PCI-2 BASED AE SYSTEM

USER'S MANUAL

Rev 3

April 2007

Part # : 6301 – 1000

Associated with: AEWIN
for PCI-2 Software
Part # : 6301-7001
Version 1.30 or Higher

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PHYSICAL ACOUSTICS CORPORATION

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MANUAL REVISION HISTORY REPORT

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Rev. 3

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2. Chapter 2: revised to Rev 3
3. Chapter 3: unchanged, Rev 0 - 1220-1001, "Sensor and Preamp Manual"
4. Chapter 4: revised to include new brochure - Rev 1.9 – 6320-1006, "AEwin Software Users Manual" unchanged

PHYSICAL ACOUSTICS CORPORATION

PCI-2

Product Bulletin

A Member of MISTRAS Holdings Group

PAC *18-bit A/D, 3kHz - 3MHz* PCI-2: *The New AE Research Tool*

2 Channels of Acoustic Emission for Simultaneous Waveforms and Feature Processing

BREAKTHROUGH!

In 1995, PAC introduced 16-bit 20 MHz A/D for AE. Now with the PCI-2, we are introducing our 18-bit **40 MSamples/sec** A/D for Lower Noise and Higher Speed.

Standard PCI

Pioneering a new 18-bit A/D architecture, the **PCI-2** is a low cost, 2-channels of simultaneous Acoustic Emission (AE) waveforms and features digital signal processing (DSP) system on a single full-size 32-bit PCI-Card, ready for operation in your PC or one of PAC's hardened PCs (for multiple channel operation).

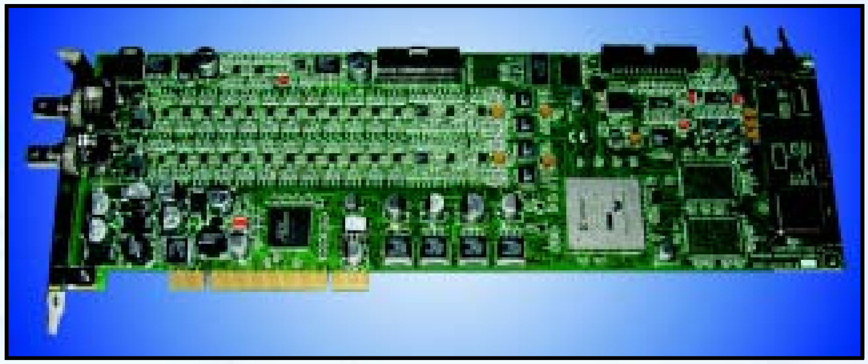

Figure 1. *PCI-2 AE System on a card.*

Superior Noise Performance and Speed

...ideal for Research/Universities

Superior low noise and low threshold performance have been achieved with this revolutionary AE system design, through the use of an innovative **18-bit A/D conversion scheme**, with up to 40 MSample/second acquisition and real time sample averaging. Via the system's pipelined, real-time architecture, this performance is attained without sacrificing AE throughput speed.

With these features and its very low cost, the PCI-2 is ideal for laboratories, universities and industrial turnkey systems, and any application where low noise, low channel count and low cost are required, as well as where the use of an existing PC is desired.

Through the high-performance PCI (Peripheral Component Interconnect) bus and Direct Memory Access (DMA) architecture, significant AE data transfer speeds can be attained, assuring a wide bandwidth bus for multichannel AE data acquisition and waveform transfer. In addition to two AE channels, the system also has **two parametric channels** for other transducers, such as strain gage, pressure, temperature, load, and more.

Data Streaming. . .*Choice of AE Systems*

Waveform data streaming capability is built within the board, allowing waveforms to be continuously transferred to the hard disk. The 32-bit PCI bus is the de-facto standard in all PC

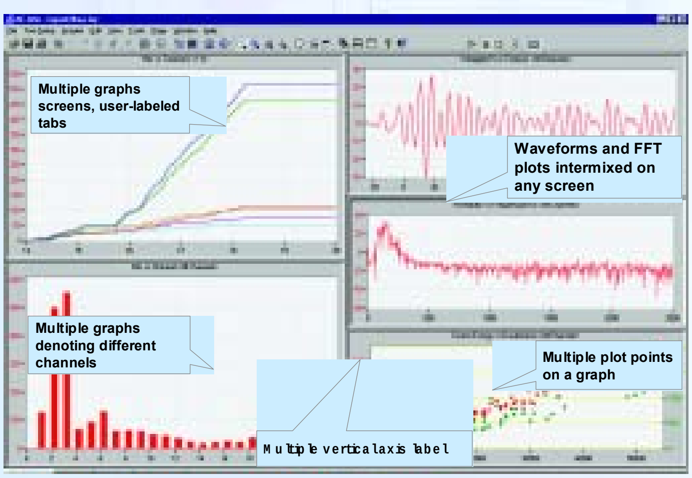

Figure 2. *Simultaneous display of AE features and waveforms.*

Applications:

- Composite materials
- Aerospace structures
- Guided lamb wave systems
- Civil structures, concrete, steel
- Advanced materials testing
- Machine Monitoring, Tool touch and wear
- Acousto/Ultrasonic systems
- Ceramics high-resolution ultrasonic imaging
- On-line monitoring systems for bridges, composite structures, process control
- Tensile testing of samples and coupons

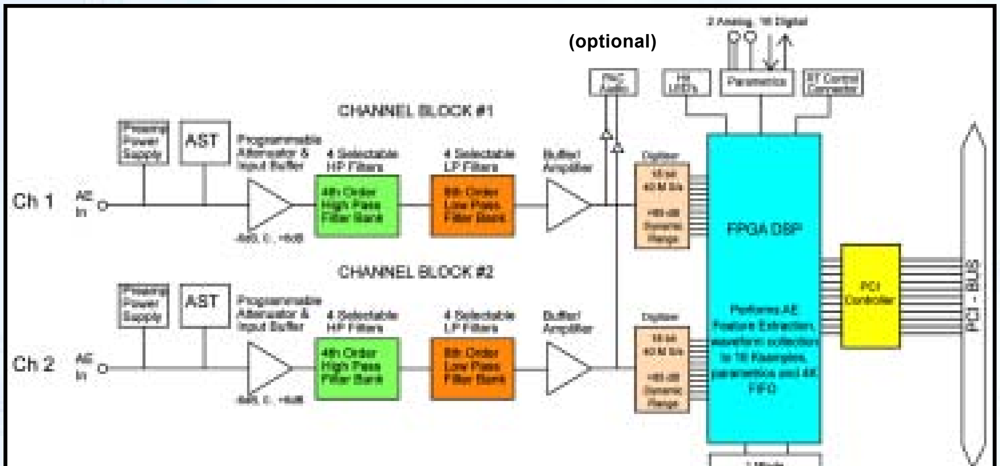

Figure 3. *PCI-2 AE System block diagram.*

computers being shipped today. PCI-2 AE System cards can be implemented inside most standard PC computers or inside one of PAC's rugged, multichannel PAC system chassis, including the 8-channel benchtop chassis, the 12-channel portable AE system or a 4-channel notebook based chassis (μ-series).

Advanced Manufacturing*. . .ISO Environment*

Due to advances in surface mount technology and high density ASIC (high density Programmable Gate Arrays) devices, PAC has been able to provide this single AE System on a board with 2 complete high-speed AE channels of real time AE data acquisition, with real time feature extraction, waveform processing and transfer, 2 analog parametric input channels and 8 digital input and output control signals.

. . .breakthrough A/D, speed, noise, quality and price. . .

User Friendly *. . .by Design*

- Software available for the PCI-2 includes the state-of-the-art **PACwin™ Software Suite.** With 25 years of Acoustic Emission application experience behind it, this Suite is comprised of three individual software packages (purchased separately); these are: AEwin™ real-time Windows acquisition, replay and analysis software, AEwinPost™ post analysis software and NOESIS™, the most complete Pattern Recognition (supervised or unsupervised) and Neural Networks software in the AE and NDT market today. *(Ask about our free software drivers for reading competitive system data files. . .so that their AE data makes sense.)*

Key Features *. . . of the PCI-2 include*

- ♦ **Very low noise**, low cost, 2 channel complete, AE system on a card, with waveform and hit processing built in, on one full size, industry standard, 32-bit PCI card.
- ♦ Internal **18-bit A/D conversion** and processing for better resolution (less than 1 dB) at very low signal amplitudes, and low threshold settings, providing superior low noise performance.
- ♦ **40 MHz, 18-bit A/D conversion** with real time sample averaging (2x or 4x) to provide enhanced accuracy beyond any existing AE system on the market.
- ♦ Built-in, **real time AE feature extraction** and DMA transfer on each channel for high speed transient data analysis at high hit rates directly to the Hard Disk (HD).
- ♦ Built-in **waveform processing** with independent DMA transfer on each channel for high speed waveform transfer and processing.
- ♦ Designed with extremely high density FPGAs and ASIC ICs, to provide extreme high performance and minimize components and cost.
- ♦ 4 High Pass and 6 Low Pass **filter** selections for each channel, totally **under software control**.
- ♦ **AE Data Streaming** is also built into the PCI-2 board allowing continuous recording of AE waveforms to the hard disk at up to 10 MSamples/sec rate (on one channel, 5 MSamples/second on 2 AE channels).
- ♦ Up to **2 parametrics** on each PCI-2 board with **16-bit A/D** converter and update rates up to 10,000 readings/second. The first parametric is a full **Instrumentation conditioning** channel providing signal conditioning including gain control, offset control and filtering options for direct sensor input. The second provides a straight +/- 10 volt input for conditioned sensor outputs.
- ♦ Hit LED, and Audio drivers are built within the PCI-2 board, so that LEDs can be attached directly and sound can be processed via the PAC PCI-Audio Card (option).
- ♦ Digital signal processing circuitry virtually eliminates drift, thereby achieving high accuracy and reliability.

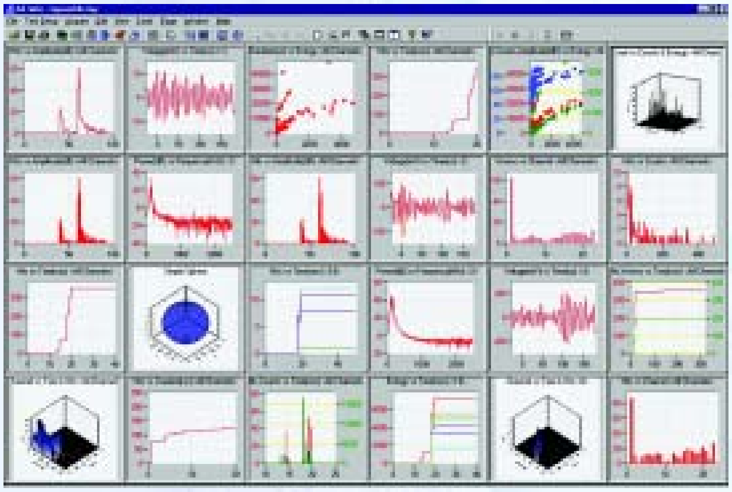

Figure 4. Many graphs per screen can be viewed in real time or replay. This screen shows some of the flexibility of AEwin™. In this overview, 2D and 3D graphs, waveforms, FFT's, line graphs, histograms, multi-plot graphs, etc. are shown.

- **Front Panel** activity lights are totally under the control of your PC to provide status on AE data as well as to give you indication of any malfunctioning of your system.
- **Audio** drives ready for high fidelity listening with your PAC PCI-Audio Card.
- **Auto Sensor** testing standard with all PAC systems for easy system/sensor self calibration and interface coupling efficiency monitoring.

System Flexibility. . . *by Design*

Standard 18-bit PCI hardware and 32-bit Windows AEwin™ software allows the customer maximum flexibility of using a PC or notebook computer. No need to change home made PCs, but ability to take advantage of today's PC speeds readily available with high performance PCI busses. Multiple AE channels (up to 8) are easily synchronized for multiple location algorithms.

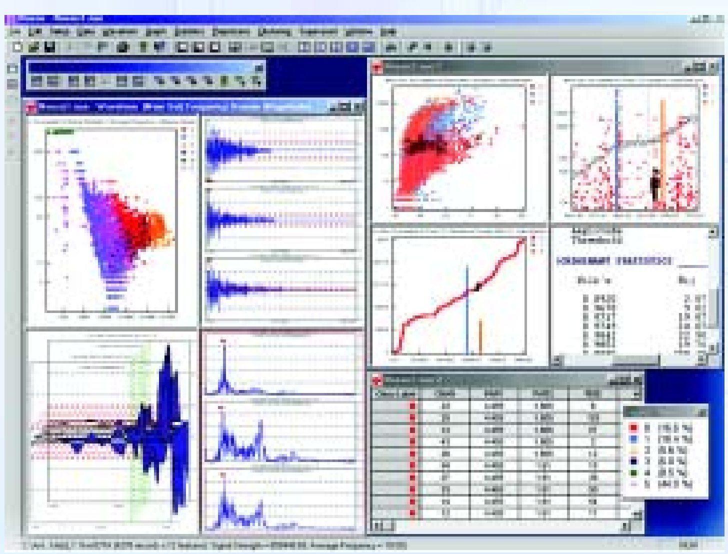

Figure 5. Noesis™ Software for the PCI-2 is sophisticated, yet user friendly and operates under Windows 2000.

Software. . . *supported by PAC's AE multichannel systems experience since the early 70's*

PCI-2 is supported by PACwin™ Software Suite, a PAC Windows Platform consisting of AEwin™, AEwinPost™ and Noesis™ *(individually purchased)*. All software runs in Windows 98, ME (Millennium Edition), 2000 and XP, thus taking advantage of standard features such as multi-tasking, graphic user interfaces, etc. and providing the ability to change AE parameters during test operation.

Multiple location algorithms are available including linear, planar, tank bottom, cylindrical, spherical (with ASME weld zones), 3-D, advanced Non-Linear Regression (NLR) location, and over-determined planar location for exceptional accuracy. All location algorithms utilize attenuation tables/curves, auto-sensor placement, and source corrected amplitude for more accurate location and AE intensity calculation.

PCI-2 Specifications:

Physical:

■ **Size:**	13.415" L x 4.3" H x 0.7" T
■ **Weight:**	1.1 lbs.
■ **Power Consumption:**	12 Watts
■ **DC Power:**	+12.0 volts, 1.0 amps -12.0 volts, 0.05 amps +5.0 volts, 1.5 amp

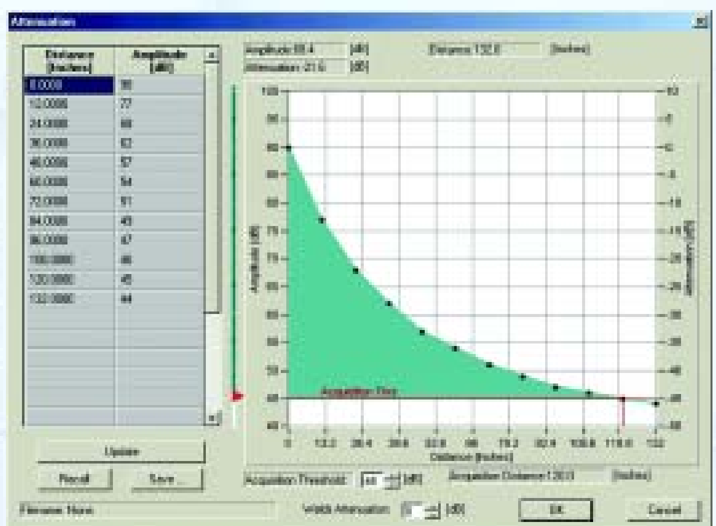

Figure 6. AEwin™ Software can use an attenuation profile of the AE response on the structure. This information is important in determining the source amplitude of an AE event. Attenuation profiles can easily be constructed and displayed in tabular and graphical form. They can be saved and recalled. AEwin™ automatically determines the amplitude at the source (Source Amplitude) and provides this as a graphable AE feature.

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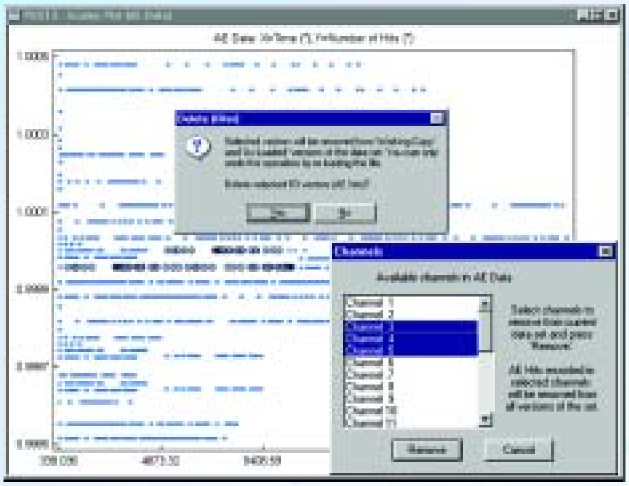

Figure 7. *AEwinPost™ offers a number of ways to filter data including: Select – Delete operation. Simply select the data to be filtered and press delete; filtering via graphical filters; and dedicated channel filters.*

PCI-2 Specifications (continued):

Environmental:

- **Operating Temperature:** 41° – 115° F (5° - 45° C)
- **Storage Temperature:** -4° – 140° F (-20° - 60° C)

Electrical:

- **AE Inputs:** 2 channels
- **Input Impedance:** 50 ohm or 1000 ohm, jumper selectable
- **Preamplifier Power:** Jumper selectable 0 volt or 28 VDC, 100 ma current limited (on BNC center conductor for phantom powering of external preamplifiers)
- **Sensor Testing:** AST built-in
- **Frequency Response:** 3 kHz – 3 MHz (at -3 dB points)

Signal Processing:

- **AE Signal Gain:** 0dB, 6 dB computer selectable input signal scaling
- **Filters:** 4 **High Pass** - computer selectable filters 1 kHz, 20 kHz, 100 kHz, 200 kHz, 4th order Butterworth

  6 **Low Pass -** computer selectable filters 100 kHz, 200 kHz, 400 kHz, 1 MHz, 2 MHz, 3 MHz, 6th order Butterworth
- **Noise: Min. Threshold:** *(3 kHz - 3 MHz bandwidth)* 17 dB without AE Sensor, 22 dB with R15 AE Sensor and 2/4/6 preamplifier, 24 dB with R15I Integral Preamp sensor

Note: Lower noise will be achieved using narrow band filtering

- **ASL Noise:** 4 dB maximum, (with no input)
- **Max. Signal Amplitude:** 100 dB AE
ASL99 dB
- **ADC Type:** 18 bit 40 MSPS per channel maximum
- **Dynamic Range:** > 85 dB
- **Sample Rate:** Computer selectable 100 kS/s, 200kS/s, 500kS/s, 1M-Samples/sec, 2 MSPS, 5 MSPS, 10 MSPS, 20 MSPS, 40 MSPS
- **Sample Averaging:** 40 MSPS with 2x averaging, for a 20 MSPS effective sample rate
- **Extracted AE Features:** Time of 1st Threshold Crossing, Time to Peak, Peak Amplitude, Signal Strength, Duration, Rise Time, Counts, True Energy, RMS, ASL, Parametric 1 & 2.

Analog Parametrics:

- **Parametric Channels:** 2 Channels
- **Parametric A/D Resolution:** 16 bits
- **Parametric Sample Rate:** 10 kHz sample rate for each analog parametric
- **Time Driven Data Rate:** Controlled by software 10 msec. to 60 seconds
- **Time Parametrics:** Both parametrics are available in time data set
- **Parametric #1 Functions:** Computer selectable Input Range ± 10.0v, ±1.0 v, ±0.10v, ±0.01v

  Computer selectable 30 Hz Low Pass filter or none

  5.0 V software programmable offset control with 12 bit DAC

  0 – 10 volt programmable excitation voltage for strain gage bridges
- **Parametric #2 Functions:** Parametric Input Range ± 10.0 v fixed, no filter

Digital I/O:

8 Digital Inputs, 8 Digital Outputs (5 v tolerant), TTL level compatible)

AE Out and Audio Monitor Interface:

Analog switch and buffer to select desired AE channel to be routed to standard PAC audio monitor board or AE output signal

LED Activity Monitor:

On board LED driver to directly drive LED's on front panel. LED minimum on-time is 0.05 seconds.

For more information:

Call (609) 716-4000

or Email us at sales@pacndt.com

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Princeton, NJ

PCI-2 Based AE System

USER'S MANUAL

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INTRODUCTION

PCI-2 BASED AE SYSTEM

USER'S MANUAL

Chapter I – INTRODUCTION

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Chapter I - INTRODUCTION

1. ACOUSTIC EMISSION AND ITS APPLICATIONS

Acoustic Emission (AE) testing is a powerful method for examining the behavior of materials deforming under stress. Acoustic Emission may be defined as a transient elastic wave generated by the rapid release of energy within a material. Materials "talk" when they are in trouble: with Acoustic Emission equipment you can "listen" to the sounds of cracks growing, fibers breaking and many other modes of active damage in the stressed material. Small-scale damage is detectable long before failure, so AE can be used as a non-destructive technique to find defects during structural proof tests and plant operation. AE also offers unique capabilities for materials research and development in the laboratory. Finally, AE equipment is adaptable to many forms of production QC testing, including weld monitoring and leak detection.

Some typical applications of the Acoustic Emission principle in testing materials are as follows:

Behavior of materials: metals, ceramics, composites, rocks, concrete:

- Crack propagation
- Yielding
- Fatigue
- Corrosion, Stress corrosion
- Creep
- Fiber fracture, delamination

Nondestructive testing during manufacturing processes:

- Material processing
- Phase transformation in metals and alloys (martensitic transformation)
- Detection of defects such as pores, quenching cracks, inclusions, etc.
- Fabrication
- Deforming processes — rolling, forging, extruding
- Welding and brazing — detects detection (inclusions, cracks, lack of penetration)
- TIG, MIG, spot, electron beam, etc.
- Weld monitoring for process control

Monitoring structures:

- Continuous monitoring (metallic structures, mines, etc.)
- Periodic testing (pressure vessels, pipelines, bridges, cables)
- Loose Part Detection
- Leak Detection

Special applications:

- Petrochemical and chemical: storage tanks, reactor vessels, offshore platforms, drill pipe, pipelines, valves, hydro-treaters
- Electric utilities: nuclear reactor vessels, piping, steam generators, ceramic insulators, transformers, and aerial devices
- Aircraft and aerospace: fatigue cracks, corrosion, composite structures, etc.
- Electronics: loose particles in electronic components, bonding, and substrate cracking.

2. OVERVIEW OF THE PCI-2 SYSTEM

The Physical Acoustics, PCI-2 "2 Channel AE System on a Card" is a 2 channel, AE data acquisition and digital signal processing system on a single full-size PCI card. Superior low noise and low threshold performance has been achieved with this revolutionary AE system design through the use of 18 bit A/D conversion, 40 MSample/second acquisition with sample averaging and automatic offset control. This performance has been achieved via pipelined, real time architecture, without any sacrifice in AE performance. With these features and it's very low cost, the PCI-2 is ideal for laboratories, Universities and industrial turnkey systems, and any application where low noise, low channel count (8 channels or less) and low cost is a requirement. Through the high performance PCI (Peripheral Component Interconnect) bus and separate Direct Memory Access (DMA) architecture for each channel, significant AE data transfer speeds can be attained, assuring a wide bandwidth bus for multi-channel AE data acquisition and waveform transfer. Additionally, a waveform data streaming capability is built within the board allowing waveforms to be continuously transferred to the hard disk. The 32-bit PCI bus is the standard computer bus connection in all PC computers being shipped today. Therefore, PCI-2 AE System cards can be implemented inside most standard PC computers or inside one of PAC's rugged, multi-channel PAC system chassis's including the 8 channel Benchtop chassis, the 8 channel portable AE system or a µ-PCI-2, 4 channel notebook based chassis.

Figure 1. Benchtop System

Figure 2. Rugged Portable Chassis

As can be seen in figures 1 and 2 a single enclosure houses the entire AE system including an integrated PC computer (and peripherals such as RW-CDROM, Hard and Floppy disk) and up to 8 AE channels (in 2 channel board increments), using the PCI-2 boards.

In addition to these standard rugged PCI-2 based system enclosures, a µ-PCI-2 chassis for use with up to 2 PCI-2 boards (4 channels) is available. This subsystem, no bigger than a notebook computer itself, is capable of being operated from a notebook computer (see figure 3). This is exciting because now it is possible to operate both the notebook computer and the µ-PCI-2 chassis on battery power to make them completely portable (battery operation is optional on the µ-PCI-2).

Figure 3. µ-PCI-2 Chassis

2.1 PCI-2 System Block Diagram

A block diagram of a typical PCI-2 based system is shown in the figure 4 below.

The example shown is for 8 channels, the maximum size configuration of a PCI-2 based system. Referring to the figure, each PCI-2 card (starting top left of the figure) is configured with parametric capabilities including 2[P], 16 bit analog A/D converted parametrics (for measuring external sensors such as temperature sensors), and 8 digital control inputs and outputs. The first parametric on the board features a differential input parametric and gain control and filtering functions (it can interface to a strain gage or Load Cell directly), while the second parametric can handle a straight +/- 10 volt input directly.

This first PCI-2 board in the system also provides master timing, synchronization and communication signals to the remaining PCI-2's in the chassis. (If a rev 3 or higher is used as the first board, it automatically provides and uses its 8-channel parametric input and disables the parametric input of the remaining boards)

A single board CPU (shown at the top right of the figure) provides all the standard resources needed by the PC computer including RAM, hard and floppy disk, RW-CD, the video output, keyboard and mouse inputs, serial COM, USB and parallel ports. In addition, the CPU board provides a high speed PCI bus path for additional cards.

Some of the cards that are in the system include multiple PCI-2 cards (shown on the left side of the figure), a 100baseT network card (this might be part of the CPU board or a standalone card and is optional), and a multi-channel Audio board.

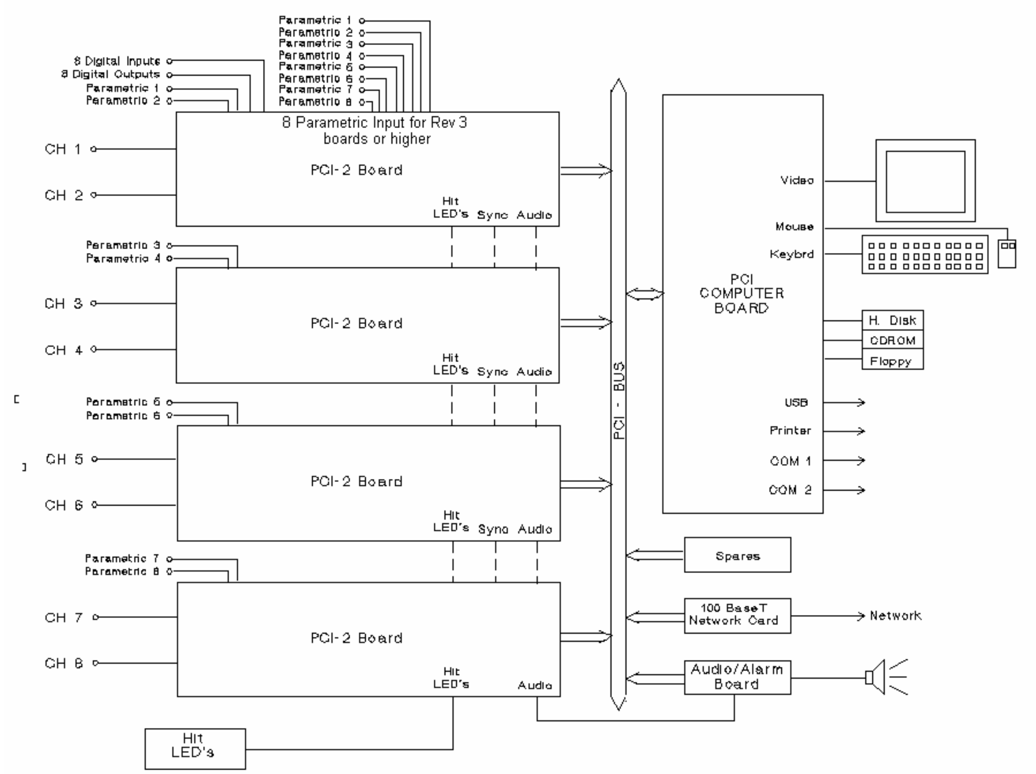


Figure 4. Block diagram of a PCI-2 Based System

[P]8 channel parametric on rev 3 or higher. Parametric 1, 3, 5 & 7 are differential input and Parametric 2,4,6 & 8 are single.

The PCI-2 based AE system and the PAC developed and manufactured PCI-2 cards take advantage of the latest PC bus standard, the "PCI" bus. Through the high performance PCI (Peripheral Component Interconnect) bus, significant AE data transfer speeds (up to 132 MegaBytes/second), can be attained, assuring a wide bandwidth bus for multi-channel AE data acquisition and optional waveform processing. The 32-bit PCI bus has become the de-facto standard in all PC computers being shipped today.

The PCI-2 based AE system is truly a new advanced development that will revolutionize your acoustic emission application. The heart of the system is the new PCI-2 card. This single board AE system is described more fully in the next section.

2.2 Overview of the PCI-2 Card

The Physical Acoustics, PCI-2 "2 Channel AE System on a Card" (see figure 5) is a 2 channel, AE data acquisition and digital signal processing system on a single full-size PCI card. Superior low noise and low threshold performance has been achieved with this revolutionary AE system design through the use of 18 bit A/D conversion, 40 MSample/second acquisition with sample averaging and automatic offset control. This performance has been achieved via pipelined, real time architecture, without any sacrifice in AE performance. With these features and it's very low cost, the PCI-2 is ideal for laboratories, Universities and industrial turnkey systems, and any application where low noise, low channel count and low cost is a requirement. Through the high performance PCI (Peripheral Component Interconnect) bus and separate Direct Memory Access (DMA) architecture for each channel, significant AE data transfer speeds can be attained, assuring a wide bandwidth bus for multi-channel AE data acquisition and waveform transfer. Additionally, a waveform data streaming capability is built within the board allowing waveforms to be continuously transferred to the hard disk. The 32-bit PCI bus is the de-facto standard in all PC computers being shipped today. Therefore, PCI-2 AE System cards can be implemented inside most standard PC computers or inside one of PAC's rugged, multi-channel PAC system chassis's including the 8 channel Benchtop chassis, the 8 channel portable AE system or a μ-PCI-2, 4 channel notebook based chassis.

Due to advances in surface mount technology and high density ASIC (high density Programmable Gate Arrays) devices, PAC has been able to provide this single AE System on a Board with 2 complete high speed, AE channels of real time AE data acquisition, with real time feature extraction, waveform processing and transfer, 2[P] analog parametric input channels and 8 digital input and 8 digital output control signals.

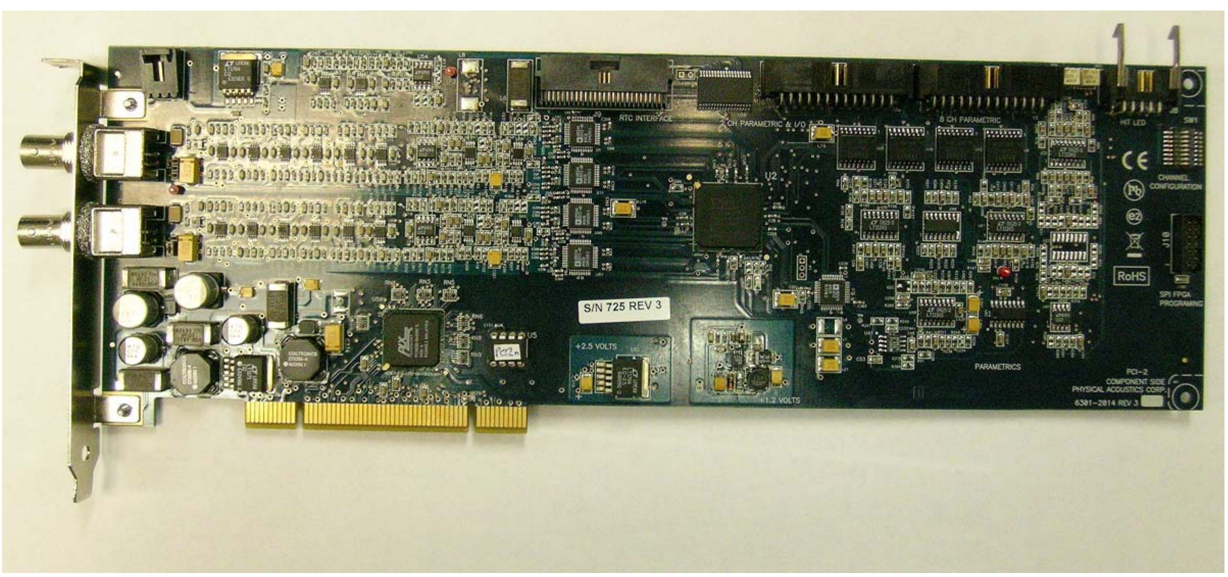


Figure 5. **PCI-2, 2 Channel AE System on a Card (rev 3 or higher)**

[P]8 channel parametric on rev 3 or higher.

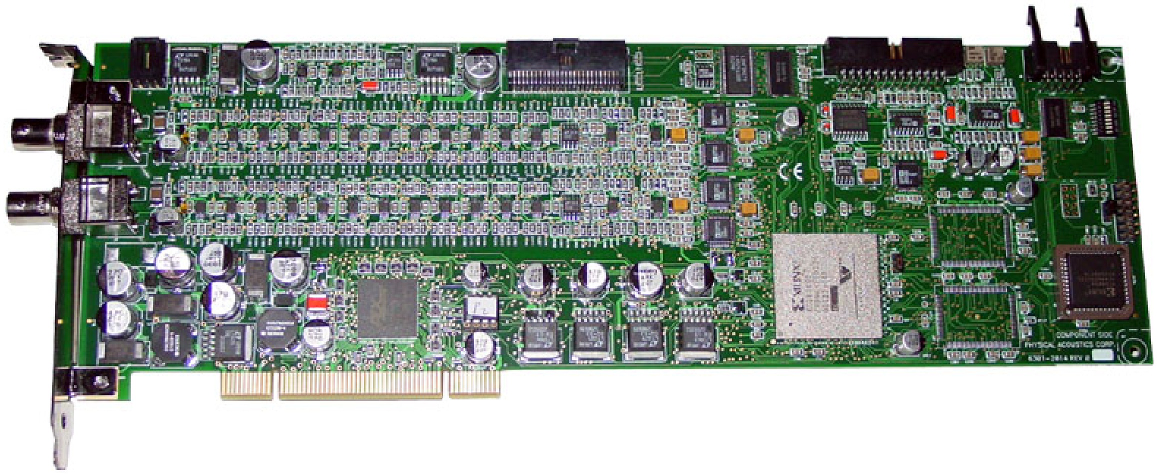


Figure 5. PCI-2, 2 Channel AE System on a Card (rev 2 or older)

2.2.1 Key features of the PCI-2 AE system on a board

Some of the key features of the board include the following:

- Very low noise, low cost, 2 channel complete, AE system on a card, with waveform and hit processing built-in, on one full size, industry standard, PCI card.
- Internal 18 bit, A/D conversion and processing for better resolution (less than 1 dB) at very low signal amplitudes, and low threshold settings, providing superior low noise performance.
- 40 MHz, 18 bit A/D conversion with sample averaging (2x or 4x) to provide enhanced accuracy beyond any existing AE system on the market.
- Built-in, real time, AE feature extraction and independent DMA transfer for each AE channel, provides high-speed transient data analysis at high hit rates.
- Built-in waveform processing with independent DMA transfer on each channel for high speed waveform transfer and processing.
- AE Data Streaming is also built into the PCI-2 board allowing continuous recording of AE waveforms to the hard disk at up to 10 MSamples/sec rate (on one channel, 5 MSamples/second on 2 AE channels).
- 4 High Pass and 4 Low Pass filter selections for each channel, totally under software control.
- 2[P] parametric inputs on each PCI-2 board with 16 bit A/D converter and update rates up to 10,000 readings/second (when attached to hit data). The first parametric is a full "Instrumentation conditioning channel" providing signal conditioning including gain control, offset control and filtering options for direct sensor input (e.g. strain gage inputs). The second provides a straight +/-10 volt input for conditioned sensor outputs.
- Designed with extremely high density FPGA (ASIC IC), to provide extreme high performance and minimize components and cost.
- The AE input can be configured with or without "phantom (28 volt) power" for powering an external preamplifier. This makes the board conducive for general data acquisition applications in addition to Acoustic Emission.
- Hit LED, and Audio drivers are built within the PCI-2 board so that LED's can be attached directly and sound can be processed via the PAC PCI-Audio Card.
- Digital signal processing circuitry virtually eliminates drift, thereby achieving high accuracy and reliability.

[P] *8 channel parametric on rev 3 or higher. Parametric 1, 3, 5 & 7 are differential input and Parametric 2,4,6 & 8 are single.*

2.3 PCI-2 Card Block Diagram Description:

A simplified block diagram of the PCI-2 board is shown in figure 6 and described below. The input signal directly from the PAC preamplifiers (or the PAC integral preamplifier sensors) is routed to each of the PCI-2 channel inputs via industry standard BNC connectors located on the rear PC metal hold-down bracket of the board. Phantom (28 volt) power for powering the preamplifiers is available (jumper selectable) on the center conductor of the AE input coaxial connector. Also, PAC's standard unique AST (automated sensor test) is built-in, providing computer controlled pulsing of each active AE channel for determination of sensor coupling efficiency and automated AE system verification.

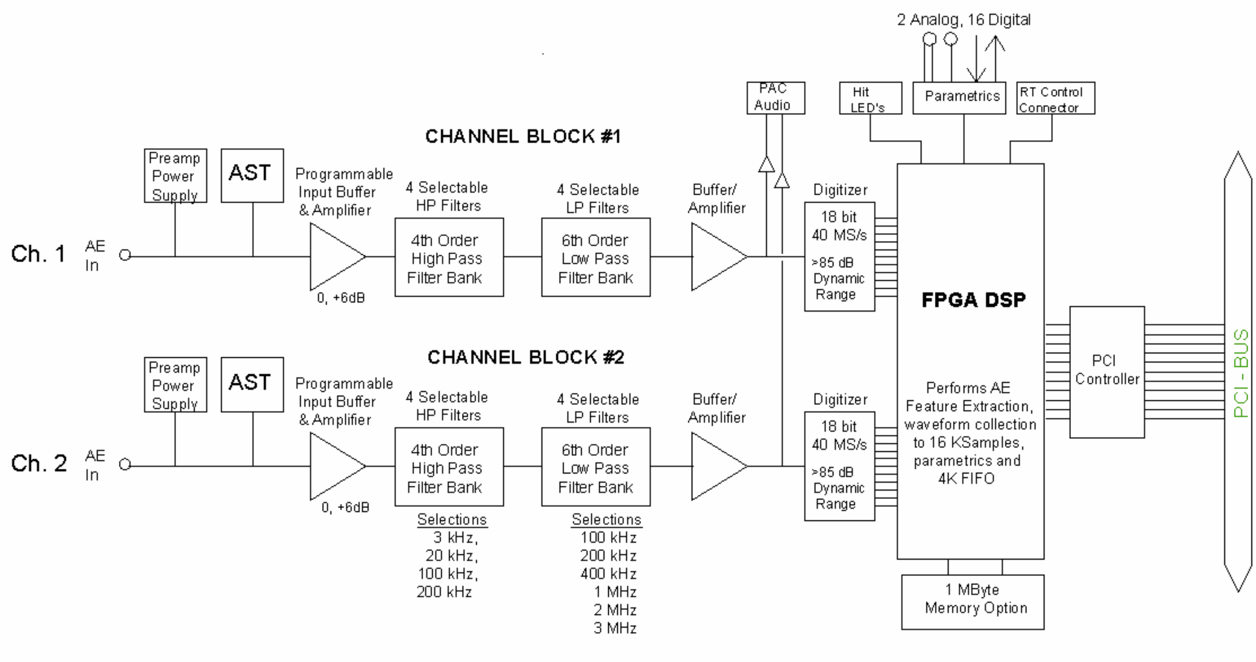


Figure 6. PCI-2 Block Diagram Description

The incoming AE signal is passed through the (computer controlled) programmable amplifier and buffer circuitry with selectable gain of 0 (no gain) or +6 dB, and passed to the selectable filter circuitry where one of 4 High Pass filters and one of 6 Low Pass filters is applied in accordance with the user programmed filter strategy (up to 24 different filtering combinations). The filtered signal is passed to the 18 bit, 40 MS/sec A/D converter module where the AE signal is digitized at rates up to 40 MSPS. The 18 bit, digital AE output is then passed to the DSP based FPGA where various computer selectable sampling options and sample averaging takes place for extreme low noise, 18 bit processing. The processed, digitized 18 bit waveform is then passed to internal Hit Detection processing and is available (upon demand) for continuous (unlimited length) streaming to the hard disk. The built-in hit detection and processing circuit performs feature extraction (which converts the detected AE signal burst into AE hits and multiple AE features instantaneously). The high-speed feature extracted data is DMA transferred to the computer for further processing through the PCI bus. Also simultaneously, the hit based waveforms (with computer selected sampling rate and length up to 15 kSamples) are processed and transferred to the computer using high speed DMA access directly to the computer for collection, further processing and storage.

Additional connectors at the top of the board (and at the top of figure 6) provide the standard important connections from the PCI-2 card. First is the Audio Output connector which provides the output conditioned AE signal for external AE monitoring and Audio Signal processing using PAC's optional digitally controlled, high fidelity, PCI-Audio Monitor card. Next is the Hit LED connector upon which Hit LED's can be directly connected. Next, is the Parametric connector featuring Analog parametric inputs, as well as 8 digital Inputs and 8 Digital Outputs for

Industrial control interfacing. The next connector is the 8-channel parametric input which is available for rev3 or higher. A PC backplate connector is available for interfacing to this connector if the board is sold separately and not with a standard PAC chassis in which the connector is available on the back panel of the PAC Chassis. The first of the Two Parametric inputs (or odd channels) is a full differential, Instrument conditioning channel with gain control (x1, x10, x100, x1000), offset control, programmable excitation source, and filtering. The second parametric (or even channels) is a standard single ended +/- 10-volt input for pre-conditioned parametric signals.

The last connector shown on the top-right of figure 6, the "Real Time Control" connector, is the interface connector for attaching additional PCI-2 cards for synchronized operation via the "Daisy Chain" ribbon cable approach.

3. TERMINOLOGY USED IN THIS MANUAL AND THE AE INDUSTRY

With AE products and now with the new PCI-2 product comes some commonly used terms relating to the system and its parts. This section introduces and defines these terms.

AE (**A**coustic **E**mission): AE is used for the abbreviation of Acoustic Emission throughout this manual and the non-destructive test industry.

AEDSP-32/16: Also known as the AEDSP board or card, this is the PAC printed circuit board, which is the heart of the MISTRAS-2001 AE system. It has two complete digital data acquisition channels and an on board Floating Point Digital Signal Processor.

ADTI: This acronym means, "Aerial Device Testing Instrument". This describes the turnkey test that is performed using the AIMS and DiSP instrument to inspect bucket trucks.

AIMS: This name (**A**coustic emission **I**ndustrial **M**ultichannel **S**ystem) describes a PAC Acoustic Emission "Knowledge Based" instrument with 16 – 56 AE channels that has been used in performing standard Turn-key procedure based inspections (such as Bucket Truck Testing with the ADTI version and Rail Road Tank Cars with the Transportation Instrument version AIMS system).

Digital AIMS: This is the name for the PAC AE product based on integrating one or more PCI-DSP4 cards into a rugged industrial rated computer and chassis to carry out turnkey procedure based inspections.

DiSP: This is the name for the PAC AE product based on integrating one or more PCI-DSP cards into a computer or PAC multichannel chassis. DiSP can be thought of as a **Di**gital **SP**ARTAN or you can think of the very advanced DSP architecture built within the DiSP.

DSP: This terminology describes the **D**igital **S**ignal **P**rocessor that resides on the PCI-DSP card. A second DSP processor resides in each waveform option board as well. A DSP is a special purpose microprocessor that is specifically made for high speed processing, data manipulation and mathematics relating to the processing of digital signals.

Command Line: The command line refers to an executable's (.EXE or .COM) program name and any special commands (usually referred to as switches or options) that follow the program name which alter the operation of that program. As an example calling the program; **MOUSE.COM /1 /L** then <ENTER> would execute the mouse program on COM port (Serial Port) #**1** and be configured for a left-handed person. In this case the command line is all the items in Bold.

DTA or Data File: A data file refers to the files generated and stored on your hard disk by the PAC programs used with the AE system when carrying out a test. All PAC data files use the **.DTA** extension (e.g. TEST0000.DTA) and can easily be recognized in file directories by looking for that file extension name.

GUI: This term stands for **G**raphical **U**ser **I**nterface. This is the stand industry term given to software, which supports a mouse and has "graphical" windowed pull-down menus. The most familiar programs that use a GUI is Microsoft's WINDOWS.

INI or Initialization File: An initialization file saves complete AE system configuration information, including data acquisition H/W setup, graph setup, location set-up, filter set-up, etc. that can be recalled into your AE system at any time to restore it to a set-up that you desire to run. All PAC initialization files use the **.INI** file name extension (e.g., MI-LOC.INI) and can easily be recognized in file directories by looking for that file extension name.

ISA Bus: This is the standard bus used in most PC compatible computers to plug in computer expansion cards. The term ISA means "Industry Standard Architecture." The bus is a 16 bit bus and can be recognized immediately by noting the two card edge connectors (one 62 pin and one 36 pin) at the bottom of the board that make up the ISA bus.

Layout file: A layout file is the nomenclature used in AEwin software, to donate the stored software setup or initialization file. All AEwin initialization (or Layout) files use the file extension "LAY" to distinguish them as a setup file.

Menu: A menu as used in this manual refers to the choices that are made on the computer screen when setting up and running the software programs supplied. These menus can be pull-down menus or just a list of functions presented on the screen.

MISTRAS-2001: MISTRAS-2001 is the name of the entire AE system including AEDSP-32/16 board(s), PAC Olive, expansion chassis (if used), sensors, preamplifiers, cables and operation software. Sometimes the word MISTRAS is used in its place.

MISTRAS: MISTRAS has two meanings depending on the context within which it is used. Generally, MISTRAS is used interchangeably with MISTRAS-2001. However the standard software supplied with the MISTRAS-2001 is also called MISTRAS. This software performs independent channel data acquisition along with Linear Location. It is similar to the DAQ software that we supply with other products such as SA-DAQ or LO-DAQ, etc. Therefore when used in the software context, MISTRAS denotes the program MISTRAS.EXE.

PAC: This is the abbreviation for Physical Acoustics Corporation, the company which is proud to provide you with the PCI-2 based system and support you in your non-destructive testing work.

PCI: The high performance PCI (Peripheral Component Interconnect) bus is a high speed PC computer bus available in most of today's PC computers. It offers 32 bit wide data paths and up to 132 Megabytes/second data transfer speeds. The 32-bit PCI bus has become the de-facto standard in all PC computers being shipped today.

PCI-2: The PCI-2 is a PCI based AE data acquisition, "AE System on a board" with 2 full and complete AE real time, 18 bit A/D, feature extraction and waveform processing channels.

PCI-8: The PCI-2 is a PCI based AE data acquisition, "AE System on a board" with 8 full and complete AE real time, feature extraction and waveform processing channels.

Olive or PC Olive: The PAC Olive is the IBM PC compatible computer that PAC markets and sells for use with its PC compatible products. PAC Olive is the computers company name and designation.

Root (or Root Directory): This corresponds to that section of your hard disk (usually C:\>), which has the boot up information, which the computer needs to initialize. All other directories and sub-directories are called from that root directory.

TSR (**T**erminate and **S**tay **R**esident): This is a PC computer program jargon for a software program that is loaded into memory and stays inactive in the background of the main program which is running until some special keys are pressed at which time it initiates and carries out its function. As an example GRAFPLUS is a **TSR**, which is always in memory, and ready to print the screen upon pressing the <Shift-Print-Screen> keys at which point it will print out the screen on the printer.

3.1.1 Glossary of Acoustic Emission Terms

The glossary is presented in two forms; First, selected key terms are shown in a logical order that shows how standard terminology is used to describe the AE process from source to data storage. Second, a more complete glossary is presented in alphabetical order. Definitions for items marked with an asterisk are drawn from ASTM E 1316, sometimes with minor changes.

3.1.1.1 Key Terms in Logical Order

Acoustic Emission (AE)	Elastic waves generated by the rapid release of energy from sources within a material.
Event (AE)	A local material change giving rise to acoustic emission.*
Source	The physical origin of one or more AE events.
Sensor	A device containing a transducing element that turns AE wave motion into an electrical voltage.
Signal	The electrical signal coming from the transducing element and passing through the subsequent signal conditioning equipment (amplifiers, frequency filters).
Channel	A single AE sensor and the related equipment components for transmitting, conditioning, detecting and measuring the signals that come from it.
Detection	Recognition of the presence of a signal (typically accomplished by the signal crossing a detection threshold).
Hit	The process of detecting and measuring an AE signal on a channel.
Signal Features	Measurable characteristics of the AE signal, such as amplitude, AE signal energy, duration, counts and rise time.
Hit Data Set	The set of numbers representing signal features and other information, stored as a result of a hit.
Event Data Set	The set of numbers used to describe an event, pursuant to data processing that recognizes that a single event can produce more than one hit.

3.1.1.2 All Terms in Alphabetical Order

Acoustic Emission (AE)	Elastic waves generated by the rapid release of energy from sources within a material.
Activation (AE)	The onset of AE due to the application of a stimulus such as force, pressure, heat etc.
Activity* (AE)	A measure of emission quantity, usually the cumulative energy count, event count, ring down count, or the rates of change of these quantities.
Amplitude (AE)	The largest voltage peak in the AE signal waveform; customarily expressed in decibels relative to 1 microvolt at the preamplifier input (dBae) assuming a 40 dB preamp. For this case, 0 dB corresponds to a 100 μvolt peak at the output of the 40 dB preamplifier and 100 dB would correspond to a 10-volt peak signal at the output of the preamplifier.

Amplitude Distribution*	A Digital display of the number of AE signals at (or greater than) a particular amplitude, plotted as a function of amplitude.
Attenuation	Loss of amplitude with distance as the wave travels through the test structure.
Burst emission*	A qualitative description of the discrete signal related to an individual emission event occurring within the material.
Channel (AE)	A single AE sensor and the related equipment components for transmitting, conditioning, detecting and measuring the signals that comes from it.
Continuous emission*	A qualitative description of the sustained signal level produced by rapidly occurring acoustic emission events.
Counts	The number of times the AE signal crosses the detection threshold. Also known as "ring down counts", "threshold crossing counts".
dBae	A unit of measurement for AE signal amplitude A, defined by A (dBae) = 20 log V_p where V_p is the peak signal voltage in microvolts referred to the preamplifier input.
Detection (AE)	Recognition of the presence of a signal (typically accomplished by the signal crossing a detection threshold).
Event* (AE)	A local material change giving rise to acoustic emission.
Event Data Set (AE)	The set of numbers used to describe an event, pursuant to data processing that recognizes that a single event can produce more than one hit.
Event Description	A digital (numerical) description of an event, comprising one or more signal descriptions and/or information extracted from them or calculated from them.
Event Energy* (AE)	The total elastic energy (in the wave) released by an acoustic emission event.
Felicity Effect*	(The reverse of the Kaiser effect) The presence of AE at stress levels below the maximum previously experienced.
Frequency	For an oscillating signal or process, the number of cycles occurring in unit time.
Guard Sensors	Sensors whose primary function is the elimination of extraneous noise based on arrival time differences.
Hit (AE)	The detection and measurement of an AE signal on a channel.
Hit Data Set	The set of numbers representing signal features and other information, stored as a result of a hit.
Intensity* (AE)	A measure of the size of the emission signals detected, such as the average amplitude, average AE energy or average counts.
Kaiser Effect*	The absence of detectable acoustic emission at a fixed sensitivity level, until previously applied stress levels are exceeded.
kHz	Kilohertz, an SI unit of frequency, 1000 cycles per second

Location*	Relating to the use of multiple AE Sensors for determining the relative positions of acoustic emission sources.
Noise	Non-relevant indications; signals produced by causes other than AE, or by AE sources that are not relevant to the purpose of the test.
Nondestructive	The development and application of technical methods to examine components in ways
Testing(NDT)*	that do not impair future usefulness and serviceability in order to detect, locate, measure and evaluate flaws; to assess integrity, properties and composition; and to measure geometrical characteristics.
Parametric Inputs	Environmental variables (e.g. load, pressure, temperature) that can be measured and stored as part of the AE signal description.
Risetime	The time from an AE signal's first threshold crossing to its peak.
Sensor	(AE) A device containing a transducing element that turns AE wave motion into an electrical voltage.
Signal (AE)	The electrical signal coming from the transducing element and passing through the subsequent signal conditioning equipment (amplifiers, frequency filters).
Signal Description	The result of the hit process: a digital (numerical) description of an AE signal and/or its environmental context.
Signal Features	Measurable characteristics of the AE signal, such as amplitude, AE energy, duration, counts, risetime, that can be stored as part of the AE signal description.
Signal Strength (AE)	The strength of the absolute value of a detected AE signal. Also known as "relative energy", "MARSE" and "signal strength".
Source (AE)	The physical origin of one or more AE events.
Source Energy (AE)	The total energy (of all forms) dissipated by the source process.
(Primary) Zone	The area surrounding a sensor from which AE can be detected and from which AE will strike the sensor before striking any other sensors.

* Definitions based on ASTM Standards, E-1316 etc.

4. AVAILABLE CONFIGURATIONS

4.1 Standard Hardware Components

A PCI-2 based system is an AE System based on using one or more PCI-2, 2 channel AE cards. A PCI-2 system can be configured in one of several ways:

- A standard PC desktop computer can be configured with one or more PCI-2 cards (which can usually be configured for up to 4 channels),
- μ-DiSP based, using the μ-DiSP chassis with a notebook computer one or two PCI-2 cards (for 4 AE channels) or,
- Use of PAC's more rugged and industrial chassis's. These chassis have been designed with appropriate industrial ruggedness, flow-through card cooling, AE Hit LED's and AE Audio output compatibility for AE monitoring using sound feedback. (Audio output is standard on the Portable unit and optional on the Benchtop series).

  PAC has two different chassis that can offer up to 8 channels of AE operation. These include;

  1. the low cost Benchtop series that can handle up to 4 boards (or 8 channels), and
  2. the rugged, field portable chassis, with up to 4 PCI-2 boards (for up to 8 channels),

  The standard PCI-2 based System includes the following internal and external hardware components.

  - PAC System Chassis with internal PC computer (μ-DiSP uses an external notebook computer)
  - High resolution Super Extended VGA Monitor, Keyboard, Mouse
  - PCI-2 Cards (2 channels per board)
  - PAC Audio Monitor board (standard in Portable systems, optional in all others including PAC Olive, μ-DiSP and Benchtop series).
  - AE Integral Preamplifier Sensors
  - Signal Cables between Preamps and PC
  - Power Cables
  - AEwin software and software options

4.2 Number of Channels

Each PCI-2 card processes 2 AE channels. All PCI-2 boards are the same. (Unlike the PCI/DSP-4, there is no need for a first board in the system being a parametric based board). The reason for this is that each PCI-2 board has 2, 16 bit parametrics built-in as standard. The number of parametrics available in the AE system then increases by 2 for each board in the system, up to 8 parametrics total. The typical PC computer can hold 2 PCI-2 cards or 4 AE channels. The standard Benchtop model chassis offers a maximum of 4, PCI-2 cards for 8 channels, and the rugged, portable chassis holds 4, PCI-2 cards for a maximum of 8 AE channels also. Each chassis holds the PC computer in addition to the PCI-2 cards, making the system a full AE system with integral computer.

The μ-DiSP chassis holds a maximum of 2 PCI-2 cards for a maximum of 4 channels, notebook controlled AE system.

4.3 PCI-2 Based System, Internal Computer Configurations

The computer used inside these PCI-2 based system chassis's, is a fully PC compatible computer. Due to the ever-changing PC specifications and the fact that continuous improvements are being made and prices changing, the following standard system is continuously subject to change. Please contact our sales department for current computer specifications.

As a standard computer, PAC provides the user with all the features that are expected in an everyday computer. Users have grown accustomed to the desktop computer and its standard and optional features. From that standpoint, these features are built within each PCI-2 based system. As a minimum, a user can expect the following PC hardware in the PCI-2 based system.

STANDARD COMPUTER FEATURES

- High Performance CPU, 2.0 GHz minimum
- At least 256 Mbytes of RAM
- At least 40 Gbytes of Hard Disk.
- one 1.44 MByte 3.5" Floppy Drives
- one ReWritable CD ROM
- Serial, Parallel I/O Interface, USB Port(s)
- Super VGA (XGA) w/16Mbyte RAM or greater
- Super VGA (XGA) Monitor, 17" (1024x768) .28 mm dot pitch, minimum
- 101 Key Keyboard
- Mouse
- Network Interface (standard in Rugged Portable optional in other computers)
- WINDOWS 2000 or better

OPTIONS

- Higher capacity Hard Disk Drives
- Additional Memory
- Other Rewritable CD's
- ZIP Drives
- Flat Screen monitors
- Printers
- Modems for Remote control
- Network Interface (for those systems where this feature is optional)
- Application Software Packages.

4.4 Sensor, Preamplifier and Connecting Cables

Each channel requires its own sensor, preamplifier and connecting cables — With very few exceptions, all PAC manufactured sensors and preamplifiers are mutually interchangeable. Some sensors have integral cables for connection to the preamplifier but most require a separate cable. Integral-preamplifier sensors have their preamplifier built into the sensor case. The length of the cable between the preamplifier and the PCI-2 based system may be selected to suit the needs of the application environment. This can be from several feet to over thousands of feet (PAC 1224 series of line drivers might be required for lengths greater than 2000 feet). The PCI-2 based system's come with standard Auto-Sensor Test capability built-in, which provides an automated method of testing 1 or multiple sensors in a system under system software control. Select integral sensors and PAC preamplifiers with integral AST option to take advantage of this tremendous capability.

Sensors: PAC manufactures a wide range of sensors. Some PAC sensors have integrated preamplifiers, reducing cabling and simplifying setup; these are the R6I, R15I, R30I, R50I and WDI type models. With the built-in "Auto Sensor Test" capability on the PCI-2, make sure you use sensors with the built-in AST as they can be used for automated pulsing and receiving and sensor coupling/sensitivity checks. Other popular sensors, used with external preamplifiers such as the separate 0/2/4, 2/4/6, In-Line series (single and differential models) and 1220A-AST preamplifiers, are the A3, R6 and R15, R30, μ30, nano-30, R50, R80, R100 and WDI sensors, to name a few. It is recommended to utilize the AST version preamplifiers with the PCI-2 to automate sensor testing.

Preamp: For passive sensors such as the A3, R6, and R15, etc., PAC has various models of Preamplifiers with built in auto sensor test. These include the 0/2/4, 2/4/6, In-Line Differential, In-Line Single ended preamplifiers. These models have been designed to condition sensor outputs to be acceptable for inputs on all PAC instruments. They each have AST (auto-sensor test) capability of self-pulsing the sensor for test of a single sensor or groups of sensors on the same structure.

Cables: The 1234-XX cable is the standard coaxial RG-58/AU cables used between PAC Integral preamplifier sensors (such as the R6I and the R15I). They are standard RG-58 50 Ohm coaxial cables to be used when connecting between the preamp outputs and the input of the AE System. PAC manufactures these in varying lengths for any application. The special (RED) sensor cables (#1230 and #1232) have been designed to optimize noise rejection of piezoelectric devices. These connect between sensors and preamps.

Power Cable: Standard 3 connector AC power cord.

4.5 Frequency Filtering

The system provides frequency filtering both in the preamplifiers and on the PCI-2 board —The 1220A and 2/4/6 preamplifiers use a plug-in filter module with a specified type and frequency value. This filter can be "high pass," "low pass" or "bandpass." The most standard selection is a narrow bandwidth, "bandpass" filter. However, with the multiple selection filter capability built within the PCI-2 cards, it is recommended that a wide bandwidth filter (1 kHz – 2000 kHz) is used and that the actual filter selection is made within the PCI-2 based system, under software control. This allows flexibility in selecting sensors and frequency ranges for the final application without requiring any internal hardware or manual filter changes. It is therefore recommended that the preamplifier use a wide bandwidth filter such as a PAC "2-14-40 BP-SYS", unless the application is settled and requires something specific, which may be selected from PAC's standard list or custom built to your needs. Other preamplifiers such as PAC's in-line series have internal fixed filters and need to be ordered with a specific frequency and gain.

In addition in the PCI-2, a bank of high performance, active filters are built within each channel on the PCI-2 card. Each channel contains 4 – "High Pass" filters, meaning that they pass frequencies above the stated cutoff frequency, and 6 – "Low Pass" filters, meaning that they pass frequencies below the stated cutoff frequency. These filters are software selectable by the AEwin software. Having 4 high pass and 6 low pass filters, each being independently selected provides many useful AE system bandwidths. The standard Filter values for the PCI-2 card are as follows:

High Pass Filters		Low Pass Filters	
HP-1	1 kHz	LP-1	100 kHz
HP-2	20 kHz	LP-2	200 kHz
HP-3	100 kHz	LP-3	400 kHz
HP-4	200 kHz	LP-4	1000 kHz
		LP-5	2000 kHz
		LP-6	3000 kHz

As an example, to make a 100 – 200 kHz BandPass filter, the user would select the HP-3 and LP-2 selections. The AEwin acquisition software has a menu to aid in this frequency selection. Refer to the AEwin software user's manual for more information on the setup menu's.

4.5.1 Using a Filters.set File

On systems that have non-standard filters there exists a special file – 'Filters.set'. The purpose of this file is to make sure that the text AEwin displays in the hardware setup dialog reflects the choices available for that channel. Systems built at the factory with non-standard filters, come with filters.set pre-configured. The following is a detailed description of this file.

When to use this file:

a) If you have non-standard filters on any data acquisition channels.
b) If you have non-standard filters and want the correct filter values shown in the hardware setup menu when you are in 'replay-only' mode.

Please understand that creating a filters.set file with frequencies that are not available in the AE channel will not make that frequency available. The purpose of this file is only to make sure that the text AEwin displays in the hardware setup dialog reflects the choices available for that channel.

When AEwin initializes it looks for a file named filters.set in the program folder of the computer. If it finds one it will load it, overriding the default filter values for all channels listed in the file.

FILE FORMAT AND DESCRIPTION:

If a semicolon ';' is the first character of a line, the line will be ignored when it is read by the program. Semicolons are for putting comments and notes into the file. Semicolons do not work as 'to end of line' comments, they can only be the first character of a line to function as a comment. Blank lines are also ignored and are ok to have in the file.

The following fields are required to define a filter. All fields must present and in the correct order (as described).

FIELD	DESCRIPTION
filter:	The number of the filter, first filter is '2', add '1' for each defined filter (if a second filter is defined set this number to '3', a third would be '4' etc.)
highpass:	The value for each of the available highpass filters, in kHz, for the channels that are defined. These values are always listed in increasing order.
lowpass:	The value for each of the available lowpass filters, in kHz, for the channels that are defined. With the exception of the first value, which is the largest value, these are listed in increasing order.
channel:	A list of channels that use the defined filter. If there are many channels using the same filter, multiple channel lines are permitted (each line must start with channel:). Also, if all channels in the system have the same filter configuration, specifying 0 for the channel sets all channels to the defined filter.

Acceptable delimiters for all fields are spaces and tabs, do not use commas or any other characters to separate fields or field entries. e.g. channel:...1,2,3,4 is not acceptable (. and , are not valid).

After you create a filters.set file (using notepad or some other pure text editor, NOT Word or Excel), you should check the AEwin hardware setup dialog and make sure that the entries for the analog filters are correct.

TYPICAL AVAILABLE FILTERS:

The following define the standard filters that are available for the PCI-DSP4

```
highpass:  10 20 100 200
lowpass:   2000 100 200 400
```

EXAMPLE:

The actual filters.set file should be placed in the program folder of the AEwin program (same folder as AEwin.exe).

Cut the following text and put it into a file named filters.set (which may already exist). Note that it is not necessary to do this as the following example uses the default filter values. If you received a board with custom filters, you need to modify the values as described above.

```
| -------------- CUT BELOW THIS LINE ---------------|
filter:    2
highpass:  10 20 100 200
lowpass:   2000 100 200 400
channel:   0
| -------------- CUT ABOVE THIS LINE ---------------|
```

4.6 Standard Software Supplied

All software provided with the PCI-2 based system whether standard or optional is installed onto the computer's hard disk and ready to run immediately upon booting the PCI-2 based system. In addition, a spare copy of the software is provided on diskette or CD for backup purposes. Software provided with the standard PCI-2 System comprises:

A. WINDOWS : This is loaded onto the system and prepared to run. The Windows CD and certificate and any associated documentation is also provided.

B. Driver S/W: Driver software (usually on CD) and a user's manual for the associated computer are also provided.

C. AEwin: AEwin is the WINDOWS based, AE acquisition, analysis and replay software program provided with the PCI-2 as standard. This extremely powerful Acoustic Emission program uses all of WINDOWS resources, providing users with a very familiar Windows interface while at the same time performing AE data acquisition, analysis and replay. Also included is waveform processing and display, multiple graphs per screen, and zonal and linear location modes as standard. Further information about the AEwin software is provided in the AEwin software user's manual (chapter 4).

4.7 Optional Software

Optional software for the PCI-2 based systems is broken down into two different categories. First, are those options which are available within the AEwin program. These options extend the capability of AEwin. The second category is those separate programs, which provide additional functions outside of AEwin. (Consult PAC for availability) includes:

4.7.1 AEwin Options

2D-LOC: Full Planar, 2 Dimensional Location Option: The two-dimensional (2D) source location option adds's a versatile planar location capability into the AEwin standard location setup. The advanced 2D Planar "Smart Location Algorithm" (SLA) can handle sensors in any position and provides accurate location information. This is regardless of whether the sensors are arranged in a rectangular, triangular, or haphazard manner. An easy setup screen allows a mouse oriented, automated or manual sensor placement and a grid type (spreadsheet) editing table. The user is also able to enter and visualize the type of structure being setup (plate, pipe, vessel, etc.). The software will take advantage of the geometry to aid in setup, sensor placement, and even in performing the location algorithm. The location algorithm takes advantage of the geometry and also uses information from each of the sensor, which have detected the event. Using the integrated attenuation analysis, the user can also visualize the detection range of a given size source event. Also, the location provides information on the actual source amplitude. The built-in Clustering capability allows multiple clusters graphs and groups, colorized cluster severity levels and zoom and history plots on a selected cluster. A section of this manual is devoted to AEwin software.

3D-LOC: Three dimensional location (3D-LOC) software adds the 3D-Location option to the existing Location setup menus. The 3D-LOC setup screen allows a mouse oriented sensor placement capability, and table editing features for accurate 3D sensor placement. The 3D-Location algorithm also a "Smart Location Algorithm" take advantage of the geometry of sensor placement as well as data from all the sensors that detected the event (up to 8), to determine an accurate source. A minimum of 4 hits in an event is needed to determine and display a 3D location. The source location plot shows the event on a 3-dimensional screen which is easily and fully rotatable, can be zoomed and panned and seen at any orientation in acquisition and replay. Clustering is also providing to show and assess groups of AE events.

SPHERE-LOC Spherical Location is another Location option added to the standard Location setup menu that provides an accurate source location on a Sphere. A user-friendly location setup menu is provided allowing for automatic placement of sensors on the structure and table based sensor location editing. A special weld setup allows the user to automatically place and visualize weld lines on the structure both in setup and on the actual location screen. A 3D spherical image is presented on the Windows display, which is fully rotatable. The image can also be zoomed or panned and cursor readout allows for easy location of events on the screen. Events can be sized on the screen for easy viewing, colors of the sphere, sensors and events are easily changed for the most pleasing result and longitude and latitude lines can be shown. The sphere transparency can be set in order to show events on the front or back of the sphere at the same time.

TB-LOCwin: Tank Bottom Location is another Location option for AEwin which allows the user to easily setup and perform tank bottom testing. A "Tank Bottom" menu item is added to the Location setup with this option allowing the user to easily set up for a Tank Bottom test by sizing and creating the tank bottom graphic, automatically placing the sensors, and carrying out a Tank Bottom location with tank display.

AEwinPOST: AEwinPost is a fully featured utility in AEwin for post processing Acoustic Emission data. The utility allows data preview using graphs, plots and tabular views. The data can be sorted and filtered through user selected actions or user defined advanced filters. Waveform viewing and feature extraction, first hit extraction and many more operations. The treated data can be exported to a new DTA or TDA file for use with AEwin.

32 Groups: 8 Location groups are standard in AEwin. This option expands the limit to 32 independent location groups. This is very useful in cases where many similar structures are being tested at the same time.

AEwin Replay: This option allows you to purchase a copy of AEwin for use on a separate analysis computer.

LeakTEC/On-Line-Crack Alarms: The LeakTEC/On-Line-Crack Alarm option in AEwin is used for detection of leaking and/or cracking conditions. There are two separate alarm types included with this option – LeakTEC alarms and On-Line Crack alarms. LeakTEC Alarms are used to monitor ASL or RMS levels during acquisition and alert the user if they stray beyond certain pre-set lower and upper limits. On-Line Crack Alarms are used to monitor hits or events during acquisition and alert the user if the hit/event or energy rates exceed certain pre-set levels. Setup is simple and highly customizable.

4.7.2 Additional Optional Programs for PCI-2 based systems

Those optional software packages that can be purchased to complement your PCI-2 based AE system include the following:

NOESIS: Noesis is an advanced pattern analysis and recognition software for use both with AE features and waveform data. This software includes Supervised and non-supervised, statistical and neural network based pattern recognition analysis and classification, data clustering and data visualization in 2 and 3 dimensional graphs. Noesis also allows for advanced post test manipulation, filtering and data visualization capabilities.

Dispersion Curves: PAC-share Dispersion Curves is a free software utility in the AEwin utilities menu that allows the user to view the various wavemodes with their frequency versus velocity relationship based on the material selection and plate thickness. This is useful in determining velocity and filter parameters for source location.

