option affects how data appears on the horizontal axis, although both options change how data is presented along the amplitude (vertical) axis.
 - **Duplicate before transformations** will create a new channel showing the data as it originally appeared before the transformation was applied. This will preserve the original view for comparison to the transformation.
 - **Autoscale after transformations** will automatically rescale all waveforms after a transformation to provide the “best fit” along the amplitude axis.
 - **Tile after transformations** tiles all visible waveforms after any transformation, and is mutually exclusive of the autoscale command. Tiling visually separates the waveforms on the screen.
- **Mark waveform edits with events**—Insert an event at points where waveform edit commands have been applied.
- **Include time value**—copies the horizontal scale values along with the waveform data when data is copied to the clipboard. This means that when you paste data from the *AcqKnowledge* screen into a spreadsheet or similar application, horizontal scale information is retained.
- **Include timestamp**—Automatically insert the time of day and the date when pasting measurements or wave data. This timestamp can be correlated with selection events to reconstruct the selected area.—useful for GLP auditing.

- **Mark selection with events in graph**—Automatically inserts a pair of Global Selection Begin and Selection End events at the selection boundaries when pasting measurements or wave data. These events will be timestamped with the time of day and the date when the paste occurred. This timestamp can be matched to the result of “Include timestamp” to recreate selected areas for reconstructing measurement results or re-executing wave data exporting—useful for GLP auditing.

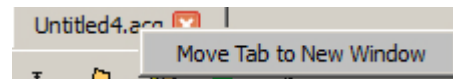
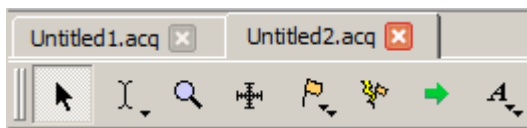
Event Summary Preferences

For the event summary that can be pasted to the journal, choose a method to group the events (i.e., type or channel), to sort the events (by time or label) and indicate whether to include all events or include only visible events in the summary. Beginning in AcqKnowledge 4.2, there is an option to include a header row at the top of the summary.

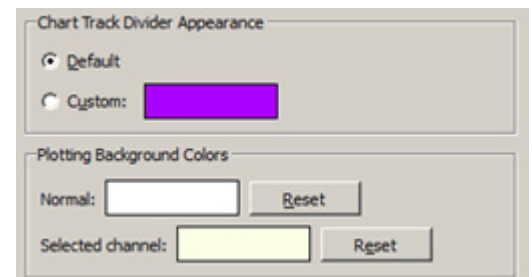
Access Event (Marker) preferences under Display > Preferences > Event summary; see page 216 for details.

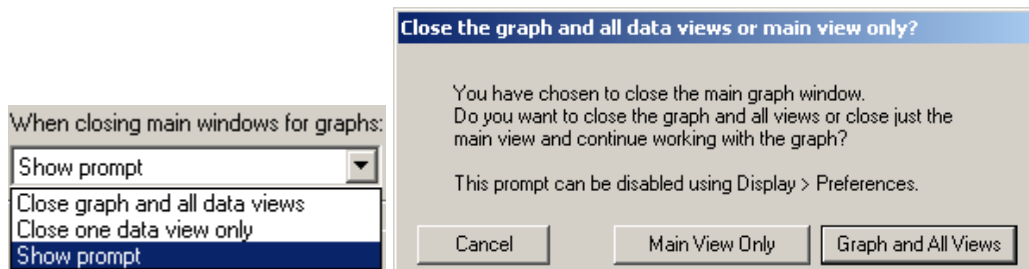
Graph Preferences

- **Display Style** can be set to **Windowed** or **Tabbed** view. Tabbed graphs can be navigated by clicking on the identifying tab at the top of the application window, or by clicking Ctrl+Tab. A tabbed graph may be moved to its own window by right-clicking on the desired graph and choosing “Move Tab to New Window” (below right). The default setting for AcqKnowledge is tabbed view. When set to **Windowed**, multiple graphs appear as separate windows, which can be positioned as desired.



- **Editing > 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, data should be copied to a higher resolution window.
- **Maximum levels of undo**—Set the maximum number of undo operations. Unlimited may be memory-intensive, depending on the detail of each operation.
- **Link selections between data views for new graphs** – automatically synchronize selected areas of data views between graphs for a new graph.
- **Enable cursor tools during acquisition** – Allows access to cursor tools while recording is in progress.
- **Show append boundary dividers** – Controls visibility of append event boundary dividers.
- **Axis controls** – Controls visibility of set screen vertical axis controls.
- **Chart Track Divider Appearance** –Users may change the color used to draw the dividers between channels tracks The Preferences > Graph panel contains "Chart Track Divider Appearance" options.
- **Default** uses operating system specific dividers, which is a light color.
- **Custom** activates a colorwell for choosing a solid color to be specified for all dividers. The preference setting and color are shared by all open graphs and data views, as this is an application-level preference.
- **Plotting Background Colors** – Starting with AcqKnowledge 4.2, customizable background colors for active graph channels are available.
- **Normal** activates a colorwell for choosing background color of the non-selected channels.
- **Selected** channel activates a colorwell for choosing background color of the selected channel.
- **When closing...** determines the degree of closing and what prompts, if any, for multiple data views.





- **Recently Used**—set the number of recently used Transform and Analysis options to list in the Transform > Recently used sub-menu; provides quick access to common options. Recently used items can also be launched using keystroke the combinations appearing in this menu.

Journal Preferences

The Journal Preferences dialog contains options controlling the format of data when it is pasted into the journal or clipboard.

- Change font type and size to any font installed on your computer.
- Wrap Journal text—Wraps text to window size.
- Tabs: Specify the tab interval to make columns more readable when you have a high precision setting.

Auto-paste results—Toggle the checkbox to enable/disable the option to paste results to independent journals.

Display Style— Choose whether Journal window is fixed, dockable on any edge of graph, or independently floating.

Hardware Preferences

- **Always work with no data acquisition hardware connected** sets the default communication for no connection so the connection error is not displayed each time the software is launched.
- **Line frequency** is specified during software installation and can be changed here. (50 Hz for Europe and 60 Hz for the Americas.). Every time data is recorded, the line frequency setting is saved along with the data. If no line frequency data was saved, the line frequency setting for the installed/active version of AcqKnowledge will be used.
- **Default analog channel display units** – Use to set default channel units to volts or millivolts.
 - Volts – displays in Volt units, visible range +/-10V (MP150 default)
 - mV – displays in Millivolt units, visible range +/- 50 mV (MP36 default)
- **Data Acquisition Hardware Priority** launches a dialog allowing the default hardware device ordering to be set. This ordering is used to establish hardware communication when the application is first launched or if none of the previously-connected MP devices are available.
- **Restore data acquisition hardware configuration on launch** – when checked, communication with the last known hardware unit will be reestablished. When unchecked, the application will search for available new hardware units.
- **When creating new graph windows use** sets the default channel and hardware options for new graphs.
 - Minimal channel setup – new graphs will use the application’s factory default channel settings for the selected hardware.
 - User-defined default channel setup – all new graphs are created with the user’s default settings. To remove established default settings, click the “Clear Default Setup” button.
 - Channel setup of last active graph – the settings of the most recently created active graph will be applied to all new graphs.
- **Auto-connect to BioNomadix Loggers** will search for any BioNomadix Loggers that may be attached to the computer and attempt to connect to the unit.

Performance Preferences

- **Use all available memory** instructs 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.
- **CPU allocation** sets the priority for CPU (system resource) allocation. For a data focus, move right, for a function focus, move left.

- If buffer overloads occur, move indicator toward *Better data transfer for high speed acquisition*.
- To allow autoscale during acquisitions or jumping between hardware units, resizing displays, or working in other programs, move toward *More responsive*.

Networking Preferences

Network data transfer and Remote Monitoring are not supported in AcqKnowledge 4.0-4.1.

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.

Respond to auto-discovery—Toggle the checkbox to enable/disable response during network data transfer.

The network data transfer feature is not intended for strict real-time delivery. It also does not provide direct control over the MP150 unit. Perform all hardware configurations manually using the AcqKnowledge interface.

Enable Remote Monitoring to allow acquisitions on the computer to be viewed remotely over a network through a client/browser interface. Acquisitions can be started and stopped remotely and graph data viewed while recording is in progress. This is handy if the AcqKnowledge computer recording the experiment is in one area and the researcher monitoring the experiment is in another.

For applications that require low latencies, high-data throughput, or direct hardware configuration and control, use BIOPAC Hardware API.

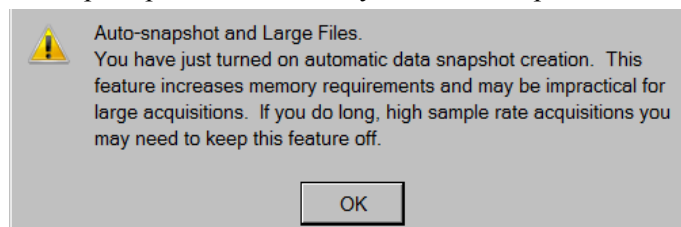
Other Preferences

- **Show menu tooltips** enables display of tooltips describing menu item functions. Tooltips appear when menu items are moused over.
- **Create Data Snapshots after acquisitions** toggles the snapshot (embedded archive) feature, which stores snapshots of original acquired data along with the graph file for easy comparison of results to original waveforms or to intermediate stages of analysis; see page 54 for details.

IMPORTANT: Archive functions do not create a new file—they are not backup functions.
Original data is copied and pasted to the end of the original file.
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.evt_

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.

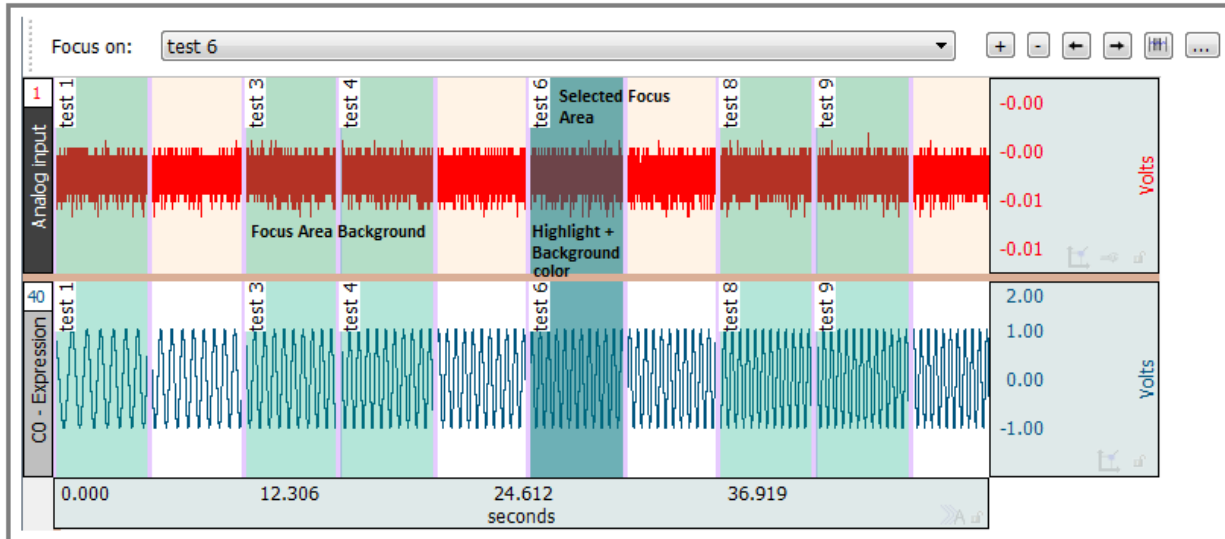


- **Reset toolbar positions**—Resets location of toolbars to default setting.
- **Create configuration file**— Create default menu configuration file to customize menu display. See page 564 for customization details.
- **Maximum number of files in File > Open Recent**—Sets the number of files that will appear in the 'File > Open Recent' list.
- **When application is launched:**—Chooses between display of Startup Wizard or a new empty graph following application launch.
- **Default audio device**—Use this option to select the default audio device to be used by the application.

Window Preferences

- **Always keep the following windows on top:** — Sets options for keeping any of the following windows active above the main application window: Input Values, Manual Control, Stimulator Control, Media Capture Preview, Media Capture Viewer, Media Playback Viewer, Gauge View.

Focus Areas Preferences



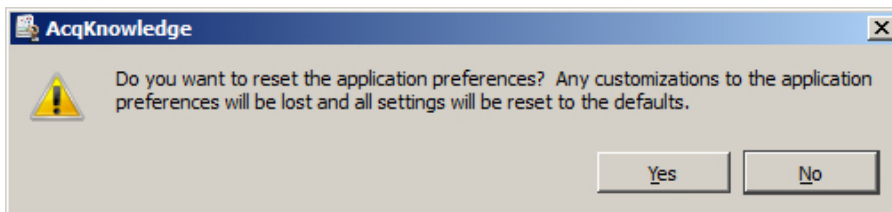
- **Show background**—Sets option for main graph visibility in the background of the selected focus area.
- **Color (background)**—Sets background color of focus areas. Click color square to change color of focus area background. (This option not active if “Show background” is unchecked.)
- **Opacity**—Sets transparency level of background. (0 is transparent, 100 fully opaque.)
- **Show borders**—When checked, borders will appear on both sides of the focus area.
- **Color (borders)**—Click to change the color of focus area borders.
- **Width**—Controls width of focus area borders.
- **Show Labels**—Controls visibility of Focus Area labels. Labels can be shown or hidden.
- **Label Position**—Controls where the Focus Area labels will appear in the graph. Options are at the top part of the waveform or the bottom part of the waveform.

Location Preferences

- **Default Map Server** – selects the map server used to display GPS tracking data in the Location Palette. The available map servers are Nokia Ovi, Google Maps or Open Map.

Resetting All Preferences to Factory Default

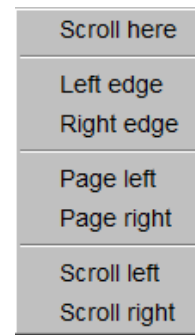
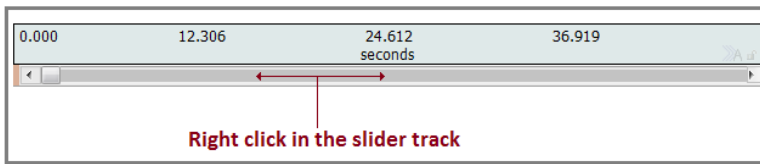
You may reset all preferences to the default factory configuration by holding down the Shift key while launching *AcqKnowledge*. This dialog will appear:



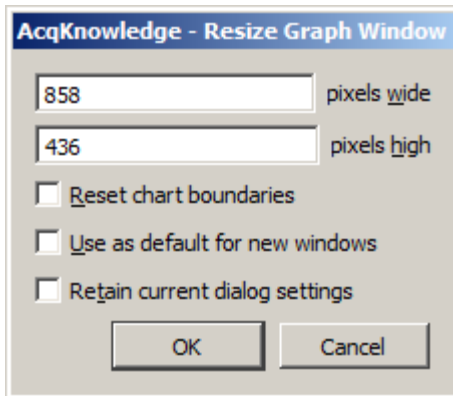
It is important to note that accepting this option will reset ALL application defaults to the factory configuration.

Scroll options

The Scroll options help navigate through large data files. Right-click below the horizontal scroll track to generate the contextual menu with scroll options.



Size window...



The Size Window function is useful for setting exact dimensions for the size of the graph window. Use this to create consistently sized windows for pasting into documents. The two text box fields are used to enter interior screen width and height, both of which are scaled in terms of pixels.

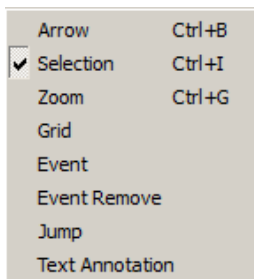
Each operating system may add additional dimensions as necessary to put in window adornments depending on the appearance configuration preference of the user (e.g. extra space for title bar of the window, any additional space put around the edges of the window frame, etc.).

When the Reset chart boundaries box is checked, the boundaries between the waveforms will be reset so that each channel “track” is the same size.

When Use as default for new windows is checked, the user-modified dimensions are applied as the default graph window size.

When “Retain current dialog settings” is checked, the dimensions used when the dialog was previously dismissed are applied to all subsequent graphs.

Cursor Style



This option allows the active cursor tool to be adjusted via the Display menu. (AcqKnowledge 4.2 and higher)

Create Data View



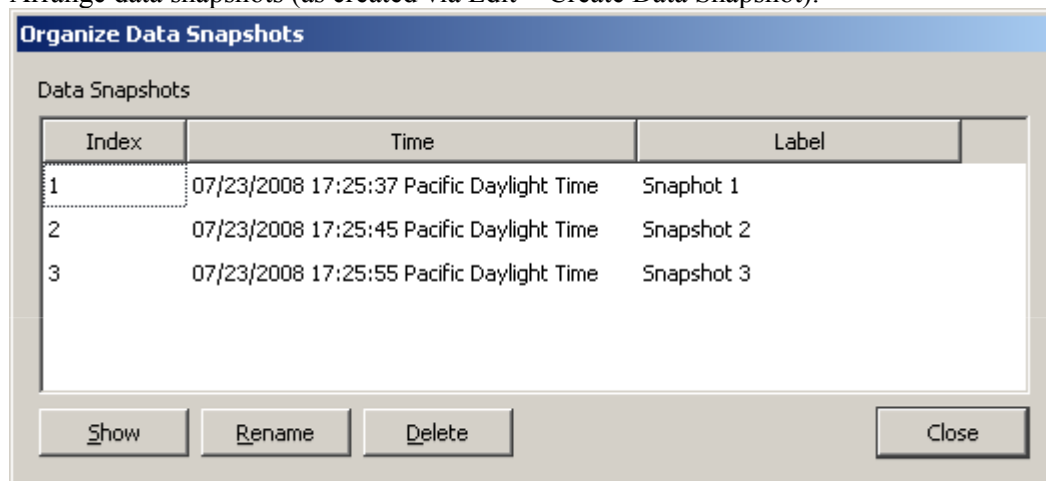
Creates a new Data View for the active (frontmost) graph and names the new window “Data View of ‘Filename’” For Data View details, see page 44.

Create Focus Area

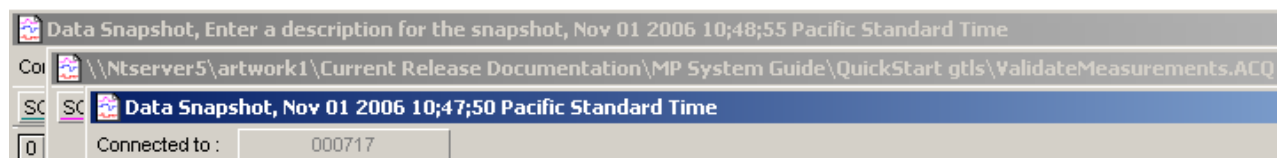
This option becomes available only when an area of data is selected, and brings up a Focus Area naming dialog. For full details on using the Focus Area feature, see page 89.

Organize Data Snapshots

Arrange data snapshots (as created via Edit > Create Data Snapshot).



Show All Data Snapshots



- 1 Manual Archive: description and time
- 2 Original file
- 3 Auto-Archive: time only

To view the embedded snapshot(s)/archive(s) associated with a graph file, choose Display > Show Original Data/All Data Snapshots. This will open a new graph window for each archive/snapshot associated with the graph. The time portion of the Filename for each graph is from the computer clock (saved with semi-colons because you cannot save a file with colons in the filename). The “Snapshot from...” graph will open with no Start button.

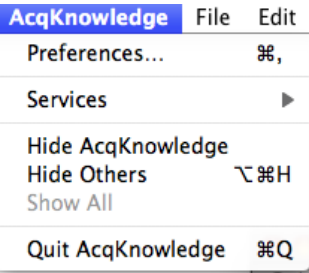
Each embedded archive is essentially a “snapshot” of the original acquired data that is stored with the graph file so you can view the archive at a later time to compare results to original waveforms or intermediate stages of analysis. Append events are not preserved in the snapshot/embedded archive file. For details on creating snapshots/embedded archives, see page 54.

Load All Data Into Memory

Use with large files to improve plotting performance, measurement response, etc. Memory can hold up to two gigabytes of data.

Chapter 19 Program & OS Menus

AcqKnowledge menu



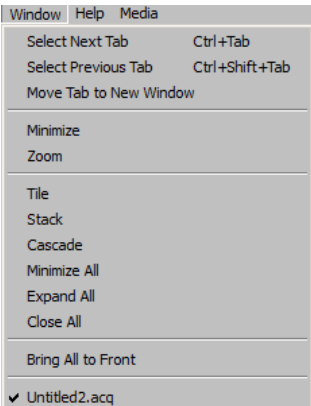
Mac OS X only—System generated menu. Use for Quit and Preferences. (Quit can also be found in the File menu.)

Window menu

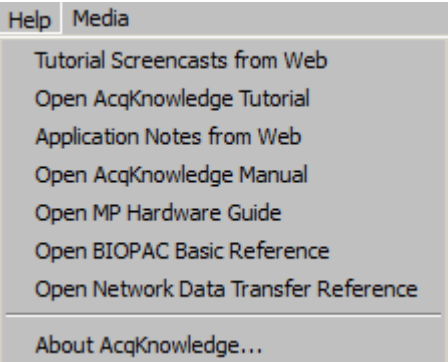
The Window menu is a standard OS function. See Windows or Macintosh OS Guide for details.

Bring All to Front

If other programs are running, this command will bring all AcqKnowledge windows to the front (on top of all other application windows); this command does not change the windows size or position. Additional options become available when the Tabbed graph display preference is selected. (Right figure)

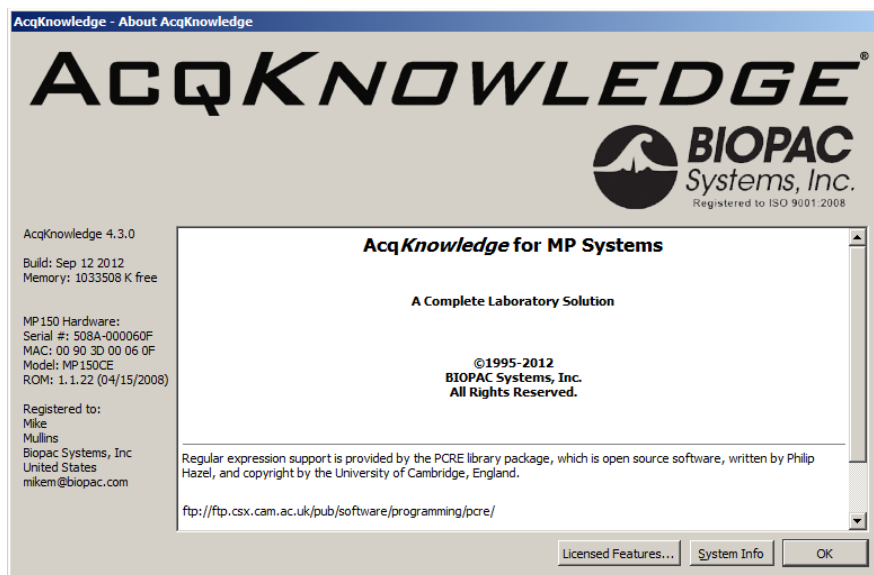


Help menu

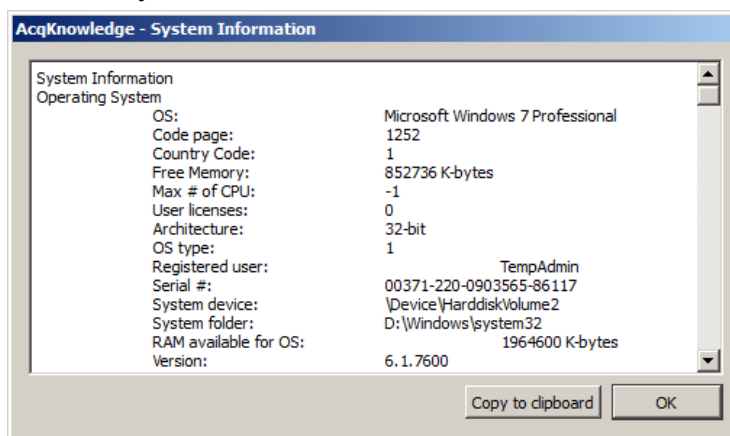


Use the User Support System pdf files for online help with the software. Selecting “About AcqKnowledge” from the Help menu generates a dialog that providing information about the AcqKnowledge software being used and system parameters, which can be useful when contacting Technical Support.

Note: For information about the MP150 data acquisition unit and firmware, click MP150 menu >MP150 Info.

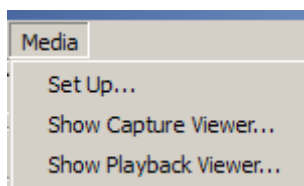


Click the System Info button for more detailed information.



The **Copy to clipboard** button makes it easy to paste system info into an email for Technical Support.

Chapter 20 Media Menu



Also applicable to multi-camera systems and CAM-HFR-A high-speed camera. For Media Menu setup for CAM-HFR-A, see page 464.

Available in AcqKnowledge 4.1 and above for Windows—Media functionality allows users to capture and playback video and/or audio with a USB web cam or firewire DV device and synchronize it with physiological information from an hardware device. The key functionality is a strong link between the video and data cursor when graphs are being used in post-acquisition mode; changing the selection in the graph window will automatically jump the video to the time corresponding to the cursor position. The reverse tie is also in place where scrolling the video will move the data cursor to the corresponding data point in the graph.

For synchronized playback of media player with AcqKnowledge cursor in data view, BIOPAC recommends that the users sample the hardware unit at least as fast as the video frame rate 30Hz. In this case, any measurement errors are limited to the basic frame rate error window (1/30 sec). For exact match of Video and Data samples, BIOPAC recommends frame rate 25 fps and acquisition rate 25 samples/second (or its derivatives).

- | | |
|-----------------------------|---|
| Set Up | Establish Sources, Output and Media parameters. Set device type for audio and or/video. Use refresh after connecting a new device to make it a selectable option. Browse using standard file open/save functionality to specify media files. If desired, set a Delay between file segments. |
| Show Capture Viewer | Use for video signal directly from a video camera; this option is disabled (grayed) in the record mode when both the Capture video and Capture audio options in the Media Setup dialog are off. |
| Show Playback Viewer | Use to play back media from the disk (stored media files); this option is disabled (grayed) if there is no media assigned to the file. |

Video Playback and Capture preview include a right-mouse contextual menu item “Grab bitmap” which, when selected, generates a Save As dialog to save the current displayed frame as a *.bmp image.

Media Notes

- :: Media capture performance is improved under Windows 8 and 7 OS. If the selected webcam drops frames because of poor performance/low quality, the degree of synchronization will be compromised. Testing indicated the Microsoft Lifecam NX-3000 gave reliable performance with no dropped frames.
- :: Several AcqKnowledge files can point (link) to the one media file.
- :: AcqKnowledge files can link to media files created by other programs. If the media file is shorter or longer than the AcqKnowledge files, just align the two files at the start.
- :: AcqKnowledge files alignment precision with the media file is user-controlled through the use of a delay function that allows a forward or backward time shift.
- :: AcqKnowledge files store the location (path) of the media file. This path is editable, so the AcqKnowledge file can link to other media files too.
- :: Media functionality does not support the *Autosave file* acquisition mode.
- :: Using the “Reset” function on appended acquisitions does not delete any previously recorded Media segments.

Synchronization Tip

To optimize synchronized playback of the media and the physiological record, use the OUT103 LED to determine the delay between the media and the data. The LED must be in view of the video camera and the LED channel must be recorded.

Media synchronization - Windows only - AcqKnowledge 4.1 and above

Option 1: MP150 and UIM100C setup using an Analog Output

- a. Connect the OUT103's 3.5 mm phone plug from the LED to one of the arms of the included Y-cable.
- b. Connect the included CBL100 to the other arm of the Y-cable.
- c. Connect the stem of the Y-cable to one of the two Analog Output connections near the bottom of the front face of the UIM100C.
- d. Connect the other end of the CBL100 to an otherwise unused Analog Channel also on the front face of the UIM100C.
- e. Use "MP150 > Set Up Channels..." (in AcqKnowledge 4.4, choose "Channels" in the left pane after choosing "MP150 > Set Up Data Acquisition...") and acquire and plot the analog channel to which the CBL100 is connected.
- f. Use "MP150 > Set Up Stimulator..." (in AcqKnowledge 4.4, choose "Stimulator" in the left pane after choosing "MP150 > Set Up Data Acquisition...") to send 5 volt pulses through the Analog Output.

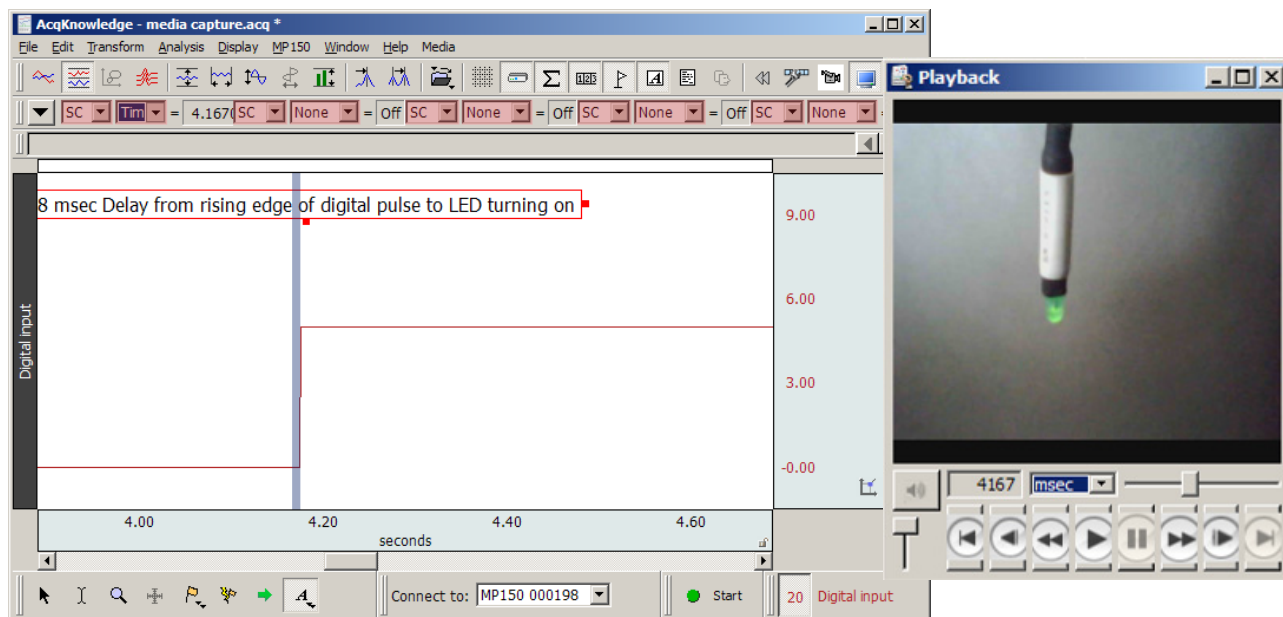
Option 2: MP150 and UIM100C setup using a Digital I/O Channel

- a. Connect the OUT103 2 mm pin adapter to the 3.5 mm plug on the OUT103 cable.
- b. Connect the red OUT103 2 mm pin to a Digital I/O channel on the rear of the UIM100C and the black pin to GND D on the rear of the UIM100C.
- c. Use MP150 > Set Up Channels to acquire and plot the Digital I/O channel the OUT103 is connected to.
- d. Set MP150 > Show Manual Control
 - set for 'Output'
 - enable the 'Set immediately' option
 - click the Digital I/O channel the OUT103 was connected to toggle between 0 to 1

If necessary, click the 'Set' button to update the manual control and output a digital pulse.

MP36R setup - additional items required

- a. Connect an OUT3 (BNC adapter) to the 'Analog Out' port on the rear of the MP36R.
- b. Connect a BSLCBL6 (interface cable: BNC to 3.5 mm) to the OUT3.
- c. Connect the OUT103 3.5 mm plug to the BSLCBL6 3.5 mm socket.
- d. Set MP36 > Output Control 'Low Voltage Stim' option
 - set Pulse width to 100 msec
 - set Pulse level to 5 Volts
 - set Reference Channel to any digital channel
 - click the 'ON' button to output a digital pulse
 - Once the LED has illuminated and you can see the square wave in the file, you can hide the channel.
 - After the recording is complete, use the I-beam selection tool to measure the offset between the LED illumination and the leading edge of the digital impulse. Use a Delta T measurement to determine the delay information; Delay may be positive or negative based on camera performance. Delay should be entered in the Linked Media row for each segment—see page 461.

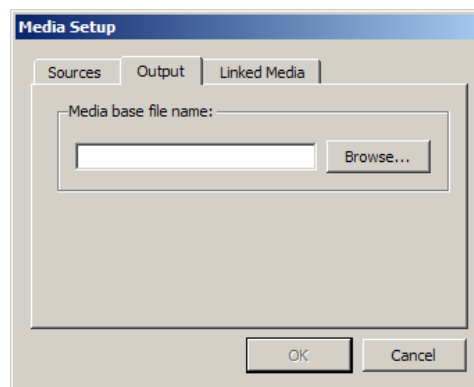
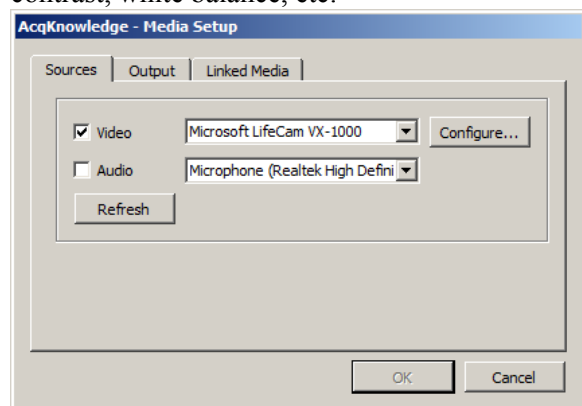


Media > Set Up

Source

Use this dialog to select media source and select audio and video to record. Click Refresh to update the list if a video or audio device is connected after the dialog was opened. When video/audio for capture is selected, an output file must also be selected. Input file name and click OK; this will close the Media Setup dialog and automatically open the media window if the Capture option is ON.

All video camera, audio (microphone) input parameters can be setup by user with the UI provided by camera manufacturer, or use the "Configure" button for direct access to camera properties, such as exposure, saturation, contrast, white balance, etc.



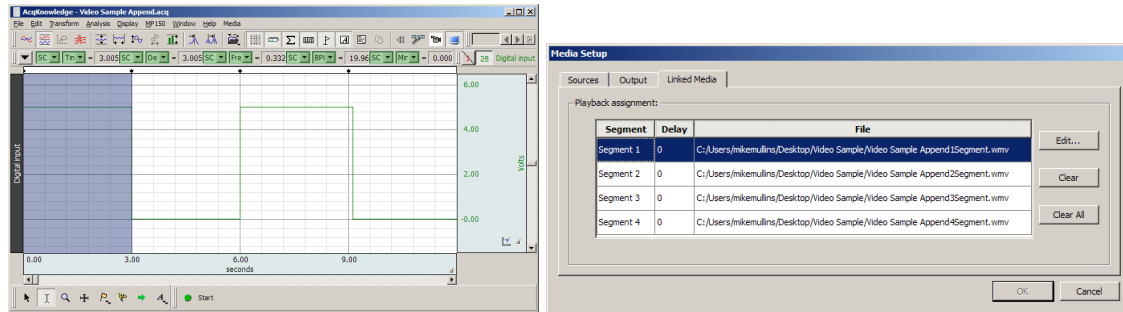
Output

Video/audio capture requires a media file specified with full name with disk location. *.avi or *.wmv file formats are supported. Users can save AcqKnowledge data and media streams onto separate hard drives.

Linked Media

IMPORTANT

An *AcqKnowledge* data file must be opened before linking to a media clip.



If media was captured with the data file, the Linked Media dialog will display a row for each appended segment in the *AcqKnowledge* data file and will list the file location of the corresponding media for each segment. The samples above show four *AcqKnowledge* data segments and four linked media Files.

Click anywhere in the row (or choose the Edit button) to set a delay to synchronize the media file with the physiological data. Delay range: Min= 1 millisecond, Max = segment duration.

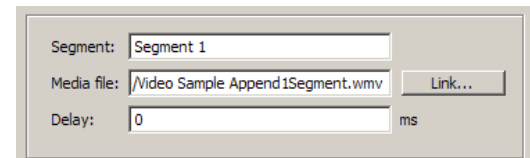
- See Synchronization Tip on page 459.

If media was not captured with the data file, click the appropriate row and click “Link” to browse to the desired media file from that segment.

Delay—Each segment can have a distinct delay. Click in the Delay cell or click Edit to generate the dialog for Delay entry.

“+” Delay places start of video file after graph start

“-” Delay places start of video file before graph start



The best possible synchronization can't be better than the video frame rate (usually 1/30 of a second).

Media > Capture

Use Set Up to assign a Source and Output to enable the Capture menu option. There are no Preview window controls and the size reflects default video camera resolution.

Playback Preview

As the media file is manually scrolled or automatically played, the *AcqKnowledge* cursor keeps moving to reflect the corresponding location in the *AcqKnowledge* graph. If the *AcqKnowledge* cursor is moved, the media file is automatically scrolled to keep time sync with the data file.

In *AcqKnowledge* 4.2 and above: Media files linked to appended data segments are loaded in sequential order. After playback of the first media segment, the cursor will automatically advance to a still-frame view marking the beginning of the next segment. The Play button must be pressed in order to play back subsequent segments.

Audio Mute button and level slider

Video Digital indicator (time in milliseconds or frame number for the segment clip) and Horizontal slider (progress bar) to navigate the media file. The start point can be set from either the media clip or the data file. For precise selection, hold the shift key and use the forward or backward arrow keys on the media player or the keyboard to move single video frame (mostly 1/30 seconds) or data point.

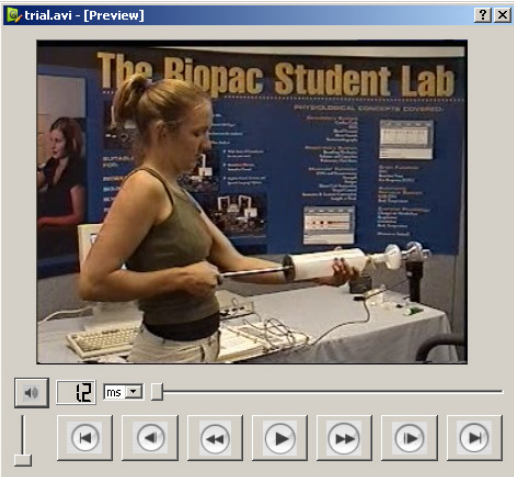
Use the scroll bar to navigate to different frames. Synchronization should be maintained with data in the graph window. This should result in a single sample selection cursor shown at the time closest to the displayed video frame.









The media window displays the text “No media assigned” in Playback Preview when the media window is visible but there is no video/audio file assignment for given data segment.

During the capture or playback of audio only, the media window will be displayed with a static musical note image as shown at right.



The Playback viewer uses standard media player controls.



	Go to previous segment / go to beginning of segment
	Step backward a frame/sample
	Fast backward / reverse rewind
	Play/ pause
	Fast forward
	Step forward a frame/sample
	Go to following segment
	Mute sound

Media Playback Example

1. Launch AcqKnowledge 4.
2. Open a saved acquisition file.
3. Select Media > Show Playback Viewer.
4. Here you can play with contents:
 - Select I-beam cursor on graph and push “Play” button on the player.
 - Change selection with I-beam on graph and see the video.

IF media is not assigned, locate the video clip for the appropriate segment:

- a.) Select Media > Set Up
- b.) Select the “Linked Media” tab
- c.) Select Segment 1 and click “Edit.”
- d.) Click “Link” and select a saved media file.



The top window shows the 'AcqKnowledge - Untitled1.acq' interface with a graph of 'Analog Input' (red waveform) over 6.00 seconds. The bottom window shows the 'Playback' viewer displaying a video of a person at a computer. The 'Media Setup' dialog is open, showing the 'Linked Media' tab with a table for playback assignment:

Segment	Delay	File
Segment 1	0	

Segment 1

Segment: Segment 1

Media file:

Link...

Delay: 0 ms

Link Media File

Organize Views New Folder

Search

Favorite Links

Folders

Biopac Student Lab
BSL 3.7
BSL Lessons 3.7
BSL Videos
Data Files
Lessons
User Support
BSL PRO 3.7
Samples
User Support

Name	Date taken	Tags	Size
John-L17a.wmv			2,230
L01cal.mpg			1,680
L02.mpg			3,590
L02cal.mpg			3,180
L03L4.mpg			3,260
L05cal.mpg			840
L06.mpg			800
L07cal.mpg			1,970
L08.mpg			1,640
L09b.mpg			1,310
L09cal.mpg			2,880
L10.mpg			1,240

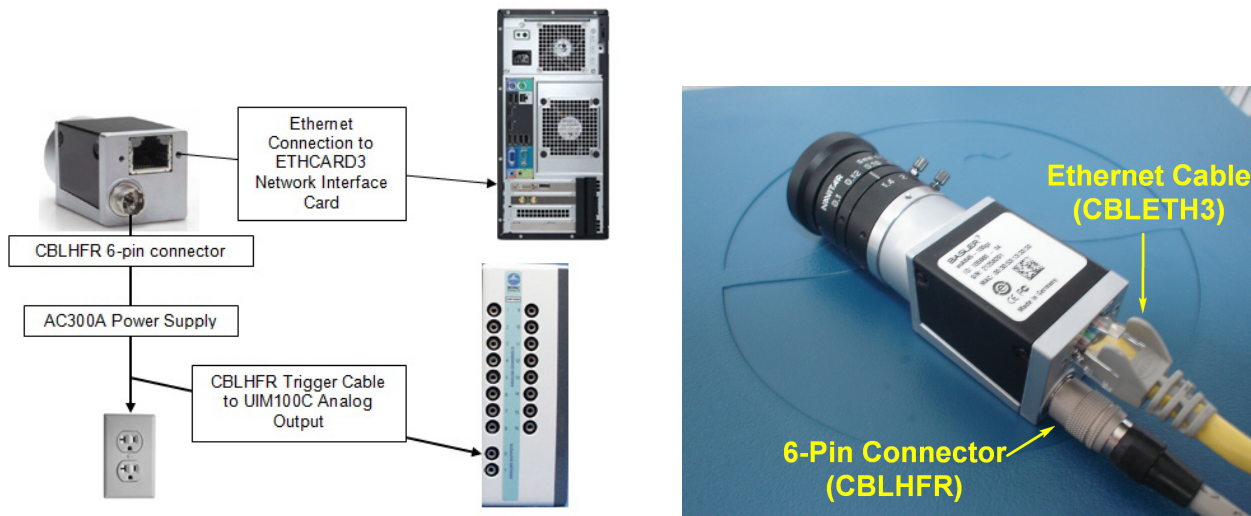
File name: L01cal.mpg

Media Files (*.avi;*.wmv;*.wmv)

Open Cancel

Media Capture Setup with CAM-HFR-A High Speed Camera

The CAM-HFR-A is a high speed camera capable of capturing more precise video at rates up to 100 frames-per-second. AcqKnowledge versions 4.3.1 and higher support use of this camera. The Media setup procedure differs from that of a standard USB camera, with the AcqKnowledge Stimulator providing a “sync pulse” between the MP150 and the camera. Therefore, no manual synchronization procedure is required. The following pages describe hardware and software setup for the CAM-HFR-A.

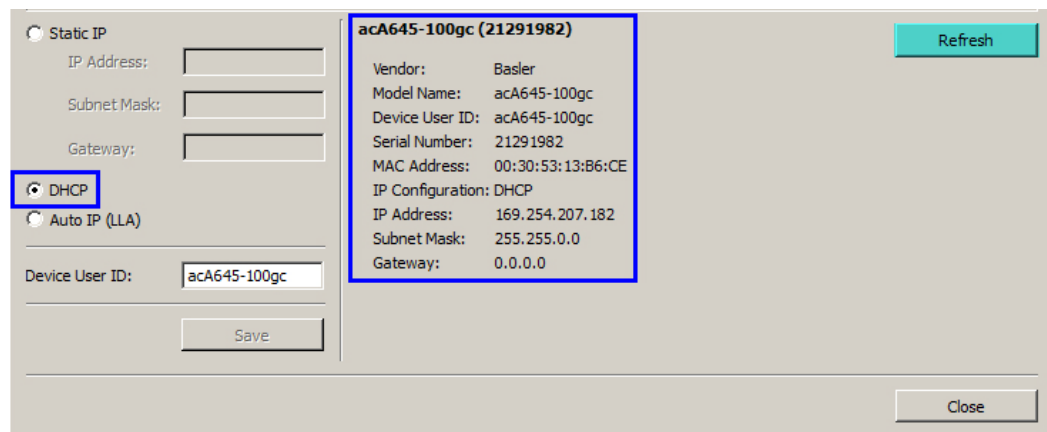


A. Connect Camera Hardware:

Before you begin:

Make sure the camera drivers and the provided ETHCARD3 Network Interface Card are installed on computer.

1. Connect the CBLHFR 6-pin-connector to the camera input.
2. Connect the female end of the CBLHFR connector to the AC300A power supply adapter cable.
3. Connect the CBLHFR Trigger Cable to a UIM100C Analog Output.
4. Plug the AC300A power supply cord into wall socket.
5. Connect the Ethernet cable between the camera's Ethernet port and the ETHCARD3 network interface card supplied with your system. Attach the 6 mm lens to camera (included as LENS-CAM-A).
6. Launch the pylon IP Configuration Tool from the Desktop shortcut to verify camera/network connection. If successful, the camera's network settings will appear in the IP configuration window as shown below. (Make sure the IP configuration is set to DHCP.)