Wavelet & Short Time FFT Analysis Software: This free utilities program is a post processing waveform based WINDOWS program for visualization and processing of waveforms in the Time/Frequency domain.

Internet & Remote Control Software: PAC Systems have options that allow them to be connected to the user's network, or the internet, and control or monitor a test from a remote computer. This software is built right into our main AE software packages as an option and is user friendly. Many times the user performs analysis at his remote computer as if he is working directly on the AE system and can start and stop a test, download data files and view live reports and graphs.

5. SPECIFICATIONS

The following specifications are broken down into two main categories. The first section (section 5.1) describes specifications associated with the entire PCI-2 based system, composed of the AE system chassis, internal computer and PCI-2 cards. The second section (section 5.2) describes the PCI-2 card in detail. Naturally, all specifications are subject to change. If there is doubt about a specification, please contact the Physical Acoustics Customer Service department.

5.1 PCI-2 Based System Specifications (Preliminary and Subject to change):

<u>Number of Channels Max:</u>

The Rugged Portable Chassis	can hold up to 8 channels or 4 PCI-2 Cards.
The Benchtop Chassis	can hold up to 8 channels or 4 PCI-2 Cards.
The μ-DiSP Chassis	can hold up to 4 channels or 2 PCI-2 cards and requires an external (notebook) computer.

<u>Dimensions & Weight (full with all boards):</u>

Rugged Portable Chassis	14.25" Wide x 8.13" High x 21.5" Deep (362mm x 207mm x 546mm, 19 Kg)	42 lbs.
Benchtop Chassis	17" Wide x 6.25" High x 17" Deep (432mm x 159mm x 432mm, 16 Kg)	35 lbs.
μ-DiSP	15.71" Wide x 3.41" High x 9.5" Deep. (399 mm x 87mm x 241mm, 2.7 Kg)	6 lbs.

<u>Operating Environment:</u>

Temperature:	10 - 45° C
Humidity:	8 – 90% Relative Humidity, non-condensing
Altitude:	10,000 feet pressure altitude
Shock:	2g, 3 axis
Vibration:	1.5g, 3 axis

<u>Internal Computer:</u>

PC Bus:	PCI & ISABus, Passive backplane computer
CPU:	2.0 Ghz or greater CPU, Pentium, Celeron or AMD
Memory:	256 Mbytes minimum
Hard Disk:	40 Gbyte minimum
Floppy:	3.5" standard
CD ROM Drive:	Rewritable CD .
Video:	3D AGP Video w/16Mbyte
Serial:	2-16C550 compatible serial ports
Parallel/Printer:	One bi-directional EPP (Enhanced Parallel Port)
USB	USB ports standard
Network Option:	10/100 Base-T standard on Large Multichannel and Rugged Portable models. Optional on Benchtop and μ-DiSP.

5.2 PCI-2 Board Specifications (subject to change):

PCI-2 board Physical Specifications

Size:	13.4" L x 4.8" H x 0.7" T
Weight:	1.1 lbs.
Power Consumption:	12 Watts
DC Power	+12.0 volts, 0.6 amps -12.0 volts, 0.10 amps + 5.0 volts, 0.8 amps

Electrical Specifications

AE Inputs:	2 channels
Input Impedance:	50 Ω or 1000 Ω, switch selectable
Preamplifier Power:	Jumper selectable 0 volt or 28 VDC, 100 ma current limited (on BNC center conductor for phantom powering of external preamplifiers).
Sensor Testing:	AST built-in
Frequency Response:	1 kHz – 3 MHz (at -3 dB points)

Signal Processing

AE Signal Gain	0, 6dB computer selectable input signal scaling
Filters	4 High Pass Computer selectable filters- 3 kHz, 20 kHz, 100 kHz, 200 kHz, 4th order Butterworth 6 Low Pass –Computer selectable filters 100 kHz, 200 kHz, 400 kHz, 1000 kHz, 2000 kHz, & 3000 kHz, 6th order Butterworth filters. 6 Low Pass –Computer selectable filters (Rev 3 or higher) 100kHz, 200kHz, 400kHz, 1.0MHz, 2.0MHz digital filter & 3.0MHz, 6th order Butterworth filters. *Note: When selecting greater than 10MSPS sampling rate, the 3.0MHz filter must be used.*

Noise (wideband):
(Filtering can lower noise even more)

Filter	ASL (no input)	Minimum Threshold
1kHz – 3MHz	4dB	17dB w/o preamp or sensor 22 dB w 2/4/6 & R15 24 dB with R15I sensor

Maximum Signal Amplitude:	100 dB AE ASL 99 dB
ADC Type	18 bit 40 MSPS per channel maximum
Dynamic Range:	> 85 dB
Sample Rate:	Computer selectable 100kS/s, 200kS/s, 500kS/s, 1M-Samples/sec, 2MSPS, 5MSPS, 10MSPS, 20MSPS, 40MSPS. – (40MSPS with 2x averaging, for a 20 MSPS effective sampling rate). - (40MSPS with 4x averaging, for a 10 MSPS effective sampling rate).

Extracted AE Features:	Time of 1st Threshold Crossing, Time to Peak, Peak Amplitude, Envelope Strength, Duration, Rise Time, Counts, True Energy, RMS, ASL, Parametric 1 & 2.

<u>Analog Parametrics;</u>

Number of Parametric Channels:	2 Channels (8 for rev 3 or higher)
Parametric A/D Resolution:	16 bits
Parametric Sample Rate:	10 kHz sample rate for each analog parametric.
Time Driven Data Rate;	Controlled by software. 10 msec. to 60 seconds.
Time Parametrics:	All parametrics are available in time data set.
Parametric #1 (#3, #5 & #7) functions:	- Computer selectable Input Range ± 10.0v, ±1.0 v, ±0.10v, ±0.01v. - Computer selectable 30 Hz Low Pass filter or none ± 5.0V software programmable offset control with 12 bit DAC - 0 – 10 volt programmable excitation voltage for strain gage bridges.
Parametric #2 (#4, #6 & #8) functions:	Parametric Input Range ± 10.0v, x1 gain, no filter.

<u>Digital I/O:</u>	8 Digital Inputs, 8 Digital Outputs (0 – 3.3 volt, 5v tolerant, TTL level compatible)
<u>Audio Monitor Interface:</u>	Analog switch and buffer to select desired channels to be routed to standard PAC audio monitor board.
<u>LED Activity Monitor:</u>	On board LED driver to directly drive LED's on front panel. LED minimum on time is 0.05 seconds.

5.3 PCI-2 Board and Bracket Connections

A board component and connector layout of the PCI-2 card is shown in figure 7, along with its PC metal bracket with BNC connectors as seen outside the AE system chassis. Also shown on the layout are all the internal connectors including J5 AE output and Audio Connector, J6 Parametric & I/O Connector, J8 Hit LED's Connector, and J9 Real Time Control Connector.

The AE input BNC connectors accept input from the AE phantom power preamplifiers or integral preamplifier sensors. AE Channel numbering sequence is shown in the figure and usually etched or imprinted on the metal bracket.

5.4 PCI-2 On-Board Jumper and Connector Description

A PCI-2 board layout is shown in figure 7. On the figure can be seen all the connectors available on the PCI-2 card for interfacing. Below is a description of each of these connectors and their use. Pin assignments for those connectors which are accessible by the user is also provided.

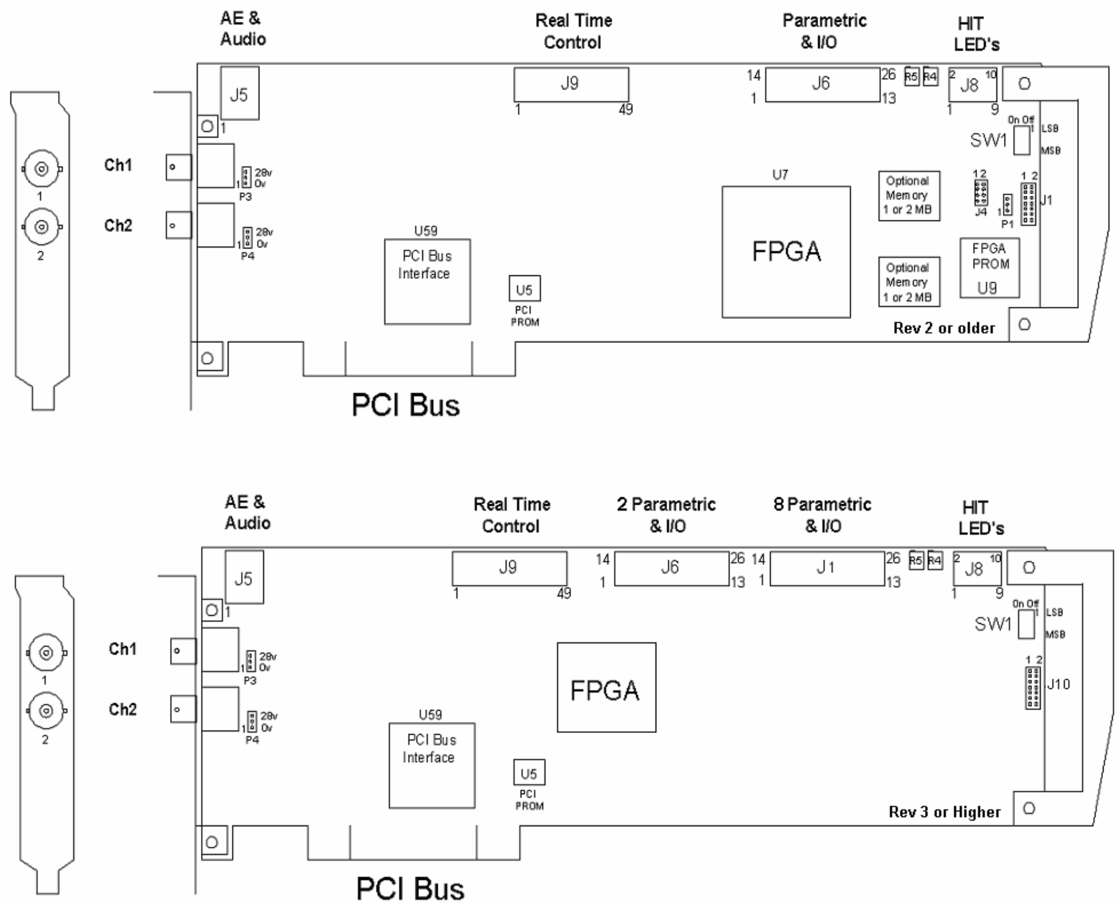


Figure 7. PCI-2 Board Layout showing key components, jumpers and Connector locations

There are 4 main connectors (1 additional for rev 3 or newer) on each PCI-2 card. These connectors are all located on the top of the board. They include the J5 Audio output connector, located on the top left of the board. Located near the center of the board on the top is the J9 Real Time control bus connector that connects between each PCI-2 card in the system. Located on the right side of the board and at the top is the J6 Parametric & I/O connector, and the J8 Hit LED output connector. The additional connector J1 is for the 8 channel Parametric.

In addition to the connectors, there are also several on-board connectors including J1 (J10 for rev 3 or higher) located on the right side of the board, near the center which a JTAG access port for internal PAC testing use. Also J4, located near J1 is a test point connector that PAC uses during initial testing of the board.

Also important are two 3-pin, user programmable jumpers, P3 & P4 located just behind the AE channel BNC connectors. These programmable jumpers select the AE input termination impedance and whether or not preamplifier power is provided out the center conductor of BNC coax connector. The jumper settings for each of these jumpers is as follows:

Jumper Setting	Condition
1-2 Connected	0 volt preamp power, 50 ohm
2-3 Connected	28 volt preamp power, 50 ohm
No connection	0 volt preamp power, 1 Kohm

PCI-2 boards are shipped with pins 2-3 connected together with a shorting jumper, providing 28 volt power to the preamplifier and 50 ohm termination. This is the default setting of the PCI-2 board.

The description and pinout of the connectors J5, J6, J8 and J9 is presented below.

5.4.1 J5 AE Output and Audio Connector Description and Pin-out

The J5 Audio Connector provides Analog AE outputs for each AE channel on the board. The AE outputs are meant to connect into PAC's Audio board, which is available for all PCI-2 based AE system chassis. The AE analog outputs can also be used for oscilloscope monitoring for test purposes. The Audio connector is a 3 pin connector. The pinout of the connector is listed on the table below. There is only one pin that requires further discussion. This is pin 2. This pin is the combination or mixing of one or both of the on-board channels as selected by the software Audio board control. The AEwin software is able to control this switching function. It can output any combination of AE output channels onto this pin to the Audio board. All these controls are user selectable via the Audio board menu control in AEwin software. The pinout of this connector is provided in the table below.

Pin #	Function	Description
1	Ground	Analog Signal Ground
2	Selected AE output	Combined (mixed) AE analog signal output . 1 or more AE output channels
3	Ground	Analog Signal Ground

J5 Audio Connector Description

5.4.2 J8 Hit LED Connector Description and Pin-out

The J8 Hit LED connector, provides outputs that can directly drive an external LED connected by the customer. We have conditioned the AE hit signal to provide a time stretched digital output which is a minimum of 50 milliseconds long or lasts for the entire hit duration, whichever is longer. We have also put this time stretched signal through an LED driver and have internally connected the LED resistor so that the user can easily just connect the LED anode to the appropriate pin of the connector and the cathode end to ground. The Hit LED connector is a 10 pin IDC connector. The pinout of the 10 pin connector is shown in the table below.

Pin #	Name/Description	Specification
1	Hit LED #1	Connect LED #1 Anode here
2	Hit LED #2	Connect LED #2 Anode here
3	Not connected	Not connected
4	Not connected	Not connected
5	Not connected	Not connected
6	Not connected	Not connected
7	Not connected	Not connected
8	Not connected	Not connected
9	Digital Ground	Digital Ground
10	Digital Ground	Digital Ground

J8 Hit LED Connector Description

5.4.3 J1 and J6 Parametric and Digital I/O Connector Description and Pin-out

The J6 parametric connector is a 26 pin IDC (Insulation displacement connector) connector. It has been designed to be connected via a ribbon cable to the rear panel of the PCI-2 based system through a DB-25 pin connector. The J6 parametric contains 2 Parametric inputs (the first being true differential), a programmable analog voltage output (for use as an excitation source for strain gage bridges), 8 programmable digital inputs and 8 programmable digital outputs. The table below provides complete information on the connector pin-out and description. The pin-out of the connector is the same at the board IDC connector and on the DB-25 connector.

Pin #	Function	Description
1	+ Parametric #1 Input	+ Differential Input +/- 10 volts
2	- Parametric #1 Input	- Differential Input +/- 10 volts
3	Parametric #1 ground	Signal Ground for Parametrics
4	Parametric #1 ground	Signal Ground for Parametrics
5	Parametric #2 ground	Signal Ground for Parametrics
6	Parametric #2 Input	Single Ended Input +/- 10 volts
7	Excitation signal ground	Signal Ground for Parametrics
8	Programmable Excitation Voltage	0 – 10 volt DC output
9	No connection	
10	No connection	
11	Digital Input 1, **Test Start Signal**	0 – 5 volt TTL Input, Active High
12	Digital Input 2, **Streaming Trigger**	0 – 5 volt TTL Input, Active High
13	Digital Input 3	0 – 5 volt TTL Input
14	Digital Input 4	0 – 5 volt TTL Input
15	Digital Input 5	0 – 5 volt TTL Input
16	Digital Input 6	0 – 5 volt TTL Input
17	Digital Input 7	0 – 5 volt TTL Input
18	Digital Input 8	0 – 5 volt TTL Input
19	Digital Output 1, **Alarm Warning Out**	0 – 5 volt TTL Output, Active High
20	Digital Output 2, **Alarm Trip Out**	0 – 5 volt TTL Output, Active High
21	Digital Output 3	0 – 5 volt TTL Output
22	Digital Output 4	0 – 5 volt TTL Output
23	Digital Output 5	0 – 5 volt TTL Output
24	Digital Output 6	0 – 5 volt TTL Output
25	Digital Output 7	0 – 5 volt TTL Output
26	Digital Output 8	0 – 5 volt TTL Output

J6 2-Parametric & Digital I/O Connector Description

When more than two parametrics are needed, a special interfacing board is available to combine these into one connector otherwise, this is not required if using rev 3 boards or higher.

Pin #	Function	Description
1	+ Parametric #1 Input	+ Differential Input +/- 10 volts
2	+ Parametric #3 Input	+ Differential Input +/- 10 volts
3	Parametric #5 Input	Single Ended Input +/- 10 volts
4	Parametric #2 Input	Single Ended Input +/- 10 volts
5	Parametric #6 Input	Single Ended Input +/- 10 volts
6	Analog Ground	Analog Ground for Parametrics
7	EXEC_VOLTAGE1	
8	EXEC_VOLTAGE2	
9	RMS - DAC Out 1	RMS Analog Output
10	RMS - DAC Out 2	RMS Analog Output
11	Digital Output 1, **Alarm Warning Out**	Active High TTL Output
12	Digital Input 7	Spare TTL Level Input
13	Digital Ground	Digital Ground
14	- Parametric #1 Input	- Differential Input +/- 10 volts
15	- Parametric #3 Input	- Differential Input +/- 10 volts
16	Parametric #7 Input	Single Ended Input +/- 10 volts
17	Parametric #4 Input	Single Ended Input +/- 10 volts
18	Parametric #8 Input	Single Ended Input +/- 10 volts
19	Digital Input 4, Inhibit All AE Channels	Active Low TTL level input
20	+12 volt power out	+12 volt power out
21	- 12 volt power out	- 12 volt power out
22	RMS - DAC Out 3	RMS Analog Output
23	RMS - DAC Out 4	RMS Analog Output
24	Digital Output 2, **Alarm Trip Out**	Active High TTL Output
25	Digital Input 1, **Test Start Signal**	Active High TTL Input
26	N/C	N/C

J1 8-Parametric & Digital I/O Connector Description (rev 3 or higher)

5.4.4 J9 Real Time Control Connector Description

The purpose of the J9 Real time control connector is to control and coordinate each of the PCI-2 cards from the first master card in the system. The connector is a 50-pin HD (high density) connector. This connector performs multiple functions. It transmits the parametrics from the parametric control circuitry, it coordinates the start and stopping of a test, it synchronizes the time of test clocks to the master one in the first PCI-2 card, and coordinates other signals between the PCI-2 boards. A daisy chain ribbon connector **must** be connected to each PCI-2 board in a multiple board system. The daisy chain connector must also be connected to any repeater card when other AE system chassis will be used. Please make sure that this connector is fastened securely to each PCI-2 card in the system and repeater card before running a test.

Since there are no user accessible connections, the pin-out is not specified.

5.5 PCI-2 Board Addressing

The PCI-2 board is a PCI (Peripheral Component Interface) board that is designed to be Plug-&-Play in a typical PC computer with WINDOWS operating system software. Upon boot-up the PC computer scans all the PCI boards in the system to determine their memory and usage requirements and automatically assigns a working address in the computer. The PCI-2 being a PCI board operates very well with this standard and traditional board addresses or hardware selections for things like interrupt selections and board addresses for the PC bus are not required.

Since there can be multiple PCI-2 boards in the PCI-2 based AE System (up to 4 boards maximum), there needs to be a way to identify which channel group (in 2 channel increments) a given PCI-2 board should be assigned to. Specific AE channels for multiple boards are set by SW-1, switches #1–6. SW-1 can be seen in figure 8 at the top right hand side of the PCI-2 card. These addresses are set using a binary pattern where SW-1, position 1 corresponds to the LSB (least significant bit) and SW-1, position 6 the MSB (most significant bit). It is programmed assuming that OFF or OPEN means a binary weight of "1" and ON or CLOSED is a binary "0." Also it is programmed where all 0's (in the chart below) correspond to board #1 (AE channels 1 - 2).

AE Board Addressing Examples: (On/Closed = 0, OFF/Open = 1)

		SW-1 Switch Positions					
Board #	Ch. #'s	6	5	4	3	2	1
#1	1 - 2	0	0	0	0	0	0
#2	3 - 4	0	0	0	0	0	1
#3	5 - 6	0	0	0	0	1	0
#4	7 – 8	0	0	0	0	1	1

When setting board addresses, please make sure that each board has a unique address and that boards are assigned in a sequential order starting from board 1 and going up.

5.6 Upgrading FPGA Firmware on PCI-2 Boards (Rev 2 or older only)

The PCI-2 board has 2 on-board PROM's that control the operation of the board's Field Programmable Gate Arrays (FPGA's). From time to time, PAC offers PROM upgrades, which improves the performance of the PCI-2 boards. The PROM's are socketed on the board for easy field replacement. Figure 7 shows the location and the IC number or "U" number of each PROM on the PCI-2 board.

U9 is located at the lower right edge of the PCI-2 card. This is the key FPGA PROM on the board. This is the PROM that programs the U7 FPGA which is responsible for the entire board's acquisition, Hit signal processing, waveform collection and processing, parametric and time driven data processing, feature extraction and processing and general board interface coordination. U5 is the second PROM on the board and is located just above the PCI bus, card edge connector. This PCI-PROM programs the initial state of the PCI interface controller IC (which is U59), and is located just to the left of U5. These PROM IC's are easy to spot because they are the only IC's in sockets. This also makes them easy to change.

Whenever you receive an upgrade package, you may receive one or more PROM's as part of the upgrade. Just look on the label on the IC to note the associated "U" number to see where it goes.

Remove the existing part by gently prying between the PROM IC and its socket using a small, flat bladed screwdriver. Install the new device by locating pin 1 on the PROM and pin 1 on the respective socket. Position the PROM over the socket so that each pin of the PROM is aligned with its corresponding socket contact. Using gentle but firm thumb pressure to press the IC fully into the socket. Inspect the IC after insertion for any bent pins or pins that may not be inserted into the socket.

5.7 AE Signal Processing Features and Specifications

The following is a list of all the controllable AE features and timing controls available on the PCI-2 board along with its resolution and maximum range. Some of these features may or may not be accessible by some of the high-level software programs but are still in the board

Signal Characteristics	Resolution	Units	Range
Time of Hit/Time of Test	0.250	Microseconds	0–407 days
(PAC) Energy	1 count	10 μvolt-sec/count	0–65,535
Signal Strength	1 count	3.05 picovolt-sec	0–1.31x10^{8} picovolt-sec
Absolute (True) Energy	1 count	9.31 x 10^{-22} Joules	2.61 x 10^{-8} Joules
Amplitude	1 dB	1 dB	10–100 dB
Rise Time	1 usec	Microseconds	0–65.5 msec
Duration	1 usec	Microseconds	0–1000 msec
Counts	1 count	Count (Threshold crossing)	0–65,535 counts
Counts To Peak	1 count	Counts	0–32,768 counts
Partial Power (w/waveform option)	0.01%	Percent of Total Power	0 – 100%
Frequency Centroid (w/waveform option)	1 kHz	KHz	1 kHz – 2100 kHz
Peak Frequency (w/waveform option)	1 kHz	KHz	1 kHz – 2100 kHz
Initiation Frequency (Rise Time based frequency)	1 kHz	KHz	0 – 65,535 kHz
Reverberation Frequency (Average Frequency of AE burst after peak)	1 kHz	KHz	0 – 65,535 kHz
Average Frequency (Average Frequency of entire AE burst)	1 kHz	KHz	0 – 65,535 kHz
RMS	0.2 millivolts	Millivolts	0–6 volts
ASL	1 dB	1 dB	0–100 dB
Threshold	1 dB	1 dB	14–99 dB

Signal Characteristics	Resolution	Range
Analog Parametric #1	0.30 µvolts (at gain 1000)	-10 to +10 volts
Analog Parametrics #2	300 µvolts	-10 to +10 volts
Absolute Energy Rate	1 count	4.295 x 10^9
HDT (Hit Definition Time)	1 usec	40 usec–65.5 msec
HLT (Hit Lockout Time)	1 usec	40 usec–65.5 msec
PDT (Peak Definition Time)	1 usec	40 usec–65.5 msec

Figure 8 shows the AEwin "Data Sets" menu. It is from this menu that AE Hit features and AE Time Driven features are selected for processing and storage.

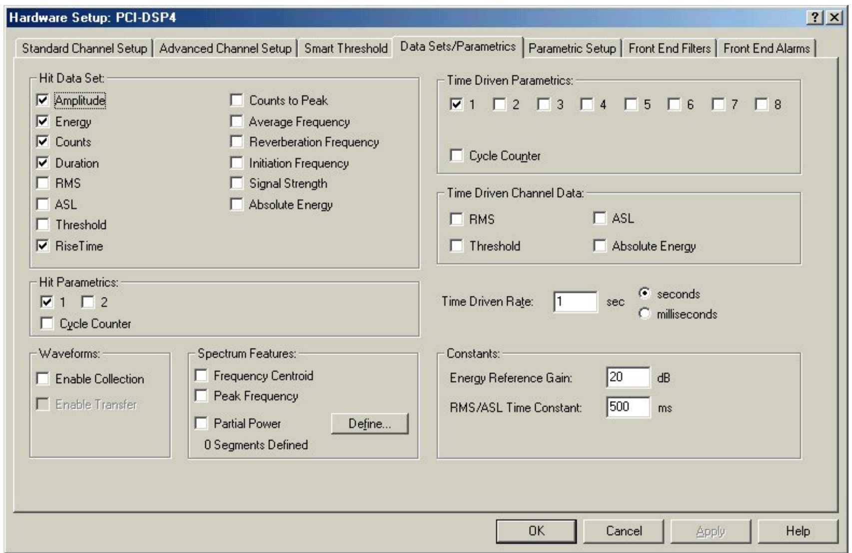


Figure 8. Datasets Menu on AEwin

Referring to the figure 8, There is an area for selecting which AE Hit Features (left side of the menu) and Time Driven AE Information. In regards to the hit features, note at the bottom of the menu, even up to 2 parametrics can be chosen to be in the hit data set. In this mode, parametric information can be updated at rates up to 20,000 times per second. In addition, note that there are 14 standard AE features (top left side of the menu).

5.7.1 AE Hit Driven Features Descriptions

Referring to the Hit based features, this section tries to provide a better definition as to what exactly each feature means to the AE user. Figure 9 shows a fictitious Acoustic Emission waveform with some of the AE features superimposed on the waveform.

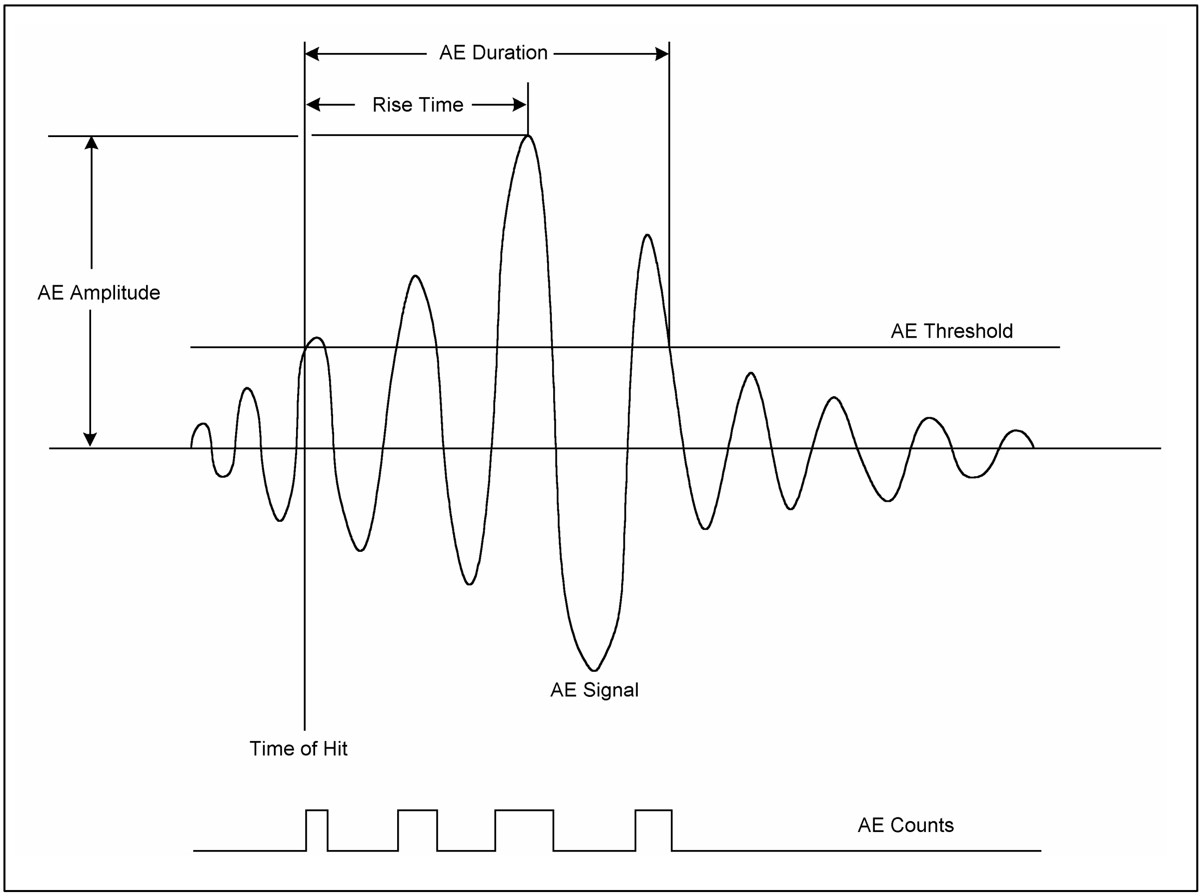


Figure 9. AE Hit Feature Extraction diagram

Following along with figure 9, the following features can be seen and described.

Time of Hit: (also known as "Time of Test" clock), This is the time at which a hit has been detected by the PCI-2. This is detected the instant that the AE Signal exceeds the AE Threshold.

Amplitude: The AE Amplitude is the maximum (positive or negative) AE signal excursion during an AE hit. The Amplitude is expressed in dB using the relationship:

$$dB = 20 \log (V_{max}/1\mu\text{-volt}) - (\text{Preamplifier Gain in dB}).$$

For example, if the preamplifier gain is 40 dB, and the maximum voltage detected is 1 volt, the amplitude is 80 dB.

Energy: (also referred to as "PAC-Energy"). PAC Energy has been a PAC AE feature parameter since 1978. "PAC-Energy" is a 2-byte parameter derived from the "integral of the rectified voltage signal over the duration of the AE hit" (or waveform), hence the voltage-time units). Although PAC-Energy has the same definition as Signal Strength, the only difference is in the sensitivity, size and dynamic range of this parameter. In other PAC instruments, such as SPARTAN's and LOCAN's, the "PAC Energy" feature is a gain dependent quantity. For example at 0 dB instrument gain, its resolution is 10 microvolts-seconds (per Energy count) while at 20 dB, PAC-Energy resolution is 1 microvolt – second (per count). However, the PCI-2, DiSP, MISTRAS-2001 and LAM doesn't have or need gain setting since they operate over the entire AE signal dynamic range (without the need for gain). Therefore, in order to allow customers who have used our products over the years relate the PAC-Energy readings from those earlier products (such as SPARTAN's and LOCAN's), we have created a control called "Energy Reference Gain". The "Energy Reference Gain" setting now provided in the "Data Sets" dialog box (bottom right of figure 8) allows you to match the value of Energy reported by our DiSP, MISTRAS or LAM, to that of a SPARTAN-2000 or other PAC instrument which has programmable gain. The value of the Energy Reference Gain can be set from the Data Sets Dialog box (Test Setup, Hardware Setup, Data Sets...). The range is 0 to 60 dB.

Counts: (also referred to as AE Threshold Crossing Counts). This AE Hit feature simply counts the AE signal excursions over the AE Threshold. In figure 9, an example shows that 4 AE counts have been generated.

Duration: AE Duration is defined as the time from the first threshold crossing to the end of the last threshold crossing of the AE signal from the AE Threshold. An example is shown in figure 8.

RMS: Root Mean Square is a measure of the continuously varying AE signal "voltage" into the AE system. RMS is an electrical engineering power term defined as the rectified, time averaged AE signal, measured on a linear scale and reported in volts. In terms of an AE hit feature, the instantaneous value of RMS voltage is collected and processed along with the other AE Features when an AE hit is detected. Since there is an averaging required, an RMS/ASL Time Constant Control is provided in the Data Sets menu to allow adjustment between 10 – 1000 milliseconds (note the RMS/ASL Time Constant entry box in the lower right side of the Data Sets menu of figure 8).

ASL: Average Signal Level is a measure of the continuously varying and "averaged" amplitude of the AE signal. This measurement is similar to that of RMS in that it is an averaged reading. The main difference is that the RMS is following the Root Mean Square and is measured in volts, whereas the ASL is following the Amplitude variation and is measured in dB. Since there is an averaging required, an RMS/ASL Time Constant Control is provided in the Data Sets menu to allow adjustment between 10 – 1000 milliseconds (note the RMS/ASL Time Constant entry box in the lower right side of the Data Sets menu of figure 8).

Threshold: The Threshold Feature records the value of the Threshold at the time of an AE Hit. This is only needed when an adaptive Threshold technique such as Floating Threshold is used as it is important to know the threshold value at the time of a hit.

Rise Time: Rise Time is defined as the time between the AE Hit start and the peak amplitude of the AE Hit. An example of the rise time measurement is shown in figure 9 for clarity.

Counts To Peak: Counts To Peak is a measure of the number of AE Counts between the AE Hit start and the Peak Amplitude of the AE Hit. In regards to the example of figure 9, there are 3 Counts to Peak shown in that example.

Average Frequency: Average Frequency has long been available in the PAC Hit data set. This calculated feature, reported in kHz, determines an average frequency over the entire AE hit. It is derived from other collected AE features, namely; AE Counts and Duration. All these features must be enabled in the Data Sets dialog box for the Average Frequency feature to be calculated. The following real time calculation is performed to determine Average Frequency:

(AE Counts) / (Duration)

Reverberation Frequency: Reverberation frequency can be thought of as the "ring down" frequency since this is the average frequency determined after the peak of the AE waveform. Reverberation frequency is a "calculated" feature derived from other collected AE features, namely; AE counts, Counts to Peak, duration and risetime. All these features must be enabled in the AE Feature dialog box for the Reverberation feature to be calculated. The real time calculation performed is as follows:

(AE counts - counts to peak) / (duration - risetime)

Initiation Frequency: Initiation Frequency can be thought of as the "Rise Time" frequency. This feature calculates the average frequency during the portion of the waveform from initial threshold crossing to the peak of the AE waveform. Initiation frequency is a "calculated" feature, derived from the AE Features: AE counts to peak and Risetime. These features must be enabled in the AE Feature dialog box for the Initiation feature to be calculated. The real time calculation performed is as follows:

(AE counts to peak) / (risetime)

Signal Strength: Signal Strength is mathematically defined as the Integral of the rectified voltage signal over the duration of the AE waveform packet. This feature is similar to the "PAC Energy" feature, except that it is calculated over the entire AE signal dynamic range and is independent of gain. The Signal Strength value can range is from 3.05pVs (1 count) to 13.01mVs. Resolution is 3.05pVs (at 1MHz or greater sample rate) and is an absolute parameter. "PAC-Energy" (which is a similar parameter) on the other hand is gain related.

Absolute Energy: Absolute Energy is 6 byte value whose units are aJ (or attoJoules). This feature is a True energy measure of the AE hit. Absolute energy is derived from the Integral of the squared voltage signal divided by the reference resistance (10k-ohm) over the duration of the AE waveform packet. The range is from 0.000931aJ to 1310.25nJ. Resolution is 0.000931aJ per count (at 1MHz or greater sample rate). This feature is available in both the Hit and the Time Driven data sets. As a hit feature, it reports the true energy of the AE hit. As a time based feature, it reports the energy in the time driven data rate interval. As a time driven feature, this is a very good parameter for monitoring continuous signals as it is independent of an hit based activity.

5.7.2 Real Time Frequency Features

The PCI-2 based system has the capability of calculating and processing frequency derived AE features in real time. Up to 6 AE Frequency based features can be processed by PCI-2 based systems. Each of these features requires that a real time FFT be performed on the received AE hit waveform. AE frequency features include; Frequency Centroid, Peak Frequency, and 4 Partial Power frequency features. Each of these are discussed below.

Frequency Centroid: Frequency Centroid (also known as the first moment of inertia) is a 2 byte value, and reported in kHz. It is a real time Frequency derived feature. The Frequency Centroid results from performing a real-time FFT and carrying out the following calculation on each FFT element (or bin):

SUM(magnitude*frequency) / SUM(magnitude).

The SUM is performed over all FFT bins, excluding DC and is reported in kHz.

Peak frequency: The Peak frequency is a 2 byte value, reported in kHz, defined as the point in the Power Spectrum at which the peak magnitude occurs. A real time FFT is performed on the waveform associated with the AE hit. The frequency, which contains the largest magnitude, is reported.

Each of these AE features, Centroid and Peak Frequency adds 2 bytes to the hit data message.

The resolution and range of the Centroid and Peak Frequency features is dependent on the sample rate and waveform length. When the sample rate is increased, the range is increased and the resolution decreased. When the waveform length is increased the range is decreased and the resolution is increased. The waveform length decreases the range because the input to the FFT is kept at 1k (by dropping samples, effectively reducing the sample rate) to limit the adverse effect of the FFT calculation on processing speed.

The front-end filters of the system and the choice of sensors used can also limit the range. Band-limited sensors, like an R15, will limit the frequency ranges around the resonant frequency of the sensor (150kHz for an R15).

Also, to improve the results of the FFT and eliminate edge effects, the waveform length and pre-trigger should be set to values which allows for the entire waveform to be captured with no signal at the start and end of the waveform.

Partial Power Features: Partial Power is a set of (up to 4) waveform and frequency based features each with a 2-byte value reported in %. Partial Power features are derived from the power spectrum of the waveform associated with a hit.

"Partial Power" AE Features are reported as a percentage and is calculated by summing the power spectrum in a user specified range of frequencies (up to four of these ranges can be specified), dividing it by the total power (across the full range of frequencies), and multiplying the result by 100.

5.7.2.1 Partial Power Setup:

A groupbox called 'Spectrum Features' is located in the Data Sets Menu (see figure 8) just below the Hit Data Set parameters. This box contains the Partial Power selection and setup boxes. The Data Sets menu can be reached through the menu structure (Test Setup -> Hardware -> Data Sets). The Partial power portion of the Spectrum Features box contains:

a. A checkbox to enable Partial Powers as a hit feature.
b. A button to bring up the Spectrum Segment Setup dialog box.
c. A text field to show how many segments are currently defined.

The partial power features will not be reported in the hit set unless the Partial Powers checkbox is checked and at least one segment has been defined.

A dialog box called Spectrum Segment Setup (see figure 10) is accessed from the 'Data Sets' dialog box issued to define the partial power features.

For each of the 4 definable segments the dialog box has a checkbox to enable the segment, an edit box for defining the start frequency and an edit box for defining the ending frequency.

The group box titled 'Total Power Range/Equal Spacing Setup' contains two edit boxes. These edit boxes serve a dual purpose. The main reason for them is to define a range of frequencies over which the power spectrum will be summed. The result of the summation is used in the calculation of total power for the partial powers calculation. Their other purpose is to allow the user to spread the frequency range evenly among the enabled segments. The spacing will be determined and spread evenly, when the user presses the 'Apply Spacing' push button, which is located to the right of the edit boxes.

CAUTION: If the edit boxes are used to set up equal spacing, always make sure the edit boxes contain the Total Power range values when the dialog box 'OK' button is pressed. Otherwise the partial powers will be based on the equal spacing range.

The dialog box also displays information based on the sample rate and hit length of the first active AE channel:

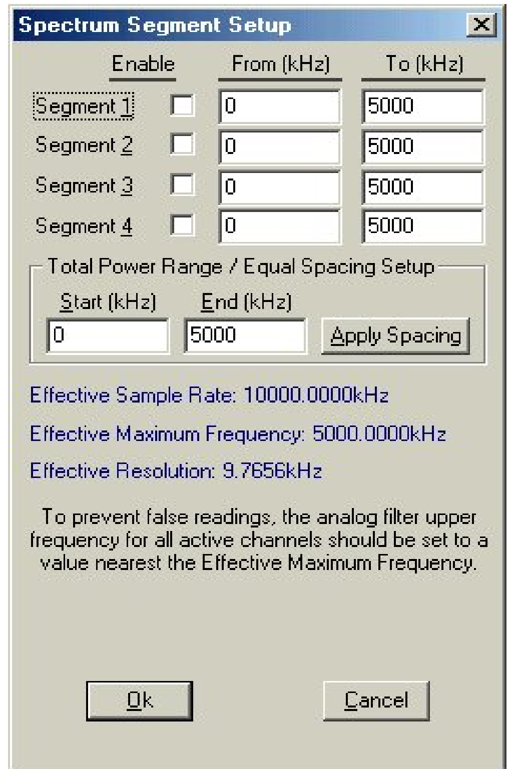


Figure 10. Partial Power setup menu

1) Effective Sample Rate:
The sample rate of the decimated waveform(the FFT calculation is always for 1k of samples). For a 1k hit length the effective sample rate is the same as the hardware sample rate. For a 2k hit length it would be half the hardware sample rate. Etc.

2) Effective Maximum Frequency:
Is one half that of the Effective Sample Rate and is the maximum frequency which can be defined for any segment.

3) Effective Resolution:
Is the Effective Maximum Frequency / 512 and is equivalent to the frequency range of a single FFT bin.

The AE system does not automatically set the input filters based on the sample rate to reduce aliasing, so the dialog box will remind the user to set the input filter to a value closest to the Effective Maximum Frequency.

The Spectrum Segments are global for all active channels, if the sample rate and/or hit length is not the same for all active channels a warning will be displayed to alert the user.

5.7.2.2 Partial Power Presentation:

The Partial Powers can be graphed as a parameter on any of the AEwin display axes, just as any other AE feature. The quantities have the name FREQPPX, where X is a number from 1 to 4 and corresponds to the Partial Power calculated from the frequency range defined by the Spectrum Segment for the same number. The Partial Power is a percentage so the graph title (and cursor readouts) will show FREQPP X% or if that can't fit FREQPPX% or if that can't fit FPPX. The format of any Partial Power feature in line dump mode is an integer from 0 to 100. The column header will be FREQPPX.

5.7.3 Time Driven AE Data

The Time Driven data set selection boxes are located on the right side of the "Data Sets" menu dialog box (figure 8). From this menu, the user can select parametrics and AE Channel Data features, recorded on a Timed basis, referred to as the Time driven data rate (TDD). The Time Driven data rate is set from the "Rate" entry box located near the middle of the Data Sets dialog box. This is the rate at which the Time driven parameters are recorded and processed by the AE system.

The AE Channel Data features include RMS, ASL, Threshold, and Absolute Energy. Each of these features have been discussed and defined in section 5.7.1 above. These are useful in monitoring continuous AE activity. One value is recorded and processed for each active channel during the AE Test.

Time Driven data is important as it gives the user an idea of how the background or continuous AE activity is changing during time, providing a trending type of result. Absolute Energy is also a valuable parameter as it provides a summation of energy over time independent of hit activity.

CHAPTER II

GETTING STARTED

CHAPTER II - GETTING STARTED

Table of Contents

1. UNPACKING AND INSPECTION

The PCI-2 system can be delivered in many forms. It may be delivered with as little as a single board with a software CD or diskettes, or as a full system in a μ-DiSP chassis with up to 4 AE channels, a Benchtop system with up to 8 channels, or a Rugged Portable system with up to 8 channels. These systems might be equipped with sensors, sensors cables, monitor, keyboard, and mouse. This chapter will cover these different situations as completely as possible in order to help the user get the system running with as few problems as possible. Since this chapter is covering installation and set-up of both boards and complete systems, some sections may not apply. As an example, for the user who has purchased an entire PCI-2 based system, all PCI-2 boards will be installed and configured and all software will be loaded on the hard disk drive of the computer. In this case, the user can skip the section on board installation and set-up inside a computer system.

1.1 System Unpacking and Inventory Check

Remove all components from the shipping cartons. Remove any packing material. Before connecting and operating the PCI-2 card(s) or PCI-2 based system, the user should verify that the system has arrived unharmed and that nothing is physically loose inside the system enclosure(s). Make sure that everything seems secure and there are no visible signs of damage to the received components or the shipping containers. If there are loose parts inside the system enclosures, remove the cover and inspect that all boards are fully seated and connected properly inside the system. DO NOT APPLY POWER TO THE INSTRUMENT IF YOU ARE UNSURE ABOUT ITS CONDITION. If there are any questions at all regarding shipment damage or the correct board or connector configuration, please call Physical Acoustics Customer Service Department immediately.

Carefully check the delivered parts against your purchase order and our shipping form. Note any back ordered items. In the event of any discrepancy please notify Physical Acoustics' Customer Service department.

Please identify all the components received against the order and in relation to figure 1 of this chapter, which shows all the typical components and their connection to form a complete PCI-2 based system. When all components are fully understood please proceed on to the PCI-2 card and system installation.

1.2 Pre-Installation Caution Notes

Before proceeding on with the installation of the boards/system, a few caution notes are necessary. These will be repeated in sections where required as well but should be considered at the start.

1.2.1 AC Power Requirements

Each system has been configured by Physical Acoustics for the voltages specified based on the purchase order or the country to which the system is going. However, before proceeding to attach any AC operated equipment to your AC power line, first be sure of the AC voltage levels that you will be connecting to and verify by reading the manufacturer label on the back panel of each AC unit that it is configured for that voltage. Since the PCI-2 system is based on PC compatible computers and accessories, each unit has a different method of selecting AC voltages. Refer to the separate user's manual for that device if there are any questions. Alternatively, the PAC Customer service department will be happy to assist you.

A second consideration with AC power is that there are many AC line cords that need to be connected in a PCI-2 based system. The user should consider placing all the cords into an AC switched (and surge protected) power strip or AC computer power manager where everything can be turned on and off with a single master power switch.

1.2.2 Ventilation

The PCI-2 cards are based on high performance powerful integrated circuits which do generate and are susceptible to heat. All systems configured by PAC have been configured with adequate cooling and ventilation in both the PC-Olive computer based systems and the industrial chassis to dissipate that heat and assure reliable continuous operation.

For those users who are installing PCI-2 cards in their own computers, it is required to place the boards in an area of the computer where an additional fan can be installed. On multiple PCI-2 card installations, PAC normally installs a cooling fan so that it blows air through each of the PCI-2 cards, parallel to the length of the card. This allows continuous air flow to blow past the critical integrated circuits on all the PCI-2 cards and draw heat from the heat sinks or IC surfaces so that they can maintain a cool temperature.

For those users who have bought a complete system from PAC with PCI-2 cards already installed, please do not remove the fan or its power and do not move the boards to other PC slots inside the computer. Either of these actions may cause a board cooling problem.

1.2.3 Other Required Documentation

The PCI-2 based AE system as delivered, is composed of hardware boards, components, software and accessories that are PC compatible and carry their own documentation and installation instructions. These components include but are not limited to the computer main-board, video board, color monitor, hard disk drive, keyboard, mouse, WINDOWS and Printer. PAC has installed these items using a factory default configuration so that it performs its basic operation in conjunction with the rest of the system. The user should go through all the documentation to be aware of the hardware and software received, follow any precautionary notes and refer to the documentation if it is desired to change any system configuration. Finally the documentation should be kept in a safe place for later reference and use. This will avoid panic calls to the factory.

2. SYSTEM INSTALLATION

When setting up the system for the first time, it is suggested that the system be set up in a convenient place so that the user can perform some trial tests in order to get familiar with the installation, set-up, operation and software. This section assumes the full PCI-2 based system receipt and installation.

Set up the system in accordance with Fig. 1. The following sub-sections provide additional setup information and instructions on each subsystem in the PCI-2 based system.

2.1 PCI-2 Based System Installation Overview

On all delivered PCI-2 based systems including the PAC Benchtop based system, the Rugged Portable AE system, the μ-DiSP based system, or a PAC Olive based computer, Physical Acoustics manufacturing has pre-set and pre-tested the system or PC-Olive computer and there is no need in gaining internal access to the computer. In this case manufacturing has done the following:

1. Computer Installation and Testing: Installed all the computer related cards, hard drive, floppy disk and CD-RW drives into the unit, installed the WINDOWS operating system software and mouse driver software. In addition this computer and all of its peripherals have been fully set up for operation at the user's required AC line voltage and fully pre-tested.
2. Computer Options Installation: Any computer related hardware and software options that were selected for use with the PC-Olive (PC-Computer) and PCI-2 based system, were installed and tested. This includes adding and testing additional memory, larger hard disk drive, modem and software, printer and printer driver, etc.
3. PCI-2 Installation and Testing: All PCI-2 boards ordered for the PCI-2 based system have been configured, installed and tested along with the required Real Time control daisy chain ribbon connector that must attach between each of the PCI-2 boards in the system. In addition, PAC has labeled the rear panel BNC connectors of the computer with the channel numbers based on the PCI-2 board configuration so that the user knows which channel is which in the system. Finally, PAC has installed extra cooling in the computer needed for reliable continuous operation of the AE system.
4. PAC AE Software and Options Installation: All standard AE software has been loaded onto the hard drive in appropriate directories with appropriate batch files to automatically initiate the PCI-2 software upon clicking on the icon on the desktop. In addition, all optional software such as 2D-LOC, 3D-LOC, SPHERE-LOC, TB-LOCwin, AEwinPOST have been enabled and authorized for use in the AEwin software. Likewise, all external optional programs have been installed with icons. This includes NOESIS, PolyModal, Wavelet Analysis software and any specific TurnKey application software packages. These will execute upon selecting the icon.

This, of course, is the easiest way to purchase and install a PCI-2 based system since all the installation details have been taken care of by Physical Acoustics. In this case the system installation is nothing more than that of connecting all the external devices to the computer as shown in Figure 1, without the need to worry about installing the internal components (which is also shown in figure 1).

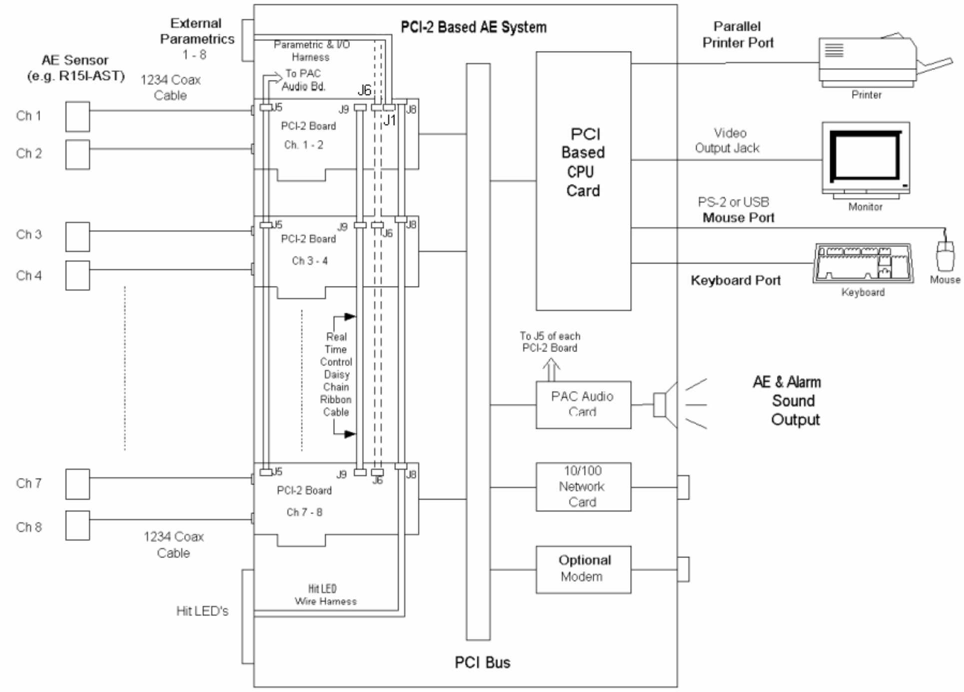


Figure 1. PCI-2 system Connection Block Diagram

2.2 PCI-2 Board Installation

If the user has purchased the PCI-2 cards alone and will be installing them in his/her own computer then a similar installation procedure as that indicated above should be followed after the PCI-2 and all the provided wiring harnesses are installed. The internal installation then would consist of the following:

1. First, make sure that each PCI-2 board is programmed via its address jumpers to be Board #1, #2 and so on.
2. Install the PCI-2 cards in the chassis in order, Board #1, #2, etc, making sure that there is adequate ventilation for a good air movement between the boards.
3. Install the "Real Time Daisy Chain" Ribbon cable to attach to each PCI-2, J9 connector in the system. Failure to attach this Ribbon cable will result in no Time of Test or Hit based parametric transfer between boards.
4. Connect up the parametric harness to the rear panel in order to gain access to the parametric inputs. If only 2 parametrics are needed, only the first PCI-2 board needs to be connected to the rear panel using the J6 connector (see figure 1). If 4 parametrics are needed, a harness connecting the first two PCI-2's needs to be connected to the J6 connector For 6 parametrics, the first 3 PCI-2 cards needs to be connected while for 8 parametrics (the maximum available), all four (4) PCI-2 boards needs to be connected to the J6 connector. If using revision 3 or newer, all 8 parametrics are available from J1 without interconnecting the 2nd, 3rd or 4th board. If the newer board is used as the 2nd, 3rd or 4th board and a 2-channel parametric is used as the 1st board, an interconnect cable is required and only the first two (of the 8 parametric channels) channel will be active on the rev 3 or newer board.
5. Connect up the HIT LED harness between each PCI-2 board, J8 connector and the HIT LED panel.
6. Connect the PAC Audio board into the system. Connect up its harness to each J5 on each PCI-2 card.
7. Make sure that each board is firmly seated and that the hold down screw as well as any hold-down bracket is properly attached.
8. Replace the cover.

In regards to installing the AEwin software, please follow the installation instructions provided in the "AEwin Software User's manual", which is chapter 4 of this manual.

2.3 PCI-2 Based System Installation

Assuming that the PC computer(or PCI-2 Based System Chassis) has been configured as indicated in the previous sections then it is ready to be connected to the peripheral items as shown in Figure 1. Most of these connections are standard ones for installing any PC computer. Also, Physical Acoustics provides labels to show exactly what should be plugged into a given connector on the PCI-2 based system. Following Figure 1 specific instructions are as follows:

- Connect the keyboard to the computer,
- Connect the video monitor to the back of the computer into the mating Video Board connector.
- Connect the printer through the printer cable to the computer's parallel port. The printer cable's 25 pin DB connector goes to the mating connector on the back of the computer and the "Centronics" connector end goes to the printer.
- Connect the mouse to the Mouse port. This might be a PS-2 (small circular connector), a USB (small flat connector), or a DB-9 connector on the back of the computer.
- Connect the AE sensors and pre-amplifiers (or integral sensor/preamplifiers) on the rear panel BNC inputs following the channel numbers as labeled.
- Connect the power cords for the computer, printer and video monitor to a suitable AC outlet. Check the rear panel labels of all equipment to be sure that each item is compatible to the intended AC power being supplied. If there are uncertainties about the configuration please refer to manuals that accompany the computer, monitor, printer, etc.

Once all these connections are made the unit is ready for powering up.

In general, if there are any questions regarding the computer connections or if the user wants a different computer configuration (Mouse Port, Video Resolution, AC Power, etc.) than that which is supplied as standard, refer to the manual or instructions that accompany that particular item since all computer related documentation has been supplied with your PCI-2 based system.

2.4 PCI-2 Based System Installation Drawings

Figures 2a, and 2b shows the front panel of the Benchtop chassis and the Rugged Portable Chassis. On it can be seen a CD-RW Drive, floppy disk drive, and AE Activity LEDs. Figures 3a, and 3b shows the rear panel of these same systems, respectively. Note the location of the connectors, position of the PCI-2 cards, CPU board the PAC Audio card and the peripheral connectors. The PCI-2 cards are installed, in order, to maintain a consistent numbering sequence. For convenience, all the AE connectors are labeled on Figures 3. All other connections including the computer keyboard, mouse, COM port, video, etc. are usually labeled on the rear panel for ease in installation. Some of the computer connections shown in the figures may not be identical to the system delivered as sometime different CPU boards are used. In cases where there are differences with the drawings, please refer to the CPU board documentation which has been delivered with the PCI-2 based system. When installing and connecting up the PCI-2 based chassis, please follow the same instructions as those given in the previous section (Section 2.1, PCI-2 system Installation). Although a PC-Olive (PC-Computer) is not shown in the figures, it will be very similar to the front and rear panel of figures 2a and 3a on the following pages.

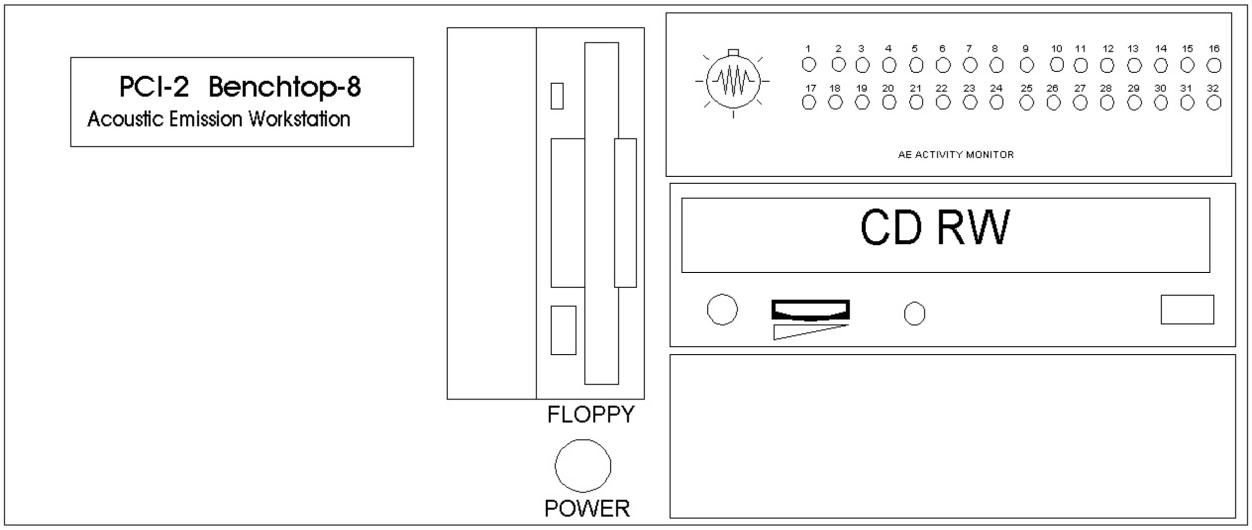


Figure 2a. PCI-2 Benchtop Chassis Front Panel

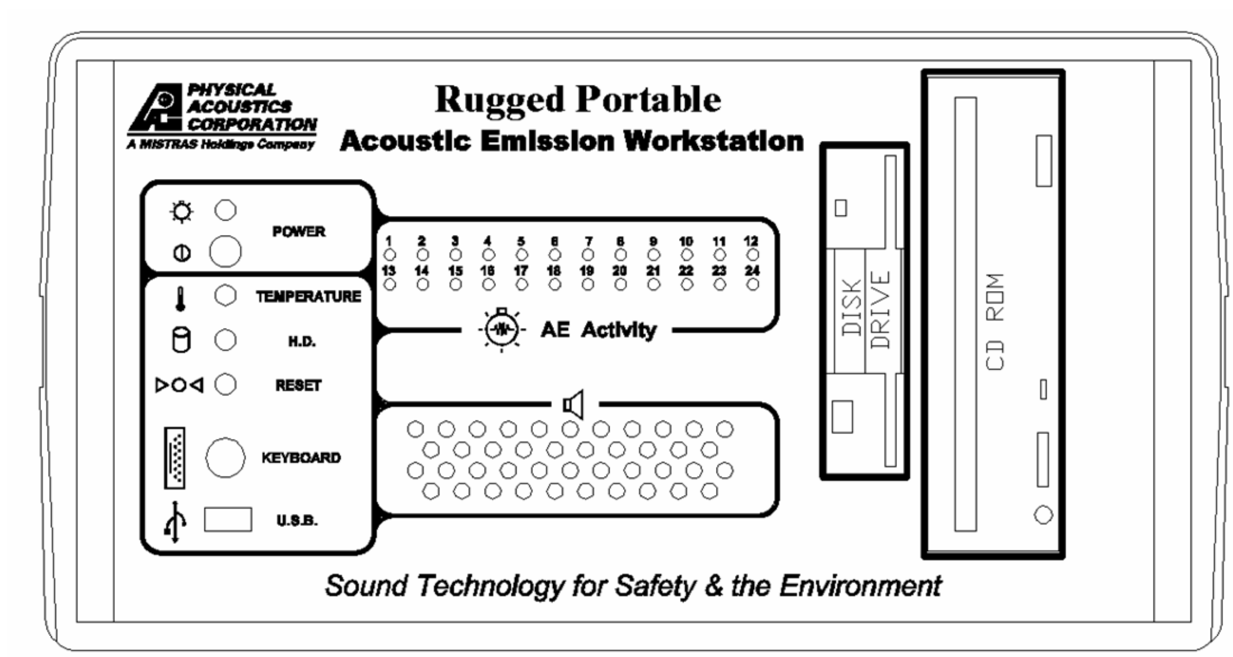


Figure 2b. Rugged Portable 8 Channel System Front Panel

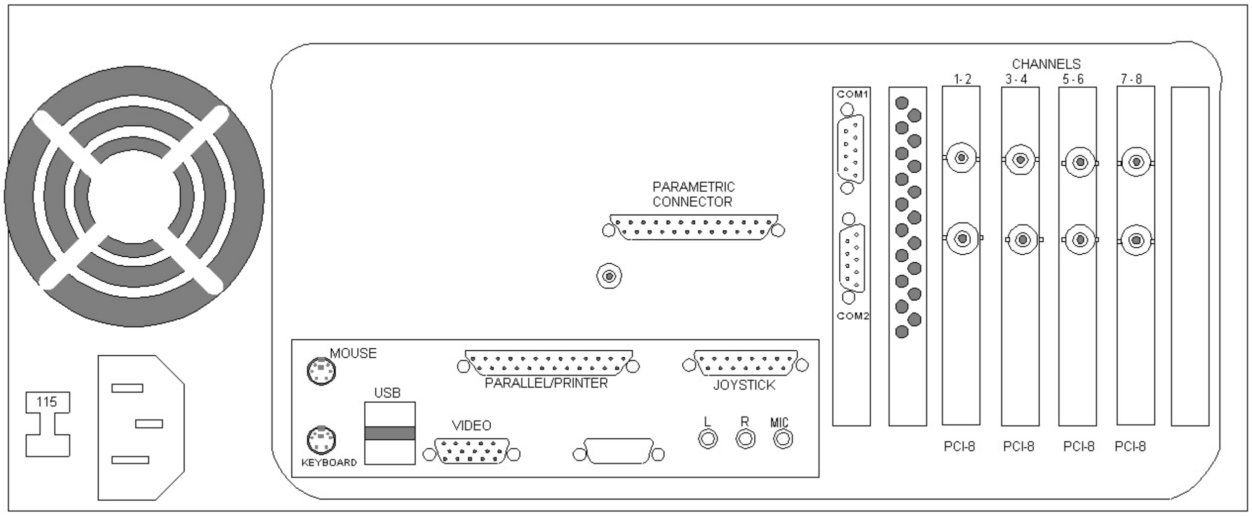


Figure 3a. Benchtop System Rear Panel

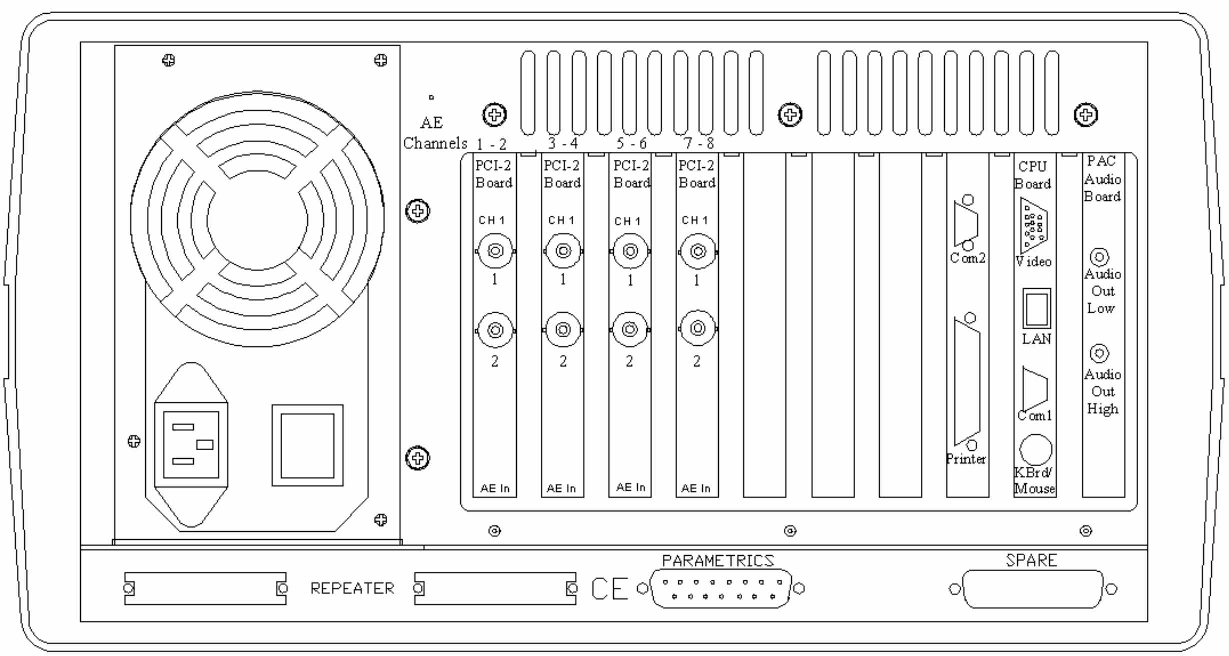


Figure 3b. Rugged Portable System Back Panel

3. TAKING YOUR FIRST DATA

The purpose of this section is to provide a quick software operational run-through, to get the operator familiar with operating the PCI-2 system using AEwin software. Please refer to the AEwin software chapter IV of this manual for full information about all its features and capabilities and full instructions for operating the software.

3.1 Starting AEwin

The first step in the process of using AEwin is booting up the program onto your PCI-2 based AE system. As the AEwin program is a standard Windows Program, it is started in the same way as any other WINDOWS program. This is accomplished either by using the "Start" command or by selecting the AEwin Icon from the WINDOWS desktop.

It is assumed that the AE computer is booted up and in its opening screen which is the desktop layout showing all the available program icons to select. If the PAC AEwin icon (as shown on the right) is on the desktop, all you need to do is select this by double clicking the left mouse button, once the mouse is positioned over the icon. If the icon is not on the desktop you can create the shortcut by referring to AEwin software manual in chapter IV.

Alternatively you can start AEwin by selecting the following sequence starting with the Start menu at the bottom left side of the screen:

Start → Programs → Physical Acoustics → AEwin

The boot-up sequence for AEwin starts by loading the executable program AEwin.exe. Once AEwin is loaded, the program searches the startup "AE Data" subdirectory for the default Layout (setup file) called "Layout.LAY". Upon finding this file, AEwin loads it and becomes fully configured and ready to run in accordance with the setup information in that default Layout.LAY file. If no Layout.LAY is found, AEwin chooses a common default starting setup, which is ready for use. In either case an AEwin startup screen similar to figure 4 will appear.

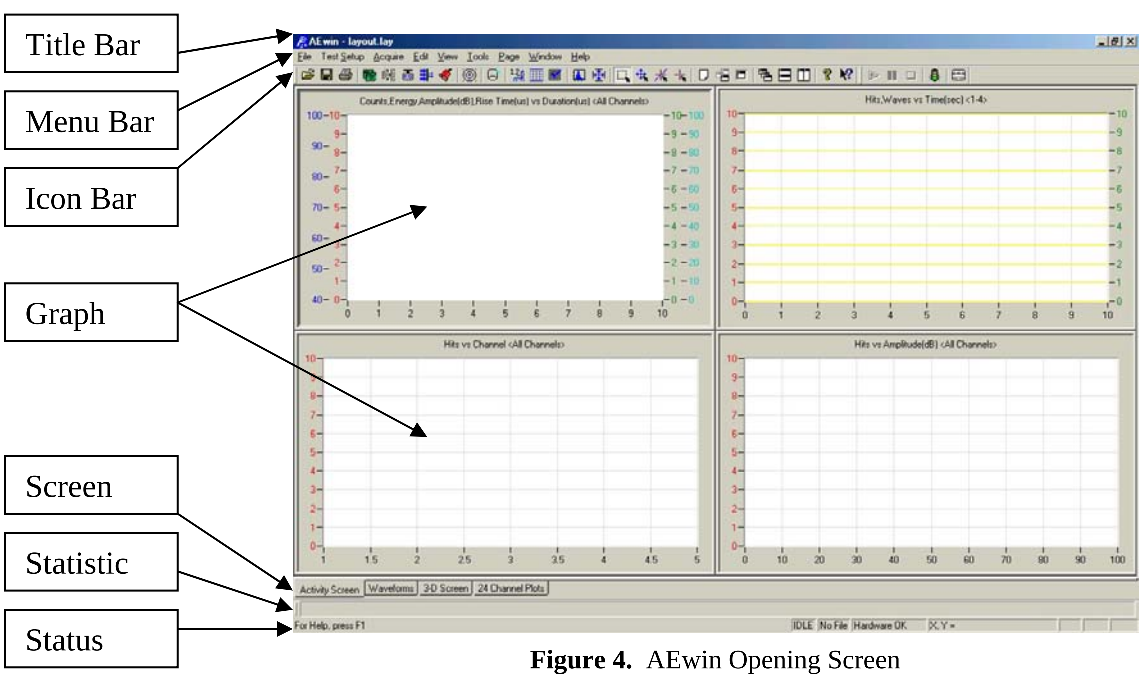


Figure 4. AEwin Opening Screen

3.2 AEwin Screen Layout Familiarization

Figure 4 shows a typical 4-graph screen layout for AEwin. Above and below the graph area are various informational, status and setup toolbars. Each bar is labeled with a name. Depending on the configuration of your layout file, you may have other toolbars or be missing some. The "View" menu in the main menu bar area, controls which toolbars are on or off. The following is a short description of each area identified on the AEwin screen. This section will get you familiar with the layout and the overall function. Chapter IV will provide detailed insight into the use of each of these functions.