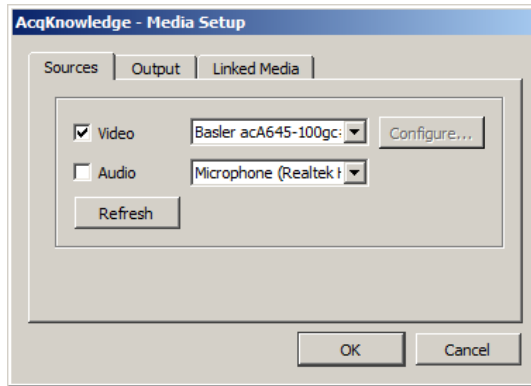


NOTE: If the camera's network settings don't appear in the pylon IP Tool Configuration window, click the “Refresh” button and highlight the camera device from the list at the top of the Configuration Tool.

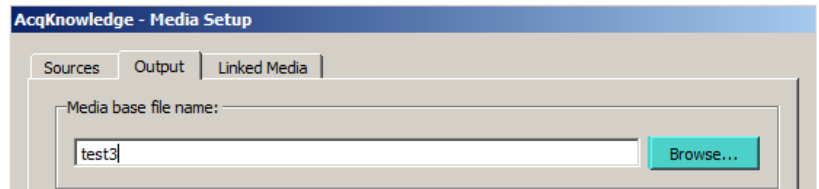
If the camera's network settings still don't appear, or appear in the pylon IP Configuration Tool window as “unreachable,” reset the IP configuration to Static IP.

B. Set Up Camera Configuration in AcqKnowledge Software:

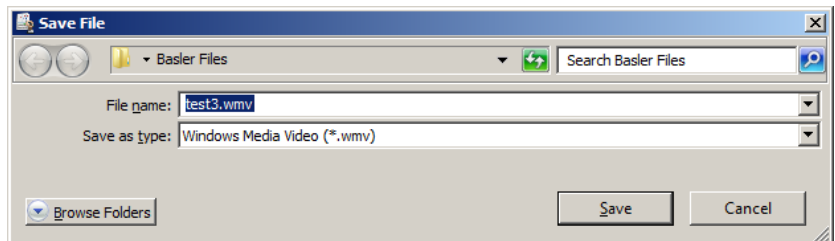
1. Launch *AcqKnowledge* and select Media > Set Up. The Basler camera should appear as selected in the “Video” list.
2. Check the “Video” option (and “Audio” if sound is to be recorded).



3. Click the “Output” tab and type in a media file name.
4. Click “Browse” and choose a format** (*.wmv or *.avi) and directory for the new media file.

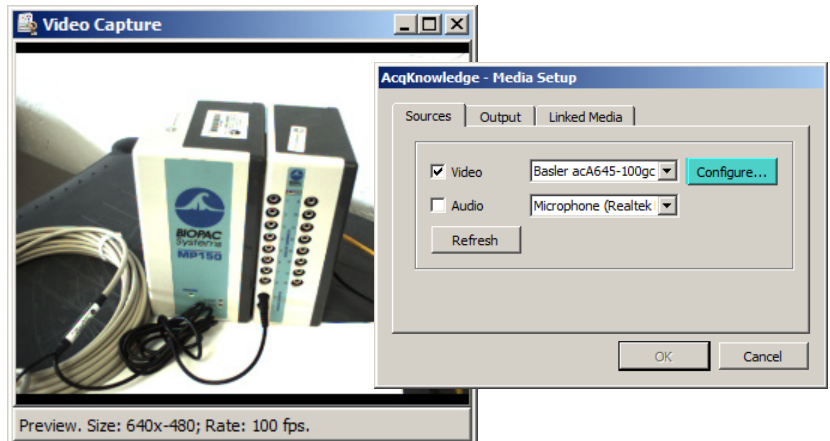


5. Click “Save.”

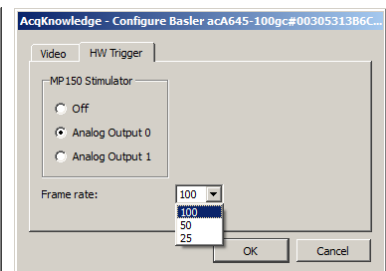
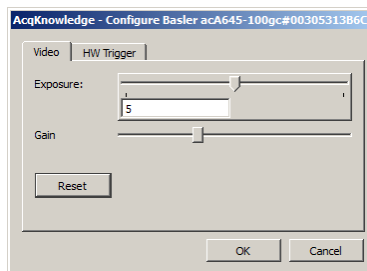


6. Click “OK” to bring up the Video Capture Viewer. This is useful for determining proper camera positioning, lighting, etc.
7. To access the “Video” properties (Exposure or Gain controls), go to Media > Set Up and click the “Configure” button.

NOTE: The “Configure” button is not active until the Media > Set Up dialog is dismissed with “OK” and reopened.



8. Click the “HW Trigger” tab to:
 - Use the MP150 Stimulator to trigger and synchronize the camera recording with *AcqKnowledge* data collection.
 - Set the camera frame rate (25, 50, or 100 fps).



**Dropped frames while recording in *.avi format are an indication that the computer may lack sufficient resources to support this larger-scale format. If this occurs, it's advisable to use *.wmv format instead.

NOTE: The CAM-HFR-A can link with only one graph at a time. A previous graph must be closed prior to connecting to a second graph, or a conflict error message will result.

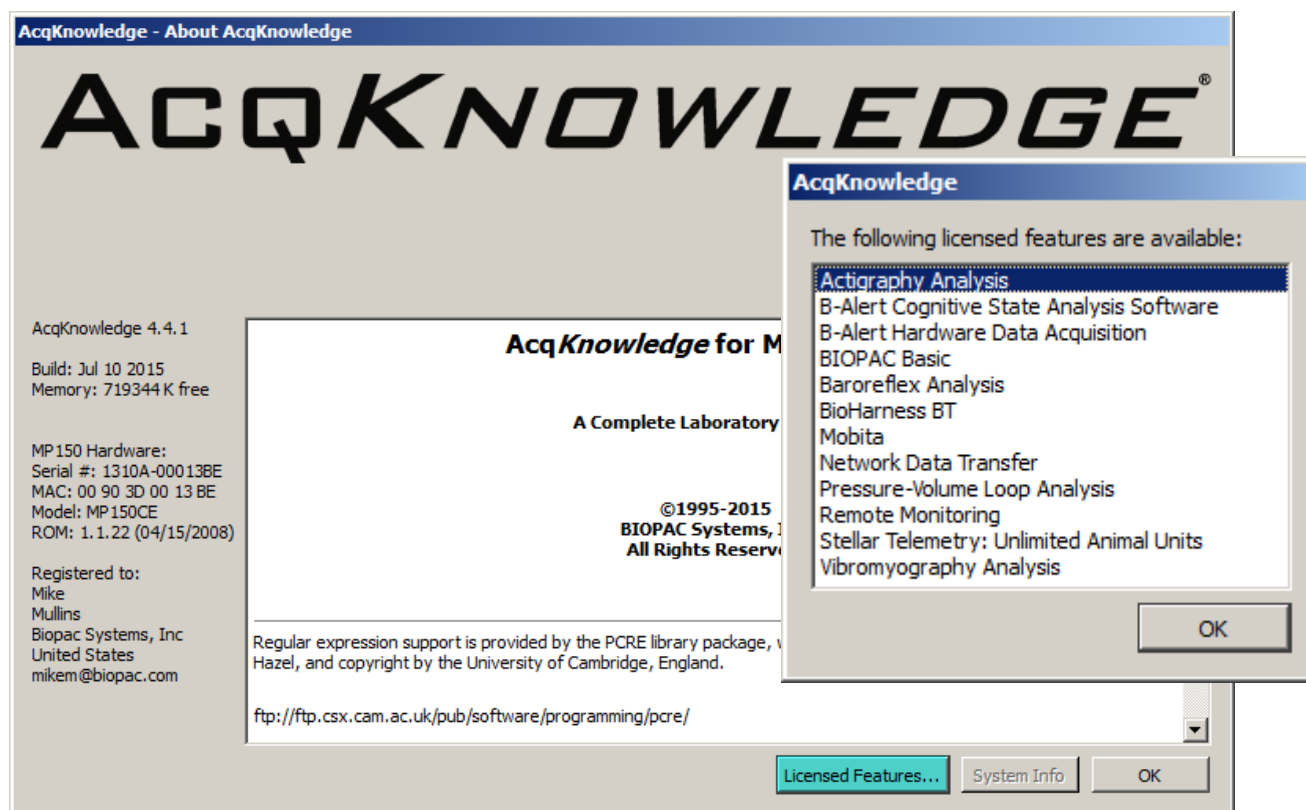
For camera specifications, see the [CAM-HFR-A Product Sheet](#) or the BIOPAC Hardware Guide.

Watch the [AcqKnowledge CAM-HFR-A video tutorial](#) for a detailed demonstration of this feature.

Part D — Licensed Functionalities

AcqKnowledge Licensed Functionalities consist of powerful optional features not included in the standard *AcqKnowledge* installation. These features become available with the purchase of an enhanced licensing level, and can be purchased individually or in a bundle at any time and added to an existing installation.

Access to the licensed features is enabled by a USB License Key provided by BIOPAC, and the USB key must be connected in order for the licenses to be active. With the license key connected, information about the available licenses can be found by going to Help > About and clicking the “Licensed Features” button.



The following chapters offer an overview of the various licensed features available from BIOPAC.

Chapter 21 Licensed Functionality: Network Data Transfer

Network Data Transfer (NDT) functionality is available through an optional license available with AcqKnowledge 4.1.1 or above. The license must be authorized to access NDT functionality. To add an NDT license to an existing MP System, please contact BIOPAC.

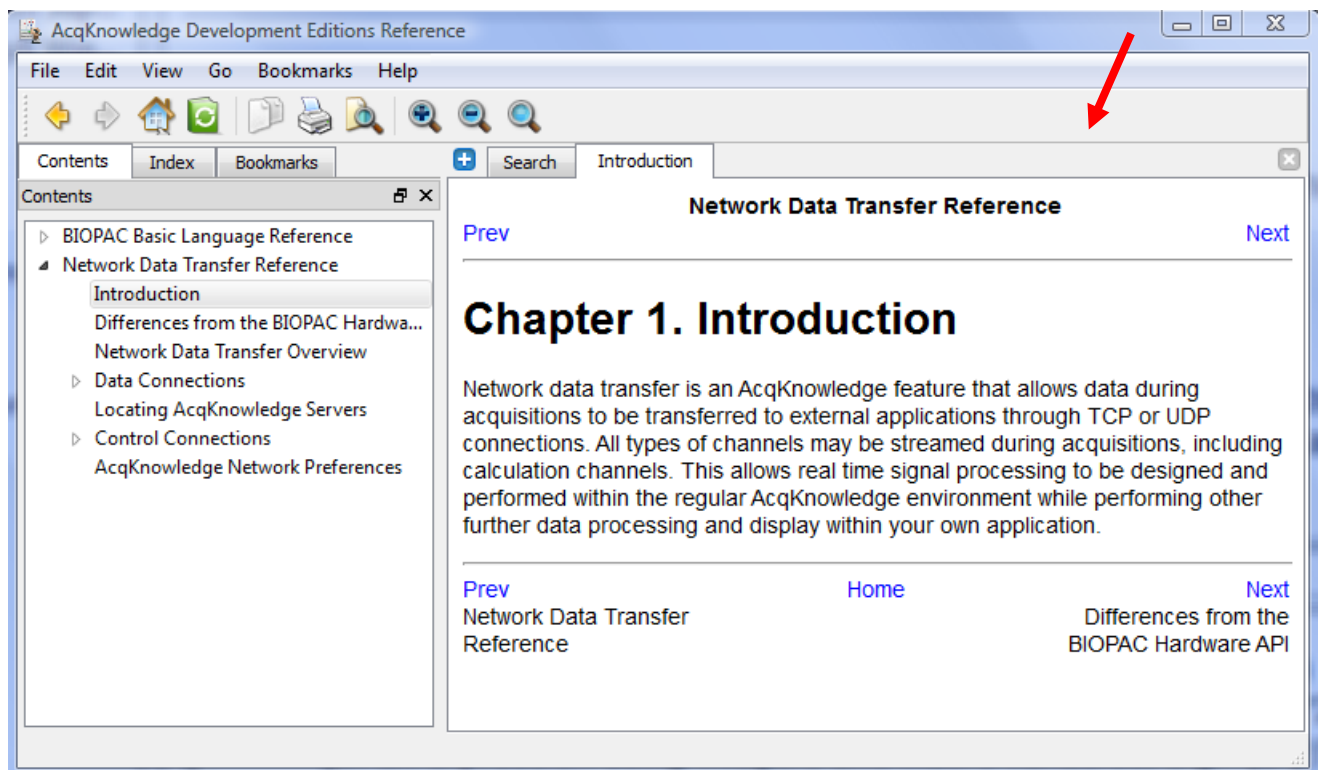
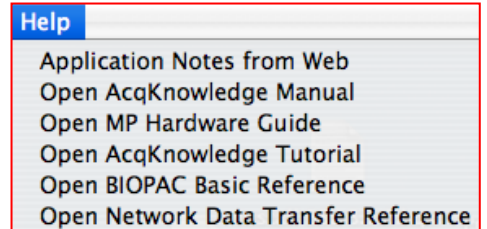


Network Data Transfer (NDT) is a real-time data transfer system that allows access to the data being acquired into a graph by AcqKnowledge for use in an external application; the AcqKnowledge process and the custom application may run on the same computer.

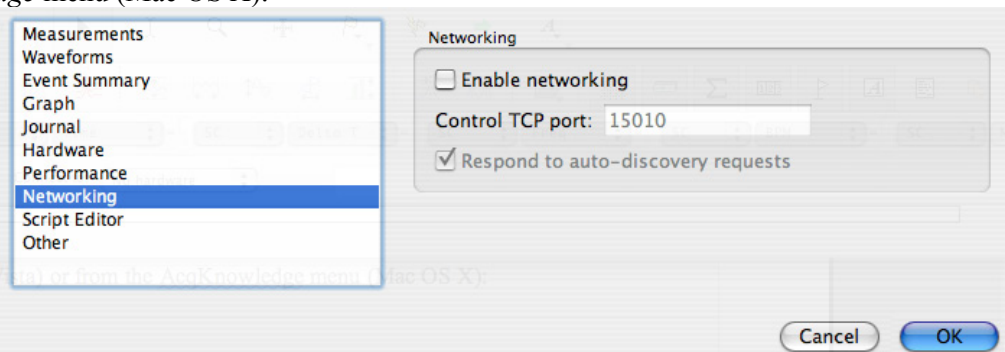
Make TCP or UDP connections to external applications and stream binary data during acquisitions. Network Data Transfer is supported in MP150 hardware only.

The NDT license

- allows Network Data Transfer functionality
- links the **Network Data Transfer Reference** under Help
- includes network data transfer Preferences



Most of the settings for the network data transfer functionality are set by clients through control connections. Several settings for the AcqKnowledge server may be set directly in the AcqKnowledge preferences. Versions of AcqKnowledge that include network data transfer functionality have an additional "Network" group of settings underneath their Preferences. These Preferences are accessed from the Display menu (Windows 8, 7/Vista) or from the AcqKnowledge menu (Mac OS X):



NDT is 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. NDT provides

- networking facilities that allow for integration into a distributed application environment
- basic control facilities to allow external applications to query and control the AcqKnowledge application state.

The NDT system is split into two separate types of connections: data connections and the control connection.

- A.** Data connections deliver data from AcqKnowledge to external applications during acquisitions.
- B.** 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.

All connections should be made using standard network protocols, either TCP or UDP. Single system image architectures should make connections using the loopback interface. It is assumed that network implementations have appropriate IP networks in place with routing between machines that can be identified either by IP address or by hostname. Firewalls must be properly configured to allow network communications between the client and server. Appropriate network configuration is the user's responsibility.

Data Connections

Data connections are used to deliver data from the 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 is sent over the single connection in an interleaved format. The

interleaved format mingles the data of all channels in order. For example, an interleaved representation of two samples from three channels of data would be: C1 C2 C3 C1 C2 C3. This is equivalent to two sample frames where a *frame* contains the data at a particular sample location for all of the channels, in this case “C1 C2 C3.” Frames are delivered sequentially over the data connection.

The single connection transfer type allows for all data to be processed from a single location and uses only one network connection resource. Single connection transfer has drawbacks including the need for the client to demux the data stream as well as account for variable sampling rates.

Variable Sample Rate Considerations

When variable sampling rate is being used, the single connection transfer type has the characteristic where not all frames have the same size. If a frame occurs at a sample position where a channel is not being sampled, that channel will not be included in the frame.

All downsampling within the *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 is different than the sampling rate of information on an upsampled channel connection. If the client is performing any time domain measurements or other computations involving the sample interval, the difference in inter-sample-interval must still be taken into account.

XML-RPC

The XML-RPC transfer type allows clients to explicitly request data from the server. Instead of data being automatically pushed to clients, the client must post an XML-RPC function call to the server. This allows the client to query the server for the most recently acquired data sample value for a particular channel. Clients that do not require continual data streams or interact with only slow moving data may wish to use this method communication method. This method returns values only; no information about sample indexes or lengths is returned.

XML-RPC has significant overhead for both client and server, so this transport method cannot handle more than a few requests per second. If faster response time is required, the client should implement either the single connection or multiple connection streaming methods.

XML-RPC is not a true data connection as it does not involve the server constructing a streaming connection to the client.

Transport Protocol

Data connections offer a choice of using either TCP or UDP as the transport protocol for delivering data to the client. Choice of protocol depends on application requirements. When a client is receiving data, it is assumed that all data connections are using the same transport protocol.

TCP/IP

TCP is the preferred transport protocol. As TCP guarantees reliable, ordered delivery, all data is simply transferred from the server to the client without any additional information. Data is streamed continuously as it becomes available. TCP is recommended for all clients that require a guarantee of receiving all information. It is also recommended for any configuration using up to two computers. The port number used for data connections is specified by the client using the control connection prior to the start of acquisition. Once a client passes along port information, the client should begin listening for connections on that port.

When using TCP data connections, the start of acquisition is signaled to clients by the establishment of a connection on an appropriate port to the client. The end of an acquisition is signaled by the termination of the connection.

UDP

UDP is a connectionless protocol that does not guarantee either delivery or properly ordered reception of packets by clients. Data connection is allowed to be switched to UDP delivery mode. The primary benefit of using UDP datagrams is that a single data stream can be multicast to a number of computers. Multicasting is not offered implicitly by the *AcqKnowledge* data connection protocol but can be achieved implicitly by requesting a data connection be bound to a broadcast address.

UDP delivery used fixed size datagrams. The default size is 512 bytes. Clients can modify this size to any fixed number of bytes prior to the start of acquisitions. The UDP packet size is stored in the template and is different for each graph. UDP clients that require a specific packet size should set that packet size prior to the start of each acquisition.

Each datagram will contain the following:

<i>Field</i>	<i>Data Type</i>	<i>Offset</i>	<i>Description</i>
Starting sample index	unsigned long (four bytes, network order)	0 byte	This indicates the starting sample position of the first sample of data contained in the packet. This number is always monotonically increasing and can be used to reassemble datagrams that are received out of order. This field is always stored in network order. Usage of htonl()/ntohl() should convert from network order into host endian.
Length of data section in bytes	unsigned long (four bytes, network order)	4 bytes	Total number of bytes in the data section. Data is sent by <i>AcqKnowledge</i> as it is available, so not all data packets will contain the same amount of data. This field is always stored in network order. Usage of htonl()/ntohl() should convert from network order into host endian.
Data section	(type and endian specified by client)	8 bytes	Data section containing the binary data that was acquired. The data is converted into the appropriate data as configured by the client.

All of the data delivery is performed as data is available from the MP unit. The actual size of the data section in packets that get delivered to the client is dependent on the speed of data acquisition and other activity on the host computer. If variable sampling rates are being used, frames will not be split up. All of the data for the final frame is contained in the UDP packet. If a frame will not fit in the amount of space in a packet, it is sent in the next packet.

There are no provisions for clients to request retransmissions of packets from the server. Clients should be aware that data may not be delivered when using UDP and should be prepared to examine sample indexes at the beginning of each packet and handle missing data accordingly (padding, warning user, etc.).

The port on which datagrams is delivered is specified by the client prior to the beginning of acquisition on the control connection. Once the client specifies its port, it should begin listening for datagrams delivered to that port. The start of acquisition is signaled by the first datagram that is sent to that port. The sample index of the first datagram corresponds to the first hardware sample of data acquired by *AcqKnowledge*. If the graph is initially empty, the index is zero.

Unlike TCP connections which get explicitly disconnected at the end of acquisitions, there is no direct messaging for UDP delivery indicating the end of acquisitions. Datagrams will not be sent to the client after the end of acquisition. Clients requiring explicit termination notification should either use TCP or implement a timeout mechanism combined with an XML-RPC `getAcquisitionInProgress` call on the control connection to locate the end of acquisitions.

XML-RPC

The XML-RPC “get most recent data sample” call will use standard XML-RPC connection semantics involving the client making an HTTP POST request to the server and interpreting the response as appropriate. Handling of XML-RPC can be performed by a library in the client's appropriate implementation language.

Real-time Delivery Guarantees

No delivery time guarantees exist for any data connection. Data is delivered to the client as it becomes available. The overall latency of the system from physical sample time to data delivery is dependent on a number of factors including network load, *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 hardware unit is always accurate.

It is only the time between the physical time corresponding to a sample and its delivery to the client application that is variable.

Clients that require strict real time guarantees or more predictable latencies should investigate using the hardware API on their local machine.

Data Formats

It is assumed that the data transfer feature is used in a mixed host environment, potentially with clients running in environments that have restricted data types. The sampled information delivered by a data connection is allowed to be controlled to appear in a variety of different formats for the client:

- 64 bit floating point – This format will always be available for all channels and may be delivered in either big endian byte order or little endian byte order. This is equivalent to a C style double data type.
- 32 bit floating point – This format will always be available for all channels and may be delivered in either big endian byte order or little endian byte order. This data type is not native to *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 – This format is available only for analog data channels. It may be delivered in either big endian byte order or little endian byte order. This is equivalent to a C style short data type. Clients receiving data in 16 bit integer format should use the control connection to determine appropriate floating point scaling factors that need to be applied to the data to convert into actual units.

Data formats should be specified by the client prior to the start of acquisition. If left unspecified, the default data format depends on channel type:

Channel Type	Default Data Type
Analog	16 bit signed integer, little endian
Digital	16 bit signed integer, little endian
Calculation	64 bit floating point, little endian

XML-RPC get most recent sample requests will always return the double type of XML-RPC (in ASCII notation).

Default Data Connection Settings

If the client does not modify any data connection settings, the following is used:

- Single connection transfer type
- TCP/IP transport protocol
- Port 15020 for single connection
- For multiple connections, each channel type (16 channels per type) is set as follows: analog channels [15020-15035], digital channels [15040-15055], calculation channels [15060-15075].
- Default data formats for each channel type as indicated in the “Data Formats” section

Note that no channels are enabled for delivery by default. Both data connection delivery and get most recent sample tracking are disabled. Clients will still need to enable channels in order to receive data.

Locating AcqKnowledge Servers

It is possible that clients and servers may be located on networks with dynamic IP addresses or other features that make establishing the connection between machines difficult. In this case, a simple UDP broadcast mechanism can be used to locate known servers.

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 is expressed in base 10 ASCII notation.

It is 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 unless the client has modified the destination by using the `changeDataConnectionHostname` command.

It is 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 XML-RPC. For example, a URL for localhost control connections would be “http://localhost/RPC2.”

TCP Port

Only one control connection may be opened by a client to a server at a time. The server will listen on port 15010 by default. As this port may conflict with other network services or may need to be modified for firewall accessibility, *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), 150 (for MP150), or 36 (for MP36R).

The client can use this value to decide between appropriate templates to download or other channel settings.

getEnabledChannels

Method name: acq.getEnabledChannels
 Parameters: string
 Return value: array populated with int

Retrieves the channels that are available for acquisition and data delivery over a data connection to the client. The type of channels that are to be returned are specified in the string parameter. The string parameter may be one of the following: analog, digital, calc. The type must be lowercase. “analog” returns information about analog channels, “digital” digital channels, “calc” calculation channels.

The enabled channels are returned as an array of channel indexes, zero-based. These are the indexes that can be validly used in calls for configuring data connection parameters.

getChannelScaling

Method name: acq.getChannelScaling
 Parameters: channel index parameter structure
 Return value: struct containing scaling

For channels that can be delivered in short integer format, the channel scaling provides the scale factor and offset used to convert the short into physical units using the formula: $\text{sample} \times \text{scale} + \text{offset}$. The scaling is returned as a structure containing two double-valued members: “scale” contains the multiplication factor, “offset” contains the offset factor.

Channels that cannot be delivered as short integers cannot be scaled. If this method is called with an invalid type of channel, a fault response is returned.

getSamplingRate

Method name: acq.getSamplingRate
 Parameters: None
 Return value: double

Returns the current sampling rate expressed in Hz. This is the rate at which data is sampled for a channel whose downsampling divider is 1.

getDownsamplingDivider

Method name: acq.getDownsamplingDivider
 Parameters: channel index parameter structure

Return value: int

Retrieves the downsampling divider for a particular channel. A channel is sampled at the base sampling rate divided by this factor. This factor is also used to determine which frames contain samples for this channel.

Data Connection Configuration Commands

While it is possible to configure data connection parameters using *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.

getDataConnectionHostname

Method name: `acq.getDataConnectionHostname`

Parameters: none

Return value: string

Returns the currently set hostname for data connections. When data connections are established on the start of acquisition, the IP address associated with this hostname is sent the data. Hostnames must properly resolve in order for data connections to be made; DNS configuration is outside of the scope of the network data transfer feature.

If this hostname is empty, data connections is made to the most recently connected client application. This is the default setting.

Hostnames are unique on a graph by graph basis and are saved in templates and graph files. Clients redirecting data to another machine should check and set the data connection hostname as appropriate prior to the start of acquisition.

changeDataConnectionHostname

Method name: `acq.changeDataConnectionHostname`

Parameters: string

Return value: 0 on success, fault on error

Changes the destination machine for data connections, the recipient of the network delivered data. If the parameter is an empty string, data connections will automatically be made to the most recently connected client. The empty setting is the default.

If non-numeric hostnames are specified as parameters, they must be resolvable. If a hostname cannot be resolved, a fault is returned. Proper DNS configuration of the server is beyond the scope of the network data transfer feature.

getTransportType

Method name: acq.getTransportType
Parameters: None
Return value: string

Retrieves the transport type that is being used to deliver data from the server to the client. The transport type is a string that is one of the following: tcp, udp. Note that the XML-RPC data delivery method may be used in addition to this transport type if channels are enabled.

changeTransportType

Method name: acq.changeTransportType
Parameters: string
Return value: 0 if successful, else fault code

Change the transport type that is used to deliver data from the server to the client. The transport type is a string that has one of the following values: tcp, udp. XML-RPC last value data delivery may be used in addition to this type provided channels are enabled properly.

getUDPPacketSize

Method name: acq.getUDPPacketSize
Parameters: None
Return value: int

Returns the current size in bytes of UDP packets that is delivered to clients. Datagrams are always this fixed byte length although each individual datagram may contain varying amounts of data.

setUDPPacketSize

Method name: acq.setUDPPacketSize
Parameters: int
Return value: 0 on success, fault on error

Changes the size in bytes of UDP packets that are delivered to clients. Each individual datagram will always be this fixed length although the amount of data sent in specific packets may vary.

getUDPBroadcastEnabled

Method name: acq.getUDPBroadcastEnabled
Parameters: None
Return value: boolean

Determine if UDP packets are sent only to the client or are broadcast to the broadcast IP of the network. Broadcasting is supported only when the transport type is UDP.

changeUDPBroadcastEnabled

Method name: acq.changeUDPBroadcastEnabled
Parameters: Boolean
Return value: 0 if successful, fault code on error

Modify whether UDP packets are sent only to the client or are broadcast to the broadcast IP of the network. Broadcasting is supported only when the transport type is UDP.

getSingleConnectionModePort

Method name: acq.getSingleConnectionModePort
Parameters: None
Return value: integer

Returns the port number on which the server will connect to the client to deliver data. This port is used only when the connection mode is set to “single” which interleaves all data over a single connection.

changeSingleConnectionModePort

Method name: `acq.changeSingleConnectionModePort`
Parameters: integer
Return value: 0 on success, else fault code

Modifies the port on which the server connects to the client to deliver data. This port is used only when the connection mode is set to “single” which interleaves all data over a single connection.

getDataDeliveryEnabled

Method name: `acq.getDataDeliveryEnabled`
Parameters: channel index parameter structure
Return value: boolean

Query whether a channel is enabled for data delivery. Channels must be enabled for data delivery in order for their data to be delivered to the client. Not all channels that are being acquired are required to be delivered to data delivery.

changeDataDeliveryEnabled

Method name: `acq.changeDataDeliveryEnabled`
Parameters: channel index parameter structure, Boolean
Return value: 0 for success, else fault code

Change whether or not data delivery is enabled for a particular channel. Data delivery can only be changed prior to the start of an acquisition. Changes to data delivery enabling are only applied on the next start of acquisition.

getMostRecentSampleValueDeliveryEnabled

Method name: `acq.getMostRecentSampleDeliveryValueEnabled`
Parameters: channel index parameter structure
Return value: Boolean

Query whether a channel is enabled for most recent data sample requests. If a client wishes to use the XML-RPC calls to fetch the most recent value of data acquired of a channel, the channel must be enabled for this functionality prior to the start of acquisition.

changeMostRecentSampleValueDeliveryEnabled

Method name: `acq.changeMostRecentSampleDeliveryValueEnabled`
Parameters: channel index parameter structure, Boolean
Return value: 0 for success, else fault code

Change whether or not a channel is enabled for most recent data sample requests. When a channel is enabled, XML-RPC calls can be used during an acquisition to return the most recent sample of data acquired (or computed) for the channel. Any changes to the enabled state of a channel is applied on the start of the next acquisition. If a client wishes to use XML-RPC calls to read the value of a channel, that channel must be enabled prior to the start of the acquisition.

getDataConnectionPort

Method name: `acq.getDataConnectionPort`
Parameters: channel index parameter structure
Return value: int

Retrieves the port on which the server will deliver the data for the channel specified in the parameters to the client. Per-channel data connections are only used if the data connection method is set to “Multiple.”

changeDataConnectionPort

Method name: `acq.changeDataConnectionPort`
Parameters: channel index parameter structure, integer
Return value: 0 for success, else fault code

Changes the port on which the individual connection is made by the server to the client to deliver the data for the channel specified in the parameters. This style of connection is used only if the data connection method is set to “Multiple.”

getDataType

Method name: `acq.getDataType`
 Parameters: channel index parameter structure
 Return value: structure

Returns the data type that is being used in the binary data streams for the channel's data. The return value is a structure with a type and endian member. The type member, named “type”, is a string and contains one of the following values: short, double, float. These strings correspond to their matching C-style data types. The endian member, named “endian”, is a string and contains one of the following values: little, big. “little” corresponds to little endian byte order, big endian bit order. “big” corresponds to big endian byte order, big endian bit order.

changeDataType

Method name: `acq.changeDataType`
 Parameters: channel index parameter structure, type structure
 Return value: 0 on success, or fault code

Changes the data type that is used for binary data streams of the channel's data. The type structure is a struct containing two members. The “type” member is one of the following strings: double, float, short. Each string corresponds to the matching C-style data type. The “endian” member is one of the following strings: little, big. Each corresponds to the matching byte endian. Bit order within a byte will always be big-endian.

Not all channels may be able to support all data types. If the channel cannot be transmitted in the requested data type, a fault code is returned.

setDataConnectionTimeoutSec

Method Name: `acq.setDataConnectionTimeoutSec`
 Parameters: integer of new timeout in seconds
 Return value: 0 on success, or fault code

Changes the timeout in seconds after which the data connections is closed when acquisitions complete. Clients may need to set this keep-alive timeout in order to receive the trailing data at the end of acquisitions. The default value is “0” seconds which terminates all data delivery connections immediately when the final sample of data is acquired.

Reading Data During Acquisition

Normally data is delivered to clients during acquisitions using data connections. Data connections are either TCP or UDP connections established from the server to the client over which the server streams the incoming data. In some languages and environments however, it may not be possible to handle continuous data streams. The following XML-RPC commands are offered to assist these types of clients. Due to the large overhead of processing connections and XML-RPC requests, this data transfer type is not recommended and TCP/UDP should be used wherever possible.

getMostRecentSampleValue

Method name: `acq.getMostRecentSampleValue`
 Parameters: channel index structure
 Return value: double, or fault code

This procedure allows clients to read the most recent data value of a specific channel during acquisitions. In order for this call to be successful, a data acquisition must be in progress and the channel must be enabled for most recent sample value data delivery. Issue a `changeMostRecentSampleValueDeliveryEnabled` call prior to acquisition to allow this procedure to be used.

getMostRecentSampleValueArray

Method name: `acq.getMostRecentSampleValueArray`
 Parameters: none

Return value: array of structures with channel info and values, or fault code

This procedure allows clients to retrieve the most recent data values of all channels during acquisitions in a single call. If clients are interested in the values of multiple channels, using this method is more efficient than performing consecutive `getMostRecentSampleValue` calls (which require an individual POST request per call).

Only channels that are enabled for most recent sample value data delivery is returned. Issue a `changeMostRecentSampleValueDeliveryEnabled` call for each desired channel prior to acquisition in order for this to return the value for a channel.

The return value is an array of structures, one per channel. Each structure contains two members. The “channel” member will contain a channel index structure with members set to appropriate type and index information for the channel. The “value” member is a double that contains the most recent sample value of the channel specified in the “channel” member.

This procedure cannot be called unless there is an acquisition in progress and there is at least one channel enabled for most recent sample value delivery.

Other Control Connection Commands

Control connections will also allow for the following additional commands to be used by clients:

loadTemplate

Method name: `acq.loadTemplate`

Parameters: base64 encoded binary *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. Only templates in PC *AcqKnowledge* 3.7.1 or Mac *AcqKnowledge* graph templates are allowed to be used with this command. The parameter must include the entire contents of the template file.

The parameter in the XML-RPC call should be a base64 parameter with the raw binary contents of a graph template file. When this parameter is decoded, it should correctly provide the contents of a template file on disk.

This function will return 0 on success, otherwise a fault code if the template could not be loaded. Once a template is loaded, the hardware settings contained within that template is used for subsequent data acquisitions. Templates for ACQ 3.9.2 and higher will retain any data connection settings that have been specified by clients. After loading a template, clients should re-send any configuration information for ports and data connection methods if they do not match the new settings from the template.

If the template data is corrupted or is incompatible with *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.

setOutputChannel

Method name: `acq.setOutputChannel`

Parameters: channel index structure, float output value

Return value: 0 on success, else fault code

Changes the voltage on the specified output channel of the MP device. For analog outputs, the value should be in the range (-10, 10) for the voltage level. For digital outputs, a value of 0 will turn the specified line off, a non-zero value will turn it on. The latency of when the output line is changed is variable and non-guaranteed. Additionally, the output channel may be modified by other areas of the software including control channels, manual user intervention, configured stimulators, etc.

The valid output channels are dependent on the type of MP device that is connected.

- MP150 units allow analog 0, 1 and all digital output channels
- MP36R units allow no analogs and digital 0-8.

Chapter 22 Licensed Functionality: Vibromyography

VMG functionality is available through an optional license available with AcqKnowledge 4.1.1 or above. The VMG license must be authorized to access VMG functionality. To add a VMG license to an existing MP System, please contact BIOPAC.

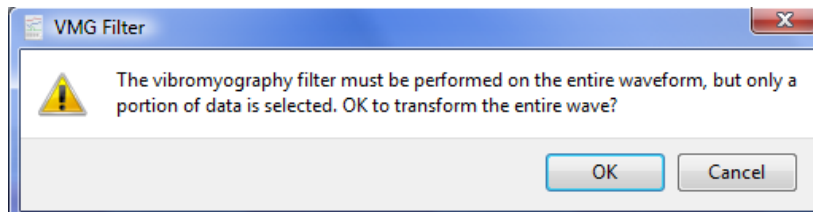


The vibromyography transducer (TSD250) uses an accelerometer to measure surface vibration during activity which is directly correlated to muscle activity; this allows for muscle force and balance to be assessed without using surface electrodes or needle probes. The VMG license allows access to software processing algorithms that are incorporated into AcqKnowledge to perform data reduction for analysis of data collected from a VMG system.

The VMG license:

- adds “Vibromyography” Calculation channel Preset with required scaling and calibration
- adds “Vibromyography Filter” option under the Analysis menu
- includes QuickStart Q45 Vibromyography (.gtl format)—the journal of the file introduces VMG and the hardware settings use Module Setup to add a “VMG Transducer” to analog channel 1 and analog channel 2 of an HLT100C module. Two calculation channels are set to the “Vibromyography” preset using analog channel 1 and analog channel 2 as the respective source channels.

The VMG analysis reduces the channel sampling rate by a factor of 32. In the AcqKnowledge software, all data in an individual waveform share the same acquisition sample rate and each channel may have a lower sample within certain parameters, see (link for variable rate sampling). It is not possible to mix sampling rates within a channel. This analysis is preformed for the entire channel or appended segment (see VMG and append on page 46x). Traditionally, if there is only a single point selected, then the entire data channel is transformed. If only a portion of the wave is selected, then the following warning will be displayed:



When OK is clicked, analysis will be performed on the entire waveform. The selected area will be maintained but the waveform regions outside the selected area will still be transformed. This matches the “Transform entire wave” checkbox operation of other transformations. Cancel exits without modifying the data.

Sampling Rate Restrictions

The Vibromyography Filter is designed to process data acquired at 2 kHz sampling rate only. If the correct sampling rate is not used (via Hardware menu > Set Up Data Acquisition > Length/Rate), results may be unpredictable.

Transducer Setup

The TSD250 VMG transducer is a MEMS accelerometer transducer used for recording vibromyography signals from major muscle groups.

- MP150: Activating the VMG license adds the “VMG Transducer” option to the MP150 module setup; it is an HLT100C high level transducer.
- MP36R Support—the MP36R system may be useful for VMG analysis as four channels allows for comparison of muscle balance between two muscle groups. No analog channel preset exists for the VMG transducers, but a Vibromyography preset exists for the calculation channel. See page 482.

Post-Analysis Selection Adjustment

After the analysis completes, the waveform sampling rate of the selected waveform will be reduced by a factor of 32. As this reduction occurs, the selected area or cursor will adjust to the nearest sample point in the processed VMG channel.

Data Modification History Name

This operation will be displayed in data modification logs (Display > Channel Info) as “VMG Analysis.” It will not have any parameters.

VMG Calculation Channel Preset

The Vibromyography calculation channel preset uses the VMG channel as its source channel. The calculation channel preset automatically applies a downsampling divider of 32 based on the acquisition sampling rate.

- The Vibromyography preset automatically adjusts the channel sampling rate by a factor of 32. After setting up the Vibromyography calculation channel, adjusting the channel sampling rate for the VMG source channel will not change the sampling rate of the Vibromyography calculation channel. The channel sampling rate can be manually adjusted.

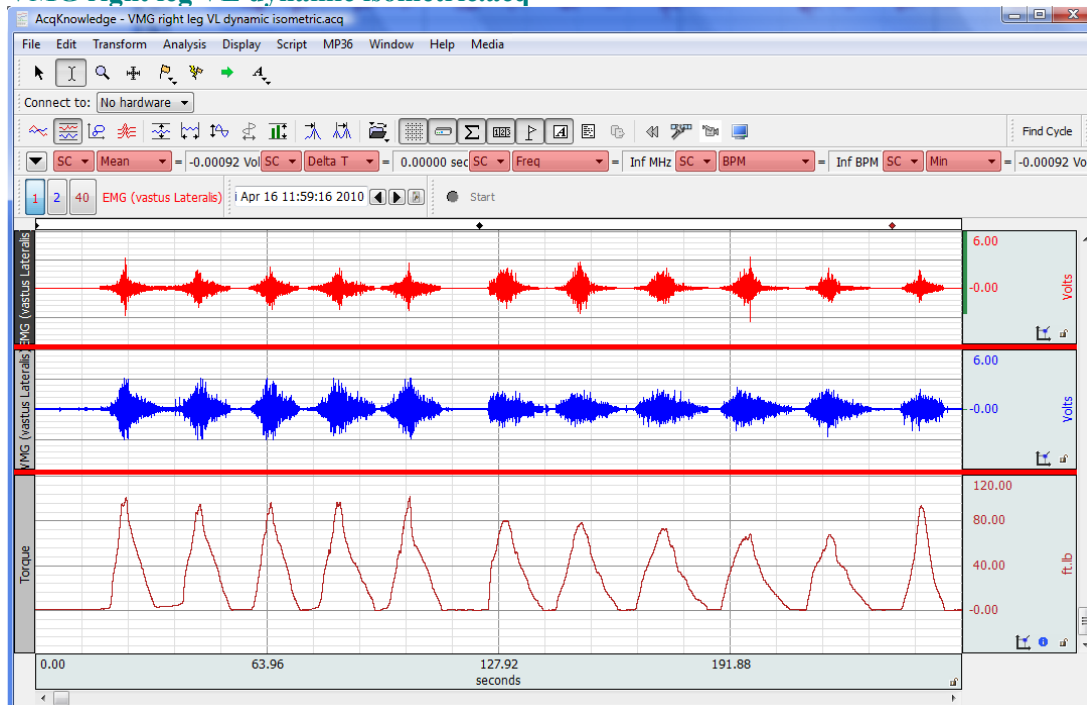
At the end of an acquisition, the Vibromyography preset automatically performs the following steps:

1. Checks for the Vibromyography license. If the license is not found, then the appropriate prompt is displayed.
2. Checks if acquisition is running in append mode. If this is the case then additional parameters are checked and the user will be prompted as needed.
3. Perform Vibromyography Analysis filtering.
4. Adjust selection to highlight only the most recently acquired data segment. If not in append mode, all data will be selected.
5. Copy the processed data to the clipboard.
6. Select the destination calculation channel.
7. Paste processed data from clipboard over the zero valued data for the appended segment (or entire channel if not in append mode).
8. Remove the duplicated channel created earlier.

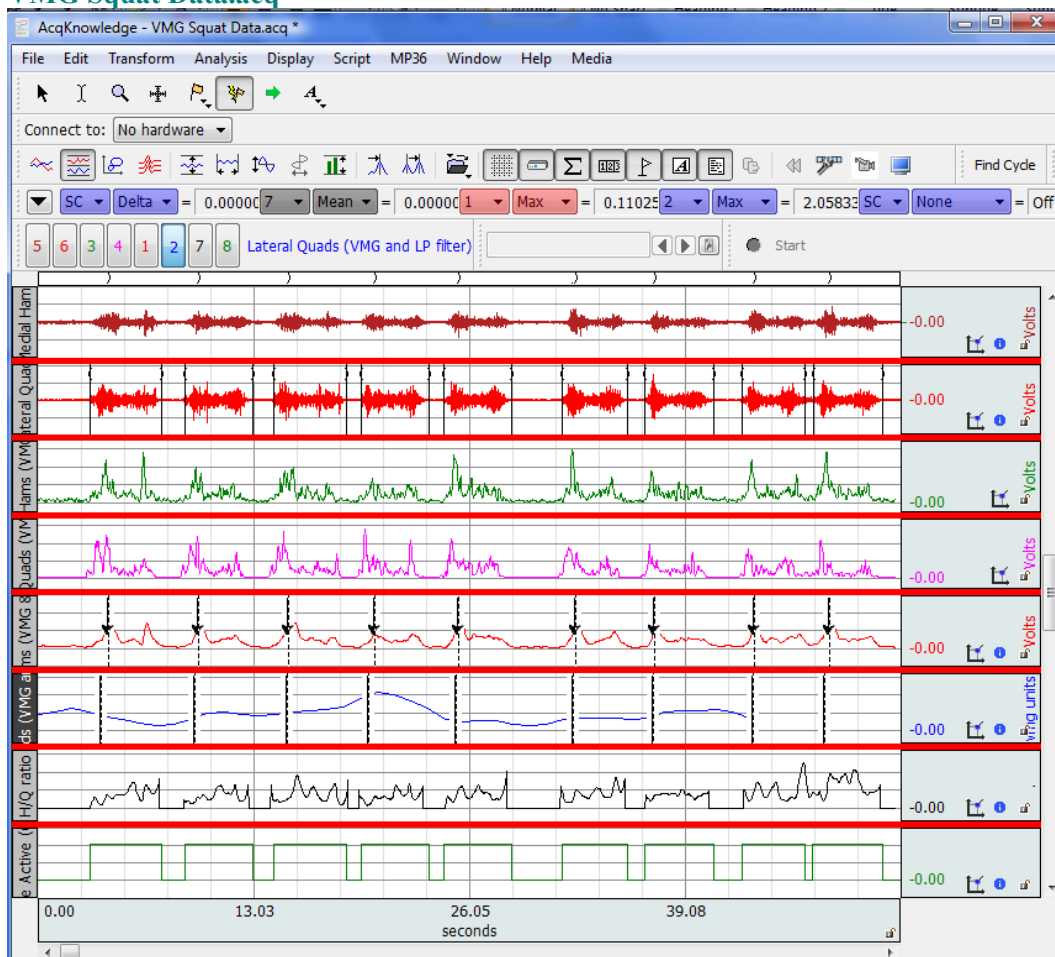
VMG Sample Data Files

Two sample data files illustrating basic VMG data and analysis results are included:

- **VMG right leg VL dynamic isometric.acq**



- **VMG Squat Data.acq**



Watch the [AcqKnowledge Vibromyography video tutorial](#) for a detailed demonstration of this feature.

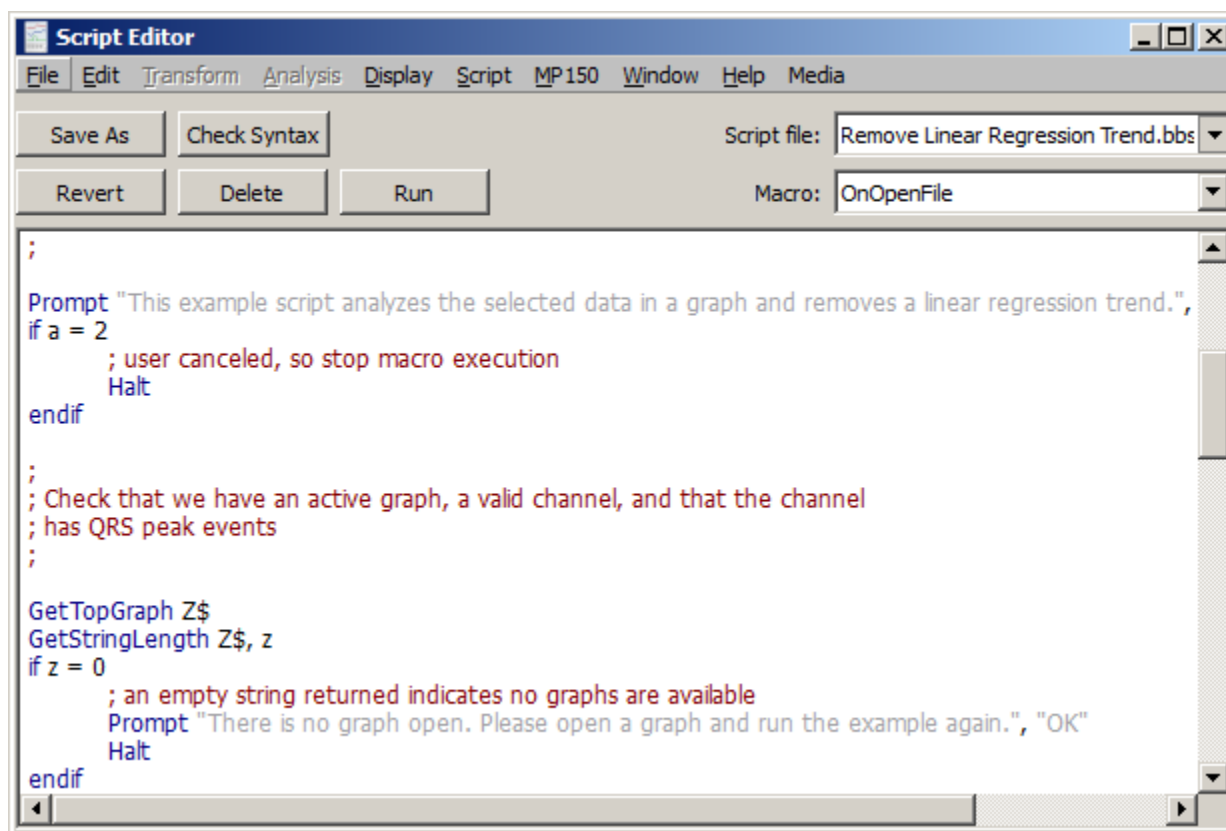
Chapter 23 Licensed Functionality: Scripting

Scripting functionality is available through an optional license available with AcqKnowledge 4.1.1 or above. The Scripting license must be authorized to access Script functionality for executing, authoring, and debugging BIOPAC Basic scripts. To add a Scripting license to an existing MP System, please contact BIOPAC.

Scripting is available for Windows Vista and Mac OS X 10.5 or above and also requires Qt SDK 4.5.0 or higher for rich dialog development.



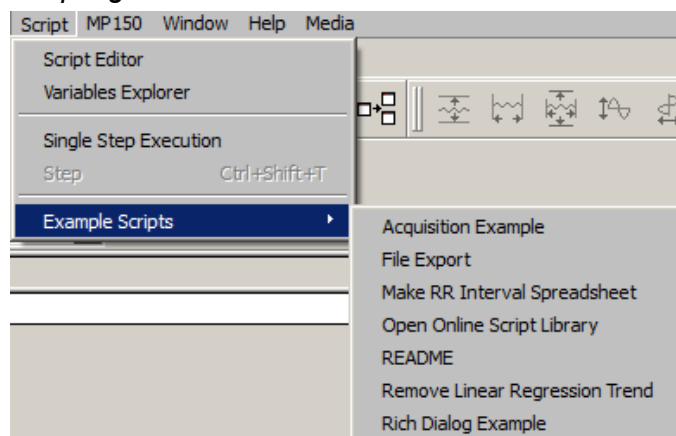
BIOPAC Basic Scripting is a scripting language development option for AcqKnowledge that allows for viewing of runtime variables, creating new script files and editing existing script files, triggering of individual script functions for testing and single step functionalities. Only users that have licensed the BIOPAC Basic feature may run user-generated scripts; if the feature is not available only digitally signed BIOPAC scripts may be executed. Scripting is available in any hardware supported in AcqKnowledge but configuration commands may not be available for non-MP hardware.



The Scripting license

- enables the Script menu
- adds the Calculation channel Preset “Run Macro”
- links the **BIOPAC Basic Reference** under Help
- adds Preferences for Scripting

Scripting Menu



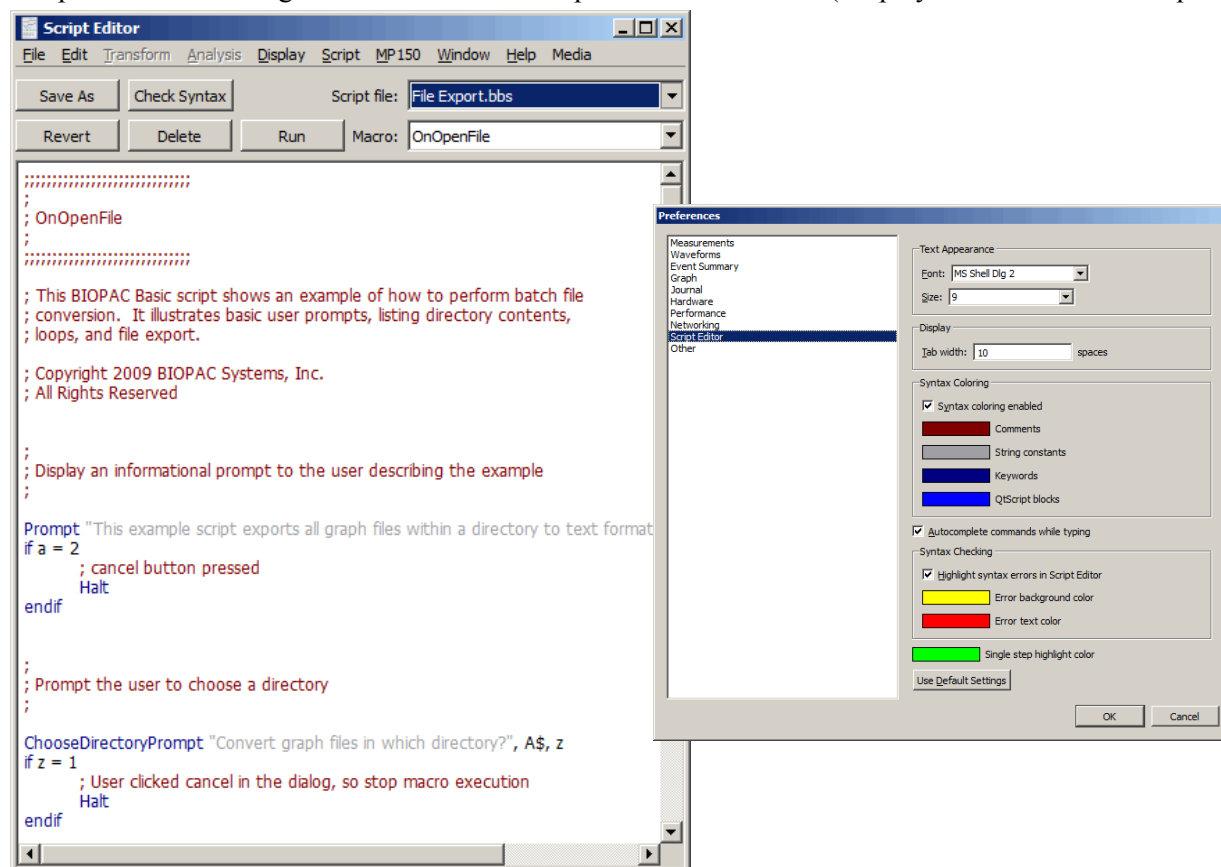
Script Editor

The Script Editor is the window used for creating and editing scripts. The window appears blank by default unless an existing script file (*.bbs) is selected or a new script is created.

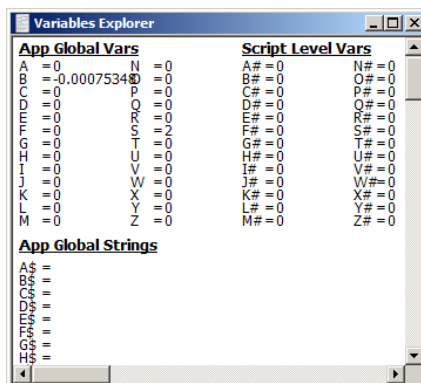
To create a new script in the Editor, select **New Script File** from the “Script file:” menu.

To open any of the existing AcqKnowledge Specialized Analysis scripts, choose **Open Analysis Script** from the “Script file:” menu and select the desired script file.

Script Editor formatting is controlled in the Script Editor Preferences (Display > Preferences > Script Editor).



Variables Explorer



Variables Explorer Window

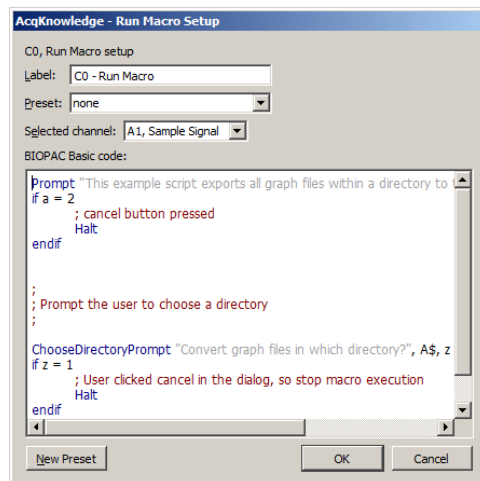
The **Variables Explorer** window (Script > Variables Explorer) shows the contents of the scripting language variables.

Single Step Execution mode (Script > Single Step execution) halts execution after each individual line of a macro, which allows for stepping through macros line by line for debugging and development purposes.

Example Scripts

Several BIOPAC example scripts and macros are available in this menu. When a script file is selected, the scripting language for the selected script is displayed in the Script Editor.

Run Macro Calculation Channel



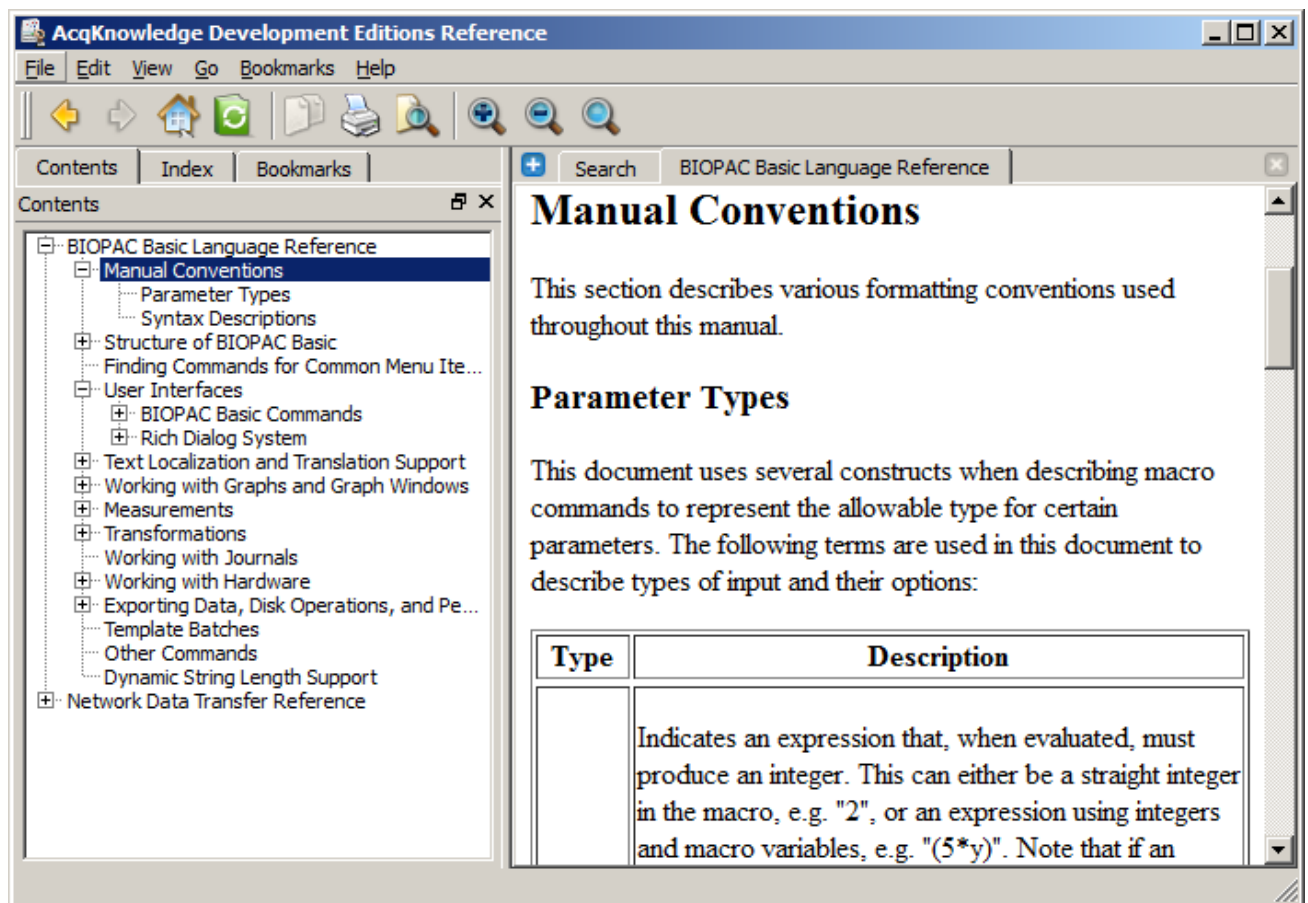
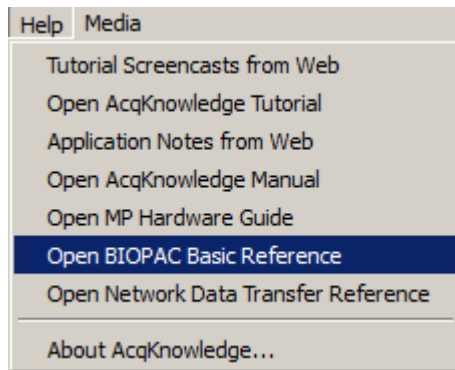
Run Macro Calculation Channel Setup Dialog

The “**Run Macro**” Calculation Channel Preset enables automatic post-processing at the end of acquisition.

Note

- Inserting an extra End in the middle of the macro creates a second macro upon saving. The second macro starts immediately after the inserted End.
- Run Macro calculation channels created with a licensed version will run if opened in a copy of AcqKnowledge without a Scripting license, but the macro cannot be edited.

To view the full online BIOPAC Basic Reference Scripting Manual, see the *AcqKnowledge* Help menu.



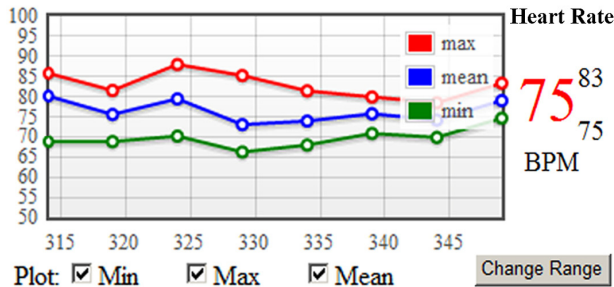
More Scripting References

For more information about creating user-defined scripts for automated analysis routines, see the [Tutorial Video](#).

Preconfigured scripts for automated routines may also be downloaded from BIOPAC [here](#).

Chapter 24 Licensed Functionality: Remote Monitoring

Remote Monitoring functionality is available through an optional license available with AcqKnowledge 4.2 or above. The license must be authorized to access Remote Monitoring functionality. To add a license to an existing MP System, please contact BIOPAC.



New! Remote Monitor

Track the welfare of the subject with alarms to warn when signals fall out of range. The system will work on any device that has access to the same IP based network as the MP150.

Simplified user interface to view subject data on another computer or mobile device – ‘bedside monitor’ display.

AcqKnowledge MP devices are generally tethered to specific computers where data acquisition is performed. In some laboratories, this computer may not be in the same location as the researcher performing the experiment. In MRI situations, for example, the data acquisition computer may be in the MRI control room but the researcher may be in a separate area. AcqKnowledge Remote Monitoring offers researchers the capability of checking on critical parameters from an alternate location.

Remote Monitoring is a client/server application capable of locating and connecting to computers running AcqKnowledge on the same network. It consists of a simple browser interface, from which acquisitions can be started, stopped and remote data viewed during and post-acquisition. Remote Monitoring is supported in MP150 hardware only.

About Remote Monitoring

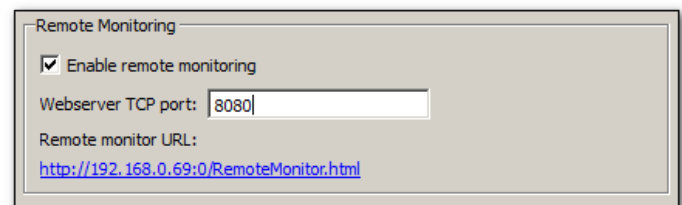
- Remote Monitoring is licensed functionality and must be activated by BIOPAC.
- Remote Monitoring is for viewing of data only. Transformation and specialized analysis of graph data is not supported within the Remote Monitoring interface.

The Remote Monitoring web interface consists of three primary pages:

- A list of open graph windows
- Configuration settings for an individual graph
- The data monitoring page.

Remote Monitoring in AcqKnowledge Networking Preferences

Remote Monitoring is enabled by default in AcqKnowledge Networking Preferences (Display > Preferences > Networking > Remote Monitoring). The **Enable remote monitoring** checkbox option activates the local machine on the network, making it visible to other local network machines also running AcqKnowledge Remote Monitoring.



The **Webserver TCP port** is the numerical port on which AcqKnowledge listens for remote requests. (This port is set to 8080 by default.) The **Remote monitor URL** is a clickable link that opens Remote Monitoring in the local machine's default web browser. **This view will display acquisitions running on the local machine only.** (This is actually an easy way to become familiar with Remote Monitoring). To view acquisitions running on machines in other network locations, the stand-alone **Remote Monitoring Client** application must be used. For further details, see the Remote Monitoring Client section on the following page.

NOTE If a Remote Monitoring preference or port setting is changed, the new preference will not be applied until the subsequent AcqKnowledge application launch.

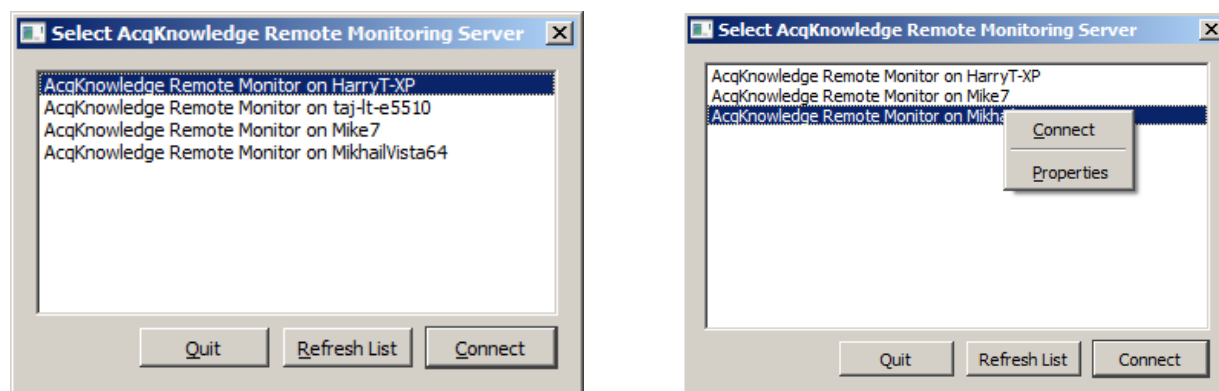
Remote Monitoring Client

The Remote Monitoring Client is a stand-alone application residing in the *AcqKnowledge* program folder. This application facilitates the remote connection to other computers running *AcqKnowledge* acquisitions on the local network. *AcqKnowledge* does not need to be running on the local machine in order to use the Remote Monitoring Client to observe remote acquisitions in progress. To launch the Client, browse to the following directory:

Main Drive:\Program Files\BIOPAC Systems, Inc\AcqKnowledge 4.2\RemoteMonitorClient.exe

AcqKnowledge.exe	4/12/2011 9:22 PM	Application
dephelperx64.exe	7/23/2010 3:21 PM	Application
dephelperx86.exe	7/23/2010 3:21 PM	Application
ecgpuwave.exe	7/23/2010 3:22 PM	Application
RemoteMonitorClient.exe	4/12/2011 7:33 PM	Application
SendMail.exe	4/12/2011 7:33 PM	Application

Double-click on the **RemoteMonitorClient.exe** to launch the application. After launching, the first presented item is the **Remote Monitoring Server** list. This is a list of other *AcqKnowledge* computers on the network that have Remote Monitoring enabled.



Quit Exits Remote Monitoring Client

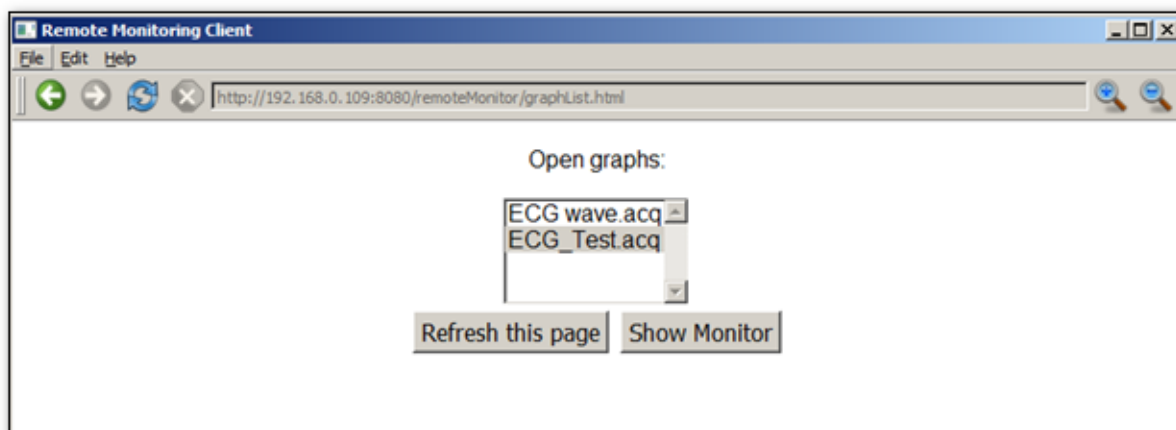
Refresh List Updates list of available *AcqKnowledge* Remote Monitor computers on network





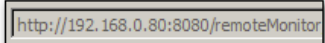


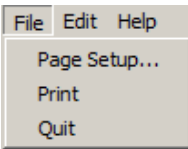
Connect Connects to the computer selected in list

The above-right figure shows a right-click contextual menu available within the Remote Monitoring Server List, which allows an alternate means of connecting to a selected computer. The Properties option displays the *AcqKnowledge* application status, along with network and hardware information about the selected computer.

Remote Monitoring Client Browser

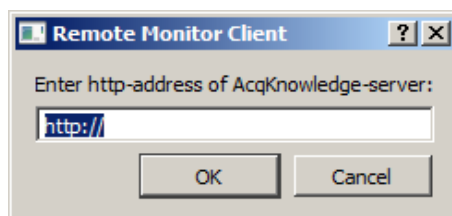
Selecting a computer from the list launches the Remote Monitor Client browser interface. The navigation buttons operate in the same manner as most Internet browser controls. See the following page for details on the Remote Client browser buttons.



Icon	Button Function	Explanation
	Back	Moves browser back one page
	Forward	Advances browser ahead one page
	Refresh	Reloads the current page
	Stop	Stops loading of current page
	Address bar	Displays I.P. address of currently-connected computer
	Zoom in	Master control for enlarging size of browser content
	Zoom out	Master control for decreasing size of browser content
	File, Edit, Help menus	<p>File contains Page Setup and Print controls for Remote Monitoring chart displays. Quit exits the Remote Monitor.</p> <p>Edit contains a Copy option. (Copy function not supported in Windows version)</p> <p>Help displays “About” information for the current version of Remote Monitoring Client*</p>

NOTE for Windows only:

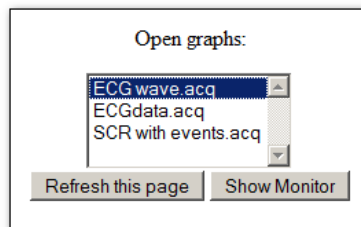
In order for the Remote Monitor Client to properly display the server list of additional AcqKnowledge computers on the network, Bonjour Service for AcqKnowledge must be installed. (The option of installing Bonjour Service is presented during the licensed AcqKnowledge 4.2 application installation). If Bonjour is not installed, the following dialog will be presented upon launch of the Remote Monitoring Client:



The I.P. address of the desired computer can be entered into the http-address field. If the address is valid, clicking OK will connect the Remote Monitoring Client to this computer. An acceptable entry should include the server IP address and UDP port number. (Example; http://192.168.1.76:8080)

Open Graphs Page

When the Remote Monitoring Client browser is launched, a scrollable list of all graph windows currently open on the selected remote machine is presented. Only one graph may be selected at a time.



Refresh this page Reloads the page and refreshes the list of available graphs.

Show Monitor Advances the browser view to the selected file's setup page.

Configuration Settings Page

After selecting a graph and clicking **Show Monitor**, the following Monitor Setup page is displayed. This page contains configurable options for data display and other viewable parameters in the Remote Monitor graph. Note that all available options are set individually per channel.

Return to Graph List [Show Monitor](#)

Monitor Setup for ECG_Test.acq

Auto-refresh Interval: 1 second

☐ Use audible alarms

Channel Setup:

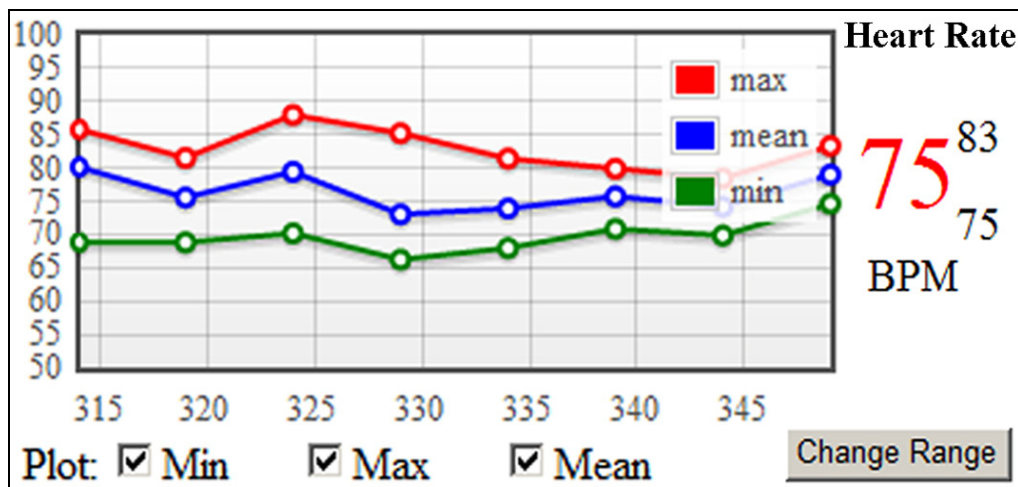
Label	Show Trend	Show Most Recent Value	Show Min/Max	Alarm Enabled	Precision
ECG	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	0
Heart Rate	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	0
R-R Interval	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	0
R-Height	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	0

[Show Monitor](#)

Control	Description
Return to Graph List	Returns browser to list of currently-open graphs. Serves the same function as the browser's 'back' button.
Show Monitor	Saves the selected setup and advances the view to the data monitoring page. ('Show Monitor' button at bottom of screen duplicates this link's function)
Auto-refresh interval	Chooses the interval at which the monitored data is being refreshed over the network. The increments range from 1-sec. to 5 minutes.
Use audible alarms	When enabled, an alarm will sound if the Remote Monitoring graph data display exceeds its maximum or minimum visible ranges. The audio sound is a one-second beep followed by one second of silence. This audio playback is supported only on HTML5 compliant browsers.
Label	Displays assigned label of the AcqKnowledge data channel
Show Trend	Displays a graphical plot of the currently monitored data.
Show Most Recent Value	If checked, the most recent value of the channel data is displayed in a large font. If unchecked, textual display of this value is omitted.
Show Min/Max	Displays minimum and maximum value of currently monitored data.
Alarm Enabled	If the channel value exceeds the current trend display range, the alarm changes the color of the textual display to red and optionally plays audio.
Precision	Sets number of decimal places following channel display values.

Data Monitoring Page

After the desired channel setup parameters are selected, choosing '**Show Monitor**' will advance the view to the data monitoring page.



If an AcqKnowledge acquisition is already in progress and data being plotted, the screen will appear similarly to above, with the graph plot tracing at intervals determined by the Monitor setup auto-refresh rate. If the acquisition has not been started prior to launching Remote Monitoring; the **Start** button will be displayed in this screen. (Remote acquisitions can be easily started or stopped from within this data monitoring page).

Control	Description
Return to Graph List	Displays scrollable list of all currently-open graphs.
“-“ and “+”	Controls for decreasing and increasing size of the input values display font.
Reset	Resets size of input values font display to default setting.
Show Monitor Settings	Returns to the “Monitor Setup” page for adjusting refresh rate, display options, and other monitoring parameters.
Start/Stop	Toggles between starting/stopping acquisition in Remote Monitoring graph.
Refresh Now	Updates data and controls on Monitoring page.
Stop Alarms	Halts any audio alarms that may be playing. Active only if Audio Alarm option is enabled.
Plot	Controls visual display of Min, Max and Mean values display of current graph
Change Range	Allows adjustment of visible ranges of the chart, similar to the vertical and horizontal scale dialogs found in the <i>AcqKnowledge</i> application. This is useful for viewing data that may otherwise appear out of range of the default scaling. Change Range only affects the data display in the Remote Monitoring window, not in the actual <i>AcqKnowledge</i> graph data. (See below for Change Range example and further details).





Default Visible range. (Note BPM data from this graph is ‘out of range’ in the above chart)





Visible range is modified via ‘Change Range’ to include entire data set. Horizontal time scale and vertical divisions were also modified.

Controls in Visible Range (Change Range) dialog

Control	Description
Return to Monitor page	Clickable link for paging back to the Monitoring screen.
Show seconds of data	Determines visible horizontal time scale in chart display.
Number of horizontal divisions	Sets the number of horizontal divisions in chart.
Horizontal axis precision	Sets number of decimal places following horizontal time values.
Vertical lower endpoint	Determines low end of vertical graph scale.
Vertical upper endpoint	Determines high end of vertical graph scale.
Number of divisions	Sets the number of vertical divisions in chart.

NOTE: **Remote Monitoring** plots are only updated in the data monitoring window while an acquisition is in progress. Once a Remote Monitoring acquisition is stopped, the graph will remain visible only as long as the browser page is displayed. After navigating away from the page, the plot will not be retained or reconstructed. To save a Remote Monitoring plot for future reference, printing a hard copy or printing to a PDF file is recommended.

*For Remote Monitoring technical support, contact BIOPAC Systems, Inc at (805) 685-0066 or support@biopac.com

Chapter 25 Licensed Functionality: B-Alert

B-Alert functionality is available through optional licenses* available with AcqKnowledge 4.2 or above (B-Alert wireless headset hardware is also necessary).

* B-Alert Headset integration: must be authorized to access basic B-Alert functionality.

* Cognitive States Analysis: must be authorized to access this enhanced functionality.

To add licenses please contact BIOPAC.



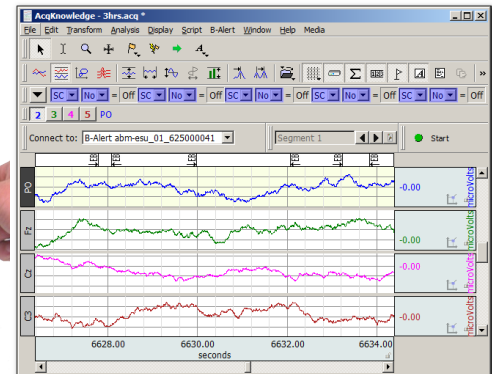
The B-Alert Hardware Data Acquisition license adds:

- Basic wireless recording of up to nine channels of raw or decontaminated EEG data

The Cognitive States Analysis Software license adds:

- Functionality described above, plus the ability to create individual baseline recordings for each subject
- Additional analysis software and specialized calculation channels

Data Acquisition and Analysis with B-Alert™



B-Alert™ X10 is a Bluetooth wireless system and sensor headset integrated with AcqKnowledge software to record up to 9 channels of monopolar EEG, plus one optional channel of ECG data. **B-Alert** data can be acquired simultaneously with BIOPAC MP150 Hardware, if additional graphs are used.

IMPORTANT NOTE: In AcqKnowledge for B-Alert:

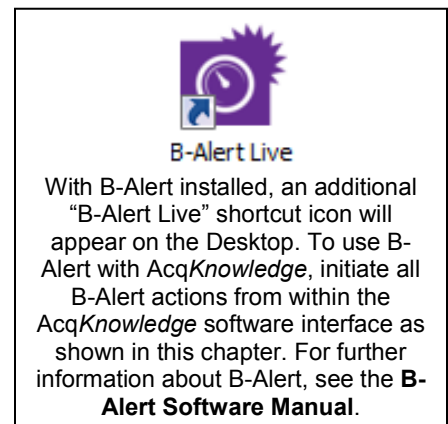
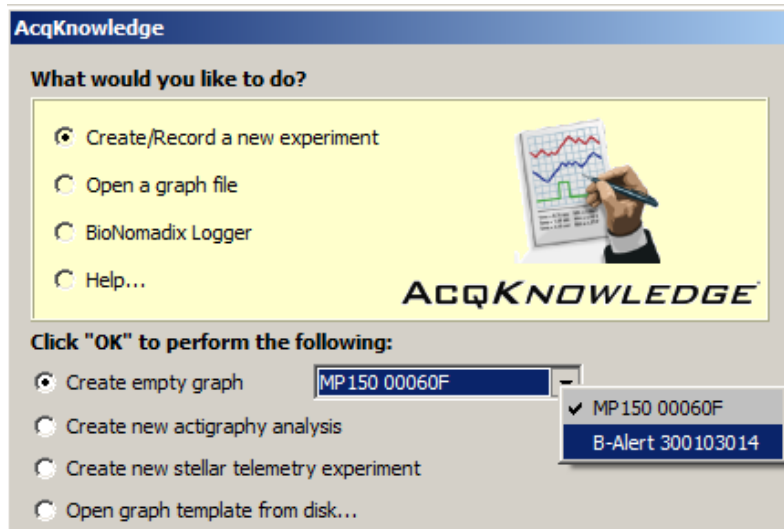
- **B-Alert** is licensed functionality and must be activated by BIOPAC
- Analog channels can be toggled on/off but not modified
- Digital channels are not supported
- **B-Alert**-specific calculation channels are available when the optional Cognitive States Analysis software license is applied (AcqKnowledge calculation channels C8 and higher can be used if configured manually)
- Data acquired with **B-Alert** is outputted in standard BIOPAC *.acq format

B-Alert™ users should refer to the **B-Alert X10 User Manual** for complete hardware setup instructions. This guide, and other B-Alert material can be found on the BIOPAC Manuals [Support](#) page.

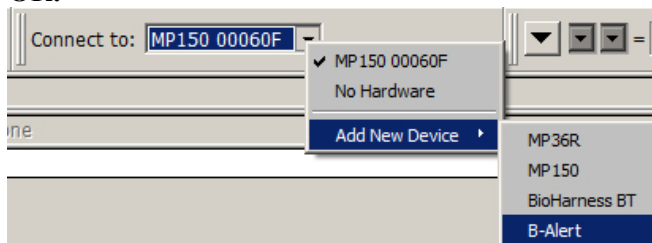
AcqKnowledge software is used to view, record and analyze data acquired with the B-Alert unit.

To launch software with B-Alert hardware:

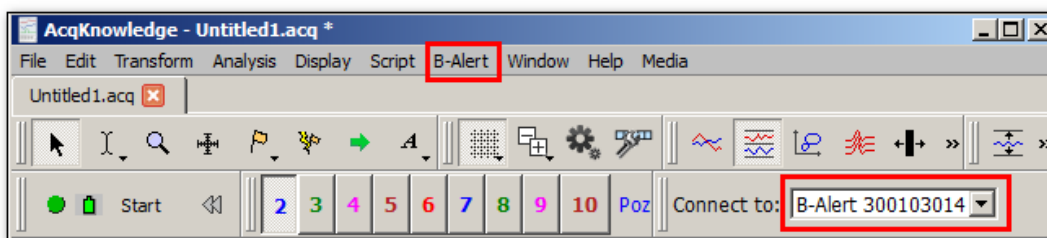
1. Connect the **B-Alert** dongle to a USB port and turn the X10 headset unit's power switch ON.
2. Choose **B-Alert** device from the AcqKnowledge Startup Wizard Hardware menu or from the 'Connect to > Add New Device' menu in the application window. (See figures below.)
3. Use the **B-Alert** menu options for acquisition and channel settings.



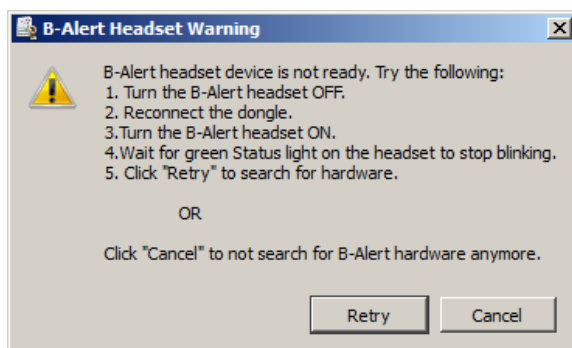
OR:



When AcqKnowledge launches in B-Alert mode, the MP menu will be replaced by the B-Alert menu and the B-Alert device ID will appear in the AcqKnowledge graph "Connect to" menu.



If the B-Alert device cannot be located or is disconnected, the following dialog will appear:



Click 'Retry' in the B-Alert Headset Warning dialog to initiate a refresh of the hardware connection.

Click ‘Cancel’ in the B-Alert Headset Warning dialog to launch the *AcqKnowledge* software in analysis mode. This operates similarly to MP150/36R “no hardware” mode, for which data can be analyzed and transformed but not recorded.

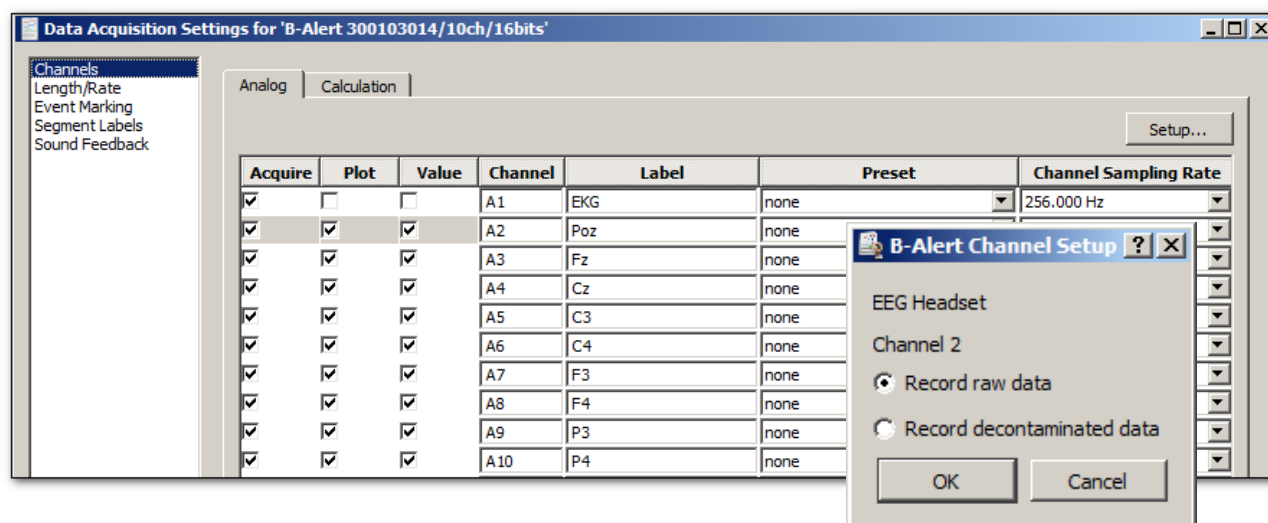
Acquisition Setup

Standard recording modes found in MP150/MP36R hardware (with the exception of Averaging) are supported in B-Alert but the acquisition sample rate is limited to a maximum of 256 samples per second. Dependent upon licensing level, there are two additional checkbox options in the B-Alert Set Up Data Acquisition > Length Rate dialog:

- **Record EEG artifacts as events:** When checked, recorded EEG artifacts are translated into visible events (eye blinks, EMG interference, etc.). When unchecked, artifacts are discarded and only data is acquired.
- **Use B-Alert Definition File:** When checked, enables use of a subject’s baseline Definition File. This option is only available if the Cognitive States Analysis license is applied. See page 501 for a detailed explanation of Definition File setup in *AcqKnowledge*.

Channel Setup

Nine analog input channels of monopolar EEG data are enabled by default in B-Alert, along with one optional ECG (EKG) channel. Channels are configurable as desired. In the standard B-Alert setup, calculation channels C8 – C15 remain available for additional online transformation/filtering of data (for C0-C7, see page 504). (Digital channels, stimulation or triggering are not supported in B-Alert hardware.)



Under the standard **B-Alert** license, the Input channel setup contains options for recording raw or decontaminated EEG data. These parameters are set individually per channel. It is possible to record raw data on one channel and decontaminated data on another.

- **Record raw data:** records unfiltered data. Any further filtering must be applied through calculation channels or transformations. (Default setting)
- **Record decontaminated data:** filtered data will be recorded for the channel. This setting applies algorithms to minimize artifact resulting from eye blinking or other small involuntary movements.

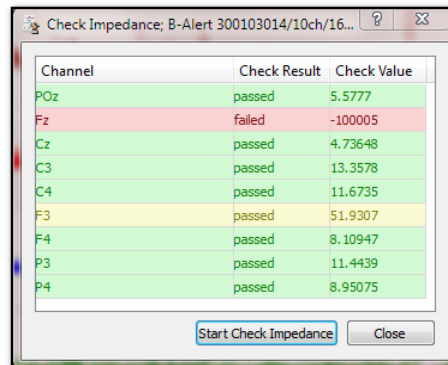
The optional **B-Alert** Cognitive States Analysis license offers additional functionality, such as creation of a baseline “Definition” file (based upon a subject’s responses to some simple cognitive tests), and access to pre-configured calculation channel setups.

B-Alert-specific Hardware Menu Options

B-Alert Headset Check Impedance...
 B-Alert Headset Benchmark Session...
 B-Alert Generate Definition File...
 B-Alert ESU Configuration ...
 B-Alert Show Brain State Gauges

B-Alert Headset Check Impedance

This item is found in the B-Alert menu, (which replaces the MP menu in B-Alert hardware configuration) and is used to initiate an impedance check to verify the headset's electrode contact quality. Results and resistance values are displayed in the dialog when the check is complete. If any of the channels fail the impedance check (as shown on Channel Fz on the right), verify that electrodes are firmly attached and making good contact, and then rerun the check.



Channel	Check Result	Check Value
POz	passed	5.5777
Fz	failed	-100005
Cz	passed	4.73648
C3	passed	13.3578
C4	passed	11.6735
F3	passed	51.9307
F4	passed	8.10947
P3	passed	11.4439
P4	passed	8.95075

B-Alert Headset Benchmark Session

Requires Cognitive States Analysis license

Use to set up an "Alertness Memory Profile" (AMP) Baseline recording of a subject's EEG definition file. The baseline (Benchmark) recording consists of a three-choice psychomotor vigilance task (3CVT) and eyes open/eyes closed.

Subject: Field for 4-digit identifier unique to subject being recorded.

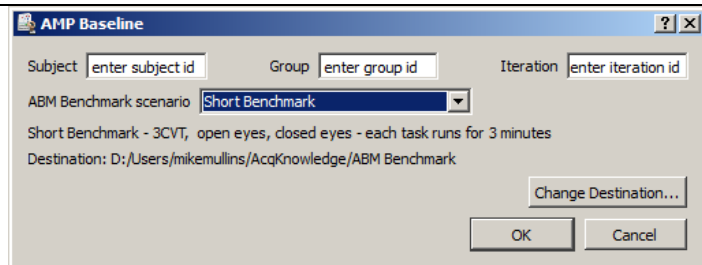
Group: Field for single-digit identifier used to distinguish the subject's group number.

Iteration: Field for single digit identifier identifying the session, if additional Baseline sessions are recorded for a subject.