Title Bar: This is a typical WINDOWS Title Bar with all the standard capabilities. At the leftmost position is the Physical Acoustics Logo (PAC Logo) Icon from which you can manage the AEwin program with functions such as minimize, restore, maximize, move, size or Close the program altogether. At the far right are the application buttons for Minimize, Restore and Close. Back on the right hand side next to the PAC Logo Icon is the program name (in this case it is AEwin) and next to that is the name of the current layout file being used by the program.

Main Menu Bar: The main menu bar provides a series of text commands running across the line, including; File, Test Setup, Acquire/Replay, Graphing, View, Utilities, Page, Window, and Help. Most of these items contain pull-down sub-menus of their own, many of which in turn contain graphical dialog boxes and prompts of their own. You narrow down the range of choices until you arrive at the specific choice you want.
To display a pull-down sub-menu from a main menu entry, simply move the mouse pointer to the name of the menu item on the menu bar and click the left mouse button. This process is known as "clicking" (or "left-clicking") on an item, and will herein be referred to as such. To use the keyboard, press the ALT key and the underlined letter of the menu item name at the same time. Once you have opened a pull-down menu item from the main menu, you can use the left and right arrow keys to move through each entry, allowing you to see the pull-down menu for each main menu entry. You can also use the up and down arrow keys to move through each selection of the pull-down menu. To select an item from a pull-down sub-menu, click on the desired action, or use the up and down arrow keys to select an action, and then press ENTER. Pressing the underlined letter of a menu item will also select that item. If an item in the pull-down menu appears "grayed out," this action is not available in the current software or at the current time. Use the <ESC> key to remove the pull-down menu display.

Most of the selections in the pull-down sub-menus will display a dialog box requesting information necessary to carry out the command you requested. A dialog box contains areas where you enter information, select options or commands, or activate controls to execute or cancel a command. There are several types of boxes and buttons available within a dialog box. These boxes and buttons are described briefly below and will be described in further detail in subsequent sections of this manual. It is important that you are familiar with dialog boxes and be comfortable using them, for they are the means by which most functions are carried out in the DiSP software.

Icon Toolbar: Many of the menu items accessible from the Main pull-down menus can also be accessed by use of the Icon toolbar just below it. Figure 5 shows the Icon toolbar.

Figure 5. Icon selection toolbar

To determine the function of any of the Icon's simply move the mouse cursor over top of the desired icon. Upon resting there for approximately 1 second the Icon's function will appear. To select an icon as a shortcut command simply click on it with the left mouse button.

Graph Area: The graph area is the most important area of the screen. This is where the AE information in the form of graphs and line listings appear regarding the AE examination status. The graph area can be set up in many ways with a minimum of 1 graph to a maximum only limited by the graph visibility. More about the graph setup, functionality and flexibility will be discussed later in the Graph setup menu.

Screen Page Tabs: AEwin can show many different graph screens, these are called screen or graph "Pages" using Windows jargon. Accessibility to viewing any screen is provided via the Page tabs located just below the graph area. The Page tabs can be named to be synonymous with the graph theme as shown in figure 8 with the 4 Page tab names, Activity Screen, Waveforms, 3D Screen and 24 channel plots.

Statistics Bar: This toolbar area is reserved for display of test statistics. Test statistics allow the user to view key Acoustic emission test indicators such as; Cumulative AE counts, Total AE Hits, Total AE Events, Total # Waveforms, Cumulative Counts, Cumulative Energy, Time of Test, Disk Free Space and Parametrics. These are very useful activity indicators during a test and very useful summary statistics after a test. The user can select any of all of these to customize his statistics display bar.

Status Bar: The Status bar (see figure 8) provides useful information regarding AEwin and test status. On the left is a Text bar providing status and help information regarding the functions being carried out. Near the center is a status bar. In figure 8 the word "Idle" appears in this bar. Other status information such as "Test Paused", "Replay", "Test Stopped" "Test Active", "Abort Test", etc. is displayed in this text field. Next to the Test status field is a filename field informing the user the name of the file being replayed or the name under which an AE test is being saved. Next to that is a system diagnostics text field. In figure 8, this status is "Hardware OK". Next to that is a cursor position, showing the current location of the Cursor on the graph. When selected, the X, Y position will be read out in actual screen units.

3.3 Navigating the AEwin Menu's

We will now pass quickly through and operate the principal menus to give you an idea of the system controls, and then you will take some data, look at some screen displays and replay an existing data file. The first time through, we suggest you just look at the menus (to get familiar with them) and use the setups provided with your AEwin installation, that have been predefined by PAC; later, you can make your own choices within the menus to control system operation. Please also refer to the proceeding software sections of this chapter for detailed information relating to function, selection and control of each of these menu functions since this section only serves as an overview.

From the Opening Screen (Figure 4), pay attention to the Main Menu Bar near the top of the screen. This specific area is shown again in figure 6. Each main menu item will be described. This brief introduction to navigating the menus is provided in order to get ready for guiding the user in the sequence of starting and replaying a test.

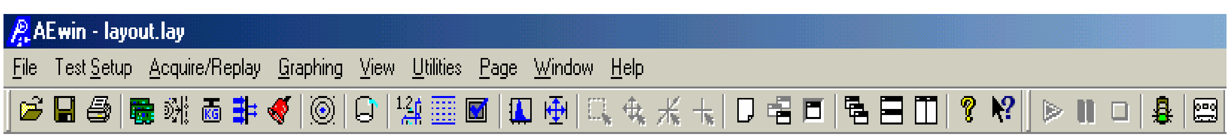


Figure 6. AEwin Main Menu and toolbar

From the Main Menu bar, use your mouse to point to the **Files** Menu and (left) click on it. An alternative method of selecting a menu item (if no mouse is present) is to press and hold the <ALT> key while pressing the underlined letter key (which is **F** in this case). After selection, a pull-down menu will appear under the Files menu. Note that the key items in this menu are that you can Open and Save a Layout file, Print and exit. The Print area provides selections to Print a page, Print a Graph, Export screen pictures to JPEG or copy a graph or screen to the Clipboard. Below the print area is a list of the latest layout files that have been used by AEwin. Finally, is the program Exit as the bottom-most menu entry. This files menu follows in the standard WINDOWS layout tradition, so it should be familiar. Note also that there are some "hot keys" defined that allow you to enter a submenu directly from the main screen (e.g. Note that **CTRL+O** , is the hot key command sequence for carrying out an "Open Layout" function). You should click the mouse onto each menu item in order to get familiar with the contents of each sub-menu for future use.

Next, move the mouse to the **Test Setup** menu area and click on that text area to activate the pull-down menu. Note that with this menu, you can carry out a Hardware setup (such as gain, features selection, select channels to be on or off, etc.), perform a location setup, add a Test Title, set-up the Statistics bar, setup up the Logistics (or test) information, setup the Audio monitor, and set up the Auto-File Close and re-open strategy for use in on-line and continuous monitoring. Below that, you can set up the display mode and line display mode. Note also that there are some "function keys" defined that allow you to enter a submenu directly from the main screen (e.g. Note that **F2**, is the hot key for entering directly into the Hardware setup). These are some defined shortcut keys that have been defined for many years and have been retained with AEwin. You should click the mouse onto each menu item in order to get familiar with the contents of each sub-menu for future use.

Next, move the mouse to the **Acquire/Replay** menu area and click on that text area to activate the pull-down menu. This menu allows you to Start a test setting your data file name, control a test (with Pause, Resume, Abort and add a time mark. The menu selection also allows you to replay a test. You should click the mouse onto each menu item in order to get familiar with the contents of each sub-menu for future use.

Next, move the mouse to the **Graphing** menu area and click on that text area to activate the menu. Note that with this menu you can go to graph setup, add, move, delete, cut copy or paste graphs. This menu is exclusively for setting up, and editing graphs. While in the Graph Setup Menu you will be able to select your graph parameters and setup the types of graphs you would like to see.

Next, move the mouse to the **View** menu area and click on that text area to activate the pull-down menu. Note that with this menu you can select which toolbars you would like to display on the screen. There are fixed positions for each of these toolbars defined on the AEwin screen, but each can be moved according to the user's preference by grabbing (left clicking the mouse) the handle (vertical bar) at the left side of the toolbar and moving it to the desired location.

Next, move the mouse to the **Utilities** menu area and click on that text area to activate the pull-down menu. If utilities are present you will be able to select which to run.

Next, move the mouse to the **Page** menu area and click on that text area to activate the pull-down menu. Note that with this menu you can create insert, delete and rename screen pages. This is an AEwin screen page management menu. You can also perform these functions with the icon keys and a right mouse click on the screen page tab.

Next, move the mouse to the **Window** menu area and click on that text area to activate the pull-down menu. Note that with this is a typical "Window" menu that you would find on any common WINDOWS program and therefore the menu contents should be familiar.

Next, move the mouse to the **Help** menu area and click on that text area to activate the pull down-menu. Note that with this menu you can get some on-line help, (after all you are reading this help file) to the operation of certain of the software. In addition, the "Options" selection informs the user which options have been installed in his/her AEwin software and the "About AEwin" informs the user to the release version and date of AEwin.

Hopefully, this menu "run through" has made you familiar with the contents of each menu and gives you a good idea of the layout and structure of the different set-up menus. For detailed discussion of each menu item and what it means, please refer to the proceeding sections of this manual.

It is now time to collect some data with AEwin. This is not intended to be a real AE test, but you can make a crude simulation of AE test (to get familiar with system operation).

3.4 Acquiring AE Data with AEwin for the First Time

This section is provided to help you understand the sequence of getting into and running an AE Test for the first time using the provided Layout (.LAY) files and also gives you insight into a more detailed sequence of carrying out an AE data acquisition test. Before starting in acquisition, you should have your AE system already set up as per the "Getting Started" section of your AE system manual. This usually entails, connecting sensors, preamplifiers and cables to the AE system, connecting up your AE system, computer keyboard, mouse and monitor and booting up your system into AEwin as previously instructed. If you are not ready to connect up the AE system to conduct some type of AE test or at least any AE experimental test on a laboratory test, then skip this section and proceed to the next major section on Replaying an AE test with AEwin.

The key to carrying out an AE test is in setting up the hardware set-ups, graphics, location setups and display modes to your particular requirements prior to entering the test. Although there are many set-up items and they might seem confusing for first time users, PAC supplies good default set-ups for most typical tests and they are an excellent starting point. As you get more familiar with the system you can modify these set-ups a little bit at a time and save your new layout (.LAY) setup files for your next AE test. This small step-by-step "Trial and Error" approach builds up your knowledge base until you are totally familiar with all the set-up options and what they mean. Until you get this knowledge please depend on the PAC prepared .LAY files.

The following are the steps that should be taken when carrying out your first AE test using the PAC supplied layout files. First we will outline the steps and next we will carry them out.

1. Load the appropriate system Layout (.LAY) file into the system in order to set-up the system to your desired operation and display conditions. We will be using the standard **Layout4.LAY** layout file in this example which sets up 4 channels for acquisition.
2. Enter the Acquire menu.
3. Select the datafile name which you want to save to disk.
4. Start Acquisition.
5. Look at various screens, graphs and data listings during acquisition.
6. Exit data acquisition.

The following is the step by step detail on starting and running your first AE test. We assume that you have sensors set up and will be exciting them in order to generate signals for AE generation or have them attached to a structure, bar or plate with a pulser or some type of simulated AE source.

3.4.1 Loading a Layout File into AEwin

From the Menu bar, use your mouse to select **Files** then select **Open Layout...** A menu window called **Open** comes up. With your mouse, select the **Layout4.LAY** file from the list of layout files so that this file name appears highlighted in the file box next to **File Name:**. This selects the Layout4.LAY as the layout file that will set up the AE hardware for a 4 channel operation with a good, complete default set-up. To finish the sequence, move the mouse to the **Open** box area on the right side of the **Open** window box and click on it (left mouse key) or press <ENTER>. Upon executing this menu, the **Layout4.LAY** Layout file is read into the program. If you had made any changes to the current layout file, a message box will pop up asking you if you want to save the changes. If yes, select yes, if no, select no. AEwin will then load and configure itself to the **Layout4.LAY** setup. This completes the reading of the LAY (AEwin setup) file.

3.4.2 Entering Acquisition

Entering acquisition involves steps 2, 3 and 4 of the above sequence. or the Mouse operated icon. To begin, left-click the mouse on the **Acquire/Replay** main menu item then click on the **Acquire** selection. Alternately, you can enter the Acquire function by pressing the **F9** function key (on the keyboard), or you can select the Acquire icon in the Acquire/Replay toolbar (see figure 11 for identification of the acquire, function key). The Acquire icon is shaped like a traffic light with the green light showing indicating that AEwin is ready to go into acquisition. This toolbar is usually to the right of the main icon toolbar or just below it. If you do not see this small 5 icon toolbar (like that shown in figure 7), it may not be turned on from the **View** menu. To activate it, simply select the Tools menu and make sure the "Acq. Controls" entry is checked. If not, click on it and it will be activated and will show up with the other toolbar icons.

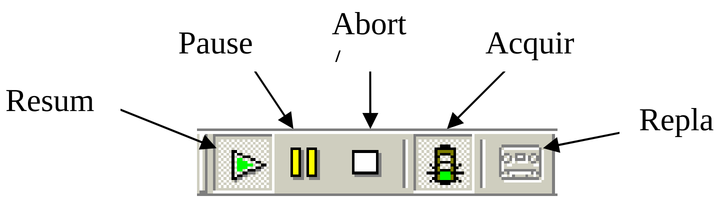


Figure 7. Acquire/Replay Icon Toolbar

Once you have selected the Acquire function, a **Test Storage** files menu box will appear to signal you to enter a data file name and whether you want to save the file to disk. (An example of the Test Storage file menu box is shown in figure 8.)

First, make sure the "Save to DTA file **(Autodump)**" box is checked if you want to save the data you will be collecting in this exercise. In AEwin, this is always automatically checked and you usually have to deselect (uncheck) it to prevent the generation of an AE data file.

Next, check the name shown in the **File Name:** box. If that name is acceptable then you are ready to start the test by clicking on the **OK** button. If you want a different name then enter the new name by typing it in when the **File Name** box is highlighted. Once you enter the name (you do not have to enter the .DTA extension) you can hit <ENTER> on the keyboard or click the **Start** button (located to the right of the Filename) with the left mouse button to begin acquisition. At this point AEwin enters the acquisition screen and waits for you to press the <ENTER> key to start the test. Press <ENTER> to start Acquisition.

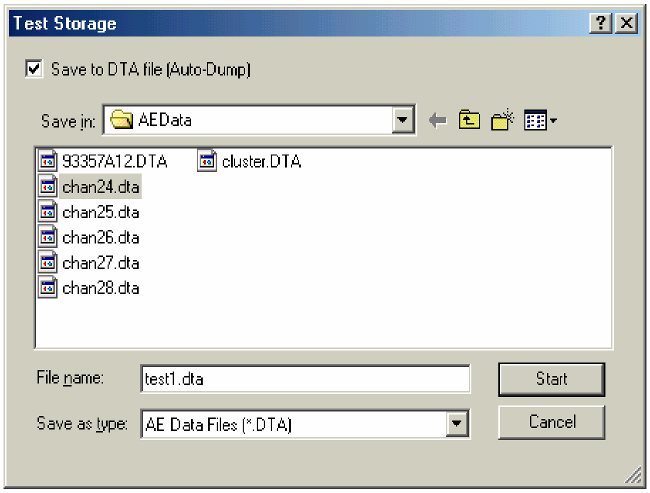


Figure 8. Test Storage Files Selection Menu

The system is now in data acquisition and is collecting and displaying AE information and displaying it on the graphs. Tap the sensor against the table your instrument is set up on or scratch it with your fingernail.

At first you will see no change in your Data Acquisition Graph but once the amount of time specified in **Test Setup → Display Mode** menu parameter "Seconds between Update" time has elapsed (it is usually set for 1 – 2 seconds), you will begin to see a visual representation of your data. Continue tapping the sensors to see the changes to the graphs to verify that you are getting waveforms and graph updates. An example plot showing the first AE graph screen page (selecting the tab, Activity Screen), is shown in figure 9. You should be seeing data visualization like that shown, where graph 1 shows a group of 4 point plots including Counts, Energy, Amplitude and Rise Time (on the Y-axis) versus Duration (on the X-axis), graph #2 (to the right) is showing #AE hits and #waveforms collected versus time, Graph #3 (below graph 1) is showing Hits versus channel and Graph #4 (lower right) is showing the Hits versus Amplitude (or Amplitude Distribution). By selecting the "waveform" tab at the bottom of the graphs you will see a display of waveforms and their associated FFT's like that shown in figure 10.

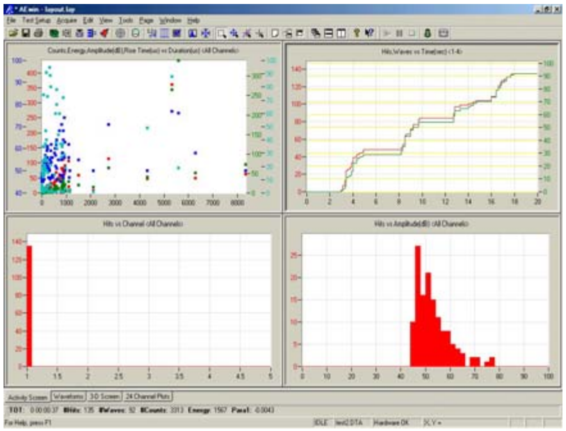


Figure 9. Example Activity Screen

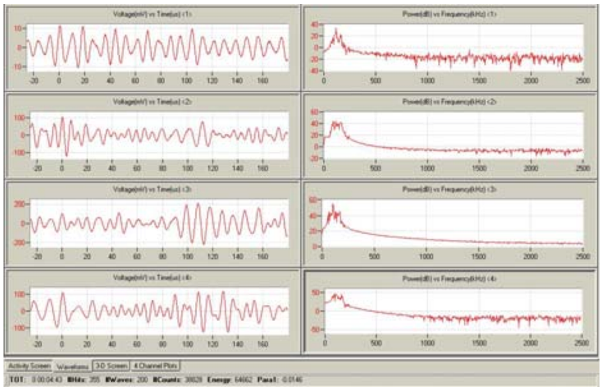


Figure 10. Example Waveforms Screen

This provides a short example of how to start your DiSP AE system with AEwin software. For more detailed information about the complete operation of AEwin, please refer to the chapter IV of this manual or the manual on disk, or the Help Menu's of the AEwin software directly.

4. USING THE PAC AUDIO/ALARM BOARD

The PAC Audio/Alarm board contains the alarm and audio controls. The board is standard on the Rugged Portable Chassis and is optional on the Benchtop series and μ-DiSP. The board is usually located in the rightmost card slot on the rear of the Rugged Portable chassis (see figure 3b). The Audio/Alarm board can be recognized by the two audio output connectors on the PC backplate of the board (see figure 3b). There are no adjustments inside and on the Audio/Alarm board as all controls are under computer control. Also, the Audio/alarm board needs no external speaker as the board is connected to the System's internal speaker. In cases where there is no internal speaker available, the Audio/Alarm board has an on-board speaker which can be used. If more power is desired, the user can plug in an external speaker to the lower Audio Output connector. This output is capable of driving a speaker directly. The top Audio output connector (called "Audio Out Low", referring to figure 3b) can be connected directly to headphones for private listening or can be connected to a PC computers Audio board input.

The Audio/Alarm circuitry is designed to produce audible tones from high frequency acoustic emission signals. This circuit can be selected to operate in either a homodyne or heterodyne mode. Operation in heterodyne mode allows the user to select the frequency of the AE signal to be monitored. Homodyne operation does not require frequency tuning and allows audio monitoring of AE signals at any frequency. To activate the dialog box for setup of the PAC Audio Monitor board select 'Test Setup' then 'Audio Monitor...'.

A sample menu is shown in the figure 11.

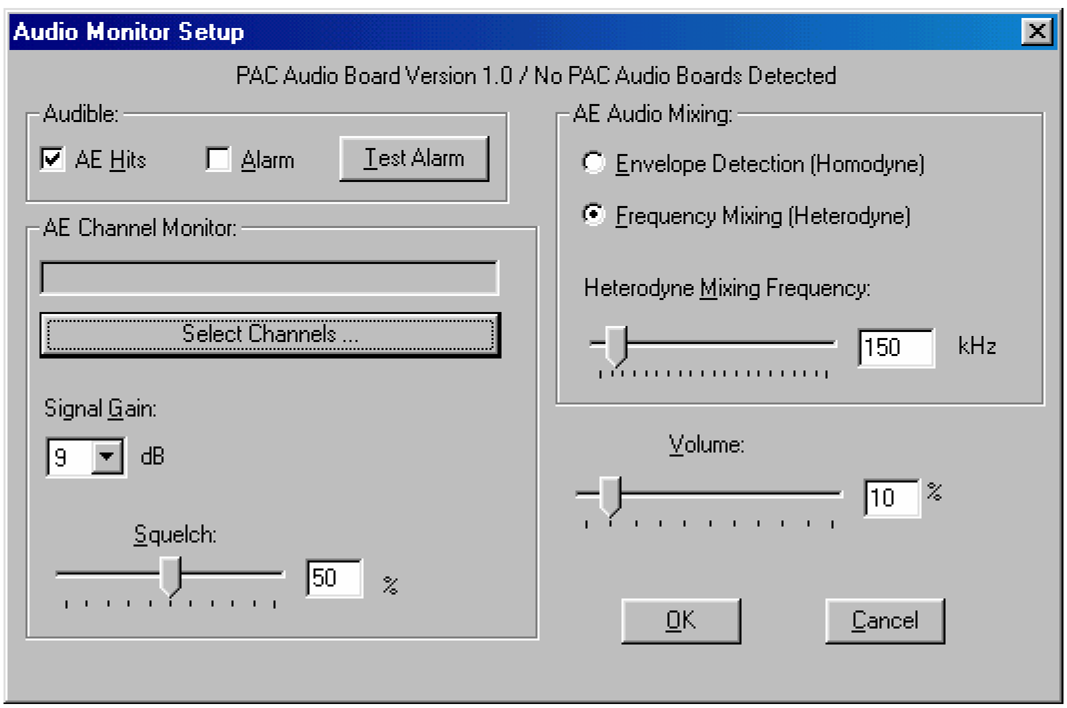


Figure 11. Audio/Alarm board Setup Menu

In the group titled 'Audible' there are two checkboxes. The first one (AE) enables the board to emit a sound when AE hits are detected. The second one (Alarm) enables the board to produce a tone whenever a front end alarm warning or trip level is exceeded (these alarms are defined in the '"Test Setup", "Alarms" dialog box). By clicking on the "Test Alarm" button you can hear how the alarm will sound. Click it a second time turn it back off.

The group titled "AE Channel Monitor" contains mutually exclusive checkboxes for "All Channels" and "Only Channel XX" operation. When "All Channels" is selected AE from any channel will produce a tone. When "Only Channel XX" is selected then only AE from the specified channel (XX) will produce a tone. The "Signal Gain" combo-box contains a list of valid gain levels for the AE channels. This allows small amplitude AE signals to be monitored. "Squelch" acts like a threshold circuit to eliminate the sound of background noise. Valid entries are from 0 to 100%. This value should be set to a level so that under conditions of no AE signals there is no audio output. Then as soon as a signal received is above the threshold as set by this control the audio output for that signal will be heard. The scroll bar located under the squelch control can be used as a mouse interface. Clicking on either arrow changes the squelch by 1%, clicking in the area between the thumb and an arrow changes it by 10%.

The group titled "AE Audio Mixing" contains mutually exclusive checkboxes for selecting the method by which the AE tones are generated. When "Envelope Detection (Homodyne)" mode is selected each hit produces a click sound. When "Frequency Mixing (Heterodyne)" mode is selected each hit is mixed with a signal whose frequency is entered in the edit box below the mode selection controls. This limits the audio to hits whose frequency is 10kHz above the selected frequency. For example, if the mixing frequency was set to 150kHz then AE signals greater than 150kHz and less than 160kHz will be heard. The scroll bar located to the left of the frequency control can be used as a mouse interface. Clicking on either arrow changes the frequency one step at a time, clicking in the area between the thumb and an arrow changes it by 50 steps. The last control is for volume. It controls the volume of both the A tones and the alarm tone. It ranges from 0 (off) to 100% (full volume).

The changes made to the dialog box will go into effect immediately. Pressing Cancel will restore the audio settings to those in effect before the dialog box was displayed. Note that the AE detection by the audio board is independent of the threshold levels of each channel so it is possible to set the board up to hear AE which is below the threshold of hits detected during a test.

The top line of the dialog box will display PAC Audio Board Version X.X if a PAC audio board is detected. If one is not, it will show No PAC Audio Boards Detected. In addition to this dialog box, another menu has been added which can be displayed during a test to change the audio board settings. This menu is displayed by pressing the Shift+F6 keys simultaneously while viewing the graphs (it cannot be displayed in the text only line dump mode). Use the Enter key to change non-numeric values, the +/- keys to change numeric values. The Page up and down keys will change the heterodyne frequency in larger steps. Pressing the ESC key exits the menu.

CHAPTER III

SENSORS AND PREAMPLIFIERS

AE SENSORS
&
PREAMPLIFIERS

USERS MANUAL

Rev 0

June 18, 2002

Part # 1220-1001

CE

AE Sensors and Preamplifiers
Users Manual

Table of Contents

1. INTRODUCTION: AE SENSORS

THE MOST IMPORTANT SINGLE FACTOR IN SUCCESSFULLY PERFORMING AN AE APPLICATION IS THE RELIABILITY OF AN AE SENSOR

High reliability is achieved by PAC's long experience in the successful design and production of numerous types of electroacoustic sensors for AE research, field and production applications. After years of continuous research and development by several members of our engineering staff, PAC is now becoming the recognized leader in the manufacturing of AE sensors. PAC's production flexibility provides the user with a large selection of transducers to fit many individual applications. The selection of the proper AE sensor depends on the specific application. Individual specification sheets have been prepared with specific recommended applications and features. Our engineers are also available to discuss your requirements, and, if necessary, to custom design sensors for your unique applications at moderate costs.

2. DETECTION OF ACOUSTIC EMISSION SIGNALS

Because an acoustic emission sensor converts the mechanical energy carried by the elastic wave into an electrical signal, the sensor is more properly termed a transducer. The transducer most often used in AE applications is the piezoelectric transducer. This choice has been dictated by the ease with which it may be built, its inherently high sensitivity, and a ruggedness which allows its use in industrial applications.

The active element of a piezoelectric transducer is a thin disk of piezoelectric material (a material which can convert mechanical deformation into electrical voltage). This disk is metalized on both faces for electrical contact, and mounted in a metal cylinder to provide electromagnetic interference shielding. The piezoelectric ceramics commonly used in AE transducers are made of small crystals of titanates and zirconates which are mixed with other materials, molded to the desired shape, and fired in a kiln. The ceramic material is then made piezoelectric by poling, which is the process of heating the material above its Curie temperature while the material is in a strong electric field.

To take advantage of the extreme sensitivity of the piezoelectric transducer, it must be attached to the material under observation in such a manner that the acoustic energy passes into the transducer with minimum loss at the transducer-material interface. The required intimate mechanical contact is achieved on flat surfaces by mechanical clamping using thin films of grease, oil or epoxy adhesive between the transducer and the material. In general, the problem of coupling is much more severe for shear wave observation because the coupling medium must be sufficiently viscous to support the shear motion.

Though it appears that a piezoelectric transducer properly coupled to a specimen should be an ideal sensor for acoustic emission work, there are some important limitations. Though the theory of piezoelectricity accurately relates the output voltage of a piezoelectric material to the stress on its free surface, complications arise when the transducer is coupled to a real material. The tightly coupled material changes the mechanical boundary conditions that existed at the previously free surface of the transducer. Hence the displacement and stress at the transducer are quite different from their values in the absence of the material.

The very complicated interaction between the transducer and what it is trying to measure has made it difficult to relate the transducer output voltage exactly to what is happening within the sample. If the acoustic wave is not a plane wave, further complications arise because of the variation in phase over the transducer surface. While these problems of the piezoelectric transducer have been troublesome in basic research aimed at trying to uncover the nature of the AE source event, the piezoelectric transducer has proven time and again to be more than adequate for most general nondestructive testing applications.

3. AE TRANSFER COUPLING

When a sensor has simply been placed on the surface of the material containing the acoustic wave it is found that the sensor produces a very weak signal. If a thin layer of a fluid is placed between the sensor and the surface, a much larger signal is obtained. The use of some type of couplant is almost essential for the detection of low level acoustic signals. Physically, this can be explained by looking at the acoustic wave as a pressure wave transmitted across two surfaces in contact. On a microscopic scale the surfaces of the sensor and the material are quite rough, only a few spots actually touch when they are in contact. Stress is force per unit area and the actual area transmitting a force is very small. If the microscopic gaps are filled with a fluid, the pressure will be uniformly transferred between the surfaces. For a shear wave with a variable strain component parallel to the surfaces, again very little strain will be transferred between the surfaces because of the few points in actual contact. In this case filling the gaps with a low viscosity liquid will not help much since such a liquid will not support a shear stress. However, a high viscosity liquid or a solid will help transmit the parallel strain between surfaces. The purpose of a couplant, then, is to insure good contact between two surfaces on a microscopic level.

A couplant is any material which aids the transmittal of acoustic waves between two surfaces, while a bond is a couplant which physically holds the sensor to the surface. Water is couplant and cured epoxy resin is a bond. Many problems have come about from using a bond in an inapplicable way. If a rigid bond is used to attach a sensor to a sample which elastically deforms during the test, the normal result is a broken bond and poor or no sensitivity to the acoustic wave. Similarly, in an experiment where the temperature is changed appreciably, the use of a rigid bonding material can lead to broken bonds due to differential thermal expansion between the sensor and the sample.

Bonding agents, then, must be chosen with great care and the primary emphasis must be put upon the compatibility of the materials under the test conditions. Usually if the bond will hold the sensor on, it will be an adequate couplant. For a compressional wave any fluid will act as a couplant. A highly viscous fluid will transfer some shear stress across the boundary which may or may not be an advantage. The most practical rule is to use as a couplant a thin layer of any viscous fluid which wets both surfaces. The sensor should be held against the surface with some pressure furnished by magnets, springs, tape, rubber bands, etc. The secret is to use as thin a layer as possible. If a rigid bond is used there must be no differential expansion between the two surfaces. In Table 3.1 a few commonly used couplants are listed along with the temperature range where they can be used.

Table 3.1

Some Common Acoustic Emission Couplants and the Approximate Temperature Range Where They Can Be Used

Dow Corning V-9 resin	-40° to 100° C
High vacuum stop cock grease	-40° to 200° C
Ultrasonic couplants	room temperature
Petroleum grease	room temperature
Water	1° to 99° C
Dow Corning 200 fluid	-273°C to -70°C and -30°C to 200°C
Salol	-40°C to 40°C
Nonaq stop cock grease	-273°C to 100°C
Dental cement	0° to 50°C
50% Indium - 50% Galium mixture	20° to 700°C

4. INTEGRAL PREAMPLIFIER SENSORS

The R3I, R6I, R151, R30I, R50I and WDI integral preamplifier sensors represent a significant advancement for the field of acoustic emission by enclosing a low-noise FET input 40 dB pre-amplifier inside a standard high sensitivity sensor. These rugged, small size AE integral pre-amplifier/sensors eliminate the need for cumbersome pre-amplifiers by incorporating two functions into one, thereby reducing equipment costs and decreasing set-up time for field applications. These sensors also come with optional "Auto Sensor Test" capability designated with an "AST" suffix after the sensor model type (e.g. R15I-AST). AST models offer an internal sensor pulsing capability when used with A or AST-capable AE systems with the AST capability such as DiSP, MISTRAS, LAM or SPARTAN 2000. AST provides an automated means of pulsing and receiving a simulated AE burst that is coupled to the structure. AST tests the entire AE signal processing chain starting with the sensor coupling, through the sensor and preamplifier, cabling and AE system electronics. This is useful for testing individual sensor coupling, verifying the response of other sensors attached nearby to the same structure, establishing inter-sensor timing parameters that can be used to determine sensor spacing and providing verification of the repeatability of the AE sensors throughout the AE test.

These integral preamplifier sensors were developed with the purpose of attaining high sensitivity and the capability of driving long cables without the need of a separate pre-amplifier. In addition, they connect directly to all existing PAC AE instruments and systems and are also compatible with other manufacturers' systems.

4.1 Features

- Small size, stainless steel construction
- Operation range — 45°C–80°C (-25°C–80°C for AST versions)
- Good RFI/EMI immunity
- Wide dynamic range (>80 dB)
- Low noise pre-amp (~2 μV)
- Single BNC input/output (power signal)
- Interchangeable with existing pre-amp/sensors
- Ideal for field/lab testing
- Auto Sensor Test option allows for sensor pulsing or self-test

4.2 Functional Description

The integral sensors are completely enclosed in a stainless steel case and coated to minimize RFI/EMI interference. In addition, care has been taken to thermally isolate the critical input stage of the pre-amplifier, in order to provide excellent temperature stability over the range of -45°C to +80°C. For ease of use, the integral sensors utilize a standard coaxial cable with BNC connector to power the pre-amp and carry the output signal. The complete block diagram of the integral sensor is shown below in Figure 1.

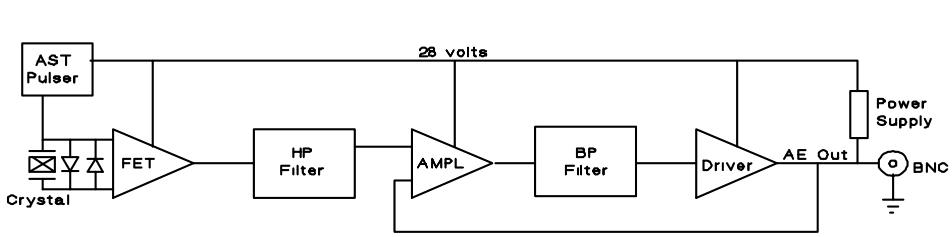


Figure 1. Integral Sensor Block Diagram

4.3 Specifications

Electrical Specifications:

- Gain: 40 ± 1 dB
- Peak Sensitivity: 30 dB ref 1 V/mBar
- Noise (RMS rti): ~2 μV
- Dynamic Range: >80 dB
- Output Voltage: >15 Vpp into 50 Ohms
- Power Required: 28 V at 100 mA
- AST Pulse: -24 Volt, 0.4 microseconds into crystal
- AST Trigger: < 2 Volts at preamplifier output (power)
- Completely enclosed crystal for RFI/EMI Immunity

Physical Specifications:

- Temperature (°C): -45 to +80 (-25–80 for AST)
- Shock Limit (g): 500
- Case material: Stainless steel (304)
- Face material: Ceramic
- Grounding: Case grounded and isolated from mounting surface
- Connector type: BNC
- Connector location: Side (TC option provides a Top mount connector)
- Directionality (dB): ±1.5
- Seal type Epoxy
- Pressure: <400 psi hydrostatic pressure

Model Related Specifications	Sensor Model				
	R6I	R15I	R30I	R50I	WDI
Sensor drive capability (w/RG-58 AU cable)	up to 3000 ft. (1000 m)	up to 1000 ft. (300 m)	up to 500 ft. (160 m)	up to 300 ft. (100 m)	up to 300 ft. (100 m)
Dimensions (dia. x ht. (mm)	29 x 40	29 x 31	29 x 31	29 x 30	29 x 30
Dimensions (dia. x ht. (in.)	1.13 x 1.6	1.13 x 1.23	1.13 x 1.23	1.13 x 1.16	1.13 x 1.16
Weight (gm)	98	70	75	70	70
Peak sensitivity Ref V/m/s)/[Ref V/mbar]	120† [-26]*	109† [-24.5]*	98† [-24]*	86† [-28]*	87† [-28]*
Operating frequency range (kHz)	40–100	70–200	125–450	300–550	100–1000
Resonant frequency (kHz)[1]	50† [90]*	125† [153]*	225† [350]*	320† [500]*	125† [500]*

NOTE 1: † Denotes response to plane waves (angle of incidence normal to face of sensor).
* Denotes response to surface waves (angle of incidence transverse or parallel to face of sensor).

5. PREAMPLIFIER INTRODUCTION

Physical Acoustics has a wide range of preamplifiers for use with our systems. There is a need for different types of preamplifiers due to different applications, specific environmental needs and cost constraints. Below is a short description of each preamplifier family in PAC's line of preamps. Following that is a specification sheet and additional information regarding each type.

2/4/6 Preamplifier Family: The 2/4/6 preamplifier family includes the 0/2/4 (meaning gain ranges of 0dB, 20 dB and 40 dB) and 2/4/6 (meaning 20 dB, 40 dB and 60 dB gain ranges). Other family members include the 0/2, 2/4 and 4/6 preamplifiers. This family of preamplifiers is meant to replace the industry's most famous preamplifier, the 1220A. This is our premiere preamplifier and is meant for laboratory use when the customer is not sure about the gain that his/her application will need or the frequency bandwidth. These preamplifiers were designed to be used with all available AE systems that have their power supplied via the output signal BNC. Provided with three selectable gain settings (switch selectable), this preamplifier operates with either a single-ended or differential sensor. Plug-in filters provide the flexibility to optimize sensor selectivity and noise rejection. These filters are supplied in the Low Pass (LP), High Pass(HP) and Band Pass (BP) configurations, and offer constant insertion loss for easy filter swapping without the need for recalibration. Auto Sensor Test (AST) allows the sensor to characterize its own condition, as well as send out a simulated acoustic emission wave that other sensors can detect. There's also a "C" version available.

1220 Series Preamplifiers: PAC's family of 1220 Preamplifiers offers the versatility of interchangeable filters for matiching different sensors and dealing with diverse noise environments. Low noise, outstanding dynamic range and superior techniques for avoiding the pickup of EMI are the cornerstones for PAC's long-standing leadership in this vital area. The family of 1220 Preamplifiers features single and differential input, switchable 40/60 dB gain and replaceable bandpass filters with values from 10 kHz to 1.5 MHz.

There are three versions of the 1220 Preamplifier: the **1220A** is powered by +28 volts, which uses the single BNC for both power and singal. This model has been replaced with the 0/2/4 and 2/4/6 family of preamplifiers. However, if there is need for this preamplifier to match those already in use, PAC is happy to supply it.

The **1220B** is powered by a separate +/-15 volt source. This uses a BNC connector for signal output and a Lemo connector for power input.

1220C also separates the power input from the signal output . It uses two separate BNC connectors, one for 28 volt power and one for signal output.

In-Line "IL" Series Preamplifiers: The In-Line series of preamplifiers are small (~1" square x 2.2" long), low cost preamplifiers, that are available for those applications where there is a known specific preamplifier requirement. These preamplifiers have a fixed gain (0, 20, 40 or 60 dB), fixed frequency bandwidth (various filters are available) and specific sensor input connection (single or differential), all which are specified at the time of purchase. The result is a very small, simple (just two connectors) and lower cost preamplifier that is easy to install and use.

1222 Charge Preamplifier: A charge preamplifier is used in cases where there is a need for long lengths of sensor input cable. Charge preamplifiers do not suffer from distance/attenuation effects like a voltage preamplifiers do. They maintain the signal amplitude regardless of distance from the passive sensor to the preamplifier. Our 1222A Charge Preamplifiers work with our entire range of single ended sensors and feature (internally) selectable 40/60 dB gain, standard PAC Pluggable filters with bandwidths of 20 – 600 kHz and built-in test signal and control. They are directly compatible with all PAC systems using the single Power/signal AE input BNC connection.

1225IS Intrinsically Safe Preamp/Sensors/Barriers: The 1225IS family of components are used in hazardous, gaseous environments that require chass IIC, Intrinsically safe (IS) apparatus. They are a direct replacement for the Physical Acoustics standard line of Sensors and 1220A preamplifiers. The IS sensors (R6-IS, R15-IS and RWD-IS) and the preamplifier (1225A) are designed and certified for use within the hazardous area, while the barrier (1225B) is attached to the preamplifier and is installed outside the hazardous area where it is connected to the AE instrument. Therefore, this series of sensor and preamplifier is used when the AE system can be installed outside the hazardous area. The 1225A IS preamplifier must be used in combination with the listed IS sensors and 1225B barrier. It features 20/40 dB selectable gain, pluggable High Pass and Low Pass filters and operates with PAC's standard single Power/Signal BNC.

1227 Series Preamplifiers: This family of preamplifiers offers 20 dB AE signal gain and very low power operation (3 milliamp typical). The 1227A is designed for standard 50 Ohm AE systems while the 1227B is designed for 600 Ohm AE systems. Both models use PAC's standard single Power/Signal BNC. These preamplifiers are very small (~ 0.7" square by 2.5" long) and low cost.

1227WT Preamplifier: The PAC 1227WT preamplifier offers 20dB AE signal gain like the 1227A with the exception that it operates in a wide temperature range of -47°C to +175°C. Also there is an optional "pulse Through" sensor calibration capability.

5.1 0/2/4 & 2/4/6 Preamplifiers

5.1.1 Description

The 0/2/4 and 2/4/6 pre-amplifiers were designed to be used with all available AE systems that has its power supplied via the output signal BNC. The 0/2/4 is supplied with 0/20/40 dB gain (switch selectable), while the 2/4/6 is supplied with 20/40/60 dB gain. These pre-amplifiers operate with either a single ended or differential sensor. Plug in filters provide the user with flexibility to optimize sensor selectivity and noise rejection. These filters are provided in the Low Pass (LP), High Pass (HP), and Band Pass (BP) configurations, and offers constant insertion loss for easy filter swapping without the need for recalibration. Automatic Sensor Test (AST) is supplied as an option. This option provides the sensor with the ability to characterize its own condition as well as send out a simulated acoustic emission wave that other sensors can detect.

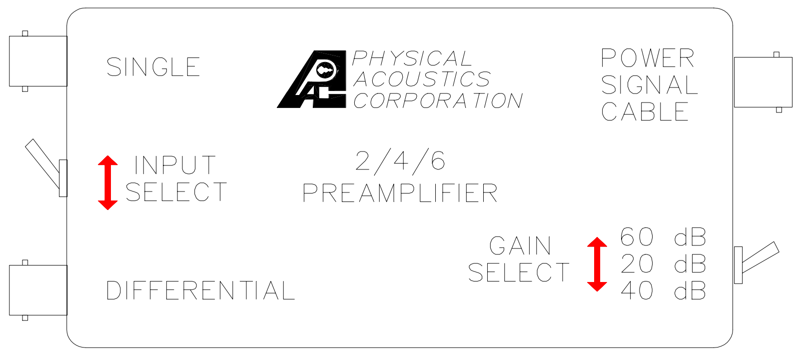


Figure 2. 2/4/6 Preamplifier

5.1.2 0/2/4 and 2/4/6 Specifications

Electrical Specifications:

- Gain Selectable: 0/2/4 - 0/20/40 dB ± 0.5% dB
  2/4/6 – 20/40/60 dB ± 0.5% dB
- Input Impedance: 10kΩ // 15pF
- Power Required: 18-28Vdc
- Operating Current: 30mA (With AST Installed)
  28mA (Without AST Installed)
- Dynamic Range: 75dB (Utilizing an R15 Sensor)
  80dB (50Ω Input)

Environmental Specifications:

Temperature: - 40° C to + 65° C

Physical Specifications:

5 1/2in(L) x 2 3/8(W) x 1 3/8(H)
13.97cm x 6.03cm x 3.49cm
Weight: 0.45lb (205grams)

2/4/6 Gain Related Specifications:

Gain Selection	20dB	40dB	60dB
· Bandwidth (-3dB):	10kHz-2.5MHz	10kHz-2.0MHz	10kHz-900kHz
· Output Voltage (50Ω Load):	20Vpp	20Vpp	6Vpp
· CMRR (500kHz):	42dB	42dB	42dB
· Noise(RMS rti):			

Filter Frequency Response Hz	**20dB** ***With R15 Sensor***	**40dB** ***With R15 Sensor***	**60dB** ***With R15 Sensor***	**20dB** ***Input Shorted***	**40dB** ***Input Shorted***	**60dB** ***Input Shorted***
135k-185k	3 µV	1.4 µV	1.5 µV	2.0 µV	1.0 µV	0.42 µV
100k-300k*	3 µV	1.8 µV	1.8 µV	2.3 µV	1.0 µV	0.8 µV
10k-2.0M	5 µV	4 µV	3 µV	4 µV	3 µV	2.5 µV

**Standard filter*

0/2/4 Gain Related Specifications:

Gain Selection	0dB	20dB	40dB
· Bandwidth (-3dB):	10kHz-2.5MHz	10kHz-25MHz	10kHz-800kHz
· Output Voltage (50Ω Load):	3Vpp	20Vpp	20Vpp
· CMRR (500kHz):	29dB	29dB	28dB
· Noise(RMS rti):			

Filter Frequency Response Hz	**0dB** ***With R15 Sensor***	**20dB** ***With R15 Sensor***	**40dB** ***With R15 Sensor***	**0dB** ***Input Shorted***	**20dB** ***Input Shorted***	**40dB** ***Input Shorted***
135k-185k	20 µV	4.8 µV	3.5 µV	20 µV	4.3 µV	2.7 µV
100k-300k*	20 µV	6.2 µV	5.2 µV	20 µV	5.8 µV	4.5 µV
10k-2.0M	30 µV	19.5 µV	11 µV	30 µV	19 µV	10 µV

5.1.3 Installation and Operation

The 0/2/4 and 2/4/6 use similar pluggable filters as the 1220A. Please refer to section 5.7 for standard filter values available for this preamplifier, however, use part number "2-14-40" rather than "1220A" when specifying filters for this family. Also refer to the section 5.7 of the 1220A preamplifier documentation for installation of filters as well as preamplifier installation.

5.2 In-Line Differential Preamplifiers (IL-XX-D)

5.2.1 Description

The Inline Differential Preamplifier was designed to be used with all available AE systems that has its power supplied via the output signal BNC. These preamplifiers are small compact, low noise differential preamplifiers (for use with differential sensors only), with fixed gain and fixed filter bandwidths. On applications where the user knows the specific bandwidth and gain required, these preamplifiers offer the most compact, low noise, low cost solution. Several different gain models are available including 0 dB gain (model IL-D), 20 dB (IL-20D), 40dB gain (IL40D) and 60dB gain (IL60D). It has an active filter built in and optimized sensor selectivity and noise rejection. Various filter values are available and are specified at the time of the purchase. Automatic Sensor Test (AST) is supplied as an option. This option provides the sensor with the ability to characterize its own condition as well as send out a simulated acoustic emission wave that other sensors can detect.

Figure 3. In-Line Differential Preamplifier

5.2.2 Specifications

Physical Specifications:
- 3.25in.(L) x 1.13in.(W) x 0.86in.(H)
  (8.26cm x 2.87cm x 2.22cm)
- Weight: 0.12lb (54 grams)

Electrical Specifications:
- Gain : 0, 20, 40 and 60 dB ± 0.5% dB
- Input Impedance: 10kΩ // 15pF
- Power Required: 18-28Vdc
- Operating Current: 30mA (With AST Installed)
  28mA (Without AST Installed)
- Dynamic Range: 80dB (Utilizing an R15 Sensor)
  90dB (50Ω Input)

Environmental Specifications:
Temperature: - 40° C to + 65° C

	IL-D	IL-20D	IL40D	IL60D
· Gain	0 dB	20 dB	40 dB	60 dB
· Output Voltage (50Ω Load):			15Vpp	15Vpp
· CMRR (500 kHz):			50 dB	50 dB
· Noise(RMS rti):			2 μV	2 μV

5.2.3 Standard Filters

Filters for the In-line differential preamplifiers are installed at the factory. Filter values must be specified at the time of purchase. The following are the standard available filter bandwidths for the In-Line differential preamps.

20 – 100 kHz	20 – 1000 kHz	50 – 500 kHz	100 – 300 kHz
100 – 1200 kHz	135 – 185 kHz	250 – 350 kHz	400 – 1000 kHz

Contact the factory for values other than those listed above.

5.2.4 Installation and Operation

Installation of the In-line differential sensors are very easy since there are only two connectors to connect and no configuration switches. Simply connect a differential sensor to the input of the of the preamplifier and connect the output of the preamplifier to the AE system channel input.

5.3 In-Line Single Ended Preamplifiers (IL-40S)

5.3.1 Description

The Inline Single Preamplifier is the lowest cost preamplifier in PAC's preamplifier line. It has been designed to be used with single ended sensors only and has a fixed gain of 40 dB (model IL-40S). It was designed to be used with all available AE systems that has its power supplied via the output signal BNC. It has "light" band pass filtering to optimize sensor selectivity and noise rejection. Automatic Sensor Test (AST) is supplied as an option. This option provides the sensor with the ability to characterize its own condition as well as send out a simulated acoustic emission wave that other sensors can detect.

Figure 4. In-Line Single Ended Preamplifier

5.3.2 Specifications

Physical Specifications:
- 3.25in.(L) x 1.13in.(W) x 0.86in.(H)
  (8.26cm x 2.87cm x 2.22cm)
- Weight: 0.12lb (54 grams)

Electrical Specifications:

· Gain:	40 dB $\pm$ 0.5% dB (Fixed)
· Input Impedance:	10kΩ // 15pF
- Input type:	Single ended inputs (signal and ground)
· Power Required:	18-28Vdc
· Operating Current:	22mA (With AST Installed) 20mA (Without AST Installed)
· Dynamic Range:	>80dB (Utilizing an R15 Sensor)
· Output Voltage (50Ω Load):	15Vpp
· Noise(RMS rti):	<2 μV

Environmental Specifications:
Temperature: - 40° C to + 65° C

5.3.3 Standard Filters

Filters for the In-line single ended preamplifiers are installed at the factory. Filter values must be specified at the time of purchase. The following are the standard available filter bandwidths for the In-Line single ended preamps.

15 – 65 kHz	30 – 165 kHz	100 – 450 kHz	215 – 490 kHz
350 – 650kHz	32 – 1100 kHz		

Contact the factory for values other than those listed above.

5.3.4 Installation and Operation

Installation of the In-line single ended preamplifiers are very easy since there are only two connectors to connect and no configuration switches. Simply connect a single ended sensor to the input BNC of the of the preamplifier and connect the output BNC of the preamplifier to the AE system channel input. Be careful not to reverse the connections as damage may occur.

5.4 1222 Charge Preamplifiers

5.4.1 Introduction to Charge Preamplifiers

Both voltage preamplifiers and charge preamplifiers can be used in AE applications. The voltage preamplifier is more stable, and easier to use then the charge preamplifier, but the charge preamplifier has some features that make it more desirable for certain applications.

The charge preamplifier has a distinct advantage with long lengths of input cable between the sensor and the preamplifier. For the example where a sensor coax cable length needs to be e.g. 50 meters, the voltage preamplifier (1220A) has a 17 dB loss in signal amplitude, where as the charge preamplifier has no loss in signal amplitude. This has been tested with an R15 sensor with a lead break from a 0.3 mm Pentel mechanical pencil.

The noise of a charge amplifier is slightly larger then the voltage amplifier due to the addition of an additional charge conversion stage. Also the length of cable affects the noise.

With a 3' input cable the Signal to Noise Ratio (S/N) of a charge amp is 5 dB smaller then the voltage amp. With a 150' input cable the signal to noise ratio of the charge amp and voltage amp is the same. The charge amplifier has the advantage in that the signal amplitude is unchanged.

5.4.2 1222 Preamp Description

The figure shows the outline of the 1222 Charge Preamplifier. It has 3 single ended BNC connectors for use with Co-axial cables. The pre-amp accepts inputs from PAC and other single ended AE piezoelectric sensors anywhere in the frequency range of 20 - 600 kHz. The following is a description of each of the connections.

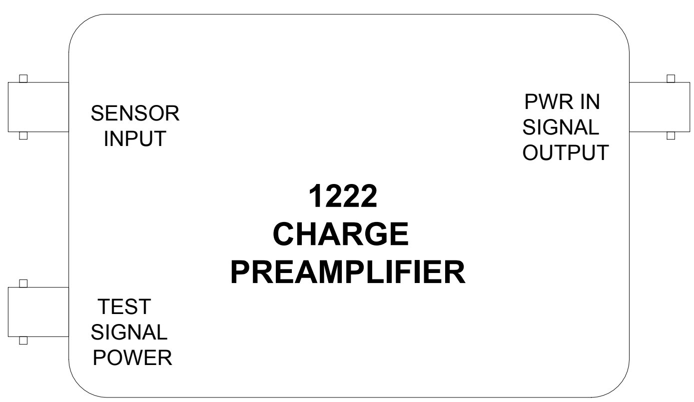


Figure 5. 1222 Charge Preamplifier

Sensor Input.
This is the input from the AE single ended sensor. The sensor cable is connected to this connector.

Power In/Signal Out.
The Power In/Signal Out connection supplies 28 volts DC power from the AE Main unit to the pre-amplifier. Also on the same center conductor is the amplified AE signal output for processing by the AE Main unit. This is accomplished by "floating" the AE signal on the DC voltage.

Test Signal Power
The Test signal power BNC connection allows for the user to initiate a pre-amp/system test by applying a 12 volt DC level to this input. Upon application of this voltage, a relay is energized inside the pre-amp that disconnects the AE sensor from the input of the pre-amp and connects a signal generator with a known voltage into the input. Applying a known signal level at the input of the pre-amplifier allows the user to monitor the entire amplification chain in the main unit thereby insuring that the AE system circuitry is functioning.

Other important features of this pre-amplifier include the following:

- 40 - 60 dB internal gain selection. Factory default set at 40 dB.
- Uses PAC pluggable Band Pass filters for a narrower frequency response which further enhances Signal to Noise and filters out unwanted lower frequency vibrations. See 1220A filter selections.

5.4.3 Specifications

Gain:	100mV/pF & 1000mV/pF (set by internal jumper) (equivalent to 40 - 60 dB gain)
Bandwidth (-1dB)	20K-600kHz
RMS Noise (RTI):	<10 µV
Dynamic Range:	80 dB
Maximum Output:	16 Volts peak to peak into 50 Ohms
Quiescent Current:	35 mA
Filter Module:	Requires standard PAC Passive Filters
Gain Accuracy:	+/-1dB
Test Signal:	Constant Sine Wave (1MHz Bandwidth) 0.5V-P Maximum Amplitude (set at 150 kHz)

5.4.4 Installation and Operation

Installation of the 1222 Charge Preamplifier is identical to that of any other typical preamplifier. Attach the single ended sensor to the signal input of the preamplifier. Then connect the Power In/Signal Out BNC to the AE system via a co-ax cable. For the test signal, connect a switched 12 volt power source to the Test signal input. Whenever power is applied, a relay will switch the sensor input to the output of a signal generator and the signal generator signal will be amplified by the preamplifier and sent to the AE system for determination if the preamplifier gain or performance has changed.

The 1222 Charge preamplifier uses the standard 1220 family of pluggable filters. Refer to section 5.7 for specific information relating to the selection and installation of filters in this preamplifier.

5.5 1227A & 1227B Preamplifiers

5.5.1 Description

This family of preamplifiers offers 20 dB AE signal gain and very low power operation (3 milliamp typical). The 1227A is designed for standard 50 Ohm AE systems while the 1227B is designed for 600 Ohm AE systems like the PAC 4610. It has been designed to be used with single ended sensors only and has a fixed gain of 20 dB. Several filter bandwidths are available and must be specified at the time of purchase. Both models use PAC's standard single Power/Signal BNC. These preamplifiers are very small (~ 0.7" square by 2.5" long) and very low cost.

5.5.2 Specifications:

Parameter	1227A	1227B
Output Impedance	50 Ohms	600 Ohms
Gain	20 dB ± 1dB	20 dB ± 1 dB
Noise (μ Volts RTI):	4 μV	4 μV
Maximum Voltage Output (Vp-p):	5 Vp-p	1.4 Vp-p
Dynamic Range:	95 dB	84 dB
Supply Voltage Range:	9 – 28 Volts	7 – 28 Volts
Supply Current:	3 mA @ 12 Volts	3 mA @ 12 Volts

Maximum Operating Temperature:	0°C - 85°C
Preamp Dimensions:	3.4" Long x 0.687" wide x 0.687" high (8.64 cm long x 1.75 cm wide x 1.75 cm high)

5.5.3 Standard Filters

Filters for the 1227 series, single ended preamplifiers are installed at the factory. Filter values must be specified at the time of purchase. The following are the standard available filter bandwidths for the 1227 preamps.

30 – 200 kHz   60 – 400 kHz   150 – 600 kHz   220 – 900 kHz

Contact the factory for values other than those listed above.

5.5.4 Installation and Operation

Installation of the 1227 single ended preamplifiers are very easy since there are only two connectors to connect and no configuration switches. Simply connect a single ended sensor to the input BNC of the of the preamplifier and connect the output BNC of the preamplifier to the AE system channel input. Be careful not to reverse the connections as damage may occur.

5.6 1227WT High Temperature Preamplifier

5.6.1 Description

The Wide Temperature Preamplifier was designed to be used in very extreme temperature environments. It is for use with all available AE systems that has its power and output signal on the center conductor. Both input and outputs of the 1227WT utilize SMA type connector (BNC's are optional). The preamplifier is built in a narrow diameter stainless steel tube for reliability and ruggedness. It is supplied with 20 dB gain and operates with a single ended sensor (only). Pulse through Sensor Testing provides the ability to allow a pulse to travel from the AE system through the preamplifier to the sensor. The magnitude of the impulse going through the preamplifier can be up to 200 volts.

5.6.2 Specifications

Environmental Specifications:

Temperature:	- 47°C to + 175°C (-50°F - +350°F)
Vibration:	>40 G @ 0 - 2 kHz
Shock:	> 5G 5 - 20 msec.

Electrical Specifications: @ - 47° C to + 175° C (-50° F- +350 °F):

· Gain Selectable:	20 dB $\pm$ 1 dB
· Bandwidth (-3dB):	$\leq$40kHz to $\geq$1.2 MHZ
· Input Impedance:	10kΩ // 15pF
· Voltage Required at Power/Signal Connector: (In normal ambient temperature environment)	18-24 VDC
· Recommended Operating Voltage: (For maximum dynamic range over full temperature)	22-23 VDC
· Operating Current:	< 35 mA (With Pulse through relay)
· Dynamic Range:	75 dB (Utilizing an R15 Sensor) 80 dB (50° Input)
· Output Voltage (50Ω Load):	2Vpp into 50°
· Noise w/R15 (RMS rti):	≤ 7 µV (20°C/68°F)

Physical Specifications:

Length	4.25 inches (10.8 cm.)
Diameter	0.75 inches (1.9 cm)
Weight	0.16 lbs. (73 grams)
Connector	SMA type

5.7 1220A, 1220B, 1220C Preamplifiers

The Physical Acoustics 1220X Series is a versatile line of low-noise cost-effective preamplifiers. They were developed for use with Acoustic Emission (AE) systems in production and laboratory applications and their circuits were designed with the latest in low noise and high reliability components. The preamplifier gains its versatility by allowing the user to select high pass, low pass, or bandpass filters, single-ended or differential input, 40 dB or 60 dB gain, and choice of three output/power configurations.

The 1220A output and power is supplied by a single conductor 50 Ohm coaxial cable with a BNC connector (PAC Model 1234). The +28 VDC operating voltage and signal run on the same line and are internally isolated in the preamplifier. A variant of the 1220A which is the 1220A-AST is externally, connection and powerwise identical to a 1220A except that a special AST (Auto Sensor Test) circuit has been added to provide a -25 volt pulse directly to the sensor attached to the preamp input when the +28 volt power is momentarily interrupted. Several PAC systems such as SPARTAN 2000, MISTRAS, DiSP and LAM have the capability built in to create an AST pulse in this manner. This capability is advantageous in multiple channel situations for determining the sensor response, coupling efficiency and distance from another pulsing sensor.

In the 1220B preamplifier, the output and power run on separate cables. The preamplifier is powered by +/-15 VDC. A 1234 cable is used for the output and the power cable is a PAC Model 1233.

In the 1220C preamplifier, the output and power are also run on separate cables, but the preamplifier uses a single-ended power supply (+28 VDC). A PAC 1234 (BNC-BNC) cable is used for the output while another PAC 1234 (or PAC 1234A, BNC to pigtail) is used for the power connections.

Below is a table showing the different values of high pass, low pass, and band pass filters available for these preamplifiers.

STANDARD PLUG-IN FILTERS

HIGH PASS		BAND PASS		LOW PASS	
PART #	FREQUENCY	PART #	FREQUENCY	PART #	FREQUENCY
1220-3H	3 kHz	1220-20-100BP	20-100 kHz	1220A-400L	400 kHz
1220-20H	20 kHz	1220-50-200BP	50-200 kHz		
1220-50H	50 kHz	1220-100-300BP	100-300 kHz		
1220-100H	100 kHz	1220-100-1200BP	100-1200 kHz		
1220-200H	200 kHz	1220-200-400BP	200-400 kHz		
1220-300H	300 kHz	1220-300-600BP	300-600 kHz		
1220-400H	400 kHz	1220-400-600BP	400-600 kHz		
1220-500H	500 kHz	1220-600-1200BP	600-1200 kHz		
1220-600H	600 kHz	1220-BP-SYS	No Filtering		

5.7.1. Specifications of the 1220 Series Preamplifiers

Environmental Specifications:

Specifications apply at 25° ± 5° C
Preamplifiers will operate from 0° to 50° C

Electrical Specifications:

Gain:	40 or 60 dB (Switch selectable)
Bandpass:	User selectable from 10 kHz to 1.2 MHz
Input:	Single or differential selectable
Input Impedance:	10 k Ohms in parallel with 15 pF
Output Voltage:	>15 Vpp into 50 Ohms
Dynamic Range:	85 dB
CMRR (500 kHz):	55 dB
Noise (RMS RTI):	<2 µV (input shorted)
Power Requirements:	1220 A, C - +28 VDC
	1220B - ±15 VDC
DC Standby Current:	25 mA

Physical Specifications:

Dimensions:	5.25" Long x 2.25" Wide x 1.38" High
	(13.3 cm) x (5.72 cm) x (3.5 cm)
Weight:	0.55 lb. (0.25 kg)

5.7.2. 1220 Preamplifier Description

Figure 6. shows a sketch of each version of the 1220 series Preamplifier.

Single Ended Connector — Connects an external single ended sensor (PAC R, µ, W, or T series or equivalent piezoelectric transducer) to the 1220 preamplifier via an industry standard single ended BNC connector.

AE Input Select Switch — Selects what mode input is being connected to the 1220 preamplifier. When the switch is positioned toward the differential connector, this means that the 1220 is connected to amplify a differential signal.

AE Differential Input Connector — Connects an external differential sensor (PAC RD, µD, WD, or TD series or equivalent piezoelectric transducer) to the 1220 preamplifier via differential BNC connector.

Power Signal Cable — Output signal and power (+28 VDC) are both present on this line. Both signals are isolated internally. Cable connects via an industry standard BNC connector (PAC 1234 cable).

Gain Select — A total preamplifier gain of 40 dB (x100) or 60 dB (x1000) is selected by this switch.

Output — Output signal is present here. Cable connects via a standard BNC connector (PAC 1234 cable).

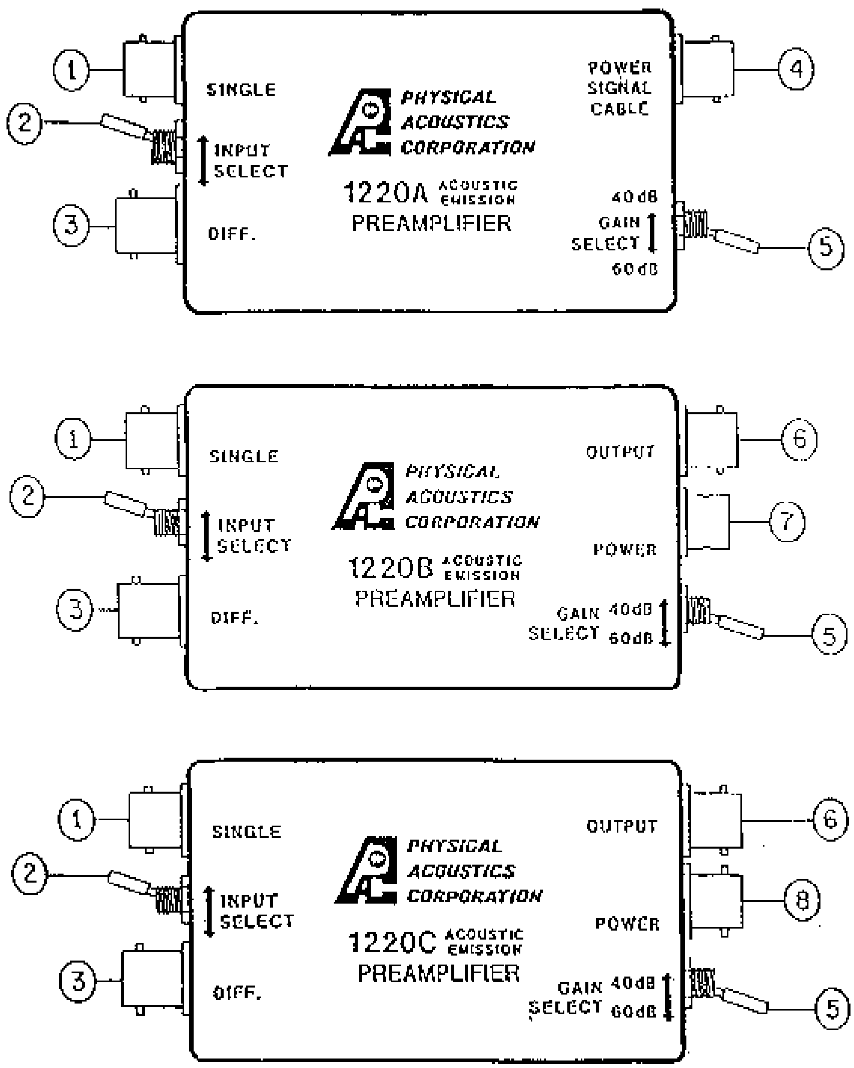


Figure 6. 1220 A, B, C External Connections/Controls

Power — +15 VDC is connected to the preamplifier here via a multipin connector. Use PAC cable #1233 or #1233A.

Pin #1 - Ground 1
Pin #4 - (-15) Volts (Green Lead on 1233 Cable)
Pin #7 - (+15) Volts (Red Lead on 1233 Cable)

Note: When using a 1220B preamplifier with a normally supplied 1233 power cable, no ground connection is made through the cable. Only a shield is provided in order to prevent possible ground loop problems (increased noise in the system). The ground is made through the shield or ground of the Output BNC connection (1234).

Power — (+28) VDC is connected to the preamplifier here via a standard BNC cable (PAC #1234 or #1234A).

Figure 7 shows wiring connections of the preamplifiers. Look up the corresponding number that describes the connection or control.

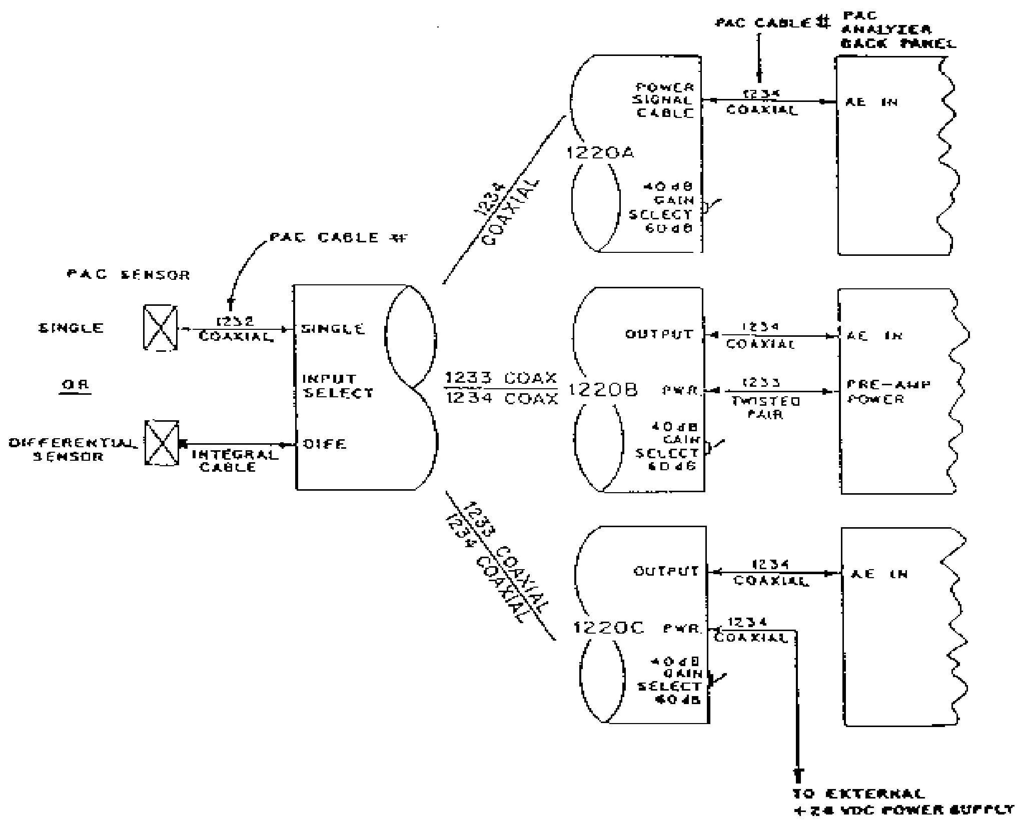


Figure 7. 1220 Wiring Connection

Operation and cable hookups differ only slightly for each version of the preamplifier. Input hookups are identical for the 1220A, B, C (Figure 7), while output connections require a different configuration.

5.7.3. Preamplifier Installation and Operation

1220A Installation and Operation

1. Connect a 1234 BNC to BNC signal cable from the preamplifier "Output" to the jack marked "AE IN" on the analyzer.
2. Select the AE input desired (single or differential).
3. Attach the appropriate sensor and cable to the preamplifier input connector (single or differential).
4. Turn system power on to energize the preamplifier.

1220B Installation and Operation

1. Connect a 1233 power cable from the 1220B connector labeled "Power to the PAC analyzer connector labeled Pre-Amp Power."
2. Connect a 1234 BNC to BNC cable from the preamplifier connector "Output" to the one on the analyzer labeled "AE IN."
3. Select the AE input desired (single or differential).
4. Attach the appropriate sensor and cable to the preamplifier input connector (single or differential).
5. Turn system power on to energize the preamplifier.

1220C Installation and Operation

1. Connect a 1234 (or 1234A BNC to pigtail) cable from the 1220C connector marked "Power" to an external +28 VDC power supply.
2. Connect a 1234 BNC to BNC signal cable from the preamplifier connector "Output" to the one on the analyzer labeled "AE IN."
3. Select the AE input desired (single or differential).
4. Attach the appropriate sensor and cable to the preamplifier input connector (single or differential).
5. Turn the system and external supply power on to energize the preamplifier.

5.7.4. 1220 Series Filter Replacement

Filter placement on the 0/2/4, 2/4/6 and 1220A, B, and C are identical. To replace a filter, remove the four Phillips head screws from the bottom lid; this will expose the preamp's inner circuitry (Figure 8).

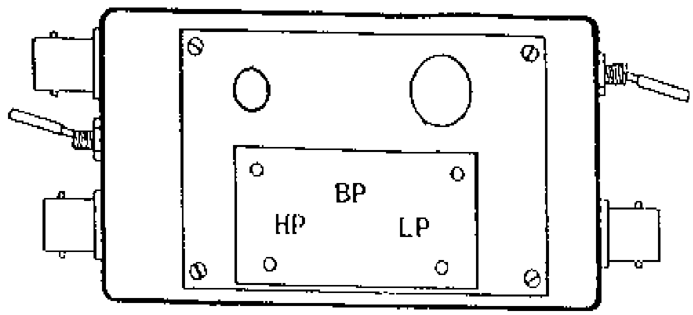


Figure 8. Internal Preamplifier Layout

The connections shown in Figure 9. should be made in order to by-pass (remove) filter in cases where the broadest possible bandwidth is desired.

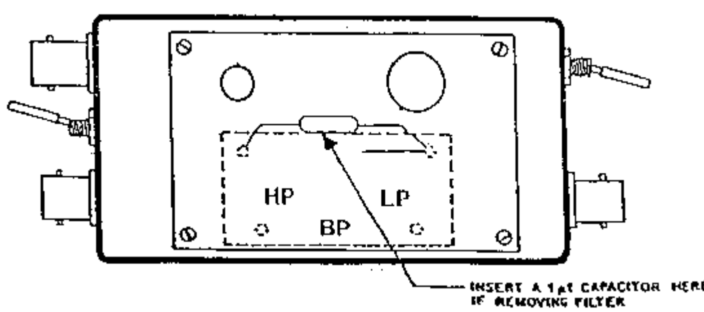


Figure 9. Removing and Bypassing a Filter Using a 1µF Capacitor

5.7.5. Circuit Description

Figure 10. is a block diagram of the 1220 series preamplifier. Internal circuitry for the 1220 A, B, C. is identical except for minor differences in the output and power distribution sections.

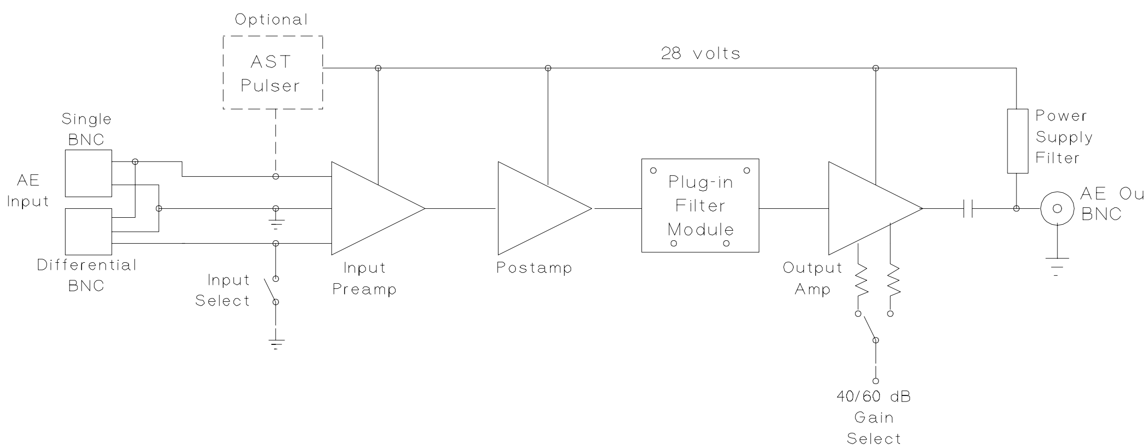


Figure 10. Preamplifier Block Diagram

Input Select — Input selection consists of a low noise differential amplifier for high gain, high common mode rejection and maximum sensitivity to low level input signals. This amplifier is then buffered by a 20 dB gain low output impedance post amplifier, which drives the PAC plug-in fifth order high pass, low pass and bandpass filters.

Gain Select — The output stage consists of a hybrid 20/40 dB gain high speed amplifier and a 50 Ohm output buffer for large power bandwidth while driving long cables. Two user adjustments are provided for calibration.

6. AUTO SENSOR TESTING

Auto Sensor Test (AST) is a unique and special capability that has been built within our SPARTAN 2000, MISTRAS, DiSP, LAM and PCI-8 systems. The AST feature allows our AE systems to control a pulser that is integral to PAC AST equipped preamplifiers and our Integral preamplifier sensors (with AST option). This allows for any AE channel to pulse the sensor, while the receiving electronics remains active. This means that the sensor can be used as a pulser and a receiver at the same time. It can therefore characterize its own condition as well as send out a simulated acoustic emission wave that other sensors can detect, thereby giving feedback as to the arrival time difference and the detection sensitivity of those nearby sensors. The other main important feature of this option is that it operates through the standard 1234 BNC cable which goes between the AE channel input and the preamplifier (and integral preamplifier sensor).

6.1 Other Automatic Sensor Pulsing Techniques

Competing methods for sensor pulsing or automated testing in AE instruments involves the use of at least 2 relays for each channel, one in the AE system for each channel and one in each pre-amplifier. When the AE system decides to pulse the sensor, it turns on a relay in the AE instrument which removes pre-amplifier power and makes connection to a digital output which puts a voltage spike through to the pre-amplifier. A relay in the pre-amplifier de-energizes when power is removed from the pre-amp. This causes the relay contacts to make electrical connection to the sensor crystal directly, and remove the pre-amp output signals from the co-axial cable path. A voltage spike now goes directly to the sensor crystal. Upon pulsing, a simulated AE event is generated that is coupled to the structure in which that sensor was in contact. This causes other sensors that are close by to detect the simulated AE event. This data when processed by the AE system gives the user information about the quality of the sensors that have detected the event. When used often, the user can determine if there has been any sensor degradation during the AE test. Unfortunately this technique is inferior to Auto sensor testing for various reasons including the fact that it cannot be used in situations where only one sensor is involved as well as other reasons that will be discussed below.

6.2 AST Application and Advantages

PAC has improved on the automated pulsing method with a unique and different scheme we call Auto Sensor Test (AST). Our scheme keeps the pulsing sensor active immediately after pulsing. This offers the following advantages in characterizing the AE event response:

1. Reading the response from the same sensor that is being pulsed gives a quality measure of that given AE channel. This includes information on sensor, coupling pre-amplifier and AE system.
2. A single sensor can be evaluated whereas in the above relay based method, this is impossible.
3. The self pulsing/receiving method provides information on the coupling quality of the sensor to the structure, whether the sensor is even attached to the cable or if the cable is shorted.
4. Since the pulsing sensor receives the AE information, it is the first hit sensor. This gives exact "delta T" measurements from this sensor to each other that detects the event. This is useful in calibrating for location. It is also useful in performing measurements such as those used in Acousto-Ultrasonics where the change in flight time is an important feature.

The way that this is accomplished is simply by sending a pulse down the preamplifier cable to the preamplifier. If the amplifier is equipped with AST capability, it has a circuit that detects this pulse. When detected, this pulsing circuitry generates a pulse with a specific pulse shape that excites the AE sensor. Since AE sensors work equally well as pulsers or receivers, the pulse causes the AE sensor crystal to deform and generate shock waves that travels throughout the structure. These sound waves travel to sensors that are on the structure and reflect, even back to the orignial pulsing sensor. The pulsing sensor which immediately reverts to a receiving AE sensor at the end of the pulse, receives the structural response signals and they are processed as a typical AE hit or event. Other sensors on the structure also detect and process the event.

The main disadvantage to the AST method is the receiving of the "main bang". This saturates the peak amplitude response of the AE system so that the pulsing sensor always registers a ~100 dB amplitude, but since this is a high "Q" type response, all the other AE features remain very low in value from the main bang alone. In this way, energy, duration and counts becomes a very good parameter for monitoring the response of the pulse.

6.3 AST Requirements

In order to perform AST on an AE system the following are needed:

1. AST (Auto Sensor Test) circuitry in the AE system. This is built as standard within all PAC multi-channel AE systems including DiSP, MISTRAS, LAM, SPARTAN 2000.
2. Preamplifiers with AST option or Integral Preamplifier Sensors with AST Option,
3. (AST) Auto Sensor Test Software. This is built standard within all PAC multi-channel AE System software including DiSP, MISTRAS, LAM and SPARTAN 2000.

From the above it can be seen that AST circuitry and software is already built into most PAC systems and is immediately ready to be put to good use. The only item that may have to be purchased is the preamplifier with AST option or the Integral Preamplifier sensors with the AST Option. PAC sells AST options with its 0/2/4 and 2/4/6 preamplifiers, its In-Line Preamplifiers, and with the 1220A preamplifiers. It is also available with our Integral Preamp sensors such as the R15I-AST, R30I-AST, WDI-AST, etc. Please consult PAC for more information on closing the loop with our AST preamplifiers and integral sensors.

In terms of software, all PAC multi-channel software has multiple AST modes. AST can be performed before and after a test providing a graphical or line dump report. AST can even be performed during a test on a single sensor or all sensors to verify their integrity, all without affecting the AE test results. One additional mode with AST is the ability of saving a previous test to use as a comparison with a later AST test. In this way, a nice report is generated to indicate the statistical deviation from the “Trained” file and provide pass/fail information as a result. Consult your software manual for more information on the use of AST in PAC’s multichannel AE systems.

7. 1224 SERIES REPEATER AMPLIFIER

7.1 Introduction

Physical Acoustics 1224 series repeater amplifiers are "in-line" driver amplifiers meant to restore the AE signal level when driving long co-ax cables. The 1224 was developed for use with Acoustic Emission (AE) systems in production and laboratory applications. Its circuitry uses low noise and high reliability components. The 1224 series repeater amplifier has been specifically designed to compensate for signal losses over long cable lengths. It is used between the AE system and the AE preamp when cable lengths exceed 1000 feet. Therefore it is recommended that 1224's be used at spacing of 1000 feet.

7.2 Specifications

Typical specifications for the 1224 series repeaters are as shown below:

1224 Specifications @ 28 Volts

Gain:	10 dB min. or 20 dB max.
Frequency response (-3 dB):	1.6 kHz to 2.5 MHz small signal 1.6 kHz to 1.0 MHz large signal
Vpk-pk output (max):	8 Vpk-pk into 50 Ohms
Static current:	20–38 mA, depending on gain setting
Supply voltage:	14–28 Volts DC
Noise "RTI":	23 µV (No filter) 14 µV (with "100 kHz low" filter)

7.3 1224 Configurations/Designations

There are several different models of 1224 as shown in the feature chart below.

Feature Chart

	1224A	1224B	1224C	1224C-LF	1224D
Combined supply/ signal line	Yes	Yes	No	Yes, on differential BNC connector	Yes
Separate supply line	No	No	Yes	Yes*	No
External gain adjust	10 or 20 dB Fixed at 20 dB	None	10 or 20 dB	10 or 20 dB	0 or 20 dB
Internal gain adjust	3 to 20 dB	3 to 20 dB	3 to 20 dB	3 to 20 dB	3 to 20 dB
Frequency range	10 to 900 kHz	10 to 700 kHz	10 kHz to 1 MHz	1.6 kHz to 1 MHz	10 kHz to 1 MHz
Input	50 Ohm or 5 kOhm	50 Ohm or 5 kOhm	50 Ohm or 5 kOhm	50 Ohm or 5 kOhm	50 Ohm or 5 kOhm

* On the differential BNC Connector, one conductor is for power and the other for the AE signal. Please note that using this repeater requires different cabling and connectors on the 5600. The main advantage of using this repeater is in applications where a very low frequency operation is desired.

7.4 Operational Description of the 1224 Repeater Amplifier

The 1224 series repeater consists of a low noise preamplifier with an internally adjustable gain to compensate for filter losses. The output of the preamplifier drives a PAC plug-in filter module. The plug-in filter module can be replaced by removing the four Phillips head screws from the bottom lid. Various high-pass, low-pass and bandpass filter configurations are available to customize the 1224 frequency response. These are the same filters as indicated in the previous section. The filter output is then fed to the output stage. The output stage consists of a hybrid 10 or 20 dB gain high speed amplifier and a 50 Ohm output buffer for large power bandwidth while driving long cables.

The 1224 repeater amplifier can be installed by simply connecting the output of the repeater amplifier toward the jack of the analyzer marked "A.E. Input." The input of the 1224 amplifier should then be connected towards the sensor or preamplifier output. The external gain switch can then be used to control the amount of gain.

CHAPTER IV

AEwin SOFTWARE

MANUAL REVISION HISTORY REPORT

Revision history for manual: 9/30/04
Part No.: 6320-1006
Manual Name: AEwin Software User's Manual
Rev. 1.9

1. Greatly expanded the section detailing the menu's and dialog boxes.
2. Revised the location and clustering sections.
3. Added sections on various AEwin options (Supervisor mode, LeakTEC/On-Line Crack Alarms, etc.
4. Updated license Activation section to include info on Hardware Security Keys.
5. Added section on PCI-2 Waveform Streaming.
6. Added Hit/Event Linking Analysis Capability

AEwinä **SOFTWARE**

Installation, Operation and User’s Reference Manual

AEwin™ Software

USER'S MANUAL

Rev 1.9

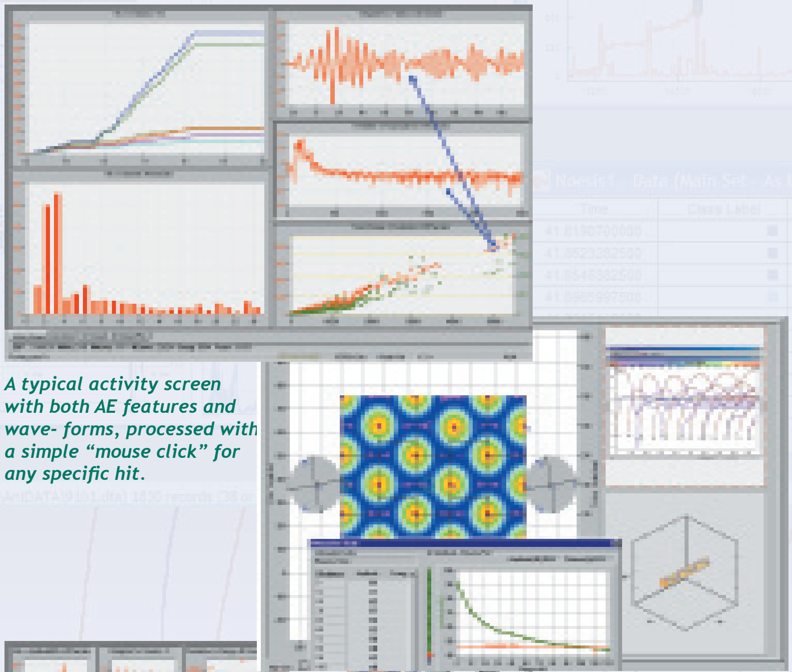
September 20, 2004

PAC Part # : 6320 – 1006

Associated with: AEwin Software for Windows
PAC Part # :
6320-7030 Rev 1.90 or Higher
6301-7001 Rev 1.56 or Higher
7030-7005 Rev 1.41 or Higher
8000-7082 Rev 1.00 or Higher
6300-7041 Rev 1.30 or Higher

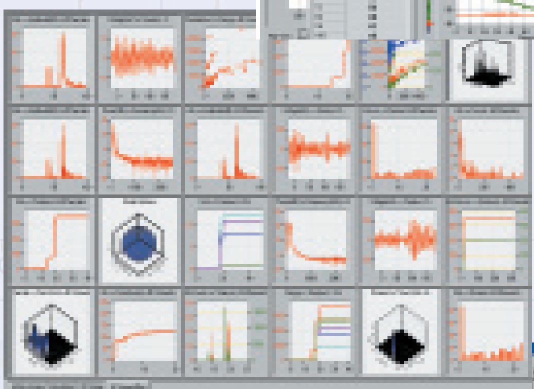
AEwin™. . . the Next Generation in AE Software . . .

For True, Real-time Windows Operation and Control of Your PAC Acoustic Emission (AE) System (DiSP, MISTRAS and SPARTAN, PCI2, SAMOS) Under WINDOWS 98/ME/2000/XP

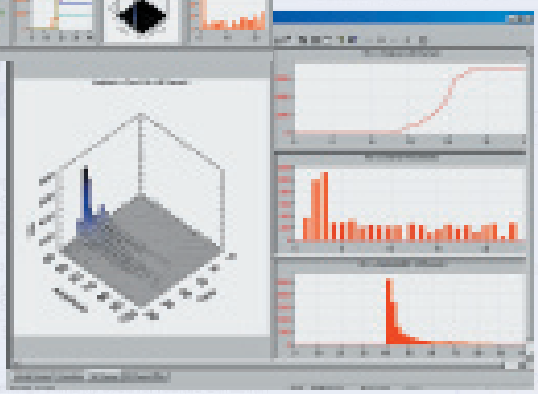


A typical activity screen with both AE features and wave- forms, processed with a simple "mouse click" for any specific hit.

Advanced AE sensor coverage based on dispersion curves with attenuation entry table and plot for accurate location.



AEwin Software, combined with advanced Digital Signal Processing hardware, enables the AE user to select and view, in real time, multiple 2-D or 3-D feature and wave-form activity graphs.



AEwin's 3-D graphing capability allows the graph to be rotated freely, using the mouse.

AEwin Features:

- 32-bit Windows Software for real-time "simultaneous" AE feature and waveform processing, display, fast storage and replay.
- Advanced DSP, polyMODAL AE processing and Fitness For Service (FFS) support.
- Full WINDOWS resources including; any screen size, printing JPGExport, networking, multi-tasking, & multi-processing.
- Complete compatibility with PAC's standard (DTA) data files, allowing you to replay and analyze all your previously collected AE files.
- Framework for easily adding graphs & graph screens.
- User controllable tool bars including: setup icons, acquisition control, line dump, status and statistics.

Graphing capabilities include:

- Exceptional 2-D and 3-D graphing capabilities that allow the setup of multiple graphs on a screen, limited only by the screen resolution.
- Hit/Event Identification that displays detailed information on selected data and highlights it in other graphs.
- Ability to set up and individually size (on screen) many different types of graphs including; 2-D line graphs, histograms, point plots, waveforms, FFTs, overlays, multiple plots on a single graph and color options.
- Capability to arrange multiple graphs on a screen.
- Toggling between multiple screens by selecting a user-labeled tab.
- Expandable to full screen with zooming and panning for close-up analysis.
- Full cursor readout capability.

Location & Clustering Option:

- Has 1, 2 and 3 dimensional location modes.
- Allows setup of multiple location groups.
- Provides mouse-oriented sensor placement and editing features.
- Allows selection of type of structure (plate, vessel, etc.) for setup, viewing and location.
- Incorporates attenuation profiling into location software (to view a sensor coverage map and provide source amplitude information).

For more information about

AEwin Software

Call: (609) 716-4000,

Email us: sales@pacndt.com or

Visit us on the Web at: www.pacndt.com

PHYSICAL ACOUSTICS CORPORATION

195 Clarksville Road, Princeton Jct., NJ 08550

MISTRAS *A World of NDT Solutions*

Table of Contents

1. INTRODUCTION

AEwin is a 32 bit WINDOWS, Data Acquisition and Replay program capable of running PAC's DiSP, SAMOS, PCI-2, MISTRAS or SPARTAN based products. AEwin uses full WINDOWS resources including: Setting of any WINDOWS available screen resolutions, Printing, Networking, Multi-Tasking, Multi-Threading, etc. It is capable of operating in WINDOWS 98/ME/2000/XP operating systems. AEwin is fully compatible with PAC's standard (DTA) data files. This allows you to replay and analyze all your previously collected AE files. AEwin is easy to learn, operate and use. The software has all the acquisition, graphing and analysis capabilities that you have come to expect in your AE system, plus many more new and enhanced features to ease your data analysis and visualization tasks. Multiple copies of AEwin can be run at once, one for acquisition with full display and analysis capabilities and one or more as Replay for additional analysis purposes.

Some of the general AE display and analysis capabilities found in AEwin's includes the following: AEwin provides a framework for easily adding graphs and graph screens to the main system WINDOW. AEwin has a very flexible line dump capability, which can be called at any time, in any screen, which can be scrolled up or down. AEwin has various user selectable tool bars including; Setup icon toolbar, acquisition control, line dump, status toolbar and statistics tool bar. AEwin has many built in, enhanced features including; Graph zooming and panning, more flexible graph setup, more graphs, and built-in filtering functions (graphical filters and Post Filtering). Printing capabilities include: Print a graph, a screen or multiple screens to a WINDOWS or network printer, to the clipboard or to a JPEG file.

Some of AEwin's graphing capabilities include:

- Exceptional 2D and 3D graphing capabilities. Multiple graphs can be displayed on a screen, limited only by the resolution of the screen itself.
- Graphs are individually sizable on a screen, making for a very flexible arrangement. The user can set up one (or more) large graphs for visualization with multiple supporting small graphs alongside or around the main ones.
- Multiple Graphs are arranged on a screen, however the user desires. Multiple screens can be setup, each accessible by selecting a user labeled tab. Therefore, a user can set themes for screen layout (e.g. Location & Cluster analysis, waveform analysis, AE activity analysis, AE Feature correlation analysis, Alarm Analysis, themes to name a few)
- Many different types of graphs can be set up including; histograms, point plots, 3-D graphs, waveforms, FFT's, multiple plots on a single graph with coloring options, etc.
- All graphs can easily be enlarged to full screen (maximized) by the touch of a button.
- All graphs have full Cursor Readout capability, either continuous or point by point movement.
- All graphs (2-D and 3-D included) can be infinitely zoomed and panned for close-up analysis.

In terms of Location determination, the standard version of AEwin has zonal and linear location modes, while the optional "Full Location" software adds 2D Planar Location capability to the list. In addition, there is also a 3D Location option available and a Spherical 3D location option. Key features regarding location include the following:

- Multiple (8) location groups standard, (32 optional), each capable of using all the AE channels in the AE system. Mouse oriented sensor setup includes; Set sensors manually (click and drop), automated sensor setup for triangular setup, and easy sensor editing drag and drop, or table entry based sensor position.
- Multiple 1 dimensional, 2 dimensional and 3 dimensional location modes.
- Flexible Clustering, cluster reporting and Cluster statistics available on any point plot graph screen (not just limited to location).
- User selectable location structure visualization to ease setup. Options include; Plate, vertical vessel, horizontal vessel, sphere, and Free, each with specific setup menu's geared for easy setup of that structure, including automated and manual placement of sensors, weld lines, nozzles, etc.
- Visualization overlay planes to ease setup and viewing of location setup and results. Overlay planes include; Sensors, grid, attenuation map, welds and nozzles.

- Advanced Location setup capabilities provides improved event detection classification, and accurate source location techniques.

The AEwin program runs under WINDOWS 98/ME/2000/XP operating systems. However, the best performance will be obtained using WINDOWS 2000/XP.

1.1 System Requirements

AEwin software requires a PAC DiSP, SPARTAN, PCI-2, MISTRAS or SAMOS System with Pentium III (or equivalent). Although lesser system computer configurations will operate AEwin, it is recommended that a 1 GHz processor, 256 megabytes RAM, 20 gigabyte hard disk and 17" display monitor with 1280 x 1024 resolution be utilized. These days this type of computer power is easily available at low cost. Please consult the factory if your computer is below these standards.

If AEwin is being installed explicitly for replay and analysis, it is also recommended to use a similar computer base as that described above.

1.2 Software Installation

The AEwin program is generally pre-installed on the AE system computer from the factory. In special instances, such as software upgrades, however, you will need to perform the installation yourself from the supplied CD. You cannot run AEwin directly from the distribution CD because the files on the disk are compressed and security protected.

If you are installing AEwin yourself, you will need to follow the simple installation instructions below. Due to the built-in software security features of this software, part of the installation process requires you to obtain an activation code from Physical Acoustics Corporation. The process is simple, you will be prompted to either call the factory or email the factory to obtain your security activation code, which you will enter to complete the installation process. This is all explained below for the example of a DiSP. Other products such as MISTRAS or SPARTAN will be very similar.

To fully install AEwin, you must perform the following steps, <u>after you have exited all running applications</u>.

1. Run SETUP.EXE from the root directory of the AEwin installation CD disk.
2. Activate the software using one of two methods:
   a) On the last screen of the setup program there is a checkbox for product activation. If this is checked when you press finish it will run the activator program automatically.
   b) To run the activator program manually it can be found at:
      Start Menu-->Programs-->Physical Acoustics-->Activate AEwin for DiSP
3. Install the PCI-DSP4 driver if you are doing acquisition. See below.
4. Install the PAC Audio driver if using an audio board. See below.

Each step in the process is described below.

1.2.1 Installing AEwin from the installation CD:

Insert the AEwin installation CD into your AE System (or PC computer). Using your mouse or keyboard, select:

Start → **Run** → and type or select **D:setup.exe**
(If your CD is other than drive D: enter that letter).

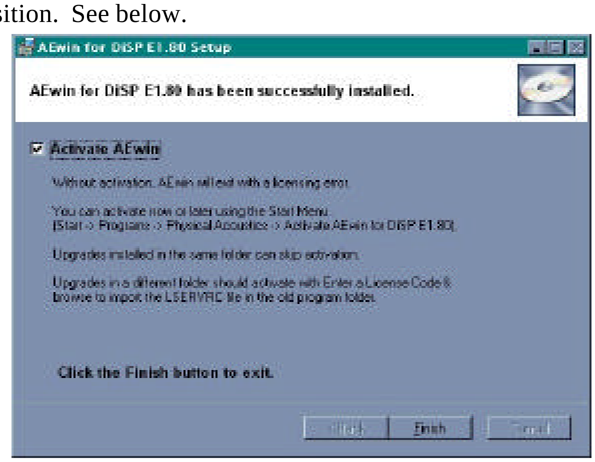


Figure 1. Installation Screen

Upon executing, you will follow a typical Windows installation process. Select all the default directories (highly recommended but not mandatory) if desired. Upon completion, of the installation, you will see the "Setup Complete" window as shown in figure 1. Note the comments and remaining steps that must be carried out. In most instances you will need to Activate AEwin before you can run it. This process can be started automatically by checking the 'Activate AEwin' checkbox before clicking Finish.

1.2.2 Activate the AEwin software using the Start Menu option

To manually activate the AEwin software, you must first select the "Activate AEwin" program. Do this by using your mouse to select the following;

Start → Programs → Physical Acoustics → Activate AEwin

This brings up the AEwin Activation screen as shown in figure 2. Selecting "Continue" will bring up the "Activation method selection" screen, shown in figure 3.

You have several methods in which to Activate AEwin _ "Telephone", "Email" and "Enter a License Code".

If you have a "Hardware Security Key" then much of this process has already been completed for you. A License Code has already been generated for you and is stored as a file ("lservrc") on your "Hardware Security Key" CD. Use the "Enter a License Code" method to activate AEwin.

If you do not have a "Hardware Security Key" then you will need to obtain a license code from PAC customer service. AEwin can be activated in this manner through either the "Telephone" or "Email" methods below.

You can "activate by telephone". If this method is selected, you will see a menu as shown in figure 4 which provides you with a telephone number to Customer Service who will help you and provide you with a License code that you can enter in while on the phone. You can "activate by email".

Upon selecting this choice you will see the screen as shown in figure 5.

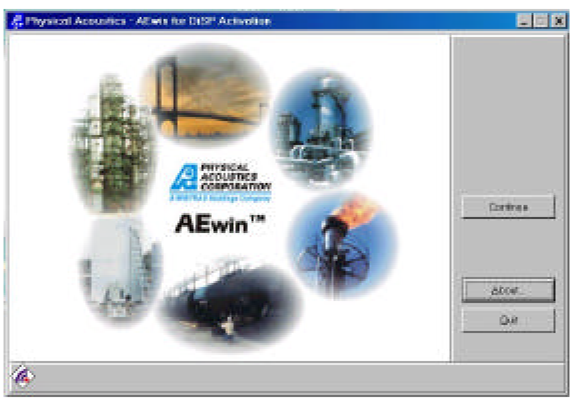


Figure 2. Activation opening screen

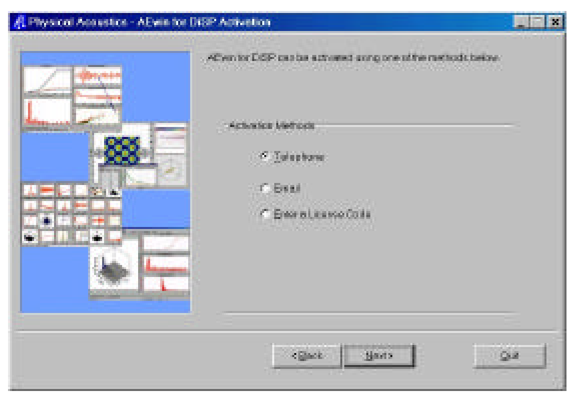


Figure 3. Choose Activation method

Your system will need to be able to access the internet to use this option. If it is internet ready, this is the easiest option to use. Just fill out all the information and press "Send Email". Your activation information will automatically be sent to customerservice@pacndt.com and your license code will be sent back to you as an email attachment.

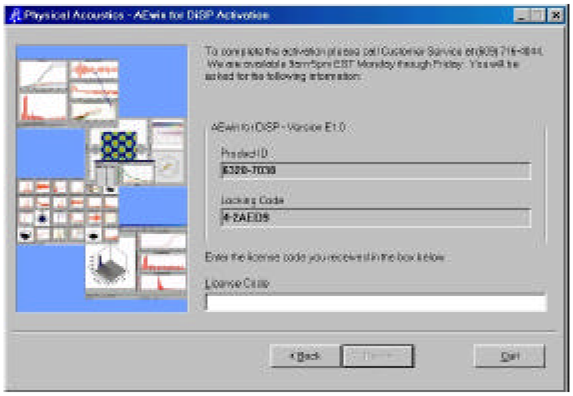


Figure 4. Activation by telephone

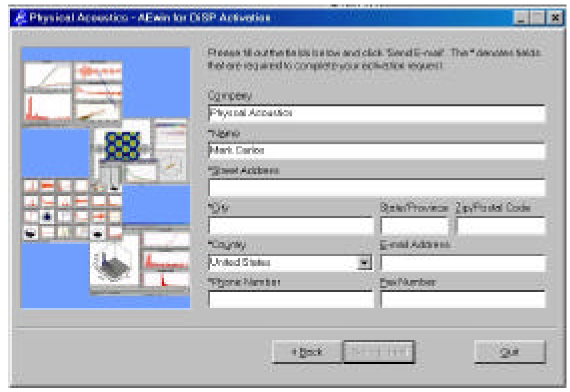


Figure 5. Activation by email

The last way to activate AEwin is by entering a license code. This method is selected once you receive your Email with the License Code or if you have written down the license code and wish to install it. Upon selecting this activation method, you will see the screen as shown in figure 6. This is a little different that that shown in figure 4 as you can either enter a number directly or you can choose the file folder just to the right of the License Code text entry box. Using the file to automatically enter the License Code is preferred to avoid making entry mistakes with the long license code number. Just select the file folder to enter a file. A screen as shown in figure 7 appears in which to select your license code file. Find the license file with the name LSERVRC and select it and the code will be entered automatically.

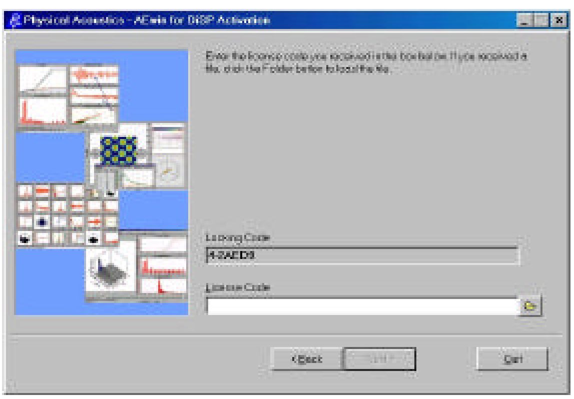


Figure 6. Enter license code screen

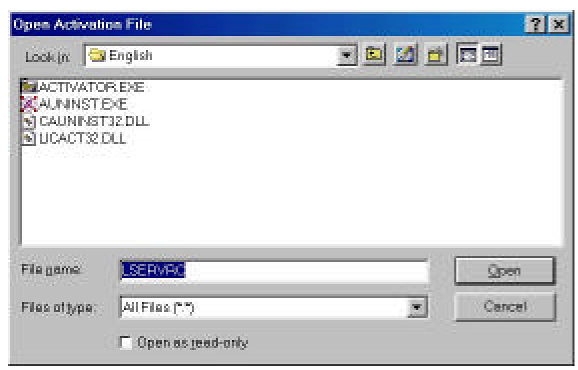


Figure 7. Selecting the LSERVRC license file

Once the License code is entered using any of the above methods, just press NEXT to continue and complete the activation process. This is it. AEwin is now installed.

At this point, your AEwin software is ready to run as a Replay program by selecting;

Start → Programs → Physical Acoustics → AEwin

If you wish to run the AEwin software in acquisition, you need to make sure that your AE board driver board driver and your PAC Audio Board driver have been installed. Please note the instructions below. The example AE board driver installation is provided for the PCI-DSP4, but MISTRAS and SPARTAN drivers will be similar.

1.2.3 Installing the Data Acquisition Board driver if you are doing acquisition

The various PAC Data Acquisition Boards (PCI-DSP4, AEDSP, etc) and Audio Monitor Cards (ISA and PCI) require a driver in order to function properly in Windows.

Normally, when Windows is first booted after installing the card it will prompt for a driver for it. Point Windows to the appropriate driver folder on the CD and follow the instructions.
The driver folders are located on the CD at the following locations:
- **MISTRAS –** Drivers\AEDSP.
- **All other boards** – Drivers\PACPci.

If for some reason you need to install a driver manually then read the document (drivers.doc or readme.txt) found in the appropriate driver folder. Use the procedures described there only if the above automatic driver installation does not work. It is not normally required to install the driver this way. But if problems arise, that is how to do it.

1.2.4 Installing the PAC Audio board driver if using the Audio Board

The Audio Monitor Board (ISA and PCI) require a driver in order to function properly in Windows.

Normally, when Windows is first booted after installing the card it will prompt for a driver for it. Point Windows to the appropriate driver folder on the CD and follow the instructions.
The driver folders are located on the CD at the following locations:
- **ISA Audio Board –** Drivers\IsaAudio.
- **PCI Audio Board –** Drivers\PACPci.

If for some reason you need to install a driver manually then read the document (drivers.doc or readmr.txt) found in the appropriate driver folder. Use the procedures described there only if the above automatic driver installation does not work. It is not normally required to install the driver this way. But if problems arise, that is how to do it.

1.2.5 Warning Notes

Please note the following warnings:

1. If the software is not activated before attempting to run it, the software terminates with a message to contact customer service for the proper activation code.
2. If the software is installed on a computer without AE hardware boards (e.g. PAC PCI-DSP4 boards) installed, the program will run in replay only mode.
3. If the software is installed on a computer with AE hardware (e.g. PCI-DSP4) board(s) installed, it will not run in acquisition mode unless the Windows drivers for those boards are installed.
4. If a PAC audio board is installed in the system, the software will not be able to control it unless its drivers are also installed.
5. If the entire system came from PAC, the drivers and software are pre-installed at the factory.

1.2.6 Installing a Shortcut Icon for AEwin on the Desktop

Once the AEwin software installed as described in the previous sections, and assuming that all the default selections have been selected, the software can be started by the following mouse operated (activated by pressing the left mouse button) sequence;

Start → Programs → Physical Acoustics → AEwin

An AEwin desktop Icon can easily be created by performing the same sequence above except pressing the right mouse button when pointing to AEwin. Upon doing this a menu will appear. You can either select “create shortcut” (which will create a second copy of the AEwin program title) and drag it to the desktop or you can select “Send to”, then select the “desktop (create shortcut)” menu button which will place this extra copy directly on the desktop.

Once created, the Icon title can be modified by left-clicking on the title. Now the program can be run directly by double clicking the AEwin Icon on the desktop.

1.2.7 Upgrading AEwin Software Using the Existing License Code

Here's how to upgrade AEwin without needing to re-activate:

An AEwin license is stored as a file, with filename, “lservrc” in the same folder as the executable (AEwin.exe). It is created during the activation process and is NOT deleted during an uninstall of AEwin. This file will only work on the computer for which it was created.

If you want to upgrade to a new version of AEwin, simply install it in the same folder as the old version (This will overwrite the old version, but will leave any user-created data/layout files unchanged). The license file will remain untouched and you won't have to re-activate. If you need to install to a different folder then you can manually move this file to the new location or run the activator again and reference the indicated file.

2. AEwin LAYOUT (.LAY) FILES AND DATA (.DTA) FILES

This section discusses the various file types associated with AEwin. The most important files you will be working with everyday with AEwin are the Setup Files (called Layout files in AEwin) and the Data files. Your working copy of AEwin will have examples of both these layout files and test data files. You will be creating, using and modifying these files in the course of your work.

The initialization or setup files, referred to as “Layout” files, distinguished by the suffix .LAY, hold all AE test setup information for the AEwin software. A .LAY file stores the hardware setup, graph setup, acquisition setup, filters, alarms and location setup. Other program settings, such as graph item colors and various preferences are stored in the Windows registry.

A .LAY file can be loaded from disk by means of the “Open Layout” option in the “File” Menu of the AEwin program. Once loaded, all the initialization information from the layout file immediately becomes effective for system operation. A .LAY file is written to disk by means of the “Save Layout” or “Save Layout As” option in the File Setup menu. All the initialization information currently established in the system is written to the file. A .LAY file can have any name followed by the .LAY extension.

There is one special .LAY file known as the Autoload file. It is distinguished by the special name Layout.LAY. The Autoload file, when present, is automatically read from disk when the AEwin program begins to run. If the Autoload file is not present, the system is set up with default values held in the AEwin program itself. The Autoload file is a convenience feature to speed your work.

AE Test Data Files are identified by the filename extension .DTA. You may specify any name for a data file using standard Windows file naming conventions. This is done in the Start acquisition dialog box from the Acquire Menu. If a new name is not entered, the system will use the default data file name e.g. TEST0000.DTA for the first data written after bootup. The next file will be TEST0001.DTA, then TEST0002.DTA, and so on. It is convenient to use numbers at the end of the filenames (e.g. ABCD000.DTA) as the system will then increment the numbers to help keep the files in order and organized.

Layout and data files may be written to any disk drive and any specified subdirectory. A good practice is to save both .LAY files and .DTA files to the same drive and subdirectory, keeping related test files together. It is also a good practice to name the files very similar (e.g. test.LAY and test0000.DTA) as this will help keep the layout files organized with the data files.

There has been an intentional name and file-extension change from the “Initialization” (.INI) file of the “Legacy” (DOS) based PAC programs to the “Layout” (.LAY) file for setup files utilized by AEwin. The file extension for a data (.DTA) file remains consistent. There is a good reason for this. Due to the extensive changes in migrating to Windows, and the many, many extra capabilities that have been added to the setting up of the system, it is impossible to keep consistency in the setup files between the previous legacy software and the AEwin software. Therefore, to avoid confusion, the extension file name has been changed. Now whenever a user sees an INI file, they will know that this can only be used with the previous legacy software, while the .LAY layout file can only be used with the AEwin software.

However, with the DTA file, the compatibility remains between the data file structure and AE .DTA data files can be read and displayed by either the DOS or the AEwin software.

3. OPERATING AEwin

The purpose of this section is to provide a quick software operational run-through, to provide a familiarization with operating and using AEwin. This is the most important part of this AEwin software user's manual as it will provide a view of the important screens and commands necessary to get AEwin setup, and running in both Replay and Acquisition modes.

3.1 Starting AEwin

The first step in the process of using AEwin is booting up the program on your AE system. As the AEwin program is a standard Windows program, it is started in the same way as any other WINDOWS program. This is accomplished either by using the "Start" command or by selecting the AEwin Icon from the WINDOWS desktop.

It is assumed that the AE computer is booted up and in its opening screen which is the desktop layout showing all the available program icons to select. If the PAC AEwin icon (as shown on the right) is on the desktop, all you need to do is select this by double clicking the left mouse button, once the mouse is positioned over the icon. If the icon is not on the desktop you can create the shortcut by referring to section 1.2.6.

Alternatively you can start AEwin by selecting the following sequence starting with the Start menu at the bottom left side of the screen:

Start → Programs → Physical Acoustics → AEwin

The boot-up sequence for AEwin starts by loading the executable program AEwin.exe. Once AEwin is loaded, the program searches the startup "AE Data" subdirectory for the default Layout (setup file) called "Layout.LAY". Upon finding this file, AEwin loads it and becomes fully configured and ready to run in accordance with the setup information in that default Layout.LAY file. If no Layout.LAY is found, AEwin chooses a common default starting setup that is ready for use. In either case an AEwin startup screen similar to figure 8 will appear.

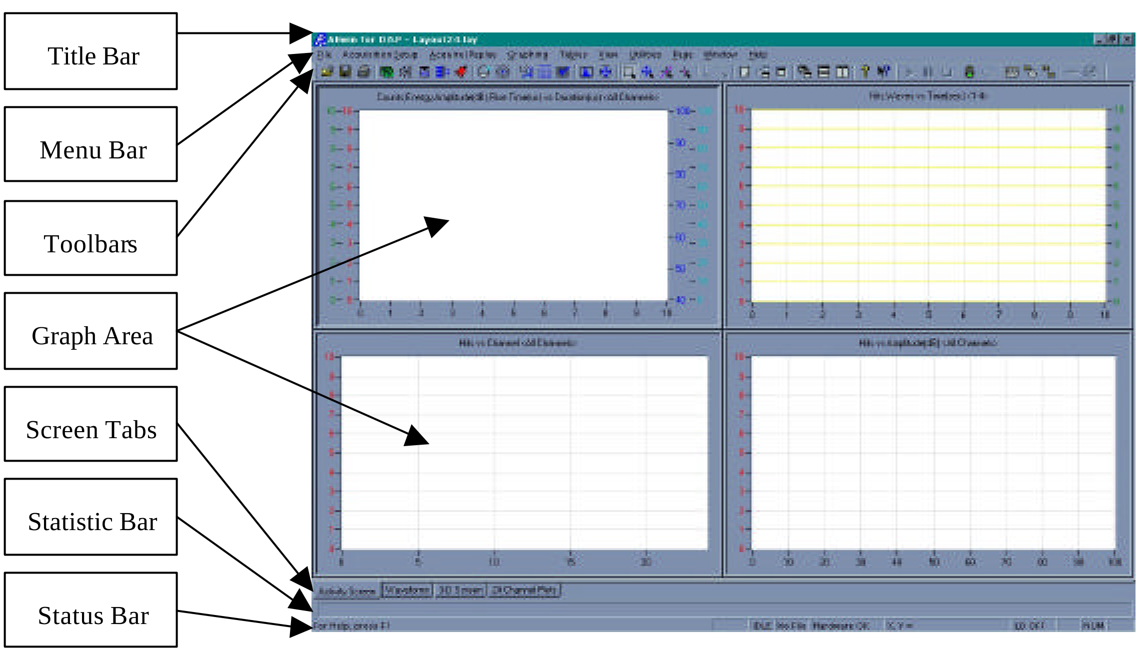


Figure 8. AEwin Opening Screen

3.2 AEwin Screen Layout Familiarization

Figure 8 shows a typical 4-screen layout for AEwin. Above and below the graph area are various informational, status and setup toolbars. Each bar is labeled with a name. Depending on the preferences selected for your program, you may have other toolbars or be missing some. The “View” menu in the main menu bar area, controls which bars are on or off. The following is a short description of each area identified on the AEwin screen. This section will get you familiar with the layout and the overall function. Further chapters will provide detailed insight into the use of each of these functions.

Title Bar: This is a typical WINDOWS Title Bar with all the standard capabilities. At the leftmost position is the Physical Acoustics Logo (PAC Logo) Icon from which you can manage the AEwin program with functions such as minimize, restore, maximize, move, size or Close the program altogether. At the far right are the application buttons for Minimize, Restore and Close. Back on the right hand side next to the PAC Logo Icon is the program name (in this case it is AEwin for DiSP) and next to that is the name of the current layout file being used by the program. If an asterisk (*) appears next to the file name, it indicates that one or more settings have been changed since the last time the layout file was loaded or saved.

Main Menu Bar: The main menu bar provides a series of text commands running across the line, including: File, Acquisition Setup, Acquire/Replay, Graphing, Tables, View, Utilities, Page, Window, and Help. Most of these items contain pull-down sub-menus of their own, many of which in turn contain graphical dialog boxes and prompts of their own. You narrow down the range of choices until you arrive at the specific choice you want.

To display a pull-down sub-menu from a main menu entry, simply move the mouse pointer to the name of the menu item on the menu bar and click the left mouse button. This process is known as “clicking” (or “left-clicking”) on an item, and will herein be referred to as such. To use the keyboard, simultaneously press the ALT key and the underlined letter of the menu item name at the same time. Once you have opened a pull-down menu item from the main menu, you can use the left and right arrow keys to move through each entry, allowing you to see the pull-down menu for each main menu entry. You can also use the up and down arrow keys to move through each selection of the pull-down menu. To select an item from a pull-down sub-menu, click on the desired action, or use the up and down arrow keys to select an action, and then press ENTER. Pressing the underlined letter of a menu item will also select that item. If an item in the pull-down menu appears “grayed out,” this action is not available in the current software or at the current time. Use the <ESC> key to remove the pull-down menu display.

Most of the selections in the pull-down sub-menus will display a dialog box requesting information necessary to carry out the command you requested. A dialog box contains areas where you enter information, select options or commands, or activate controls to execute or cancel a command. There are several types of boxes and buttons available within a dialog box. These boxes and buttons are described briefly below and will be described in further detail in subsequent sections of this manual. It is important that you be familiar with dialog boxes and be comfortable using them, for they are the means by which most functions are carried out in the AEwin software.

Icon Toolbars: Many of the menu items accessible from the Main pull-down menus can also be accessed by use of the Icon Toolbar and Acquisition Control Toolbar just below it. Figure 9 shows the Icon toolbars.

Figure 9. Icon Toolbars

To determine the function of any of the Icon’s simply move the mouse cursor over top of the desired icon. Upon resting there for approximately 1 second the Icon’s function will appear. To select an icon as a shortcut command simply click on it with the left mouse button.

Graph Area: The graph area is the most important area of the screen. This is where the AE information in the form of graphs and line listings appear regarding the AE examination status. The graph area can be set up in many ways with a minimum of 1 graph to a maximum only limited by the graph visibility. More about the graph setup, functionality and flexibility will be discussed later in the Graph setup menu.

Screen Page Tabs: AEwin can show many different graph screens, these are called screen or graph "Pages". Accessibility to viewing any screen is provided via the Page tabs located just below the graph area. The Page tabs can be named to be synonymous with the graph theme as shown in figure 8 with the 4 Page tab names, Activity Screen, Waveform Screen, 3D Screen and 24 channel plots. Using the right mouse button and clicking on a page will display a 'context' menu from which pages can be added, inserted, deleted or renamed. The context menu is also a quick way to add new graphs and close existing graphs.

Statistics Bar: This toolbar area is reserved for display of test statistics. Test statistics allow the user to view key Acoustic emission test indicators including: Cumulative AE counts, Total AE Hits, Total AE Events, Total # Waveforms, Cumulative Counts, Cumulative Energy, Time of Test, Disk Free Space, Parametrics and others. These are very useful activity indicators during a test and very useful summary statistics after a test. The user can select any or all of these to customize his statistics display bar.

Status Bar: The Status bar provides useful information regarding AEwin and test status. On the left is a Text bar providing status and help information regarding the functions being carried out. Near the center is a status bar. In figure 8 the word "Idle" appears in this bar. Other status information such as "Test Paused", "Replay", "Test Stopped" "Test Active", "Abort Test", etc. are displayed in this text field. Next to the Test status field is a filename field informing the user the name of the file being replayed or the name under which an AE test is being saved. Next to that is a system diagnostics text field. In figure 8, this status is "Hardware OK". Next to that is a cursor position, showing the current location of the Cursor on the graph. When selected, the X, Y position will be read out in actual screen units.

3.3 Navigating the AEwin Menus

This section provides a detailed reference of AEwin's major menu items and dialog boxes. The first time through, we suggest you just look at the menus (to get familiar with them) and use the setups provided with your AEwin installation, that have been predefined by PAC; later, you can make your own choices within the menus to control system operation.

From the Opening Screen (Figure 8), pay attention to the Main Menu Bar near the top of the screen. This specific area is shown again below. Each main menu item will be described. This brief introduction to navigating the menu's is provided in order to get ready for guiding the user in the sequence of starting and replaying a test.

Figure 10. Main menus and toolbars

3.3.1 File Menu

3.3.1.1 New Layout

The 'New Layout' menu item is used to remove all graphs and pages and restore the graph layout to a default setting of one page and one simple graph. This command does not alter any other settings.

3.3.1.2 Open Layout…

The 'Open Layout…' menu item is used to load a specified layout file's setup information into AEwin.

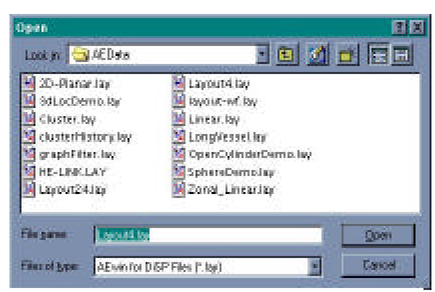


Figure 11. Open Layout…

3.3.1.3 Save Layout/Save Layout As…

The 'Save Layout…' and 'Save Layout As…' menu items are used to save the setup information in AEwin to a specified layout file. When the 'Save Layout As…' item is clicked the 'Save As' dialog is displayed. Here you can enter a new layout filename to create or an existing one to overwrite. Once this is done you will see the layout filename you entered on the upper left corner of the screen. You can use 'Save Layout…' from then on to update the file with any changes you have made since you have last saved.

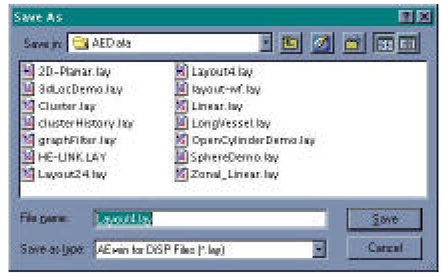


Figure 12. Save Layout…

3.3.1.4 Specify Data Folder…

The 'Specify Data Folder…' menu item opens a dialog box of the same name. It is used to select the default folders for storage of Data and Layout files. These are the folders that are displayed by default in the various Open/Save Layout and Acquire/Replay dialog boxes. The 'Layout File Folder' is also where AEwin looks for the autoload 'Layout.lay' file on startup. By default these are both set to the AEData folder found in the installation folder of AEwin.

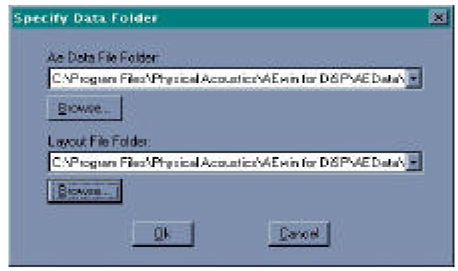


Figure 13. Specify Data Folder

3.3.1.5 Print Page(s)/Print Graph…

The 'Print Page(s)…' and 'Print Graph…' menu items are used to print a graph or multiple pages of graphs. 'Print Graph…' is used to send the currently selected graph to the printer, zoomed as much as possible while still retaining aspect ratio. 'Print Page(s)…' is used to send a selection of pages to the printer one page at a time, each page zoomed as much as possible while still retaining aspect ratio. You can select 'All pages' or a range of pages.

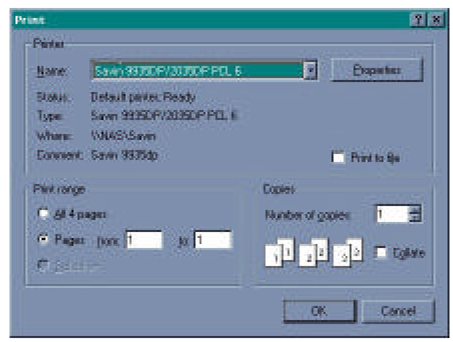


Figure 14. Print…

3.3.1.6 Export to JPG…

'Export to JPG…' is used to save pages as JPEG files in the same way that 'Print Page(s)…' sends pages to the printer. Here you enter a base filename and a destination folder. Each page will be saved as a separate JPEG file with it's name formed from the combination of the base name and the page's title. e.g. If you had 2 pages named 'waveforms' and 'activity' and you set the base name to be 'TEST' then the two files will be named 'TESTwaveform.JPG' and 'TESTactivity.JPG'.

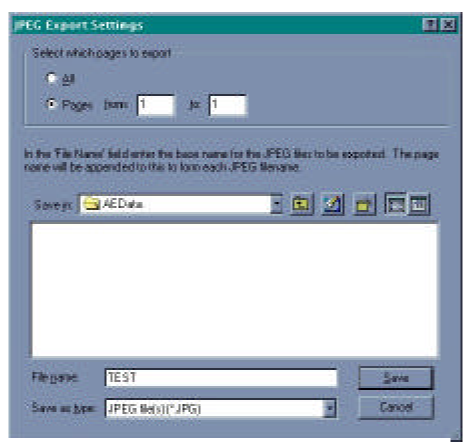


Figure 15. Export to JPG

3.3.1.7 Copy Screen to Clipboard

'Copy Screen to Clipboard' is used to save an image of the entire screen to the clipboard. This image can then be pasted in other applications such as word processors and image editors.

3.3.1.8 Exit

'Exit' is used to terminate the AEwin program. If you have made any unsaved changes to your current layout AEwin will prompt you to save your layout first, exit without saving or cancel.

3.3.2 Acquisition Setup Menu

3.3.2.1 Hardware…

This is the dialog box where all hardware settings are selected before the test. There are a number of property pages that each deal with a different part of hardware setup. Each is described below. Note that there are some differences in this dialog box between products. For instance 'AEwin for Spartan' has a Gain setting but no Waveform Setup whereas 'AEwin for DiSP' has no Gain setting but can have Waveform Setup if the Waveform option has been installed. Features specific to one or more types of hardware are noted by the names of the applicable hardware types. These types are briefly described below.

Name	Description	Waveforms
ICC	2 Channel card for **Spartan** systems. *	Not Available
DSP4	4 Channel card for **Spartan** systems. *	Not Available
AEDSP	2 Channel card for **Mistras** systems.	Standard
PCI-DSP4	4 Channel card for **DiSP** systems.	Optional
SAMOS	8 Channel card for **SAMOS** systems.	Standard
PCI-2	2 Channel card for **PCI-2** systems.	Standard

* ICC and DSP4 cards can be used simultaneously in the same system.

3.3.2.1.1 Standard Channel Setup

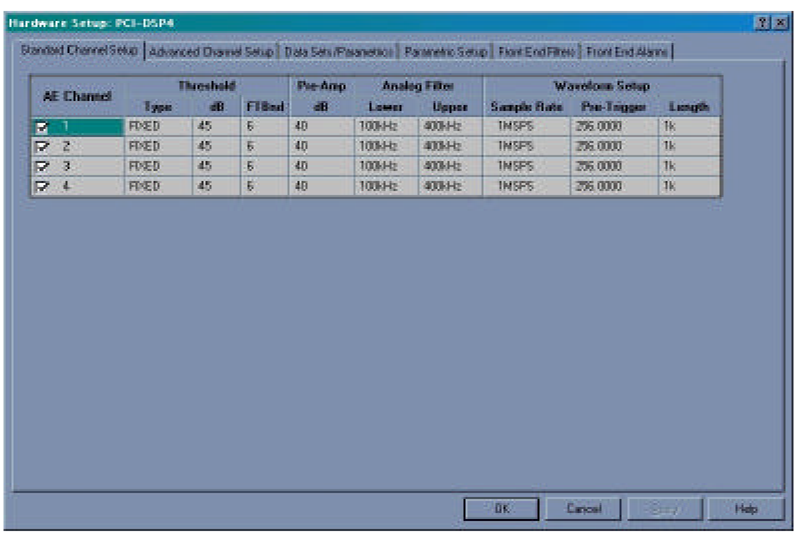


Figure 16. Standard Channel Setup

In the ‘Standard Channel Setup’ page you can enable or disable each channel and edit their common settings. If your system has the waveform option installed you can also edit each channel’s waveform settings.

AE Channel – You can enable a channel by clicking its checkbox.
Threshold – ‘Fixed’ threshold is used when you want the threshold to remain unchanged at the ‘dB’ level you set (in the dB column). ‘Floating’ threshold is used under conditions of high, varying background noise. When floating threshold is selected, the value shown in the ‘dB’ column represents the threshold level at the start of the acquisition, the threshold will vary to 6dB (or FTBnd value on systems that have this column) above the current ASL reading for that channel. The threshold will not go below the initial value specified in the ‘dB’ column. Threshold is the prime variable that controls channel sensitivity.
Gain (dB) [ICC/DSP4, SAMOS, PCI-2] – Enter the hardware gain here.
Pre-Amp (dB) – Enter the pre-amp gain of your sensor’s pre-amplifier here.
Analog Filter [not available for ICC] – The Lower and Upper drop-down list boxes allow you to select from the available analog filter values for low pass and high pass filters on each active channel. This is done by simply selecting the desired value from the drop down list boxes. Note that if waveform analysis is desired, these values should be kept below ½ of the Sample Rate. Make sure to raise your Sample Rate if this becomes an issue.
Sample Rate [only with waveform option] – This is the rate at which the data acquisition board samples waveforms on a per second basis. A sample rate of 1 MSPS (Mega Samples Per Second) means that one waveform sample is taken every µsec. A sample rate of 2 MSPS means that one waveform sample is taken every ½ µsec., etc. The sample rate can be selected by clicking on the down arrow on the drop down list box, then clicking the mouse on the desired sample rate.
Pre-Trigger [only with waveform option] – This value tells the software how long to record (in µsec.) before the trigger point (the point at which the threshold is exceeded). The user may enter a value in µsec in the pre-trigger edit box. The minimum allowable pre-trigger value is zero. The maximum allowable pre-trigger value is calculated by dividing the hit length by the sample rate in MHz. If, for example, the hit length was 1 k (1 k = 1024) and the sample rate was 4 MHz, then the maximum allowable pre-trigger value would be 1024/4 = 256 µsec.
Hit Length [only with waveform option] – This determines the size of a waveform message. Clicking the down arrow on the drop-down list box for Hit Length will display a list of allowable hit lengths from 1 k to 15 k. At a 4 MSPS sampling rate, a hit length of 1 k will allow up to 256 µsec. of data, a hit length of 2 k will allow 512 µsec of data (2 * 256), and so on.

3.3.2.1.2 Advanced Channel Setup

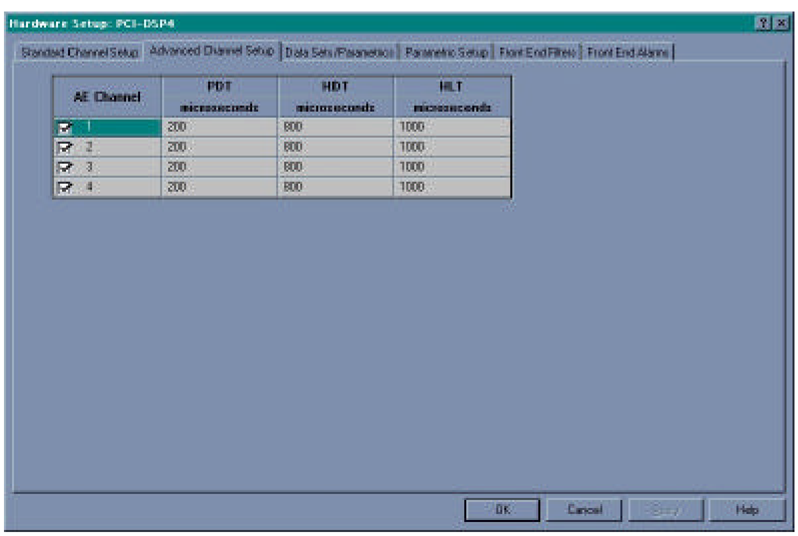


Figure 17. Advanced Channel Setup

In the ‘Advanced Channel Setup’ page you can enable or disable each channel and edit Peak Definition Time (PDT), Hit Definition Time (HDT), and Hit Lockout Time (HLT).

PDT, HDT and HLT are timing parameters of the signal measurement process. Their function is discussed in full in Appendix 4. In brief, a proper setting of the PDT ensures correct identification of the signal peak for risetime and peak amplitude measurements. Proper setting of the HDT ensures that each AE signal from the structure is reported as one and only one hit. With proper setting of the HLT, spurious measurements during the signal decay are avoided and data acquisition speed can be increased. Recommended values for general-purpose testing are:

	PDT	HDT	HLT
Composites, Non-Metals	20-50	100-200	300
Small Metal Specimens	300	600	1000
Metal Structures (high damping)	300	600	1000
Metal Structures (low damping)	1000	2000	20000

3.3.2.1.3 Data Sets/Parametrics

AEwin features user-selectable data sets. This means that if you do not plan to use all the measurable AE parameters, you can leave some out and enjoy the compensating advantages of higher data throughput speed and more economical use of storage space. Selecting Data Sets/Parametrics from the Hardware Setup dialog box displays the Data Sets/Parametrics page that follows.

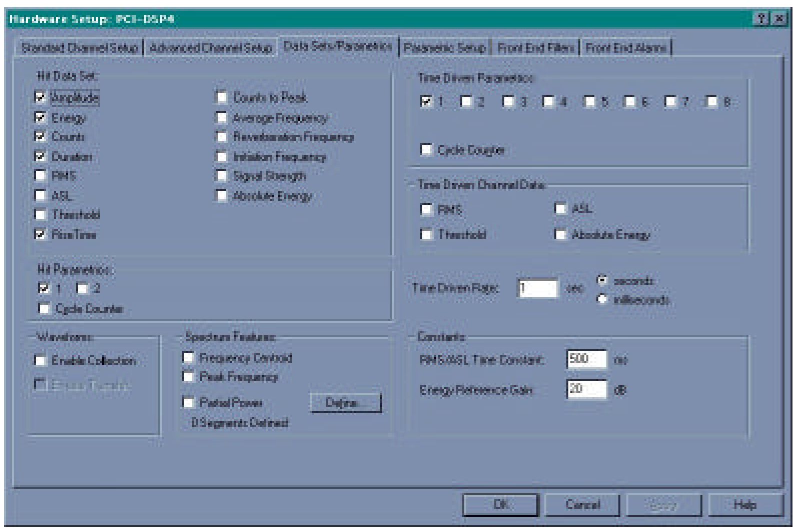


Figure 18. Data Sets/Parametrics

Note that the above figure is specific to the DiSP product. Your product may have more/fewer options available.

Hit Data Set
This box allows you to select which measured parameters are to be included in the description of each AE hit. The parameters to be included are so marked with a check in the checkbox next to the parameter. Parameters can be included/excluded from the data set by selecting or deselecting the checkbox next to the parameter. "Time of test" is not shown because it is always included in the data set.

Hit Parametrics
This box allows you to select which parametric inputs are to be included in the description of each hit. A maximum of two parametric inputs (e.g., external load signals), or one parametric input plus the cycle counter, can be included in the Hit data set. These items, however, must also be included in the Time Driven Data Set, otherwise an error message will appear.

Waveforms
This box is available if you have the waveform option installed.

Enable Collection – This checkbox is used to signal the data acquisition board(s) to acquire waveforms. If this checkbox is unchecked then the board(s) will not be able to collect waveforms for the duration of the test.

Enable Transfer – This checkbox is used to signal the data acquisition board(s) to transfer collected waveforms to the software for processing/display and (if auto-dump is enabled) saving to a data file. If this checkbox is unchecked then the waveforms will not be visible to the user and won't be saved in a data file until the checkbox is turned on. Unlike Enable Collection this checkbox can be toggled on/off at any time during a test. When Enable Transfer is OFF the system can experience a boost in performance especially at high data rates if you are saving to a data file. Turning Enable Collection OFF can grant a greater performance boost at very high data rates as the system concentrates on hit-based data.

Spectrum Features

This box is available if you have the waveform option installed. Spectrum Features are derived from the power spectrum of the waveform associated with a hit:

1) Frequency centroid - the center of mass of the power spectrum graph.
2) Peak frequency - the point where the power spectrum is greatest.
3) Partial Powers - see 'Partial Power Features' below.

You must check Enable Collection in the Waveforms box for these features to be usable. Transfer of waveforms can still be set off so that the system can record spectrum features without recording waveforms.

Partial Power – Partial Power is a feature which is derived from the power spectrum of the waveform associated with a hit. It is a percentage and is calculated by summing the power spectrum in a specified range of frequencies (up to four of these ranges can be specified), dividing it by the total power in another range of frequencies, and multiplying the result by 100.

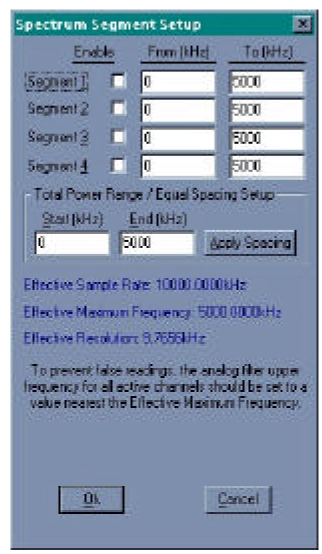


Figure 19. Spectrum Segment Setup

To use partial power you must

1) Check the partial power checkbox.
2) Define at least one partial power segment. To do this press 'Define'. This brings up the Spectrum Segment Setup dialog box described below.

Spectrum Segment Setup is used to define the partial power features. For each of the 4 definable segments the dialog box has a checkbox to enable the segment, an edit box for defining the start frequency and an edit box for defining the ending frequency.

The group box titled 'Total Power Range/Equal Spacing Setup' contains two edit boxes. These edit boxes serve a dual purpose. The main reason for them is to define a range of frequencies over which the power spectrum will be summed.

The result of the summation is used in the calculation of total power for the partial powers calculation. Their other purpose is to allow the user to spread the frequency range evenly among the enabled segments. The spacing will occur when the user presses the 'Apply Spacing' button which is located to the right of the edit boxes.

CAUTION: If the edit boxes are used to set up equal spacing, always make sure the edit boxes contain the Total Power range values when the dialog box 'OK' button is pressed. Otherwise the partial powers will be based on the equal spacing range.

The dialog box also displays information based on the sample rate and hit length of the first active AE channel:

1) Effective Sample Rate – The sample rate of the decimated waveform (the FFT calculation is always for 1k of samples). For a 1k hit length the effective sample rate is the same as the hardware sample rate. For a 2k hit length it would be half the hardware sample rate. Etc.
2) Effective Maximum Frequency – This is one half that of the Effective Sample Rate and is the maximum frequency which can be defined for any segment.

3) Effective Resolution - This is the Effective Maximum Frequency / 512 and is equivalent to the frequency range of a single FFT bin.

The system does not automatically set the input filters based on the sample rate to reduce aliasing, so the dialog box will remind the user to set the input filter to a value closest to the Effective Maximum Frequency.

The Spectrum Segments are global for all active channels, if the sample rate and/or hit length is not the same for all active channels a warning will be displayed to alert the user.

Time Driven Parametrics and **Time Driven Channel Data**

Additional to the hit descriptions, AEwin allows the recording of RMS, ASL, Threshold, Absolute Energy, Cycle Counter and Parametric inputs, at regular time intervals even in the absence of AE activity. These are called Time Driven messages. This box allows you to select a set of features for them.

Time Driven Rate – This controls the frequency of the readings and the data to be included in the records. Time driven data is useful for leak monitoring and for recording changes in load and background noise levels. Also, time driven data can be used for updating hit data graphs, involving parametric values or time, even when no hits are coming in. The interval you set must lie in the range 10 msec to 1,800 sec and must be a multiple of 10 msec. Typical values are in the range 1000-60,000 msec (1–60 seconds). For frequent parametric value updates, you may like to choose a short interval, but this leads to lengthy disk files and data listings, so it is not necessarily the best choice. When the time driven data set is used to update graphs, it is a good idea to set the rate less than or equal to the 'Seconds Between Updates' field selected in the Display Mode dialog box.

Constants

RMS/ASL Time Constant [not in DSP4/ICC] – The time constant can be set from 10ms to 1000ms in steps of 10ms. Previous versions of the program had a fixed time constant of 500ms.

Energy Reference Gain [PCI-DSP4 and AEDSP only] – In some PAC instruments, such as SPARTAN, Energy is a gain dependent quantity. However, some systems (like DiSP and MISTRAS) don't have a gain setting so the Energy was designed to give a reading as if 20dB of gain were applied. The Energy Reference Gain allows you to match the value of Energy reported by system to that of a SPARTAN-2000 or other PAC instrument which has programmable gain. The value of the Energy Reference Gain has a valid range of 0 to 60 dB.