ABM Benchmark scenario: Choose the type and length of the baseline recording. The following recording lengths are supported:

- Short Benchmark – 3CVT (three-choice Psychomotor Vigilance Task, 3 minutes per task)
- Medium Benchmark – VPVT (Visual Psychomotor Visual Task, 5 minutes per task)
- Long Benchmark – APVT (Auditory Psychomotor Vigilance Task, 20 minutes per task)

After setting up the required fields, click OK to launch the baseline recording user interface, which will resemble the example to the right. A series of onscreen step-by-step instructions will follow.



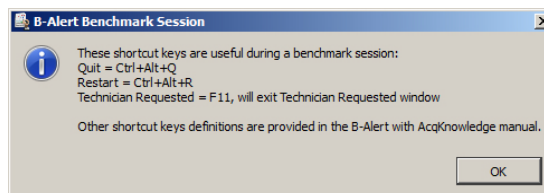
AMP Baseline

Subject: Group: Iteration:

ABM Benchmark scenario:

Short Benchmark - 3CVT, open eyes, closed eyes - each task runs for 3 minutes

Destination: D:/Users/mikemullins/AcqKnowledge/ABM Benchmark

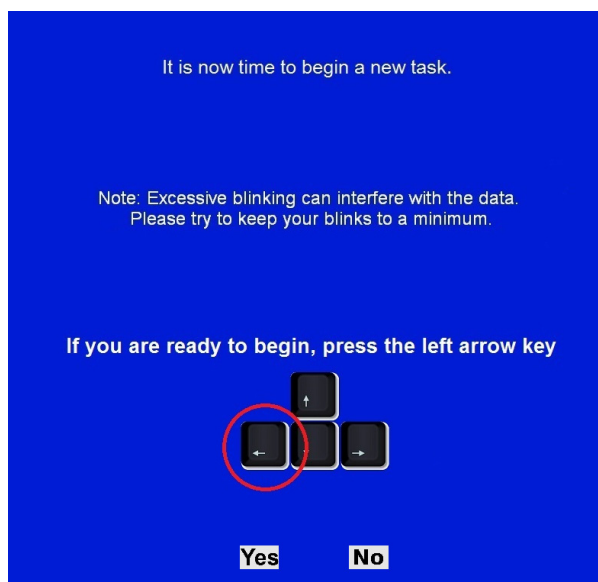


B-Alert Benchmark Session

These shortcut keys are useful during a benchmark session:

Quit = Ctrl+Alt+Q
 Restart = Ctrl+Alt+R
 Technician Requested = F11, will exit Technician Requested window

Other shortcut keys definitions are provided in the B-Alert with AcqKnowledge manual.



For more details about the Benchmark recording user interface and additional software controls, refer to the Benchmark section of the **B-Alert** Software Manual.

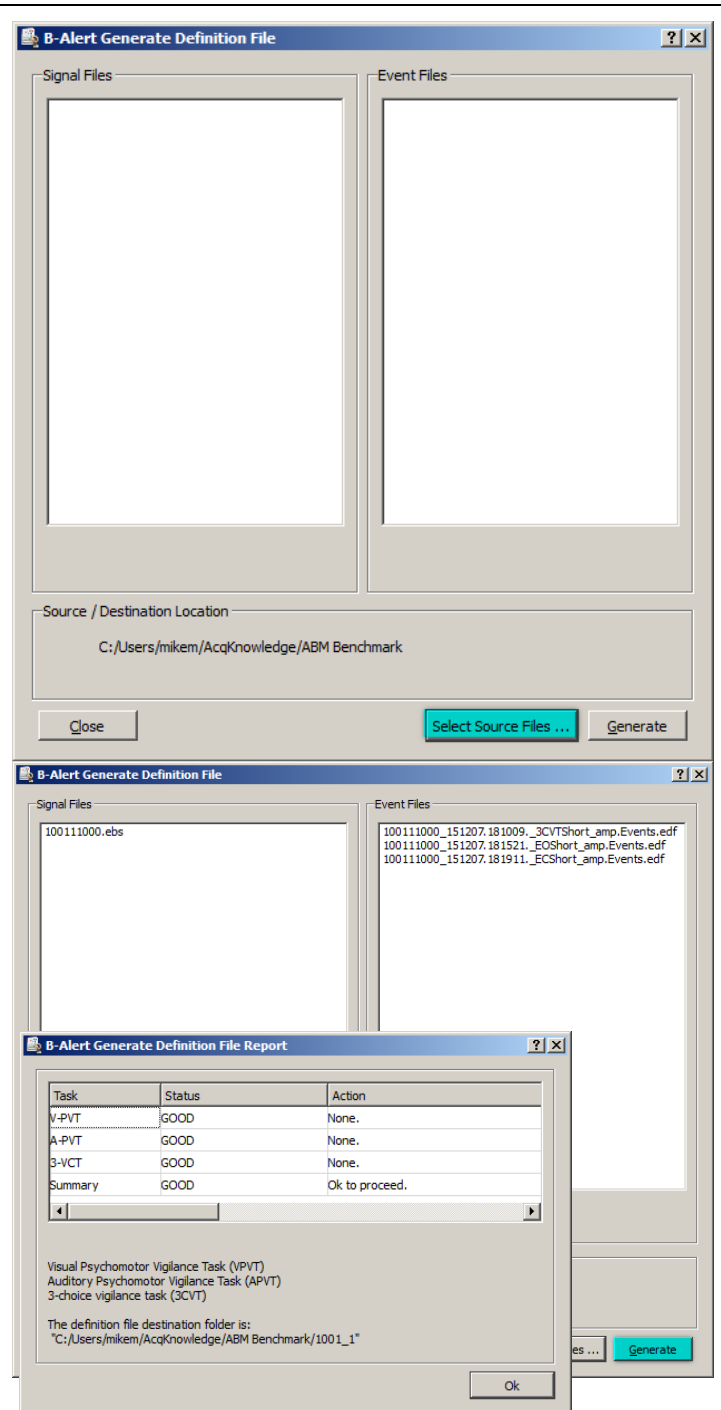
B-Alert Generate Definition File

Requires Cognitive States Analysis license

Use this option to generate or recreate a definition file from a previous Headset Benchmark session.

After completing a Benchmark session (see previous page), a definition (.def) file is automatically generated and saved to the subject folder. This *.def file is used to generate the Benchmark Report file. If the *.def file needs to be recreated, the "B-Alert Generate Definition File" option can be used. **Note:** The previous Benchmark Signal *.edf and all baseline Events *.edf files must be located within the same folder, and have the same 9-digit number for a definition file to generate properly. Follow the steps below to create a definition file:

1. Choose "B-Alert > B-Alert Generate Definition File."
2. Click **"Select Source Files..."**.
3. Navigate to the desired folder containing the Benchmark session *.ebs "Signal" file.
4. Select the *.ebs "Signal" file and click "Open."
5. Select the "Event" (*.edf) files (a minimum of three must be selected) and click "Open."
6. Click **"Generate"** to create the new definition file and report and save them to the Benchmark destination folder. Once created, the individualized .def file can be reused across sessions (for Cognitive State and/or Workload Metric classifications) for a given individual.
7. See page 501 for further details about using and assigning a definition file.



B-Alert ESU Configuration

The B-Alert ESU unit is a multi-channel external synchronization unit that serves as a communication interface between the B-Alert unit and the computer. It allows for synchronization of data between the B-Alert hardware and other third-party data acquisition devices.

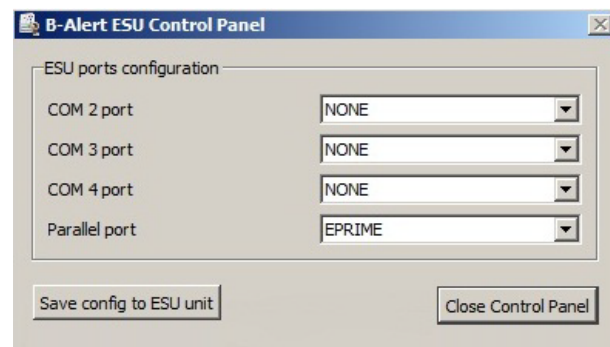
For more information about the B-Alert ESU unit, see the B-Alert with AcqKnowledge Quick Guide or the B-Alert Software Manual.

NOTE: Before configuring the ESU settings, the ESU must be paired with the B-Alert unit via a Bluetooth connection.

- B-Alert headsets are shipped paired to either a B-Alert Dongle or an ESU. If the pairing is lost, the devices must be re-synced using the “Sync” option in the B-Alert Live software’s “Operations” menu. For more information, see the “Sync Device” troubleshooting section in the B-Alert with AcqKnowledge Quick Guide or the B-Alert Live Software Manual.

To Configure the ESU in AcqKnowledge:

1. Plug the ESU unit into a computer USB port.
2. In AcqKnowledge: choose B-Alert > B-Alert ESU Configuration.
3. In the ESU Control Panel, use the pop-up menus to configure ESU third-party data (three serial COM ports and one parallel port) as desired (see below).

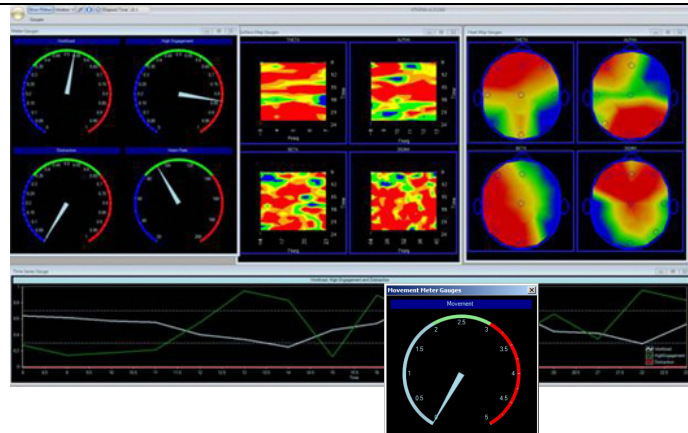


4. Click “Save config to ESU unit” to save the settings.
5. Wait until the “saved configuration” confirmation dialog appears. Restart the ESU by unplugging it and then re-plugging into the computer’s USB port.

B-Alert Show Brain State Gauges

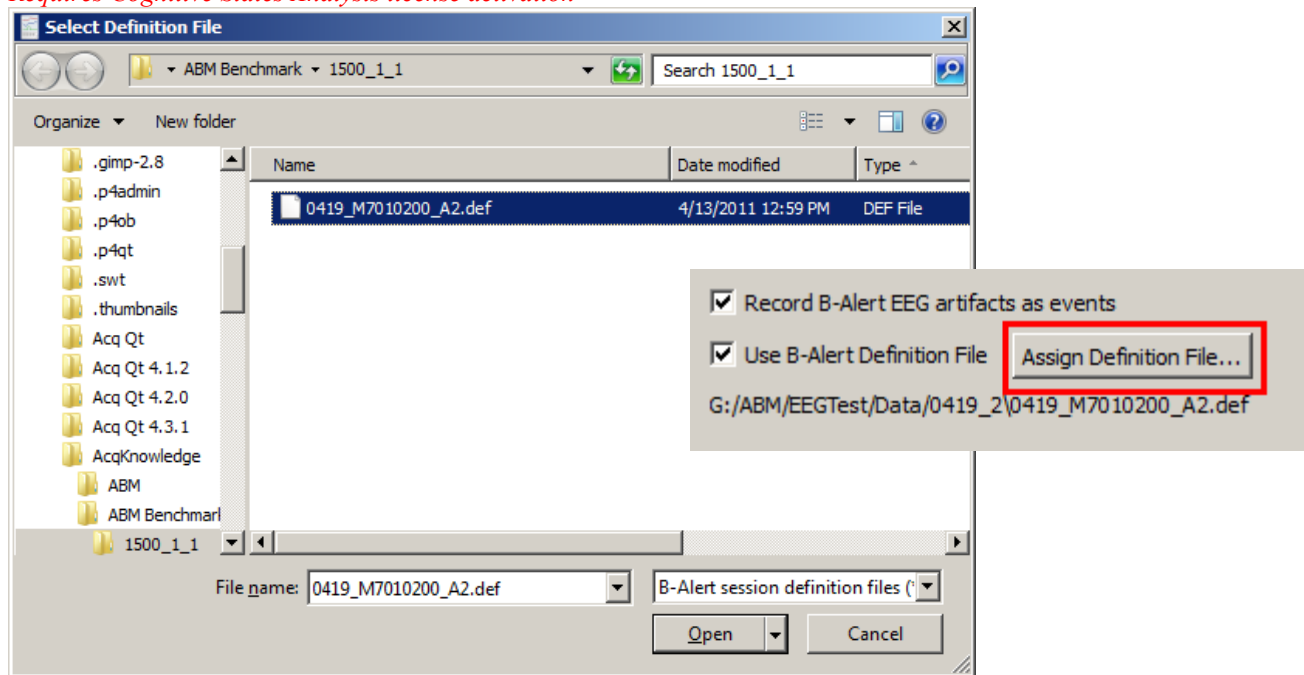
Requires Cognitive States Analysis license activation

Displays real-time views of B-Alert headset data as it is being acquired. Information includes Meter Gauges (*Top Left*) with Engagement, Workload and Drowsiness (along with Heart Rate) Time Series (*Bottom*) Movement Meter Gauge (*Bottom right*) Heat maps (*Top Right*) display EEG power spectral densities (PSD) in both spatial and temporal maps for the traditional Hz bands (Beta, Alpha, Theta, Sigma).



Assign Definition File

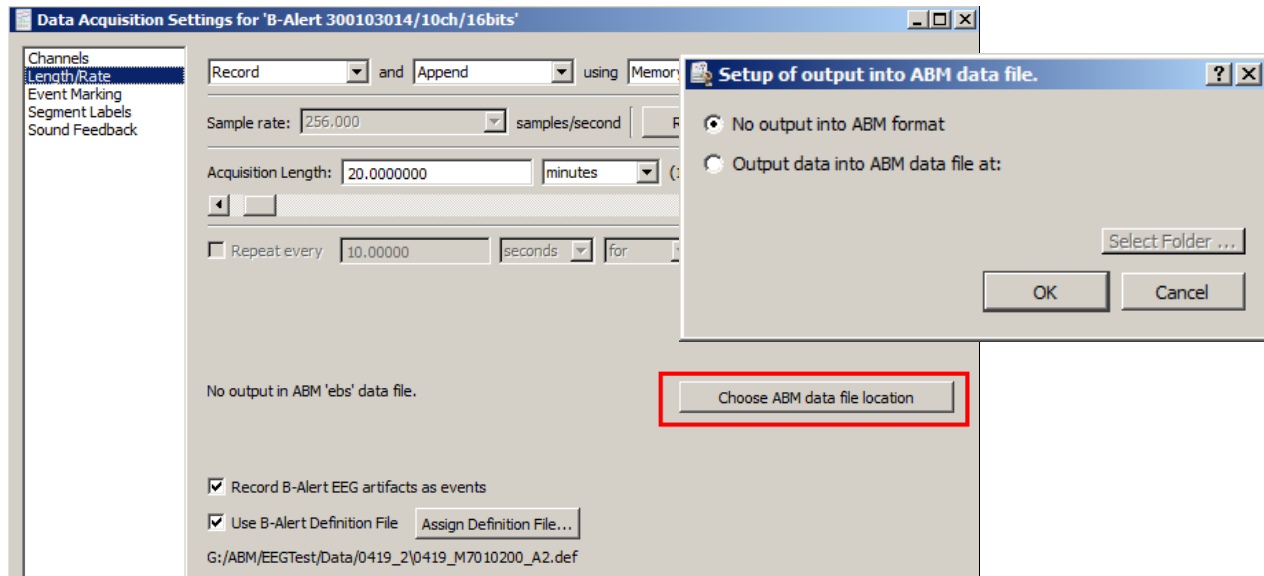
Requires Cognitive States Analysis license activation



The Definition File is created when the subject undergoes an initial baseline EEG recording while responding to some simple onscreen tests, or can be recreated from an existing Benchmark session via the “B-Alert Generate Definition File” menu item. (The Definition File setup is configured in the B-Alert Headset Amp Baseline dialog, referred to on the previous pages). The file is saved to the directory containing the subject’s B-Alert profile folder. Once created, a subject’s Definition File will always be referenced for subsequent recordings and analysis.

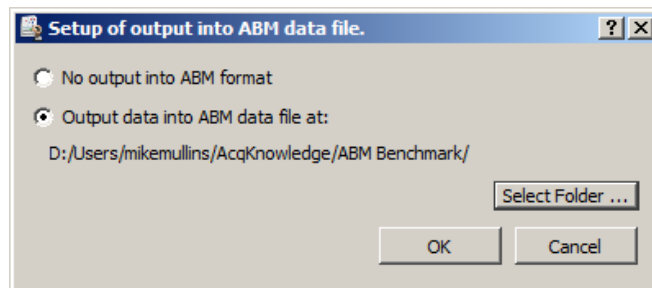
Output to ABM File Format

Acquisition setup options are available for controlling data output to a separate B-Alert ABM file format, which contains an “*.ebs” extension. Outputting to *.ebs format can be useful for preventing raw EEG data from being overwritten while recording in decontamination mode. (AcqKnowledge does not save the original raw EEG data within the default *.acq file format if the decontamination option is applied.) To access these output options, open B-Alert > Set Up Acquisition, and choose “Choose ABM data file location.”

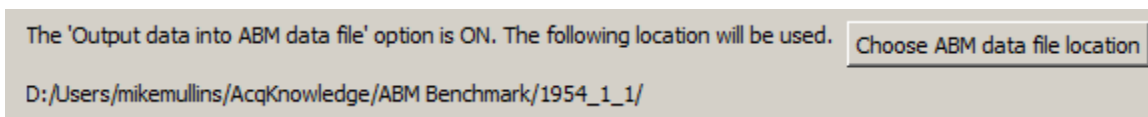


The following options will be presented:


- **No output into ABM format:**
Data files will be outputted in AcqKnowledge *.acq format only. No external B-Alert *.ebs output created.
- **Output data into ABM data file at:**
The ABM raw data file is outputted to the default file path, or a user defined path can be selected.

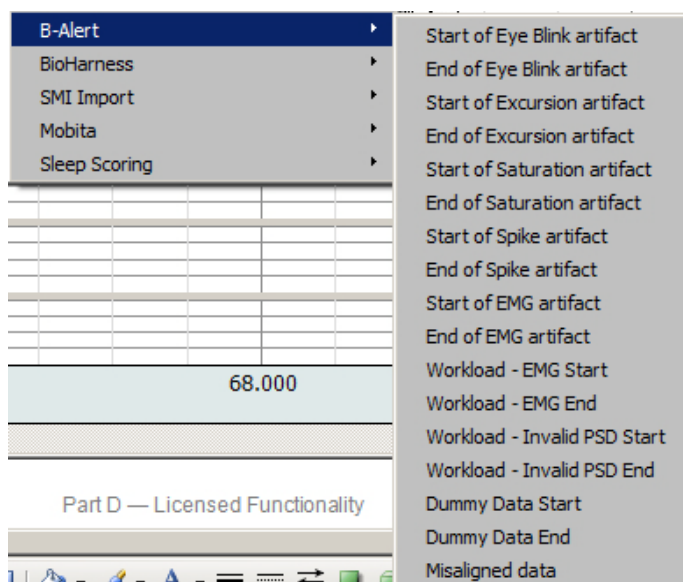


When the above “**Output data into ABM data file at**” option is selected, the full ABM *.ebs data file path and file name will appear in the Acquisition Setup dialog after clicking OK. (See example figure below.)



Other B-Alert Setup Options are:

- **Record B-Alert EEG artifacts as events:**
When this option is selected, artifacts appearing in the B-Alert data (i.e., eye blinks) will be assigned event markers as these artifacts are detected during the recording. B-Alert events can also be manually assigned to recorded data while in progress or in post-acquisition analysis by using the Event tool . For more details on the AcqKnowledge event marking system, see page 215.



Event types supported for B-Alert recordings

- **Use B-Alert Definition File:**

When this option is selected, the Benchmark definition file will be used for the recording (requires Cognitive States licensing level).

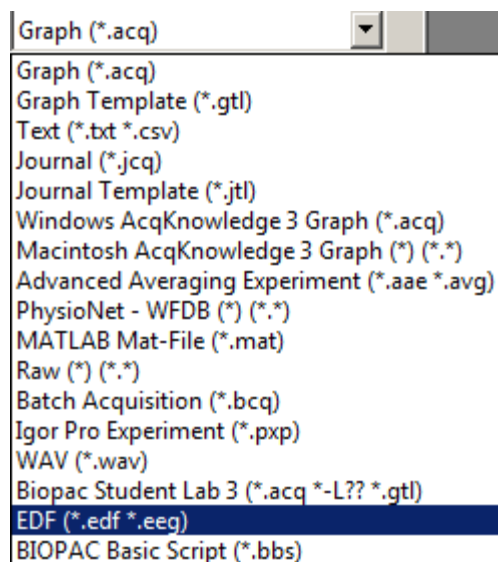
- **Assign Definition File:**

Use this option to navigate to and select a different definition file for the recording.

Opening the ABM Data File

The outputted ABM *.ebs format data file can be opened in *AcqKnowledge* by choosing File > Open, browsing to the file location and selecting “EDF” format from the file type list. For a complete list of outputted ABM data see the Data Output table on page 505.

NOTE: Even though the file extension in the output dialog appears as “*.ebs”, the file will open in *AcqKnowledge* by choosing “EDF” format.



Linked Acquisitions in B-Alert

Linked acquisitions are supported in B-Alert. In a Linked Acquisition session, different hardware device types can acquire data simultaneously into individual graphs. B-Alert acquisitions can be synchronized with and triggered by an MP150 unit and the multiple data recordings merged into one graph at the end of the session.

NOTE: In order to use “master synch device” mode to link signals between B-Alert and MP150 hardware, a CBLX10 cable is necessary. See the MP Hardware Guide for more CBLX10 details.

To connect the CBLX10 for an MP150/B-Alert linked acquisition:

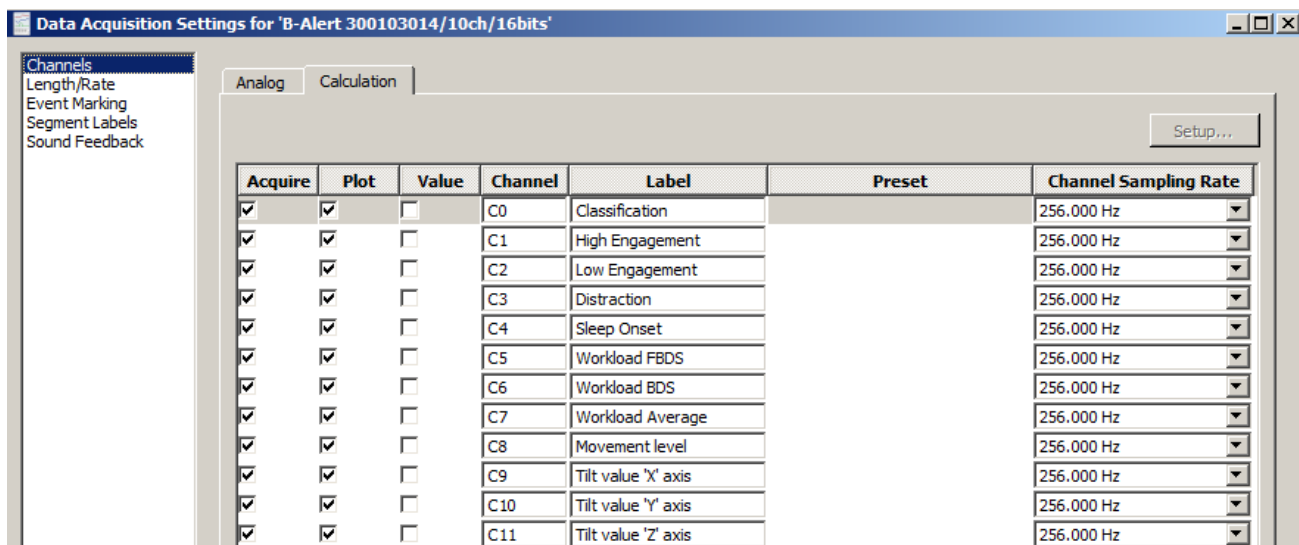
1. Plug the black connector into an Analog Output on the UIM100C module connected to the MP150.
2. Plug the blue connector into the 2-pin (ECG) input on the top of the B-Alert unit.
3. In *AcqKnowledge*, choose “MP150 > Set Up Data Acquisition > Set Up Linked Acquisitions” and select “Use the master synchronization” as the synchronization method to pair and synchronize data obtained during linked MP150 and B-Alert X10 acquisitions. This is the only configuration where the “Master Sync Device” radio button is active.

IMPORTANT: About 10-12 seconds after starting a linked MP150/B-Alert X10 acquisition, and verifying that both independent signals are being plotted correctly in *AcqKnowledge*, disconnect the CBLX10 from the B-Alert headset to avoid introducing extraneous noise into the B-Alert signal.

For further details on setting up Linked Acquisitions, see page 235 or watch the [Tutorial](#) video.

Cognitive Analysis Calculation Channels

Pre-configured calculation channels C0 – C11 become available when a subject’s B-Alert Definition File is active. These signals are mapped from the Definition File and extract cognitive workload, high/low engagement, distraction, drowsiness, movement and tilt angle data. The channel setups and presets are not editable but can be enabled or disabled as desired.



For specific information on additional B-Alert GUI software controls, see the **B-Alert** Software Manual.

Data Output

The following data is collected during a B-Alert experiment and merged into a standard *AcqKnowledge *.acq* file:

Real-Time Output file name	Description
Data file	
.edf	European data format containing nine raw and nine decontaminated EEG channels, raw ECG channel, plus derived heart rate, head movement value and head movement level
_Impedance.csv	Lists the values obtained for each channel each time impedance was measured
Automatically Generated during Acquisition – for all EEG Channels	
_Ref_Raw.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands labeled by channel (no edge-effect window)
_Ref_Class.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands labeled by channel (with Kaiser window)
Automatically Generated during Acquisition – Derived Signals	
_HR_beat.csv	Presentation of heart rate based on beat-to-beat interval
_HR_epoch.csv	Beat-to-beat heart rate interpolated to sec-by sec value
Optionally Generated with B-alert Cognitive State Classifications	
_Classification.csv	Probabilities for sleep, distraction, low and high engagement, cognitive state from DFA with greatest probability, probability of high workload based on forward and backward digit span (FBDS), backward digit span (BDS), and average of FBDS and BDS
_Diff_Raw.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands for differential channels: FzPO, CzPO, FzC3, C3C4, and F3Cz (no edge-effect window)
_Diff_Class.csv	Absolute PSD from 1 to 40 Hz, relative PSD from 1 to 40 Hz, and EEG bands for 5 differential channels FzPOz, CzPO, FzC3, C3C4, F3Cz (with Kaiser window)
_Zscore_class.csv	Updates and applies mean and standard deviation with each new second to provide z-scores for B-Alert cognitive states (sleep onset, distraction, low and high engagement, three workload measures)
_Zscore_psd.csv	Updates and applies mean and standard deviation with each new second to provide z-scores for PSD for all channels requested in initialization process

Chapter 26 Licensed Functionality: PV Loop Analysis

PV (Pressure-Volume) Loop Analysis is available through an optional license available with AcqKnowledge 4.3 or above. The license must be authorized to access this Analysis tool. To add a license to an existing MP System, please contact BIOPAC.



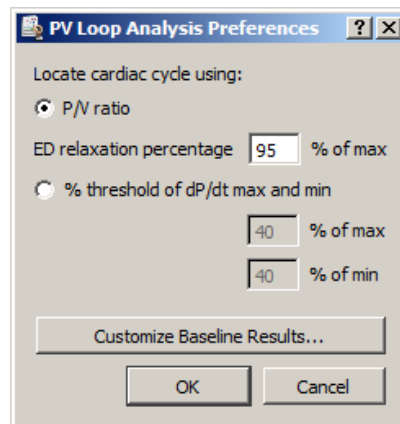
Pressure-volume loops (a.k.a. PV Loops) measure blood pressure and flow from a catheterized system. This analysis tool extracts various measures of heart function, including contractility, elasticity and ventricular characteristics. Sophisticated algorithms in this advanced analysis feature help circumvent the laborious visual process of identifying loop ranges while allowing the inclusion or exclusion of individual loops in the analysis output. Extracted measurements can be saved to an Excel spreadsheet, and selectable XY data views clearly show a wide range of outputted data. A pressure-volume loop graph template containing the necessary analog/calculation channels, data views and custom toolbars is included with the feature. (Q46-Pressure Volume Loop.gtl) PV Loop Analysis is supported in MP150 hardware only.

Loop Location

The two primary time locations for an individual PV loop range from the end systole (ES) point where the aortic valve closes, and the end diastole (ED) point where the mitral valve closes. On a PV loop XY plot, the end systole point is located at the top left corner of the loop and the end diastole is at the bottom right corner of the loop. An individual loop is defined as the extent from one end diastole to next end diastole, the equivalent of one heart beat.

PV Loop Analysis Preferences

PV Loop Analysis Preferences are accessed via the Analysis > PV Loop menu and offer two methods for locating cardiac cycles.

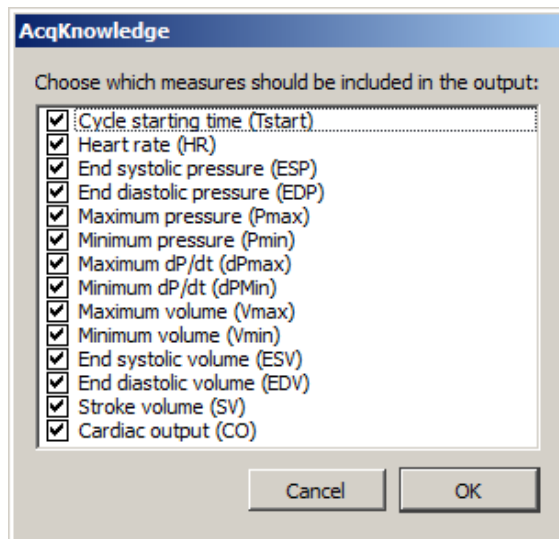


PV Loop Analysis Preferences dialog

PV Loop Analysis Preference Controls	Description
P/V ratio	When selected, ES and ED are located by analyzing the ratio of pressure over volume.
ED relaxation percentage	Percentage that P/V ratio must fall from ES in order to locate ED.
% threshold of dP/dt max and min	When selected, ES and ED are located using the pressure signal derivative only.
% of max	Defines percentage of the positive pressure derivative local maximum for ED.
% of min	Defines percentage of the negative pressure derivative local minimum for ES.
Customize Baseline Results	Displays a checkbox dialog for selecting measures to be included or excluded from baseline analysis. (See next page for complete list of available measures)

Baseline Analysis

Baseline analysis extracts basic single-loop measures over selected data ranges. These measures are used to assess proper positioning of the catheter for calibration and for assessing various changes during the experiment. Baseline analysis is accessed via Analysis > Pressure-Volume Loop > Baseline Analysis, or via the “Analyze Baseline” button on the PV Loop graph template. Measures to be extracted or excluded are accessed in the Preferences > Customize Baseline Results menu.



Available Baseline Analysis measures

The figure below shows a partial view of single-loop Baseline Analysis measures. The Save icon on the top left is used to save the measures to an external Excel file.

The image shows a window titled "Baseline Analysis Per-loop Measurements" with a menu bar (File, Edit) and a toolbar containing a Save icon. Below is a table with 7 columns (A-F) and 8 rows of data. The first row contains headers: Tstart, HR, ESP, EDP, Pmax, Pmin. The subsequent rows contain numerical values.

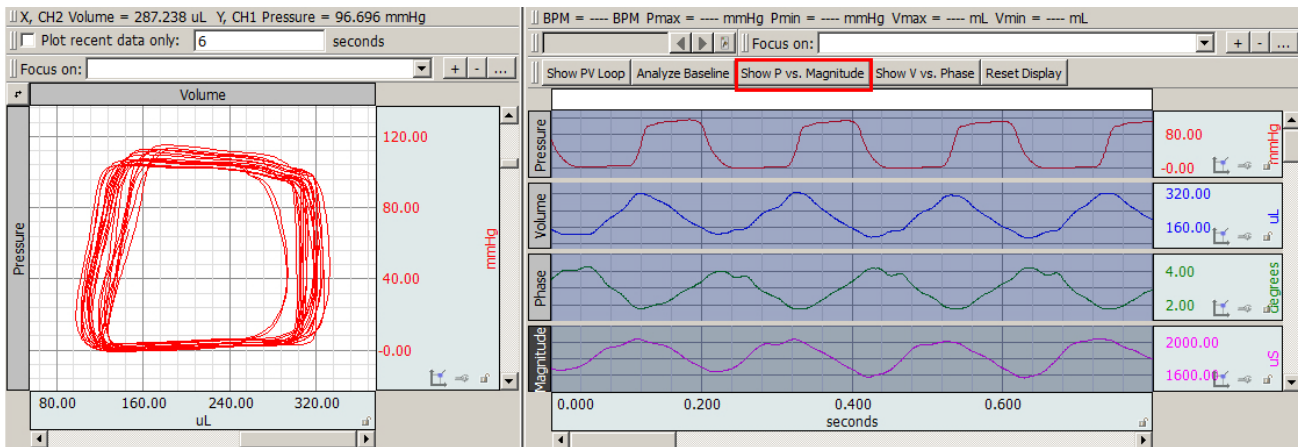
	A	B	C	D	E	F
1	Tstart	HR	ESP	EDP	Pmax	Pmin
2	0.108	287.081	111.244	9.38151	115.183	0.146491
3	0.317	289.855	107.784	9.02226	112.921	-0.292545
4	0.524	292.683	108.17	9.63438	111.351	-0.186165
5	0.729	291.262	109.714	9.23502	112.255	1.37073
6	0.935	288.462	110.898	9.74076	113.373	2.10275
7	1.143	287.081	107.585	9.75384	112.495	0.372766
8	1.352	288.462	105.309	10.3529	109.807	-0.452116

Locate ES and ED Boundaries

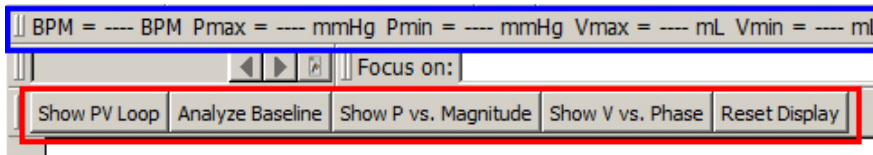
This option is accessed via “Analysis > Pressure-Volume Loop > Locate ES and ED Boundaries.” It locates the ending systole and ending diastole boundaries in a selected area and inserts events into the graph marking their location.

Realtime Display

Realtime display during PV Loop acquisitions involves setting up multiple views, toolbars and calculation channels specifically tailored for PV Loop analysis. For convenience, a Pressure Volume Loop Quickstart graph template is included with AcqKnowledge software. This template is configured for MP150 hardware and contains all above-mentioned setups, as well as two additional toolbars for realtime and post-processing data display.



PV Loop Quickstart showing graph data and Pressure vs. Magnitude XY data view



The above figure shows the additional toolbars present in the PV Loop Quickstart template, with toolbar functions explained below.

- Recent Values toolbar (outlined in blue)

The Recent values toolbar extracts the following measurements in real time from the cardiac calculation channels 42-46. (Values are displayed during acquisition.)

Heart Rate (BPM)

Maximum Pressure (mmHg)

Minimum Pressure (mmHg)

Maximum Volume (mL)

Minimum Volume (mL)

- Custom Button toolbar (outlined in red)

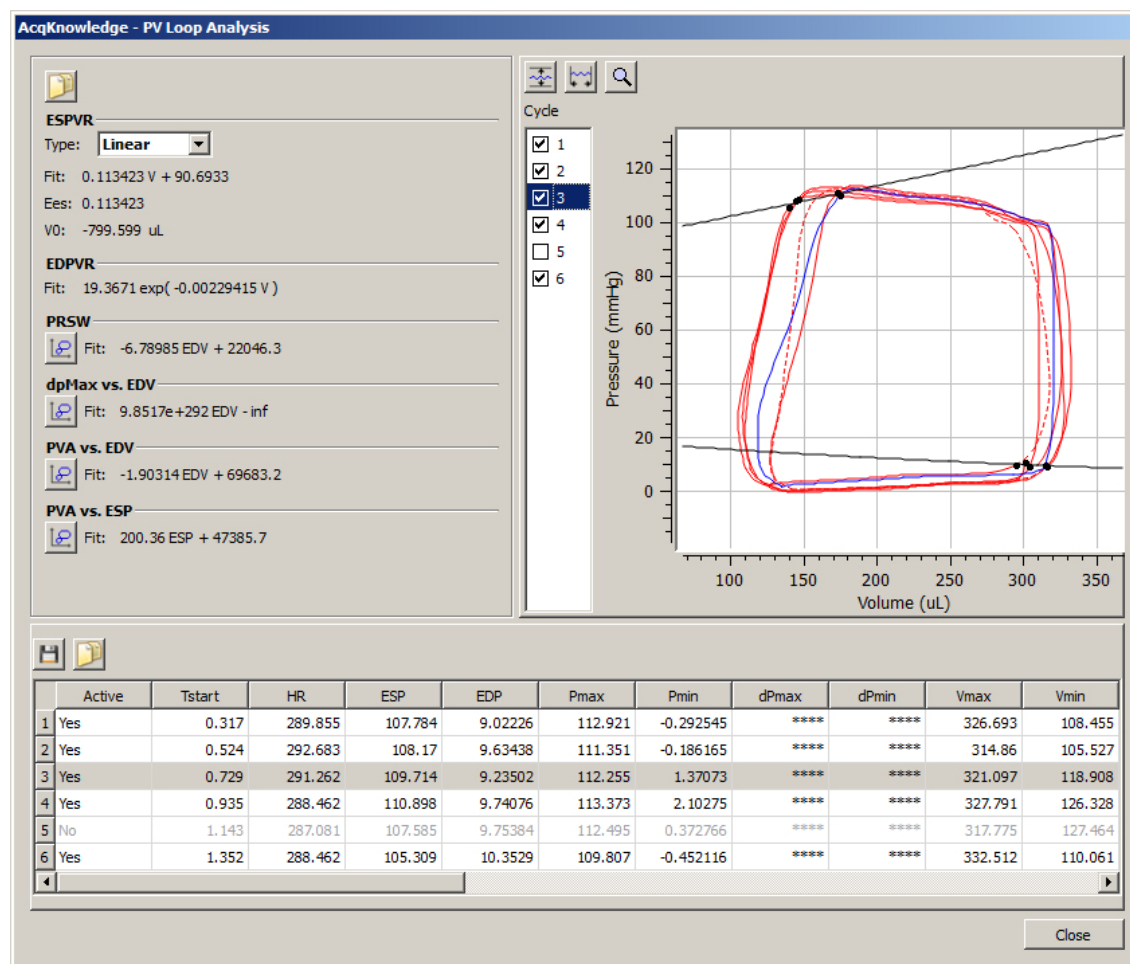
This toolbar provides quick access to the following functions during recording and in post-processing

Show PV Loop	Displays the Pressure Volume Loop in XY view. Plot shows most recent 6 seconds of pressure (X) vs. volume (Y). Useful for viewing experimental effects or determining catheter positioning.
Analyze Baseline	Performs baseline analysis on selected graph data. (A shortcut to choosing Analysis > Pressure Volume Loop > Baseline Analysis.)
Show P vs. Magnitude	Displays the Pressure vs. Magnitude data in XY view. Plot shows most recent 6 seconds of pressure (X) vs. Magnitude (Y). Useful when positioning the catheter.
Show V vs. Phase	Displays the Volume vs. Phase data in XY view. Plot shows most recent 6 seconds of pressure (X) vs. phase (Y). Useful for viewing oscillating muscle contributions in the signal.
Reset Display	Sets the display back to the default view.

Full PV Loop Analysis

After all pressure volume data has been acquired, it may be analyzed in detail using the full static analysis tool. This is accessed via Analysis > Pressure-Volume Loop > PV Loop Analysis. This tool enables the examination of all loops within the selected area of the graph. PV Loop Analysis is a manual process where outliers are defined both visually and through determining how different sets of loops affect defined parameters. When activated, if End Diastolic and End Systolic events are already present in the selected data, they will be used to define the loop boundaries. If none are present, new events will be defined using the desired location method and preferences.

The full PV Loop dialog appears as follows:



The PV Loop Analysis dialog is divided into three basic panes.

- **Loop display** (right pane)
- **Multiple loop measures** (left pane)
- **Per loop measures** (bottom pane)

The loop display shows an XY plot of volume vs. pressure. Individual loops are drawn using the waveform plot color of the pressure channel. Overlaid in black on top of the loops are two best fit curves for end systolic pressure volume relationship (ESDVR) and end diastolis pressure volume relationship (ESPVR). Use the checkboxes under 'Cycle' to include or exclude individual loops in the plot analysis. Excluded loops will appear as dotted lines and the actively selected loop will be outlined in blue. Excluded loops will also be grayed out in the per loop measure display (bottom pane).







The loop display can be rescaled by clicking on the XY graph's vertical and horizontal axis in the same manner as in any graph, and then modifying the scaling parameters.




Use the controls in the upper left of the loop display region to autoscale vertically, horizontally, and zoom data.

Multiple loop measures

Once a set of loops has been identified, various models are constructed showing ideal boundaries of pressure and volume extents for varying cardiac cycles. Additional relationships between per-loop measures are also extracted to help assess overall cardiac condition. Multiple loop measures include the following relationships and controls:

ESPVR (End Systolic Pressure Volume Relationship)	Theoretical maximum pressure for any given volume.
Type	Use to select the equation upon which to base the PV loop curve fit: Linear or quadratic.
Ees	Index of overall myocardial contractility.
V0	Theoretical volume of loop at zero pressure.
EDPVR (End Diastolic Pressure Volume Relationship)	Passive filling properties of ventricle, reciprocal of ventricular stiffness.
PRSW (Preloadable recruitable stroke work)	Pressing  displays a plot showing linear regression between stroke work and diastolic volume between loops.
dpMax vs. EDV	Pressing  displays a plot showing maximum change in pressure vs. end diastolic volume.
PVA vs. EDV	Pressing  displays a plot showing pressure volume area vs. end diastolic volume.
PVA vs. ESP	Pressing  displays a plot showing pressure volume area vs. end systolic pressure.
Other controls	Pressing  copies the loop-specific measures to the clipboard. Pressing  saves the loop-specific measures to an Excel file.

Per loop measures



	Active	Tstart	HR	ESP	EDP	Pmax	Pmin	dPmax	dPmin	Vmax	Vmin
1	Yes	0.317	289.855	107.784	9.02226	112.921	-0.292545	****	****	326.693	108.455
2	Yes	0.524	292.683	108.17	9.63438	111.351	-0.186165	****	****	314.86	105.527
3	Yes	0.729	291.262	109.714	9.23502	112.255	1.37073	****	****	321.097	118.908
4	Yes	0.935	288.462	110.898	9.74076	113.373	2.10275	****	****	327.791	126.328
5	No	1.143	287.081	107.585	9.75384	112.495	0.372766	****	****	317.775	127.464
6	Yes	1.352	288.462	105.309	10.3529	109.807	-0.452116	****	****	332.512	110.061

The bottom pane of the analysis window contains a table display of individual loop analysis results. Each loop occupies one row. Comparative measures are automatically updated upon any changes to included loops.

Each per loop measure is recorded in its own table column. The following hemodynamic measures are reported:

Measure	Abbrev.	Formula	Units	Description
Heart rate	HR	$\frac{60}{(t_{ED} - t_{start})}$	BPM	Provides the heart rate.
End systolic pressure	ESP	$P(t_{ES})$	mmHg	Blood pressure at end of systole.
End diastolic pressure	EDP	$P(t_{ED})$	mmHg	Blood pressure at end of diastole.
Maximum pressure	Pmax	$\max P(t), t \in (t_{start}, t_{ED}]$	mmHg	Maximum pressure within the loop, left endpoint exclusive right endpoint inclusive.
Minimum pressure	Pmin	$\min P(t), t \in (t_{start}, t_{ED}]$	mmHg	Minimum pressure within the loop, left endpoint exclusive right endpoint inclusive.
Maximum dP/dt	dPmax	$\max \dot{P}(t), t \in (t_{start}, t_{ED}]$	mmHg / sec	Maximum change in pressure within the loop, left endpoint exclusive right endpoint inclusive.
Minimum dP/dt	dPmin	$\min \dot{P}(t), t \in (t_{start}, t_{ED}]$	mmHg/sec	Minimum change in pressure within the loop, left endpoint exclusive right endpoint inclusive.
Maximum volume	Vmax	$\max V(t), t \in (t_{start}, t_{ED}]$	ml	Maximum volume within the loop, left endpoint exclusive right endpoint inclusive.
Minimum volume	Vmin	$\min V(t), t \in (t_{start}, t_{ED}]$	ml	Minimum volume within the loop, left endpoint exclusive right endpoint inclusive.
End systolic volume	ESV	$V(t_{ES})$	ml	Volume at ES.
End diastolic volume	EDV	$V(t_{ED})$	ml	Volume at ED.
Stroke volume	SV	$V(t_{ED}) - V(t_{ES})$	ml	Volume of blood ejected.

Measure	Abbrev.	Formula	Units	Description
Cardiac output	CO	$SV * HR = \frac{60[V(t_{ED}) - V(t_{ES})]}{(t_{ED} - t_{start})}$	ml / minute	Amount of blood pumped per unit time.
Ejection fraction	EF	$100 \frac{SV}{EDV}$	(none)	Percent of the end diastolic volume ejected during each contraction.
Maximum power	MaxPwr	$\max(P(t)\dot{V}(t)), t \in (t_{start}, t_{ED}]$	$\frac{mmHg * ml}{s}$	Maximum cardiac power within the loop, left endpoint exclusive right endpoint inclusive. With appropriate factors may be converted into Watts.
Parallel power	PIPwr	$\frac{MaxPwr}{V(t_{ED})^2}$	$\frac{mmHg}{ml * s}$	
Stroke work	SW	$\sum_{t=t_{start}}^{t=t_{ED}-\delta} \frac{(P(t+\delta) - P(t))(V(t+\delta) + V(t))}{2}$ <p>where $\delta = intersampleinterval$</p>	mmHg * ml	Work performed by the ventricle to eject the stroke volume. Equivalent to the area of the PV loop.
Arterial elastance	Ea	$\frac{ESP}{SV}$	mmHg / ml	Measure of arterial load for measuring coupling between heart and arterial system.

Relaxation Constant

The relaxation constant, or **tau**, is a measure of the shape of pressure decay during ventricular relaxation. The relaxation period is defined as the time of minimum change in pressure until the time when the pressure signal has dropped under the EDP of the previous loop (or to ED if no previous loop is located). Multiple methods are used to extract tau:

Method	Description	Units
Tau Weiss	<p>Tau parameter in best fit of pressure data to:</p> $P_0 e^{\frac{-t}{\tau}}$ <p>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.</p>	(unitless)
Tau Logistic	<p>Tau parameter in best fit of pressure data to the zero asymptote logistic:</p> $\frac{F_A}{1 + e^{t/\tau}}$ <p>where t is the time coordinate shifted such that t is 0 at the time of dP/dt minimum. Let us fix the initial endpoint such that $F_A = 2P_0$.</p> <p>The logistic fit is computed by the best linear fit to the equation $cT = Y$ where $T = t$ and $Y = \ln(\frac{2P_0}{P(t)} - 1)$, such that $\tau = \frac{1}{c}$.</p>	(unitless)
Tau Glanz	<p>The Raff-Glanz relaxation constant method is described in http://circres.ahajournals.org/content/48/6/813.full.pdf. This extends the Weiss method by allowing a non-zero asymptote to be incorporated into the relaxation model such that the formula is:</p> $P_0 e^{\frac{-t}{\tau}} + P_E$ <p>To solve for the constant, the slope a of the best fit linear regression of the series of points $[P(t), \dot{P}(t)], t \in \text{relaxationperiod}$ resulting in $\tau = -\frac{1}{a}$.</p>	(unitless)
Tau Mirsky	<p>Time interval between dP/dt minimum and when P drops below a threshold of $\frac{P(t_{ES})}{2}$.</p>	ms

Comparative Measures

After multiple loop measures are extracted, the following additional measures may be extracted for each loop to examine its relationship to the volume-relationship analyses of a set of loops and expected theoretical baselines. These measures are based upon various multiple loop measures and should be recomputed any time they are changed due to modifications to the set of loops included in the analysis: (See following page.)

Measure	Abbrev.	Description	Units
Pressure volume area	PVA	Provides a measure of the total mechanical energy produced by a ventricular contraction. From the set of loops the ESPVR model provides the theoretical baseline volume at zero pressure V_0 . The PVA for a loop is then determined from the following formula: $\frac{P(t_{ES})[V(t_{ES}) - V_0]}{2} - \frac{P(t_{ED})[V(t_{ED}) - V_0]}{4} + SW$ where SW is the stroke work for the loop.	mmHg * ml
Potential energy	PE	Provides a measure of the elastic potential energy built during the systole and stored in the ventricular wall at the onset of relaxation. From the set of loops the ESPVR model provides the theoretical baseline volume at zero pressure V_0 . The PE for a loop is then determined from the following formula: $PVA - SW$ That is the total mechanical energy minus the actual work used to eject the stroke volume.	mmHg * ml
Efficiency	Eff	Provides the fraction of the total mechanical energy used to eject the stroke volume: $\frac{SW}{PVA}$	(unitless)
Maximum time varying elastance	E _{max}	The normalized time varying elastance for an individual loop is adjusted from the theoretical baseline volume at zero pressure V_0 and is given by the Suga and Sagawa formula: $E(t) = \frac{P(t)}{V(t) - V_0}$ For a given loop, the maximum value of E(t) will occur when pressure is highest and volume is lowest, or at the time of ES: $E_{max} = \frac{P(t_{ES})}{V(t_{ES}) - V_0}$ This is also the slope of the line connecting V_0 with ESP within the XY loop plot ¹ .	mmHg / ml

 See the [AcqKnowledge PV Loop Analysis video tutorial](#) for a detailed demonstration of this feature.

Chapter 27 Licensed Functionality: Baroreflex Analysis

Baroreflex Sensitivity Analysis (BRS) functionality is available through an optional license available with AcqKnowledge 4.4 or above. The license must be authorized to access BRS functionality. To add a BRS license to an existing MP System, please contact BIOPAC.



Baroreflex analysis measures the relationship between blood pressure and heart rate and is derived from measures of blood pressure and ECG. The body regulates blood pressure to ensure proper blood flow to organs underneath different conditions, e.g. supine to standing. Baroreflex sensitivity is a measure of how quickly the blood pressure system compensates for changes in conditions, such as would be observed in increasing or decreasing exercise. Variations in baroreflex sensitivity are useful as a comparative measure between subjects and for assessing various external impacts.

The Baroreflex licensed functionality adds two additional measures to the Specialized Analysis > Hemodynamics menu.



Baroreflex Sequence Analysis

Baroreflex Sequence analysis method produces measures of Baroreflex sensitivity (BRS) by automatically locating time periods to analyze. Analysis results can be outputted to a graph channel and/or spreadsheet. The output format is selected in the Hemodynamics global preferences.

The Graph channel output consists of two channels:

- “Local BRS – Ascending” with values set to the BRS estimate slope during the time periods of all ascending Heart Rate and Systolic Blood Pressure sequences.
- “Local BRS – Descending” will have its values set to the BRS estimate slope during all time periods of descending Heart Rate and Systolic Blood Pressure sequences.

Sequence Analysis Setup Dialog

Choosing the Baroreflex Sequence Analysis option produces a dialog with the following controls:

Source channels:

- **ECG Lead II** – Selects the ECG channel for detecting heart rate
- **Blood Pressure** – Selects pressure channel for extracting systolic pressure

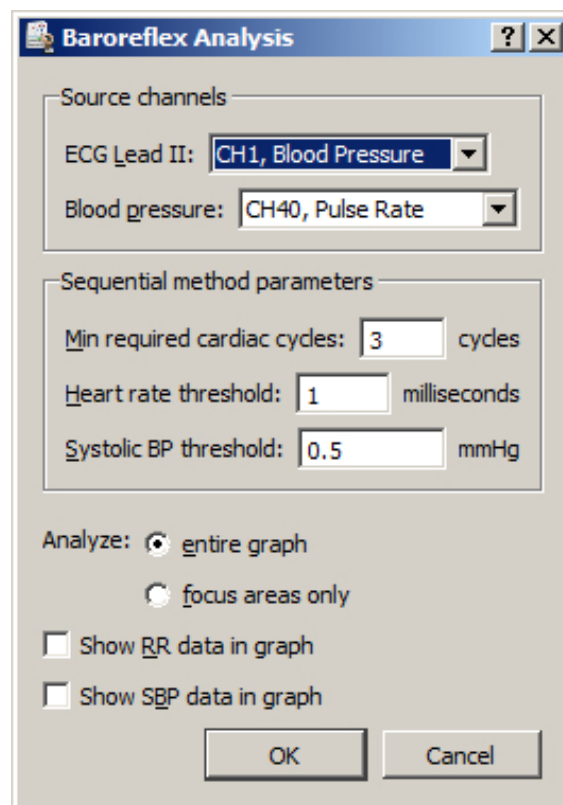
Sequential method parameters:

- **Min required cardiac cycles** – Minimum number of increasing or decreasing cardiac cycles required to initiate a sequence analysis operation
- **Heart rate threshold** – Minimum heart rate change required to initiate a cardiac analysis operation
- **Systolic BP threshold** – Minimum systolic blood pressure change required to initiate a BP analysis operation

Analyze:

- **entire graph** – The entire graph is analyzed for Baroreflex measures
- **focus areas only** – Only defined focus areas are analyzed for Baroreflex measures
- **Show RR data in the graph** – Outputs the RR interval as a graph channel
- **Show SBP data in the graph** – Outputs the systolic blood pressure data as a graph channel

Note When “focus areas only” is selected, the entire graph is still scored for QRS events and systolic BP events, but only defined focus area data is included in the analysis output.



Baroreflex Sequence Analysis description references can be found on page 518.

Baroreflex Slope Analysis

The **Baroreflex Slope** analysis method uses linear regression to determine a measure of Baroreflex sensitivity (BRS). The analysis output area displays the current BRS estimate and the slope of the best linear regression fit to all of the cardiac cycles included in the analysis.

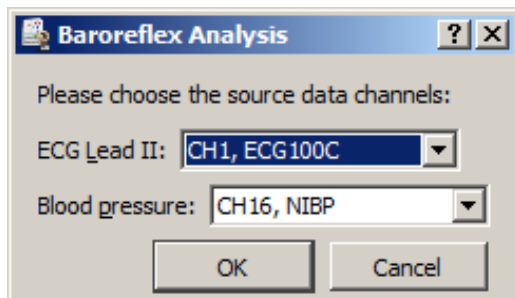
First, a source time interval is defined in the cardiac recording, generally located around regions of induced change in blood pressure. The pairs of heart rate and systolic pressure within this time interval are extracted. A linear regression of these coordinates is computed, with pressure as the x coordinate and heart rate interval as the y interval. BRS is defined as the slope of the best fit linear regression, in units of ms/mmHg.

The slope method is useful when correlating with studies using this method, performing validations, or when areas to be measured are very well known. This method can only be used on an area of selected data. If attempted on unselected data, a dialog will appear prompting for data selection with the I-beam tool or a defined focus area.

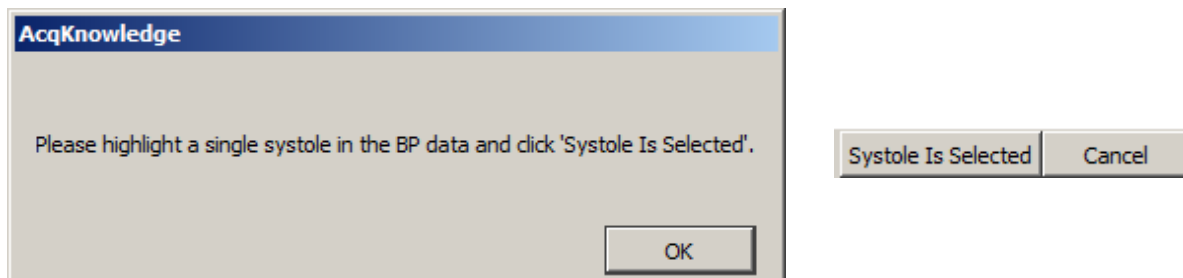
Baroreflex Slope Analysis description references can be found on page 518.

Slope Analysis Setup Dialog

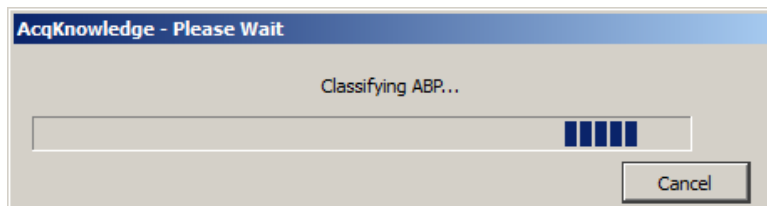
Choosing the Baroreflex Slope Analysis option produces the following dialogs:



In the initial dialog, the ECG and blood pressure channels are selected (above).



The subsequent dialogs prompt for the highlighting and selection of a systole in the BP data (above).



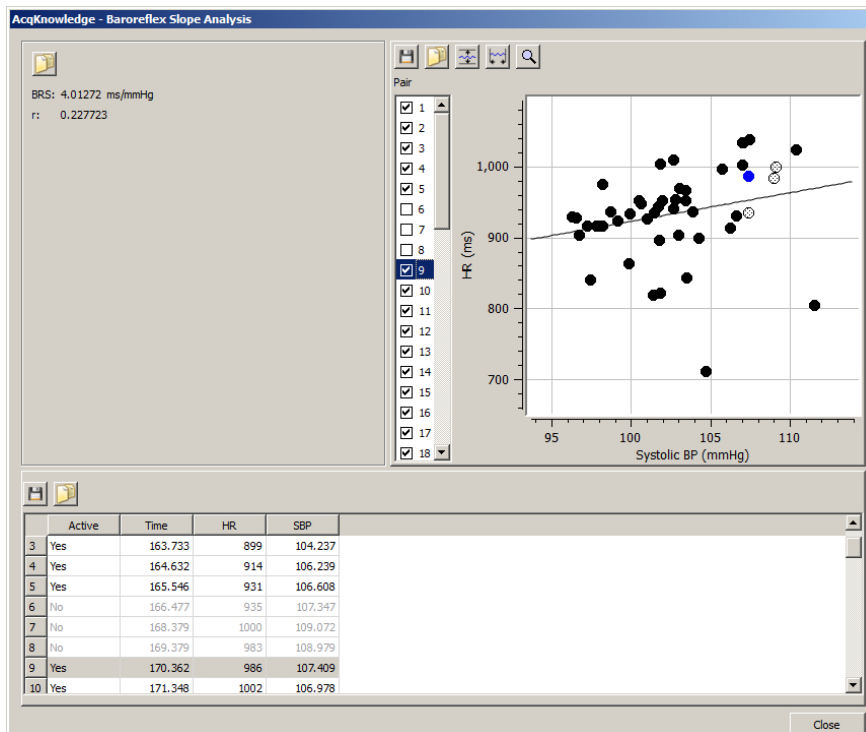
Following systole selection, the arterial blood pressure events are scored. This can take some time, depending on the width of the selected area (above).









An interactive plot (see next page) will appear, and displays the best present linear curve fit and the cardiac cycles as points on an XY plot of systolic blood pressure versus heart rate.

Include or exclude points from analysis by checking or unchecking the numbered cardiac cycle boxes, or by clicking on individual points while holding down the ALT key. When individual points are excluded or included, the best linear fit will be automatically recalculated. The cardiac cycle table at the bottom of the analysis window provides a tabular spreadsheet view, and includes:

- Active (checked) or hidden (unchecked)

- Time on horizontal scale that cardiac cycle occurred
- Heart Rate (HR) in milliseconds
- Systolic Blood Pressure (SBP) in mmHg



Control	Description
 <p>BRS: 4.01272 ms/mmHg r: 0.227723</p>	The analysis output area in the upper left corner displays the current BRS estimate, the slope of the best linear regression fit to all cardiac cycles included in the analysis. Underneath it the present r value, goodness of fit, is displayed. These values are updated dynamically if plot data is modified. The “Copy” button in this area copies the text to the clipboard.
	Copies the plot to a *.jpeg file.
	Copies the plot data to the clipboard.
	Autoscales the plot vertically.
	Autoscales the plot horizontally.
	Toggles between selection and zoom mode in the plot.
Pair <input checked="" type="checkbox"/> 1 <input checked="" type="checkbox"/> 2	<p>The “Pair” checkboxes allow for dynamic interaction with the individual heart rate (HR) and systolic blood pressure (SBP) points (also referred to as pairs). This is useful for visual identification and the exclusion of outliers.</p> <ul style="list-style-type: none"> • Check/uncheck a box to show or hide a point, or click a point while holding down the ALT key. Active points appear like this: ● • Hidden points appear like this: ○ • Click on a point to highlight it. The highlighted point will also be selected in the cardiac cycle table in the lower part of the screen. Highlighted points appear like this: ●
 	Click the left icon above the cardiac cycle table data to save table data to an Excel spreadsheet; click the right icon to save it to the clipboard.

Baroreflex Sequence Method Description

The **Baroreflex Sequence** method is described in the following papers:

Kuusela, Tom; “On the Analysis of Baroreflex Sensitivity,” 2010.

Reyes del Paso, Gustavo A; “A program to assess baroreceptor cardiac reflex function,” “Behaviour Research Methods, Instruments & Computers,” 1994, 26 (1), 62-64.

The sequence method first applies criteria to the heart rate and systolic pressure signals to locate time ranges for analysis. Given a minimum number of samples n , a minimum rate of change in heart rate RR_{thresh} , and a minimum rate of change in systolic blood pressure P_{thresh} , the sequence of RR and pressure intervals is examined for time ranges of rising and falling signals.

As indicated in section 2.5 of the Reyes del Paso paper, the pressure value at index u will actually be paired with the heart rate value at index $u+1$. This one index delay is estimated to provide a better estimation of BRS.

A rising time interval is defined as a time range where at least n consecutive data points $i \in \{j, k\}$ exhibit $RR(i+2) - RR(i+1) > RR_{thresh}$ and $P(i+1) - P(i) > P_{thresh}$, that is the heart rate and pressure signals are increasing by at least their thresholds inbetween consecutive data points. These intervals must be at least n samples but will be extended until the first sample where the signals either decrease or the increase is underneath the appropriate thresholds.

A falling time interval is defined as a time range where at least n consecutive data points $i \in \{j, k\}$ exhibit $RR(i+2) - RR(i+1) < -RR_{thresh}$ and $P(i+1) - P(i) < -P_{thresh}$, that is the heart rate and pressure signals are decreasing by at least their thresholds inbetween consecutive data points. These intervals must be at least n samples but will be extended until the first sample where the signals either increase or the decrease is less than the appropriate thresholds.

For each of these defined periods, the baroreflex sensitivity is computed using the slope method. That is, the best linear fit for each individual sequence with pressure as the x coordinate and heart rate as the y coordinate will be computed. As with the range identification, the source data used for this regression analysis will be the pressure at index u paired with the heart rate at index $u+1$. The slope of this best fit line is the local BRS, expressed in units of ms/mmHg.

The default values of the thresholds and count are defined in section 4 of the Kuusela paper as follows:

$n = 3$, $RR_{thresh} = 1ms$, $P_{thresh} = 0.5mmHg$.

Because of the delay applied to the heart rate signal from the systolic pressure, the slope method may not be directly used to validate local BRS measures from the sequential method.

Baroreflex Slope Method Description

The **Baroreflex Slope** method is described in the following papers:

Kuusela, Tom; “On the Analysis of Baroreflex Sensitivity”, 2010.

Patakas, D., Louridas, G. et. Al; “Reduced baroreceptor sensitivity in patients with chronic obstructive pulmonary disease”, Thorax 1982; 37:292-295.

Chapter 28 Licensed Functionality: Actigraphy

Actigraphy Analysis functionality is available through an optional license available with *AcqKnowledge* 4.4 or above. The license must be authorized to access Actigraphy tools. To add an Actigraphy license to an existing MP System, please contact BIOPAC.



Actigraphy is the long term study of accelerometer data correlated to subject activity. One of the primary uses of actigraphy is to conduct sleep studies in which subjects are relatively motionless for extended periods. With this *AcqKnowledge* licensed feature, long term data recordings acquired with accelerometers and BIOPAC's wireless BioNomadix, Mobita or BioHarness systems can be employed to empirically detect periods of waking and sleep. Using Actigraphy, researchers have the ability to noninvasively measure a subject's activity level, and analyze the resulting data to assess sleep disorders and other sleep related criteria. These types of studies usually span at least one day and often encompass several weeks of data.

The purpose of the *AcqKnowledge* Actigraphy analysis tool is to import and process accelerometer data from graph data files and perform further data reduction into meaningful sleep metrics. A new file format (actigraphy analysis file or *.act) allows multiple recordings to be stored and analyzed for individual subjects across multiple time periods.

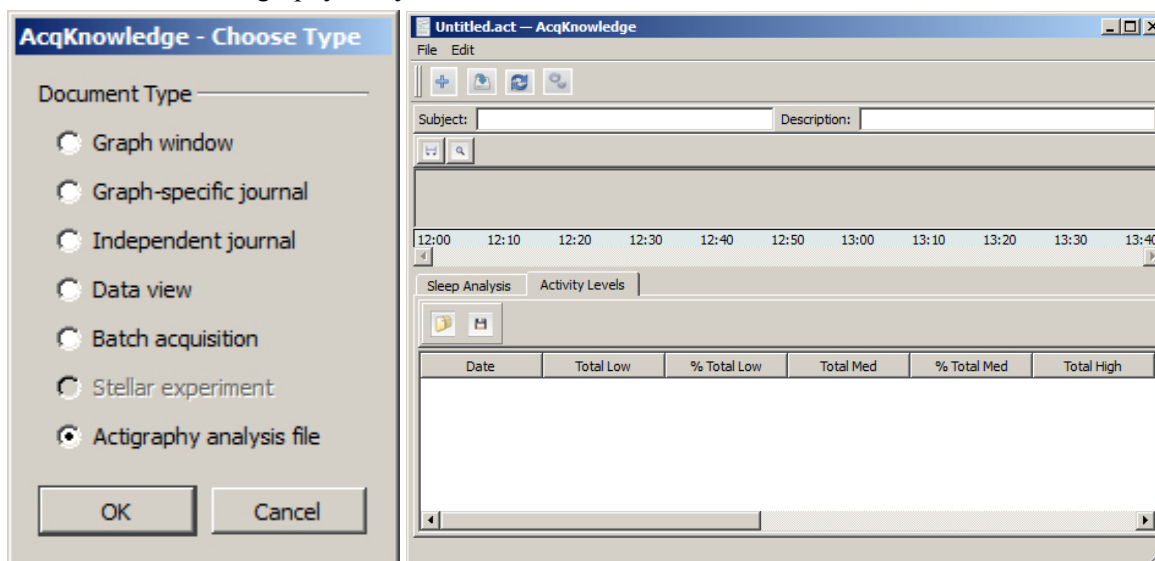
Actigraphy User Interface

A separate user interface and file format is employed for saved actigraphy analysis files within *AcqKnowledge*. The actigraphy analysis (*.act) file retains the following information and settings:

- Subject name and description
- One or more activity records. Each activity record contains the calendar date starting time and activity count data (1 minute epochs)
- Time used to separate days (default is 12:00 PM)
- Sleep onset interval detection setting
- Low activity level threshold
- High activity level threshold
- Previous analysis results for each day containing activity records (primary sleep onset, end, sleep deprived measures, and activity level analysis)
- Number of visible activity level count plots
- Index of last visible tab of analysis results in the window (sleep vs. activity)

Creating Actigraphy Files


To create a new actigraphy analysis file, select "Create new actigraphy analysis" in the Startup Wizard, or choose "File > New > Actigraphy analysis file."



This creates a blank actigraphy analysis window similar to the example above.

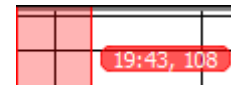
Importing Raw Accelerometer Data

AcqKnowledge records raw accelerometer data which must be imported and processed into activity counts for use in actigraphy analysis.

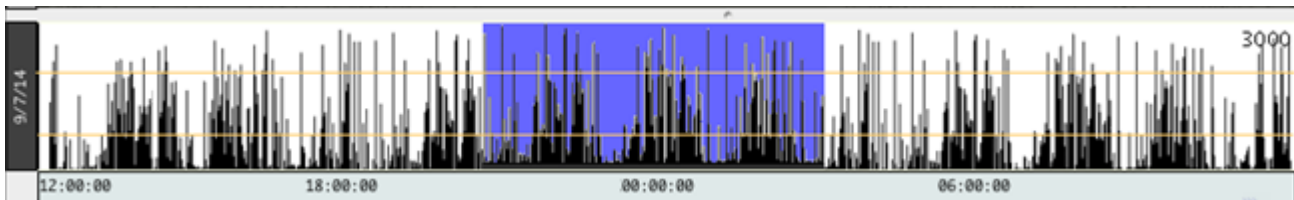
To import data from an external accelerometer sleep study file, click the  toolbar button in the Actigraphy Analysis window, navigate to the raw data file's location and choose "Open." Once the data is imported, it (along with the extracted sleep and activity level measures) can be saved as an actigraphy analysis (*.act) file.

After accelerometer data is imported into the main Actigraphy window, (or after an existing actigraphy analysis file opened) the raw data appears in graph format in the upper "activity count plot" area of the window, with all data correlating to a navigable and scalable horizontal time scale. The default scaling is for a 24 hour period, but data can be zoomed by clicking and dragging over any portion of the activity plot data.

During zoom, the rescaled clock time is displayed in red at the right border of the zoomed area. (Right)



The activity count plot area displays activity data for the subject. Its overall vertical area is split up into a variable number of plots, controllable within the Analysis Settings (see page 522). Each plot represents 24 hours of activity data. The leftmost plotted position is the starting time where time periods are to be split. The vertical label for the plot is set to the calendar date at that starting time position and the horizontal axis shows time of day in a 24 hour time format. Every time the window is first opened, data is horizontally scaled to show all 24 hours. Data plotting is vertically autoscaled so the bottom of each individual plot is zero and the top of each plot area is the maximum activity count within the entire data set.



Following data import, multiple measures are extracted and displayed in column format in the lower pane of the Actigraphy window. This pane is divided into two tabbed categories, *Sleep Analysis* and *Activity Levels*, with each category displaying its own set of measurements.

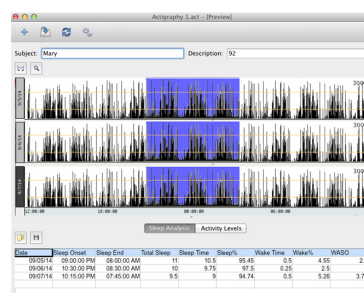
Sleep Analysis Activity Levels									
Date	Sleep Onset	Sleep End	Total Sleep	Sleep Time	Sleep%	Wake Time	Wake%	WASO	
09/05/14	09:00:00 PM	08:00:00 AM	11	10.5	95.45	0.5	4.55	2.5	
09/06/14	10:30:00 PM	08:30:00 AM	10	9.75	97.5	0.25	2.5	4	
09/07/14	10:15:00 PM	07:45:00 AM	9.5	9	94.74	0.5	5.26	3.75	

All extracted measures can be exported to a text (*.txt) or Excel spreadsheet format.

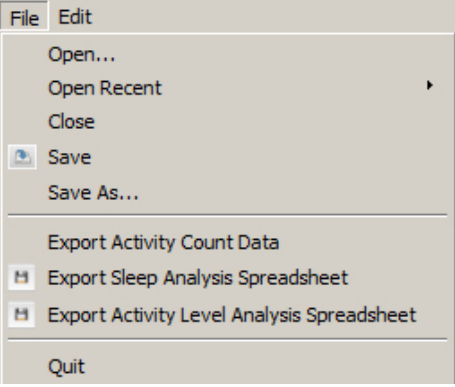
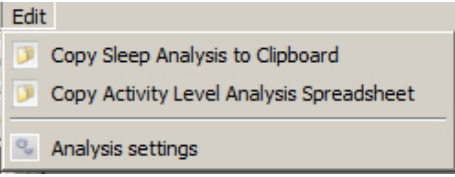






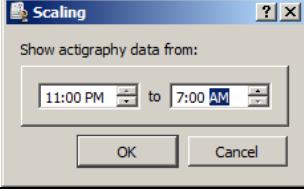
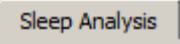
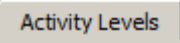


Opening an Existing Actigraphy File

To open an existing actigraphy analysis file, choose File > Open in the analysis window, navigate to the *.act file location and click "Open."


Below: Actigraphy Analysis window populated with accelerometer sleep data (Max OS X version).

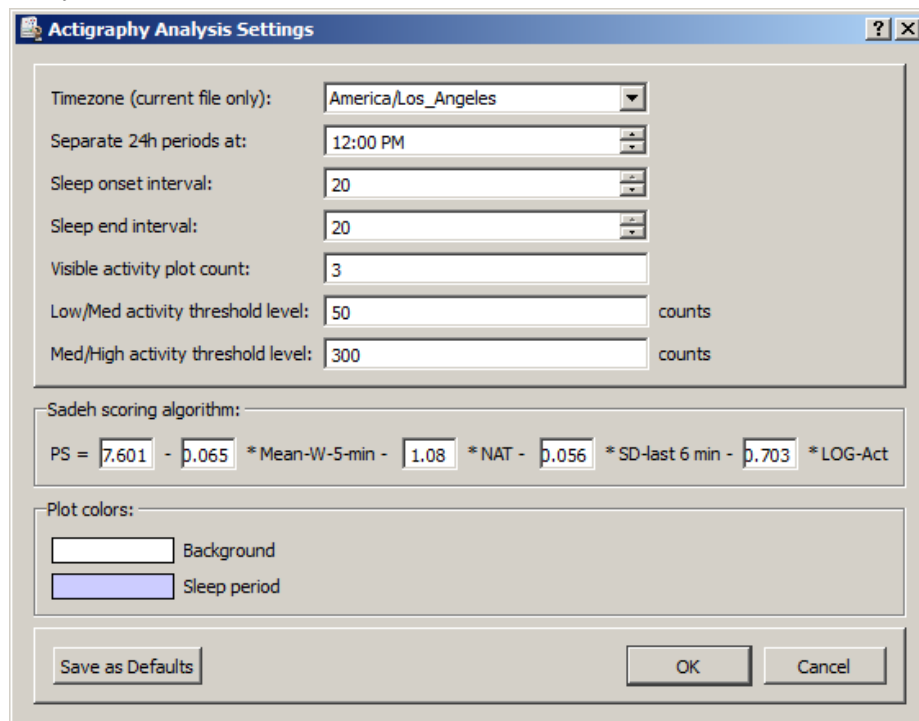


The following table explains the various menus, options and controls in the Actigraphy Analysis window:

Item	Description
	<p>File > Open – displays File Open dialog for navigating to existing *.act (actigraphy) files.</p> <p>Open Recent – displays most recently opened *.act files.</p> <p>Export Activity Count Data – saves all raw accelerometer data to a text format.</p> <p>Export Sleep Analysis Spreadsheet – saves all sleep derived measures to a spreadsheet format.</p> <p>Export Activity Level Analysis Spreadsheet – saves all Activity Level Analysis measures to spreadsheet format.</p> <p>Quit</p>
	<p>Edit > Copy Sleep Analysis to Clipboard – Exports sleep derived measures to clipboard.</p> <p>Copy Activity Level Analysis Spreadsheet – Exports activity level analysis information to clipboard.</p> <p>Analysis settings – opens the Actigraphy Analysis Settings setup dialog. See details on page 522.</p>
	<p>Add/Import – use to navigate to and import external accelerometer data file into the Actigraphy Analysis “activity plot” window.</p>
	<p>Save – saves any changes to the imported data file and Actigraphy window settings.</p>
	<p>Reanalyze – manually reanalyzes data to locate primary sleep periods and repopulates the derived measure table.</p>
	<p>Settings – opens the Actigraphy Analysis Settings setup dialog. See details on page 522.</p>
Subject: <input type="text" value="Laura"/>	<p>Field for entering text identifying Subject.</p>
Description: <input type="text" value="Sleep Study #17"/>	<p>Field for entering text describing pertinent study information.</p>
	<p>Autoscale – horizontally utoscales the activity plot data back to the original 24 hour period.</p>
 	<p>Scaling – time scaling button. Opens setup dialog for adjusting the time range of the Actigraphy window’s plotting area.</p>
	<p>Tab for displaying sleep derived measures extracted from the data file under analysis. For a list of specific sleep derived measures, see page 524.</p>
	<p>Tab for displaying activity level measures extracted from data file under analysis. For a list of specific activity level measures, see page 524.</p>
	<p>Copy text – copies sleep derived measures to clipboard. (Performs same function as Edit > Copy Sleep Analysis to Clipboard).</p>
	<p>Export spreadsheet – exports sleep derived measures to a spreadsheet. (Performs same function as File > Export Sleep Analysis Spreadsheet).</p>

Actigraphy Analysis Settings

As stated in the previous section, choosing “Edit > Analysis settings” (or clicking the  toolbar button) generates the Analysis settings setup dialog. This is where important parameters are selected and applied to the Actigraphy Analysis file.



The following table describes the various parameters available in this dialog.

Actigraphy Analysis Settings Controls

Item	Description
Time Zone (current file only):	Indicates the time zone in which the time data is being analyzed. This varies on a file-by-file basis and is set to the computer's time zone when the file is first created.
Separate 24h periods at:	Provides the cutoff where data is split into new 24 hour blocks for analysis. Only one primary sleep period is allowed per block, so this should be set to a time when the subject is expected to be awake. Default setting is 12:00 PM.
Sleep onset interval:	Selects the time interval for detecting onset of sleep. 10, 15, or 20 minute intervals are available. Default value is 20 minutes.
Sleep end interval:	Selects the time interval for detecting end of sleep. 10, 15, or 20 minute intervals are available. Default value is 20 minutes.
Visible activity count plot:	Selects the number of 24 hour activity plots to display in the actigraphy analysis window. Default value is 3.
Low/Med activity threshold level:	Threshold level used for separating the low and medium activity bands. Default value is 50.
Med/High activity threshold level:	Threshold level used for separating the medium and high activity bands. Default value is 300.
Sadeh scoring algorithm:	See below for separate explanation of this algorithm and associated settings.
Plot colors:	Clicking either option generates a colorwell for modifying the background or sleep period plot colors.
Save as defaults:	Saves any modified settings as a new default for subsequent Actigraphy analyses.

Sadeh Scoring Algorithm for Wake/Sleep Classification

After the activity count has been extracted from the accelerometer data, each data epoch is classified as either a **sleep** or a **wake** interval based upon a formula cited in a widely-acclaimed sleep study publication, “[Activity-Based Sleep-Wake Identification: An Empirical Test of Methodological Issues \(1994\)](#)” by Avi Sadeh, Katherine A. Sharkey and Mary A. Carskadon.

Sadeh (1994) proposed one of the classic formulas referenced in multiple papers. Given the activity count **sequence** A , this heuristic defines the “probability of sleep”.

The following table contains derived measures with formulas as described in Table 1 of Sadeh (P. 202):

Measure	Description	Abbreviation	Formula(s)
Mean-W-5-min	Windowed mean of overall activity count in the present interval and the 5 minutes prior to and after the present interval.	M	$M(i) = \frac{\sum_{k=i-5}^{k=i+5} A(k)}{11}$
SD-last 6 min	Standard deviation of a 6 minute activity window including the present interval.	S	$A(i) = \frac{\sum_{k=i-5}^{k=i} A(k)}{6}$ $S(i) = \sqrt{\frac{\sum_{k=i-5}^{k=i} (A(k) - A(i))^2}{5}}$
NAT	Number of intervals within an 11 minute window centered on the current interval having activity counts within this example range [50, 100).	N	$T(i) = \begin{cases} 1 & \text{iff } 50 \leq A(i) < 100 \\ 0 & \text{iff } A(i) < 50 \vee A(i) \geq 100 \end{cases}$ $N(i) = \sum_{k=i-10}^{k=i+10} T(k)$
LOG-Act	Natural logarithm of the current activity count plus 1.	L	$L(i) = 1 + \ln A(i)$

Given these source parameters, the probability of sleep **PS** is defined on page 202 of Sadeh (1994) as:

$$PS(i) = 7.601 - 0.065M(i) - 1.08N(i) - 0.056S(i) - 0.703L(i)$$

If PS is negative, the minute at **interval** i is classified as a waking interval. If PS is zero or positive the interval is classified as a sleep interval.

The default scoring algorithm can be modified if desired in the Sadeh scoring algorithm portion of the Actigraphy Analysis setup window. All fields for described measures are editable.

Sadeh scoring algorithm:

PS = - * Mean-W-5-min - * NAT - * SD-last 6 min - * LOG-Act

Sleep Derived Measures (Sleep Analysis)

After the primary sleep period has been located, it will be further subdivided into “bouts.” A “bout” is a contiguous section of data that has been classified as either wake or sleep.

Once the primary sleep period has been located in the data file, the following measures are extracted:

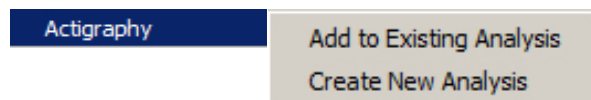
Measure	Description
Date	This is the calendar date for the start of the primary sleep period. For most normal sleep periods the ending time will be assumed to be the next day; the date is for the start of the sleep cycle.
Sleep Onset	Starting time of the primary sleep period.
Sleep End	Ending time of the primary sleep period.
Total Sleep	Total duration of primary sleep interval.
Sleep Time	Number of minutes in the primary sleep interval classified as sleep.
% Sleep	Total percentage of the sleep period that was spent in the sleeping state.
Wake Time	Number of minutes within the primary sleep interval classified as waking.
% Wake	Total percentage of the sleep period that was spent in the waking state.
WASO (Wake After Sleep Onset)	Number of minutes after the initial sleep onset period to the first epoch classified as waking.
Sleep Bouts	Total number of sleep bouts within the primary sleep period.
Mean Sleep Bout Len	Average length of a sleep bout in minutes.
Wake Bouts	Total number of wake bouts within the primary sleep period.
Mean Wake Bout Len	Average length of each wake bout within the primary sleep period.

Activity Level Measures

The following measures are extracted from Activity Level Analysis.

Measure	Description
Date	Calendar date and starting time of the period being analyzed.
Total Low	Total low activity time for the entire period in minutes.
% Total Low	Percentage of the entire period spent in the low activity state.
Total Med	Total medium activity time for the entire period in minutes.
% Total Med	Percentage of the entire period spent in the medium activity state.
Total High	Total high activity time for the entire period in minutes.
% Total High	Percentage of the entire period spent in the high activity state.
awakeLow	Time spent in a low activity state when subject was not sleeping.
awakeLowPercent	Percentage of time subject was in a low activity state when not sleeping.
awakeMedium	Minutes in the medium activity state while subject was not sleeping.
awakeMedPercent	Percentage of time subject was in a medium activity state when not sleeping.
awakeHigh	Minutes in the high activity state while subject was not sleeping.
awakeHighPercent	Percentage of time subject was in a high activity state when not sleeping.

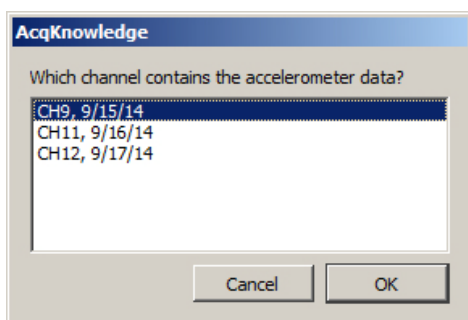
Actigraphy Specialized Analysis



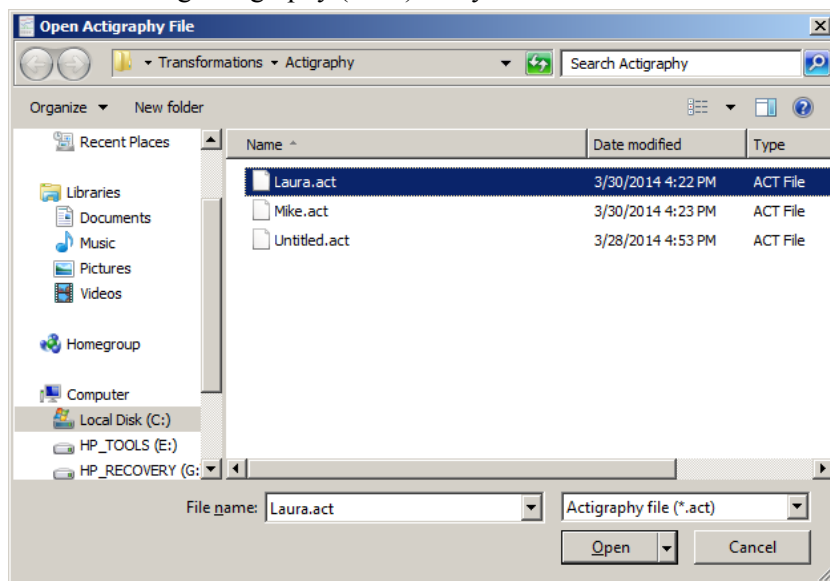
The Specialized Analysis menu contains options for performing Actigraphy import and analysis on any currently-open *AcqKnowledge* data files. These options are defined as follows:

- **Add to Existing Analysis** – allows a channel of data in the graph to be added to a pre-existing actigraphy analysis. This operation may be used often after importing or recording the next set of data from a subject. To add to an existing analysis:

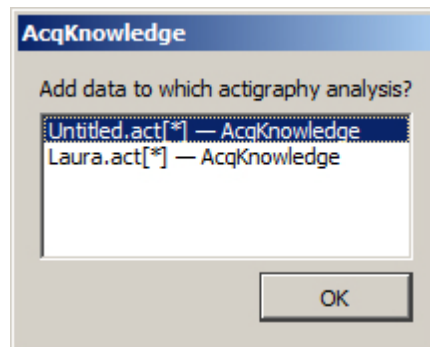
1. Open the graph containing the accelerometer data to be added to the existing Actigraphy analysis file.
2. Choose Specialized Analysis > Add to Existing Analysis.
3. If the graph contains multiple channels, select the channel containing the accelerometer data to be added and click OK.



4. Choose the existing Actigraphy (*.act) analysis file to add the new data to and click “Open.”



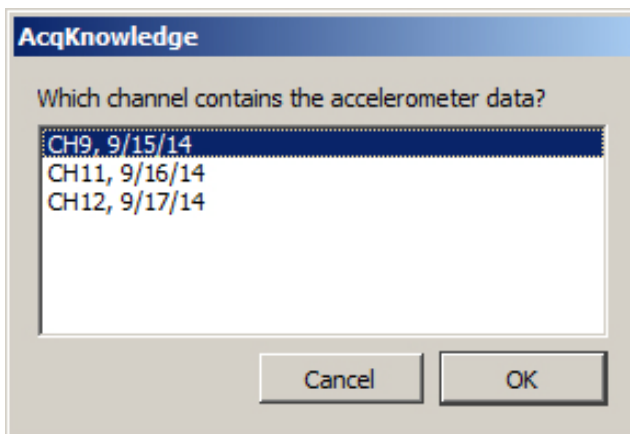
Note If multiple Actigraphy analysis files are open, you will be prompted to select the desired file:



- **Create New Analysis** – Imports and performs Actigraphy analysis on the currently-open *AcqKnowledge* graph.

To create a new Actigraphy analysis from the currently open file:

1. Choose Specialized Analysis > Create New Analysis.
2. If the graph contains multiple channels, you will be prompted to select the desired channel for import.



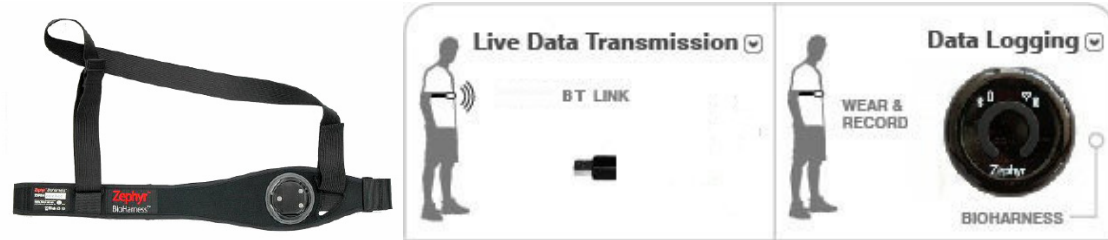
3. In the Actigraphy analysis window, choose File > Save as to save the new Actigraphy (*.act) analysis.

▶ Watch [Actigraphy Tutorial Screencast](#) for a detailed demonstration of Actigraphy.

Chapter 29 BioHarness Bluetooth

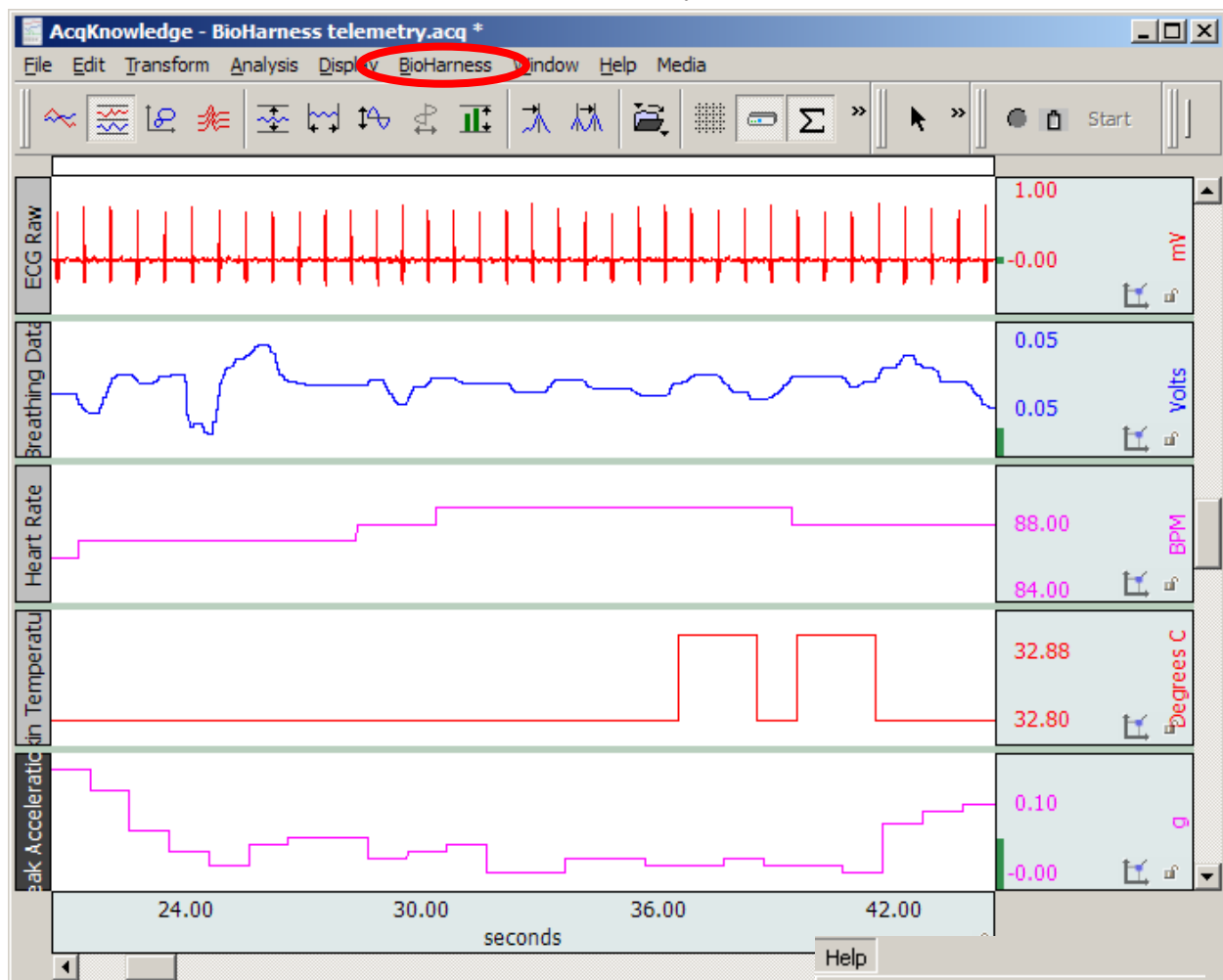
A specially licensed version of *AcqKnowledge* is included and required when used with BioHarness.