3.3.2.1.4 Parametric Setup

The Parametric Setup page allows you to scale the voltages measured at the parametric input, such that the system displays the corresponding load or pressure values. This page also allows you to tell the system what units (kN, psi) you want displayed on your graph axis and printouts, and it allows you to select from four available filters on gain.

The Parametric Scaling process used by AEwin is:

Displayed Value = (Measured Voltage x Multiplier) + Offset

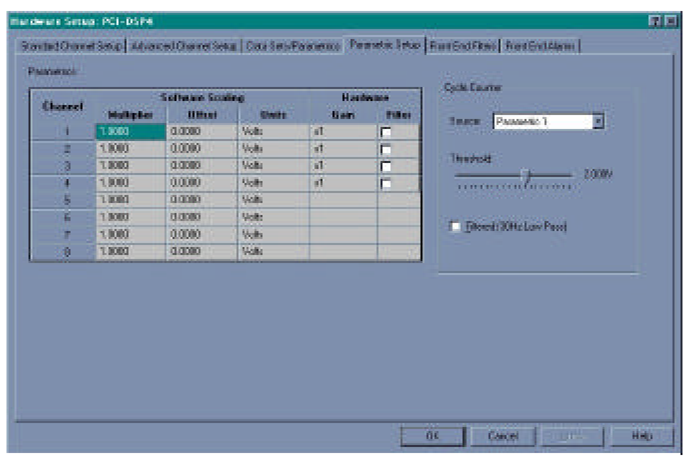


Figure 20. Parametric Setup

The default values set up in the delivered Autoload file are 1.00, 0.00 and "Volts" so that the system will display the raw voltage delivered to the Parametric Input socket on the rear panel.

To scale the output of a linear load-measuring transducer, the easiest way to find the correct Multiplier and Offset is to go into a simulated test and turn on the Line Listing Display (F7). From the display read the parametric voltages for two widely separated loads. Suppose these readings are V1 at load L1, and V2 at load L2. The correct values for Multiplier and Offset are then:

Multiplier = (L1 - L2) / (V1 -V2)
Offset = (V1*L2 - V2*L1) / (V1 - V2) = L1 - Multiplier * V1

Once you click OK to exit this dialog the scaled values of the parametric input will now appear on all graph displays and data listings. Minimum and maximum values for graph axes should be specified in the scaled values, and the entered unit will appear on the graph (e.g., 0–1000 psi). The raw data on disk will contain the original voltage readings and the scaling will be done again each time the file is replayed.

The Hardware section allows you to select from one of four available values for a hardware gain filter. Most cards (all except ICC) contain a programmable amplifier as well as a 30 Hz Low Pass filter for better resolution and less noise in the data collection process.

The **Cycle Counter** section allows you to control the source and threshold of the cycle counter [PCI DSP-4, AEDSP only].

- The Source can be selected as parametric 1-4 (on most data acquisition boards).
- The Threshold slide control allows you to set the threshold for the cycle counter. The cycle counter counts every time a signal crosses the threshold. The threshold can be set within a -10.00 volts to +10.00 volts range. This voltage should be set based on the load signal coming into the system. It should be set low enough to assure constant, accurate triggers.
- The Filtered checkbox allows you to enable an independent 30 Hz low pass filter on cycle counter.

3.3.2.1.5 Front End Filters

Selecting this action allows you to set up the "front end filters." These filters apply accept/reject criteria to the hit descriptions as the data is processed in the data acquisition board, so that rejected hits or waves do not even reach the main processor board.

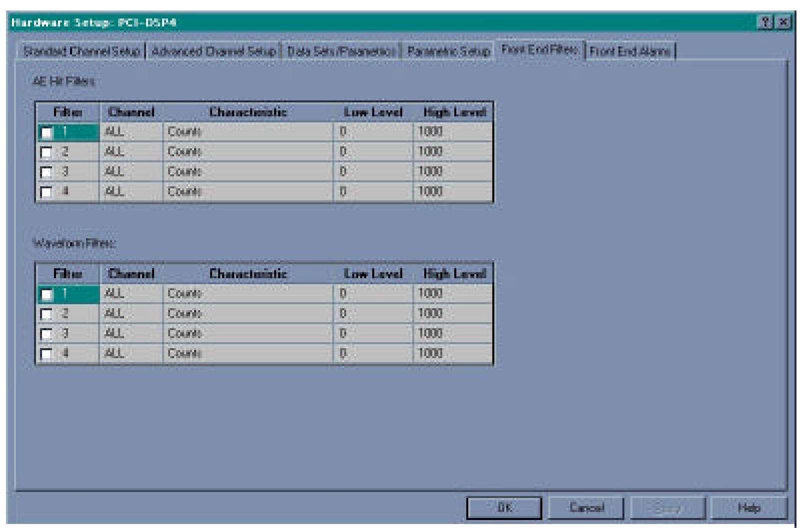


Figure 21. Front End Filters

There are two kinds of front-end filters: **AE Hit Filters** reject hits and any waveforms associated with them based on the criteria you set. **Waveform filters** work the same way but reject only the waveforms, allowing the hits to remain. The setup is identical for both.

There are four filters available at the present time. All four filters will always be displayed. To activate a particular filter simply check the 'Filter' checkbox associated with the filter you want to use.

Use the Channel drop-down list box to select which channel (or all channels) to filter on.

Use the Characteristic drop-down list box to select an AE Characteristic to filter on. Each hit will be individually screened to see whether the measured value of the specified characteristic falls in the acceptance range from LOW LEVEL to HIGH LEVEL, inclusive. For the message(s) (hit and/or wave) to be accepted, the hit must fall in the acceptance range for all active filters affecting that channel. Change the filter LOW and HIGH levels by entering new values in the text boxes. If a hit is not within the acceptance range, the message(s) will be eliminated from the front end signal processing.

3.3.2.1.6 Front End Alarms

There are four alarms defined in the alarms page. This page is almost identical to the front-end filter page with the exception that the user may select the type of alarm to be Single Channel Single Hit or Single Channel Cumulative. An alarm is generated if one or more of the alarm criteria is exceeded. Upon alarm, the PC computer speaker will sound, and an alarm output on the I/O connector will indicate an alarm. In addition, an alarm popup box will appear on the screen indicating if the alarm is a warning or a trigger, which alarm was exceeded and the value that triggered the alarm. To reset the alarm click the 'Clear All Alarms' button on the alarm popup box. See section 3.3.3.6 entitled 'Display Last Alarm' for more information.

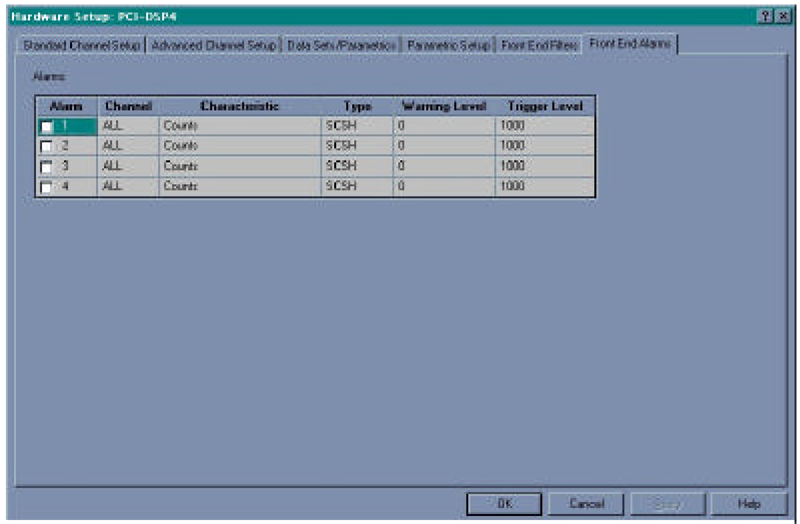


Figure 22. Front End Alarms

3.3.2.1.7 DeltaT Front End Filters (MISTRAS only)

MISTRAS Delta-T Front End Filters are used to eliminate "on board" AE hits which are part of the same event but outside the acceptance range selected in the DeltaT Filters Setup page.

A DeltaT Filter is located within each MISTRAS (AEDSP) board, so that this filter can only eliminate "on board" AE hits. This type of filter is very useful for cases where linear location is used. It will successfully filter hits that come from the outer areas of the sensors and beyond. Delta-T Front end Filters are very useful in 2 channel MISTRAS systems.

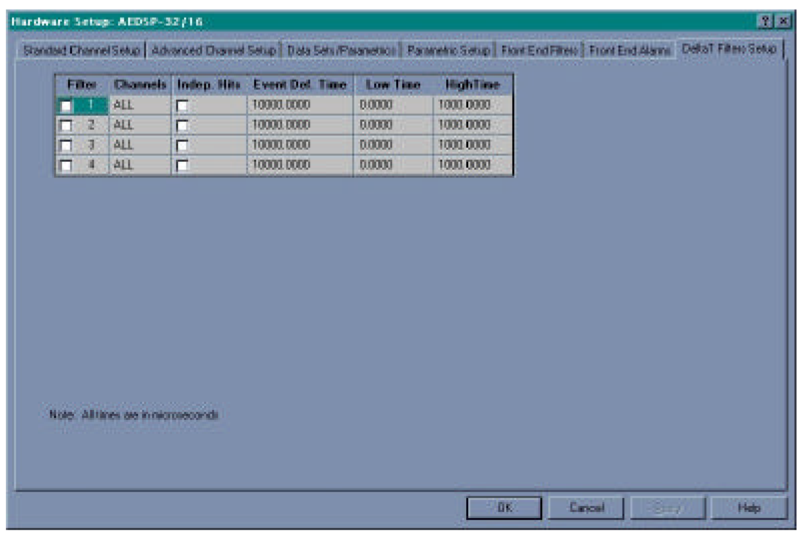


Figure 23. DeltaT Front End Filters

In cases where more than two channels are needed (such as planar location) a front end filter cannot be used since the hit information is not available from other MISTRAS boards. For this situation a "high end" filter is needed and Graph Filters can be used for this purpose. See the section on Graph Filters for more information.

The DeltaT Filters page is very similar to the Front-End Filters page discussed previously. Four different filters are available to allow programming of each board differently. Alternatively, the first filter can be chosen as an "ALL," which will have all boards filter using the same set-up parameters.

Each menu item and its function is discussed below.

Filter: This toggles between On and Off just like the Front End Filter page does.

Channel: This selects the MISTRAS channel numbers for the DeltaT filter. Because the DeltaT Filters operate on a per board basis, *pairs* of channels must be selected (e.g., 1-2, 3-4...) or ALL channels may be selected.

Indep. Hits: Allows independent hits (those hits not associated with an Event) to be accepted or rejected for transmission to the high-end, at the discretion of the user.

Event Def. Time: This is the maximum event time (in µsec) required in order for the AEDSP-32/16 to identify paired hits on the board as events. This should be set at the maximum time expected for an AE signal to propagate from the first to the second sensor plus 10% over range.

Low Time: This is the lower limit of acceptable Delta-T values in µsec. Below this is not an acceptable difference and the hits will be discarded. Negative numbers can be used. For delta-T filters, a hit occurring closer to the even channel is assigned a negative delta-T.

High Time: This is the higher limit of acceptable Delta-T values in µsec. Above this is not an acceptable difference and the hits will be discarded. As above, negative numbers indicate that the hit occurred closer to the even channel

The information set up in the DeltaT Filter page is downloaded into each specified AEDSP board with the rest of the set-up information. Upon acquisition, each AEDSP board has software event detection and filter routines implemented as follows:

As hits are received from both channels, the board has an event detection queue whereby it checks hit pairs (hits on opposite channels) against the Event Definition Time to determine if it is an event. To provide for asymmetric acceptance ranges between two sensors, the delta-T is always calculated from the lower numbered sensor to the higher numbered sensor. Hits whose delta-Ts are longer than the Event Definition time are considered independent hits. In this case, the first hit will pass to the high end as an independent hit.

In those cases where an event is detected (hits that have a delta-T within the Event Definition Time) its Delta-T is checked against the high and low levels for that board. If the Delta-T is outside of the range set in the "Low Level" and "High Level" fields (less than the Low Level and higher than the High Level), then both hits will be rejected and neither hit nor waveform data will be passed to the high end. If the Delta-T is within the "Low Level" and "High Level" values then the hits (and waveforms) are allowed to pass to the high end.

Delta-T filters are activated independently of any location processing. This allows use of Delta-T filters in tests with extremely high data rates, whereby the data is stored and analyzed later with the slower location algorithm.

3.3.2.1.8 PCI-2 Waveform Streaming (PCI-2 Only)

3.3.2.1.8.1 Background

The PCI-2 AE System on a Card is capable of streaming waveform data continuously into physical memory on the PC. It uses an onboard DMA controller to read samples from each channel's 4K FIFO and transfers them into a circular buffer in the computer's memory. When a stream to disk event is detected (this being a threshold crossing, an external digital trigger, a manual trigger, or a set periodic interval), the waveform is pulled out of this buffer and written to the output data file. This data file (with a WFS extension) is created separately from the normal acquisition data file (with a DTA extension) used to store collected AE data. Once the output file is created it can be viewed and analyzed with the WaveViewer program supplied on the installation disk.

3.3.2.1.8.2 Waveform Streaming Setup

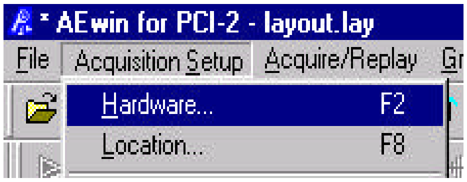
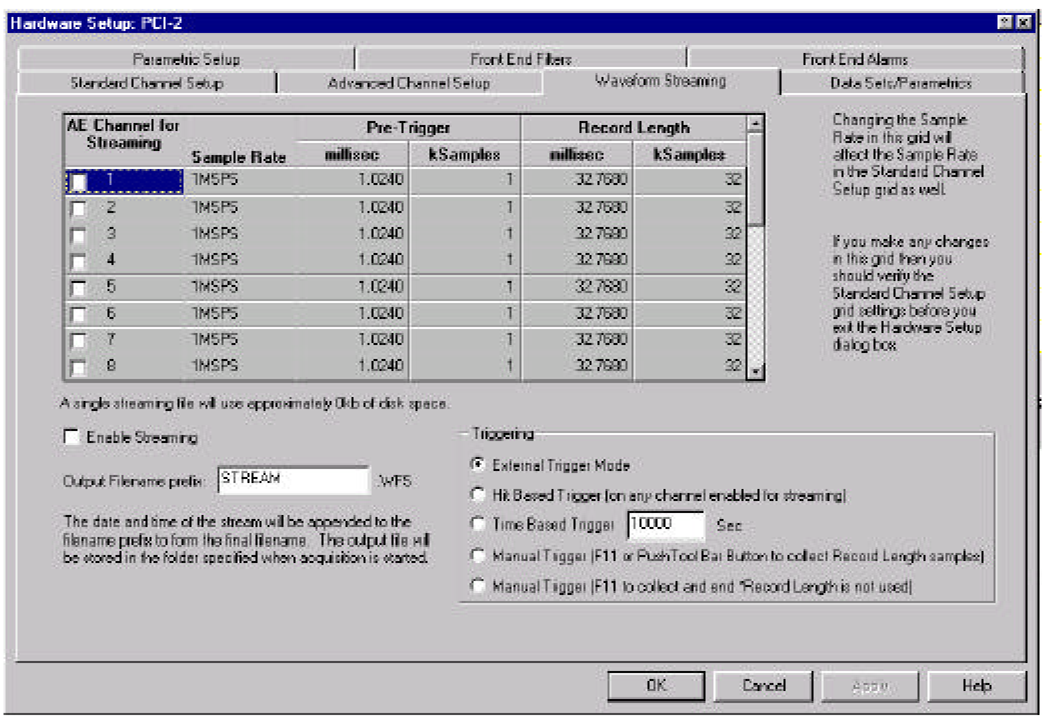


Figure 24. – Hardware Setup

Waveform streaming settings are located under the Hardware menu item under the Acquisition Setup menu (Hardware Setup Figure) or by pressing the F2 accelerator key on the keyboard. This will display the Hardware Settings dialog box. The waveform streaming setup is accessed by clicking on the Waveform Streaming tab near the top of the Hardware Setup dialog box.

3.3.2.1.8.3 Per Channel Waveform Streaming Settings

AE Channel for Streaming:
Selects a channel for streaming. When streaming is triggered, data from all selected channels will be stored to the file. Click the box to toggle this setting. A checked box indicates that a channel is enabled for streaming. A channel must be enabled for AE data collection to be able to stream. The program will enforce this by automatically enabling any channel that is enabled for streaming. If it is undesirable to have AE data from a channel that is streaming, go to the Standard Channel Setup and set the channel threshold type to ‘Fixed’ and raise the threshold level to its highest value (typically 99 dB).



AE Channel for Streaming	Sample Rate	Pre-Trigger millisec	Pre-Trigger kSamples	Record Length millisec	Record Length kSamples
1	1MSPS	1.0240	1	32.7680	32
2	1MSPS	1.0240	1	32.7680	32
3	1MSPS	1.0240	1	32.7680	32
4	1MSPS	1.0240	1	32.7680	32
5	1MSPS	1.0240	1	32.7680	32
6	1MSPS	1.0240	1	32.7680	32
7	1MSPS	1.0240	1	32.7680	32
8	1MSPS	1.0240	1	32.7680	32

Figure 25. – Hardware Setup Dialog, the Waveform Streaming Setup Section

Sample Rate:
Selects the sample rate. This setting is the same as the one in the Standard Channel Setup. If it is changed here, it will automatically be changed in the Standard Channel Setup (and vice versa) because AE and streamed waveforms are always collected at the same sample rate. Channels on the same board must have the same sampling rate (channel 1 = channel 2, 3=4…) but different rates are allowed between boards.
Also, the system cannot transfer more than 10MSPS total. This means 1 channel can be enabled at 10MSPS or 2 channels at 5MSPS… Always try to keep the total MSPS for all enabled channels as low as is possible. Changing the sample rate also changes the time value for pre-trigger and record length.

Pre-Trigger:
This is the amount of data that occurred prior to the actual trigger of the streaming that should be saved to the file. It cannot exceed either 32k samples or 4 seconds whichever is smaller. The pre-trigger amount cannot exceed the record length, because the record length includes the amount of pre-trigger. The value can be entered as either kilo-samples or milliseconds. When one value is entered into its field, the program will automatically calculate the other value. The program always stores the value as the number of kilo-samples, therefore it may not be possible to obtain an exact value in milliseconds.

Record Length:
This is the total amount of data that will be streamed once the stream is triggered. The value can be entered as either kilo-samples or milliseconds. When one value is entered into its field, the program will automatically calculate the other value. The program always stores the value as the number of kilo-samples, therefore it may not be possible to obtain an exact value in milliseconds.

3.3.2.1.8.4 Waveform Streaming Trigger Modes

Each time a valid trigger is detected, a new file is opened for streaming. Any trigger condition that is met while a stream is in process is considered to be invalid and is ignored.

External Trigger:
In this mode the streaming is triggered when an external pulse is applied to Pin 12 of J6 (digital input #2) of the PCI-2 board that contains channels 1 and 2. The pulse should be TTL level, normally low. It should go to a high state for at least 1 microsecond before returning to low. Theoretically it is possible to trigger this input with a pulse that is only 50 nanoseconds wide. Precautions should be taken to make sure that the input signal is clean or false triggers could occur. The signal must return to a low state for at least 10 microseconds before returning high to trigger another stream. If a stream is in process when the trigger input goes from low to high, the transition will be ignored and will not affect the current operation. The input must go from a low state to a high state while streaming is idle in order to trigger any streaming.

Hit Based Trigger:
In this mode the streaming is triggered whenever an AE hit is detected on any of the channels that are enabled for streaming. Additional hits that occur while streaming is in process do not affect the triggering.

Time Based Triggering:
In this mode streaming can be set to occur on a regular periodic basis. Make sure that the record length is less than the specified interval. Otherwise, for example, if the stream is to be 1.5 seconds long and the interval is set to every 1 second, the interval from 1.5 to 2.0 seconds will not be stored to a file. The first interval begins when acquisition is started.

Manual Trigger:
There are two types of manual triggers. Either will start when either the F11 key or the 'Trigger a Waveform Stream' acquisition toolbar button is pressed.
In the first case the stream will terminate when the number of samples specified in the record length field is reached.
In the second case either the F11 key or the 'Trigger a Waveform Stream' acquisition toolbar button needs to be pressed to terminate the stream.

3.3.2.1.8.5 General Waveform Streaming Settings

Enable Streaming:
This must be checked in order for streaming to be available during acquisition. This is a quick way to enable and disable the feature while still preserving all of the settings.

Output Filename Prefix:
This specifies the first part of the name of the output data file. It can be changed to any valid Windows filename characters. It is recommended that this be used to differentiate the data from different tests or experiments. The second part consists of the date and time that the stream was triggered.

Filename example: **`STREAM20040804-090744.WFS`**
`PREFIXYYYYMMDD-HHMMSS.WFS`

Here, STREAM is the default prefix. Following the prefix is the time and date of the stream. Four digits of year (Y), two digits of month (M), two digits of day (D), a hyphen, two digits hour (H, 0-23), two digits of minutes (M) and two digits of seconds (S). In the case of the example, the stream was started on Aug 4, 2004 at 9:07:44am.

3.3.2.1.8.6 Suggested Procedure for Configuring Waveform Streaming

- Select the channels for streaming from the first column by clicking on the check box.
- Select the sampling rate for each channel. Channels located on the same AE acquisition board must have the same sample rate. The program will enforce this.
- Select the pre-trigger. This can be a specified in milliseconds or K samples (1K samples = 1024 samples). It is easier to specify milliseconds, but if the sampling rate is subsequently changed, the milliseconds value will be recalculated and displayed.
- Select the recording length in milliseconds or K samples (1K samples = 1024 samples). There is no set limit on recording length other then the hard disk available. But the amount of physical memory on the computer does affect the ability to view the data using the WaveViewer program. For file lengths greater then 1.5Gbytes at least 256 Mbytes should be installed. As with pre-trigger, subsequent changes to the sampling rate will force the millisecond value to be recalculated and displayed.
- Select the Triggering Mode
- Specify the Output Filename Prefix
- Click the Enable Streaming Check Box. This box must be checked for streaming to be enabled.
- Press the 'Apply' button to verify the settings, fix any errors that show up.
- Go back to the Standards Channel Setup and verify that the waveform settings are acceptable.

Figure 26. – Status bar indicating that streaming is enabled

After configuring all options the system can be put into acquire mode to begin data collection. If waveform streaming is enabled, the status bar at the bottom of the AEwin window will display "Waveform Streaming Enabled".
When a waveform save is triggered the text in the status bar will indicate it.

Figure 27. – Status bar indicating that streaming is in progress

When the waveform save is complete the text in the status bar indicate it.
This message will persist for 4 seconds before reverting to "Waveform Streaming Enabled" text.

Figure 28. – Status bar indicating that streaming is complete

The file is placed in the last folder that was used to save a DTA file. If an acquisition is done and Autodump is enabled (producing a DTA file), the streaming data file will be created in the same folder. If Autodump is off, the streaming data will be placed in the last folder that was used for AE data. The streaming file is always created and there is no way to disable it. The destination folder for the streamed data cannot be specified without also saving AE data.

3.3.2.1.8.7 Viewing a Streamed File

Once a WFS file is created it can be viewed using the WaveViewer software package. This is included on the PCI-2 installation CD. Please see the WaveViewer User's Guide for complete instructions on using the software and viewing waveforms.

3.3.2.1.8.8 Waveform Streaming Performance and Trouble Shooting

The rate at which waveforms can be saved to a data file is a function of many different variables. The card is capable of streaming up to 20 Mbytes per second. This would correspond to 10M samples per second to memory. Unfortunately the path from memory to the data file is dependent on hard disk performance and CPU utilization, so it is not possible for us to say what the highest achievable rate will be. The DMA controller requires physical non-paged memory in order to operate. If the sampling rate of the PCI-2 card is set to 100Ksamples per second and the duration of the waveform is greater then 4 seconds then the amount of memory required is (100Ksamples)*(2 bytes)*(4 seconds)*(2 channels) = 1600K. If the sampling rate of the card is set to 5M samples per second, then the physical non-paged memory requirement increases to (5Msamples)*(2 bytes)*(4 seconds)*(2 channels) = 80,000,000 bytes. So there must be enough physical memory to map the buffer. The normal AE hit and waveform processing of the card also required physical memory as well. If AEwin locks too much physical memory, then overall OS performance will decrease. Because of these difficulties AEwin will not allocate more than 20% of physical memory for its use. If there is insufficient physical memory available on your system to allocate the waveform DMA buffers the following error message will be displayed during waveform streaming setup:

Insufficient Physical Memory, Reduce Recording Length

If this happens, you can reduce the sampling rate or the waveform length until there is enough physical memory for the buffers. Another option is to increase the physical memory installed in the system.

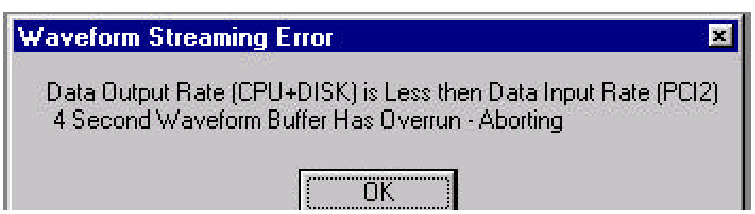


Figure 29. – Buffer overrun error

For long duration waveform saves the possibility exists that the CPU will not be able to write the waveform data to the output file at an equal or greater rate than the waveform is being read from the PCI-2 card. If this happens then the buffer overrun error message will appear.

There are several solutions to this problem. First is to reduce the CPU utilization by turning off non-essential items. Disable the line listing display. Reduce the number of plots. Disable AE hit waveforms. Don't save AE data to disk. Other options include reducing the sampling rate of the channels or the number of channels being written to the data file. Upgrade you hard disk or add more physical memory.

3.3.2.2 Channel Group Setup… (for Non-AEwin Products)

The 'channel group setup…' dialog box is used to define and edit channel groups. A 'channel group' is simply a named list of channels. You can select this group in graph setup instead of selecting channels individually. The names of any channel groups selected for a graph are displayed on the graph's title for easy identification.

To create a group, click the Add Group button. This brings up a dialog box shown at right. From here you can name the new group and select it's member channels.

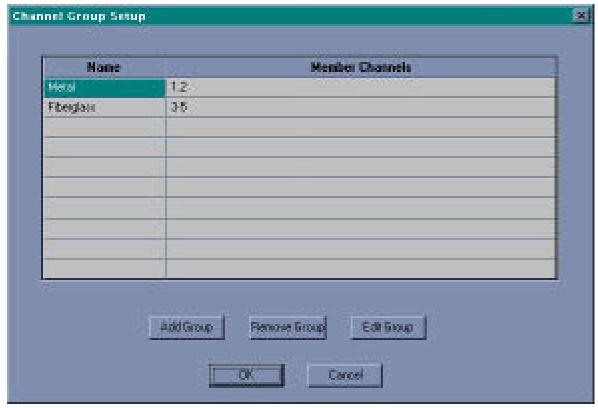


Figure 30. Channel Group Setup

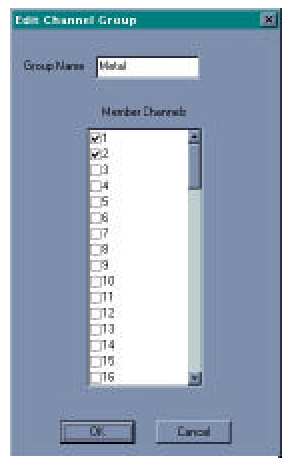


Figure 31. Edit

To modify an existing group, highlight it and click the Edit Group button. This brings up the same dialog box. To delete an existing group, highlight it and click the Remove Group button. Note that when you remove a channel group it is automatically removed from any graphs it was selected in.

3.3.2.3 Location…

The Location Setup dialog box is used to define and enable event groups (location groups). Use of Location involves more that just this dialog, however. For a full description of the Location dialog as well as other Location details see section 4.

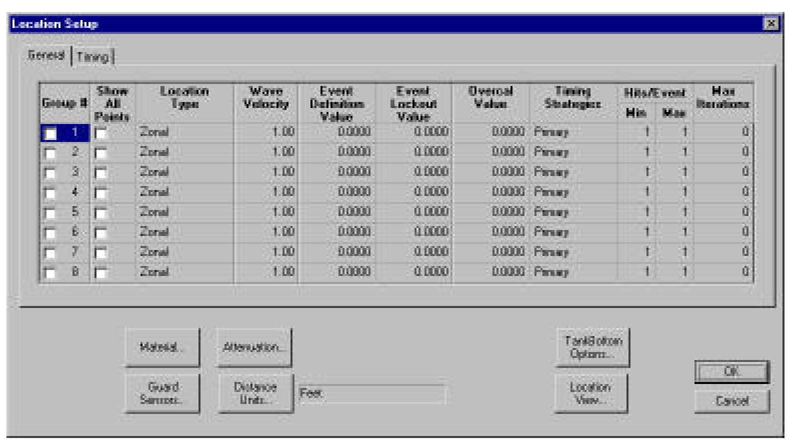


Figure 32. Location Setup

3.3.2.4 Title…

‘Title…’ is used to set the Test Title. It can be displayed on the statistics bar using the Statistics menu described below.

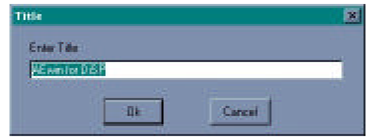


Figure 33. Title

3.3.2.5 Statistics…

‘Statistics…’ is used to toggle the various test statistics on or off, as well as to customize the Free Space Alarm. Any number of statistics can be on at any one time.

- Test Title: Displays the test title set in the ‘Title’ dialog box.
- Time of Test: Displays the elapsed time since the start of the test or replay.
- Test Point Time: Displays the elapsed time since the last test point (user-requested time mark).
- AE Hits: Displays the total number of AE hits recorded so far during the current test or replay.
- Events: Displays the total number of located events recorded so far during the current test or replay.
- Waves: Displays the total number of waveforms recorded so far during the current test or replay.
- Test Point: Displays the total number of test points (user-requested time marks) recorded so far during the current test or replay.
- Cumulative Counts: Displays the total number of counts recorded so far during the current test or replay.
- Cumulative Energy: Displays the total number of energy counts recorded so far during the current test or replay.
- Free Space: Displays the current amount of free space left on the disk on which the data file you are replaying or acquiring.
- Parametrics: Displays the value of the specified parametric from the most recent hit or time data message recorded or replayed during the current test or replay.
- Cycle Counter: Displays the value of the cycle counter from the most recent hit or time data message recorded or replayed during the current test or replay.

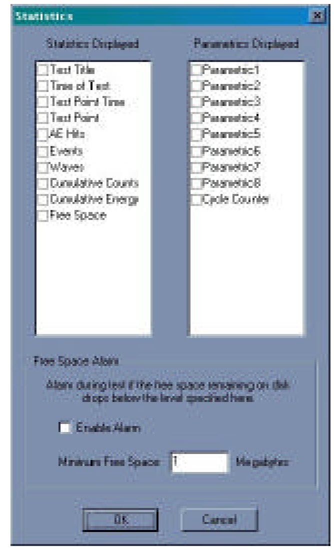


Figure 34. Statistics

Free Space Alarm

The ‘Free Space Alarm’ is designed to warn the user in the event that the amount of free disk space remaining has run low during a test. To enable this alarm, check the ‘Enable Alarm’ checkbox and set a minimum threshold (in Megabytes), below which the alarm will sound.

3.3.2.6 Logistics Information…

The ‘Logistics Information’ dialog box is used to store information about a test. The Title column contains eight editable fields to be used as descriptions of the information that is to be entered by the tester into the field to the right of the title field (Field column). Examples of useful titles would be date of test, location of test, tester name(s), item being tested, identification or serial number, weather condition, etc.

The Field column also contains eight editable fields that may be filled in now, or at test time, with information about the test to be performed. This information can then be preserved in the Layout and Data files.

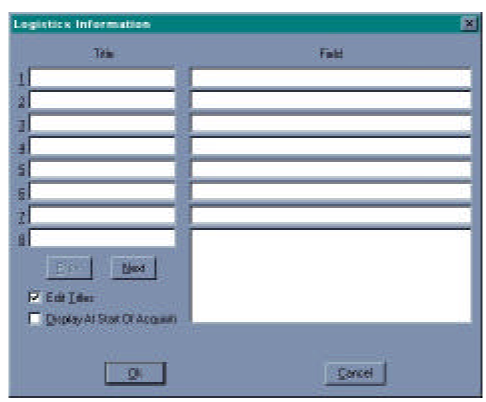


Figure 35. Logistics Information

In addition to these two columns of fields, there are several check boxes and buttons located at the bottom of the screen:

Edit Titles - When this item is checked, the information in the Title column fields can be accessed and edited. When this item is not checked, the information in the Title column fields will be for display purposes only, therefore, all text in the Title column will be grayed out and inaccessible.

Display at Start of Test - Checking this box will cause the logistics information dialog box to automatically be opened after initiating a new test. When this convenient option is checked, you will not have to remember to update the logistics information each time a test is begun, because the program will automatically prompt you for logistics information each time a new test is begun.

3.3.2.7 Audio Monitor…

The audio monitor board contains the (audible) alarm and audio controls. The circuitry is designed to produce audible tones from high frequency acoustic emission signals. This circuit can be selected to operate in either a homodyne or heterodyne mode. Operation in heterodyne mode allows the user to select the frequency of the AE signal to be monitored. Homodyne operation does not require frequency tuning and allows audio monitoring of AE signals at any frequency.

To activate the dialog box for setup of the PAC Audio Monitor board select 'Acquisition Setup' then 'Audio Monitor...'.

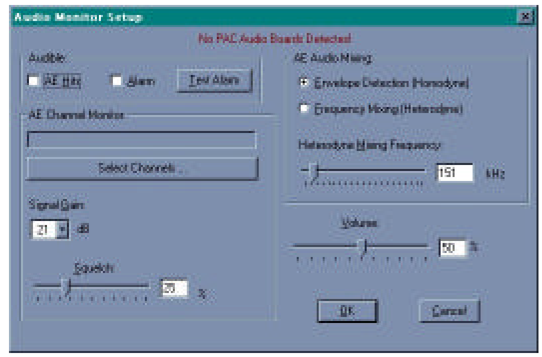


Figure 36. Audio Monitor Setup

In the group titled 'Audible' there are two checkboxes. The first one (AE) enables the board to emit a sound when AE hits are detected. The second one (Alarm) enables the board to produce a tone whenever a front end alarm warning or trip level is exceeded (these alarms are defined in the 'Acquisition Setup', 'Alarms' dialog box). By clicking on the 'Test Alarm' button you can hear how the alarm will sound. Click it a second time turn it back off.

The group titled 'AE Channel Monitor' contains controls for selecting monitored channels as well as setting gain and squelch. Click 'Select Channels' to choose which channels are to be used by the audio monitor. The 'Signal Gain' combo box contains a list of valid gain levels for the AE channels. This allows small amplitude AE signals to be monitored. 'Squelch' acts like a threshold circuit to eliminate the sound of background noise. Valid entries are from 0 to 100%. This value should be set to a level so that under conditions of no AE signals there is no audio output. Then as soon as a signal received is above the threshold as set by this control the audio output for that signal will be heard. The scroll bar located under the squelch control can be used as a mouse interface. Clicking on either arrow changes the squelch by 1%, clicking in the area between the thumb and an arrow changes it by 10%.

The group titled 'AE Audio Mixing' contains mutually exclusive checkboxes for selecting the method by which the AE tones are generated. When 'Envelope Detection (Homodyne)' mode is selected each hit produces a click sound. When 'Frequency Mixing (Heterodyne)' mode is selected each hit is mixed with a signal whose frequency is entered in the edit box below the mode selection controls. This limits the audio to hits whose frequency is 10kHz above the selected frequency. For example if the mixing frequency was set to 150kHz then AE signals greater than 150kHz and less than 160kHz will be heard.

The last control is for volume. It controls the volume of both the AE tones and the alarm tone. It ranges from 0 (off) to 100% (full volume).

The changes made to the dialog box will go into effect immediately. Pressing Cancel will restore the audio settings to those in effect before the dialog box was displayed.

Note that the AE detection by the audio board is independent of the threshold levels of each channel so it is possible to set the board up to hear AE which is below the threshold of hits detected during a test.

The top line of the dialog box will display PAC Audio Board Version X.X if a PAC audio board is detected. If one is not, it will show No PAC Audio Boards Detected.

3.3.2.8 Auto File-Close…

In most tests all data from test-start to test-end is saved to a single data file. In long tests it is sometimes desirable to instead split the data into multiple files . When the Auto File-Close feature is active during acquisition the program can automatically stop the test and start a new test under user-defined conditions. The default result is a numbered set of data files. Optionally it can close the file and begin saving data to another file without stopping the test. The result in this case is a numbered set of 'continued' data files which can be replayed together as if they were one file.

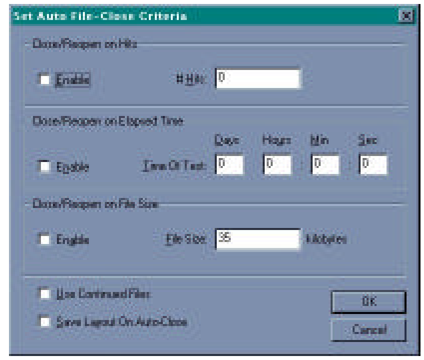


Figure 37. Auto File-Close

The program will name new files by incrementing the name of the first file. (i.e.: if the name entered for the first file is test0001.dta, then subsequent files will be named test0002.dta, test0003.dta, etc.)

If checked the program will also re-save the current layout every time a file is automatically closed. This saves the name of the new file in the layout as the default data file name for future tests.

3.3.2.8.1 Enabling and Customizing Auto File-Close

You can enable the Auto File-Close feature and set the conditions under which it will work in the 'Set Auto File-Close Criteria' dialog box seen in the figure above. There are three conditions under which an Auto File-Close operation will take place:

a) <u>#Hits</u>: Whenever the total number of hits in the test equals the #Hits value or a multiple of it, an Auto File-Close operation is performed. (i.e.: If #Hits is 1000 then an Auto File-Close will happen at 1000 hits, 2000 hits, etc.)
b) <u>Time of Test</u>: Whenever the elapsed time equals the 'Time of Test' or a multiple of it, an Auto File-Close operation is performed. (i.e.: If 'Time of Test' is 1hr 10 min then an Auto File-Close will happen every 70 minutes.)
c) <u>File Size</u>: Whenever the current file size equals 'File Size' then an Auto File-Close operation is performed. (i.e.: If 'file size' is 64kb then you will end up with a string of files, each one approximately 64,000 bytes in size.). Note that file sizes will vary especially at high data rates.

You can enable any or all of these conditions.

3.3.2.8.2 Using Continued Data Files

If the 'Use Continued Files' box was checked the program will close the file in 'continued' form and open a new file, without stopping the test. The resulting set of files are referred to as a continued file set. They differ from normal data files as follows:

- Every file in the file set (except the last one) has an internal link to the next one. This means that when you replay one of these files it will look for the next file(s) and replay them also. (It can only find them if they are in the same folder.)

3.3.2.8.3 Replaying Continued Data Files

a) To replay the entire file set in order: Replay the 'first' file (the one with the name you gave it when you started the test) in the file set. The entire file set (if present in the same folder) will replay as if it were one file.
b) To replay the file set from a certain file onward: Replay the file from which you want to begin replay. The file set from that point on will replay as if it were one file.

c) To replay a single file only: Since the files are linked the program will always try to find and replay all files that come after the selected one in order. To replay only one file you must first copy it to another folder (or move/delete the others) then replay it as you would any other. Eventually it will reach the end of the file and will warn you that it can't find the next file. If you want to eliminate this message from future replays of this file you must remove its link using the Time Order/Repair utility (see the next section for details).

Note that if the program encounters a 'gap' in the file set (i.e.: a missing file) it will display the "File Not Found" error described above. It can't replay beyond this point because the link is, in effect, broken. You can pick up where it left off by starting a new replay of the next existing file in the set.

3.3.2.8.4 Removing the Link From a Continued Data File

To remove the link from a continued data file (other than the last file which has no link) run the Time Order/Repair utility on it. This will allow you to replay this file without the "File Not Found" warning being displayed. Doing this will prevent any files 'after' this one from being replayed as part of the complete file set, so be sure to make a copy first. Time Order/Repair will ask you if you want to replace the continue message with an abort message. Click 'Yes' in response.

3.3.2.9 Auto Alarm Reset

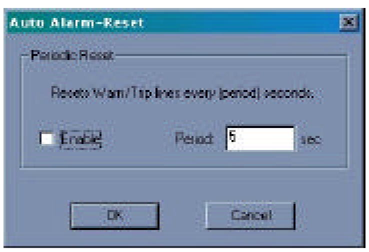


Figure 38. Auto Alarm-Reset

Figure 39. Auto Alarm-Reset

The Auto Alarm Reset dialog box is used to automatically reset alarms based on a user set criteria. This dialog box can be accessed through either the Acquisition Setup menu and the Alarm Status/Test dialog box. There are two types: Periodic and Conditional.

<u>Periodic:</u> If the Periodic Reset feature is enabled it will (during a test) reset ALL active alarm Warn/Trip lines every time a period of time elapses equal to that set in this dialog.

<u>Conditional:</u> The Conditional Reset feature is used in conjunction with 'High End' alarms. High-End alarms include the 'Free Space' alarm (set in the Statistics Setup dialog box), LeakTEC and On-Line Crack alarms (if this option is enabled). If this feature is enabled, a high-end alarm is automatically reset when the condition that caused it's triggering no longer exists. i.e. : If the 'Free Space' alarm is triggered because the amount of free space on the disk dropped below 5 Megabytes and the user then deleted enough files to raise the free space remaining above 5 Megabytes the alarm would automatically reset.

3.3.2.10 Alarm Status/Test

The 'High End Alarm Status/Test' dialog box is used to view and alter the status of various alarms in AEwin. A table of alarm types is displayed either on the left or the top of the dialog box. Each cell represents one type of alarm (such as Free Space Low), or condition (such as 'Not in Acquisition'). If a cell is checked it means that that alarm is triggered or that condition is true. You can reset an alarm simply by unchecking it. Note that doing so will not prevent that alarm from triggering again in the future (or automatically clearing itself if Alarm-Reset is enabled).

Figure 40. High End Alarm Status/Test

You can reset or set ALL possible alarms by clicking the appropriate button on the right side of the dialog box. In the center of the dialog box are colored indicators that display the status of the Alarm Output Lines (warn and trip). They are colored green if they are reset (low) or red if they are set (high). You can silence the audible 'beeping' sound without resetting the alarm(s) by clicking 'Silence Alarm'.

3.3.2.11 ASL Alarm…

ASL Alarms are used in conjunction with Internet Monitoring. Unlike Front-End or Graphical Alarms, ASL Alarms do not sound an audible alert or display a dialog box when triggered. Instead they save their alarm data in the STA files.

You can set alarm criteria on a channel by channel basis. Any channels not checked are not evaluated for alarms. The Low Level and High Level you set define the acceptable (inclusive) non-alarm range.

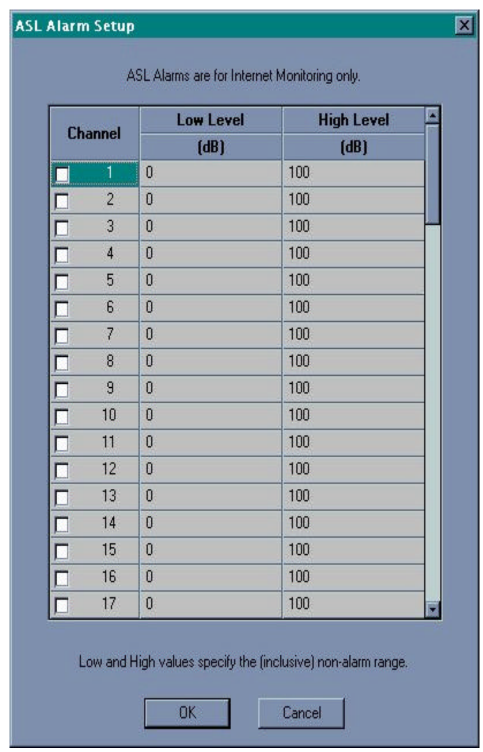


Figure 41. ASL Alarm Setup

3.3.2.12 Voltage Time Gate Setup…

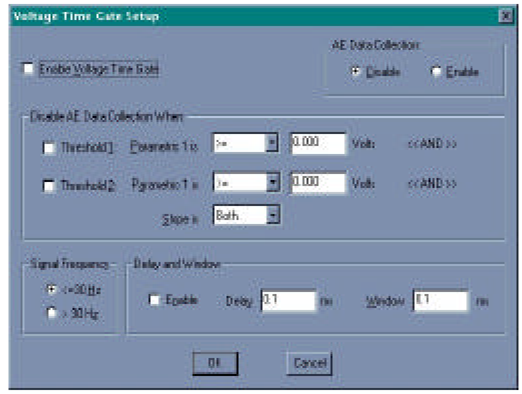


Figure 42. Voltage Time Gate Setup

Voltage Time gate is used for parametric based AE data filtering. It is controlled by parametric 1 and allows the user to eliminate the collection of all AE data that occurs when the parametric falls outside a pre-selected range of values and other criteria.

AE data collection is either Enabled or Disabled. It specifies what to do when the voltage-time gate is generated.

Each threshold is specified with a level in Volts and >= or <=, which indicates whether the signal has to be above or below the level in order to satisfy the threshold. Activation of each threshold is independent of the other; the user can activate either, both or no threshold at all.

The slope control can be POSITIVE, NEGATIVE or BOTH. It is satisfied if the parametric is rising, falling or at any time.

The slope and all active thresholds must be satisfied in order to generate a voltage-time gate. This allows the user to restrict the gate to crossings of thresholds with the parametric specifically changing a certain way (rising or falling).

Delay and Window specify an optional time window (the 'time' part of voltage-time gate). When enabled they cause the gate to be a time window of controlled duration, starting with some delay after the moment that the threshold and slope criteria are met.

Signal Frequency specifies a low-pass or high-pass filter that is applied before the parametric is fed into the voltage-time gate processing circuit. This provides the ability to respond to signals that change slowly (most cases) or quickly (fatigue cycles, etc). There are two settings, one for parametric signals below 30 Hz and one for above 30 Hz.

3.3.2.13 Internet Monitoring Setup…

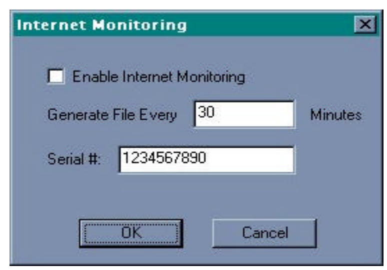


Figure 43. Internet Monitoring

This dialog box allows you to setup the Internet Monitoring feature of AEwin. This is used in conjunction with other PAC 'Remote Monitoring' applications purchased separately. Please refer to their documentation for details.

From this dialog box you can:
- Enable/disable internet monitoring.
- Set the time interval between file generations.
- Set the serial number for your unit.

3.3.2.14 Display Mode…

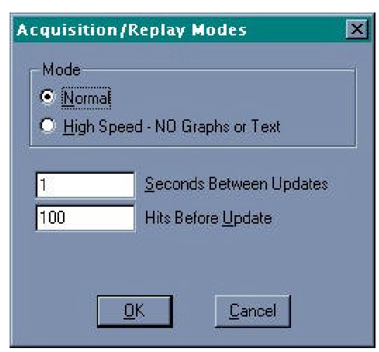


Figure 44. Display Mode

Display mode allows you to select the form of display for the AE data, as well as the frequency of graph updates, via the Acquisition/Replay Modes dialog box.

There are two Acquisition/Replay modes available in AEwin:

- Normal: This is the standard mode for acquisition and replay. Statistics, graphs, tables and the line display are all active in this mode.
- High Speed: This mode is used to achieve maximum data acquisition

speed in tests where a very high emission rate is expected. Graphs, tables and the line display are inactive in this mode. Only selected statistics will be displayed and updated; the priority task is transferring data to disk for analysis later.

Seconds Between Updates, Hits Before Updates

During data acquisition and replay, graphs and tables are redrawn (updated) at intervals determined by these settings. They are updated whenever the specified time has elapsed or the specified number of hits has occurred since the last update, whichever comes first. Depending on the anticipated data rate and test duration, you will want to select an update rate that is fast enough to keep you current without having the screen constantly redrawing. Type in the desired values in the text boxes provided. Recommended values for initial use are 3 seconds, 100 hits. Since screen updates affect overall data acquisition rate, in high data rate situations, the user may want to use larger intervals.

3.3.2.15 Line Display…

The Line Display shows a data listing in numeric format. This listing shows all the AE parameters, the parametric and other test messages as numbers in a row. There is one row for each message, plus a title row every time it is needed. The title row shows the user which parameters are being displayed and where they are being displayed. This depends on which active parameters were selected for display in the Line Display Setup dialog box.

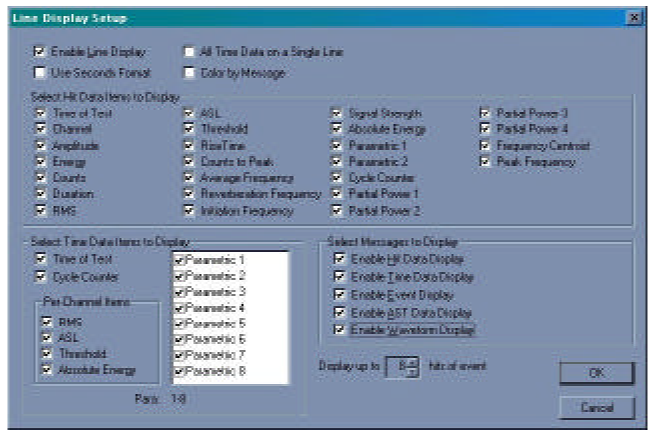


Figure 45. Line Display Setup

Here is a typical illustration:

ID DDD HH:MM:SS.mmmuuun PARA1 PARA2 CH RISE COUN ENER DURATION AMP

- The ID is the message ID. This will be 1 for a data message, 2 for a time driven message, 172 for a waveform message and 128, 129 or 130 for a test control message. A test control message is a RESUME, PAUSE, or STOP message.
- The TIME column is the time of hit read from the time of test counter. This time is displayed in days, hours, minutes and seconds from the start of data acquisition, with resolution to 250 nanoseconds.
- The PARA1 column is for parametric number one. The listed reading is scaled according to the values entered for Multiplier and Offset in the Parametric Scaling dialog box.
- The PARA2 column is for parametric number 2. Again the reading is scaled according to the values entered in the Parametric Scaling dialog box.
- The CH column is for the channel number if the message was of type 1 or an AE data set.
- The RISE column is for RISE TIME. The range of this variable is from 0 to 65535 µseconds.
- The COUN column is for threshold crossing COUNTS. The range of this variable is from 0 to 65535 counts.
- The ENER column is for ENERGY. The range of this variable is from 0 to 65535 energy counts.
- The DURA column is for signal DURATION. The range of this variable is from 0 to 16,777,762 µseconds.
- The AMP column is for AE AMPLITUDE. The range of this variable is from 0 to 100 decibels.

In the Line Display Setup dialog box you can:

- <u>Enable Line Display:</u> Note that the display can be visible (see section on View menu) but not enabled. Turning the display off can boost performance on very high data rate tests.

- Use Seconds Format: With this option you can display TIME in seconds (total) rather than HH:MM:SS.mmmuuun format.
- All Time Data on a Single Line: With this option Time Data messages (ID 2) are displayed using only a single line (each) rather than several shorter lines.
- Color By Message: With this option you can have the various messages colored by message ID. This can make the display easier to read, though it is not recommended for very high data rate tests.

The Line Listing Display can be made visible by pressing F7 or through the View menu.

3.3.2.16 Preferences…

The Preferences dialog box is used to modify settings that are not specific to any layout. These settings are remembered from session to session so you generally only need to set them once. They are:

- Only Show Installed Channels: With this item enabled, Hardware Setup will only display entries for channels that represent hardware installed on the unit. If it is disabled then Hardware Setup will display entries for up to 80 channels, including those that do not exist. This can be useful if you want to create layout files for use on other machines.
- Pre-enable Autodump: With this item enabled the 'Auto-Dump' checkbox in the Data Storage (Acquire) dialog box will be checked by default, otherwise it is unchecked by default.

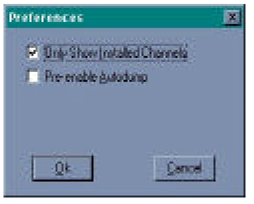


Figure 46. Preferences

3.3.3 Acquire/Replay Menu

3.3.3.1 Acquire…

An AE test is begun via the Acquire... menu item or by pressing F9. This will display a dialog box prompting you for information before the test begins.

This dialog box is very similar to the Save Layout dialog box discussed earlier, in which you are prompted for a filename, in this case to store AE data. The exception here are the checkboxes in the upper left corner:

- Auto-Dump: If this box is checked, it means that Autodump is ON and the test data will be recorded to the filename you specify in this dialog box. If you want a permanent record of your data, make sure that Auto-Dump is ON**.** If it is OFF, no data will be written to disk and your record will be limited to the real-time graphic displays.
- Enable Event Linking and Cluster/Area History: If this box is checked then support for these features will be enabled in acquisition. If it is not checked then event linking and cluster/area history will not function for the duration of the test, but the system will exhibit better performance at high data rates. If you expect high data rates then be sure to uncheck this and save the data to a file (Auto-Dump on). You can then use Event Linking and Cluster/Area History during a replay if needed.

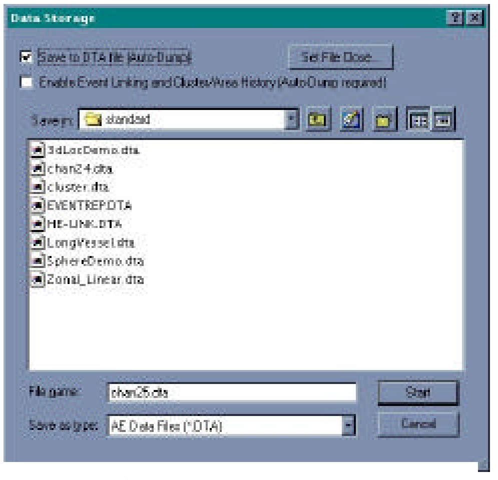


Figure 47. Data Storage

If Auto-Dump is ON, the program will save data to the filename specified. The program will then automatically increment the last letter or digit of the filename specified in the Test Storage dialog box each time you enter acquisition with AUTODUMP ON without specifying a different data filename.

The data file is automatically closed and reopened every second. This assures that the worst case data loss is one seconds worth if power fails. A manual update to disk can be accomplished by pressing pausing/resuming the test.

3.3.3.2 Replay…

This box is essentially the same as the Acquire dialog box discussed in the last section. Because Autodump is not needed here, it is not an option in this dialog box.

Once the filename has been selected, the controls are essentially the same as for Data Acquisition. During the replay, the system reads data from the disk, updating the graphs/tables at the rate specified in the Display Mode dialog box. The replay automatically ends when it finishes replaying the requested data file. If the file specified data file is a 'Continued file' (described in sections 3.3.2.8.2 and 3.3.2.8.3) then it replays the next file in it's continued file set.

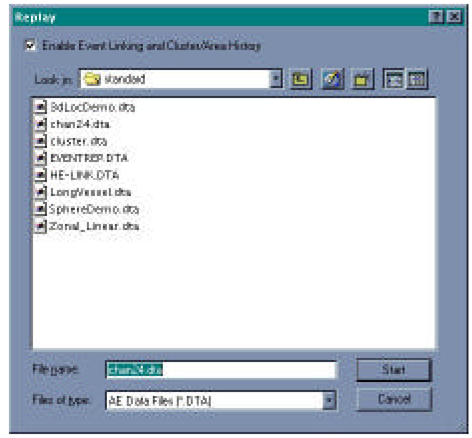


Figure 48. Replay

3.3.3.3 Resume/Pause/Stop/Abort

These four commands are used to control the test or replay.

- Pause: Click Pause to temporarily halt a test or replay.
- Resume: Click Resume to continue a paused test or replay.
- Stop: Click Stop to terminate a paused test or replay. This is the proper way to end a test. Any buffered data is saved (if auto-dump is on).
- Abort: Click Abort to terminate a non-paused test. This is a quick way to exit a test and can be used even if the hardware is not responding. It is recommended for use only in emergencies or when data isn't being saved to disk as any buffered data is lost.

3.3.3.4 Time Mark

Click this command to add a Time Mark (a.k.a. 'Test Point') to the data during test. This message represents a point in time of significance to the tester (i.e.: beginning of loading cycle, important observation, etc.). It is saved with the data for future replays and is displayed on all time-based graphs (graphs that have 'time' as their x-axis parameter) as vertical bars. It is shown on the Line Listing Display as an ID 211 along with it's time of test.

The statistic 'Test Point' displays how many Time Marks (Test Points) have been added to the data.

3.3.3.5 Turn Waveforms ON/OFF

Click this during data acquisition to toggle waveform transmission on or off. These commands are only available if you have the Waveform option installed.

3.3.3.6 Display Last Alarm…

Click this to view the Alarm dialog box. This displays information on all alarms detected during the current test (or previous test if no longer in test). Use the drop down list box in the lower left corner to select which alarm to view. You can Clear (all) the alarms by clicking the 'Clear Alarms' button. This resets any alarm output and turns off the audible alarm (if on).

This command is available only if there has been alarm activity during the current test (or the last one if ended).

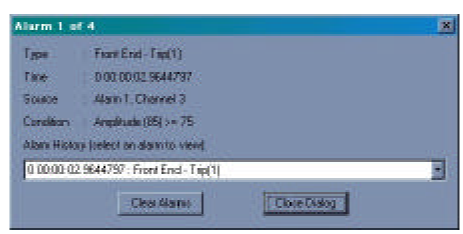


Figure 49. Display Last Alarm

3.3.3.7 AST

The purpose of the Auto Sensor Test is to verify that nothing has gone awry with the sensors before or after a test. The Auto Sensor test will run a short acquisition test, while pulsing through to each sensor sequentially, using the current settings in the Test and Hardware Setup menus. An AST test should be run before and after an AE test and results compared to make sure there were no sensor sensitivity changes. Also, in order for AST to work, 1220A-AST preamps or Integral Sensors with the AST option (e.g., R15I-AST) are required. The AST Dialog Box is used to setup and begin the AST.

The results of the AST will be displayed on the screen, and/or saved to a file. This is done by selecting the "output Results to Screen" and/or the "Output Results to text file" check boxes. If the "Output Results to text file" box is chosen, you may accept the default filename for the text output file or select a new output filename, either by typing the filename in the Filename text box, or by selecting to overwrite an already existing filename through the Select Output File button.

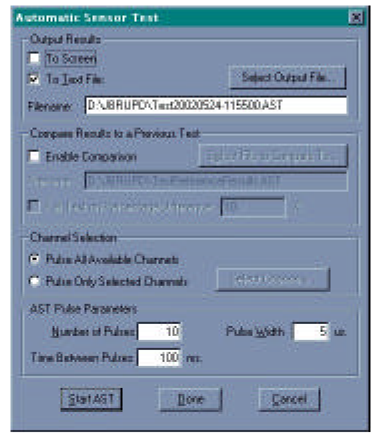


Figure 50. AST

The results of the AST will be compared to a previous baseline test run if the "Enable Comparison" box is checked. A filename must be supplied either by typing a filename in the Filename text box provided, or by selecting a filename through the Select File button.

The AST pulse is generated automatically by the system following the pulse characteristics shown in the bottom of the dialog box. These characteristics may be changed by typing the appropriate values in the text boxes provided. The characteristics and their legal ranges are:

Number of Pulses: This is the number of times a single sensor will be pulsed. Each active sensor set in the Channel Settings dialog box will be pulsed this number of times. This number must be in the range of 10 to 250.

Pulse Width: This time, specified in µsec, determines the length of the pulse. It must be in the range of 1 to 20.

Time Between Pulses: This time, specified in msec, determines how far apart the pulses are.

Selecting Done will save AST settings, and exit this dialog box without starting the test.

Selecting Start AST will start the Auto Sensor Test. If "Enable Comparison" was chosen, the files supplied in the filename box will be read and used to calculate a percent change for delta-T, amplitude, and energy for all active sensors defined in the Channels Settings of the Hardware Setup Menu.

The results will be displayed, on the screen, written to a file, or both, depending on the options selected in the AST Dialog Box. On screen will be displayed the test setup parameters (Pulses Output, Pulse Width, Pulse Interval) and the actual results one line per receiver channel, one page per pulser channel.

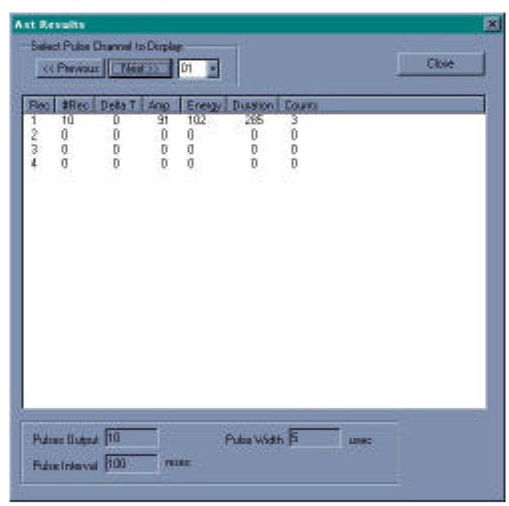


Figure 51. AST Results

The report file will contain this information plus the date and time of the AST and the baseline report file used for comparison, if one was specified.

3.3.3.8 Pause Replay On Timemark/Pause

These menu items are used to automatically pause replay whenever a timemark or pause message is replayed. You can toggle these items on or off individually. They allow you to quickly jump to various pre-set points of interest in your data (time marks and pauses set during acquisition). You can resume replay in the normal fashion by pressing F9 or clicking Resume.

3.3.4 Graphing Menu

3.3.4.1 Graph Setup…

The 'Graph Setup…' dialog box is used to customize an existing graph (created using the 'New Graph' or 'Copy/Paste Graph' commands). You can enter this dialog box by selecting (right clicking) a graph and selecting 'Graph Setup…' from the Graphing menu or by right-clicking the graph and selecting 'Graph Setup…' from the menu that pops up. The appearance of this dialog box will vary depending on the type of graph. The example at right is representative of a simple activity graph.

Section 3.7 details the procedure for creating and customizing graphs. Below is a brief description of the various graph types available and the major pages of the graph setup dialog box.

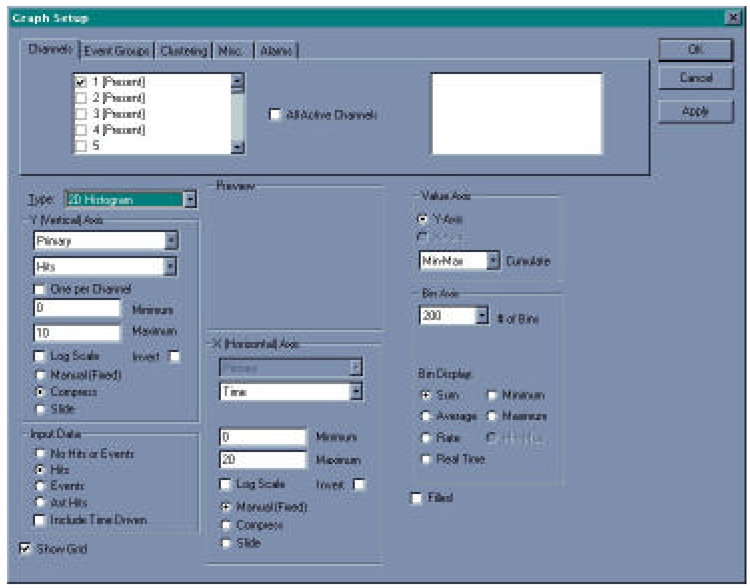


Figure 52. Graph Setup

Graph Types:

- <u>2D Histogram</u> – This is the standard Bar (if 'Filled') or Line (if not 'Filled') graph. You can define multiple plots or use the 'One per Channel' checkbox to automatically create one plot for every enabled channel (max 6). The X-Axis is known as the 'Bin' Axis and is divided into a user-defined number of 'bins'.
- <u>2D Scatter (Point Plot)</u> – This is the basic point plot graph. Multiple plots can be defined.
- <u>2D Binned Scatter</u> – This variant of '2D Scatter' uses a different strategy for data display. It divides the graph area into a grid measuring 200 bins high by 200 bins wide. Thus, every dot represents not a discrete point but actually a small range of values. The advantage of this over '2D Scatter' graphs is that it can display large amounts of data quickly. 2D Scatter graphs can slow down when burdened by more than 100,000 points or so, and will eventually run out of memory around 650,000 points (depending on the setup). This can be a problem during extremely long tests and replays. 2D Binned Scatter graphs do not suffer from this 'data overload'. The disadvantage is a slight loss of resolution. Due to the binned structure there are only 200 possible values across an axis for a total of 40,000 possible distinct points. To calculate the resolution of a graph axis divide it's full scale by 200.
- <u>2D Colored Scatter</u> – This variant of '2D Scatter' is nearly identical in operation to '2D Binned Scatter' but uses a single plot which is colored by value. On the right-hand side panel you choose the 'Color Feature' (counts, duration, etc), define the various color level maximums (or choose 'compress') and set the display mode. The color levels define what color a point on the graph is based on it's value. For instance assume you set the color feature to be energy and set level 1 (yellow by default) to be 1000 and level 2 (purple) to 2000. If you get a single hit with energy 600 the point displayed will be yellow in color. If you got a single hit with energy 1001 then this point would be purple. Sum, Average, Minimum and Maximum modes display (the color

of) the sum, average, minimum or maximum values respectively of all points that occupy the same grid location. ‘Count’ mode ignores the color feature and simply displays a count of the number of points that occupy the same grid location.

- <u>3D Histogram</u> – This is the standard 3D bar graph. It operates in much the same way that 2D Histograms do. Both the X and Z axes are ‘Bin’ axes.
- <u>3D Scatter (Point Plot)</u> – This is the standard 3D point plot graph. It operates in much the same way that 2D Scatter graphs do except with a depth (Z) axis.
- <u>Waveform</u> – Standard single plot Waveform graph.
- <u>Power Spectrum</u>– Standard single plot Power Spectrum graph.
- <u>Spherical Location</u> – This graph type is used exclusively for the display of spherical events.
- <u>Cylinder Location</u> – This graph type is used exclusively for the display of cylindrical events.

The ‘Channels’ page (at right) allows you to select which channels and/or channel groups will be active on your graph. Select channels from the left panel and channel groups (if any are defined) from the right panel.

Figure 53. Channels

The ‘Event Groups’ page (at right) allows you to select which event groups will be active on your graph.

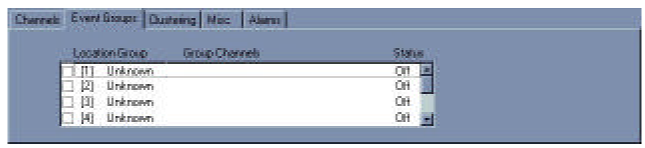


Figure 54. Event Groups

The ‘Clustering’ page (at right) allows you to customize your graph to display cluster information. See section 3.8 for details.

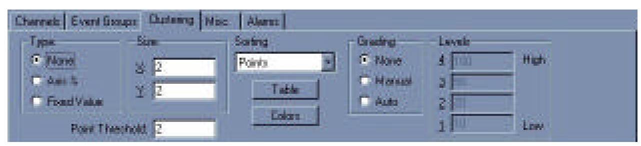


Figure 55. Clustering

The ‘Misc’ page (at right) allows you to set various graphing options that don’t fall into any other category. From here you can turn on the ‘color legend’. This displays a small chart on the right of the graph describing what each color means. You can also designate your graph to be a ‘history’ graph. See section 3.10 for details on how to use the Cluster/Area History feature.

Figure 56. Misc.

The ‘Alarms’ page (at right) allows you to enable and customize Graph Alarms on your graph. See section 3.11 for details on Graph Alarms.

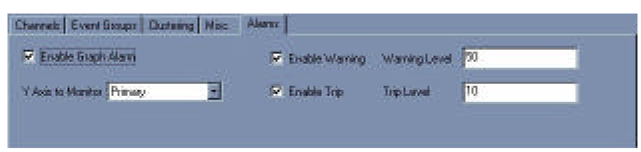


Figure 57. Alarms

3.3.4.2 Graph Filters…

Graph Filters are used to restrict the data that gets plotted on a particular graph by specifying a graph parameter (such as amplitude, energy, duration, parametric) and a range of values to either plot (accept) or not plot (reject). The parameters can be same as or different from the graph axis parameters of the graph to which they are applied. They only affect the data being plotted, they do not affect the data going to the disk. The Graph Filter dialog box is launched by either right-clicking on a graph and selecting 'Graph Filters' or by selecting Graph Filters from the Graphing pulldown of the main menu.

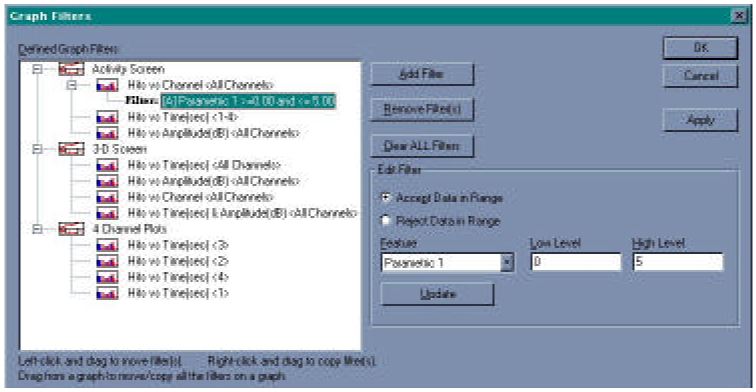


Figure 58. Graph Filters

The left side of the dialog box contains a tree control showing the 'Defined Graph Filters'. This control displays information in three levels. At the highest level are the currently defined pages of graphs. The next level shows all the graphs that belong to a page. The final level shows all the filters that are defined for the graph. If a given level has a '+' sign to its left then it contains items which are hidden. Left-click with the mouse on the '+' to expand the level. Expanded levels have a '-' to the left of them. Left-click on the '-' to compress the level. The text for the screen is the same text that is used on the 'Page Bar' at the bottom of the page. The text for the graph is the same as the caption above the graph. When the dialog box is first displayed it highlights the graph that is currently selected. So if the dialog box is displayed by right-clicking a graph and then selecting 'Graph Filters' the graph that was clicked on will be the graph that is highlighted. Filters are displayed with the format [A/R] Feature >=Low Level <=High Level. [A/R] will be [A] for accept filters and [R] for reject filters. The buttons to the right of the tree control are enabled or disabled depending on which item is highlighted in the control.