Data Acquisition and Analysis with BIOPAC BioHarness™



IMPORTANT NOTE: In *AcqKnowledge* for BioHarness

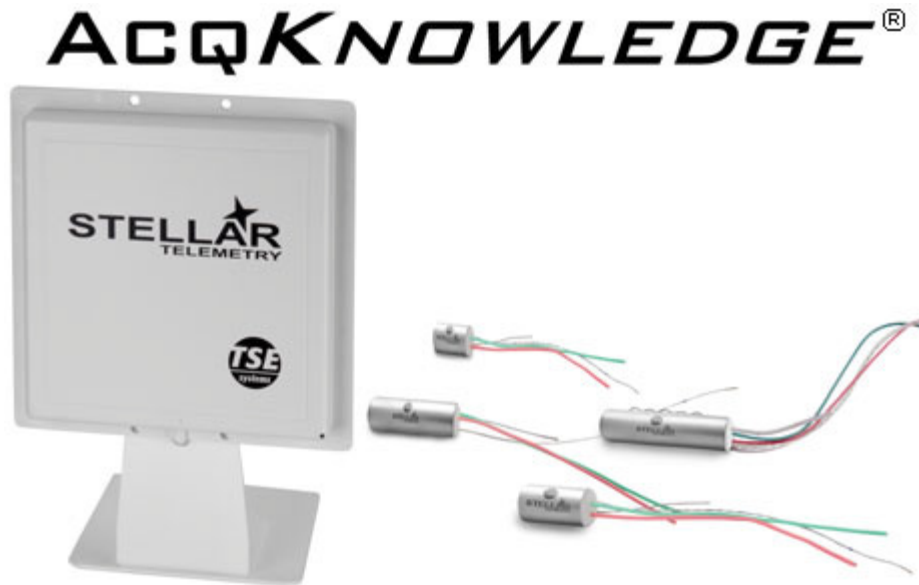
- **BioHarness** menu replaces the **MP** menu
- Analog channels can be turned on/off but not changed
- Other functionality remains the same



BioHarness™ users should see the **BioHarness User Guide** available under the Help menu and installed to the User Support folder in the program folder.

Chapter 30 Stellar Telemetry

Stellar Telemetry Control interface for existing Stellar Small Animal Telemetry System & Implants is available through optional licensing available with AcqKnowledge 4.4 or above. The license(s) must be authorized to access functionality for the specified number of implants. Please contact BIOPAC to discuss licensing options.



Stellar Telemetry System

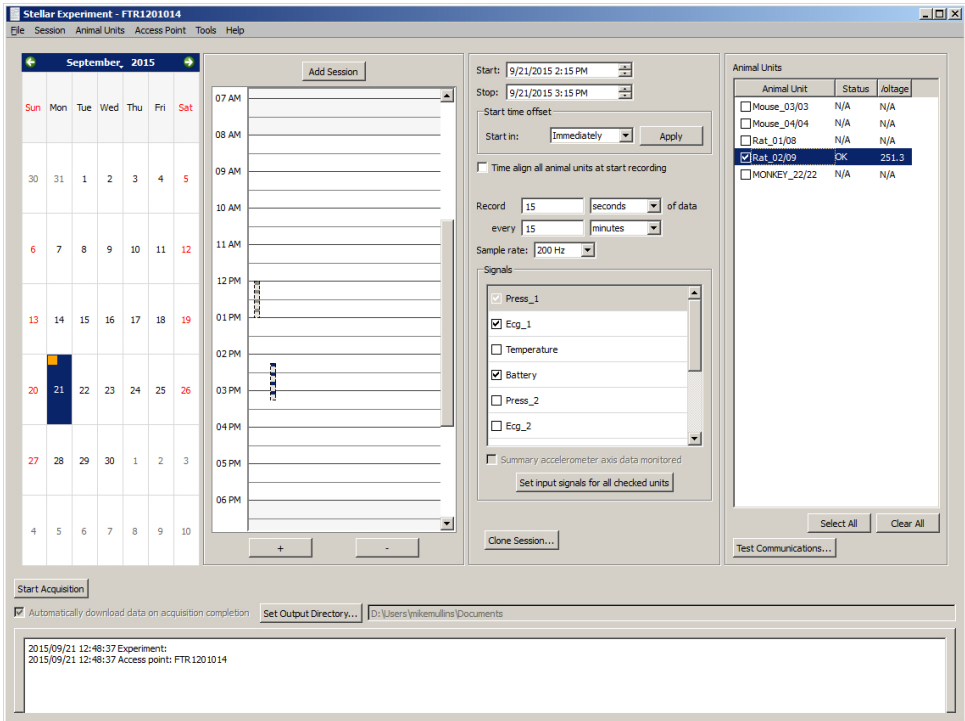
The Stellar Telemetry System wirelessly acquires and logs physiological data from single or multiple animal subjects. The system consists of a small implantable recording device with an antenna and USB base station for communicating with the implanted units. AcqKnowledge software is used to configure Stellar experiments and analyze blood pressure, ECG, temperature, and accelerometer data imported from the logging sessions. Specific data recording parameters, such as the desired signal type, recording schedule, duration/repetition interval, and selection of animal subjects are set up beforehand in AcqKnowledge, whereas the import, display and analysis of resulting data are performed following the logging session. Stellar Telemetry is a licensed feature of AcqKnowledge, and activated with a BIOPAC-provided iLok USB License Key. The number of *animal units* (allowable animal subjects controlled per experiment) is determined by the specific quantity of animal units purchased in the software license.

This chapter describes how AcqKnowledge software is used with the Stellar Telemetry System. For information on the Stellar System hardware (setup of implantable devices, antenna and base station), see the Stellar Telemetry User Guide. For Access Point hardware driver installation and troubleshooting, see the Access Point Configuration Guide.

Before you begin: *It is important to note that the Stellar Telemetry System may lose communication with the Access Point if the computer is allowed to go to sleep, resulting in a loss of data. To prevent this from occurring, disable the computer's sleep mode prior to conducting a Stellar experiment. To disable, go to "Control Panel" > "Power Options" and set the "Change when the computer sleeps" option to "Never."*

Stellar Experiment Interface in AcqKnowledge

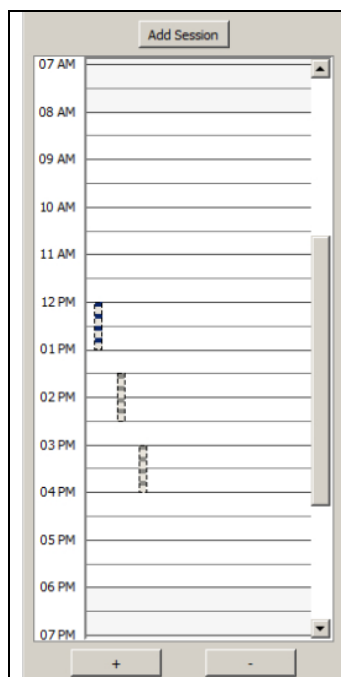
Stellar experiments are configured in AcqKnowledge in a dedicated experiment setup window. Launch the experiment setup by selecting "New Stellar Experiment" or by choosing File > New > and selecting "Stellar Experiment" in the "Choose type" option dialog.



Stellar Experiment Setup Window

Description of the Stellar Calendar Controls

CONTROL	DESCRIPTION
<p>Visual Calendar view</p>	<p>This is the calendar view in the left pane. Interactive calendar indicating date/time of scheduled logging sessions. Scheduled sessions are highlighted with orange squares. Double-clicking a date defines a new session. If a session has already occurred, double-clicking the date launches and displays <i>AcqKnowledge</i> graph files containing data acquired during that date's session. The month display can be advanced or regressed by using the arrows to the right and left of the current month display or by clicking on the month and selecting from the list (right).</p>
<p>Graphical Day view</p>	<p>Scrollable 24 hour representation of the selected calendar day. Vertical bars represent scheduled session intervals, with one “session bar” per scheduled session. Double-clicking an empty time slot creates a new 60 minute session. Single-click an existing session bar to select and highlight it. While a session is running, the active session bar becomes shaded in black, indicating elapsed time of the session in progress. The session start/end time can be adjusted to the nearest 15-minute interval by dragging the edge of a selected bar upward or downward. For more precise scheduling, adjust the start/end time using the navigation arrows in the Start and Stop fields, to the right of the Day View.</p> <p>Graphical Day View Buttons:</p> <p>Use the “Add Session” button to quickly add a session to the schedule. (This performs the same function as double clicking on a date in the Visual Calendar as described above.)</p> <p>Graphical Day View Contextual Menu:</p> <p>Graphical Day View supports the following contextual menu items. To display the contextual menu, right-click a session bar in the Day View.</p>



- **Delete:** Removes the selected session
- **Clone:** Shortcut to the “Clone Session” setup dialog (see below)
- **Delete cloned sessions:** Removes cloned sessions.

Zoom Controls:

Use the “+” and “-” buttons to zoom in or out on the graphical day view grid for optimal viewing of scheduled sessions.

Start Acquisition

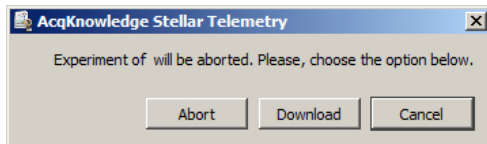
Start Acquisition

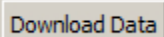
Abort Acquisition

Abort Acquisition

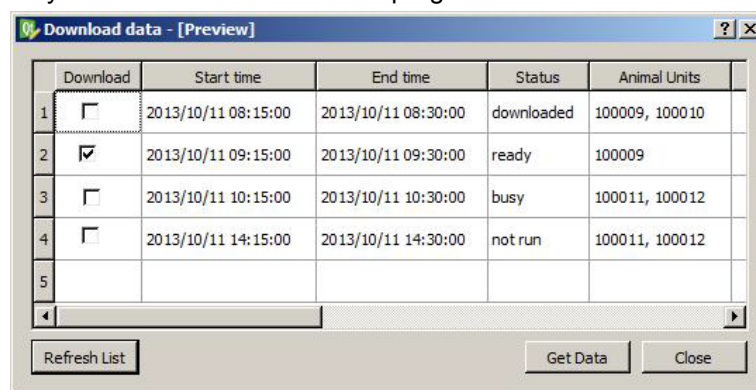
Stellar data logging will begin with the next scheduled session. Scheduled sessions do not start automatically. They must first be initiated using the “Start Acquisition” button.

During an active logging session, an “Abort Acquisition” button becomes available, which enables the session to be ended prematurely if necessary. The session can then be aborted (cancelled) or the available data downloaded (see below).



Download Data button


Allows sessions to be downloaded manually at any time. This button is only visible while a session is in progress.

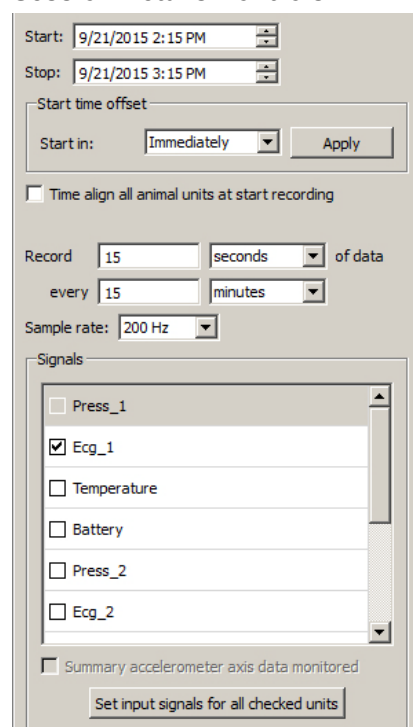


The manual download window consists of the following elements and controls:

Session List: This list displays all available sessions, status, scheduled start and stop times and animal units. The “Download” checkbox selects a session for manual download.

Refresh List: Updates status of listed sessions.

Get Data: Activates downloading process of selected sessions.

Session Details Controls


Start: 9/21/2015 2:15 PM

Stop: 9/21/2015 3:15 PM

Start time offset

Start in: Immediately Apply

☐ Time align all animal units at start recording

Record 15 seconds of data

every 15 minutes

Sample rate: 200 Hz

Signals

- ☐ Press_1
- ☒ Ecg_1
- ☐ Temperature
- ☐ Battery
- ☐ Press_2
- ☐ Ecg_2

☐ Summary accelerometer axis data monitored

Set input signals for all checked units

Sets specific scheduling parameters for the session.

Start: Displays and adjusts the start time of the scheduled session.

Stop: Displays and adjusts the stop time of the scheduled session.

Start time offset – Start in: Allows the session to be automatically scheduled to start two minutes (or more) from the present time. Clicking Apply schedules the selected time offset.

Time align all animal units: Sessions of all animal units will be started at the same start time. The start time is calculated based on the “Start” value plus 15 seconds for every animal unit in the session. Time aligned recording is useful when external stimuli or dosing is occurring at a known fixed clock time

Record – of data: Sets the duration of the data recording.

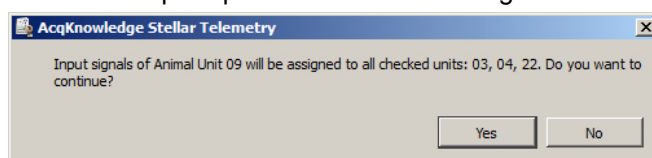
every: Sets the repetition interval of scheduled recordings.

Sample rate: Sets the data acquisition rate in samples per second (Hz). Available sample rates are 100, 200, 500 or 1000 Hz, the default being 200 Hz.

Signals: Selects the physiological signals to acquire during the session, with option to show or hide the continuous battery voltage level. Available signals are Blood Pressure (2), ECG (2), Temperature and Accelerometer (X, Y, & Z axes).

Summary accelerometer axis data monitored: Checking this option combines the three axes accelerometer data into a single integrated accelerometer signal.

Set input signals for all checked units: Use this option to apply the same input channels to all selected animal units. Signals not supported by a particular animal unit will be ignored. Using this option will generate a confirmation prompt similar to the following:

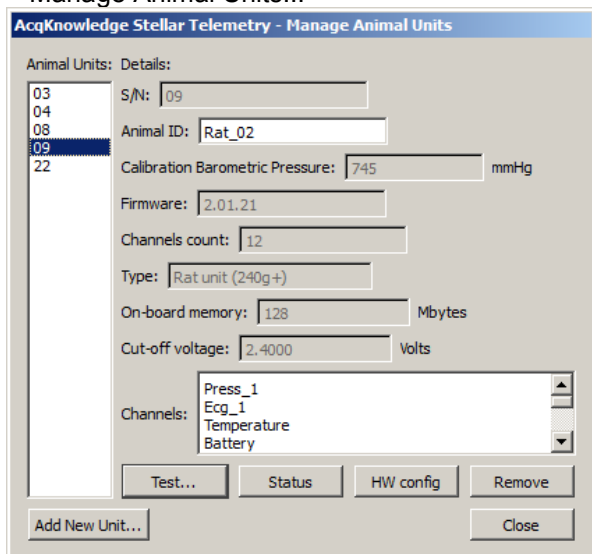


<div>Clone Session button</div> <div><div>Clone Session...</div><div>AcqKnowledge Stellar Telemetry - Clone Session</div><div>Repeat this session once every 15 minutes</div><div>Until: 4/11/2014 2:46 PM</div><div>OKCancel</div></div>	<p>Configure multiple instances of a given session without manually repeating the session setup. This is useful when an experiment extends over many weeks or months and the sessions need to be frequently repeated.</p> <p>Selecting “Clone Session” launches the following setup dialog, allowing selection of session repetition intervals and duration.</p>															
<div>Animal Units</div> <div><div>Animal Units</div><table><thead><tr><th>Animal Unit</th><th>Status</th><th>Voltage</th></tr></thead><tbody><tr><td><input type="checkbox"/> Mouse_03/03</td><td>N/A</td><td>N/A</td></tr><tr><td><input type="checkbox"/> Mouse_04/04</td><td>N/A</td><td>N/A</td></tr><tr><td><input type="checkbox"/> Rat_01/08</td><td>N/A</td><td>N/A</td></tr><tr><td><input checked="" type="checkbox"/> Rat_02/09</td><td>OK</td><td>251</td></tr></tbody></table></div>	Animal Unit	Status	Voltage	<input type="checkbox"/> Mouse_03/03	N/A	N/A	<input type="checkbox"/> Mouse_04/04	N/A	N/A	<input type="checkbox"/> Rat_01/08	N/A	N/A	<input checked="" type="checkbox"/> Rat_02/09	OK	251	<p>An “Animal Unit” refers to a specific Stellar transmitter implanted in an animal subject. This option controls which available animal units are to be included in the session. The displayed information includes unit serial number, animal ID, and last known status.</p>
Animal Unit	Status	Voltage														
<input type="checkbox"/> Mouse_03/03	N/A	N/A														
<input type="checkbox"/> Mouse_04/04	N/A	N/A														
<input type="checkbox"/> Rat_01/08	N/A	N/A														
<input checked="" type="checkbox"/> Rat_02/09	OK	251														
<div>Test Communications button</div> <div><div>Test Communications...</div><div>AcqKnowledge Stellar Telemetry - Animal Unit Communication...</div><table><thead><tr><th></th><th>Animal Unit</th><th>Test Status</th></tr></thead><tbody><tr><td>1</td><td><input type="checkbox"/> Mouse_03/03</td><td>N/A</td></tr><tr><td>2</td><td><input type="checkbox"/> Mouse_04/04</td><td>N/A</td></tr><tr><td>3</td><td><input type="checkbox"/> Rat_01/08</td><td>N/A</td></tr><tr><td>4</td><td><input checked="" type="checkbox"/> Rat_02/09</td><td>OK</td></tr></tbody></table><div>Start TestClose</div><div>Select AllClear All</div></div>		Animal Unit	Test Status	1	<input type="checkbox"/> Mouse_03/03	N/A	2	<input type="checkbox"/> Mouse_04/04	N/A	3	<input type="checkbox"/> Rat_01/08	N/A	4	<input checked="" type="checkbox"/> Rat_02/09	OK	<p>“Pings” the animal units and provides feedback on the communication status. “OK” indicates a successful communication. “Error” indicates a failed communication with an animal unit.</p> <p>Possible causes of communication failure:</p> <ul style="list-style-type: none">• Animal unit may be out of radio range of the access point.• Animal unit may be in use for a recording by another access point.• Animal unit may be frozen and require a magnetic reset.• Animal Unit battery may be dead (in which case the unit must be replaced).
	Animal Unit	Test Status														
1	<input type="checkbox"/> Mouse_03/03	N/A														
2	<input type="checkbox"/> Mouse_04/04	N/A														
3	<input type="checkbox"/> Rat_01/08	N/A														
4	<input checked="" type="checkbox"/> Rat_02/09	OK														
<div>Automatically download data on acquisition completion</div>	<p>After the final session is completed, data is automatically downloaded from active animal units into the output directory. (Currently, this option cannot be disabled.)</p>															
<div>Set Output Directory button</div>	<p>Chooses directory where <i>AcqKnowledge</i> graphs containing downloaded data will be stored. If undefined, the default path is the user's Documents directory.</p>															

Stellar-specific Setup Window Menus

File Menu	
> New Experiment	Creates a new experiment window.
> Open Experiment...	Displays a “File > Open” dialog for opening a Stellar experiment file from disk.
> Open Experiment for downloading	Opens a Stellar experiment file from disk (*.ase format) and activates manual data downloading based on the settings stored with experiment file.
> Save Experiment	Saves any changes to the current experiment.
> Save Experiment As	Displays a “Save As” dialog allowing the experiment to be saved to a new file on disk.
> Close	Closes the current experiment window, prompting to save any changes to the experiment.
> Quit	Exits <i>AcqKnowledge</i> .

Session Menu	
> New Session	Adds a new session to an experiment on the date selected in the Calendar view.
> Clone...	Displays dialog for cloning the selected session. (Performs same function as “Clone Session” button.)
> Delete	Deletes a selected session after a confirmation prompt. Disabled if no session is selected.
> Delete cloned sessions	Deletes a selected cloned session after a confirmation prompt. Disabled if no cloned session is selected.
> Start Acquisition	Reschedules a selected session to start immediately. Dimmed if an acquisition in progress or no session is selected.
Animal Units Menu	
> Add New Animal Units...	<p>The License CD contains the purchased animal unit configuration files. To add an animal unit:</p> <ol style="list-style-type: none"> 1. Choose “Add New Animal Units.” 2. Navigate to the License CD and select the file(s) with a *.set extension. 3. Click “Open.”
> Test Communications...	Performs the same function as the “Test Communications” button in the setup window.
> Manage Animal Units...	<p>Use to select or modify the animal unit configuration.</p> <p>Animal Units: Lists available animal units</p> <p>Details > S/N: Displays serial number of currently selected unit.</p> <p>Animal ID: Editable field for displaying additional information about animal unit, name, etc.</p> <p>Calibration Barometric Pressure: Indicates barometric pressure at the time the animal unit was calibrated.</p> <p>Firmware: Displays animal unit firmware version.</p> <p>Channels count: Displays unit’s available input channels.</p> <p>Type: Displays animal unit information.</p> <p>On-board memory: Displays installed memory of animal unit.</p> <p>Cut-off voltage: Displays lowest battery voltage allowable to run data acquisition.</p> <p>Channels: Displays list of animal unit input channels.</p> <p>Test...: Performs short (2-sec) test acquisition of the selected unit</p> <p>Status: Displays status information of the selected animal unit. This option is only available between recordings. Status results are not returned during an active recording.</p> <p>HW config: Displays hardware configuration of selected unit. This option is only available between recordings.</p> <p>Remove: Removes selected animal unit from the list.</p>



Add New Unit: Performs same function as “Add New Animal Units” in the Animal Units menu.

Access Point Menu

> Get Info...

Displays current access point information, including serial number, communication status, and current barometric pressure.

> Change Access Point...

NOTE: This functionality is not currently supported. Only one access point may be used with the software at a time

Tools Menu

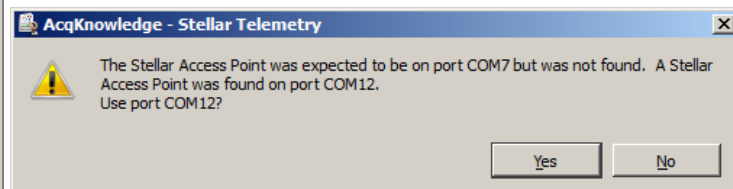
> Stellar Preferences

Set the following important parameters in the Stellar Preferences dialog:

Path to Stellar Setting Folder – Displays the path location of Stellar access point and animal units setup files.

Browse – Selects the path to location of Stellar access point and animal units setup files.

Access point COM port – Dropdown list of supported COM port numbers. The selected COM port must match the USB port number assigned to the access point. If the COM port preference setting AcqKnowledge does not match the actual COM port assigned to the access point, the following prompt will be displayed:



Choosing “Yes” will change the preference setting to match the correct COM port used by the access point.

Path to Barometric Pressure Log file – Displays the path location of the “Stellar_BaroPressure.log” file.

Browse – Selects the path to location of the “Stellar_BaroPressure.log” file.

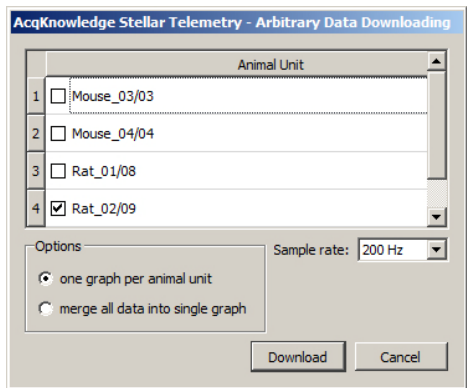
Clear BP file – Used to delete the Barometric pressure log file.

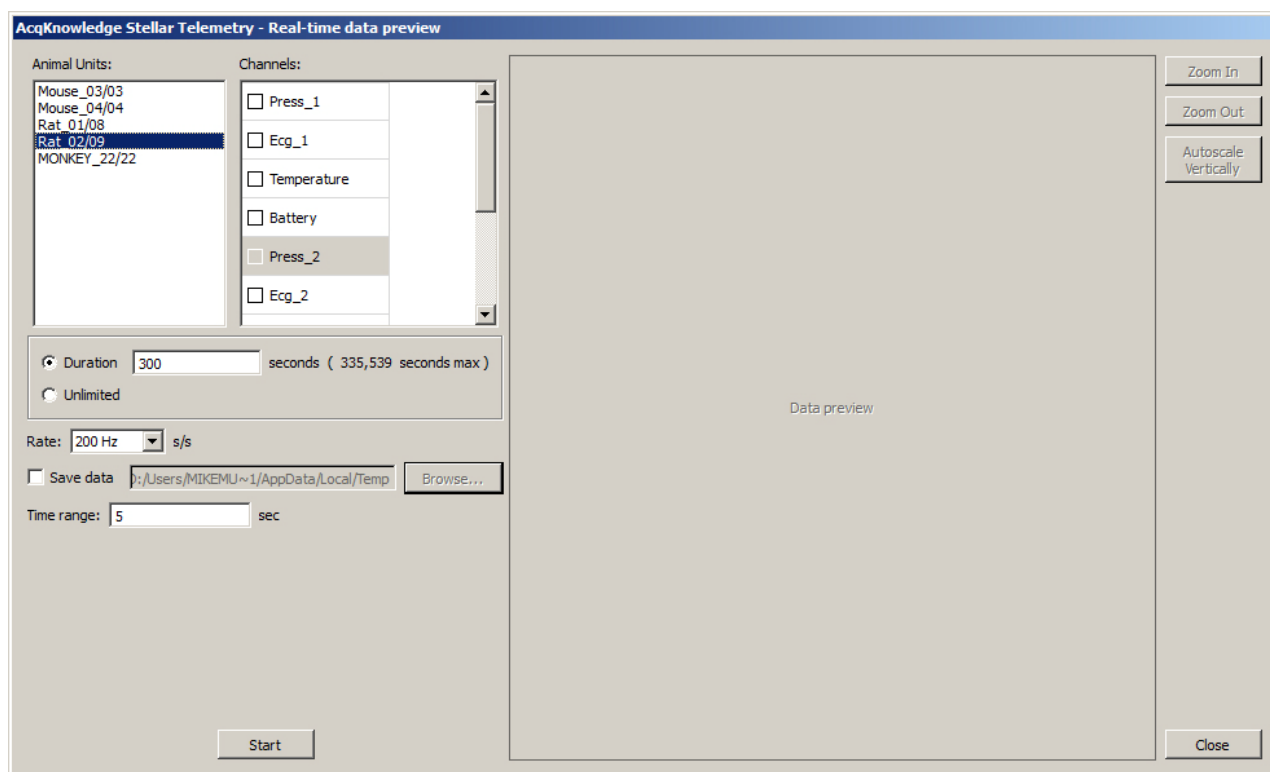
Default path to save data files – Displays the default location of Stellar data files.

Browse – Opens a browse window for setting an alternate data file path.

Set default – Resets the filepath to the original default file path. (User’s Documents folder)

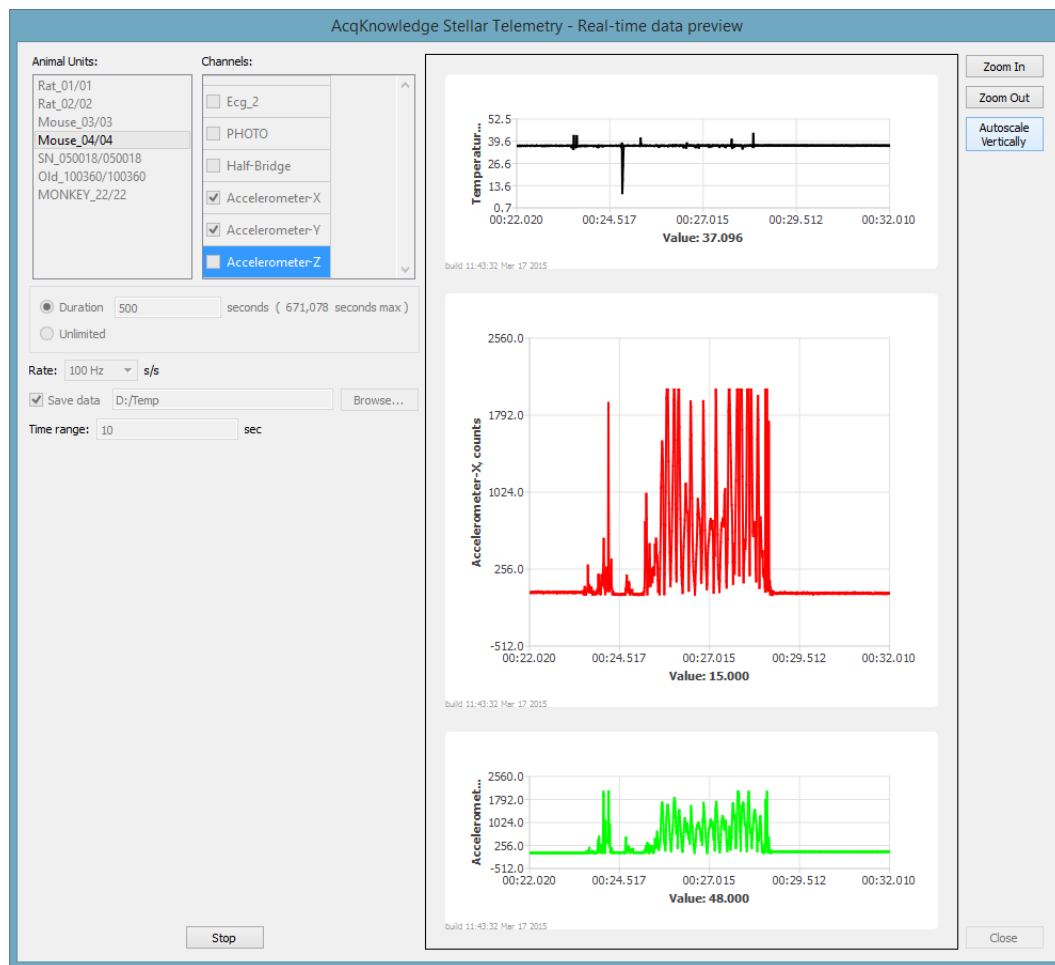
Show Log View – Displays the Journal log view by default for new experiments to show real-time experiment information. (This may also be controlled via the Options menu in the Scheduler window.)

> Show/Hide Log (Journal)	When “Show” is selected, real-time experiment status information is displayed at the bottom of the Scheduler window. This field resembles the <i>AcqKnowledge</i> Journal, but is not user-editable. (See below example.)
<pre> 2014/04/09 14:35:01 ===== 2014/04/09 14:35:01 STARTING. Session with start time 2014/04/09 14:35:00, end time 2014/04/09 14:36:00: 2014/04/09 14:35:01 STARTING. On AU = 000020. AP = FTR1201014. Rate = 200, Blocks = 3. BP = 1, T = 0, ECG = 0, Battery = 0. Interval: 00:15:00 2014/04/09 14:35:10 STARTED. Session with start time 2014/04/09 14:35:00, end time 2014/04/09 14:36:00. Animal units: 000020. 2014/04/09 14:35:10 WAITING. Session to complete at 2014/04/09 14:36:00 2014/04/09 14:36:09 GET DATA. On AU = 000020. AP = FTR1201014. Rate = 200, Blocks = 3. BP = 1, T = 0, ECG = 0, Battery = 0. Max Samples: 3072 2014/04/09 14:36:14 COMPLETED. Session with start time 2014/04/09 14:35:00, end time 2014/04/09 14:36:00. Animal Units: 000020. 2014/04/09 14:36:14 ===== 2014/04/09 14:36:15 SAVED. Session with start time 2014/04/09 14:35:00 and end time 2014/04/09 14:36:00 saved to file 'D:\Users\mikemullins\Documents 2014/04/09 14:36:15 COMPLETED. Stellar experiment completed successfully. </pre>	
> Print Log	Opens a dialog for printing contents (or a selection) of the log and for setting the desired print parameters.
> Copy Settings to Clipboard	Copies experiment settings to clipboard in text format.
> Import data from animal units 	Downloads data from selected animal units into an <i>AcqKnowledge</i> graph. <ol style="list-style-type: none"> 1. Select the animal units for data import via the Animal Unit checkboxes. 2. Select the option to create separate <i>AcqKnowledge</i> graphs for each selected animal unit or to merge all animal units into the same graph. 3. Choose the sample rate at which the animal data unit was acquired. This information is critical for accurate display of the imported data. 4. Click “Download.”
> Import data from backup file	To protect the animal unit data, <i>AcqKnowledge</i> creates a raw data backup file every time data is downloaded from the selected animal unit(s). Backup files are located at pre-defined folder titled “%temp%.” Backup file names appear in the following format: STELLAR_YYYY_MM_DD_HH_mm_ss.txt. Use this menu item to select backup file(s) and import the data into <i>AcqKnowledge</i> .
> Real time data preview	This option allows for the previewing of plotted data prior to initiating the actual experiment, and is helpful for configuring the real time data recording and plotting. Parameters such as Animal Unit, input signals, sample rate and duration can be modified and the result plotted in real time after clicking the “Start” button. Data preview graphs can be autoscaled vertically while in progress for enhanced data display. See the following page for a full explanation of the Real time data preview options.



Real time data preview setup options

Animal Units	Displays the animal units available for preview. Only one animal unit at a time may be selected.
Channels	Displays the channels available for preview. Multiple channels may be selected.
Duration	Sets the length of preview in seconds.
Unlimited	Choosing this option allows the preview to run until manually stopped.
Rate	Use this option to select the sample rate for the data display. Sample rates of 100, 200, 500 and 1000 s/s are supported.
Save data	Use this option to choose a path to save the preview data to a *.txt file format. This option is available when the duration is set to seconds. It is not supported for unlimited data previews.
Time range	Use this option to set a horizontal scale range for the data preview display. (Horizontal autoscaling is not supported in the preview graph.)
Start	Toggles between Start/Stop of data preview. When clicking Start/Stop it may take a few seconds for the application to respond before starting or stopping the preview. When this occurs, a "Please wait" dialog will appear. Avoid repeated mouse clicking within the application window during this time or AcqKnowledge may become temporarily unresponsive.



Real time data preview in progress after clicking “Start”

Animal units and Channels selected for Real time data preview are displayed as in a moving graphical format while the preview is in progress. The preview signals can be autoscaled vertically but not horizontally, so it is important to set the horizontal display in the “Time range” field prior to clicking “Start.” Enhance the preview vertical display using the “Zoom In” or “Zoom Out” buttons. (2x zoom is supported.)

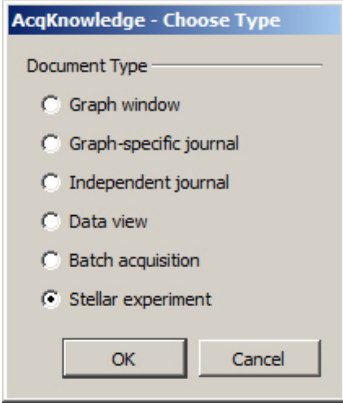
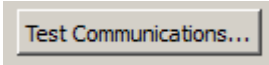
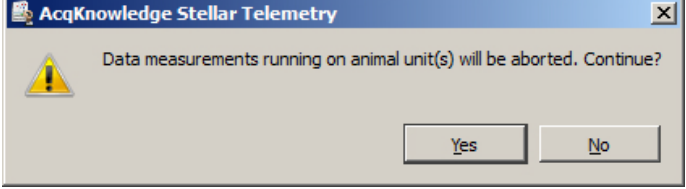
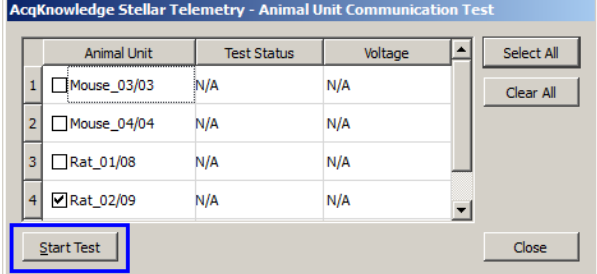
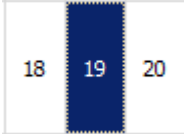
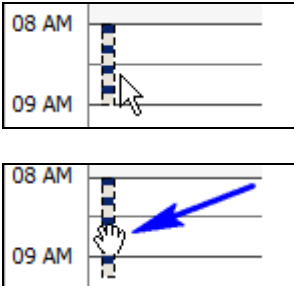
Real time data previews set to duration of seconds can be saved in *.txt file format to a user-defined location. These saved files can be reopened in AcqKnowledge using the following steps:

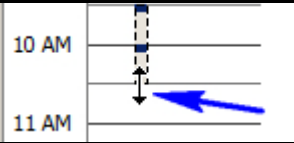
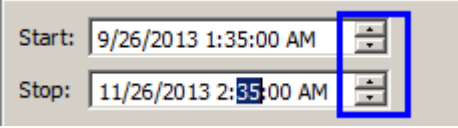
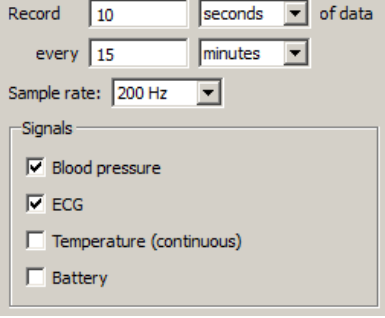
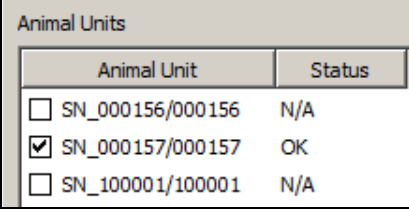
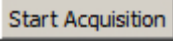
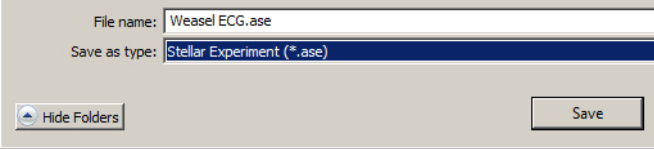
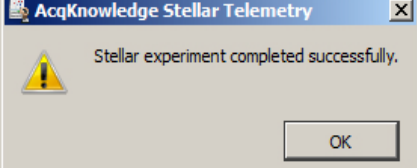
1. File > Open and choose “*.txt, *.csv” as the files of type.
2. Navigate to the saved preview *.txt file and open using the following import settings:

The 'AcqKnowledge - Read text file options' dialog box is shown. It contains the following settings: 'Wave data starts on line' is set to 6; 'finishes at' is set to 'the end of the file'; 'Sample rate interval' is set to 10 milliseconds; and 'Column delimiter' is set to comma. There are 'OK' and 'Cancel' buttons at the bottom right.

Running a Stellar Experiment

The example below is a guide to scheduling and conducting a Stellar experiment. These steps assume that the Stellar hardware is set up correctly, and successful hardware connection between the Access Point and the Animal Unit has been established. For hardware setup instructions, see the “Access Point Configuration and Troubleshooting Guide.”

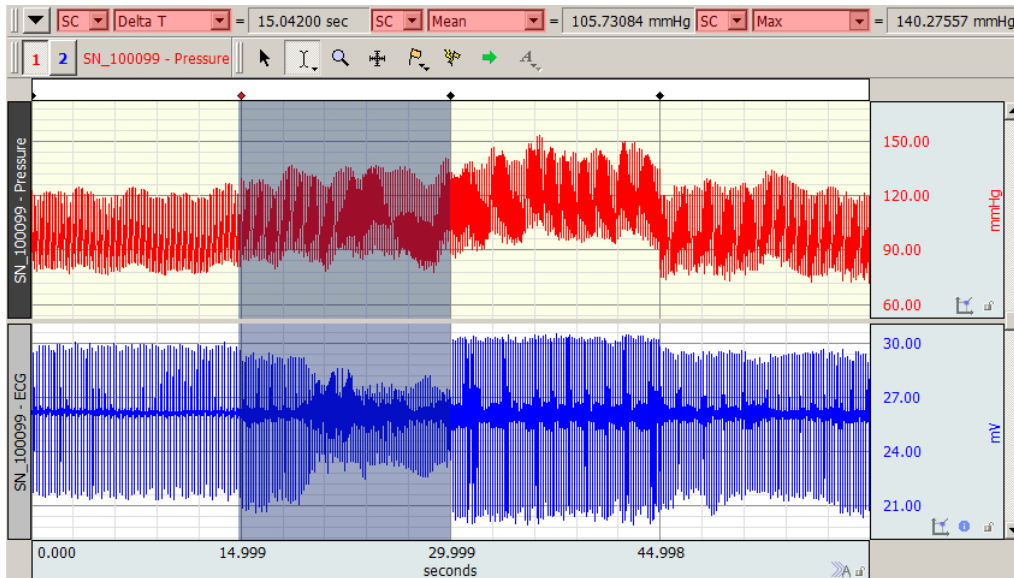
<p>1. In <i>AcqKnowledge</i>, launch a new experiment. (File > New > Stellar Experiment). This will launch the Calendar window. A “Create new stellar telemetry experiment” option is also available in the <i>AcqKnowledge</i> Startup window.</p>					
<p>2. Prior to session setup, you must first test the Animal Unit communications status.</p> <p>3. Click “Test Communications.”</p>					
<p>4. Click “Yes” to the resulting dialog to continue.</p>					
<p>5. Enable the check boxes corresponding to the Animal Units to be used during the session and click “Start Test.”</p> <ul style="list-style-type: none">A successful connection is confirmed by a Test Status of “OK.” <table border="1" data-bbox="238 1274 797 1327"><tr><td>4</td><td><input checked="" type="checkbox"/> Rat_02/09</td><td>OK</td><td>250.9</td></tr></table>	4	<input checked="" type="checkbox"/> Rat_02/09	OK	250.9	
4	<input checked="" type="checkbox"/> Rat_02/09	OK	250.9		
<p>6. The Calendar will default to the current date. If the session is to be scheduled for a future date, click on the desired date to highlight.</p>					
<p>7. Choose a time for the experiment to start by double-clicking in the Graphical Day View region or by clicking the “Add Session” button. This highlights a one-hour time period with a series of squares called a “session bar.” Each black and white square represents a 15-minute time block.</p> <ul style="list-style-type: none">Hold left mouse button down to drag the highlighted session bar to a different location on the time scale. The bar can be dragged up or down in 15-minute increments or greater.					

<ul style="list-style-type: none"> Position the left mouse button over the session bar border and drag the arrow cursor up or down to adjust the session length. 15 minute increments or greater are supported. Conversely, the session length can be more precisely modified by using the spinners in the “Start/Stop” fields. 	 
<p>8. Select the recording length, repetition, sample rate, and the signal types to be acquired.</p>	
<p>9. Select Animal Units to be included in the session by checking the corresponding boxes.</p>	
<p>10. Once the recording parameters and Animal Units are selected for the session, click “Start Acquisition.”</p>	
<p>11. Choose a file name for the experiment.</p> <ul style="list-style-type: none"> The session will start at the scheduled time and display the imported data in an <i>AcqKnowledge</i> graph when concluded. 	 

Import and Display of Stellar Data in AcqKnowledge

Following completion of a scheduled experiment, the logged Stellar data is downloaded to an AcqKnowledge graph for review and analysis. Stellar-optimized analysis tools enable selective viewing and spreadsheet output of recorded data for all selected animal units.

- Physiological signals extracted from the Stellar experiment are imported into an AcqKnowledge graph and displayed as separate channels.
- Repeated recordings (for example, 15 seconds every 15 minutes for the duration of the session), are displayed as appended segments.



Saving Graphs and Settings from Stellar Experiments

It is important to note that Stellar experiment data files and Stellar experiment settings are stored separately. Graphs containing data imported from Stellar experiments are in standard AcqKnowledge *.acq or *.gtl format, and like all AcqKnowledge graphs, are opened and saved via the main application window “File” menu.

Conversely, Stellar experiment settings and parameters are saved and opened via a separate File menu in the Scheduler window. (See Stellar-specific Scheduler menus on pages 3-5.) Stellar experiments are saved in *.ase (AcqKnowledge Stellar Experiment) format and contain the following settings:

- Access Point ID
- Output directory
- List of Animal Units with their last known status
- List of Animal Unit IDs included into the session
- Start Date/Time
- End Date/Time
- Single Record duration: value and time units
- Interval between recordings: value and time units
- Sample rate in Hz
- Input signals for the recording session: (Blood Pressure, ECG, Temperature, Accelerometer, Battery voltage)

Stellar Analysis in AcqKnowledge

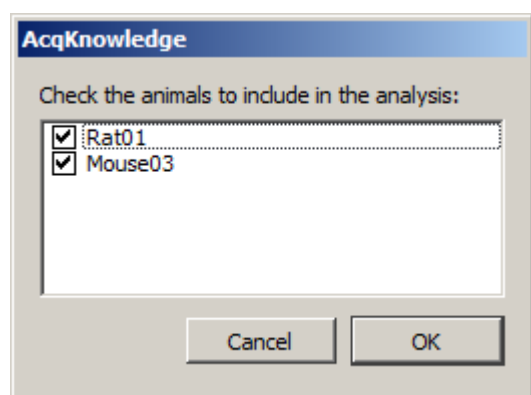
After the logged Stellar session is downloaded into an *AcqKnowledge* graph, data can then be extracted and examined using the Stellar specialized analysis tools. Access these tools by using the Analysis > Stellar menu option in the main graph window.