Add Filter: Will be enabled when a graph or filter is highlighted. Selecting it creates an empty filter under the highlighted item. The user must then use the controls in the 'Edit Filter' group to define the filters. <u>The 'Update' must be pressed to change the filter</u>.

Remove Filter(s): This will be enabled as long as a filter is defined in any Screen or Graph that is highlighted or if a filter is highlighted. Pressing it will remove either the single filter that is highlighted or all the filters that belong to a highlighted graph or all the filters in all the graphs of a highlighted screen. When the button is pressed another dialog box will appear that will prompt for verification. The filter removal operation can be canceled at this point**.**

Clear ALL Filters: This will be enabled as long as a filter is defined. Selecting it will remove all filters. When the button is pressed another dialog box will appear the will prompt for verification. The filter removal operation can be canceled at this point. The filter is defined by using the controls in the Edit Filter group. These controls will only be active if a filter is highlighted in the 'Defined Graph Filters' control.

Accept/Reject: Determines if the data will be accepted (plotted) or rejected if it passes the filter test (i.e. falls in the range of the low and high levels).

Feature: Selects the feature used as a filter. The choices are the same as the graph parameters. Note that all graph parameters are listed here. The user must make sure that the selected parameter makes sense. Only hit data can be filtered (all time driven data will plot). If the graph is an event graph, then only the features from the first hit sensor will be used in the test and the event will plot based on the result of the test on the first hit data.

Low/High Level: Determines the range of the filter. The range is inclusive of the limits (as denoted by the <= and >= in the graphical representation of the filter in the 'Defined Graph Filters' control). Any floating point value can be entered and the range is not validated.

Update: This button must be pressed to change the values in the 'Defined Graph Filters' control. The Apply button takes the filters as they are defined in the 'Defined Graph Filters' control and applies them to the system. Pressing the Cancel button after pressing Apply will not restore the filters to they state they were in before the dialog box was displayed.

<u>Drag and Drop:</u>
The text below the 'Defined Graph Filters' control explains how to move or copy a filter or group of filters.
If a filter is dragged with the left mouse button it can be moved to another graph by dropping (release the mouse button) on a target graph.
If a filter is dragged with the right mouse button it can be copied to another graph by dropping (release the mouse button) on a target graph.
If a graph is dragged then all the filters in the graph will be moved/copied to the target graph.
If the target graph is off the display, hold the dragged item very close to the top or bottom of the control to initiate auto-scrolling.
If the target graph is in a collapsed page or graph ('-' to the left of the target), hold the dragged item over the collapsed page or graph and it will automatically expand.

<u>Tips:</u>
- Reject is used over accept. If one filter on a graph is defined as [R] Amplitude >=0 <=50 and another filter on the same graph is [A] Amplitude >=45 <=50 then no hit will be plotted. The [A] filter winds up filtering out all hits with Amplitudes > 50 and <45. The [R] filter removes all the hits in the [A] filter range because it includes the entire range of the [A] filter. Think carefully about what is to be accomplished and test the graph first whenever possible.
- No more that 20 filters per graph can be defined.
- The graphs indicate if they have any filters defined by placing 'Flt' on the caption at the top of the graph. To quickly make sure that there are no filters, bring up dialog and check the Clear Button status. It will be disabled (grayed out) if there are no filters on any graphs.
- Don't forget to press the Update button whenever a filter is added or modified.

3.3.4.3 Colors

The 'Colors' submenu is used to set the various colors used in AEwin.
- <u>Cluster Colors:</u> Set the colors of the various cluster grades used on cluster graphs.
- <u>Colored Scatter Graph:</u> Set the colors of the various levels used by Colored Scatter Graphs.
- <u>Plot Colors:</u> Set the colors used by the plots of all other graph types. 'Plot 1' is used by all graph types other than Colored Scatter Graphs. 'Plot 2' through 'Plot 6' are used only by graphs that can use multiple plots (2D Histogram, 2D Scatter, 2D Binned Scatter).
- <u>Sensor Color:</u> Set the color of sensor icons used on event-based graphs.
- <u>Structure Color:</u> Set the color of the structure used on event-based graphs.
- <u>Legs Color:</u> Set the color of the legs used on spherical location graphs.
- <u>Graph Background Color:</u> Set the background color of the graph frames.

3.3.4.4 New/Move/Close Graph or Table

- <u>New Graph:</u> Use this command to create a new graph. The new graph will be a copy of the currently selected graph. If no graph exists then the new graph will be a simple 2D Histogram of hits vs. time. Use graph setup to customize it.
- <u>Move Graph or Table:</u> Use this command to move a graph or table using the mouse.
- <u>Close Graph or Table:</u> Use this command to close the selected graph or table.

3.3.4.5 Cut/Copy/Paste Graph or Table

- Cut Graph or Table: Use this command to cut a graph or table, presumably for later pasting on another page.
- Copy Graph or Table: Use this command to copy a graph or table, presumably for later pasting on the same or other page.
- Paste Graph or Table: Use this command to paste a cut or copied graph or table onto the current page.

3.3.4.6 Turn Waveform Threshold Lines On/Off

Waveform graphs can be displayed with horizontal lines denoting the threshold and a vertical line denoting the time of first threshold crossing. Use these commands to turn the display of these threshold lines on or off on all waveform graphs. You can also turn threshold lines on or off on individual graphs by right clicking the graph and checking (or unchecking) 'waveform thresholds'.

3.3.5 Tables Menu

With this menu you can create specialized tables. A table is a window that displays mainly text-based information instead of graphical information. Like graphs, tables can be moved, resized and closed from commands on the 'Graph' menu.

3.3.6 View Menu

With this menu you can select which toolbars and information bars you would like to display on the screen. There are fixed positions for each of these toolbars defined on the AEwin screen, but some (Toolbar, Acq. Controls, Line Listing Display) can be moved according to the user's preference by grabbing (left clicking the mouse) the handle (vertical bar) at the left side of the toolbar and moving it to the desired location. The settings on this menu are saved internally (i.e.: not in the layout file).

3.3.7 Utilities Menu

This menu contains a number of useful 'utility' programs for post-test analysis of datafiles. See the Appendix at the end of this chapter for details.

3.3.8 Page Menu

With this menu you can create insert, delete and rename screen pages. This is an AEwin screen page management menu. You can also perform these functions with the icon keys and a right mouse click on the screen page tab.

3.3.9 Window Menu

This is a typical "Window" menu that you would find on any common WINDOWS program and therefore the menu contents should be familiar. It allows you to arrange your graphs in cascade or tile patterns as well as edit their window settings. Select 'Maximize Graph' to enlarge the active graph , and 'Restore Graph' to return it to it's normal size.

3.3.10 Help Menu

With this menu you can get some on-line help to the operation of certain features of the software. In addition, the "Options" selection informs the user which options have been installed in his/her AEwin software and the "About AEwin" informs the user to the release version and date of AEwin.

3.4 Acquiring AE Data with AEwin for the First Time

This section is provided to help you understand the sequence of getting into and running an AE Test for the first time using the provided Layout (.LAY) files and also gives you insight into a more detailed sequence of carrying out an AE data acquisition test. Before starting in acquisition, you should have your AE system already set up as per the “Getting Started” section of your AE system manual. This usually entails, connecting sensors, preamplifiers and cables to the AE system, connecting up your AE system, computer keyboard, mouse and monitor and booting up your system into AEwin as previously instructed. If you are not ready to connect up the AE system to conduct some type of AE test or at least any AE experimental test on a laboratory test, then skip this section and proceed to the next major section on Replaying an AE test with AEwin.

The key to carrying out an AE test is in setting up the hardware set-ups, graphics, location setups and display modes to your particular requirements prior to entering the test. Although there are many set-up items and they might seem confusing for first time users, PAC supplies good default set-ups for most typical tests and they are an excellent starting point. As you get more familiar with the system you can modify these set-ups a little bit at a time and save your new layout (.LAY) setup files for your next AE test. This small step-by-step "Trial and Error" approach builds up your knowledge base until you are totally familiar with all the set-up options and what they mean. Until you get this knowledge please depend on the PAC prepared .LAY files.

The following are the steps that should be taken when carrying out your first AE test using the PAC supplied layout files. First we will outline the steps and next we will carry them out.

1. Load the appropriate system Layout (.LAY) file into the system in order to set-up the system to your desired operation and display conditions. We will be using the standard **Layout4.LAY** (or **Layout2.LAY** on Spartan and PCI-2 systems) layout file in this example which sets up 4 (or 2) channels for acquisition.
2. Enter the Acquire menu.
3. Select the datafile name which you want to save to disk.
4. Start Acquisition.
5. Look at various screens, graphs and data listings during acquisition.
6. Exit data acquisition.

The following is the step by step detail on starting and running your first AE test. We assume that you have sensors set up and will be exciting them in order to generate signals for AE generation or have them attached to a structure, bar or plate with a pulser or some type of simulated AE source.

3.4.1 Loading a Layout File into AEwin

From the Menu bar, use your mouse to select **Files** then select **Open Layout...** A menu window called **Open** comes up. With your mouse, select the **Layout4.LAY** (or **Layout2.LAY**) file from the list of layout files so that this file name appears highlighted in the file box next to **File Name:**. This selects it as the layout file that will set up the AE hardware for a 4 (or 2) channel operation with a good, complete default set-up. To finish the sequence, move the mouse to the **Open** box area on the right side of the **Open** window box and click on it (left mouse key) or press <ENTER>. Upon executing this menu, the selected Layout file is read into the program. If you had made any changes to the current layout file, a message box will pop up asking you if you want to save the those changes. If yes, select yes, if no, select no. AEwin will then load and configure itself to the selected layout’s setup. This completes the reading of the LAY (AEwin setup) file.

3.4.2 Entering Acquisition

Entering acquisition involves steps 2, 3 and 4 of the above sequence. or the Mouse operated icon. To begin, left-click the mouse on the **Acquire/Replay** main menu item then click on the **Acquire** selection. Alternately, you can enter the Acquire function by pressing the **F9** function key (on the keyboard), or you can select the Acquire icon in the Acquire/Replay toolbar. The Acquire icon is shaped like a traffic light with the green light showing indicating that

AEwin is ready to go into acquisition. This toolbar is usually to the right of the main icon toolbar or just below it. If you do not see this small toolbar (like that shown below), it may not be turned on from the **View** menu. To activate it, simply select the Tools menu and make sure the "Acq. Controls" entry is checked. If not, click on it and it will be activated and will show up with the other toolbar icons.

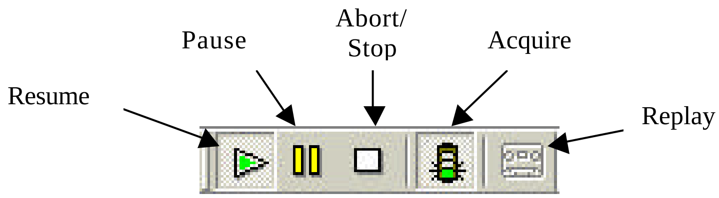


Figure 59. Acquire/Replay Icon Toolbar

At this point the Acquire function, a **Data Storage** files menu box will appear to signal you to enter a data file name and whether you want to save the file to disk. (An example of the Data Storage file menu box is shown in figure 60.)

First, make sure the "Save to DTA file **(<u>A</u>uto-Dump)**" box is checked if you want to save the data you will be collecting in this exercise. In AEwin, this is always automatically checked and you usually have to deselect (uncheck) it to prevent the generation of an AE data file.

Next, check the name shown in the **File <u>N</u>ame:** box. If that name is acceptable then you are ready to start the test by clicking on the **<u>O</u>K** button. If you want a different name then enter the new name by typing it in when the **File <u>N</u>ame** box is highlighted. Once you enter the name (you do not have to enter the .DTA extension) you can hit <ENTER> on the keyboard or click the **Start** button (located to the right of the Filename) with the left mouse button to begin acquisition. At this point AEwin enters the acquisition screen and waits for you to press the <ENTER> key to start the test. Press <ENTER> to start Acquisition.

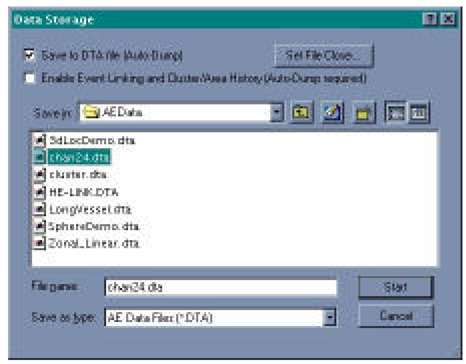


Figure 60. Data Storage

The system is now in data acquisition and is collecting and displaying AE information and displaying it on the graphs. Tap the sensor against the table your instrument is set up on or scratch it with your fingernail.

At first you will see no change in your Data Acquisition Graph but once the amount of time specified in **Test Setup → Display Mode** menu parameter "Seconds between Update" time has elapsed (it is usually set for 1 – 2 seconds), you will begin to see a visual representation of your data. Continue tapping the sensors to see the changes to the graphs to verify that you are getting waveforms and graph updates. An example plot showing the first AE graph screen page (selecting the tab, Activity Screen), is shown in figure 61. You should be seeing data visualization like that shown, where graph 1 shows a group of 4 point plots including Counts, Energy, Amplitude and Rise Time (on the Y-axis) versus Duration (on the X-axis), graph #2 (to the right) is showing #AE hits and #waveforms collected versus time, Graph #3 (below graph 1) is showing Hits versus channel and Graph #4 (lower right) is showing the Hits versus Amplitude (or Amplitude Distribution).

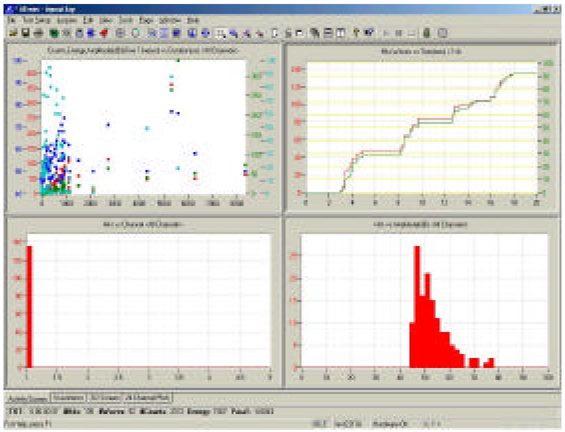


Figure 61. Example Activity Screen

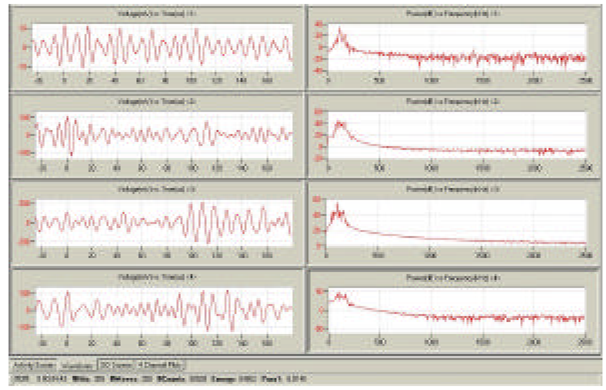


Figure 62. Example Waveforms Screen

3.4.3 Actions within Data Acquisition

There are several actions you can take in acquisition to view the graphs and other modes in the instrument. Try these items to see what happens.

3.4.3.1 Selecting and Viewing the Different Screen Pages

You can scroll between screens to view the activity between the different AE graph screen pages. This can be done simply by left clicking the mouse on any of the AE graph screen page Tabs located just below the graphs on the left. In the example Layout file, we have defined four different graph screen pages. They are the Activity Screen (shown in figure 61), Waveforms (figure 62), 3-D Screen (figure 63) and the 4 channel plots (figure 64).

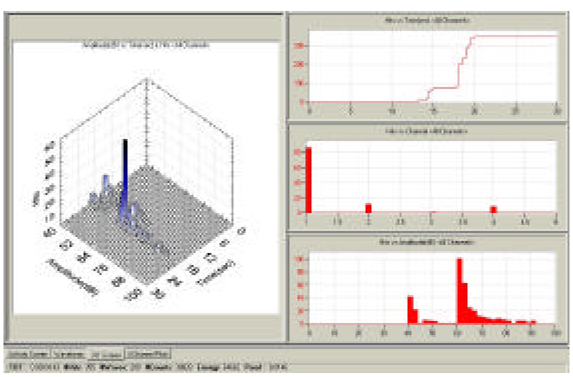


Figure 63. Example 3-D Screen

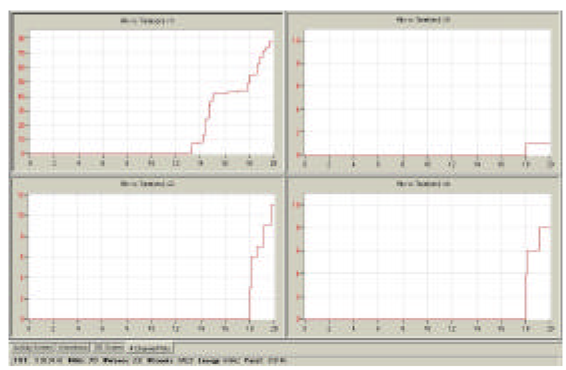


Figure 64. Example 4 channel screen

These graph screen pages give a good idea to the capabilities and the graph types that you can create with AEwin. On the Activity Screen page, you can see multiple point plots on one graph, multiple line graphs (AE Hits and Waves versus time) as well as bar charts. On the Waveforms Screen page (figure 62), you can see waveforms on each of 4 channels with the associated FFT located alongside the waveform for each of these channels. On the 3-D Graphs screen page (figure 63), you can see a nice 3-D plot with 3 associated graphs alongside. This graph shows that you can setup 3-D graphs (which can be rotated) with AEwin. It also shows that you can size your graphs differently. On the 4 channel plots (figure 64) you can set up graphs with multiple plots on them, one for each channel so you can link AE with other test parameters. This can all be done in acquisition. As you observe and change graph screen pages, the test continues.

There are many other things that can be done within acquisition. This includes maximizing a graph to full screen, zooming in on certain areas of a graph, viewing cursors and cursor readouts, printing graphs, saving graphs to a data file or the clipboard, just to name a few.

3.4.3.2 Zooming and Panning on a Graph Region

To zoom a graph, please note the graph associated toolbar icons for zoom, pan, and cursor select. This set of toolbars is near the center of the icon toolbar. This toolbar section is shown and defined in figure 65.

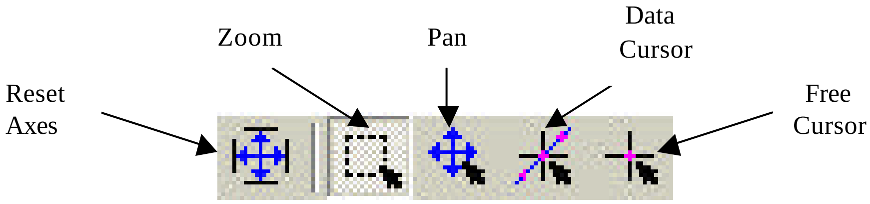


Figure 65. Zoom, Pan, Cursor Control Toolbar Icons

To use, select a graph by clicking on it. A good graph to demonstrate these functions on is the Activity Screen Point plots (see upper left graph of figure 61). Select the graph by clicking on it. Next, click on the zoom icon. This is probably already selected. Next, with the mouse cursor, define a zoom rectangle by pointing to the starting point on the screen where you want one corner of the zoom rectangle to be. Next, press and hold the left mouse button and drag the mouse to the point where you want the zoom box to end. You will see the dotted box as you drag the mouse. As soon as you let go, the graph will zoom and only the area that you selected in your zoom rectangle will be displayed in that graph. You will see that the axis scales have changed as well as the number of points in the point plot. You can now pan the plot (move around the zoomed area) by selecting the Pan icon button, moving your mouse pointer to the center of the graph screen that you have zoomed, click the left mouse button and move the mouse around. You will see the graph pan as you move the mouse. You can continue panning in one direction by letting go of the left mouse button, repositioning the mouse and pressing down on the left mouse button again, and moving the mouse. You can even pan un-zoomed graphs (but there is not a lot of sense in doing that). Zooming and panning can be done on any 2 dimensional graph.

Once done and you want to return that graph back to the unzoomed state, simply press the "Reset Axes" icon. This is the leftmost icon shown in figure 65. This will bring the graph and its axes back to the normal setting.

3.4.3.3 Zooming, Panning and Rotation of 3-D Graphs

Zooming, Panning and Rotation of 3-D graphs can be accomplished but not in the same way as that for 2-D graphs. For 3-D graphs, this requires a combination of the mouse and keyboard to accomplish. Before starting this exercise, click the Graph Screen Page tab "3-D Screen" and follow along to get familiar with the controls. You should see a graph like that shown in figure 63.

Rotating the graph is the easiest function. All you need to do is place your mouse pointer somewhere near the middle of the 3-D graph, press the left mouse button and while holding the left mouse button down, move the mouse slightly around in a circle. You will see the rotation of the graph change. You can position it anywhere you want.

To zoom, simply place the mouse pointer somewhere near the center of the 3-D graph and when ready, press the **ALT** button on the keyboard, and while holding that down, press and hold the left mouse button down. Then slightly move the mouse down (while holding the ALT button and the left mouse button depressed). As you move the mouse down the 3-D graph will zoom. As you move the mouse up, the graph will shrink.

To pan the 3-D graph, place the mouse pointer somewhere near the center of the 3-D graph, depress and hold the **SHIFT** button on the keyboard down and at the same time depress and hold down the mouse left button. Then slightly move the mouse around to see the graph pan.

Once done and you want to return that graph back to the un-zoomed state, simply press the "Reset Axes" icon. This is the leftmost icon shown in figure 65. This will bring the graph and its axes back to the normal setting just like in the case of the 2-D graphs.

3.4.3.4 Using the Position Readout Cursor

Two cursor control icons are shown in figure 65. The cursor readout controls are active in both acquisition and replay just as zoom and pan controls are. Each cursor provides a slightly different function. The "Data Cursor" identified above in figure 65, provides a discrete cursor movement only to legal data points on the screen. For example, for a waveform or a point plot, the Data cursor would only be able to identify actual existing data points. This therefore follows actual points on the screen. The other cursor, called the "Free Cursor", identified as the rightmost cursor in figure 65, will be able to be moved to any location on the screen and provide a continuous position that is graph based and not data based.

The Cursor readout position is located on the status bar at the lower right side of the AEwin screen. The position readout is identified by the **X,Y =** readout box. The position readout will be in actual graph value readings such as Hits, Amplitude, etc. If the graph is a multiple plot graph, the data point read out will be for the exact graph point, so it will be correct regardless of how many plots are on a graph. If the graph is a Binned Scatter or Colored Scatter graph then the readout will display the range of values represented by the data point.

The cursor readouts can be used on any graph screen. Simply select a graph screen by clicking on it. For this example, lets use the Point plot again on the Activity screen. First click on it. Next, select one of the cursors. Once a cursor is selected, it usually is drawn with the center at the origin of the graph (the lower left corner). Note the small hollow circle which identifies the center. Next you need to position the mouse pointer over the center of the cursor and grab the cursor by pressing and holding the left mouse button down. Once done you can move the cursor around the graph. If you have selected the Data cursor, you might have a little trouble moving it around the first few times but you will get used to moving from point to point. The "Free Cursor" is a little easier to operate. Anyway, as you are moving the cursor around (with the left mouse button depressed), you can see the graph coordinates changing as you move. This is a very handy feature to have.

3.4.3.5 Maximizing a Graph to Full Screen

Sometimes you have many graphs on a screen and it is a little difficult to see the axis values clearly. You can expand any graph to full screen by right-clicking the mouse in the desired graph area, and selecting the menu item "Maximize Graph" from the graph menu. You can select the same function from the Main Menu bar, **Window → Maximize Graph** selection. To restore the graph to its normal size and place on the screen, simply, right-click the mouse in the graph area and select "Restore" or **Window → Restore Graph**.

3.4.3.6 Printing any or all Graphs

You can print out any graph, any graph screen or all graph screens, using the various Print commands located in the File menu. To print a given screen of multiple graphs or to print out all screens, simply select the "Print Page(s)" from the files menu. To print out a single graph first click on the graph, then select the "Print Graph" menu item from the files menu. You can also export a graph or screen to a JPEG file by selecting the "Export to JPG" menu item on the files menu or you can "Copy Screen to Clipboard".

3.4.3.7 Pause, Resume, Abort The Test

The Pause, Resume and Abort functions are provided on the Acquisition/Replay Icon toolbar as shown in figure 59. The icons are fashioned after similar visual controls used in the Audio tape recorder business. To pause your test, simply press the Acquisition/Replay icon labeled **Pause**. In pause you can see the test status box change to "Test Paused". You can also see the Time of Test clock stop. At this point, the system will stop collecting AE data, will flush all buffers to disk, but the test will not be exited and the AE data file will remain open. Someone might want to Pause during a test to ignore some event that might add noise to the test (such as pressure or loading ramp -up's, etc.). To resume, just press the **Resume** icon button located next to the Pause button. This restarts acquisition and the Time of Test clock starts back up again showing the new and current time, taking into account the pause time. To Abort the test, simply click the button labeled **Abort** (see figure 59). Selecting this function stops the test and saves only the data to the data file that already exists on disk. The only difference between the Abort and the standard exiting of a an AE test is that the buffer contents are ignored in the case of an abort while <u>ALL</u> data is saved and written to the AE data file in a normal test exit. This function was mainly implemented for SPARTAN products as it could take the ICC's many seconds (when AE data rates were high) to empty their buffers. The abort function was convenient in those cases where the user wanted to quickly stop a trial test without waiting for data in the buffers to clear. The abort function is not needed in newer products as the transfer rates are very fast.

3.4.4 Exiting Data Acquisition

To exit data acquisition, first Pause the test by pressing the **Pause** icon button (see figure 59). Then stop the test by pressing the **Abort/Stop** key (the Abort/Stop key becomes a STOP function key, whenever the system is in Pause). Upon receiving the Pause, all buffers are flushed to disk and upon receiving the Stop, the AE data file is closed and AEwin exits acquisition. The Status box (lower center of screen) indicates "IDLE" meaning that AEwin is ready to perform another test or a replay.

If you have made any setup changes before, during or after acquisition and you want to update the .LAY (layout) file (which you should), you may do so by going to the file menu and choosing **<u>S</u>ave Layout...** or **Save Layout as…** menu item. "**Save Layout**" will overwrite your existing layout file with the new information, while "**Save Layout as…**" will allow you to rename the layout file as a new file. Then you can follow the guidelines to save the new .LAY file. Enter a name such as TEST1.LAY. It is not recommended to overwrite the existing Layout.LAY file since you may always want to keep this default layout file in case of problems in the future. As computer experience dictates, you should always save your work before carrying out a new task such as acquisition in case for any reason the power or computer fails or that you simply forget after the test to save the LAY file. This is always a good practice.

3.5 Operational Sequence of Replaying AE Data

This section helps you understand the sequence of preparing for, recalling and replaying your previously recorded AE test using the PAC provided system Layout (.LAY) files and AE data (.DTA) files. It also gives you insight into a more detailed sequence of data analysis and manipulation of data during replay.

Replaying an AE test is almost identical to that of acquiring data. As a matter of fact many of the same steps that have been carried out to perform data acquisition are repeated. The following are the sequential steps that should be carried out when replaying an AE test using the PAC supplied Layout and AE data files. First we will outline the steps and next we will carry them out. For more details on the actual operation of software and menu items please refer to the proceeding sections of this manual.

1. Read the appropriate system Layout (.LAY) file into the system in order to load the system to your desired set-up and display conditions. We will be using the **Layout4.LAY (**or **Layout2.LAY** on Spartan and PCI-2 systems) layout file in this example.
2. Enter the Replay function.
3. Select the data file (with .DTA extension) name which you want to replay. We will be calling the datafile "Chan24.DTA" for our replay.
4. Start Replay.

5. Move between the various screens, graphs and data listings during and after replay.
6. Carry out some data manipulation functions during replay.
7. Exit Replay.

The following is the step by step detail of replaying an AE data file using the PAC provided **Chan24.DTA** data file. For a replay test, you do not need to have any sensors connected to the instrument since you will be playing previously recorded AE tests.

3.5.1 Loading a Layout File into AEwin

This is identical to section 3.4.1 but is repeated here. From the Menu bar, use your mouse to select **Files** then select **Open Layout...** A menu window called **Open** comes up. With your mouse, select the **Layout4.LAY** (or **Layout2.LAY**) file from the list of layout files so that this file name appears highlighted in the file box next to **File Name:**. This selects it as the layout file that will set up the AE hardware for a 4 (or 2) channel operation with a good, complete default set-up. To finish the sequence, move the mouse to the **Open** box area on the right side of the **Open** window box and click on it (left mouse key) or press <ENTER>. Upon executing this menu, the Layout.LAY layout file is read into the program. If you had made any changes to the current layout file, a message box will pop up asking you if you want to save those changes. If yes, select yes, if no, select no. AEwin will then load and configure itself to the Layout.LAY setup. This completes the reading of the LAY file.

3.5.2 Entering Replay

Entering replay involves steps 2, 3 and 4 of the above sequence. To begin, click the mouse on the **Test Setup** main menu item. On the submenu, click on **Display Mode**. Make sure the **Normal** mode is selected. Also verify that the **Seconds Between Updates** is set for 1 or 2 seconds (this selects the graph update rate) and that the **Hits Before Update is 1000**. If not, set these values by clicking the mouse onto the particular box whose value you want to change and edit those numbers by typing new one's and deleting old one's with the delete or backspace keys on the keyboard. If you want, set in your desired values. When done, click the **OK** window on the bottom of the menu to execute the changes.

Now you are ready to enter the begin replay. This can be started by clicking that icon (that looks like a cassette tape, see figure 59), or pressing the <F10> Function key on the keyboard or by selecting **Replay** from the **Acquisition/Replay** menu. Once selected, a **Replay** window comes up to signal you to select a data file name for replay. Check the name highlighted in the **File Name:** box. If that name is acceptable then you are ready to replay the test by clicking on the “Start” button. If you want a different file name to replay, then use the mouse to select it in the listed data file names. In this case you want to select the name **Chan24.DTA**. Click the mouse on that entry. Then, to begin replay you can hit <ENTER> on the keyboard or click the “Start” button on the menu. At this point AEwin begins replay and is displaying AE information as it appeared during data collection on the test.

3.5.3 Actions within Replay

All the actions carried out during acquisition can be carried out during replay. Please refer to section 3.4.3 for details relating to replay actions. There are several actions you can take in replay to view the graphs and other modes in the instrument. Try these items to see what happens.

3.5.4 Exiting Replay

There is no need to exit replay, when the file is finished replaying, AEwin returns to the Idle status waiting for the user to continue manipulating the graphs in replay, enter replay to analyze another file, make changes to the setup before continuing or enter acquisition.

3.6 Using Line Listing Mode

Line (Dump) listing mode is a very familiar feature and function of PAC’s AE software. PAC has provided a “line by line” listing capability with all its AE products for many years. This has also been referred to as “Line dump” in the past but now we refer to it as “Line listing mode”. The line listing mode allows the user to monitor any and all types of messages being processed by the AE instrumentation. The information is in a “line by line” text format listing offering an additional monitoring capability over the graphing of AE data. With Line listing mode, the user can watch messages related to AE Hits, Events, Time driven data (parametrics), comments, Auto Sensor Test (AST), waveforms and administrative messages. Watching the line listing scroll by, shows how the data coming in is being processed, giving the user an idea as to the AE activity and severity. In AEwin, the Line listing has been improved with the following features over the capabilities found in our other legacy software programs:

- the ability to scroll the line listing up or down (used to only scroll down),
- the ability to select which data can be shown on the line listing
- flexible display of the line listing with the AE graphs, the line listing can be adjusted to take up a small part of the screen, operate within a floating textbox or take up the entire screen.

These features do add some extra utility to the line dump listing that makes it even more important and useful in AE testing. The rest of this section explains how to use these capabilities in AEwin.

The line listing mode can be used in acquisition or replay, and offer the same flexibility in both, however, it is recommended to use this mode sparingly in acquisition as its use might slow down the data acquisition speed by a significant amount. It is therefore recommended to use this when data acquisition rates are low, before a test as a prescreening method or after a test in replay.

The line listing mode color-codes the messages in order to make them easier to spot as they are scrolling by. Please note the following message types and colors as identified below.

Line Listing Message Type	Line listing Color
AE hit data	Blue
AE Event data	Violet
AE waveforms	Blue
Time Driven Data (e.g. Parametrics, ASL, RMS, etc.)	Green
Administrative messages (Pause, Resume, Alarm, etc.)	Red

3.6.1 Enabling Line Dump Listing for Viewing

In normal use, AEwin is kept in graph mode and the line listing is not displayed (as shown in figure 59). In order to view the line listing, two steps need to be performed. First, one has to “Enable” the Line listing mode, and then the line listing mode needs to be selected for viewing. This is done as follows (whether in acquisition or replay).

To Enable the line listing mode, simply click the mouse as follows;

Test Setup → Line Display → Select “Enable Line Display” Checkbox

To Display the “Line Display”, simply press the **F7** function key or click the mouse as follows;

View → Line Listing

As mentioned above, the function key **F7** provides a shortcut to toggling the line listing on and off, once the Line Listing mode has been “Enabled” in the Test setup menu.

Note that whenever the line listing is displayed, it displaces the existing graphs based on its size and location. To restore the graphs simply press one of the “Tile” functions (Tile horizontally or vertically).

The line listing shown above shows various messages. The top line shows a message ID 2 or Time Driven message, while the message ID 1 is an AE hit message and ID 173 is a waveform message. As can be seen, all messages start with a time of test stamp and all data is in time order. In addition, the Time driven message shows some time driven based parametric readings while the AE hit message shows various AE hit based features.

3.6.2 Modifying The Line Display

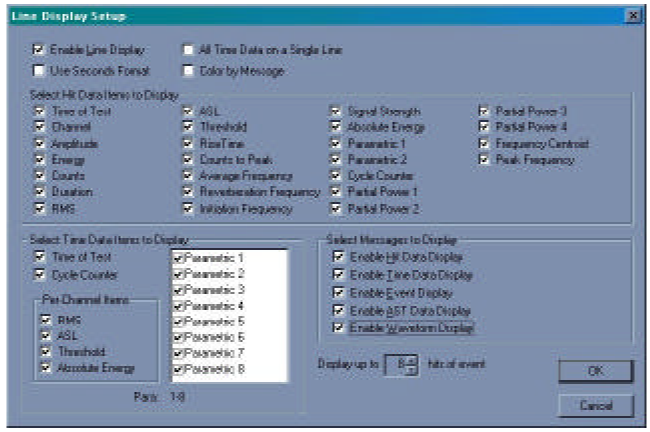


Figure 66. Line Display Setup

Many times the user wants to view a limited set of messages in the line listing screen. For example, maybe it is only important to look at AE hit messages or even just a few features in an AE hit message, even though it is desired to collect much more comprehensive data then that to be viewed. The Line Display Setup menu (click the mouse on Test Setup menu, then select the Line Display menu) allows the user to select exactly which data is to be viewed in the line listing display. The figure at right shows the Line Display Setup menu. There are 4 sections to this menu. The Enable Line display at the top of the menu was discussed in the previous section, make sure the checkbox is clicked if you want to enable the line display mode. The next section is called the "Hit Data Items". These are all the AE features that could be displayed on the line listing, if all the features were enabled in the **Test Setup → Hardware → Data Sets/Parametrics** menu. Simply check those AE hit features you want to view in the line display, even though all the features selected in the Data Sets/Parametric menu will be processed to graphs and the data file.

The "Time Data Items" (shown on the bottom left of the Line Display Setup menu), allows the user to select which Time driven data will be displayed with the Time driven data message. The final "Messages" area (to the bottom right of the Line Display Setup menu), allows the user to select which messages will be displayed. In all cases, just click those checkboxes to enable their display in the Line Listing display.

This menu is accessible in acquisition or replay and can be changed at any time.

3.6.3 Sizing and Moving the Line listing Display

The line listing display, when selected to be viewed, pops up as a full width, anchored text box and anchor's itself just below the AEwin toolbar. However, the Line listing display can be moved, floated or re-sized, simply by using standard WINDOWS functions. To float, just "double click" on the border of the window. Once floated, the Line Listing Display window can be sized using typical WINDOWS sizing capabilities of moving the mouse to the edge of the window border until the double sided arrow appears. Then the user can left click the mouse and drag the window side to be larger or smaller as desired. The user can also move the floating Line Listing Display window anywhere on the screen simply by left clicking the mouse when the mouse cursor is in the title bard (the blue title bar at the top of the Window) and can also anchor the Line Listing Display anywhere on the screen top, bottom, side, by moving one of the Line Listing Display Window edges to intersect with the side where it is to be anchored.

Once the Line Listing Display has been moved, this position will be remembered.

3.7 Clustering Setup and Operation

The purpose of Clustering is to automatically identify and associate groups of hits or events which meet user controlled "spacing" criteria. These clusters are drawn on a point plot screen around the data to visually identify active region(s). Cluster data can also be shown in a tabular form, allowing a quantitative assessment of the activity. Clustering offers the user computer-aided processing to identify regions of AE activity.

Cluster analysis (Clustering) can be activated on any 2D scatter type point plot, regardless of whether it is a Hit or Event (Location) based graph. Clustering in a location graph identifies active areas that require follow-up for defect growth, while clustering on a Hit based point plot graph usually identify hits/events with similar AE feature based pattern's which can lead to hit classification of that data.

The clustering can be turned on and configured from the top of the graph setup menu. The steps in setting up and running a clustering application are defined below. We will be using the example layout and data files, **Cluster.LAY** and **Cluster.DTA**.

Step 1. Set up your Point plot graph and test it to make sure it meets your requirements. The point plot can be a Y-Position versus an X-Position location graph, or it may be an AE feature versus AE feature (e.g. Amplitude versus Duration, etc) plot. When we plot an AE feature versus a feature, we usually call it a "Correlation" graph, referring to the way we are trying to "correlate" one AE feature against another to see how and if they are related. Our example **Cluster.LAY** layout and data file **Cluster.DTA,** shows the example of a Duration versus amplitude Point plot. Please select these, and test and replay the file to become familiar with it.

Step 2. Next we must configure the Clustering function. We do this in the Graph Setup menu by selecting the right tab labeled "Clustering" at the top of the Graph Setup menu (see figure 67).

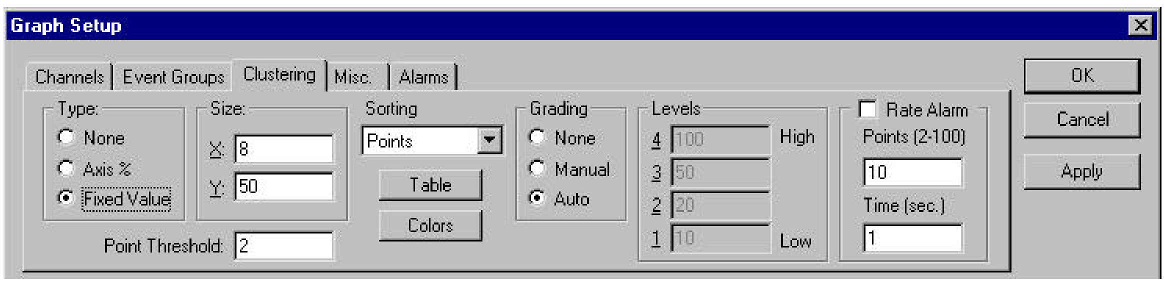


Figure 67. Clustering setup menu (at top of Graph Setup Menu)

Once selected, there are several clustering related parmaters to be adjusted. This includes setup of the cluster size, point threshold, sorting & grading options. Each of these are described further below.

Type & Size: Type controls how we want the Size parameter is interpreted. Setting Type to None turns clustering off. Using Fixed Value allows you to enter the dimensions of the cluster you want into the Size X & Y field directly in axis units. In this case, this is the distance that 2 points must be within to form a cluster. Once the cluster is formed, the distance from the center of cluster to any new points must be less than half this value. Axis % allows you to enter the percentage of the axis range you want to use as the cluster size. For example, a Size X entry of 10 means the cluster can be as large as 10% of the X axis. For example, if Size X were 10 & the X Axis Maximum & Minimum are set to 10 & 50, then to form a cluster 2 points must be within 10% of 40 from one another or within a distance of 4. For graphs using autoscaling & Axis %, the internal size used does not change as the graph scale changes. Instead it is fixed at the value corresponding to the percentage of the initial axis limits.

Point Threshold: Point threshold is the minimum number of data points that must be in the cluster before it is reported. Internally the software maintains a list of up to 100 clusters on a graph, but it will only report clusters that are above the threshold. If your Input Data is set to Hits, the number of points in the cluster is the number of hits. If the Input Data is set to Events, then it corresponds to Events. The minimum number of points that can be in a cluster is 2, but clusters containing just 2 points are not usually of much interest. You can increase the Point Threshold beyond 2 (up to 100) to decrease the number of clusters reported in the Cluster Table.

Sorting: Sorting controls how clusters are reported in the cluster table. The available choices are Points, Energy, Counts, Counts to Peak. The cluster table displays clusters sorted from highest to lowest by one of these quantities. In order for Counts To Peak to be useful, you must have actually collected Counts To Peak as part of your data set. Otherwise the software simply treats it the same as sorting on Counts. When a cluster table is displayed in the current graph window, you can use Ctrl-F6 to control the sort. Pressing Ctrl-F6 toggles the sorting through the list of available options.

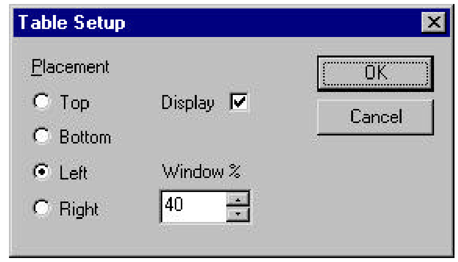


Figure 68. Table Setup

Table: The Table button brings up the Table Setup dialog box shown at the right. The Display checkbox controls whether or not a cluster table is shown in the graph window. The F6 key is a keyboard shortcut for turning the cluster table on & off. The Placement setting controls where the table appears relative to the graph. The Shift-F6 key shifts the table through each of the 4 positions. The Window % setting controls how much of the graph window allocated to the cluster table. If the text in the table grows too large for its window, scrollbars will appear to allow you to see all the text.

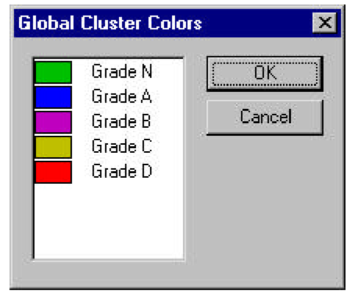


Figure 69.
Global Cluster Colors

Colors: The Colors button brings up the Cluster Colors dialog box shown at the right. You may also access this dialog directly using the Graphing pulldown Colors submenu. Look for the Cluster Colors menu option. This dialog allows you to configure what colors are used in the cluster table & when drawing the cluster rectangles on the graph. These colors are used by all graphs doing clustering. Double clicking one of the entries will cause a standard Windows color dialog to appear allowing you to select a new color for the selected grade.

Grading: The Grading selection controls how clusters are colored. After the clusters are sorted, a grade level is assigned to each cluster based on the sorted quantity. Choosing None causes all clusters to be classified as N (not significant) & they are drawn & reported in the Grade N color. Choosing Auto grades clusters by their percentage of the maximum observed in the sorted quantity for all clusters. It just divides the maximum observed value into 5 equal ranges (<20%, <40%, <60%, <80%,<=100%). For example, if the clusters are sorted on Points & the largest clusters had 250 points in it, then the grading levels used would be 50, 100, 150 & 200. If the Grading is set to Manual, then the Levels section will enable & you can enter your own grading levels. That can be convenient when you want to compare the cluster results from 2 different graphs as it allows you to enforce the same grading levels on both graphs.

Levels: The Levels section is used when the Grading parameter has been set to Manual. It disables when Grading is set to Auto or None. Clusters are drawn in up to 5 colors corresponding to 5 different grades. This section controls the boundary levels between the manual grades. If you are sorting on Points, have Grading set to Manual & entered levels of 10, 20, 50 & 100, clusters with less than 10 points are graded N & by default colored green (see Colors to change). Clusters with less than 20 points would be graded A, less than 50 are B, less than 100 are grade C and any with 100 or more points are considered grade D.

Rate Alarm: The Rate Alarm can be used to monitor a graph for concentrations of activity that occur at high rates. The checkbox allows for simple on/off control. The Rate Alarm has 2 parameters, Points & Time. The Points setting specifies how many points must be observed within the Time period to set off the cluster rate alarm. The number in the Points field can range from 2-100, while the Time setting is specified in seconds & can be any floating point number. For proper functioning, a Time value greater than 0 should be entered or else the alarm will trigger anytime data is added to a cluster. Likewise a large entry like 3.4E+38, the floating point maximum, causes problems as well as it would be so long that the alarm would never trigger. If the software receives enough points in one cluster within the alarm time, a cluster alarm will be generated. For the settings above, that would be 10 points within 1 seconds of one another.

The Cluster Rate Alarm is implemented to not generate extraneous messages. If the user says to check for 10 events in 1 sec., the cluster has to collect at least 10 points before the rate is ever checked. Once the 10th point comes in, the software adds 1 sec. to the time of the first point & checks to see if the 10th occurred before or after that time. If it occurred before that time, then the rate is higher than the user setting & an alarm message is generated. When the cluster gets an 11th point, it's time will be compared with that of the 2nd data point. If the new data maintains the rate above the user cluster rate & the cluster has already generated an alarm message, the cluster stays in the alarm state and does NOT generate a new alarm message. If a cluster is in an alarm state & a new data point comes in after the alarm time, then the cluster alarm state will be reset to no alarm. If the cluster later on gets more data that is again above the user specified cluster rate, it will generate another cluster alarm message. Basically, if the system is flooded with hits, one message will be generated & nothing else until the hit rate drops below the user threshold to reset the cluster & then the hit rate comes back up. When a cluster alarm is generated, the software will generate a status message in the line display reporting the cluster ID & current cluster information.

That is all that's needed to setup clustering.

Step 3. As shown in the example above, we'll used Fixed Value clustering, with X set to 8 & Y set to 50. We'll use Auto Grading and sort on the number of Points. Clicking on the Graph Setup OK button will save the settings. These are the settings in the Cluster.lay example layout file.

Step 4. Now we are ready to run a test and view clustered data. We will replay the Cluster.dta data file and maintain the setup as provided in the Cluster.lay layout file. Upon replaying the file we see a result as shown in figure 70.

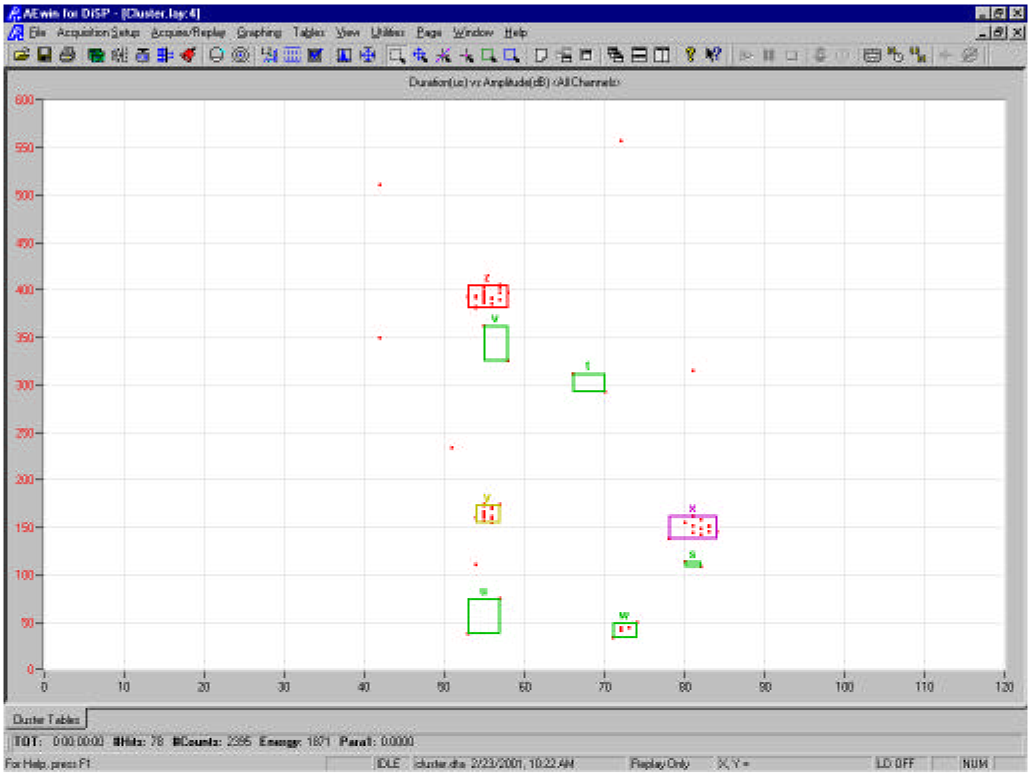


Figure 70. Cluster Graph

From the graph, we can see that we have identified 8 clusters based on the cluster configuration that we have set up. We can also see that there are cluster letters associated with each cluster and that each cluster is colored. The clusters are labeled with a letter starting with "z" as being the most intense and "a" being the least intense. Up to 26 clusters can be reported with the clustering capability built in the software.

It is nice to see this graphical representation of the clustered data, but we may also want to see a tabular listing. We can do this by pressing the F6 function key from the keyboard. When we do this, we get a cluster table as shown in figure 71. This cluster table shares the window with the cluster graph. By pressing the F6 key, you toggle the cluster table on/off.

Cluster	ID	Points	Total Energy	Total Counts	Avg. X	Avg. Y	min Xrange	max Xrange	min Yrange	max Yrange
z	2	28	309	1539	55.43	392.36	53.00	58.00	381.00	405.00
y	1	18	68	415	55.50	164.33	54.00	57.00	155.00	174.00
x	3	13	1206	294	81.62	150.23	78.00	84.00	138.00	162.00
w	5	5	64	33	72.40	42.60	71.00	74.00	34.00	50.00
v	4	2	14	55	56.50	343.50	55.00	58.00	325.00	362.00
u	6	2	5	3	55.00	56.50	53.00	57.00	38.00	75.00
t	7	2	13	3	68.00	302.50	66.00	70.00	293.00	312.00
s	8	2	109	33	81.00	111.00	80.00	82.00	108.00	114.00

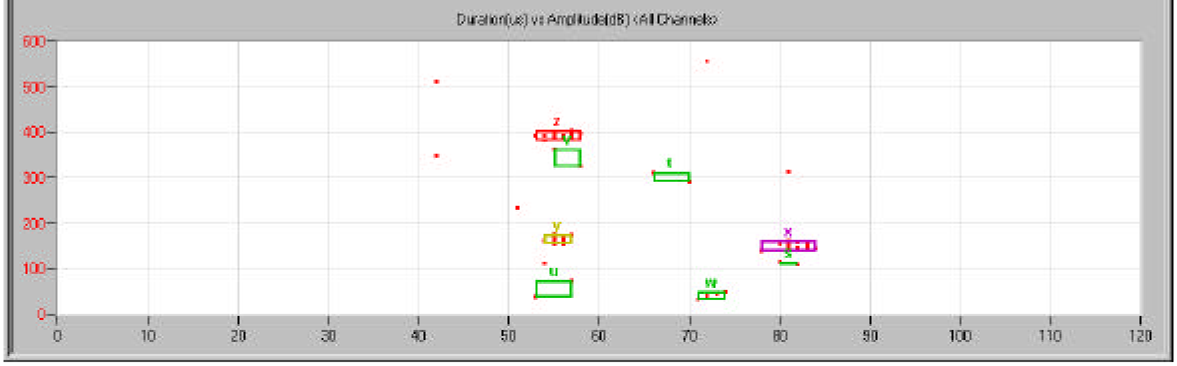


Figure 71. Cluster Table

The Cluster table has the following columns. The leftmost shows the cluster letter, starting with z as the highest. Next is the cluster ID, this is the identification number assigned when the cluster was formed. Next is the Points. This indicates how many points (hits or events) are in a given cluster. The Total Energy is the accumulated energy in the cluster from all the hits or events. The Total Counts is the same for the AE Counts. The Xrange & Yrange min & max values identify the boundary points of the cluster while the Avg. X and Y values identify the center of the cluster. The cluster table is colored in accordance with the color of the cluster box on the Cluster graph.

Step 5. The final step in the process of setting up and running the clustering function is adjustment to get the optimal results. This is accomplished by changing some of the Cluster configuration settings, replaying the test until you feel that you have the most likely and logical results. Maybe you have too many clusters and have set the size too low. Maybe you have set your threshold too low and need to adjust it up. Maybe we should be sorting on energy rather than the number of points, etc.

In our setup, we set the cluster threshold at 2 which is a bit low. We can also see by figure 71 that there are 4 of the 8 clusters with only 2 hits within the cluster. Lets get rid of these by going back to the graph setup menu and changing the Point Threshold to be 3 instead of 2. After we click the OK button, we'll find the cluster table has been updated & now only hold 4 of the original 8 clusters. Note also that those points that are not part of the cluster seem to be randomly spaced, which tells us that it does not seem that these points or hits should have been identified as a cluster. Experiment further to get familiar with the clustering function.

3.8 Graphing in AEwin

The graphing capability in AEwin is very impressive, as it should be since data visualization is very important in AE testing. AEwin is able to provide multiple graphs, multiple plots within a graph, multiple graphs on a screen (or "Page" using Windows terminology), and multiple screens (Pages) full of graphs. The graph types can multi-dimensional (2D and 3D) graphs, multi-colored graphs and multiple graph types including: Point plot, Histograms, Waveforms and Spectrum graphs. Graph axes can be set up to be fixed scaling (always stays at a fixed minimum and maximum value), automatic scaling (compression or sliding scale) logarithmic or linear scaling. The graphs can be set up to plot anything versus anything, limited only by the operators imagination.

Before getting into setting up Graphs in AEwin, it is important to define the terminology used in graphing on AEwin. This will be used throughout the manual.

Plot: A plot is defined as a single graph within a graph (or graph window). Since a graph can be set up with multiple graphs inside, we need to distinguish the difference between the word graph as a graph window and the fact that there can be multiple graphs in a single graph window. We therefore call this a plot. So now we can say there are multiple plots within a graph or graph window.

Graph: A graph is a single Window on a Screen or Page. A graph is controlled by the Graph setup menu. The graph can have multiple plots of the same type within it, but these are all set up by a single specific graph setup menu.

Screen or Page: A screen or Page is the graph(s) that show up in the display area of the AEwin screen. This the area between the top and bottom tool bars (see figure 8). A screen or page has a page tab located at the bottom of the screen to select between the screen pages.

Now that we have definitions we can provide an example. Figures 61 –64 show examples of different screens. Four are shown, Figure 61 shows what we have labeled as an activity screen. The page tab at the bottom of the screen has been labeled "Activity Screen" to let the user know what types of graphs are set up on this screen page. Figure 62 shows a waveform and FFT screen page. Its tab also identifies it as "Waveforms". Figure 63 shows an example of a 3D screen page with the appropriate Screen Page tab labeling. Figure 64 shows an example of some channel by channel line plots with an appropriate screen page tab.

In regards to graphs, figures 61 – 64 show multiple graphs on each screen. Figures 61, 63 and 64 shows a 4 graph screen while figure 62 shows an 8 graph screen. There is no limit to the number of graphs that can be placed on a screen, the only limitation is a physical one, pertaining to the readability of the graphs. As far as multiple plots on a graph, the top two graphs of figure 61 shows graphs with multiple plots. On the top left plot there are 4 different point plots on one graph, while in the top right graph there are two line plots.

The figures 61 – 64 which are provided by the example **Layout4.LAY** and the data file **Chan24.DTA** give a good idea as to the functionality of AEwin as far as graphing is concerned. Since all the major examples for graphs and graph setups can be found in this **Layout4.LAY** file, it provides an excellent reference for how to set up the different types of graphs. Please use this example as such. The following subsections will provide information on how to generally set up a graph and screen page.

3.8.1 Graph Setup Procedure

The following is the step-by-step process in setting up graphs in AEwin. This assumes that you are starting from a very simple single screen, single graph arrangement, into a multiple graph, multiple screen setup.

1. Before starting, give a little thought to the number of screen pages your application will need, what the theme will be for each screen page (for tab labeling considerations) and how many and what type of graphs you would like on each screen. The better you plan this out, the easier and faster the graphing setup process will be. Use as an example the theme provided (and theme tabs) in the **Layout4.LAY** (or **Layout2.LAY** on Spartan or PCI-2 systems) layout file whose graphical results are shown in figures 61 – 64.
2. Find an existing Layout file that gets you partially to your goal. You can then edit that layout file to meet your exact needs. It is always easier to start with an existing layout. You can easily copy and past graphs that have already been setup, saving a lot of time. If this is not possible, select **File → New Layout** which will start with 1 screen page (labeled Page 1) and one graph (a Hits versus Time graph).
3. Create the number of screen pages that you need by adding and deleting screen pages, then edit the Page tab titles to the desired name or description of what that page will contain.
4. Create the number of graphs you need in each screen page by adding or deleting graphs.
5. Size your graphs as desired and tile them as desired so that they are laid out in the order that you wish.
6. Individually setup each graph in each graph screen to get the desired result. Enter the graph setup menu for each graph by right clicking the mouse when it is inside the graph, then select the first pop-up menu called "Graph setup" to enter the graph mode.
7. Once you are done setting up your graph(s), test them out in acquisition or replay to make sure they act as expected. There will always be the need for some adjustment, you will rarely get things perfect the first time.

3.8.2 Screen Page and Tab Management

As with all Windows operations, there are various ways to add and edit Screen pages. The most convenient is by Right-clicking your mouse on an existing page Tab, adjacent to where you want to add the page. A Page/Graph setup menu will appear. To add a New Page after the selected page, simply select **the New Page** menu item. To insert a new page before the selected page, select the **Insert Page** menu item. In either case, a new page and page tab will appear. The page tab will be labeled as "Page X".

There are other ways to add a page including selecting the **New Page Icon** from the icon toolbar (looks like a blank page), which will always place a new page at the end of the screen page tab list. You can also go to the main menu bar and select the **Page** Menu to make the **New Page** and **Insert Page** selections.

Once you have created a new page, it will be empty (no graphs). You will add the desired graphs and will label the page tab. You may add as many graphs as you wish to the screen page.

To label the page tab simply right-click on that tab and select the Rename Page menu item. This will allow you to enter a page name. There are no major restrictions to naming a page tab. However do not make the page tab title too long as it might take up too much space.

There is one other screen page editing function, which allows you to remove or delete a screen page. Simply right click on the screen page tab and select the **Delete page** function. The screen page and tab will immediately disappear. If you had graphs in the screen page that you deleted, they will be deleted as well.

3.8.3 Adding, Placing and Sizing Graphs on a Screen Page

Once you have a Screen Page set up, you need to begin adding and placing graphs on it. If you know how many graphs you want and what types they will be you can quickly add and edit the graphs. If all the graphs are to be the same style (e.g. waveform graphs, one for each channel), you should start by adding a graph, defining it and then copying it as many times as you need. Then you can size the graphs and create the layout (position of the graphs) as desired and then you can edit the graph setup to finalize the graph function. If each graph is to be different, you can either copy similar graphs and paste them into the new screen page or you can simply add as many graphs as you want on the screen and edit the graph setup for each graph added.

To add a graph to the graph screen, simply right-click you mouse anywhere in the screen page and select the **New Graph** menu item. Alternatively you can left-click the new graph icon from the icon toolbar menu. This icon shows 3 staggered graphs. Additionally you can add a new graph by selecting the **Graphing → New Graph** main menu selection. Whichever way you select a new graph, a single graph will appear. To add multiple graphs on the screen, simply perform this function multiple times.

Once you have selected the number of graphs you want on the screen, you need to tile them. Tiling allows you to place them next to each other so that each part of every graph can be seen. There are two tiling options. You can use **Tile Horizontal** or **Tile Vertical**. The most convenient way to perform this function is to select one of these functions from the icon tool bar. The Tile Horizontal icon is shown as two graphs stacked on top of one another while the **Tile Vertical** icon shows two graphs side by side. Alternatively you can select these from the **Window** main menu. Tile Horizontal will favor a length-wise positioning of the graphs and will usually make the graphs longer than taller. Tile Vertical will give preference to a vertical direction. Choose one of these to place the graphs in a nice ordered manner.

Once the graphs are placed on the screen, we can alter their sizes. We do this using the standard Windows conventions of moving the mouse to the edge of a graph until we see a double arrow and then left-click the mouse and move the edge in or out to make the graph larger or smaller. We can also move graphs by right-clicking on the graph and selecting the **Move Graph** menu item. An example of sizing graphs can be seen in figure 63 where we have sized the 3D graph to be larger than the associated graphs.

The final function that we need to perform is that of editing or setting up the graphs to perform the desired display function.

3.8.4 Graph Setup Function

This section discusses the graph setup menu and how to set up a graph. First, we select the graph that we want to modify. We do this by right clicking the mouse when it is inside the graph region of the graph that we want to work on. Once we do that a menu appears. This menu gives us many choices but we will select the top one called "Graph Setup". Upon selecting this a graph setup menu appears like that shown to the right.

This shows us how we have setup the Graph setup menu for a Hits versus Time graph. It gives us a lot of insight into how the graph setup menu works and how to set it up. Lets note first the layout of the menu. We see at the top of the menu, a selection area for Channels, Event Groups, Clustering, Misc and Alarms. These settings allow us to configure those items. When in the Channels Tab, we can select which channels and/or channel groups will be displayed on the graph that we are setting up. In this case we are selecting all active channels for viewing in the graph. You can see that we have no groups set up in Event Groups if you select that tab. Clustering allows you to set up parameters that link closely spaced hits/events together for point plot graphs. Misc allows you to set various options like turning on/off the legend control. Alarms allow you to create and customize graph alarms on this graph.

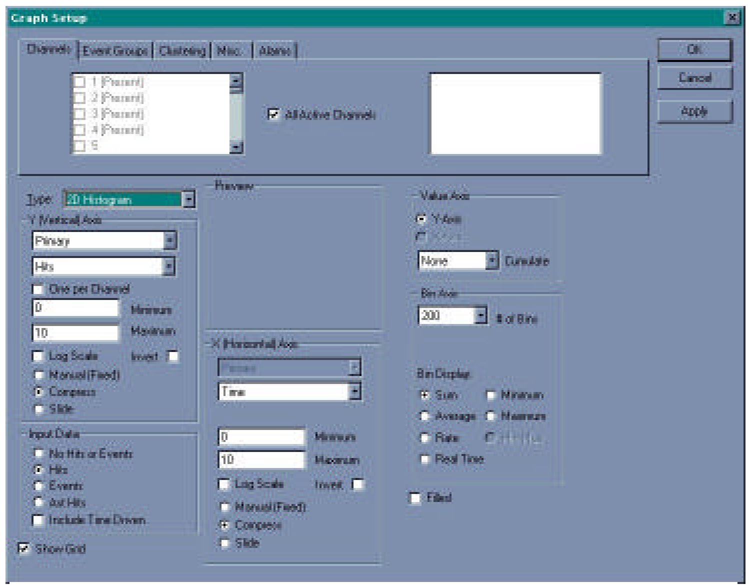


Figure 72. Graph Setup Menu for Hits versus Time Graph

The next menu area is the Graph Type selection box. This is located just below the Channel, Event Group and Clustering selection area. Various graph types can be selected included 2D Histograms, 2D Scatter (Point Plots), 3D Histograms, waveforms, Power Spectrum plots, etc. With the selection of the graph type the graph setup menu below this may change to offer the special configurations needed by that graph type. For the hits versus time application we will use the 2D Histogram.

Below the Graph Type selection, is the Y-Axis setup menu area. Going down one item at a time in this menu is the Plot # selection within the graph. This selection allows you to select more than one plot to be graphed. The one being selected for setup is the one shown. We have only selected one plot in this graph called the "Primary".

Next is the Y- Axis parameter to be plotted on the graph. By clicking this, you can see many selections. However, we have selected Hits. This will display the number of hits (on all channels) detected, on the Y-Axis.

The checkbox "One per Channel" allows us to select a unique per channel plotting color that will give us a multiple color by channel plot. In our case for hits and all active channels, if we selected this checkbox, we will get a multiple plot graph, each plot a different color based on the hits from that one channel, up to 6 plots on one graph. If not checked, we will only get one color plot.

The next two edit boxes allow us to set the starting Y-axis settings (minimum and maximum).

The next checkbox “Log Scale” allows us to set a log or linear graph scale.

The next 3 radio buttons are related, allowing you to select one type of graph scaling. “Manual (Fixed)” will force the graph limits as set above to remain fixed. “Compress” will compress the graph so that the minimum graph value remains but the maximum keeps changing as the graph limit is exceeded. And the “sliding” selection will allow both the minimum and maximum limits to change or slide as data is received that is beyond the current limits.

The next box allows us to select what type of Input data we are plotting. In our case since we are plotting hit data, we want to choose the Hit data for plotting.

Below this is a checkbox for displaying the a grid on the graph.

The next column to the right, shows the graph preview at the top and then the X-Axis settings.

The X-axis settings have similar setup boxes as were described for the Y-Axis and will not be described here. Just note how they have been set up to display the Time parameter and that we have set up the minimum and maximum graph values and a compression scaling so that we can see all data from the start of the test.

The last column on the right changes according to the graph type being set up. If a 3-D graph were being set up, this would be the column for the Z-axis setting. If a Point plot were being set up, there would be no extra column as the points do not need to be conditioned for display.

Since we have selected a graph type of 2-D Histogram, a “Value and Bin Axis” setting menu appears. The Value axis sets which axis the histogram or bars will grow. For our example we are selecting the Y-Axis as the Hits will grow in the vertical direction. We set a cumulate mode if we want the data in the histogram to build upon the previous bin or bars.

The bin axis settings allow us to set the resolution and how the data that makes up a bin get counted in the histogram bar (or what we call a bin). In general, the larger the number of bins, the finer the bars. If your bin axis is time you usually want to have a very high number. If your bin axis is channels, you would like to match the number of bins and channels. In terms of the bin display, you can choose whether you want to sum up all the data in the bin or if you want to average the data in the bin or if you want a rate to be displayed (e.g. Hits/second). To understand, this assume that we have a test for 100 seconds and that we have 100 bins. Each bin will contain one second’s worth of data. We can decide to “add it up” and display it as a bin sum, average the amount of data received in that time period or display a rate. In this case since the bin size is 1 second, all the numbers would be the same for this setting, but for any other case, they would be different.

Learn more about these settings by making changes and seeing the effect.

At the bottom of the third column is a histogram setting that allows you to fill the histogram bars or keep them hollow.

Please note and try to make sense of all the selected menu settings. Although it might look complex at the start, if you have gone through these settings, one at a time you will see that all is quite simple. Exit the graph menu by selecting the OK button at the top right of the Graph setup menu.

By looking at the top of the graph we see its graph title of “Hits vs. Time (sec) <all channels>”. This summarizes what is being displayed. First is the graph type “Hits vs. Time (sec)”. Next we are displaying data from all channels.

Now that we are finished, we see that we have set up a Hits versus time graph and are ready to test it. Test it and make any corrections, until you get the desired result. If we have other graphs, we set them up in a similar way, one at a time until all the graphs are set up.

Now we are ready to proceed with a test or a replay. As a reminder, always save your Layout file before trying it out. It is not fun to have all your work disappear because power went down or something happened to lose the layout.

3.9 Hit/Event Linking and the Data Lookup Display Dialog Box

Hit/Event Linking is a way to retrieve hit/waveform or event information on specified points on all types of scatter graphs (“2D Scatter”, “2D Binned Scatter”, “2D Color Scatter”, “3D Scatter”, “Spherical Location”, etc.). Once a point or area is selected a dialog box is displayed showing a mini-linedisplay containing the hit or event messages linked to that point (or all points in that area). The associated waveform(s) or power spectrum(s) (if any) are displayed above it. Furthermore, a simple location plot is available with most location modes that displays the location of all selected event points. The user can hide/display and customize this plot as desired.

During hit/event linking small cursors (crosshairs) are placed on all other valid 2D scatter/binned/color graphs highlighting the selected hit or the first hit of the selected event.

Hit/Event linking can be performed at any time during or after a test that has autodump ON or a replay. A data file MUST be present for this feature to be available. Changing location settings will disable hit/event linking until a new test (with autodump on) or a replay is performed.

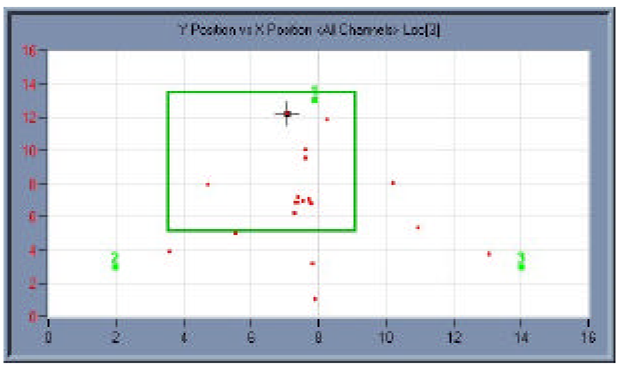


Figure 73: Area-Based Hit Event Linking

Figure 74: Point-Based Hit Event Linking

3.9.1 Procedure

1) Start a test with autodump ON or begin a replay.
2) Select a graph to work with by left-clicking on it. It’s border will darken.
3) Select the point(s) to work with. There are two ways to do this:
   a) Point-based: You can select an individual point by using the data cursor. Activate the ‘Data Cursor’ from the toolbar. Position the cursor over the desired point. Then right-click the graph and select ‘Hit/Event Linking’ from the menu that pops up.
   b) Area-based: You can designate a rectangular area on a 2D graph. Activate ‘Area Hit/Event Linking Mode’ from the toolbar. If you are working with a 2D Scatter or 2D Binned Scatter graph that has multiple Y axes defined it will prompt you to select which Y Axis to work with. Then use the mouse to select an area on the graph (as if you were zooming).

   This begins the Hit or Event linking process. Depending on the graph and the size of the datafile this may take some time. Once finished, the Data Lookup Display dialog box will be displayed and the cursors will be positioned on the appropriate graphs.
4) The cursors can be cleared by right clicking any graph and selecting ‘Clear Lookup Cursors’, or by exiting the dialog using the ‘Exit and Clear Cursors’ toolbar button. Exiting the dialog using the ‘Exit’ toolbar button will leave the crosshairs on the graphs.
5) You do not have to exit the dialog to perform another hit/event link operation. Repeat steps 2 and 3 at any time to refresh the dialog with new data.

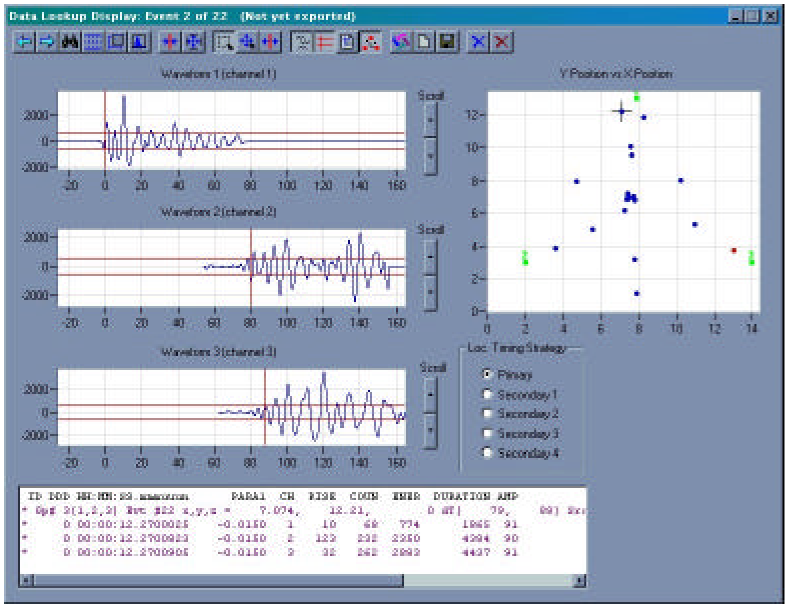


Figure 75: Data Lookup Display Dialog Box

3.9.2 Controls

The Data Lookup Display dialog box has a number of controls, most of which are located on a toolbar at the top of the dialog. These are described below. As you move the mouse cursor over each toolbar button a ‘tooltip’ will popup to display the button’s name. Some of these controls are only available in event linking. Other controls are only available if the Waveform Option is present.

<u>Prev/Next Buttons</u>: If there are multiple hits/events associated with the selected point(s) then you will be able to view all of them. Use the prev/next buttons to step through them sequentially. The cursors (crosshairs) on any 2D point plot graphs will move appropriately.

<u>Select Button</u>: Instead of using the Prev/Next buttons to step through a large number of hits/events, the ‘Select’ button can be used to jump to the desired hit/event by simply entering it’s hit/event number.

<u>View All Hits/Events Button</u>: You can view all selected hits or events together by clicking the ‘View All’ button. This will popup a dialog box with a large line display showing all hits or events associated with the selected point or area. If you are working with a Hit-based graph (as opposed to an Event-based one) then you can export these hits to a new data file by clicking “Export to DTA”. This cannot be done with events here. You can export events one at a time from the main dialog box. See section 3.9.3 below.

<u>Set Power Spectrum Width Button</u>: Clicking this button will open a dialog box allowing you to set the power spectrum width. You can set a specified width or accept the default.

<u>Location Graph Setup Button</u>: Clicking this button will open the ‘Location Graph Setup’ dialog box. From here you can customize the location graph, by selecting axis parameters, limits and autoscaling.

<u>Reset Unexported User Changes Button</u>: Clicking this button will reset any unexported changes you have made by use of the time-of-arrival cursor. Once you ‘Export’ the current hit/wave/event the change becomes permanent in the exported file and cannot be reset.

<u>Reset Axes Button</u>: Clicking this button will allow you to reset the axes of one or more graphs. A dialog box will be displayed for you to specify which graphs. You can also reset a waveform graph by right clicking it and selecting ‘Reset this graph’s axes’.

Select Zoom Mode Button: Clicking this button will select the 'Zoom' mode for all graphs and clear the previously selected mode. In Zoom mode you can use the mouse to select an area of a graph to view in greater detail. Use the 'Reset Axes' button to view the original graph again.

Select Pan Mode Button: Clicking this button will select the 'Pan' mode for all graphs and clear the previously selected mode. In Zoom mode you can use the mouse to drag the viewable window of graph to view data that is currently beyond the graph axes limits. Use the 'Reset Axes' button to view the original graph again.

Select Cursor Mode Button: Clicking this button will select the 'Select Cursor' mode for all graphs and clear the previously selected mo de. In 'Select Cursor' mode you can use the mouse to drag the red 'Time of Arrival' cursors on waveform graphs forward or backward to effectively change it's time of arrival. While in this mode the mini line-display is replaced with a table showing the time of arrival for each graph. If you do this and then click the 'Force Recalculation of Event' button the event location will change and the new (modified) location will be displayed on the location graph as a black X. Use the 'Reset Unexported User Changes' button to undo these changes (but only BEFORE you export them).

Synchronize Waveform Display Button: When this button is checked the waveforms will be displayed in the same time reference. i.e. If the second waveform in an event has an arrival time 20 us after the first waveform then the entire waveform will be positioned 20 us to the right so it's time of arrival (red line) will be positioned at 20 us. If the button is not checked, then all waveforms are left justified on the graphs (their time or arrivals will be positioned at 0 us). This does not modify the waveforms in any way. It is simply a display preference.

Display Threshold Lines Button: When this button is checked, red horizontal lines appear on the waveform graphs showing the threshold. When this button is unchecked these lines are hidden.

Display Power Spectrum(s) Button: The power spectrums can be viewed by clicking the 'Display Power Spectrum(s)' toolbar button. This will replace the waveform graphs with corresponding power spectrum graphs. Click it again to return to viewing waveforms.

Show Location Graph Button: The location graph can be displayed by clicking the 'Show Location Graph' toolbar button. Clicking it again will hide the location graph. Note that this graph is only usable in event linking and only when the event being viewed has more than one hit. You can customize this graph by clicking the 'Location Graph Setup' toolbar button.

Force Recalculation of Event Button: After changing the time of arrival of one or more waveforms in an event, click this button to recalculate the event location. If successful, the new event will be shown in the mini line display and the location graph will be modified to show an X at the location of the modified event. If a new event location could not be created using the new time of arrivals then the mini line display will show a message indicating the problem. Use the 'Reset Unexported User Changes' button to undo these changes (but only BEFORE you export them). Note that certain actions can automatically force a recalculation of the event. These actions include: Changing the location timing strategy and exporting the event.

Export As (New File) Button: Clicking the 'Export As (New File)' button allows you to create a new datafile and export the currently selected hit/wave or event to that datafile. See section 3.9.3 for details.

Export Button: Clicking the 'Export' button allows you to export the currently selected hit/wave or event to a datafile. If you have already specified a datafile for export then it will use that datafile. If not then you will be prompted to specify a new datafile name as if you had clicked the 'Export As (New File)' button. See section 3.9.3 for details.

Exit Button: Clicking this button will close the Data Lookup Display dialog box without clearing the cursors (crosshairs) placed on other graphs to denote the current hit (or first hit of the current event).

Exit and Clear Cursors Button: Clicking this button will close the Data Lookup Display dialog box and clear any cursors (crosshairs) placed on other graphs to denote the current hit (or first hit of the current event).

Loc Timing Strategy Radio Buttons: The bandpass filters and timing strategies defined in the 'Timing' page of the 'Location Setup' dialog box can be applied to the waveforms/events. Use the radio buttons in the 'Loc. Timing Strategy' section to select a strategy. The waveform/power spectrum graph(s) and the mini-line display will be refreshed to show it after filtering. The default 'Primary' strategy does not apply a filter. Note that the selected strategy must have an enabled filter for a filter to be applied. See section 3.9.7 for information regarding the 'Custom Arrival' timing feature, which is particularly useful in this dialog box.

Scroll Buttons: The 'Scroll' buttons (next to each graph) are used to change which waveform is displayed in a particular graph. They allow you to 'scroll' through the list of waveforms up or down as desired. This is particularly useful when the selected event has more than 3 waveforms.

3.9.3 Exporting Hits, Waves and Events

One feature available in the Data Lookup Display dialog box is the ability to 'export' the current hit/wave or event to a new datafile. This can be used as a powerful and flexible way of filtering data, as you can decide on a case by case basis what to export to the new file. If you have made any changes to the time of arrival(s), then these changes are exported as well (see section 3.9.4). To export the currently selected hit/wave or event simply click the 'Export As (New File)' button and enter a filename for the new datafile when prompted. After you do this the title of the dialog box will indicate that the currently selected hit/wave or event has been exported. Subsequent exports to the same file can be accomplished by selecting a new hit/wave or event (prev/next/select buttons) and clicking the 'Export' button.

For Systems that have the Moment Tensor Option: When you perform an export on a system that has the Moment Tensor Option you will be asked if you want to export to PT files as well. This is used for moment tensor (Sigma3D). If you aren't using this then click 'no'. See the file 'Waveform Event Synchronization.doc' for details.

3.9.4 Changing the Time of Arrival of a Waveform and Recalculating an Event

Another powerful feature of the Data Lookup Display dialog box is the ability to 'Modify' a hit/waveform's time of arrival, and (if event-linking) recalculate the event location. To do this, simply use the 'Select Cursor' mode and use the mouse to drag the (red) time of arrival cursor on a waveform graph to the desired point in time. As you do this you will see the new time of arrival updated on a table in the mini line display. If you are in event linking then you can recalculate the event location by clicking the 'Force Recalculation of Event' button. This will recalculate the event using the new time of arrivals. If your event has more than 3 hit/waves then you might have to use the scroll controls to access some of the waveforms to modify.

If you export a hit/wave or event that has been modified in this manner then the changes will be saved to the new datafile and accessible using the 'Custom Arrival' timing feature in location (see section 3.9.7).

3.9.5 Other Features

1) All settings in the Data Lookup Display dialog box are saved when the layout file is saved. This includes the various on/off preferences ('display threshold lines', 'show location graph', etc), location graph setup and custom power spectrum width.
2) If the hit/event linking dialog box is open when a 'cluster/area history' operation is performed then the dialog box will be updated with it's data.

3.9.6 Notes

1) Try loading the 'HE-LINK.LAY' layout file and replaying 'HE-LINK.DTA'. Hit/Event linking works well on this example dataset.

2) “2D Binned Scatter” and “2D Colored Scatter” graph types store their data in a ‘binned’ grid structure much like a Histogram (though in 2 axes). This means that each ‘point’ on these graphs represents an area rather than an absolute point. The cursor display (near the bottom right corner of the screen) shows the extent of the area represented by the point. Hit/Event linking will locate all hit/events that fall into that area (lower bound inclusive, upper bound exclusive).
3) Selected hit/events are not highlighted with crosshairs on “3D Scatter” and “Spherical Location” graph types, though hit/event linking can be initiated from them.
4) It is possible to perform hit linking on TRA datafiles even though they lack hits. In this case only the waveforms will be displayed.
5) Event Linking functionality can be disabled by unchecking the “Enable Event Linking” checkbox in the Acquire/Replay menu (this setting is NOT saved in the layout). Doing this may result in a modest performance improvement in high data rate tests with large numbers of events. Once disabled it cannot be re-enabled until a new test or replay is performed. Disabling Event Linking will not disable Hit-Linking functionality.

3.9.7 Custom Arrival Timing Feature

When a user-modified waveform is exported it is saved in it’s unmodified state to the new datafile. The user-modified TOA (time of arrival) is also saved for future use. This can be accessed through the use of the ‘Custom Arrival’ timing feature.

Before starting the replay, enter location setup. Set one of the timing strategies in the timing page of the location setup dialog box to the ‘Custom Arrival’ feature. If you want location plots to use the modified TOAs then select this strategy in your location group’s ‘Timing Strategies’. Or, you can simply set the Primary strategy to ‘Custom Arrival’ so all location groups will use it. Since ‘Custom Arrival’ only works in replay, this will default to ‘FTC’ (First Threshold Crossing) during acquisition.

<u>If you want to see the modified TOAs in hit/event linking:</u>
When the Data Lookup Display dialog box is opened it will plot the locations and waveforms based on the currently selected ‘Loc Timing Strategy’. Note that the dialog will remember your previous setting and use it by default the next time it is loaded. If this strategy uses a ‘Custom Arrival’ timing feature then all the locations will be plotted using the modified TOAs. If this strategy doesn’t use a ‘Custom Arrival’ timing feature then all locations will be plotted using the original TOAs.

Once the Data Lookup Display dialog box is loaded you can switch strategies through the use of the ‘Loc Timing Strategy’ radio buttons. Doing so will NOT re-plot all locations but it will re-plot the current one AND reposition the TOA cursors on all current waveforms. You can switch back and forth between a timing strategy that uses ‘Custom Arrival’ and one that doesn’t to view the difference between the two.

3.10 Cluster/Area History

Cluster History and Area History provide the ability to view detailed graphical information about AE activity in a specified area on a 2D Scatter, Binned Scatter or Colored Scatter graph (called the ‘source’ graph). This area can be defined by selecting a cluster (Cluster History) or by designating an area manually (Area History). This information is displayed on any number of graphs defined and designated by the user as ‘History Graphs’. These graphs remain inactive until the user starts a Cluster or Area History process. When the user does so the software ‘replays’ the data contained in the selected cluster or area onto all history graphs. The history graphs then remain active for the remainder of the test or replay, accepting/displaying any incoming data that would fall within the original bounds of the cluster or area at the time the process was started. This process can be repeated any number of times during a test or replay.

3.10.1 Setup

1) To use Cluster History you need to create at least one cluster graph before starting the process, usually before starting the test or replay. Area History does not require this.

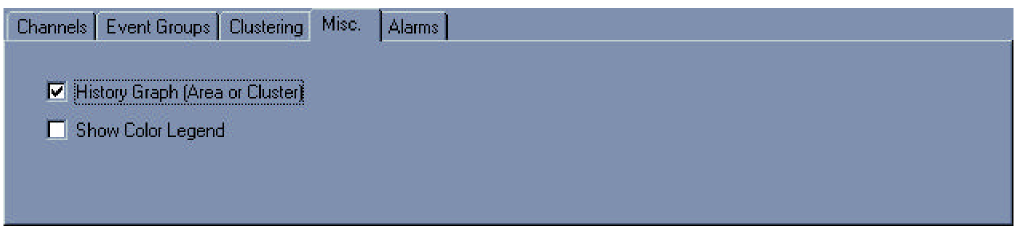


Figure 76. History Graph Checkbox

2) Create as many history graphs as desired. This can be done at any time before you start the history process. Any graph can be designated as a ‘History Graph’ by checking the ‘History Graph (Area or Cluster)’ checkbox on the ‘Misc’ page of graph setup. The graph’s title will then include the ‘(Hst)’ tag.
3) Start an acquisition test (with autodump on) or a replay.

Figure 77. Context Menu

3.10.2 Starting a Cluster History Process

Cluster History is started by right clicking on a cluster graph and selecting ‘cluster history’ from the menu that pops up. If this option is grayed out then it means one of the following:

1) There are no clusters on the specified graph.
2) You disabled ‘Event Linking and Cluster/Area History ’ from the Acquire/Replay dialog when you started the current test or replay.
3) You started a test without autodump on.
4) You started a history process or Hit/Event Linking process that hasn’t completed yet.

If there are more than one cluster available on the selected cluster graph then the program will prompt the user to select one from a list.

3.10.3 Starting an Area History Process

Area History involves manually designating a rectangular area on the graph. Activate ‘Area History Mode’ (blue square) from the toolbar.

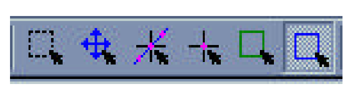


Figure 78. Area History

If this option is grayed out then it means one of the following:
1) The active graph is of an invalid type (i.e.: histogram, waveform, 3D graph, etc).
2) You disabled 'Event Linking and Cluster/Area History' from the Acquire/Replay dialog when you started the current test or replay.
3) You started a test without autodump on.
4) You started a history process or Hit/Event Linking process that hasn't completed yet.

If you are working with a 2D Scatter or 2D Binned Scatter graph that has multiple Y axes defined it will prompt you to select which Y Axis to work with. Then use the mouse to select an area on the graph (as if you were zooming).

3.10.4 Execution

The Cluster/Area History process is detailed below:
1) All history graphs are re-initialized. Any data on them (from a previous history process) is cleared.
2) The setup of all history graphs are modified to reflect the setup of the source graph.
   - Channel sets, location group sets, and the data source (hits/events) are made identical to the source graph.
   - The min/max limits of any graph axes which share the same graph quantity as on the source graph are changed to reflect the limits of the cluster or area.
3) Special graph filters are set on all history graphs to reject any future incoming data that does not fall within the (original) cluster or area from being displayed. These filters persist until changed by another history process, the user turns off the 'History Graph' checkbox on the graph or until the end of the test/replay.
4) All history graphs are enabled. This allows them accept and display historical and future incoming data.
5) Historical data (the data within the cluster or area) is displayed on all history graphs.

3.10.5 Notes

1) A Cluster/Area History process can be started at any time during or after a test that has autodump ON or during/after a replay. A data file MUST be present for this feature to be available.
2) It is important to note that the bounds of a history graph reflect the bounds of the cluster or area at the time when the process was started. These bounds do not change if the cluster itself grows.
3) Cluster/Area History on event based source graphs is disabled if the 'Enable Event-Linking and Cluster/Area History' checkbox on the Acquire/Replay dialog is disabled before the current test or replay begins.

3.11 Graph Alarms

'Graph Alarms' is a feature that enables certain graph types to trigger an alarm whenever data is plotted on them above one or two pre-set thresholds ('warning' and 'trip'). They are available on 2D Histograms, 2D Scatter graphs, Binned Scatter graphs and Colored Scatter graphs during data acquisition.

3.11.1 How to setup a graph alarm:

An 'Alarms' tab is available in graph setup (for graph types that can use them).
1) Check the 'Enable Graph Alarm' checkbox to turn on graph alarm functionality for this graph.
2) Check the 'Enable Warning' checkbox to enable the alarm 'warning' level. Check the 'Enable Trip' checkbox to enable the alarm 'trip' level. Either or both may be used at the same time.
3) Set the vertical axis thresholds for the alarm levels you have enabled.
4) Select which vertical axis controls the graph alarm (Primary, Secondary-1, etc).

3.11.2 How an alarm is detected/triggered:

Graphs that have an enabled graph alarm will display horizontal lines at the levels of the thresholds set in graph setup (Green for warning, Red for trip).

A graph alarm 'Warning' will trigger when all of the following occurs.
- The 'warning' level is enabled for that graph.

- New data is displayed on this graph at or above the green threshold line.
- No graph alarm (Warning or Trip) is currently active (on this graph).

An alarm 'Trip' will trigger when all of the following occurs.

- The 'trip' level is enabled for that graph.
- New data is displayed on this graph at or above the red threshold line.
- No graph alarm trip is currently active (on this graph).

'New' data is defined as any data that is plotted after the alarm was last reset. Note that the alarm is automatically reset at the start of the test.

3.11.3 What happens when an alarm is triggered:

When a graph alarm is triggered several things happen:

- The audio monitor (if installed) sounds an audible beeping sound. This continues until the alarm is cleared or the test ends.
- The alarm output (WARNING or TRIP as appropriate for the level) is set high. This stays high until the alarm is cleared or the test ends.
- An alarm message (16) appears in the Line Display in red, and is saved to the datafile if autodump is on.
- A small dialog box appears, displaying the conditions of the alarm. The alarm can be cleared by clicking the 'Clear Alarm' button. You can exit this dialog without clearing the alarm if you wish. It can be accessed later by selecting 'Display Last Alarm…' from the Acquire/Replay menu.

3.11.4 Tips:

1) Graph alarms are checked when the graphs are refreshed. If you want to increase the rate at which they are checked then you should increase the rate at which the graphs are updated. See the settings in 'Display Mode…' under the 'Test Setup' menu.
2) Note that data does not have to be in the visible portion of the graph to trigger an alarm. Panning/Zooming of the graph will not hinder graph alarm operation.
3) It is recommended that 2D Scatter (not Binned/Colored) graphs that have a graph alarm enabled use only Manual scaling on the Y (vertical) axis. Using compression or sliding scale won't hinder graph alarm operation but it may slide the threshold line off the visible portion of the screen.

3.12 List of Shortcut Keys

The following is a list and short description of all the shortcut keys available in the software. Many of the shortcut keys follow in the tradition of PAC's DAQ and LOC software programs and should be familiar. Others follow standard WINDOWS conventions. Menu items usually do list the shortcut key, but the full list is provided below for convenience.

F1	Help Menu
Shift + F1	Context Sensitive Help
F2	Hardware Setup
F3	Graph Setup
F4	
Ctrl + F4	Close (Delete) Graph
Shift + F4	Delete Page (Entire Graph Screen)
F5	
F6	View Cluster Table (Toggle)
Ctrl + F6	Controls Cluster Table Sorting
Shift + F6	Shifts Cluster Table Position
F7	View Line Dump (Toggle)
F8	Location Setup
F9	Acquisition
Shift + F9	Acquire to Existing File
F10	Replay
F11	
F12	

Ctrl + C	Copy Graph
Ctrl + D	File New
Ctrl + H	Window Tile Horizontal
Ctrl + N	Add New Graph
Ctrl + O	Open Layout File
Ctrl + P	Print Page
Ctrl + S	Save Layout
Ctrl + T	Window Tile Vertical
Ctrl + V	Paste Graph
Ctrl + X	Cut Graph
Ctrl + W	Waveform Collection (Toggle)
Ctrl + Shift + C	Copy to Clipboard
Ctrl + Insert	Copy Graph (same as Ctrl + C)
Shift + Insert	Paste Graph (same as Ctrl + V)
Ctrl + Alt + O	Options Dialog

4. LOCATION

The purpose of this section is to familiarize you with setting up and using the software location modes. Location is the process of collecting incoming hits into events & analyzing the arrival times of the hits in an event to produce a source location. The individual location modes have several key differences which are summarized in the table below.

Location Mode	Hits Used	Description	Analysis Type	Required Option
Zonal	1	Trivial solution to location. Identifies the sensor closest to the source using the relative arrival times of the hits. Returns the first hit sensor coordinates as source location.	Single	Standard
Linear	2	Designed for 1 dimensional location on a line. Performs linear interpolation between 2 sensors' coordinates based on differences in the arrival times of the first 2 hits in the event.	Single	Standard
Tank Bottom	3	Designed for analyzing 2D circular arrays of sensors.	Single	Tank Bottom
2D Planar	3-8	Designed for an arbitrary array of sensors on a 2D plane.	Regression	Full
2D Planar (xy) 2D Planar (yz) 2D Planar (xz)	3-8	2D Planar designed to complement 3D Location. Locates using just 2 of the 3D coordinates & ignores the 3rd. Useful for some events that fail normal 3D Location.	Regression	3D
Cylinder	3-8	2D Planar analysis wrapped around a 3D cylindrical shell. The ends of the cylinder may be open or have flat, spherical or elliptical endcaps. Assumes sound travel through cylinder shell rather than its interior.	Regression	Full
Conical	3-8	2D Planar wrapped around a 3D conical shell.	Regression	Full
Spherical	3-8	2D Planar wrapped around a 3D spherical shell again assuming sound travel via the shell only.	Regression	Spherical
3D Location	4-8	2D Planar extended to 3D coordinates assuming sound travel directly through space rather than via an external shell.	Regression	3D Location
3D T0 Location	5-8	3D Location with time zero input. Assumes all events are signaled via one channel that accurately indicates the absolute start time of an event.	Regression	3D T0 Location

The most important difference in the location modes is the geometry they are designed for. The geometry in turn affects the number of hits used per event to calculate the location. The type of analysis also affects the number of hits used in an event. The single analysis modes use just enough hits to create one set of simultaneous equations which are then solved to extract the source location coordinates. A more complex approach uses more hits & multiple regression analysis to produce the source location that best fits all the available data. By using data from extra sensors, the regression modes yield a more accurate source location with improved immunity to errors in the individual arrival times. For more details, see the section 4.1, Theoretical Background.

Two location modes, zonal & linear, are standard features. Others are location enhancements that require additional licensing options. If you are not sure what locations options are enabled in your software, look for the Options dialog available on the Help pulldown menu. It will show a checkmark next to any purchased options. If you wish to purchase additional license options for other location modes, contact Physical Acoustics Corp. at 1-609-716-4000.

4.1 Theoretical Background

The following section provides a brief overview of the math behind location. It is definitely not required that the average user to comprehend this material. It's purpose is to educate the inquisitive & allow the user additional insight into what location is doing behind the scenes.

The fundamental basis for the location calculation is just the simple time-distance relationship implied by the velocity of the sound wave. The absolute arrival time, t, of a hit in an event can combine with the velocity, v, of the sound wave to yield the distance, d, from the sensor to the source.

$$d = v * t \tag{1}$$

The distance between 2 points depends on the geometry of the problem. The majority of the location modes are a variation of 2 dimensional source location in a plane, although in many cases the 2D plane will wrap around a 3 dimensional object. For 2 points in a flat plane, the distance equation is just the Pythagorean theorem expressed in Cartesian coordinates:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \tag{2}$$

This calculation is complicated by the lack of knowledge of the exact time the event originated. To get around that problem, all the times are considered relative to the first hit in the event. Each arrival time difference implies a difference in distance to the sensor relative to the distance to the first hit sensor. For the second hit sensor relative to the first hit sensor, a difference equation can be written as:

$$t_2 - t_1 = (d_2 - d_1)/v \tag{3}$$

The distance equation (2) can be combined with the difference equation (3) to yield:

$$t_2 - t_1 = [\sqrt{(x_2 - x_S)^2 + (y_2 - y_S)^2} - \sqrt{(x_1 - x_S)^2 + (y_1 - y_S)^2}]/v \tag{4}$$

where x_S & y_S are the unknown coordinates of the source. This equation contains 2 unknowns & cannot be solved by itself. To get a second equation with the same 2 unknowns, a 3rd hit is added to the event producing analogous equation:

$$t_3 - t_1 = [\sqrt{(x_3 - x_S)^2 + (y_3 - y_S)^2} - \sqrt{(x_1 - x_S)^2 + (y_1 - y_S)^2}]/v \tag{5}$$

These simultaneous equations can then be solved for x_S & y_S, although the algebra is fairly complex. Tank Bottom location uses this particular approach to produce a source location from 3 hits as did the original version of 2D Planar location before it was extended to include multiple regression analysis.

If there are additional hits added to the event, there is a question of how to use the extra information. In the case of Tank Bottom location, the algorithm simply takes the extra hits & tries them 3 at a time to produce extra source locations. It iterates through all the 3 hit combinations of the hits in the event until it exhausts them or runs into a user specified maximum. The problem with this approach is that it produces more than one source location per event & if there is any error in the timing values, the source location can be wildly incorrect. A better approach would be to average the data somehow to produce a single location.

Multiple regression analysis does just that, although it does not actually average the results of multiple 3 hit calculations directly. Rather it searches for the location that best fits all the all the available data. Each additional hit basically adds an extra equation to the set of simultaneous equations given above as (4) & (5). This can be generalized as:

$$t_i - t_1 = [\sqrt{(x_i - x_S)^2 + (y_i - y_S)^2} - \sqrt{(x_1 - x_S)^2 + (y_1 - y_S)^2}]/v \tag{6}$$

If one defines

$$\Delta t_i = t_i - t_1 \tag{7}$$

one can write:

$$\Delta t_i = [\sqrt{(x_i - x_S)^2 + (y_i - y_S)^2} - \sqrt{(x_1 - x_S)^2 + (y_1 - y_S)^2}]/v \qquad (8)$$

Equations (7) & (8) give 2 ways of calculating the Δt of the ith sensor. Using the known arrival times of the hits, equation (7) calculates the observed time difference, $\Delta t_{i,obs}$,. For a given set of source location coordinates, equation (8) defines the calculated time difference, $\Delta t_{i,calc}$. Multiple regression analysis is a general purpose algorithm that minimizes the difference between 2 quantities which in this case are the observed & calculated Δt values. To do that a quantity called χ^2 (chi square) is calculated. In our case, it is defined as a sum across all sensors in the event:

$$c^2 = \Sigma(\Delta t_{i,obs} - \Delta t_{i,calc})^2 \qquad (9)$$

This quantity is also called the fit value and is dependent on the x,y coordinates of the source location . The sum is recalculated for each potential source location. Assuming no error in the data, χ^2 will have a value of 0 at the source location. The location code searches for the values of x_S & y_S that minimize the value of χ^2. The process is an iterative search, because it is not possible to directly write down simple equations for the values of x_S & y_S that minimize χ^2.

The search is performed using one of 2 algorithms, either a Simplex search (3D or 2D Planar modes) or Powell's Method (Spherical, Cylinder & Conical Location). Both search methods are based in general on code & algorithms described in Numerical Recipes in C, 2nd edition (NRC). The code has obviously been heavily adapted for the problem of acoustic emission source location, so there are significant variations from the NRC originals. The interested user may, however, find more information about Simplex & Powell fitting & searching in NRC in chapter 10 & more information on regression analysis in chapter 15.

The math gets more complicated when extended to 3 dimensions or involves wrapping around a 3D object, but the approach is still basically the same. An important point is that the regression approach is no longer over determined in the case of the event containing the minimum number of hits, i.e. 3 hits for 2D Planar. In that case, however, regression analysis turns out to be mathematically equivalent to solving the complicated algebra of equations (4) & (5) & yields the same location coordinates.

4.2 Location Setup Dialog

When setting up location groups, you use the Location Setup dialog box (F8 shortcut key). It has 2 tabs labeled General and Timing. Source locations are produced by analyzing events. Events are just collections of hits & their associated time of arrival. The settings on the General page control how hits are combined into events & how events are analyzed by the location modes to produce source locations. The settings on the Timing page control how the time of arrival of each individual hit is determined and even whether or not a hit is considered significant or excluded from the location analysis.

You should be aware of the F5 function key. It allows the user to quickly set all rows in a column of the grid to the value of the current cell. It works on both the General & the Timing tabs. In the example setup shown below, pressing F5 would set all rows of the Overcal column to the current cell's value of 200.

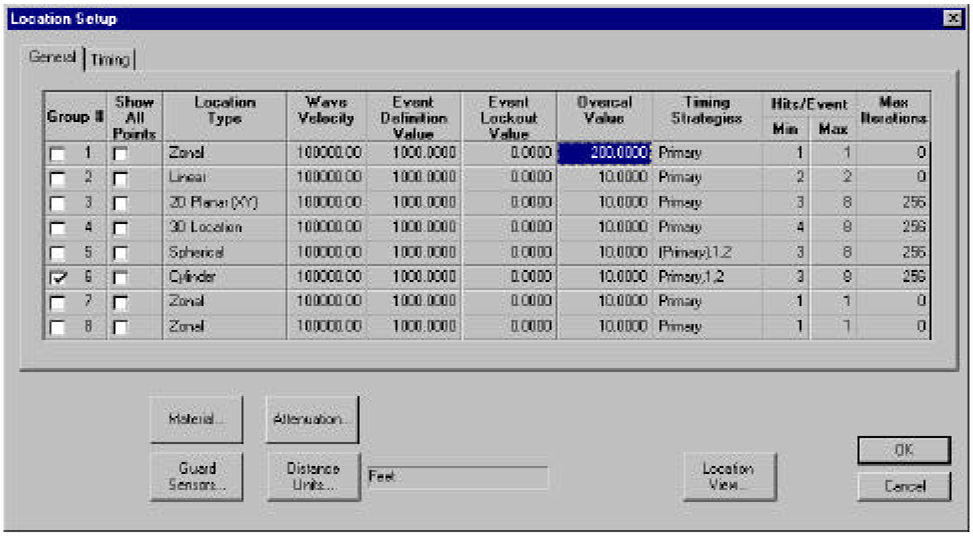


Figure 79. Location Setup – General Page

4.2.1 General Tab Settings:

The layout for the General tab is shown above. The grid on the General page of Location Setup contains a list of location groups & their type. If you click an entry in the Location Type column, an arrow appears allowing you to change the type. As mentioned above, many location types (3D, Spherical, Cylinder) appear only if you have purchased the appropriate option.

Group #: This column acts as an On/Off setting. Unchecked groups are ignored when doing a replay.

Show All Points: This column allows the user to show all source results for events that this group can successfully locate. Independent of which groups have Show All Points checked, the software always allows all enabled groups to analyze a given event to get the best results for each group and then compares the results from all successful groups to come up with a best result. For example, linear location is always presumed to give a better result that zonal location, if there are enough hits(2) to produce a location. If no groups have Show All Points checked, the software will report one source location per event & it is the best result that is shown on graphs & in the line display. There are times when a side-by-side comparison of the results of 2 locations groups are useful. In that case you can mark the groups as Show All Points & then whatever source locations they can calculate will be reported. The software will appear to sometimes produce more than one source location per event & if you look at the line display, you will see extra event listings with the same first hit times. The extra location results will also show up as extra points on your graphs too, but they only count as 1 event in the Statistics bar. In all cases you will see the software's best result as one of the points. There will be times when an event cannot be located by more than 1 group, so having Show All Points does not guarantee a result from a given location group. It is only a guarantee that you will see it, if it can produce a useful result.

Location Type: The Location Type column lets you specify which location mode to use with this particular location group. If you click on a cell in this column, a down arrow appears on the right hand side of the cell. If you click the down arrow, a drop down list of the available location choices will appear. The available choices do depend on the software licensing options as mentioned in the introduction, so you may not see all the location modes that are discussed in this manual.

Wave Velocity: The Wave Velocity is the expected rate of propagation of the acoustic emission signal you wish to monitor. It is entered in the user's Distance Units per sec. For example, if the Distance Units are in Inches, then the Wave Velocity takes units of Inches/sec. If the user's Distance Units are time based, this column is ignored by the location algorithm. The Materials button will allow you to access a database of known velocities for various materials. See the section on the Material Properties dialog for more information. It is always recommended that you determine the appropriate value by measuring the velocity on your test structure using, for example, pencil lead breaks.

Event Definition Value: This Event Definition Value is the length of an event in the user's Distance units. If the user's Distance Units are time based, then it is directly the maximum time allowed between first & last hits in an event. If the user units are distance based, the length is later converted to time units using the velocity entered in the Wave Velocity column. The velocity units are the user's Distance Units per second. For example, if the Distance Units is set to meters, then the velocity units are meters/sec.

Event Lockout Value: The Event Lockout Value is also a length of time or distance entered in user units, but it controls the interval between consecutive events. The Event Lockout of the last located event blocks events in all location groups until it has expired. The Event Definition Value & the Event Lockout Value are both specified relative to the start of the event (time of test of the first hit). An Event Lockout Value of 0 allows overlapping events in 2 *different* location groups. Overlapping events are not permitted in the same location group no matter what the Event Lockout Value is. An Event Lockout Value larger than the Event Definition Value allows hits to be ignored after an event, for example, if reflections could generate extraneous acoustic signals.

Overcal Value: The Overcal Value or more fully the over-calibration value is also a length that is specified in the user's Distance Units. Before data acquisition or a replay begins, the software calculates a table of calibrated time differences between sensors using their known coordinates & the user entered wave velocity. The Overcal Value is also converted to a time value if needed. After the first hit in an event, these calibrations times are compared to the time difference of later hits relative to the first hit sensor. In order for a hit to be included in the event, it's time difference must be less than this calibration time, but there is an allowance for a margin of error. The time difference can be higher than the calibration time by the Overcal Value & still be included in the event.

Timing Strategies: The Timing Strategies column is used to specify which strategies listed on the Timing page will be applied to a particular location group. You set up the strategy on the Timing page, but you control whether it is used with a particular location group using the Timing Strategies column. See the section on the Timing page for information on the settings for strategies & use of the Timing Strategies column.

Hits/Event Min & Max: The Hits/Event (Hits per Event) columns are related to the regression modes. In theory, the multiple regression can sum across any number of sensors (hits) in a given event when calculating a fit, but there are limits in the code. First the absolute minimum number is determined by the mathematical requirements specific to the location mode. For Spherical, Cylinder Location and all 2D Planar regression modes, the event must contain at least 3 hits to produce a location. For 3D Location a minimum of 4 hits are required to analyze an event & produce a location. All regression modes can make use of up to 8 hits in an event.

The Hits/Event Min & Max settings allow the user control over the analysis between these limits. For example, in 2D Planar, a minimum of 3 hits are required to produce a location result, but then this is not an over determined result. If there is an error in the timing data of any one of the 3 hits, the location calculated will be in error. With 4 or more hits, the regression analysis produces a best fit location that averages out errors in the data. Thus, the user might want to adjust the Hits/Event Min setting to 4 for 2D Planar to eliminate analysis of 3-hit events. This will reduce the number of events observed & generally reduce scatter in the results. In some cases, the user might want to only look at events with a specific number of hits. Setting the Hits/Event Min & Max settings to 4 will limit the analysis to events with 4 or more hits using only the first 4 hits to form the event.

Max Iterations: The Max Iterations column is also related to the regression modes. In this case, the setting controls the maximum number of locations evaluated in the search for the best fit location. It is not strictly speaking the same as the number of times through a search loop for 2 reasons. First some searches can test a variable number of locations during one pass though the loop. Second other searches use loops within loops. Due to the variable nature of the search algorithms, the actual number of locations tested can be slightly higher (0-3) than the Max Iterations setting. A lower Max Iterations setting will terminate long location analyses sooner, but the higher speed results in lower accuracy in the best fit location produced.

When the Location Type is not set to an regression mode, the Max Iteration column & the Hits/Event Min & Max columns will be disabled. In that case the Max Iterations column displays 0 as iterations are not used for the other modes. The Hits/Event Min & Max settings will be updated with the number of hits required for the location mode. For example, the Linear location mode requires 2 hits to produce a location and if Location Type is set to Linear, Hits/Event Min & Max will both display 2 & the user will not be able to adjust the setting.

4.2.2 Timing Tab Settings:

Timing strategies processes hits and their accompanying waveform to produce a time of arrival. A list of arrival times a series of hits is grouped together to form an event. The location modes analyze the arrival time differences (delta t's) in the event to calculate the source location. For an enabled location mode, the software always analyzes the event at least once. The first analysis is performed using only the arrival times from the Primary Strategy. If you use additional strategies with one of the regression modes, the software performs a second event analysis to refine the source location by adding the arrival times produced by the secondary strategies (1-4) to the event.

The settings for the strategy are on the Timing page, but you control which location groups use them with the Timing Strategies column on the General page. When you click on a cell in the Timing Strategies column, the Select Strategies dialog appears as shown below.

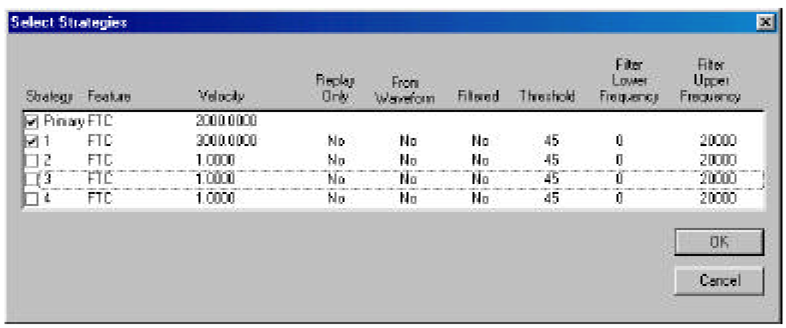


Figure 80. Select Strategies Dialog

Simply check or uncheck the strategies you want to use. The dialog summarizes the current strategy settings from the Timing page. After you click on OK, the cell in the Timing Strategies column will update to list the enabled strategies. A notable exception is the Primary Strategy which always appears in the list as either Primary or (Primary).

With additional strategies enabled, unchecking the Primary Strategy causes the arrival times from the Primary Strategy to be omitted from the second event analysis, but they are still used to perform the first analysis. If the location mode cannot produce a useful source location after the first analysis, the software will not attempt to refine the location with the secondary data. In that respect the Primary Strategy acts like a filter for the second analysis even when the Primary results are not being used in the second analysis. To reflect this implied filtering, the Timing Strategies column displays (Primary) whenever the Primary Strategy is not to be included in the secondary analysis. In the figure showing the General settings page above, Location group 5 has Strategies 1 & 2 turned on with the Primary turned off and displays "(Primary),1,2". Unchecking all the strategies is equivalent to checking only the Primary Strategy. In both cases the event is analyzed just once with the Primary Strategy and the Timing Strategies column just displays "Primary"

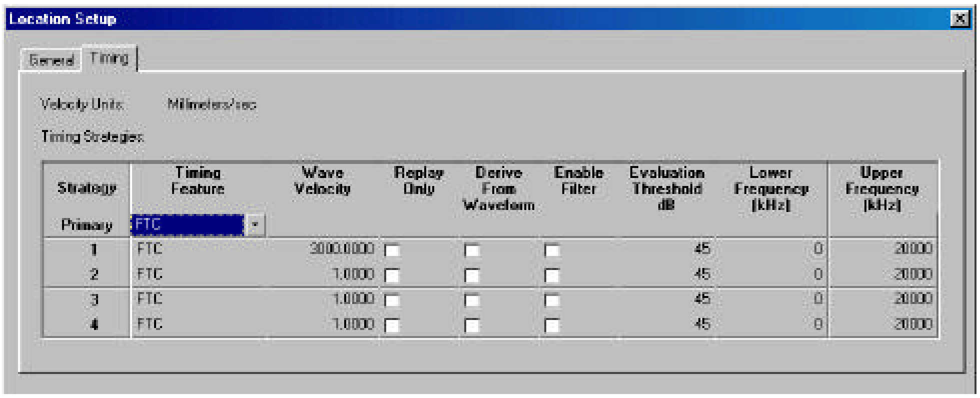


Figure 81. Location Setup – Timing Page

The current layout for the Timing page of the Location Setup dialog is shown above. For each strategy there are a number of options available. Those to the right of Derive From Waveform are all related to waveform processing.

For the Primary Strategy the only available option is the Timing Feature option. The other columns are not used because they are unneeded or not allowed for the Primary Strategy. For example, the Primary Strategy always uses the velocity associated with the location that is listed in the Wave Velocity column on the General page. The Primary Strategy is always applied during both acquisition & replay. The Primary Strategy relies on the results reported by your hardware in a single hit message, so waveform processing options are not available. The software later searches & pairs each hit message with an accompanying waveform message making the waveform processing options available for the secondary strategies.

Timing Feature: The Timing Feature column controls how the arrival times for a hit are determined. There are 2 basic choices: FTC (First Threshold Crossing) and Peak Timing (PT). All the arrival times are based on the time of test associated with the hit and a variable offset. During data acquisition, the hardware actually sets the time of test of a hit based on a threshold crossing where the Threshold level is controlled by the user in the Hardware Setup dialog. The FTC setting actually just defaults the arrival time to the time of test for the hit with no offset. The Peak Timing parameter adds the risetime (RT) as determined by the hardware to the hit time of test. Risetime is defined as the delay between the first threshold crossing and the highest amplitude peak during the Peak Definition Time (PDT). The risetime feature must be enabled in the Data Sets tab of the Hardware Setup dialog for this option to work.

In addition to FTC and PT there is a third timing feature called Custom Arrival. This is used when replaying a datafile that has had the time-of-arrival of some or all of it's waveforms modified through hit/event linking. If this timing feature is used when replaying such a datafile then the modified time-of-arrival's will be used instead of the original ones. For any other timing feature, the original time-of-arrivals will be used. Custom Arrival is designed for use in replay. If it is used during acquisition it will default to FTC behavior.

Wave Velocity: The Wave Velocity column contains the velocity used during analysis by the location modes. The regression modes use a velocity to convert arrival time differences into differences in distances to the sensors. There is a velocity associated with each hit arrival time. For the Primary Strategy that velocity always comes from the location group Wave Velocity setting. During the second analysis, the velocity from the secondary strategies are used when the arrival times are added to the list of hits in the event.

Replay Only: The Replay Only checkbox controls whether the strategy is applied during both data acquisition and replay or only in replay mode. Since secondary strategies cause events to be analyzed twice & the arrival times may be extracted from a digitally filtered waveform, secondary analysis can slow data acquisition rates. In cases where high data acquisition rates are important, you may prefer to postpone the secondary analysis until after data acquisition is over. The Replay Only flag just makes it easier to disable the strategy during acquisition without having to continually access the Location Setup menu to toggle the strategy on or off.

Derive from Waveform: The Derive From Waveform checkbox controls whether the strategy attempts to extract the arrival time from the waveform. If it is disabled (unchecked), the arrival time can still vary from that produced by the Primary Strategy if the Timing Feature for the secondary strategy varies from the Primary Timing Feature setting.

Enable Filter: The Enable Filter checkbox controls whether a digital is applied to the waveform before the arrival time is determined.

Evaluation Threshold: The Evaluation Threshold is similar to the Hardware Setup Threshold used during data acquisition. If the Timing Feature is set to FTC (First Threshold Crossing), the Threshold directly impacts the arrival time or even whether an arrival is detected. The Evaluation Threshold is applied to the waveform after the optional digital filter is applied. Note that the Hardware Setup Threshold affects what data is recorded during acquisition. The user can set the Evaluation Threshold to values higher than the Hardware Setup Threshold used during data acquisition & simulate the results that would have been recorded during acquisition with a higher Threshold. Beware, though, setting it to lower values cannot reveal data that was not recorded in the first place.

Upper & Lower Frequency: Lower Frequency & Upper Frequency columns control the bandpass cutoff frequencies. Turning on the digital filter & adjusting the filter cutoff frequencies can help isolate individual acoustic emission modes with differing wave velocities. Note that you should be aware of the sampling rate used during acquisition and avoid setting the Lower Frequency cutoff above ½ the lowest sampling rate on any channel. You should also avoid targeting frequency ranges that your sensors do not respond to or that have been removed by your hardware's analog filters. Otherwise you could be analyzing meaningless waveforms.

4.2.3 Distance Units Dialog

Pressing the Distance Units button opens the Distance Units dialog box. The user can select his desired units from the dropdown list. The user is given an option of converting old numerical values to the new units by simply checking the "Convert all numerical values based on new units." option. This will cause the event definition value, event lockout value, the overcal settings, the wave velocities & sensor positions to be updated as appropriate.

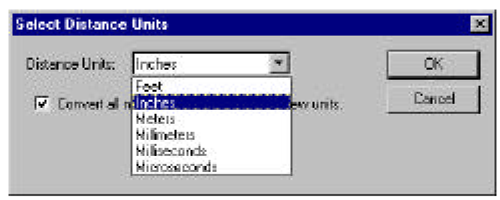


Figure 82. Distance Units

4.2.4 Material Properties Dialog

Pressing the Material… button opens the Material Properties dialog box. This dialog box is just a simple database of velocities for acoustic emission in various materials. When you find a useful velocity, simply highlight it & press Ctrl-C, Ctrl-Ins or right click & select Copy. You can then insert it into any field in the Location Setup dialog with Shift-Ins or Ctrl-V.

If you wish to add some of your own numbers, you can simply type a new entry for the Material Name, fill in the velocities & press the Add button. The Delete button removes an entry from the database, while the Update button lets you replace bad values.

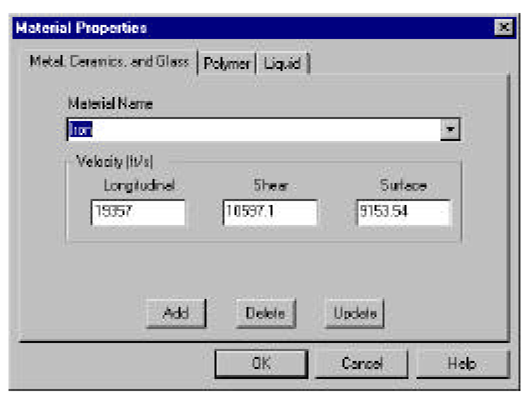


Figure 83. Material Properties

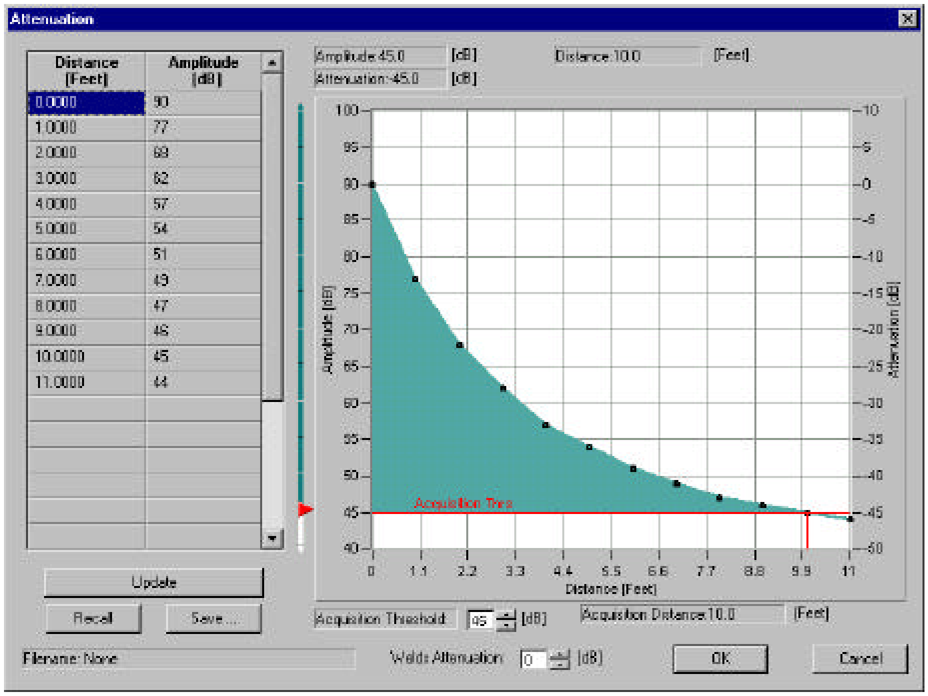


Figure 84. Attenuation Dialog

4.2.5 Attenuation Dialog

Pressing the Attenuation… button opens the Attenuation dialog box shown below. The sole purpose of this dialog is to allow the software to account for the decay of the acoustic emmission as a function of distance travelled & to estimate of the initial amplitude at the source. It uses the amplitude observed at the first hit sensor, the distance to the source for the event and the attenuation table entered by the user in this dialog. The attenuation table documents amplitude as a function of distance. The units of distance are controlled by the Location Setup Distance Units setting. The Update button will causes the graph to display the current values in the table. The user may use the Save & Recall buttons to save or recall an attenuation table to/from the disk

The basic procedure uses the table to calculate the difference between an amplitude at the source & at the observed distance from the source. If the source to first hit sensor dis tance falls within the range of values in the table, an amplitude at that distance is calculated using linear interpolation between the 2 nearest distances in the table. Using the table above as an example, if the source was determined to be 2.5 feet from the first hit sensor, the table has the 2 closest entries as 68 at 2.0 feet & 62 at 3.0. The amplitude predicted at 2.5 feet would be 65 (= 68 – (68-62)*0.5). The correction applied to the amplitude at the first hit sensor would be 25 dB (= 90 - 65). If the first hit amplitude was 60, the line display would report a Source Amplitude of 85 for this example. The amplitudes are not extrapolated beyond the maximum distance. If the distance is beyond the maximum distance in the table, only the maximum correction of 46 (= 90 – 44) is applied. If the user never accesses this dialog to fill in the table, no correction is applied & the source amplitude reported is identical to the amplitude of the first hit sensor.

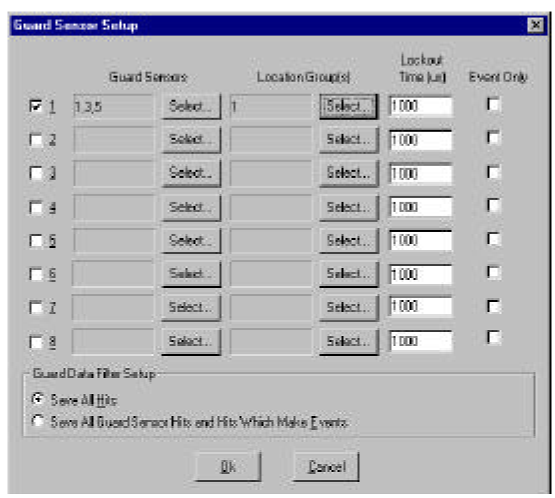


Figure 85. Guard Sensor Setup

4.2.6 Guard Sensor Dialog

Pressing this button opens the 'Guard Sensors' dialog box. Guard Sensors can be used to lockout out events on selected location groups whenever a hit is first detected on a guard channel. It is designed for situations in which one wishes to ignore events that originate outside of the location group.

In the example setup shown, sensors 1, 3 & 5 are protecting Location Group 1 from outside events. If there is a hit on sensors 1, 3 or 5, then Location Group 1 will not process any events for the next 1000 us. If the Event Only flag were checked, only the next event on Location Group 1 would be locked out instead of being locked out for the next 1000us. The Lockout Time field would also be disabled as it's value would no longer be used.

The Guard Data Filter Setup controls what hits get saved into the DTA file during acquisition, if guard sensors are enabled. The default setting is to just save all hits, but you can restrict the data saved to just those hits that make up events & the guard sensor hits. This can be useful in situations where external noise creates a large number of hits that end up being useless for the purpose of location. Not only do the extra hits take up space in the data file, but they also slow down replays of the data file too.

4.3 Location View & Sensor Placement Dialog

Before discussing the Sensor Placement Dialog, there is one important point about the physical placement of your sensors that you should understand and it applies to all of the regression location modes. *You can place sensors anywhere, but you will get better results with the regression location modes if your sensor layout is made up of an evenly spaced triangular array of sensors. The optimal arrangement would be a triangular grid made up of equilateral triangles, but the regression modes do not require exact equality of the triangle legs or even regular spacing between the sensors.* ***Avoid creating triangles with one very long or very short side, however, as they do not work well for locating sources.***

Pressing the Location View button in the Location Setup dialog opens the Sensor Placement dialog box. shown here. The 2 main areas are the actual view of the sensors in the left-hand side of the dialog & a listing of their coordinates in the right-hand side. The grid area for the sensor coordinates also has tabs that will display the coordinates of any welds and nozzles created. You can change the color of the sensors using the Graphing menu to access Sensor Color on the Colors submenu.

When using the Sensor Placement dialog, there are 2 ways to add new sensors. When working with the grid, pressing the INS key adds a new sensor. The F2 key allows you to edit its coordinates & move it to the correct location. Alternatively you can right click the sensor view area to get a context menu like the one shown to the right. Place Sensor & Next Sensor allow you to put a new sensor at the current position. Next Sensor numbers it automatically using the next available sensor number. Place Sensor will ask for a sensor number. You can also use AutoPlace Sensors to create a grid of sensors with regularly varying coordinates. You work with welds & nozzles in a similar manner. The exact menu you see may differ from that shown here as it depends on the Structure.

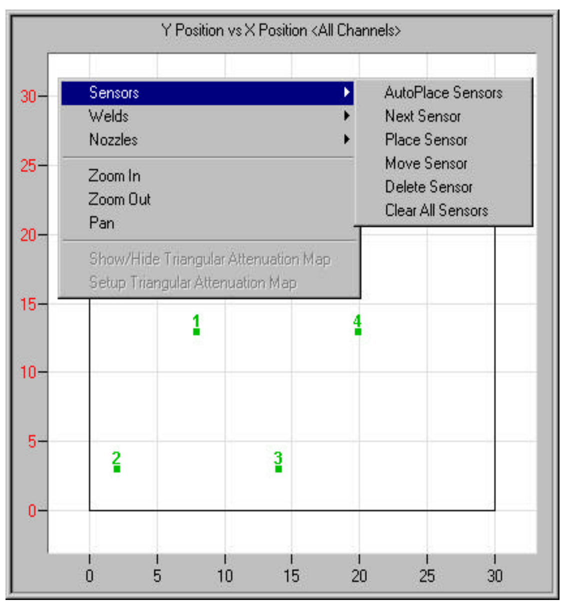
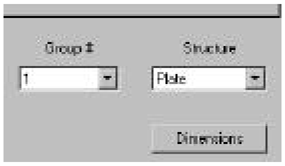


Figure 86. Sensor Menu



The Structure list is just below the grid area. Support for welds, nozzles, manual placement of sensors & autoplacement of sensors varies with the Structure setting. When creating a sensor layout for a new location group, the first thing you should do in the Sensor Placement dialog is to set the Structure list. The Group # setting allows you to quickly switch to editing the sensors for another location group without having to return to the Location Setup dialog. If you made changes to the current settings, you are prompted to save them.

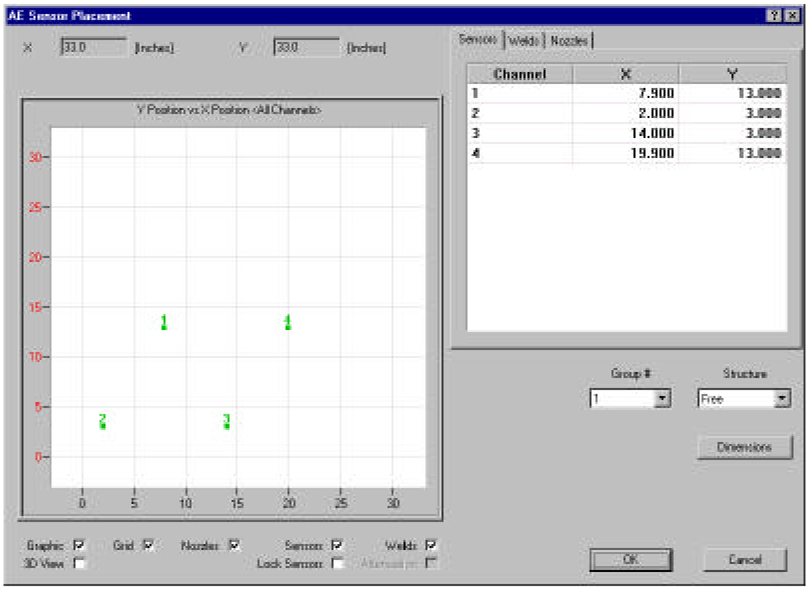


Figure 87. AE Sensor Placement

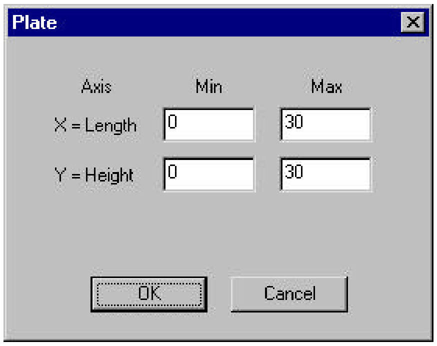


Figure 88. Plate

Below the Structure setting is the Dimension button. If you click it, one of the dimensions dialogs will appear. They are also specific to the type of Structure. The one shown to the right is for the Plate structure. When working with a new location group, the second thing you should do in Sensor Placement is to fill in the dimensions for the structure you are working with. The dimensions affect the scaling of the sensor view area. If you have incorrect values entered, some sensors may not be visible in the sensor view.

Figure 89. AE Sensor Placement Checkboxes

Below the sensor view area, there are a number of checkboxes that control the sensor view. The Nozzles, Sensors & Welds checkboxes control whether or not those objects are displayed. Likewise the Grid checkbox controls whether or not the sensor view shows a Cartesian grid to facilitate placing of sensors. The Graphic checkbox controls whether or not a representation of the structure is drawn on the graph. The Lock Sensors checkbox disables moving of sensors with the mouse. The 3D View checkbox will toggle the display between 2D & 3D views of the sensor layout, if that structure type supports both 2D & 3D views. Finally the Attenuation checkbox enables if you have used the Attenuation dialog to enable the calculation of source amplitudes. Checking Attenuation in the Sensor Placement dialog causes the sensor view to display an attenuation map as a series of concentric rings around each sensor as shown below.

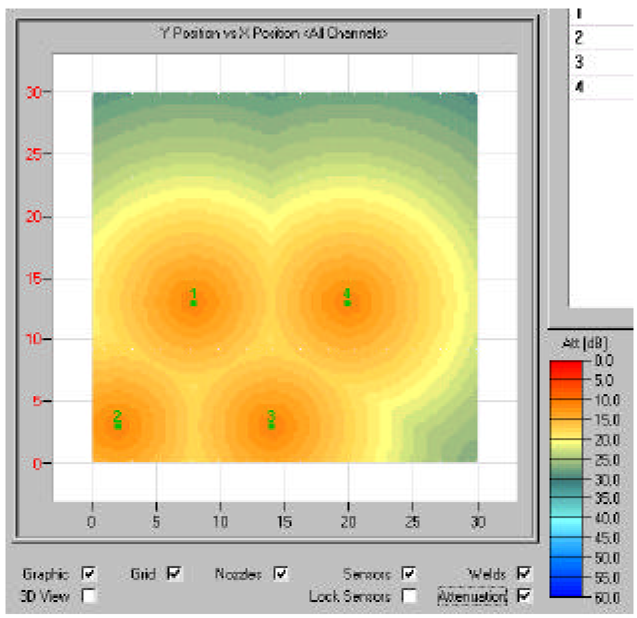


Figure 90. Attenuation

4.4 Notes on Regression Location Modes

As mentioned in the section describing the Sensor Placement Dialog, there is a point that all users should understand about the regression location modes & it is important enough to bear repeating. *You can place sensors anywhere, but you will get better results with the regression modes if your sensor layout is made up of an evenly spaced triangular array of sensors. The optimal arrangement would be a triangular grid made up of equilateral triangles, but the regression modes do not require exact equality of the triangle legs or even regular spacing between the sensors.* ***Avoid creating triangles with one very long or very short side, however, as they do not work well for locating sources.***

In general, you can just read the section on the location mode you are interested in using. All the regression location modes are a variation on 2D Planar, however, so you might also want to read it as well. If you'd like more information on setting up a Zonal, Linear or Tank Bottom location group, see the Examples section.

4.4.1 2D Planar & 2D Planar (XY)

There is no fundamental difference between 2D Planar & 2D Planar (XY) location except on the menus. Enabling 3D Location also enables 2D Planar (YZ) & 2D Planar (XZ) location. To distinguish the standard 2D Planar from those 2 modes, it is relabeled 2D Planar (XY) location whenever the 3D Location option is enabled. 2D Planar (YZ) & 2D Planar (XZ) location are discussed in the section on 3D Location.

For 2D Planar location, a particularly difficult problem is locating the source of an acoustic emission event, if all the hits are from sensors in a straight line (linear events). For linear events, even if a distance from the line can be determined, there is no way to distinguish positive & negative directions away from the line. Random error in the data can also make determining the distance from the line highly suspect. The software filters out linear events and does not attempt 2D Planar location on them. To avoid lots of linear events that will be ignored, avoid laying out your sensors like the bad layout shown below.

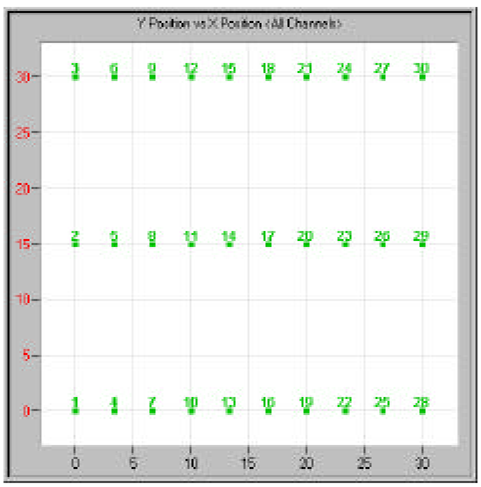


Figure 91. Bad 2D Planar Layout

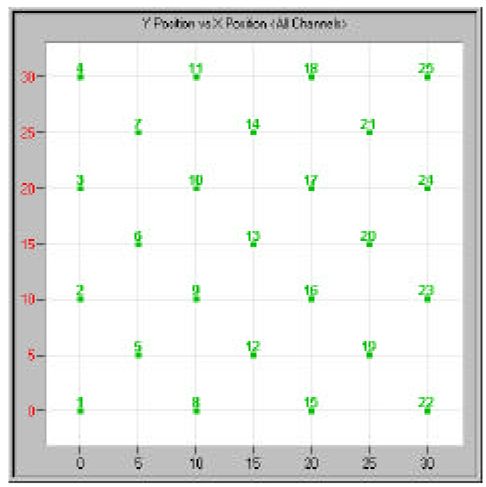


Figure 92. Good 2D Planar Layout

A better layout would have all distances in between the sensors approximately equal. Triangles with one very long side or one very short side can also cause problems as they approach becoming a straight line of sensors. The ideal 2D Planar layout would be made up of equilateral triangles, but exact equality of all sides is not required as shown in the good layout above . As mentioned in the introduction, you should avoid creating triangles with one very long side or one very short side. Events based on triangles with one very long or very short side become linear events when one side goes to infinity or to 0. Short of those limits, though, they can still act similar to the linear events, and won't accurately locate any sources outside of the triangle..

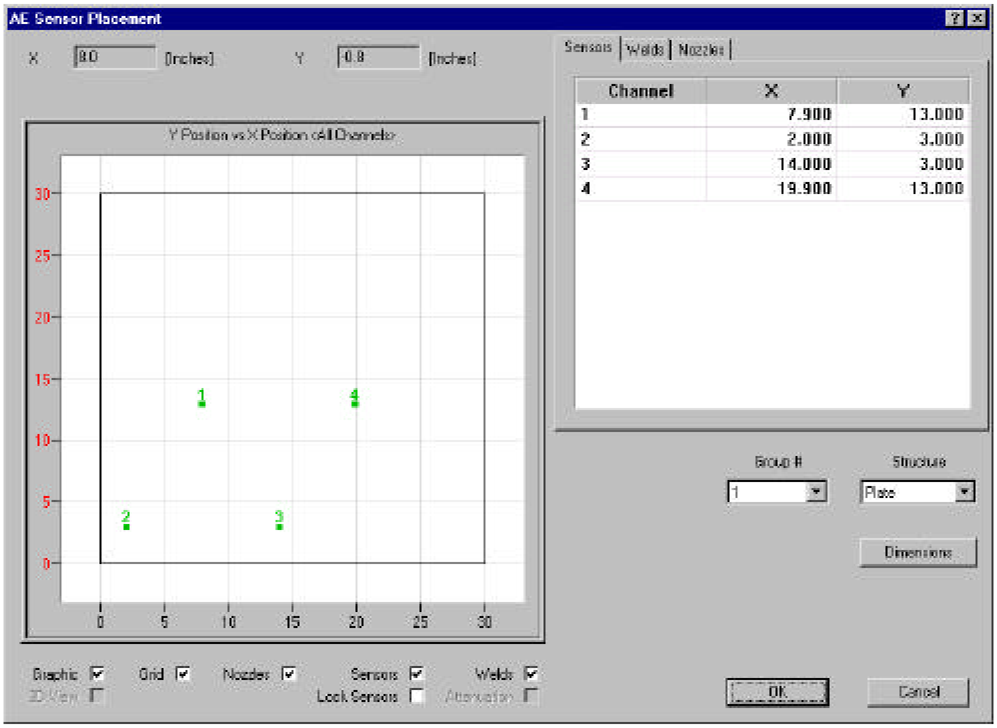


Figure 93. 2D Planar Sensor Placement

Here is Sensor Placement set up for a 2D Planar mode with the Plate structure. 2D Planar location is designed to work with either the Free or Plate structures. Although there isn't any difference in 2D Planar & 2D Planar (XY) location during analysis, there is one difference in Sensor Placement. A 2D Planar (XY) location group has the option of displaying the sensors in 3D graph, if the user wishes it. For a 2D Planar (XY) location group with the structure type set to Free, the 3D View checkbox enables. The user may use it to toggle between 2D & 3D views of the sensors. The checkbox disables for the Plate structure, though.

The Dimensions dialog for both the Free & the Plate structure contain the max/min limit settings for both the X & Y axes. These settings control the scaling of the graph in the sensor view of Sensor Placement. For the Plate structure, they have added significance. When 2D Planar is analyzing events, it will restrict results location groups using the Plate structure to points on the plate. To allow locations close to the limits to report, the software uses a tolerance of 2% of the axis length when deciding whether it is an acceptable result. For example, if x has a minimum value of 0 and a maximum value of 100, then results with an x coordinate greater than 102 or less than -2 are thrown out as invalid. If you don't want to limit your results, just set the Structure type to Free.

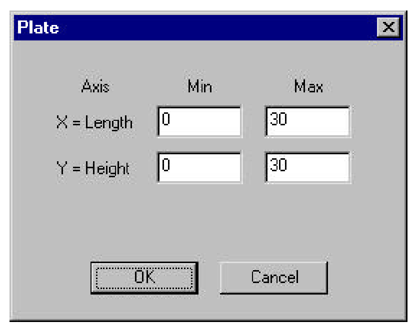


Figure 94. Plate

After setting up the sensors & a 2D Planar location groups, you will want to create a location graph. Use the Graphing pulldown menu's New Graph option & then configure the graph using the Graph Setup dialog box (F3 shortcut key). To the right is a 2D X-Y location graph based on the 2D Binned Scatter graph type where the location group is using a Plate structure. If you create a 2D Binned Scatter, 2D Colored Scatter or 2D Scatter graph that uses X & Y Position, the graph will automatically draw the sensors on the plot for any location groups selected on the Event Groups tab. In the Graph Setup dialog, make sure that the Input Data is set to Events and use the Event Groups tab to select which location group(s) to use for source information. Below is the corresponding Graph Setup dialog to illustrate the typical settings.