Analyze Stellar Data

Stellar Telemetry Analysis of 'StellarImport_Rat01_Mouse03 with KVC.acq'

Session Index	Start Time	DeltaT (sec)	Rat01 - Temp (deg C)	Rat01 - Battery (Volt)	Mouse03 - Temp (deg C)	Mouse03 - Battery (Volt)
1	Sun Jan 11 0	15.36	21.2924	207.571	37.4871	265.386
2	Sun Jan 11 0	15.36	21.2924	207.571	37.4871	265.386
3	Sun Jan 11 0	15.36	21.2924	207.649	37.4871	265.386
4	Sun Jan 11 0	15.36	21.2924	207.571	37.4871	265.386
5	Sun Jan 11 0	15.36	21.2924	207.571	37.4871	265.386
6	Sun Jan 11 0	15.36	21.2924	207.571	37.4088	265.386
7	Sun Jan 11 0	15.36	21.2924	207.571	37.4871	265.386



Creates a spreadsheet output of combined data from selected animal units included in the session. All measurements are selectable in the Stellar Analysis preferences and include the following:

- Delta T (duration of each recording interval)
- Mean Systolic Pressure
- Mean Diastolic Pressure
- Mean Mean Pressure
- Standard Deviation Systolic Pressure
- Standard Deviation Diastolic Pressure
- Mean Pulse Pressure (systolic pressure minus diastolic pressure)
- Standard Deviation Pulse Pressure
- Mean Heart Rate from Pressure
- Mean Heart Rate from ECG
- Standard Deviation Heart Rate from ECG
- Standard Deviation Heart Rate from BP
- Mean P-P from ECG
- Standard Deviation P-P from ECG
- Mean Temperature
- Battery
- Barometric Pressure (mmHg)
- Activity Sum (measures overall activity during the entire recording segment by summing all activity count data)

Note that outputted measurements are dependent upon the signal types selected in the setup window.

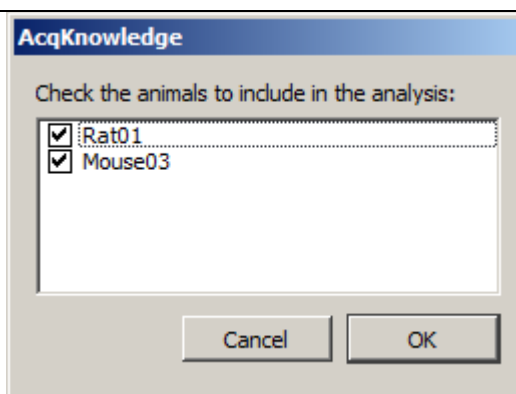
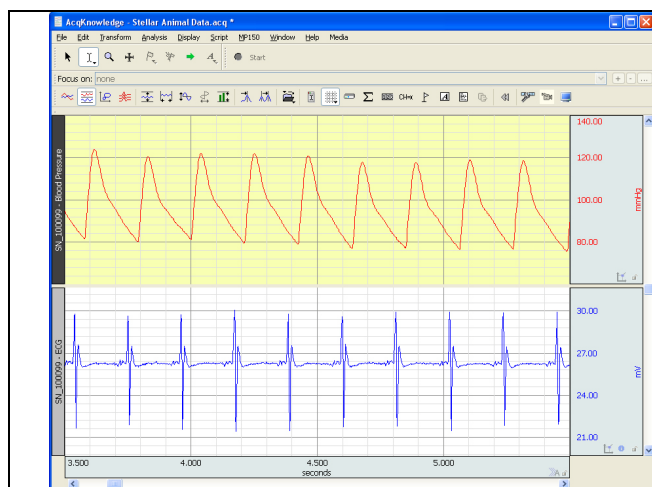
If the session includes multiple animal units, the rows extend outward to accommodate all subjects and displays measurement data for each.

Show average ECG

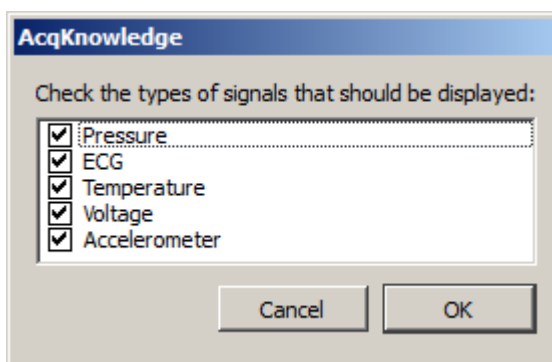
This option averages the ECG signal and provides the average ECG waveform for the entire acquisition period. When selected, *AcqKnowledge* performs an ensemble average ECG complex for each recording session and then overlaps them to obtain the average.

View Signals for Specific Animals

The following parameters can be adjusted using the "View Signals" controls:



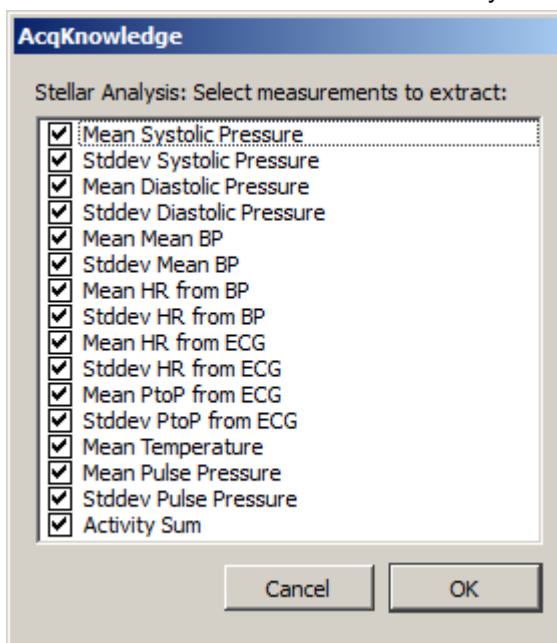
The above option selects the animal units to be included in the graph. Unchecking an animal unit hides the graph channel containing the deselected unit.



Show or hide the various signal type channels acquired during the session for a better view of a particular signal.

Preferences > Stellar Analysis: Select measurements to extract

Use this option to select or deselect the measurements to be included in the analysis.



Preferences > Heart Rate Range

Use this preference to enhance the accuracy of heart rate ranges extracted during analysis. This option (based upon the *AcqKnowledge* Find Rate windowing algorithm,) can help improve results by reducing the standard deviation of BPM values falling outside of the defined range. These results appear as selected measurements in the “Analyze Stellar Data” spreadsheet output.

In general, adjusting the maximum BPM to a lower value helps prevent excessive motion artifact from adversely affecting the heart rate results.

This preference is also useful for tuning the heart rate “window” for a specific subject type and experimental condition, or in cases where the 700 BPM default maximum heart rate may not be applicable.

To set the Heart Rate Range preference for an experiment:

1. Analysis > Stellar > Preferences
2. Dismiss the initial “Select measurements” dialog.
3. Enter the desired minimum BPM value into the top field.
4. Enter the desired maximum BPM value into the bottom field.
5. Click OK to apply the settings.

The example below shows how mean heart rate and standard deviation results can be enhanced by lowering the maximum heart rate range from a default value of 700 BPM (left) to 300 BPM (right).

56023 - Mean HR from ECG (BPM) (CH1)	56023 - Stddev HR from ECG (BPM) (CH1)	56023 - Mean HR from ECG (BPM) (CH1)	56023 - Stddev HR from ECG (BPM) (CH1)
166.019608	81.2977369	153.180505	14.8308058
127.442673	16.3411845	127.442673	16.3411845
119.07607	9.05015577	119.07607	9.05015577
108.028482	11.5076062	108.028482	11.5076062
109.886304	10.9902428	109.886304	10.9902428
154.557763	94.8174003	135.221167	35.2295007
144.951621	11.7752942	144.951621	11.7752942
133.544329	44.2635671	129.486757	5.78133416
153.638255	85.0186415	136.676308	20.2107231
129.97489	53.84373	123.006982	9.58501232
108.859904	11.8379417	108.859904	11.8379417
104.863876	12.7436838	104.863876	12.7436838

For more information about the *AcqKnowledge* Find Rate feature and windowing setup, see page 341.

Chapter 31 Mobita



Mobita is a portable wireless system for acquiring ECG, EMG, EEG, EOG, EGG and accelerometer data via a dedicated WiFi network. This hardware system is controlled by a specially-licensed version of *AcqKnowledge* (versions 4.4 and greater only).

The Mobita package consists of:

- *AcqKnowledge* software
- Battery-powered data acquisition unit
- USB WiFi dongle
- Detachable docking station (for charging unit, and connecting to computer via USB interface to download logged data and change the recording configuration)
- Detachable “confiCap” (for connecting various electrode leads, allowing wireless acquisition and data logging of up to 32 analog data channels, and up to 64 calculation channels)

The Mobita unit also has a built-in tri-axial accelerometer function, with the “X,” “Y,” and “Z” accelerometer channels appearing immediately below the available analog channels in the *AcqKnowledge* channel setup.

The purpose of this chapter is to provide an overview of the *AcqKnowledge* software interface as it relates to connected Mobita hardware. For details on Mobita installation, network setup and hardware, see the Mobita Installation and Mobita Hardware guides.

AcqKnowledge Interface in Mobita

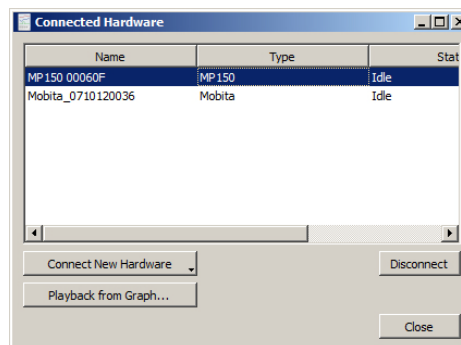
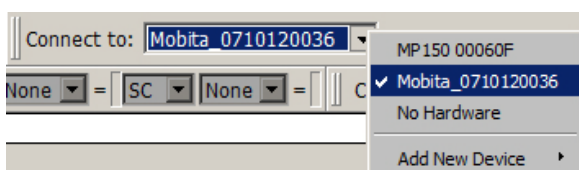
AcqKnowledge with Mobita looks nearly identical to the user interface seen when using MP150 or other supported data acquisition hardware types. Standard *AcqKnowledge* functionality is supported, with the following limitations:

- Acquisition rate is limited to a maximum of 2000 samples per second. (Other available rates are 1000, 500, 200 s/s.)
- Recording length is dictated by the maximum amount of available card storage memory in the Mobita unit. The default recording length is the standard 1800 seconds (30 minutes).
- Stimulator controls are not supported.
- One optional digital channel for use with a trigger signal is supported depending on the connections available on the cable.

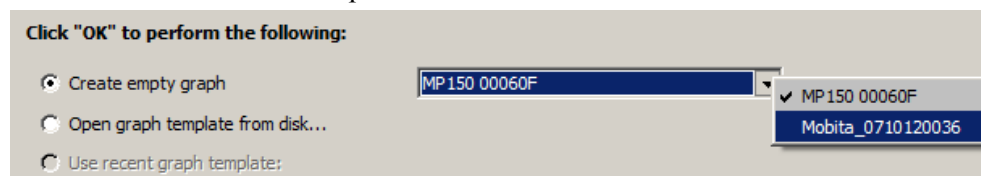
Upon launching *AcqKnowledge* with Mobita, the **Set Up Data Acquisition** window is presented with the Analog Channels tab active. Set up the desired channels and acquisition parameters here before continuing.

Selecting or Adding Mobita Hardware in AcqKnowledge

If additional hardware types were used prior to Mobita installation, the Mobita hardware can be enabled by selecting it from the “Connect to” hardware list (below left), or be added as a recognized hardware type via Hardware > “Manage Hardware Connections” and choosing “Connect New Hardware” (below right).

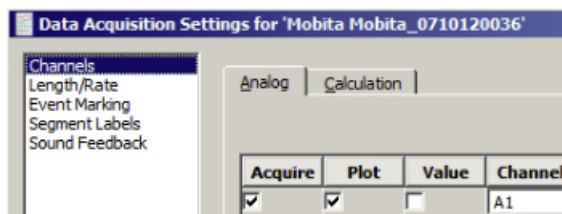
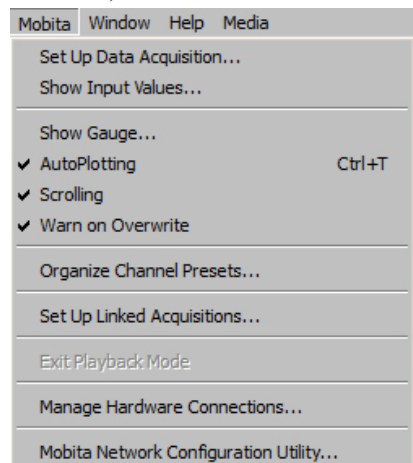


Mobita hardware can also be selected upon application launch in the Startup Wizard following Mobita installation and network setup.



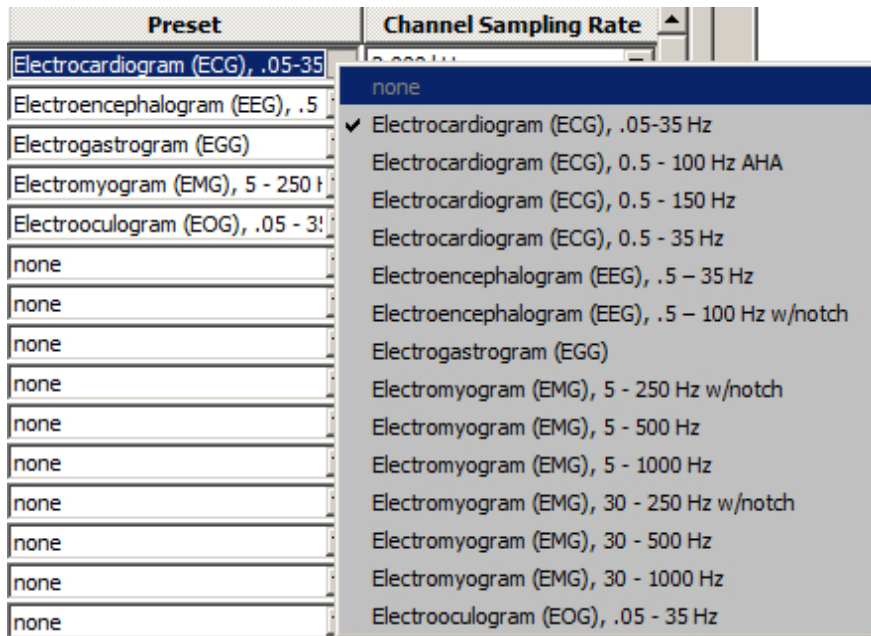
Mobita Menu

The Mobita hardware menu will look familiar to AcqKnowledge users. The “Set Up Data Acquisition” window brings up standard AcqKnowledge options for channel and recording setup. (The “Set Up Data Acquisition” window is presented by default upon application launch, with Analog Channels display enabled.)

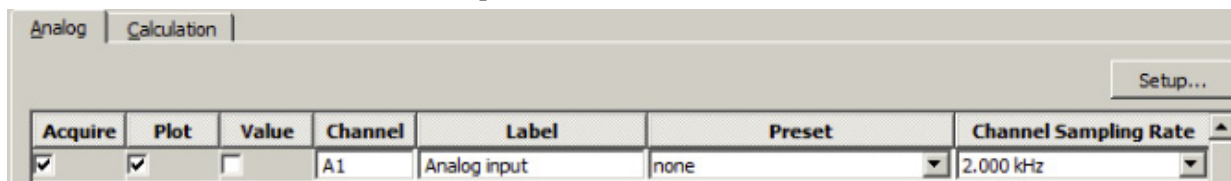


Mobita Analog Channels Setup

Up to 32 analog channels are available, with the following available presets and default filtering:



In Mobita, (as in other AcqKnowledge hardware types) channel labels, sample rates and setups are customizable, and user-defined channel presets can be created and saved.

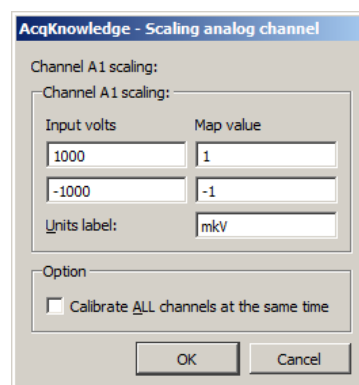
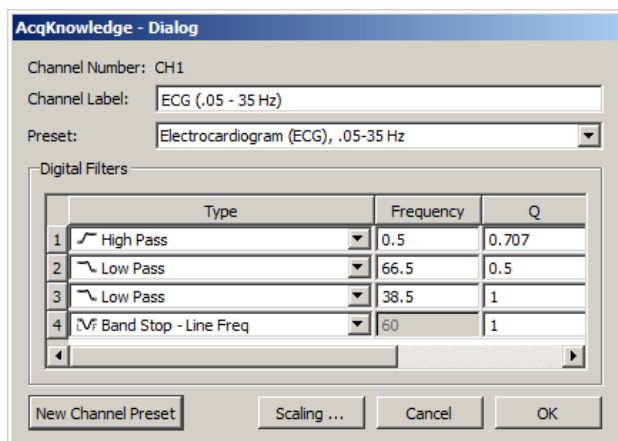


Note Mobita accelerometer channels are fixed at absolute levels and have no configurable preset options.

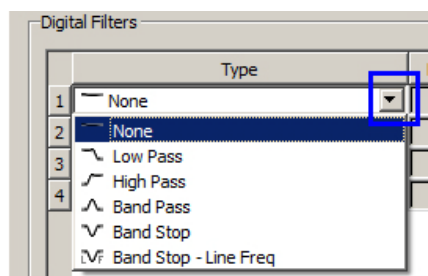
Analog Channel Digital Filters

The Analog tab's "Setup" button displays options for setting IIR filters and modifying scaling parameters for the selected channel. Up to four IIR filter types are supported per channel. The bundled presets shown above have default filter settings, but these can be modified and saved as unique channel presets if desired. (See following page.)

The below example shows default filters, scaling settings and units for the ECG (0.5 – 35 Hz) analog channel preset:

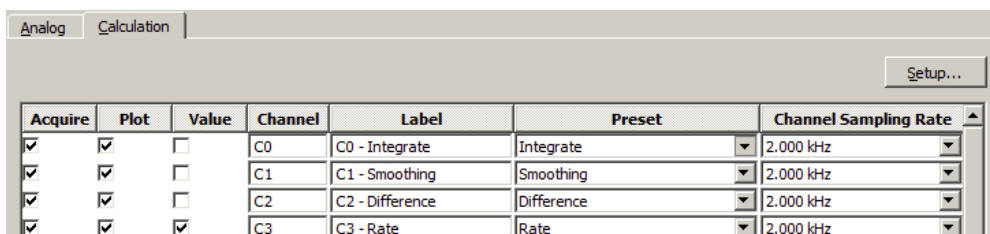


To set a filter manually, select a filter type from the pop-up menu (see below).



For details about *AcqKnowledge* IIR filters, see page 288. See also **Appendix B – Filter Characteristics**.

Mobita Calculation Channels

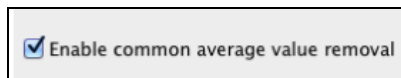


Mobita Calculation channels and associated presets operate in standard *AcqKnowledge* fashion. Choose the Calculation tab, enable a channel and select the desired preset and analog source channel. The “Setup” button opens a dialog for modifying default parameters of the selected online transformation.

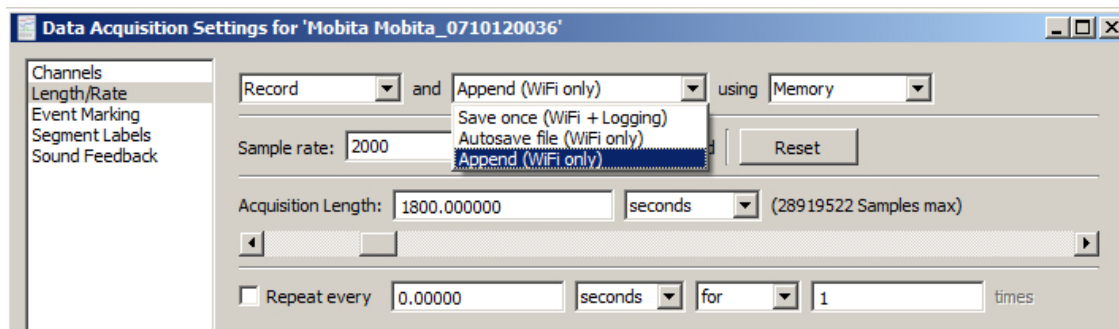
Enable Common Average Value Removal

“Enable common average value removal” is a checkbox is found at the bottom of the acquisition setup (Length/Rate) window. This option is helpful for removing common mode interference, noise, and motion artifact.

If disabled, signal and noise artifact will need to be removed manually in post-processing. BIOPAC recommends keeping this option enabled for optimal data quality.



Mobita Acquisition (Length/Rate) Settings



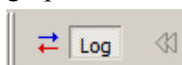
The following acquisition modes are supported in Mobita hardware:

Append and Autosave

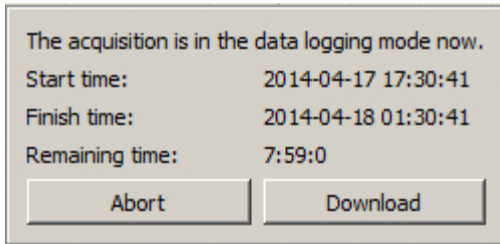
Append and Autosave modes are available for WiFi communication only, with no data stored to the Mobita hardware. Memory or disk storage options are supported both acquisition modes.

Save once (WiFi + Logging)

“Save once”(memory or disk) mode supports both WiFi communication and data logging. During “Save once” acquisition, data is logged on the Mobita hardware and streamed wirelessly into the *AcqKnowledge* graph. When acquiring data in this mode, note the “Start/Stop” button status is replaced by “Log.”



Mobita will log data for the selected acquisition length, or until hardware memory is filled to capacity. When the acquisition is complete, all logged data will be present in the AcqKnowledge graph. If the “Log” button is clicked before the acquisition is complete, (or if the subject wanders out of wireless range), a logging status dialog is presented:

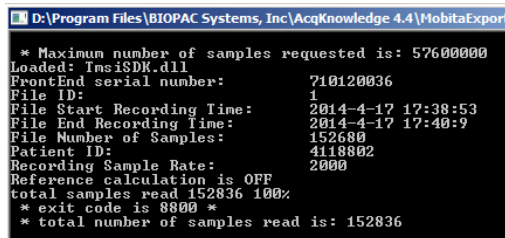


During this state, data plotting in AcqKnowledge stops, but data continues to be logged into Mobita hardware. The start/finish times are displayed, along with a countdown of remaining logging time.

“**Abort**” option: Data logging to Mobita is cancelled. The “Log” button in AcqKnowledge reverts to “Start.” Before acquiring new data or changing the acquisition mode, the Mobita hardware must be reset via the USB docking station. For information about resetting the hardware or changing acquisition modes, see page 548.

Note: All data logged prior to choosing “Abort” is retained in the graph.

“**Download**” option: You will be prompted to confirm the download and connect the Mobita hardware to a USB port. (Download of logged data is not supported in WiFi mode.) Upon connection, the logged data is downloaded and imported into the graph. During download, a screen similar to the one below will appear:

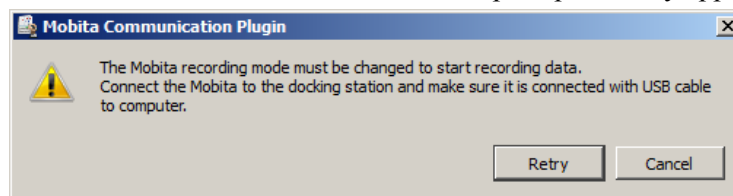


After the download screen closes, the logged data is imported into the AcqKnowledge graph at an accelerated rate. The import duration is dependent on the length of the logged acquisition.

Changing Acquisition Modes or Resetting Hardware

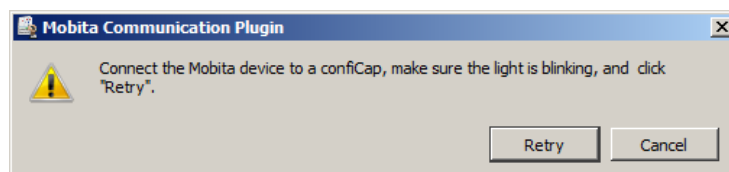
To change acquisition modes, or to reset the Mobita hardware after logging data, use the following steps.

1. Select the desired acquisition mode in Mobita > Set Up Data Acquisition.
2. Click “Start.”
3. Follow the onscreen communication prompts as they appear. (Shown below.)



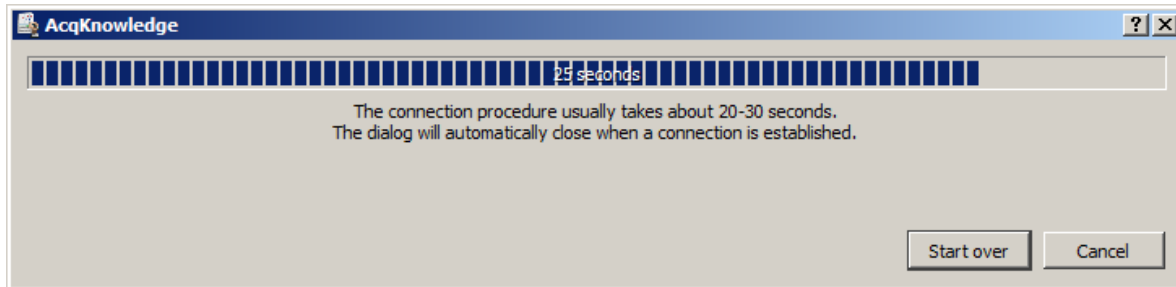
Communication Prompt 1

Important: After connecting the docking station, wait for the blue light on the Mobita unit to illuminate before clicking “Retry.”



Communication Prompt 2

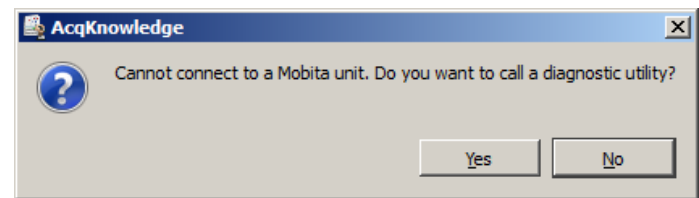
- After clicking “Retry” in the confiCap communication prompt, the following connection dialog will appear.



- When Mobita connection is established, this dialog will close automatically and the recording will start in the selected acquisition mode.

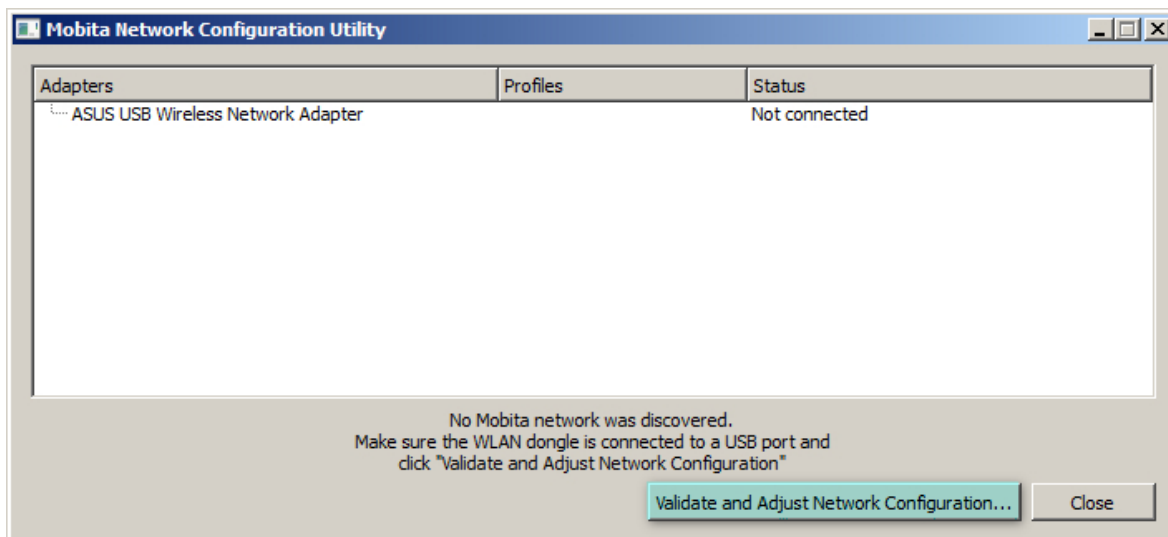
Mobita Network Connection Utility

If it becomes necessary to restore the connection to the Mobita hardware and/or ASUS USB network adapter, you may see this connection message:

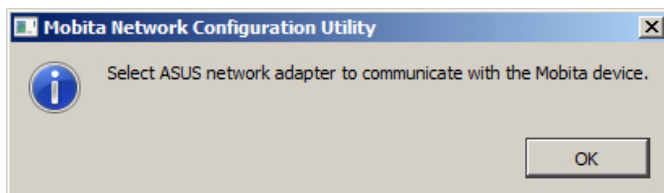


To re-establish the connection, use the Mobita Network Connection Utility as follows:

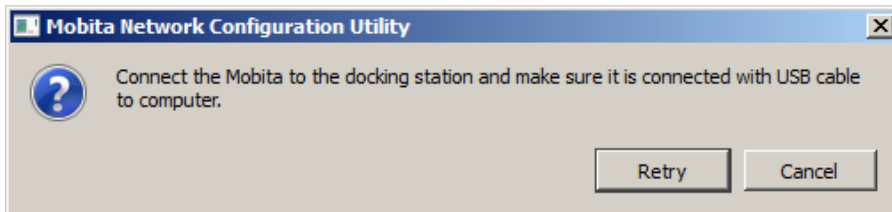
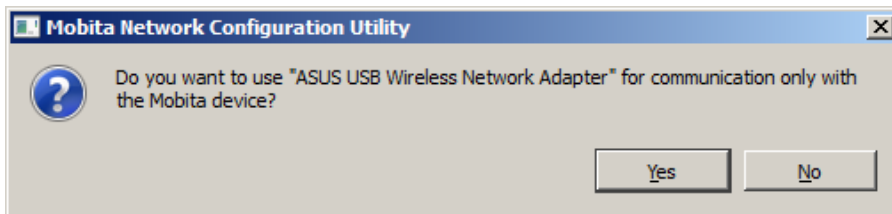
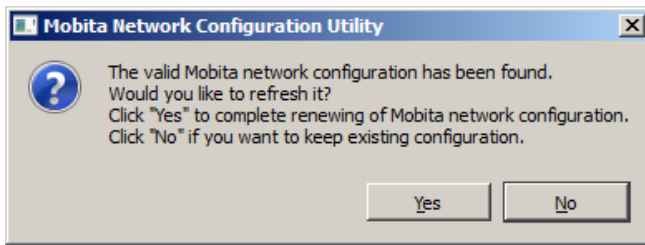
- Mobita menu > Manage Network Configuration Utility.
- Click “Validate and Adjust Network Configuration.”



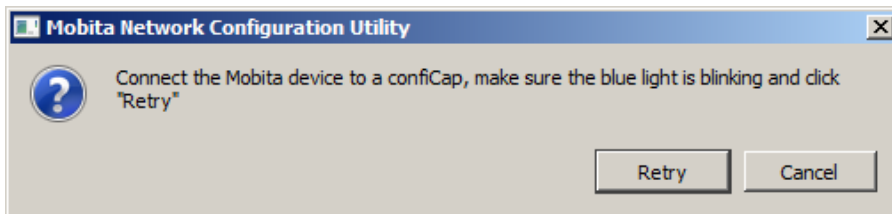
- If the USB adapter connection needs to be re-established, you may see the following communication prompt:



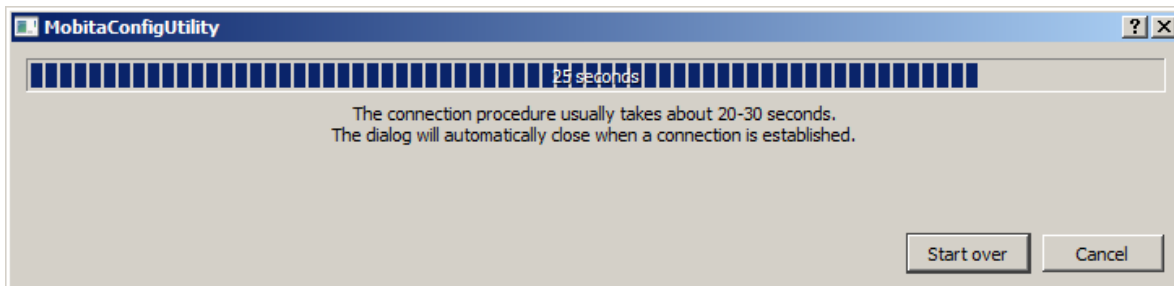
4. If this prompt appears, highlight the ASUS USB adapter in the “Adapters” list and click “Validate and Adjust Network Configuration” again. (Make sure the adapter is connected or it will not appear in the list.)
5. Click “Yes” and “Retry” to the following four prompts as presented.



Important: After connecting the docking station, wait for the blue light on the Mobita unit to illuminate before clicking “Retry.”




6. After connecting and clicking “Retry,” wait for the connection to be established (20-30 seconds).



7. After the connection dialog closes, the hardware connection is complete. Close the Mobita Network Configuration Utility.

NOTES:

- Mobita functionality is supported in Windows 7 and 8 only. Not supported in Windows XP or Vista.
- Mobita with *AcqKnowledge* requires an Administrator user account. It is not functional for Limited accounts.

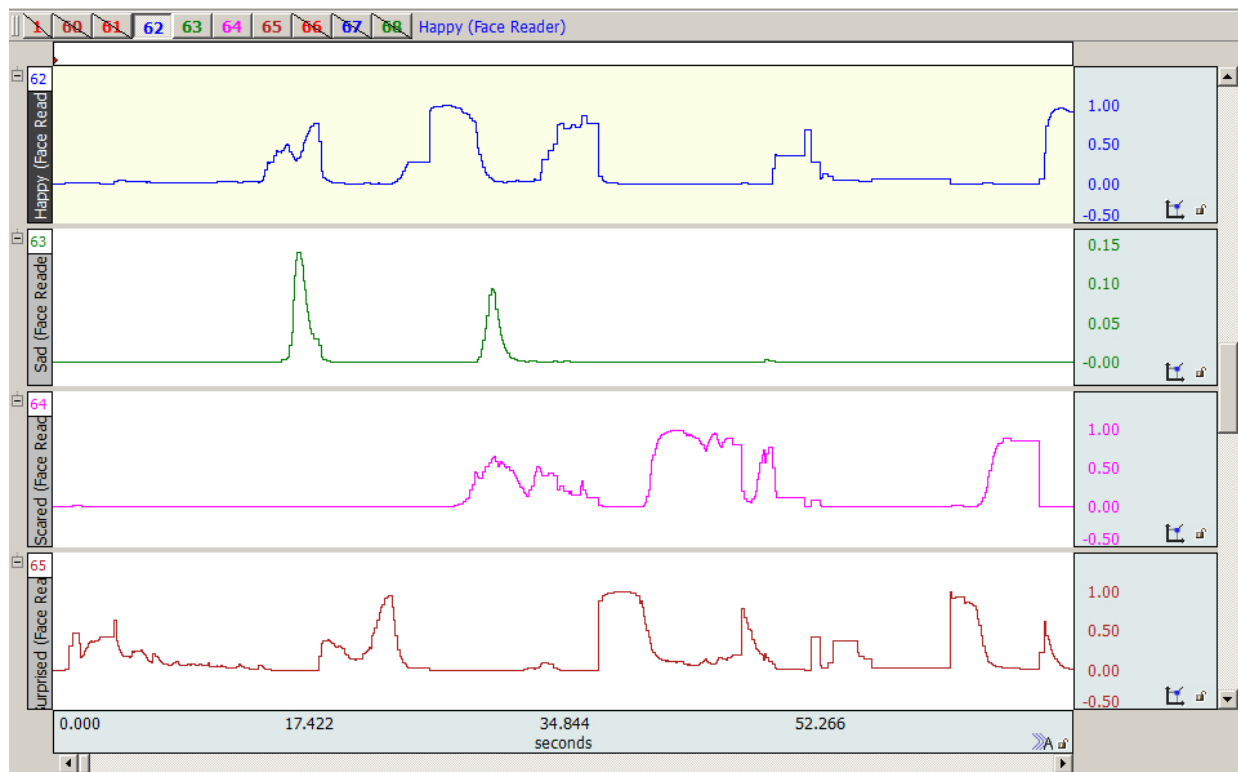
 For a detailed look at Mobita configuration, watch the Tutorial video [here](#).

Chapter 32 FaceReader

FaceReader™ with AcqKnowledge is available through optional licensing in AcqKnowledge 4.4.2 and above. Contact BIOPAC for licensing details.

FaceReader™ is the premier professional software for automatic analysis of facial expressions. Emotion reading software locks onto a subject's face and analyzes facial movements to classify subject's response. Easily integrate with physiological parameters from an MP150 Research System or eye tracking data. Start AcqKnowledge to begin recording, and FaceReader data is automatically synchronized and recorded in the same graph file. Monitor data in the FaceReader display for real-time feedback. Classifications include:

- Happy
- Sad
- Scared
- Disgusted
- Surprised
- Angry
- Contempt
- Neutral



Seamless Integration – easily integrate and synchronize physiological data or eye tracking through AcqKnowledge.

Complete Facial Expression Analysis – accurate modeling of the face by describing over 500 key points delivers objectivity in observations.

Useful for a Variety of Applications – psychology, educational research, consumer behavior research, usability studies, and neuromarketing research.

How Does FaceReader Work?

FaceReader software uses the computer's (or external) camera, a still photo, or a video image to detect and analyze a subject's emotional state by utilizing the facial action coding system (FACS) first developed in the 1960s by Swedish anatomist Carl-Herman Hjortsjö and later expanded by Dr. Paul Ekman. The FACS algorithm is capable of interpreting the tiniest of facial movements, rendering an accurate and nuanced interpretation of a subject's emotional responses. This automated state scoring has become popular in advertising and neuromarketing for assessing subject feedback to videos and other stimuli, and is also often used as another measure during self-assessment studies.

The FaceReader licensed feature allows response classifications to be selectively recorded as channels in an *AcqKnowledge* graph, and includes the following functionalities:

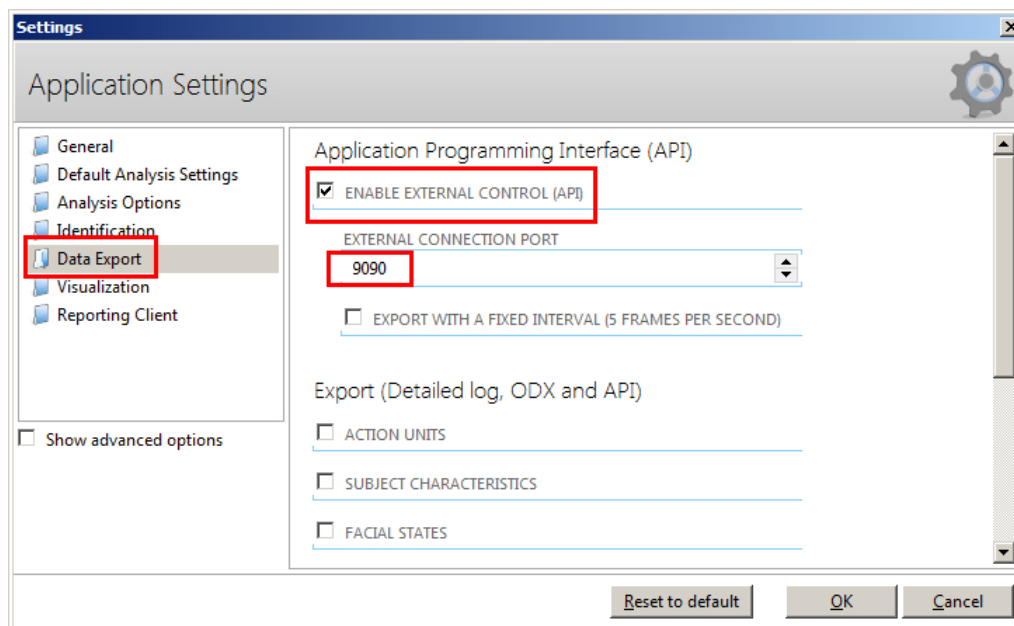
- Receive emotional state data from FaceReader in real-time
- Store emotional state data in *AcqKnowledge* graph files
- Incorporate emotional state data with other physiological signals and data analysis

AcqKnowledge FaceReader options become visible when the optional FaceReader license has been activated. Additionally, Noldus FaceReader software must be installed on the *AcqKnowledge* computer, or on a networked computer or server. See the Noldus FaceReader Software Reference Manual for installation and configuration instructions (i.e., FaceReader software and camera setup.)

Using FaceReader with *AcqKnowledge*

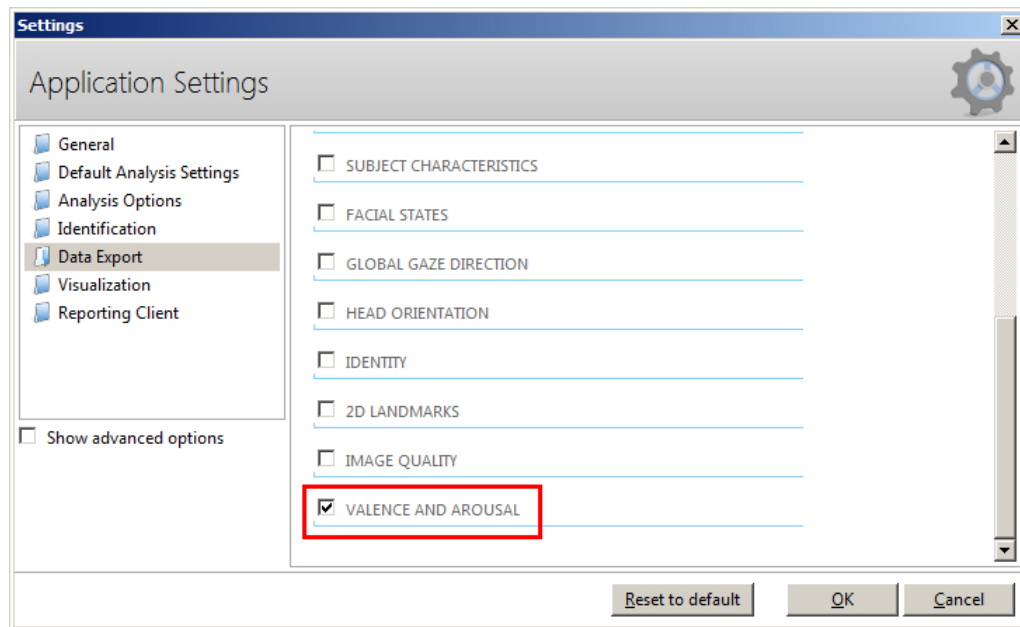
To configure FaceReader for use in *AcqKnowledge*:

1. Launch the Noldus FaceReader software and create a new project.
2. Choose “File > Settings.”
3. Select “Data Export” and check the “Enable External Control (API)” option.
4. Note the External Connection Port number. The default setting of 9090 shouldn't need to be changed unless there is a conflict with another application:



Enabling data connection in the FaceReader software settings

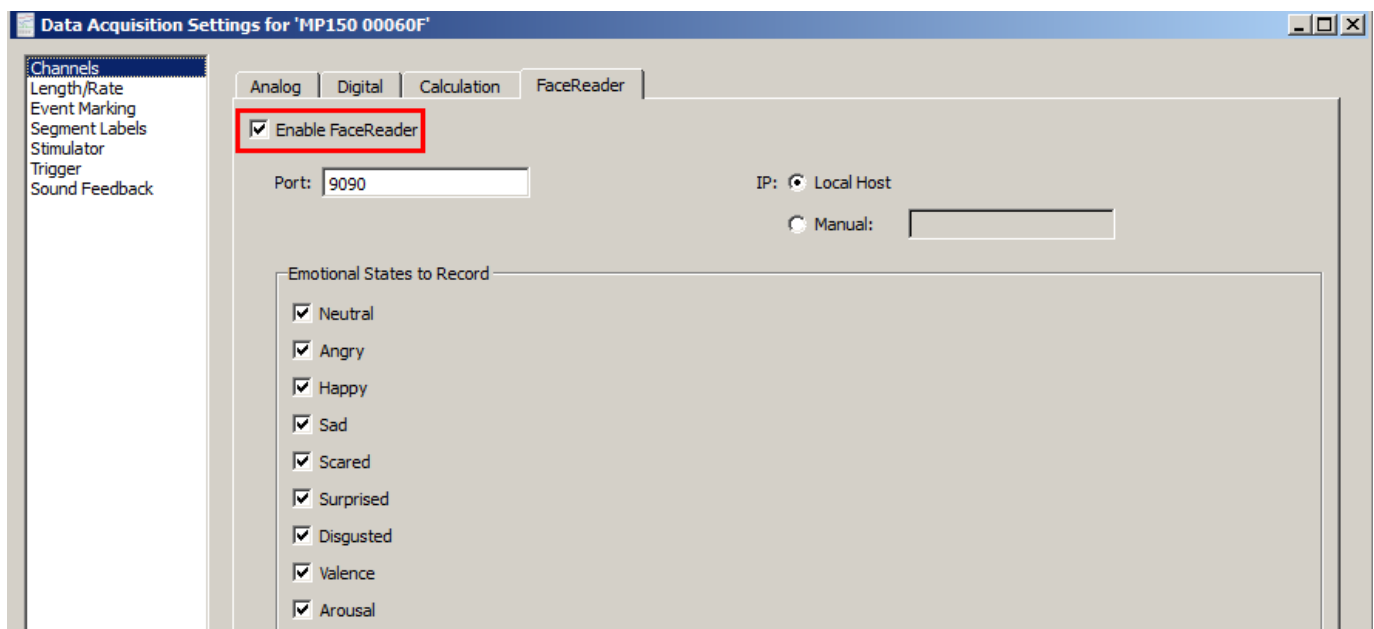
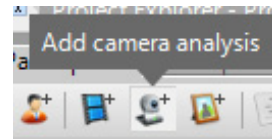
5. To record overall valence and activity signals, scroll to the bottom of the Application Settings screen and check the “Valence and Arousal” option (see below figure). For more information on valence and arousal signals, see page 555.



6. Click OK to exit the Application Settings screen.

Creating a FaceReader Project and Recording in AcqKnowledge

1. After performing the above configuration steps 1-5, launch the FaceReader software and choose “Create New Project.”
2. Add a participant to the project.
3. Add a camera analysis (Camera toolbar icon in FaceReader software UI) and note the camera preview for positioning the subject.
4. Launch or return to AcqKnowledge. (If necessary, create a new graph.)
5. Choose MP150 > Set Up Data Acquisition > Channels and click the “FaceReader” tab.



6. Check the “Enable FaceReader” checkbox.
 - If the FaceReader software is installed on the local AcqKnowledge computer, select “Local Host” as the “IP” setting and use the default Port number of “9090.”

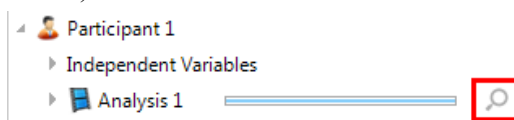
- If the FaceReader software is installed on another networked computer, choose the “Manual” option and enter the I.P. address of the FaceReader computer. (The I.P. address can be found by choosing Start > Run “cmd” and using the “ipconfig” command.)
7. Select the desired “Emotional States to Record” signals.
 8. Exit the Channels > FaceReader setup screen and click the *AcqKnowledge* “Start” button. (At least one *AcqKnowledge* Analog channel must be enabled in order for the recording to start.)
 9. The selected Emotional State data will be recorded into a new set of channels alongside other *AcqKnowledge* data.
 10. Click “Stop” to halt *AcqKnowledge* FaceReader recording.

TIP: In the *AcqKnowledge* FaceReader tab, click the “Save as Graph Template” button to permanently save the Port setting and selected Emotional States for future sessions.

Creating *AcqKnowledge* Graphs from a Saved FaceReader Analysis

Existing saved FaceReader analyses can be extracted into an *AcqKnowledge* graph, even if the analysis was not originally performed using *AcqKnowledge*. To do this:

1. In FaceReader, open an existing project.
2. Open the Analysis for the project (click the magnifying glass icon to display the saved video.)



3. Launch *AcqKnowledge* and make sure FaceReader is enabled in the application (See Steps 5-6 above).
4. Click “Start” in *AcqKnowledge*. The recorded FaceReader analysis will be displayed in *AcqKnowledge* graph channels.

FaceReader Signals

FaceReader records various emotional states and displays the analysis in real-time. As previously explained, this analysis is extracted as graph channels in *AcqKnowledge* software. FaceReader implements a neural network trained on the following facial expressions:

- | | | |
|-----------|-------------|-------------|
| • Neutral | • Sad | • Disgusted |
| • Angry | • Scared | |
| • Happy | • Surprised | |

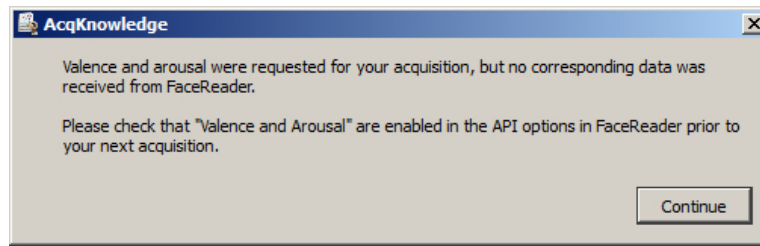
These recorded expressions are used to extract the subject’s dominant emotional state during the response period, otherwise known as “valence.”

Valence and Arousal

Valence and Arousal are two additional high level signals derived by FaceReader. Valence is used as an indicator of a subject’s overall emotional state based on sum of positive emotions minus the sum of negative emotions, and ranges in value from 1 to -1. (The most positive emotional state being 1, the most negative -1.) Arousal is used as an indicator of whether a subject is active or inactive and is based on average activity of the various facial action units within the last 60 seconds. A value of 0 corresponds with an inactive subject and a value of 1 with an active subject.

The seven emotional states, plus the derived valence and arousal signals provide useful high-level information about a subject. FaceReader also provides tools for extracting other lower level facial information, including state of standard FACS action units, general gaze direction, head orientation, eyes open/closed indicators and other parameters. These high-level signals are relevant for psychophysiology.

If “Valence” and “Arousal” Emotional States are selected in the *AcqKnowledge* FaceReader tab but have not first been configured for output in the FaceReader software, the following dialog will appear.

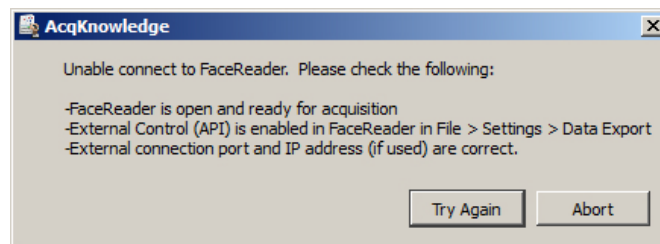


If this occurs:

1. Return to the FaceReader software, choose “File > Settings.”
2. Scroll to the bottom of the Application Settings screen and check the “Valence and Arousal” box.
3. Click OK to exit the FaceReader Application Settings screen.
4. Return to *AcqKnowledge* and rerun the FaceReader recording to verify that valence and arousal data are present.

Connection Issues

If, after clicking “Start” *AcqKnowledge* fails to establish a connection with FaceReader, the following dialog will appear:



If FaceReader and *AcqKnowledge* are installed on the same computer:

Check the IP port setting for both applications as shown on pages 553 and 554. The port settings should match. (The default is 9090.) This port number may need to be changed if there is a conflict with another application.

If FaceReader is installed on a different computer on the network:

Make sure the I.P. address of the FaceReader computer is correctly entered in the *AcqKnowledge* FaceReader tab’s **Manual** field. Auto-location of the I.P. address is not supported, so this value must be entered manually.

To determine the I.P. address of the FaceReader computer:

1. On the FaceReader computer, choose Start > Run.
2. Type “cmd” to bring up a command window.
3. Type “ipconfig” and press the Enter key.
4. Note the I.P. address.
5. Return to the *AcqKnowledge* computer.
6. Enter the I.P. address in the *AcqKnowledge* FaceReader tab’s **Manual** field and click OK.

```
Ethernet adapter Local Area Connection:

Connection-specific DNS Suffix  . : 
Link-local IPv6 Address . . . . . : fe80::d5da-cdb9:f602:fca1%25
IPv4 Address. . . . . : 192.168.0.186
Subnet Mask . . . . . : 255.255.255.0
Default Gateway . . . . . : 192.168.0.5
```

Camera Connection Issues

For certain types of USB cameras, the camera connection may become lost following a FaceReader analysis session. If this occurs, unplug and reconnect the camera before continuing with a subsequent analysis. It is recommended that an integrated camera be used if possible and set as the default camera.

For further instruction and technical details about Noldus FaceReader software, see the FaceReader Software Reference Manual.

For more information about the *AcqKnowledge* FaceReader Licensed Feature, visit www.biopac.com.

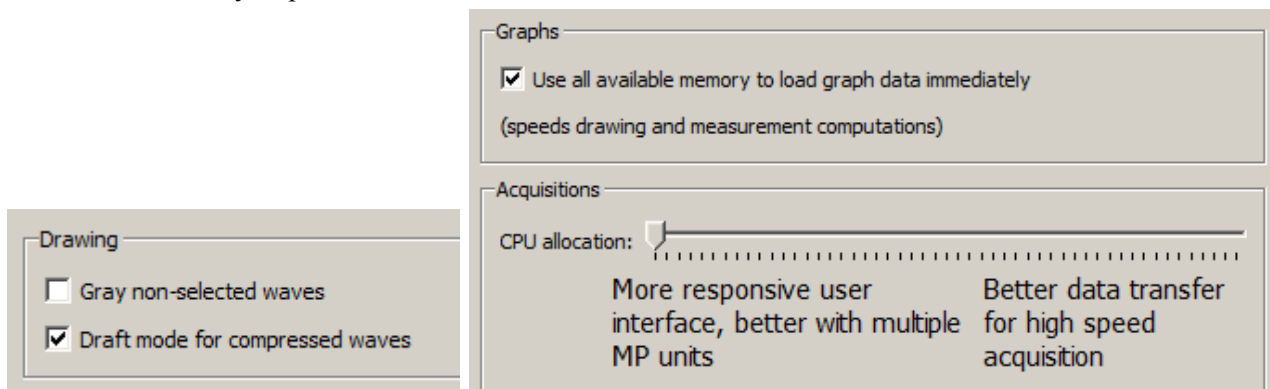
Part E — Appendices

Appendix A - Frequently Asked Questions

Q: I have a large data file and it seems to take a long time to redraw the screen. Is there anything I can do to speed it up?

A: Yes. 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 (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.



- (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 you have a high-resolution video card (one capable of displaying millions of colors), you may want to reduce the resolution to speed up plotting time.

- (4) Load all data into memory; see page 455 for details.

Q: Can I use other software with the MP System (MP150 or MP36R)? 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 (MP150 or MP36R) can accept as inputs.

Q: I imported a text file and the time scale is wrong. What happened?

A: When a text file is imported, AcqKnowledge assumes (by default) that the data was sampled at 100 Hz or 100 samples per second. This is arbitrary, and there are two ways to adjust this. Both methods involve Calculating the interval between sample points. To calculate the sampling interval, 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 before the data is read in, or if the data is already present, change the time scale in the Display > Horizontal scale dialog.

For instance, if 20 minutes of data was originally collected at 2Hz and is read into 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 the Options button in the File > Open dialog and change the value in the Sampling Interval dialog. To change the time scale after data has been read in, adjust the units per division in the Display > Horizontal axis dialog. If the data are time-domain data, you can adjust the seconds/sample interval at the bottom of the dialog. This value defines the interval between sample points, and can be changed to fit the rate at which the data was originally acquired.

Q: I just filtered a waveform and now my data file is huge. Why is that?

A: When *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 data acquisition unit seems to be connected, but I can't acquire data. What should I do?

A: This can be caused by one of several conditions:

- (a) Check to make sure that the MP data acquisition unit is ON and, if so, that all the connections to the MP data acquisition unit were made properly. When the MP data acquisition unit is powered up, a light on the front panel of the MP data acquisition unit will illuminate. If the power light will not illuminate, check to make sure the proper power supply is connected. The power supply that comes with the MP data acquisition unit is rated at 12 VDC @ 1 Amp, and using other power supplies may result in damage to the MP data acquisition unit.
- (b) If the proper power supply is connected but the power light still does not illuminate, disconnect the power supply and check the fuse in the back of the MP data acquisition unit. The fuse is a standard 2.0 Amp fast blow fuse, and can be changed by unscrewing the fuse cap and replacing the fuse.
- (c) If the power light does illuminate, the next step is to see if the busy light (next to the power light on the front panel of the MP data acquisition unit) illuminates when the MP data acquisition unit is powered up. When the MP data acquisition unit is powered up, the busy light should illuminate for three or four seconds and then extinguish.

NOTE: The busy light is normally off (except at startup), but it will remain on while data is being acquired and will illuminate for the duration of each trial when data is being acquired in averaging mode. If the busy light does not illuminate when the system is powered up or does not turn off after a few seconds, contact BIOPAC at one of the locations listed in Appendix A.

Q: I set up the channels but I only seem to be acquiring noise. What's wrong?

A: A number of phenomena can cause this. Check to make sure that the settings in the Set Up Channels dialog correspond to the channel switch settings on the amplifier modules and/or direct analog connections to the 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 to the 52] power or approximately 4.5 E15. Accordingly, the effective decimal accuracy will be between 15 and 16 digits.

Appendix B - Filter characteristics

Filter types

AcqKnowledge employs two types of digital filters:

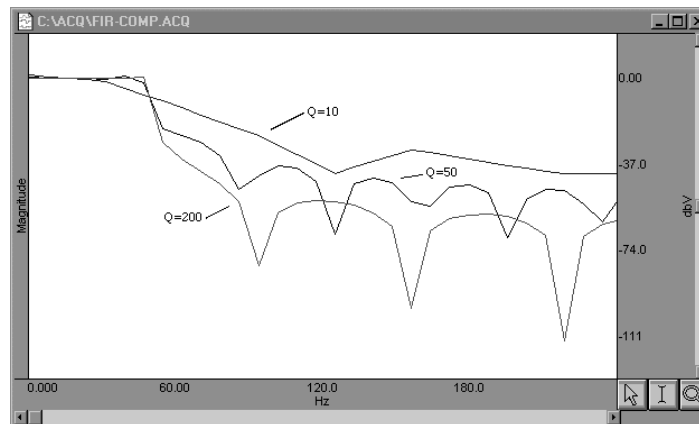
- (a) Finite Impulse Response (FIR) perform filtering calculations online (during an acquisition) or post-processing (after an acquisition).
- (b) Infinite Impulse Response (IIR) perform filtering calculations online (during an acquisition) or post-processing (after an acquisition).

Although the similarities between the two types of filters outweigh the differences, some important distinctions remain.

1. IIR filters tend to be less accurate than FIR filters. Specifically, IIR filters tend to cause phase distortion or “ringing.” When the phase of a waveform is distorted, some data points on a waveform are shifted (either forward or backward in time) more than others. This can result in the intervals between events (such as the Q-R interval or the inter-beat interval in an ECG waveform) being slightly lengthened or shortened compared to the original signal. In practice, however, the effect of this distortion is usually minimal since the frequencies which are most distorted are also attenuated the most. By contrast, FIR filters are phase linear, which means that the interval between any two sample points in the filtered waveform will be exactly equal to the distance between the corresponding sample points in the original waveform.
2. IIR filters have a variable Q setting that defines the filter response pattern, but FIR filters do not have a Q component. The optimal Q of an IIR filter is 0.707, with lower values resulting in a flatter response and higher values resulting in a more peaked response. The default Q for all IIR filters is 0.707 (except for Band pass filters where Q defaults to 5), which is appropriate for nearly all filter applications.

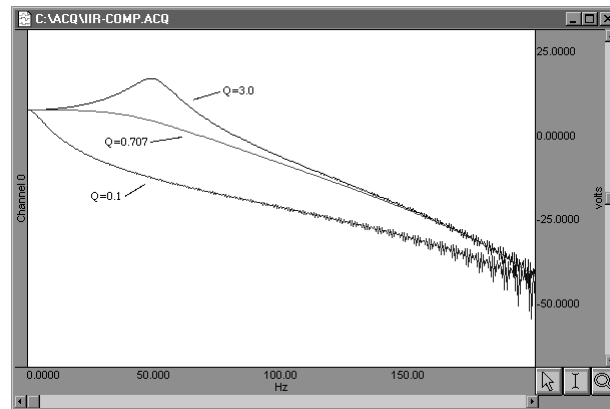
In the examples on the following page, the filter responses of several different types of filters are compared. All of the filters are 50 HZ low pass filters operating on the same data.

The first graph shows how the number of filter coefficients in FIR filters (Q) affects the filter’s frequency response. Note that as the number of coefficients (Q) increases, the filter becomes more accurate. A good rule of thumb is to set $Q \geq 2(f_s / f_c)$, where f_s = sampling rate and f_c = cutoff frequency.



FIR filter performance as a function of number of coefficients (Q)

The next graph shows how the pole or zero locations of the filter, as related to filter “peaking” (specified by Q), affect the frequency response of the filter. The “ Q ” in this case is not to be confused with the Q from the FIR filter. Note how increasing “ Q ” in the IIR filter case affects filter “peaking.”



FIR filter performance as a function of changes in pole or zero locations

Coincidentally, the FIR ($Q = 10$) and IIR ($Q = 0.707$) filters have very similar responses in this case.

Technically, the coefficient setting for FIR filters determine the number of multiplies performed by the filtering algorithm. In practical terms, it determines how “steep” the frequency response of the filter is. Filters with a large number of coefficients have a steep roll-off, whereas the frequency response of filters with a smaller number of coefficients is not as steep.

Window Functions

Window functions are used for two purposes in *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).

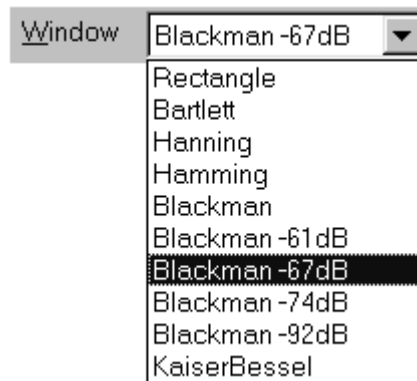
Another way to minimize edge effect with an FIR filter is to increase the number of coefficients used to transform the data.

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 $n = \sum_{0}^{N-1} n$ and A, B, C and D are constants:

$$A - B \cos \frac{2\pi n}{N} + C \cos \frac{2\pi 2n}{N} + D \cos \frac{2\pi 3n}{N}$$

The table below details the different parameter values for each type of window.

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 (MP150 or MP36R) stores the data in as compact a format as possible. Each sample takes up roughly two bytes of storage space. When a waveform (or a section of a waveform) is transformed (i.e., filtered or integrated) each data point takes up roughly eight bytes of storage space. As a result, file size can change drastically after transforming one or more waves.

Note AcqKnowledge data files greater than 2 GB can be opened, but edit, transformation and analysis operation cannot be performed.

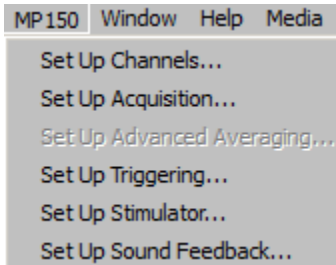
The following tips can help you get the most out of your MP System (MP150 or MP36R) when working with large data files.

- Remove waveforms
Since each waveform adds to the total size of the file, try removing (or copying to another file) some of the waveforms from a multi-channel file. This is especially true 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 308) 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, much larger data files can typically be stored to disk rather than memory. Loss of power to either the computer or the MP unit can result in data loss. To avoid potential data loss, connect both the computer and MP power supply to an uninterruptible power supply.
- Use the Append mode
The Append mode allows 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.
- Compress Files
Use the File > Save As > Compressed option to store or transfer data

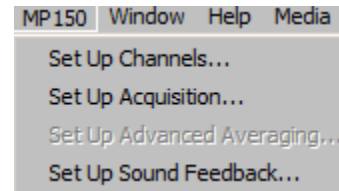
Note Copy/Paste, Merge Graphs, and Transformations require AcqKnowledge to allocate additional memory and then load the data into memory; when these operations are executed on large data files, the application may crash.

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 “Set Up Triggering” and “Set Up Stimulator” options from the MP150 menu, as shown below:



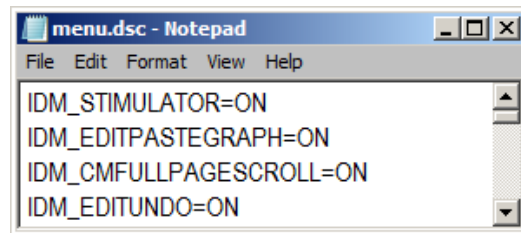
Default MP menu



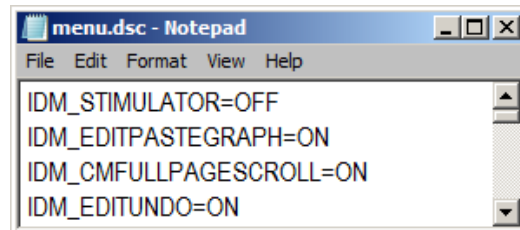
Customized MP menu

Follow the simple procedure below to customize menu display for your own needs.

1. With the AcqKnowledge application closed, navigate to the menu.dsc file:
DRIVE:\ProgramData\BIOPAC Systems, Inc\AcqKnowledge 4.4\menu.dsc
2. Open the menu.dsc file in Notepad.



3. 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 IDM_STIMULATOR 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.



4. Save the changes to the menu.dsc file and close it.
5. Restart AcqKnowledge.
6. Check your menu listing.

To reactivate a menu item set to OFF, just repeat the above procedure and type “ON” for the desired menu item.

To revert a customized menu.dsc to the factory default, choose Display > Preferences > Other and select “Create default menu configuration file.” After choosing “yes” in the subsequent dialog, the application must be closed and relaunched in order for the change to take effect.

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

Appendix E—Locking/Unlocking the 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.

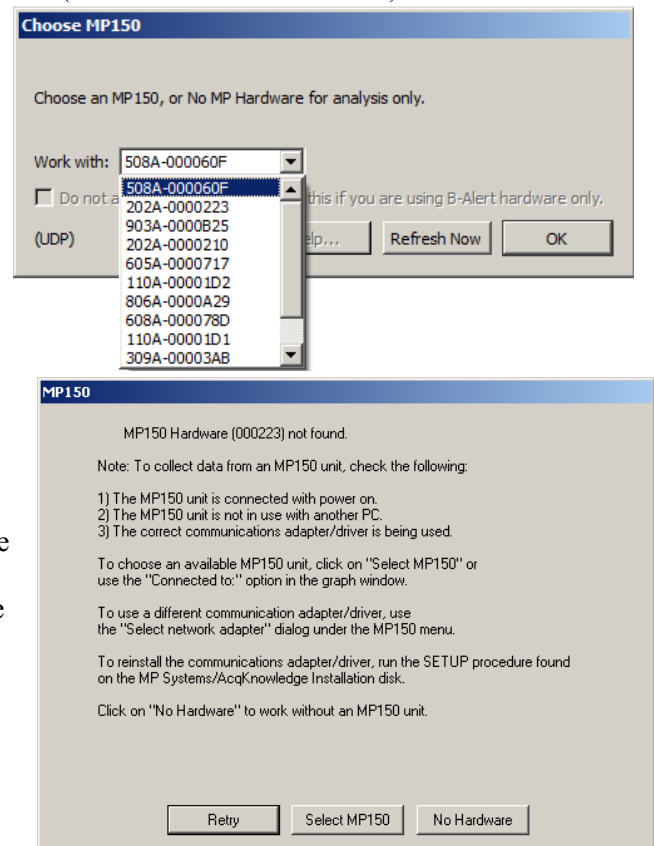
Theoretically, two or more workstations (WS) could be connected to one MP150 at the same time, but the MP150 cannot perform independent acquisitions simultaneously, so in such cases one or all connected WS would receive corrupted/invalid data and/or crash.

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 MP150 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 MP150 unit), as expected. To resolve this issue, unlock or power cycle the MP150 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

MP150 firmware is upgraded automatically. Unless a firmware warning is displayed at application launch, your MP150 already has the latest firmware revision and no further action is necessary. If a firmware warning is displayed, contact BIOPAC technical support for more information.

Firmware Rollback Switch

IMPORTANT!

Use the Firmware Rollback Switch only if the MP150 fails to operate after a Firmware Upgrade.

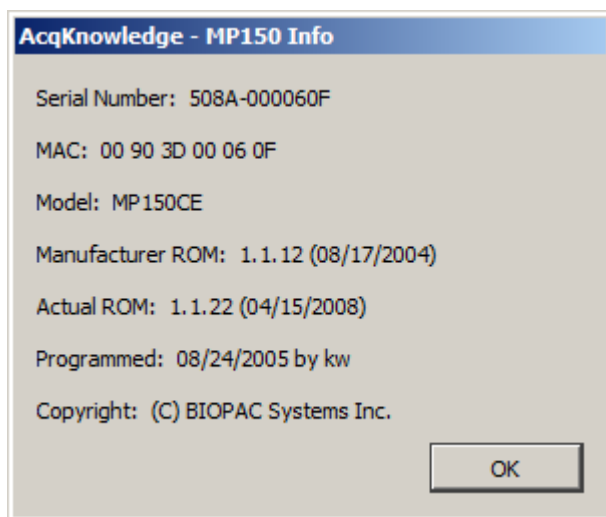
In all other cases, just turn the MP150 power OFF and then ON and check the results of the Start up/Self-Test.

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*.

INDEX

A

A/D boards (third party), 558
 About
 About *AcqKnowledge*, 456
 About MP150 (menu option), 238
 Absolute value, 146, 294
AcqKnowledge, 23, 31–55
 Accuracy (storage and operation), 559
 Acquire checkbox, 35, 111
 Acquire, Setup Channels option, 168
 Acquisition
 Acquisition Length, 36, 161
 High speed, 563
 Long, 563
 Overview, 106
 Set Up, 36, 114
 Start acquisition, 37
 Troubleshooting, 559
 Adaptive filtering
 Calculation channel, 154
 Transformation, 283, 289
 Adaptive scaling, 76
 Adjust grid spacing, 432
 Alpha waves, 283, 322
 Amplitude scale, 27, 75, 115
 Analog channels, 35, 114–15
 Gain setting, 116
 Analog triggers, 174
 Analysis functions, 73
 Annotation, text, 60
 Append mode, 158, 563
 Application Notes, 30
 Arbitrary curve fitting, 103, 315
 Arbitrary sample rate, 308
 Arbitrary scale (units), 434
 Arbitrary stimuli, 184
 Arc cosine, 146
 Arc sine, 146
 Arc tangent, 146, 294
 Archive options, 54
 Area (measurement), 95
 Artifact rejection, 165
 Atan. *See* arc tangent
 Attenuation, Manual Control, 234
 Auditory Brainstem Response testing, 30
 Auto threshold detect, 344
 Automated Tissue Bath Analysis, 30
 Automator Integration and Scripting, 25
 Autoplot, 244
 Autoposition Hidden Annotations, 61
 Autosave file, 158, 167
 Autoscale after transformations, 449
 Autoscale horizontal, 46
 Autoscale Horizontal, 431
 Autoscale waveform, 47
 Autoscale Waveforms, 429
 Averaging

 Advanced Averaging setup, 165
 Average (moving), 127
 Average over samples, Integrate option, 130, 131
 Averaging Application Note #AS131, 30
 Averaging mode, 36
 Averaging setup, 164
 Off-line Cycle/Peak Detector (MAC), 330
 Overview, 162
 Axis adjustment. *See* horizontal scale, vertical scale

B

Band filter, 285
 Base 10 logarithm, 147, 295
 Blood pressure analysis. *See* rate calculations
 BPM
 BPM calculation, 346
 BPM measurement, 96
 BPM, Rate function, 134
 BSL File Import, 251

C

Calculate (measurement), 97
 Calculation channels, 35, 122–23
 Calibration, 114–15
 Capacity dimension measurement, 97
 center horizontal, 40
 center vertical, 40
 CH# Output Control, 189
 Channel
 Channel boxes, 88, 435
 Channel label, 88
 channel sample rate, 113
 Channel sample rate, 36
 Channel setup, 114
 Chaos Analysis
 Detrended Fluctuation Analysis, 353
 Optimal Embedding Dimension, 353
 Optimal Time Delay, 353
 Plot Attractor, 354
 Chart mode, 435
 chooser, 270
 Clear, 274
 Clear all, 274
 Clip data, Calculation channel Function, 138
 Clipboard, 95, 277–78
 Close
 File menu command, 260
 Close prompts, 260
 Coefficients (FIR filters), 286, 560
 Color, 433
 Comb Band Stop
 Calculation channel, 140
 Transformation, 289
 Compare Waveforms, 431
 Compression
 down sampling, 308
 Save As option, 267

- Connect endpoints, 294
- Constant (K), Calculate measurement option, 97
- Control channel
 - Calculation channel, 149
 - Integrate Calculation option, 128
- Convolution, 298
- Copy, 274
 - Acquisition Settings, 278
 - Graph, 278
 - Measurement, 277
 - Wave data, 278
- Correlate (measurement), 97
- Correlation, 296, 298
- Correlation Coefficient
 - Specialized Analysis, 354
- Correlation dimension measurement, 97
- Cosine, 146
- Count peaks, 346
- Create Data Snapshot, 54
- Cubic spline interpolation, 308
- Customizing menu display, 452, 564
- Cutoff frequency, 286
- Cycles/Peaks detect, 3D Output, 331
- Cycles/Peaks tab, Cycles/Peaks detect, 326

D

- Data View, 44
- Delay
 - Calculation channel option, 148
 - Trigger Set Up, 175
- Delta measurements, 98
- Derivative, 302
- detrending, 317, 392
- Difference
 - online calculation, 133
 - transformation function, 307
- Digital
 - Digital channels, 35, 115–22
 - Digital filters, 283–88, 561
 - Digital I/O channels, Manual Control, 233
 - Digital output, 149
 - Digital triggers, 173
- Digital Outputs Control, 191
- Disk
 - Space, sampling rate impact, 36
 - Space, storage mode impact, 248
 - Storage option, 36, 160, 563
- Display
 - Menu commands, 427
 - Preferences, 563
- DLC, Ethernet protocol, 451
- Draft mode, 449
- Duplicate waveform, 275
- dZ/dt Specialized Analysis
 - Classifier, 394
 - Derive from raw Z, 394
 - Remove motion artifacts, 401

E

- ECG Analysis
 - Automated ECG App Note, 30
 - Detect and Classify Heartbeats, 351
 - ECG Interval Extraction, 378
 - Heart Rate Variability, 388
 - Locate Animal ECG Complex Boundaries, 352
 - Locate Human ECG Complex Boundaries, 351
- EDA analysis, 355
- edge effects, 561
- Editing
 - Cursor tool, 59
 - Edit menu, 272
 - Features, 73
- EGrid cursor, 59
- Eigenanalysis (PCA), 323
- Electrode Checker, 171
- Embedded archive, 54
- Ensemble Average, 374
- Epoch Analysis, 375
- Ethernet protocol, 451
- European Data Format (EDF)
 - Open, 256
 - Save, 266
- Event (Marker)
 - Graph Selection, defining via, 231
 - Hotkey Setup, 218
 - Location, 221
 - Measurements, 228
 - Overview, 215
 - Palette, 220
 - Preferences, 216
 - Printing, 230
 - Toolbar, 216
 - Tooltips, 216
 - Variable Sampling Rate and, 231
 - Waveform editing, 231
- Event amplitude measurement, 99
- Event count measurement, 99
- Event definition cursor, 59
- Event location measurement, 99
- Event marker, 28
- Events, 51
- Events, R wave location, 389
- e^x power of a data point, 146
- Excel Spreadsheet Export, 267, 350
- Exp Exponential, 294
- Exporting data, 53, 252
- Expression, 140–52, 309
- Expression evaluator, 140–52
- Expression measurement, 99

F

- FAQ, 558
- Fast Fourier transformations. *See* FFT
- FFT, 318–22, 561
- File Compatibility for Specialized Analysis, 349
- File format prompts, 268
- File menu commands, 248

File size, 559, 563

Filter

- Calculation, 139
- characteristics, 560
- response, 287

Find, 341

- Find Cycle/Peak, Mac OS X, 325

Finite impulse response filters. *See* FIR filter

FIR filters, 283, 286, 560

Firmware Rollback Switch, 567

Focus areas, 89

Font, journal, 451

Formula

- Area, 95
- BPM, 96
- Correlation, 97
- Delta, 98
- Delta T/F/X, 98
- Freq (Frequency), 99
- Integral, 100
- Lin_reg (Linear regression), 101
- Mean, 102
- Slope, 104
- Stddev (Standard deviation), 104
- Threshold, 138

Fourier

- FFT Fast Fourier transformation, 318

Fourier Linear Combiners

- Calculation Channels, 153
- Transformations, 292

Frequency

- frequency spectrum, 322
- Horizontal scale, 434
- measurement (Freq), 99
- rate calculation (Hz), 346

Frequency Bands, HRV analysis, 390

Frequently asked questions, 558

Friendly Grid Scaling, 82

Function

- Calculation, 141
- Equation (Expression) commands, 146

G

Gain setting, 116

Gastric Wave Analysis, 352

- Gastric Wave Coupling, 352

Gauge, 240

Getting Started, 23

GLP audit

- include timestamp, 449
- mark selection with Events, 449, 450

GLP guidelines, customizing menus for, 26

Graph template files (gfl)

- Open, 252
- Quick Start Files, 125, 252
- Save As, 262

Graph window, 34

Gray non-selected waves, 449

Grid

Adjust spacing, 432

GridReset, 432

H

Hardware. *See* note on page 10

Heart Rate Variability, 30, 388

Help menu, 456

Hemodynamic Analysis, 376

- ABP Classifier, 377
- Arterial Blood Pressure, 377
- ECG Interval Extraction, 378
- LVP Classifier, 381
- MAP Classifier, 383
- Measurements App Note, 30
- Monophasic Action Potential, 382

High pass filter, 284

Histogram, 313

Hold button, SIV, 232

Hold relative position

- Horizontal Scale, 74

Horizontal

- Axis, 27
- scale, 45
- Scale, 45
- Scroll bar, 74

Human Subjects, Safety, 213

Hyperbolic

- Cosine, 146
- Sine, 147
- Tangent, 147

I

I/O channels, Manual Control, 233

I-beam tool

- selection cursor, 59

IBI Inter-beat Interval, 134, 346

IFFT. *See* inverse FFT

Igor Pro Experiment

- Open (import), 255
- Save As (export), 265

IIR filters, 283, 288, 560

Impedance Cardiography Analysis, 394

- Body Surface Area, 394
- Derive dZ/dt from raw Z, 394
- dZ/dt Classifier, 394
- dZ/dt remove motion artifacts, 401
- ICG Analysis, 397
- Ideal Body Weight, 400
- Pre-ejection Period, 400
- Preferences, 402
- VEPT, 401

Independent Component Analysis, 324

INF (measurement value), 91

Infinite impulse response filters. *See* IIR filters

Information Dimension measurement, 100

Initial offset, 74

Input Values Setup (SIV), 232

Insert

- Events, 51
- Waveform, 275
- Installation. *See* note on page 10
- Integral
 - measurement, 100
 - Transformation function, 301
- Integrate
 - formulas, 304
- Integrate Calculation (online), 127
- inter sample interval, 255, 264
- Interpolate pastings, 450
- Interpolation method, resampling, 308
- Intraventricular Pressure Wave analysis, 30
- Inverse mean square error, 298

J

- Jewett Sequence, ABR testing for, 30
- Journal, 53
 - Copy Measurements, 95
 - Paste options, 279
 - Preferences, 451
 - Show Journal, Mac OS X, 281
- Jump-to tool (correlates data views), 60

K

- K (Constant), Calculate measurement option, 97
- Kurtosis measurement, 101

L

- Latency, 163
- Left Ventricular Pressure
 - LVP Classifier, 381
- Limit data, Calculation channel Function, 138
- Limit math command, 295
- Lin_reg (linear regression measurement), 101
- line plot, 436
- Linear (FFT option), 321
- Linear interpolation, 308
- Ln natural logarithm, 295
- Locate SCRs, 361
- Location Palette**, 437
- Locked MP150, 565
- Log, 147, 295
- Low pass filter, 284, 302
- Lung Volume analysis, 30
- LVP Analysis, 30
- Lyapunov measurement, 102

M

- Macintosh® system requirements, 24
- Magnetic resonance imaging
 - Specialized Analysis, 403
- Manual Control (digital I/O), 233
- Manual stimulator controls**, 178
- Math
 - Calculation, 136–37
 - Functions (Transformation), 294

- Waveform Math, 310
- MATLAB
 - Open (import), 254
 - Save As (export), 264
- Max measurements, 102
- Max T measurement, 102
- Mean
 - Mean square error, 298
 - Measurement, 102
 - Removal, 297, 320
- Mean subtraction, Integrate option, 128
- Measurement, 50, 91
 - Cycles/Peaks Output, 330
 - Preferences, 448
 - Preferences for Journal, 451
 - Presets, 94
 - Table of Explanations, 95
- Media menu (capture or playback), 458
- Median measurements, 102
- Median T measurement, 102
- Memory
 - Load all data into, 455
 - Storage option**, 36, 160
 - Use all available memory, 451
- Menu configuration file, 452
- Menu display, customizing, 452, 564
- Merge Graphs, 276
- Min (minimum) measurement, 102
- Min T measurement, 102
- Modeling
 - Linear
 - Autoregressive transform, 314
 - Lin_reg measurement, 101
 - Nonlinear, 315
 - NLM measurement, 103
- Modeling, Autoregressive, 314
- Moment measurement, 103
- Monophasic Action Potential, 382
 - MAP Classifier, 383
- Moving average, 306
- MP, data storage option, 160
- MP150
 - Locked/Unlocked, 565
 - MP150 Serial Number, 237
 - MP150 Info (menu option), 238
- MP150 System
 - Features, 26
 - Overview, 23
- MP150 System Requirements, 24
- Mutual information measurement, 103

N

- Natural logarithm, Ln, 295
- Network Data Transfer (NDT), 467
- Neurophysiology
 - Specialized Analysis, 407
- New
 - Data View, 248
- No hardware mode, 237
- Noise, 559

- Calculation channel Function, 138
- Math command, 295
- Rejection (auto threshold detect, 344
- None (measurement option), 103
- Nonlinear modeling, 315
 - NLM measurement, 103
- Normalized cross correlation, 299

O

- Off-line Averaging, Cycle/Peak Detector (MAC), 330
- Online filtering, 139
- Open (file command), 251
- Open for Playback, 257
- Options button, Open Text file, 252
- Options, Input Values, 232
- Organize Channel Presets, 245
- Organize List, Preferences, 205
- Output continuously. Stim. Setup, 178, 201
- Output Control, 187
 - CH# to Output, 189
 - Preferences, 188
 - Pulses, 192
 - Stimulator – OUT3 adapter, 192
 - Stimulator—BSLSTM, 192
- Output tab, Cycles/Peaks detect, 330
- Overlap
 - Overlap Waveforms, 430

P

- P300 measurements, 165
- Pad with..., 318
- Padding (resampling interpolation), 308
- Paste, 274
 - Acquisition settings, 279
 - Measurement, 279
 - Wave data, 279
- Pause mode (Append to disk), 159
- PC-compatible files, 262
- Peak
 - Detect (Find Rate option), 344
 - Find Cycle (Peak Detector), Mac OS X, 325
 - Minimum, 346
- Peak-to-Peak (P-P measurement), 103
- PEP Pre-ejection Period, 400
- Phase, 321
 - Distortion, 560
- Phasic EDA options, 363
- PhysioNet
 - Save As (export), 263
- PICT files, 278
- Playback mode, 43
- Plot
 - Plot on Screen, Setup Channels option, 168
- Plotting data, 35, 244
- Poincare plots, 386
- Power Spectral Density, 317
- Power supply, 559

- P-P (peak-to-peak measurement), 103

Preferences

- Display Preferences, 444
- Journal preferences, 451
- Menu configuration file, 452
- Output Control, 188
- Undo max, 450
- Presets, 112
 - Organize Channel Presets, 245
- Pretrigger, 175
- Principal Component Analysis, 323
- Principal Component Denoising, 413
- Print, 28, 55, 270–71
- PSD Options, HRV analysis, 390
- Pulse Sequence Output Control, 194
- pulse stimuli, 182
- Pulses Output Control, 192

Q

- Q coefficient, filter setting, 139, 288, 560
- QRS Detector, HRV analysis, 389
- Questions, frequently asked, 558

R

- Ramp waves, 183
- Rate
 - calculation, 133–36, 311
 - detector algorithm, 30
- Rate mean measurement, 103
- Rate median measurement, 103
- Rate standard deviation measurement, 103
- Raw data
 - Open (import), 255
 - Save As (export), 264
- Record
 - Start acquisition, 169
- Record/Record last, 158
- Recursive formulas, 143
- Remove
 - last appended segment, 275
 - mean, 297, 320
 - trend, 320
 - waveform, 275, 563
- Remove Projection, 298
- Remove Projection Template, 298
- Remove Trend, Specialized Analysis, 413
- Repeat mode, 167, 245
- Repositioning Events (Marker), 221
- Resample, 308
- Resampling Interpolation, 308
- Reset
 - Append acquisition button, 159
 - reset chart boundaries, size window, 454
 - Reset Chart Display, 432
 - reset thresholds, Integrate setup, 128
 - reset trigger, Integrate setup, 128
- Reset Grid, 432
- Resource allocation, 452

Respiratory Sinus Arrhythmia, Specialized Analysis, 387
 RS-232/RS-422 signal, 558

S

Safety Notice, 21
 Sample
 measurement, 103
 Rate, 160–61, 563
 Rate, Acquisition rate, 36
 Rate, Channel, 35, 36, 113
 Rate, Stimulation signal output, 176
 Save, 53
 Save (File command), 261
 Save as (File command), 261, 268
 Save once (Acquisition setup), 158
 Save Settings, Preferences, 193, 205
 Scaling, 114–15
 Scaling, Friendly Grid Scaling, 82
 Scope mode, 38
 Scroll, 45, 73
 Menu option, 244
 Segment Labels, 238
 Select
 All, 275
 Area, 49, 272
 Area for measurement, 92
 Channel, 47, 88
 Cursor tool, 59
 Waveform, 47, 88
Selection Palette, 436
 Selection tab, Cycles/Peaks detect, 329
 Serial number, MP150, 237
 Set template, 296
 Set Up
 Acquisition, 36
 Channels, 109, 114
 Triggering, 173
 Set wave positions, 432
 Shortcuts
 Keyboard, 65
 Toolbars, 57
 Show
 All Data Snapshots, 54
 Display menu options, 435
 Input values, 111
 Input Values, 232
 Input Values Setup options, 232
 Modified input, 319
 Signal averaging. *See* Averaging mode
 Sine, 147, 295
 Size window, 454
 Skew measurement, 103
 Slope (measurement), 104
 Smoothing
 online calculation, 132
 transformation function, 306
 Smoothing Baseline Removal, 363
 Snapshot data after acquisition, Preference, 54
Sound Sequence Output Control, 201

Specialized Analysis Package, 347, 348
 File Compatibility, 349
 Specifications. *See* MP Hardware Guide
 Spectral analysis. *See* FFT
 Spectral subtraction, 419
 Spectrum Analyzer Palette, 441
 Square
 Square, 147
 Square Root, 147, 295
 Waves, 182
 Standard deviation measurement, 104
 Start acquisition, 37
 Starting an acquisition, 169
 Statistics (Waveform Statistics dialog), 444
 Status indicator, 37
 Status indicator, software, 169
 Stddev (standard deviation) measurement, 104
 Step plot, 439
 Stimulation. Dual, 181
 Stimulator
 Stimulator Reference Channel, 213
 Stimulator - BSLSTM, 192
 Stimulator Manual Control, 234
 Stimulator setup, 176
Stimulator, manual controls, 178
 Stimulus signal, 163, 165, 176, 199
 STM100C Manual Control, 234
 Stopping an acquisition, 169
 Sum measurement, 105

T

Tab interval, Journal, 451
 Tangent, 147
 Tau (time constant), 315
 Template functions, 296
 Text Annotation, 60
 Text files, 53, 254
 Textual value display, 76
 Threshold
 Math command, 295
 Tile waveforms
 Tile after transformations, 449
 Tile Waveforms, 428
 Time
 Expression source, 142
 measurement, 105
 Set Horizontal Time scale, 434
 Time scale after importing, 558
 Timestamp, journal preference, 449
 Tone stimuli, 182–83
 Toolbars, 57
 Transform, 50
 Math commands, 294
 Menu commands, 282
 Remove Projection, 298
 Specialized Analysis Package, 347, 348
 transition latency, 422
 Triggering, 173
 Troubleshooting, 558

U

UDP, Ethernet protocol, 451
Undo, 273
User Support System, 19

V

Value (measurement), 105
Values checkbox, 35, 111
 Show input values, 232
Variable Sampling Rate, 36, 113, 176
 data processing notes, 144
 Event plotting and, 231
VEPT, 401
Vertical axis, 27, 115
Vertical scale, 47, 75
Viewing data, 45
VO₂ measurement, 30

W

Warning
 Before overwrite data, 245
 Hardware not found, 32
Waterfall Plot, 423
WAV files, 256

Waveform

Arithmetic dialog, 97
Color, 433
Math transformation, 310–11
Selection, 47, 88
Statistics dialog, 444

Wavelet Denoising, 424**Window**

Find Rate option, 344
Functions (filter, FFT), 561
Menu, 456

Windows® system requirements, 24**Working in AcqKnowledge, 31****X**

X/Y mode, 38, 39
 X/Y loop area analysis, 30
X-axis T/F/X (measurement), 105

Z

Zap, event cursor, 60
Zoom
 Cursor tool, 49, 59
 Zoom previous, 431

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ACKNOWLEDGEMENTS

Technical Writer: Jocelyn Mariah Kremer, Mike Mullins, with input from Alan Macy, Frazer Findlay, Edward Peterlin, and Kelly Stephens.

Cover and frontispiece illustrations: Creative Resource Group, Santa Barbara, CA.

Created with Microsoft Word for Windows, JASC, Inc. JasCapture, FastStone Capture, Adobe Photoshop and Corel Draw 7.

Manual Revision: *AcqKnowledge* 4.4.2 and licenses

PDF 4.27.2016