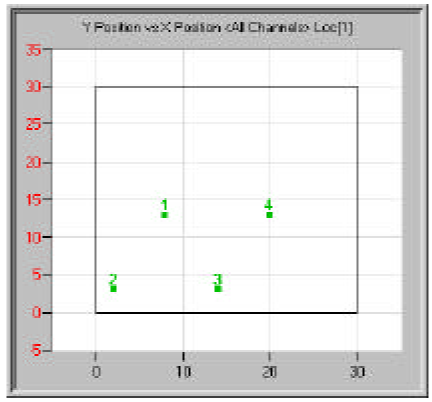


Figure 95. 2D Planar Graph

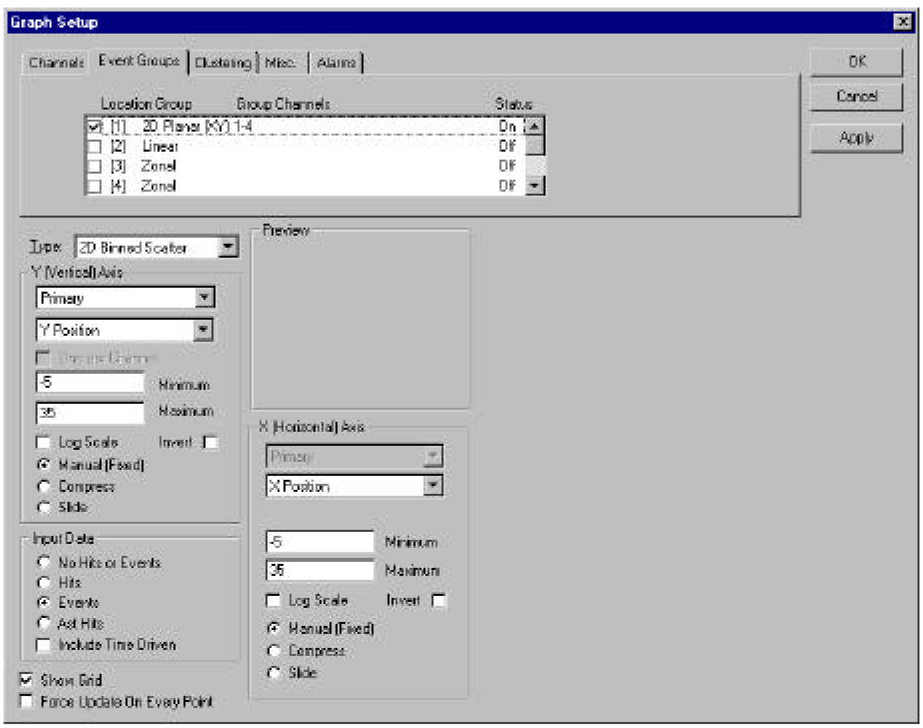


Figure 96. 2D Planar Graph Setup

4.4.2 3D Location, 2D Planar (YZ) & 2D Planar (XZ)

Primarily this section focuses on 3D Location, but 2D Planar (YZ) & 2D Planar (XZ) are related. All 3 location modes are designed to use 3D coordinates. The 2D Planar (YZ) & 2D Planar (XZ) modes are similar to normal 2D Planar & 2D Planar (XY) location with the exception that you can enter 3D coordinates & have the software locate the source while ignoring either the X or Y coordinate. The reason these modes are useful relates to a problem with sensor placement & event handling for 3D Location.

The equivalent of the linear event problem for 2D Planar location is a problem with planar events for 3D Location. A planar event is one in which all the hits are on sensors in the same plane. For planar events, it is hard to determine distance from the plane not to mention distinguishing sources in the positive direction from those in the negative direction. The 3D Location algorithm filters out planar events and does not attempt to locate them as the distance from the plane is often quite simply useless.

Because of the planar problem, you will get better results if you set up your sensors to minimize the number of sensors that line up across the body of the test structure. Avoid using a rectangular grid layout that lines up sensors on opposing faces of your structure. Instead try to stagger the sensors, so that no 2 sensors are directly across from one another. The bad sample layout above uses a rectangular approach with 3 rows of 3 sensors directly opposite one another. The good layout uses a triangular approach by staggering each row on one side by half the sensor-sensor distance and then it inverts the pattern on the opposite wall. The diagram may not show it well, but sensor 4 is below the midpoint of sensors 1&2, above the midpoint of 7&8 and across from the midpoint of 12&13. Both sides have 3 rows of sensors, but the left-hand side has 3-2-3 pattern of sensors, while the right-hand side has a 2-3-2 pattern of sensors. This staggering minimizes the number of sensor planes through the body of the structure.

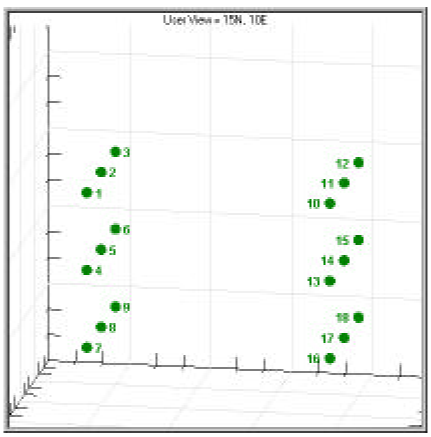


Figure 97. Bad 3D Location Layout

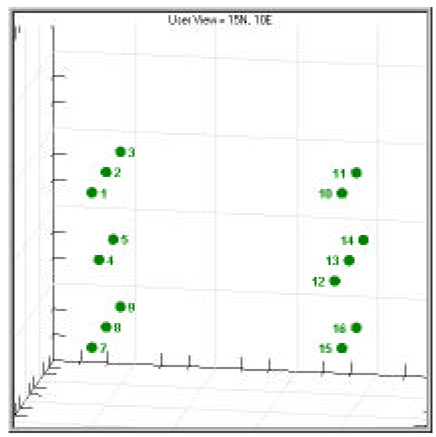


Figure 98. Good 3D Location Layout

One problem with 3D Location filtering out planar events is that pencil lead breaks will not locate with 3D Location unless the lead break is energetic enough to register with a sensor on one of the other faces. A good alternative in this case are the 2D Planar (XZ) & (YZ) location modes. The distinction between them is what sensor coordinates they use when fitting the data. Both allow you to enter 3D coordinates, but ignore one of the values when locating. 2D Planar (XZ) use the X & Z sensor coordinates & ignores the Y values. 2D Planar (YZ) ignores the X coordinate. They are useful when doing pencil lead breaks by sensors confined to one face of your structure. With the 3D Location option enabled, 2D Planar (XY) will allow you to enter 3D coordinates & only locate using the x & y coordinates. Fundamentally that's no different than the standard 2D Planar location. Both are ignoring the z coordinate , but as a convenience one allows you to enter a non-zero value for Z.

For best performance, any 2D Planar groups using 3D coordinates should be confined to just one face of the test structure. Parallel sensors on an opposing face could appear as duplicate sensors with identical coordinates when the 3rd unused coordinate is ignored & that would lead to errors in the event location calculations. You should also note that during acquisition a result from a 2D location mode does not necessarily imply that the source was confined to the 2D location plane. Just as for planar events in 3D Location, distance from the plane is indeterminate. You can draw a perpendicular to the 2D plane at the best fit location and the source event could be anywhere on the line. Of course for pencil lead breaks, you will know in advance that the source is confined to a given face and be able to check your sensors before starting acquisition.

For 3D Location, the Sensor Placement dialog shown here allows you to directly enter X, Y, Z coordinates for any groups that are considered a 3D Location group with the right structure type. 3D Location is designed to use either the Free or the Box structure types.

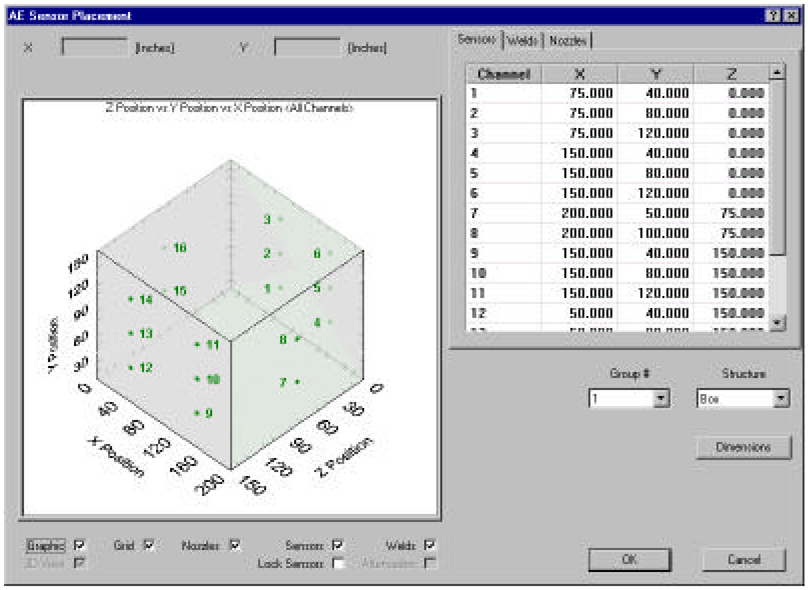


Figure 99. 3D Sensor Placement

The Dimensions dialog for the Box & Free structures is similar to the one for the 2D Free or Plate structures with the addition of max/min settings for the Z axis. Similar to the way the Plate structure limits 2D Planar results, the Box structure acts as search limits for 3D Location. If any location results are more than 2% above or below the limits, the result will be considered bad & is thrown out. For example, if Z Min is 50 & Z Max is 150, then any location results where z is above 152 or below 48 will be filtered out. As with 2D Planar, using the Free structure avoid imposing any limits on the results.

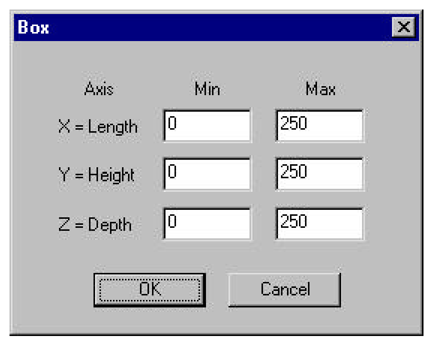


Figure 100. Box

You cannot graphically enter 3D sensor locations in Sensor Placement, but you can graphically see the sensors in the 3D view. If you do not see a grid column for Z or a 3D view of your sensors, go back to the Location Setup dialog & make sure the group type is set to 3D Location, 2D Planar (YZ) or (XZ). Also make sure you have the structure type set to Free or Box.

Use the INS key & F2 to insert a new sensor & edit its coordinates in the grid. As an alternative to creating all the sensors manually, you can also use the AutoPlace Sensors option to create a grid of sensors with varying x,y coordinates & a fixed z coordinate of 0. You would then manually edit the z coordinates of each sensor. Note that you can use AutoPlace Sensors multiple times without erasing the old sensors. That allows you to build up a 3D grid one layer at a time. Right click the graph in Sensor Placement to find AutoPlace Sensors.

To create a location graph for 3D Location, use the 3D Scatter graph & set each axis to X, Y & Z Position which correspond to the x, y & z coordinates of a located source point. The graph to the right is a 3D Scatter graph set up as a location graph. As shown below, Graph Setup has the Input Data is set to Events & the Event Groups tab has the 3D Location group enabled. If you create a graph that uses X, Y & Z Position, the graph will automatically draw the sensors and structures on the plot for enabled location groups.

For 3D Scatter plots, both the sensors & the data points are drawn as small cubes. You may use the Graphing Colors menu to change the colors. The data points use the color assigned to Plot 1 under Plot Colors and are drawn slightly smaller than the sensor points. If you would like larger points, right click your graph & turn on the Large Scatter Graph Points. Both the sensor points & the data points will get larger.

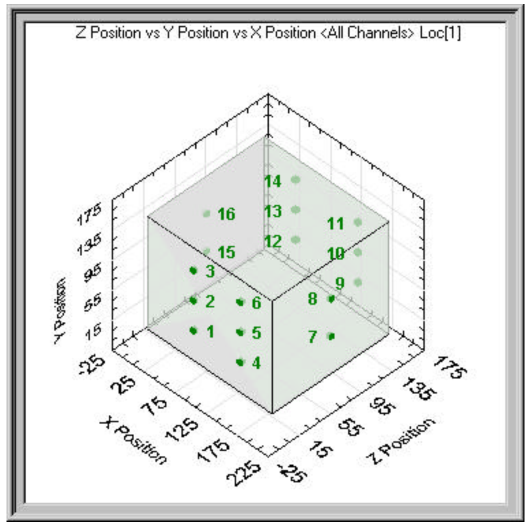


Figure 101. 3D Graph

Graph Setup for the example graph above is shown here. It sets the X (Horizontal) Axis to X Position, Y (Vertical) Axis to Y Position & Z (Depth) Axis to Z Position. You may prefer to remap the axes, if you are used to discussing z as height. For example if you are used to z being vertical, y being horizontal and x being out of the plane of the monitor(paper), set the X (Horizontal) Axis to Y Position, the Y (Vertical) Axis to Z position and the Z (Depth) Axis to X Position. You may also want to change the positive direction of the Z (Depth) Axis. The Invert checkboxes will let you specify whether the positive direction is in or out of the monitor. Similarly you can also invert the horizontal & vertical axes.

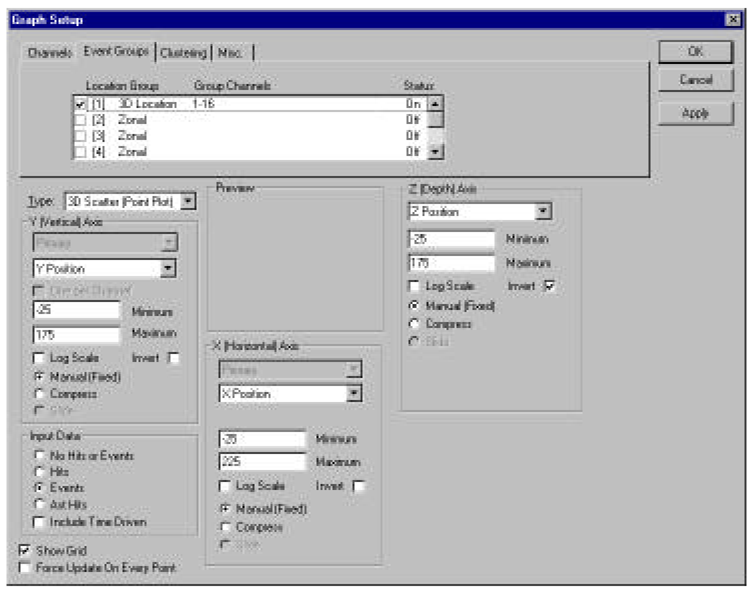


Figure 102. 3D Graph

You can also create 2D location plots using X, Y & Z Position settings on a 2D Binned Scatter graph as done in the section on 2D Planar. If you do, the sensors will also draw on the 2D plots using 2 of the 3 sensor coordinates ignoring the unused dimension. For example, an X & Z Position graph would show the sensors at their x & z coordinates & ignore their y coordinate. This allows you to create front, top and side views of your structure as shown below. These graphs also illustrate another benefit to staggering your sensor locations – legible sensor markers. If your sensors line up on opposing faces, you will end up with overlaid sensor markers on the 2D graphs. That can make them hard to read.

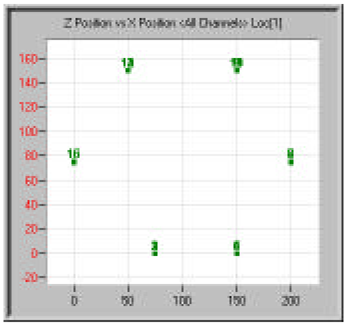


Figure 103. Top View

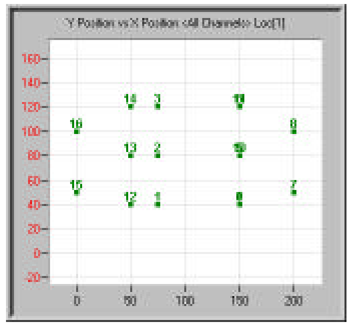


Figure 104. Front View

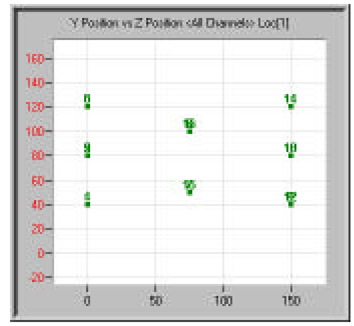


Figure 105. Side View

4.4.3 Spherical Location

Using Spherical location is similar to using the 2D Planar location mode, although there are differences in the coordinate system used & & how a typical location plot is set up. Mathematically, Spherical location behaves like 2D Planar where both axes wrap back around on themselves. There aren't any new pitfalls in sensor placement, but the linear event problem that affects 2D Planar also affects Spherical. If you attempt location using just 4 sensors on the equator of a sphere, Spherical location would always fail as all events would be due to sensors in a straight line. For better results, use at least 6 sensors (north & south poles & 4 evenly spaced on the equator). The maximum number of sensors is limited only by the number of available hardware channels. When using more than 6 sensors, it is recommended that you stagger alternate rows of the sensors to yield a triangular grid and produce more locatable events.

The Sensor Placement dialog has been enhanced to allow you to directly enter theta & phi coordinates anytime the structure type is set to Sphere as shown here. Sensor coordinates are entered in degrees. Theta is defined as the north/south angle (latitude) and should be between +90 and –90. +90 is 90 degrees north (top of the sphere), while –90 is 90 degrees south (bottom of the sphere). Phi is the east/west angle (longitude) and ranges between +180 & –180. A phi of +90 is 90 east (right), while –90 is 90 west (left) relative to the origin. +180 (east) and –180 (west) are actually the same location due to the wrapping of the sphere. A white + symbol marks the theta, phi origin of 0,0. You can quickly generate sensor layouts with the AutoPlace Sensors dialog. Just right click the graph in the Sensor Placement dialog. Alternatively you can use the INS key to manually insert a new sensor & then edit the sensor coordinates on the sensor grid.

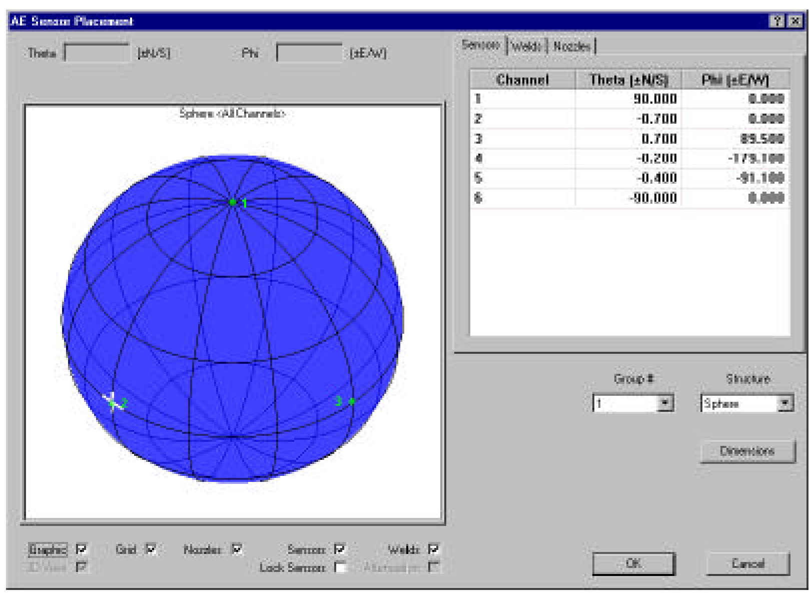


Figure 106. Spherical Sensor Placement

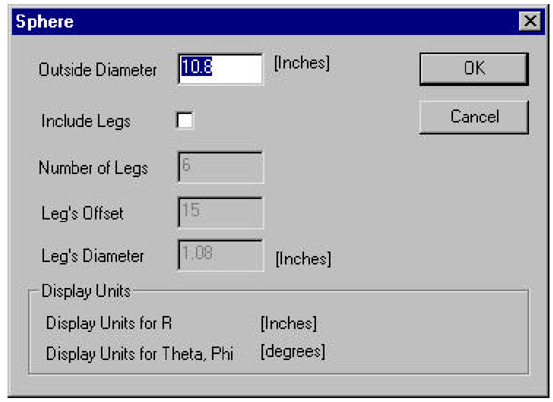


Figure 107. Sphere

Spherical location is designed to work only with the Sphere structure type. You will receive a warning if you attempt acquisition or replay with a Spherical location group that attempts to use any other kind of structure. The Dimensions button allows you to set the diameter of the sphere. The drawing of the sphere in Sensor Placement does not change in size with the diameter, but the diameter is a key parameter required when making use of the sensor coordinates in the location calculations. If your diameter is set incorrectly, location will often fail all spherical events.

There is an Include Legs option in the Dimensions dialog that allows the drawing of the sphere to show support columns if desired. Spherical location does not directly support location on the legs, but you could use Cylinder location on the legs, if location on the legs is required. You can specify the number of legs, their diameter and the offset in degrees of the first leg. The rest of the legs are drawn evenly spaced around the sphere.

After setting up the sensors & each of the location groups, you will want to create location graphs to display the results. It is possible to use any of the standard 2D graph types and display theta or phi on one of the axes. Just pick Theta Position or Phi Position from the list of available features. The easiest way, however, is to use a Spherical Location graph like the one shown at the right.

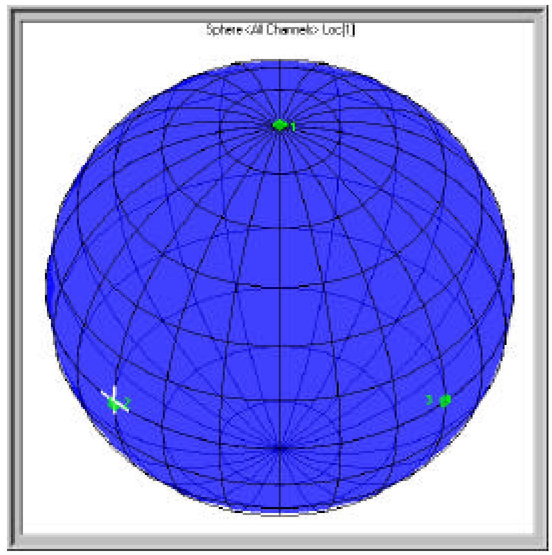


Figure 108. Spherical Graph

In use, a Spherical Location graph can contain a maximum of 4095 data points. During acquisition or replay, the newest data points replace the oldest ones on the graph once the 4095 point limit is reached.

When viewing the Spherical Location plot, you can use the mouse to rotate the sphere by clicking & dragging with the left mouse button. If you use the wheel on a wheel mouse or hold down the Alt key while clicking & dragging with the left mouse button, you can make the sphere larger or smaller. Holding down the Shift key while clicking & dragging pans the sphere up/down/left/right. The Reset Axes button on the toolbar will cause the sphere to revert to the view originally specified by the View Direction settings in Graph Setup.

Here is the Graph Setup dialog configuration for the graph shown above. Unlike the normal 2D & 3D graphs, for the Spherical Location plot you do not specify the axis quantities or the data type (always plots events), so the Input Data and X & Y Axis settings are disabled. The graph will automatically draw sensors on

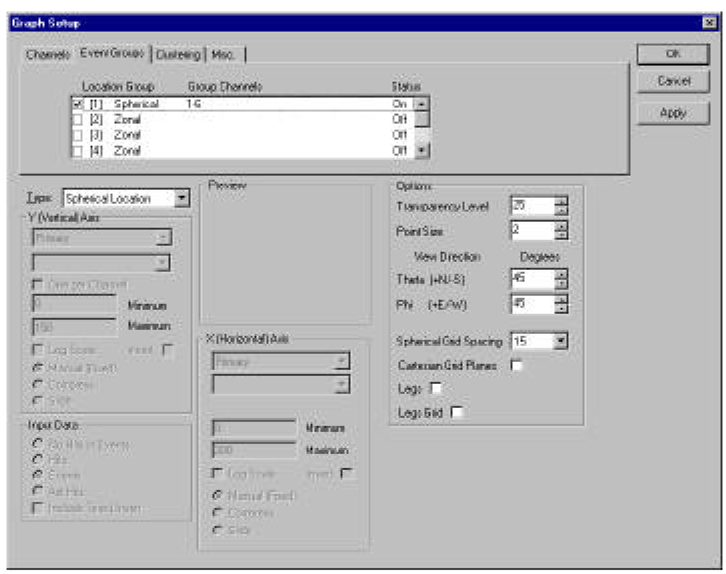


Figure 109. Spherical Graph Setup

the plot for any spherical location groups selected on the Event Groups tab. If you do not see a sphere on the graph after you exit Graph Setup, go back into Graph Setup & make sure at least one spherical location group is selected in Event Groups.

There is an Options section specific to the Spherical Location plot. It contains Transparency Level, Point Size, View Direction, Spherical Grid Spacing & Cartesian Grid Planes. Here is brief description of what they do.

Transparency Level: The Transparency Level can vary between 0 and 100%. When set to 0%, the sphere becomes opaque & points that plot on the back side of the sphere are not visible. If you use 25 or 50%, the points on the back side become visible, but are a darker shade than those on the front side.

Point Size: Point Size directly affects the size of the data points & the sensor markers. The Spherical Location plot draws both the sensors & the data points as small diamonds. A bigger Point Size yields bigger data points & bigger sensor markers. The sensor markers are always slightly larger than the data points. You may also use the Graphing Colors menu to change the colors of the sensors, data points and the sphere (structure color). The data points use the Plot 1 color in Plot Colors.

View Direction: The View Direction setting in Graph Setup controls what angle the sphere is viewed from using the same conventions as the sensor coordinates. This allows you to create top, bottom and side views of your sphere. For example, if you enter Theta = -90 and Phi = 0, the sphere will draw as if you are looking directly at the south pole. Below is a page of sample graphs from the SphereDemo.lay example file.

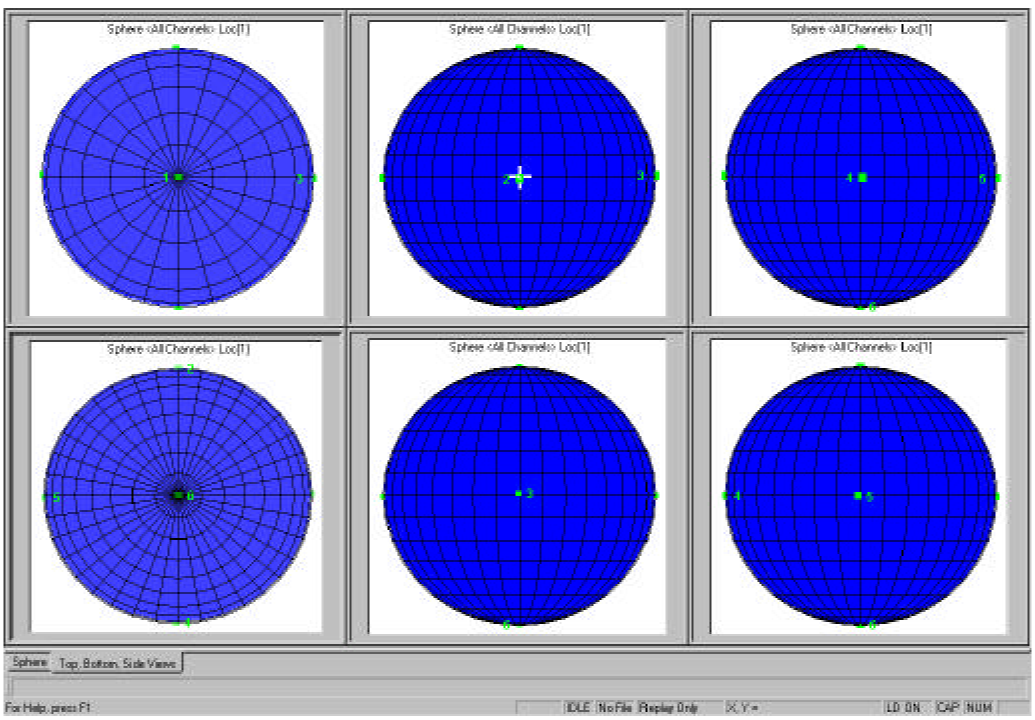


Figure 110. Spherical Graphs

Spherical Grid Spacing: The Spherical Grid Spacing parameter controls how a grid is overlaid on the sphere. Available choices are 10, 20, 30, 45, 90 degrees and None.

Cartesian Grid Planes: The Cartesian Grid Planes checkbox allows you to toggle on/off an X, Y, Z frame of reference.

Legs: The Legs checkbox controls the display on the graph of any support columns defined for the structure.

Legs Grid: This option turns on an additional grid for the legs.

4.4.4 Cylinder Location

Cylinder Location is designed for locating source emissions on a cylinder with either flat, elliptical, or hemispherical endcaps or no endcaps at all. It is similar to 2D Planar Location with the x, y coordinates being the unwrapped cylinder distances, but one or both of the axes wraps around the body of the cylinder.

When setting up your sensors on your cylinder, there are several guidelines to keep in mind. As with 2D Planar, the software cannot successfully locate any source when all the hits are from sensors in a single straight line. The advice on good vs. bad sensor layouts for 2D Planar applies here too. Avoid rectangular sensor layouts where the distance between rows differs greatly from the distance between columns as shown in the Bad 2D Planar Layout diagram. As stated before, the optimal arrangement would be a triangular grid made up of equilateral triangles. For Cylinder location, also be sure your sensor triangles on the heads are not significantly different in size than the triangles on the body especially if your cylinder has flat heads. If you do so, you may get spurious event locations clustering along the head-body border.

Sensors that are 180 degrees apart can also cause mathematically invalid events too. Geometrically, it is similar to problem with a straight line of sensors. If an event consists of a sensor on one side of the cylinder & 2 others exactly 180 degrees around the body, there is no way to distinguish source locations in the positive direction from the negative . Generally it is recommended that you use 3 sensors around the circumference of the cylinder in a given row. If you must use 2 sensors per ring around the cylinder, definitely stagger the alternate rows or else you will not see any locatable events.

Use the Sensor Placement dialog shown below to set up the cylinder as well as place your sensors. Cylinder location is only designed to be used with the Horizontal or Vertical Vessel structure types. For Cylinder location, the Structure list in Sensor Placement *must be* set to either Horizontal or Vertical Vessel (cylinder) as shown above. You will receive a warning if you attempt acquisition or replay with a Cylinder location group that attempts to use any other kind of structure.

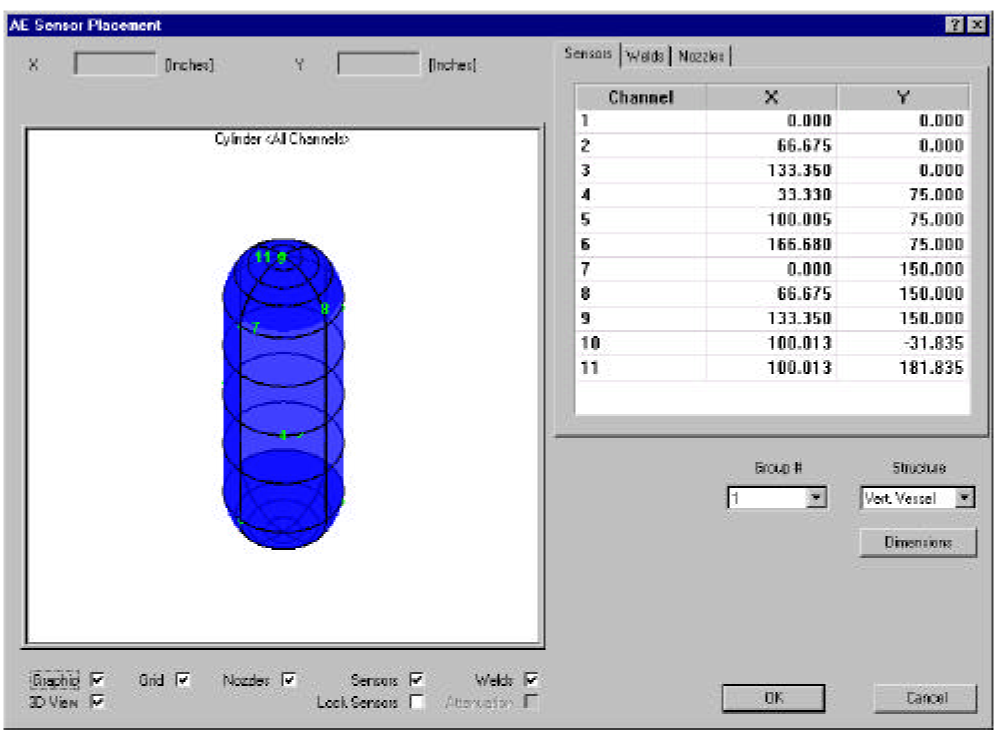


Figure 111. Cylinder Sensor Placement (3D View)

By default, Sensor Placement shows a 3D cylinder view. If you prefer a 2D view, simply uncheck the 3D View option at the bottom of the dialog & you will be presented with an unwrapped 2D view of the cylinder shown below.

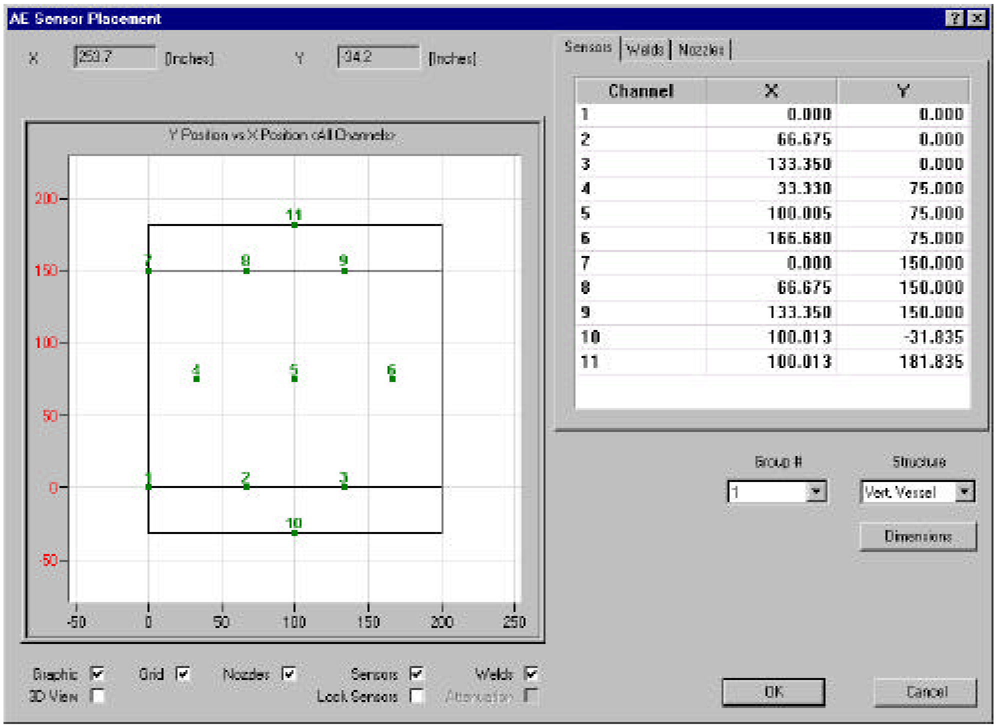


Figure 112. Cylinder Sensor Placement

The Sensor Placement dialog in 2D view & 2D location plots draws a rectangle to represent the body of the cylinder based on the user entered dimensions. You use the Dimensions dialog shown to the right to enter an Outside Diameter and the Height (vertical) or Length (horizontal). For a Horizontal Vessel, the rectangle extends along the x axis from 0 to Length and along the y axis from 0 to the circumference calculated from the user entered Outside Diameter. For a Vertical Vessel, the rectangle extends along the x axis from 0 to the circumference and along the y axis from 0 to Height.

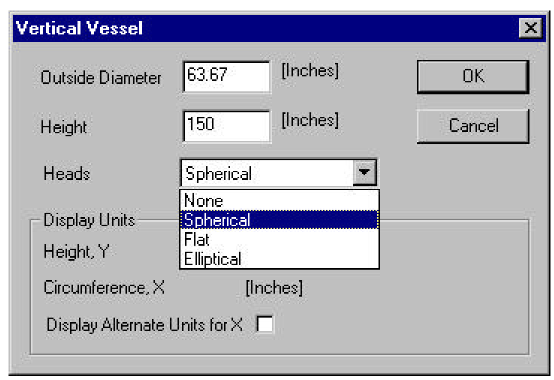


Figure 113. Vertical Vessel

Both dimensions are also vital to accurate source calculations. The Diameter is used to allow for the wrapping around the cylinder circumference. The Height or Length in combination with the Diameter is used in eliminating 2D locations off of the cylinder body caps itself.

There is also a dropdown list to select the type of Head on the cylinder. Available choices are Spherical, Flat, Elliptical & None. If a head type other than None is selected, the body rectangle drawn in Sensor Placement will have 2 additional rectangles on the top & bottom (Vertical Vessel) or left & right ends (Horizontal Vessel). The head rectangles extended the body rectangle by a distance determined by the head type. For Spherical or Flat, it is the length of the cap radius which is also the body radius and half the user entered diameter. In the horizontal case, the rectangle will extend along the x axis from –radius to Length+radius, while in the vertical case the y axis will run from –radius to Height+radius. For Elliptical heads, a 2:1 ratio is assumed between the body radius & the perpendicular head radius, so the distance is ½ the body radius or ¼ the user entered diameter.

You can quickly generate rectangular & triangular sensor layouts with the AutoPlace Sensors dialog available by right clicking on the sensor view. If you are using the 2D view of the cylinder, you can also manually place sensors on the cylinder by right clicking. After using either option, you can edit the coordinates of the sensors if structural features (valves, nozzles, welds) require shifting sensors around. Just enter the x,y coordinates in the user's preferred distance units.

When you enter sensor coordinates & you are not including the caps, express your x, y coordinates with a lower limit of 0 and an upper limit of the circumference or the length/height. For example, when working with a vertical cylinder of height 150 and diameter 63.66 (circumference = 200), express x as a value from 0 to +200 and y as value from 0 to +150. Basically, just make sure your sensor is visible in the body rectangle drawn in the Sensor Placement dialog.

If you are using Spherical or Flat heads, these limits are widened for the y axis by the radius to –31.83 to +181.83. These extensions allow for the entry of sensors on the heads. For this vertical cylinder, a pole sensor on the bottom cap would have a y coordinate of -31.83. The x coordinate for a cap on a vertical cylinder corresponds to a rotation angle, but is entered as a fraction of the body circumference. In this case the limits are 0 to +200 and sensors placed 120 (=360/3) degrees apart are separated by 66.67 (=200/3). For a cap sensor placed directly at the pole of the hemisphere, the rotation angle is unimportant in the source location calculations, but a value of half the circumference will place the sensor halfway up the cap rectangle border. In the case of the vertical cylinder shown above, the pole sensor on the bottom cap is at -31.83, +100 (any x really) and +181.83, +100 for the top cap.

When you are finished setting up your sensors & ready to actually do data acquisition, you will need a location graph to display the results of the source location calculations. You can either use a standard 2D graph as described in the section on 2D Planar location or you can use a Cylinder Location graph. Like the Spherical Location graph, a Cylinder Location graph is limited to 4095 data points with newer points replacing older ones once the limit is reached. A Cylinder Location graph is shown at right and it's corresponding Graph Setup dialog settings are below. It has an Options section that is very similar to the one for Spherical Location. See the section on Spherical Location for a description of the options common to both.

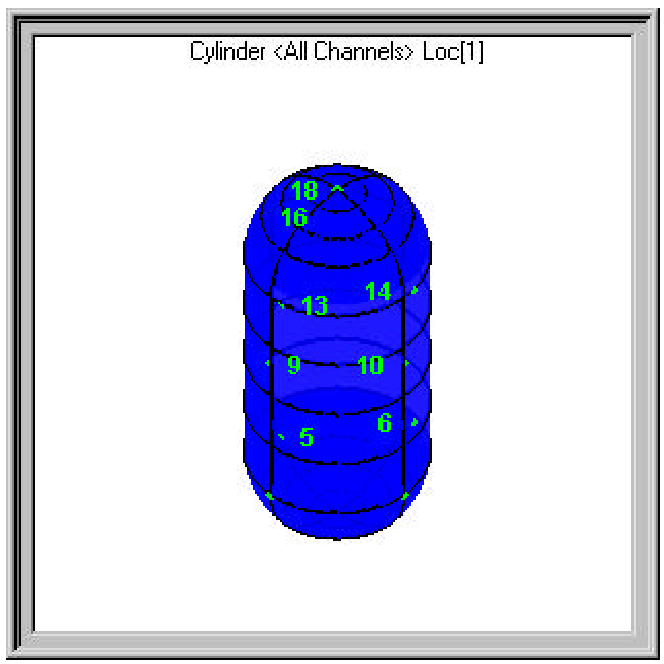


Figure 114. Cylinder Graph

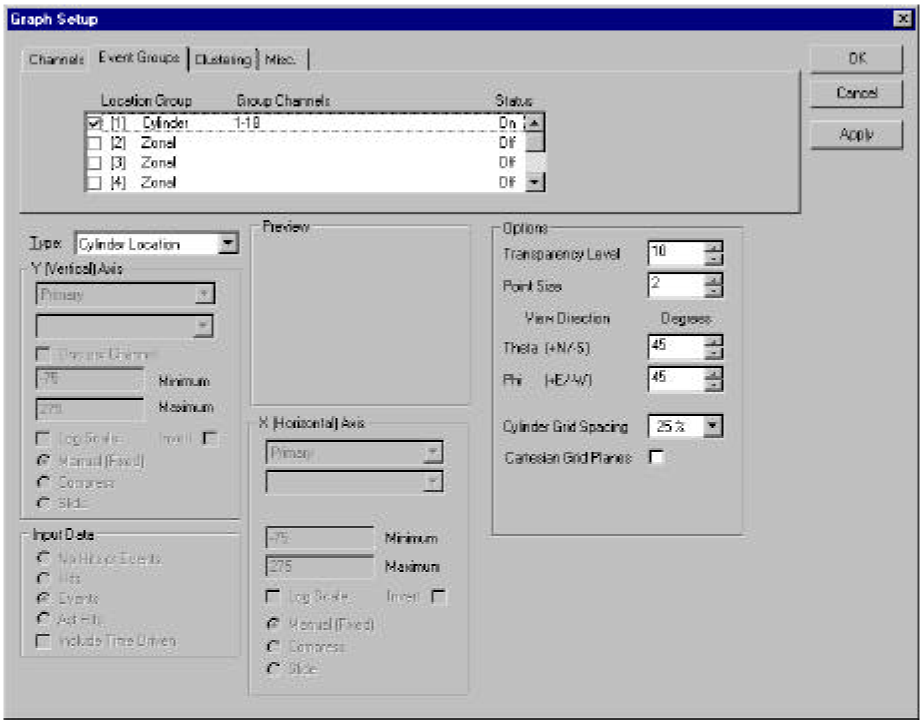


Figure 115. Cylinder Graph Setup

The Spherical Grid Spacing option is replaced by the Cylinder Grid Spacing option, although it behaves in a similar fashion. You may set the Cylinder Grid Spacing to None, 10%, 20%, 25%, 50% or 100% to control the appearance of a grid overlaid onto the surface of the cylinder. The percentages are applied to the heads & the body separately as the dimensions for the 2 regions can vary greatly. If the user selects a grid spacing of 25%, the body will be divided up into 4 equal regions and the head will also be divided up into 4 regions. If the user selects 100%, only the boundary between the heads & the body will be marked. Cylinder Location graphs always use Events as the Input Data, but as for the 2D graphs, make sure you set the Events Groups to the appropriate location group or your graph will not show any data & will not draw the cylinder associated with the group.

4.4.5 Conical Location

Conical location is set up almost identically to Cylinder location mode. In Location Setup, the user selects Conical for the Location Type on the General tab. The other settings in the table are described in the section on the Location Setup dialog. In Sensor Placement, set the Structure list to Vert. Cone or Horiz. Cone as shown on the next page.

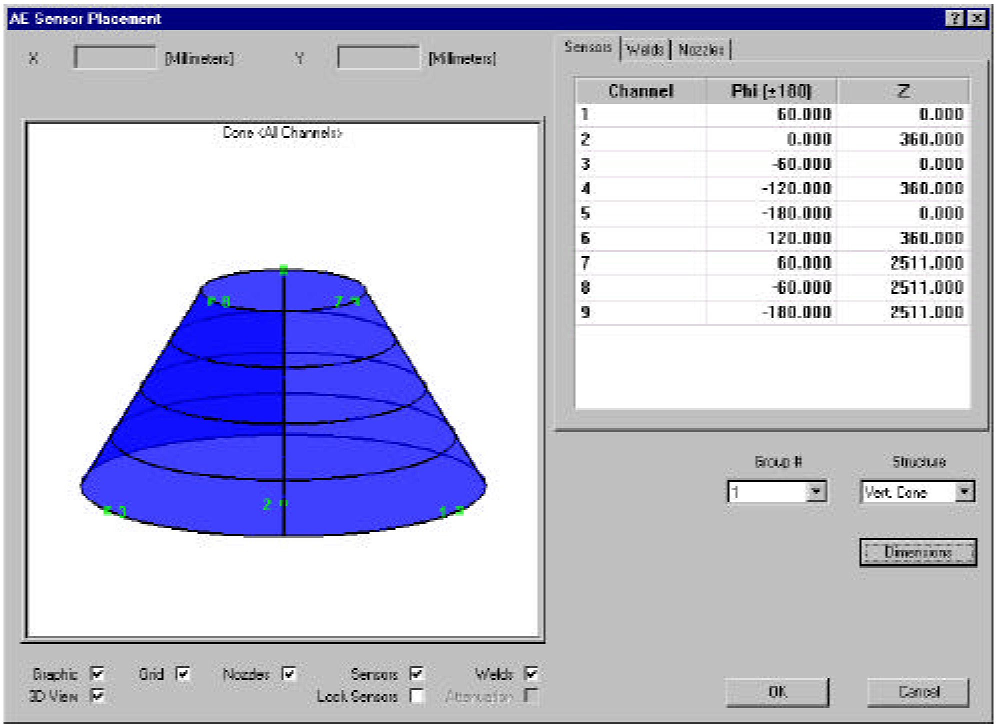


Figure 116. Conical Sensor Replacement (3D View)

The Dimensions button calls up the Cone dimensions dialog allowing the user to enter the upper & lower diameters as well as the height (or the left & right diameters & length, if horizontal). The height or length has added significance when conical location is analyzing data. Conical results are limited to source locations to within +/- 2% of the height. In other words, points located wildly off the cone body are thrown out as bad results.

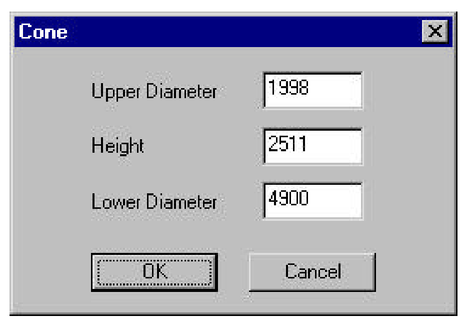


Figure 117. Cone

Sensor coordinates are entered as Z & Phi. The Z axis is the cone axis independent of horizontal vs. vertical configuration. Z starts at 0 at the bottom of the cone & goes up to the height of the cone (or 0 at the left & up to the length). Phi should be entered between -180 to +180 degrees to keep the sensors within the 2D drawing of the unrolled cone, although location will work with values from 0-360 as well.

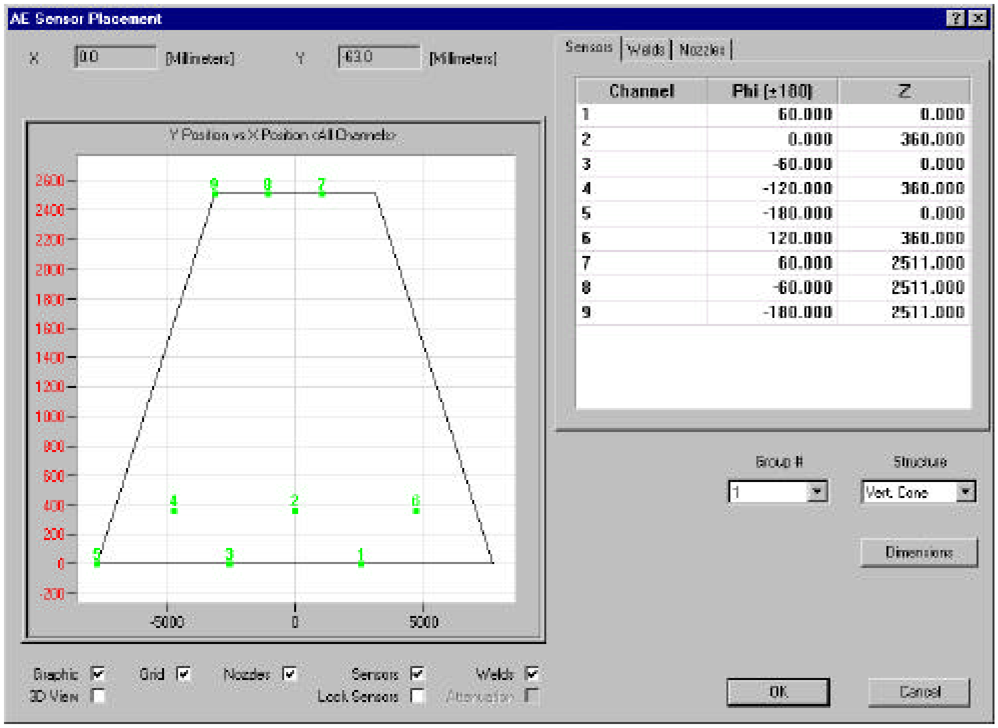


Figure 118. Conical Sensor Placement

You can toggle between 2D & 3D graphs in Sensor placement with the 3D View checkbox. The 2D view translates the phi value into a fraction of the circumference. The trapezoid is drawn from +circumference/2 to -circumference/2 where the diameter depends upon the z value in the cone.

There is also a 3D Conical Location graph similar to the Cylinder Location graph as another graph type in Graph Setup. It has options similar to those for the Cylinder Location graph & the Spherical Location graph. See their sections for a description of these options.

In use the 3D Conical Location graph looks like the 3D graph in Sensor Placement. The sample layout, ConicalDemo.lay, gives an example on the 3D Cone page. A Conical Location graph can contain a maximum of 4095 data points. During acquisition or replay, the newest data points replace the oldest ones on the graph once the 4095 point limit is reached.

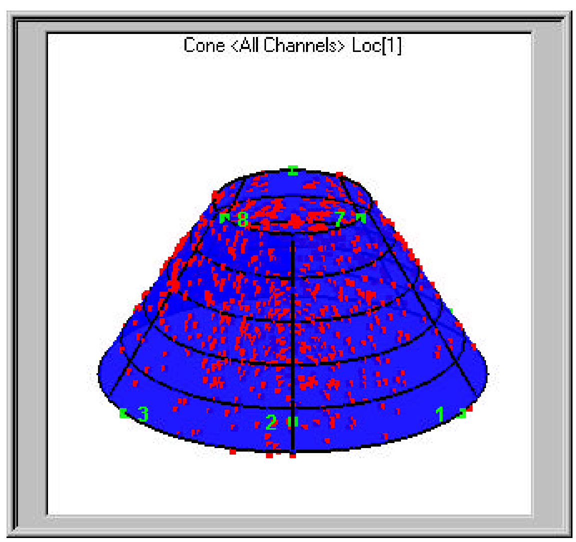


Figure 119. Conical Graph

4.5 Location Examples

It is not feasible to provide detailed examples of all location modes in this manual. There are, however, example layout files & sample data files for each location mode. When you are starting out with a new location mode, you can simple recall the sample layout & inspect the location related menus (Location Setup, Sensor Placement & Graph Setup dialogs). After you learn how the example is set up, you can make changes to better reflect your test setup & save the modified layout under a new name. Below is a table summarizing the example layouts & data files for the various location modes.

Location Mode	Layout File	Data File
Zonal	Zonal_Linear.lay	Zonal_Linear.dta
Linear	Zonal_Linear.lay	Zonal_Linear.dta
Tank Bottom	TankBot.lay	TankBot.dta
2D Planar	2D-Planar.lay	HE-Link.dta
Cylinder	OpenCylinderDemo.lay	LongVessel.dta
Conical	ConicalDemo.lay	ConicalDemo.dta
Spherical	SphereDemo.lay	SphereDemo.dta
3D Location	3dLocDemo.lay	3dLocDemo.dta

In addition to the example files, there are detailed examples given here to illustrate how to use Zonal, Linear, 2D Planar & Tank Bottom location. The steps in setting up and running a location test are pretty similar no matter what location mode you are using. Here is an overview of those steps:

1. Create a layout file with the hardware set up appropriately (e.g. the correct number of sensors turned on, detection threshold set properly).
2. Bring up the Location Setup dialog (=F8 key) and start by setting the distance units.
3. Next fill in the location group information. Enable the group & select the Location Type. Enter the Wave Velocity, Event Definition Value & Overcal Value. If this is your first time working with location, leave the Event Lockout Value, Timing Strategies, Max Iterations, Min & Max Hits/Event at the default values. That applies to all the settings on the Timing page as well. These parameters are more fully described in section on the Location Setup dialog under the headings of General Tab Settings & Timing Tab Settings.
4. Next define the sensor locations on the structure using the Sensor Placement dialog. Use the Location View button in Location Setup to display it.
5. In Sensor Placement, start by selecting the Structure type and then click on Dimensions to enter the appropriate structure information.
6. Now create your sensors by right clicking the sensor view area & or using INS & F2 in the sensor grid.
7. When finished, click OK in both the Sensor Placement dialog & in the Location Setup dialog.
8. Next create a suitable location graph using the Graphing menu (New Graph) & configure it using the Graph Setup dialog (=F3 key). See the notes on individual location modes for information on the appropriate location graphs.
9. Now we are ready to run a trial AE test using pencil lead breaks to verify that everything is set up properly. If everything works, you're ready for acquisition.
10. If you end up staring at an empty graph, here is a list of things to double-check. Some are obvious, but personal experience shows them to be easy mistakes.
    a. Is the Input Data set to Events in Graph Setup?
    b. Is this location group checked on in the Event Groups tab of Graph Setup?
    c. Is this location group checked on in the Group # column of Location Setup?
    d. Are there any events from the group in the Line Display?
    e. If there are events, are the axis limits in Graph Setup wide enough to see the positions?
    f. If no events, are the Location Setup settings reasonable? Did you look up a velocity like 10,000 ft/sec & enter 10,000 when it should be 120,000 because the Distance Units are Inches? Verify the Event Definition & Lockout Value are reasonable given your sensor spacing & structure type. They all use the same units, so the values should be related to sensor-sensor spacing.

4.5.1 Set Up and Testing of a Zonal or Linear Location Group

As an easy to set up layout, we will be using two sensors located 30 inches apart. This sensor layout will be used to illustrate Zonal location in this section & Linear location in the next section. We will be using example layout and data files called Zonal_Linear.lay and Zonal_Linear.dta which are installed in the AEData directory under your software program directory, for example "C:\Program Files\Physical Acoustics\AEwin for DiSP\AEData". If you do not have these sample files, we will be showing the setup screens so that you can duplicate the setup and conduct your own acquisition test.

In this section we will be setting up a Zonal Location Test following the steps identified above. For the example, we are assuming that we have two sensors in Channels 1 & 2 of the AE system.

Step 1. Start by using the File pulldown menu to access the Open Layout menu option or press Ctrl-O. Select the layout file named, "Zonal_Linear.lay" & recall it.

Step 2. Enter the location setup menu by either pressing the F8 keyboard function key, clicking on the Toolbar icon that looks like a "bullseye" target called "Location Setup" or select Location on the Acquisition Setup pulldown menu.

The Location Setup dialog will be displayed as shown below. This is the first menu that needs to be set up in accordance with our step by step procedure. By default, the General page displays. Notice the General tab near the top left of the dialog box. The General page of Location Setup allows you to control the setting of the individual location groups. Up to 8 location groups can be set up, although an additional licensing option provides for up to 32 groups.

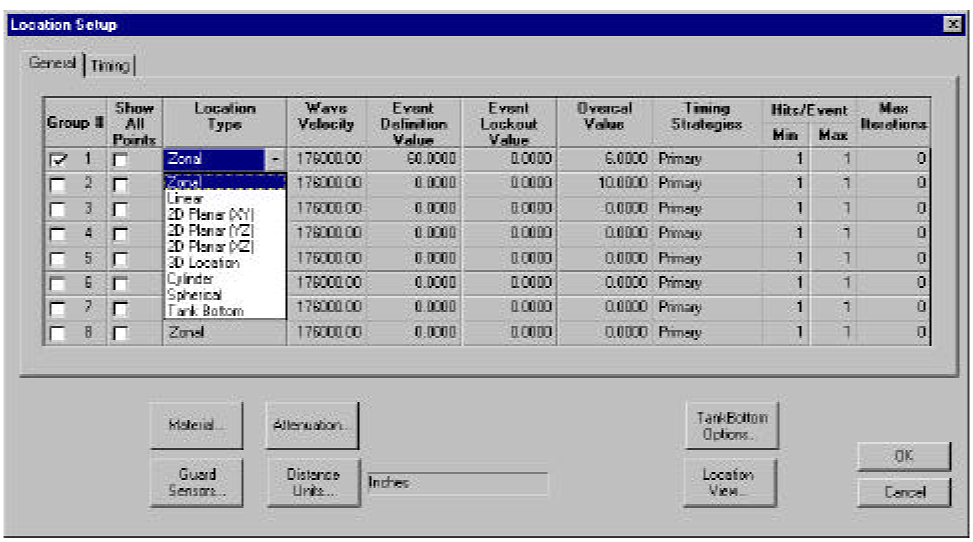


Figure 120. Setting up Location Group Information

In addition, near the bottom center of the dialog, the user can set up the location distance units. Various selections including Metric, English and time units can be selected for distance units. Selecting a real distance value is most appropriate since the values read out can be directly measured when trying to locate a source on a structure. Use the Distance Units button to select inches as in this example.

Step 3. In this example, we will select a Zonal location group as group #1. Follow the Group #1 line and enter the information as shown. First select the zonal group. This is done by left-clicking the mouse on the right side of the Group #1, "Type" box. A dropdown list will appear to allow the user to select from the various alternatives (Zonal, Linear, etc.). Select Zonal.

For the Wave Velocity, the velocity entered will be related to your Distance Units setting. In this case, we've selected inches as our units, so the velocity is in inches/second. You can look up a velocity using the Material Properties dialog by clicking on the Material button. The database contains values for Longitudinal, Shear & Surface velocities. It is often better to directly measure the velocity using the AE system. Simply use the Line Display mode to determine the actual transit time (Δt) to traverse between two sensors. You can then divide the distance between the two sensors by the Δt to arrive at the estimated velocity. In order to determine this correctly you really need to simulate the type of defect you are trying to detect. Enter the desired velocity in the edit box. In our example, we used an aluminum bar and a pencil lead break as a source. Although the Longitudinal velocity is 249,000 inches/second and the Shear velocity is 123,000 inches/second, we experimentally determined a test velocity of 176,000 inches/second.

For the Event Definition Value, we want to select a generous Event Definition using the same units as the Distance Units selected. This should be set to make sure that from any point in the location array, a minimum desired number of sensors will be hit, forming an event. In our example, two sensors 30 inches apart, the Event definition should be at least 30 inches to make sure that the two sensors get hit within a single event. We have entered 60 in the example above.

For Event lockout Value, we enter a value (in the selected distance units) to assure that the there is enough time (or distance) for all additional hits and reflections related to the event have had a chance to die down. The amount of time or distance selected will be the "dead" time as we wait for the event to die down. In this example, we will leave it at the default of 0 as reflections are not expected to be a problem for this setup.

The Overcal value is also set in the selected distance units and is usually set at an amount of approximately 10% to assure that minor variations in wavepath velocity are not ignored by the location algorithm. When you are just learning to use location, it is best to leave the settings on the Timing page & the Timing Strategies column at the defaults. The Max Iterations, Min & Max Hits/Event cannot be changed for Zonal as they are not used by it. They only apply to the regression location modes. All of these parameters are more fully described in section on the Location Setup dialog under the headings of General Tab Settings & Timing Tab Settings.

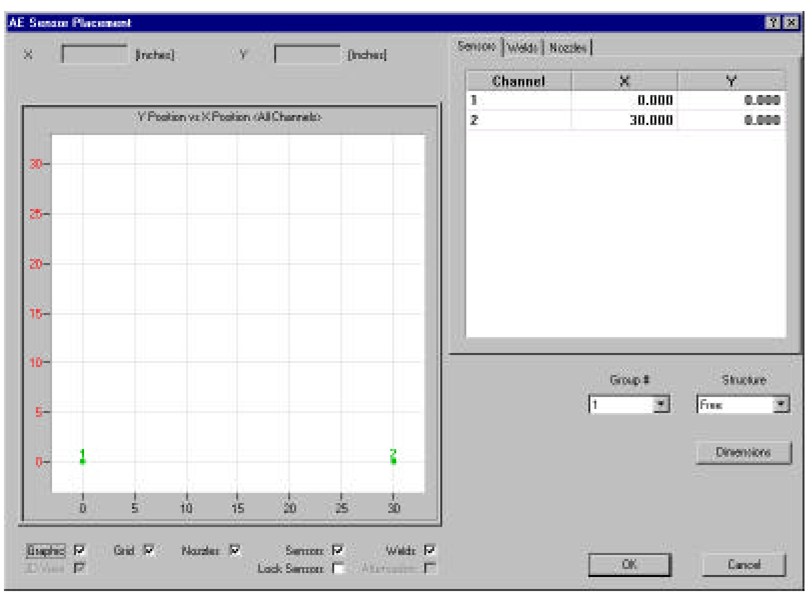


Figure 121. Sensor Placement Dialog

Step 4. Once the location group settings have been entered, we can move on and define the sensor placements. This is done with the Sensor Placement dialog. Click on the Location View button on the bottom right side of Location Setup to display it. The figure above shows the Sensor Placement dialog box. There are 2 main area to the dialog box. The sensor layout view on the left-hand side and the sensor grid with the coordinates of individual sensors on the right hand side.

When we click Location View, the sensor layout for that particular location group is displayed. If we had group 1 highlighted, but wanted to display the sensors for group 5, we could change the group displayed with the Group dropdown listbox just below the sensor grid. Select Group 1, if it is not already selected.

Step 5. Next, we need to select the "Structure". The Structure setting is also just below the sensor grid & just to the right of the Group setting. This is currently set to Free. Free allows sensors to be placed anywhere without worrying about the specific structure geometry such as a plate, box or sphere.

Next, we set the Structure dimensions. For the Free structure, this isn't required for location, but the dimensions control the axis limits of the graph in the sensor view area. To change them we click the "Dimensions" button and the Free dimensions dialog shown at the right appears. Here we've set the X and Y minimum and maximum values to 0 & 30.

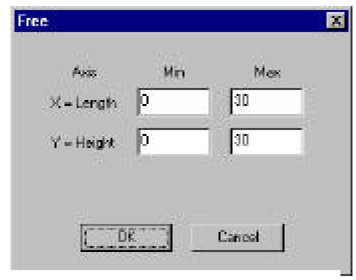


Figure 122. Free

Step 6. We are now ready to create our sensor layout. In Sensor Placement example above, you can see that the sensors have already been placed at the bottom of the graph area, at locations of (0, 0) and (30, 0) using an (X, Y) arrangement. The software makes it very easy to place and move sensors on the screen and to get them in an exact position.

To place a new sensor, we right click inside the graph region. The context menu to the right appears. The menu options we want to concentrate on are on the Sensors submenu allowing you to perform various functions related to sensor placement.

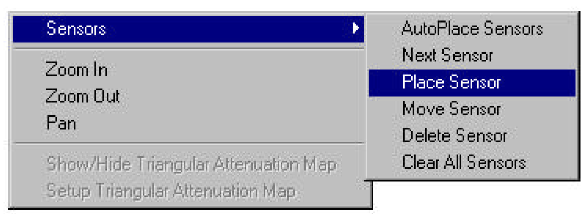


Figure 123. Place Sensor

Since we want to place a sensor, simply select and click on the "Place Sensor" selection. Upon doing so a small menu box comes up asking you to verify the number of the sensor to be placed or to change it. When you're done, click OK and the mouse cursor will change to a red sensor icon with a crosshair cursor. Each time you click you will generate another sensor in your layout. Notice the x,y coordinates of the mouse cursor are shown above the sensor view area. When you are finished placing sensors, right clicking will return the mouse to its normal arrow shape. Simply follow the right click with a left click off the menu, if you don't need any of the context menu options. Whatever you do, don't press the ESC key. That is equivalent to pressing the Cancel button for the dialog & you'll lose all your changes to the sensor layout.

There are 2 ways to move sensors around to correct bad placement. First, the right click Sensors menu has a Move Sensor option. When you select it, the mouse cursor changes to a red sensor icon with a 4-headed crosshair cursor. To use it, click on the sensor you want to move. The sensor will turn red. Now click a second time at the spot where you want to move the sensor & it will shift to the new location. Right clicking ends the Move Sensor mode.

If after graphically placing or moving a sensor, its placement is still not accurate enough, you can alter the position to an exact value by modifying the X or Y value in the sensor grid. Simply left-click the mouse to highlight the desired box to be changed and enter the exact value, followed by the Enter key. Alternatively, press the F2 key to edit the current value.

Note the other sensor placement and edit capabilities provided by the submenu. You can automatically place the "Next" sensor by number by pressing the "Next Sensor" button. In this case the sensor channel number selection box does not come up. It simply enters the Place Sensor mode using the next highest number sensor. Please note and experiment with these sensor placement management selections.

By now you may have added several sensors to your setup that you want to delete. Do this by right clicking over the sensor you want to delete and then select "Delete Sensor". The mouse cursor with change to a red sensor with a crosshair labeled "del". When you click on a sensor, a "Delete this sensor?" message box asks for confirmation. Click "Yes", to delete the sensor from the graph and from the table. Again right clicking puts the cursor back to normal. Return to the original sensor layout as shown above when you are finished exploring the Sensors menu options.

Step 7. In the previous steps we have fully defined the location setup. The next step in the process is to set up graphs to see our location in acquisition or replay. We do this by first saving our sensor placement & location setup. Click the OK button in Sensor Placement & then in Location Setup. DO NOT CLICK Cancel in either one as you will lose any changes you made while in these dialog boxes. This is a very good time to save your layout on disk as well using the File pulldown Save Layout As menu options. If you don't need to rename the layout, you can just use Ctrl-S to update the current layout on disk.

Step 8. Next we need to create a suitable location graph. If you have been following along with our example layout file called Zonal_Linear.lay, you will be seeing a screen like that shown below. In this screen you can see two graphs. The first or top graph is set up already as a location graph. Since this is being set up for zonal location, we will only see the activity in a histogram or bar chart type of arrangement.

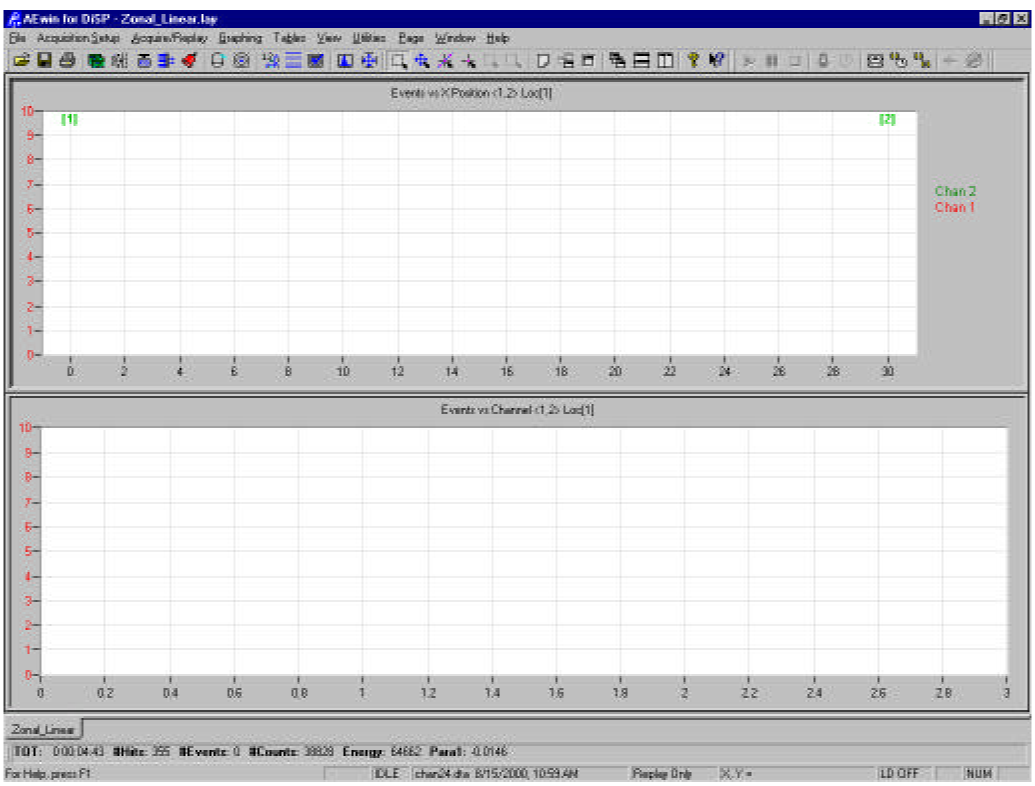


Figure 124. Zonal – Linear Location Graph

Assuming that this graph was not already set up in the desired location mode, lets go through the steps of setting up the graph for a Linear or Zonal location. First, we select the graph that we want to change to the location graph. We do this by right clicking the mouse when it is inside the graph region of the graph that we want to work on. Once we do that a menu appears. This menu gives us many choices but we will select the top one called “Graph Setup”. Upon selecting this a graph setup menu appears like that shown below.

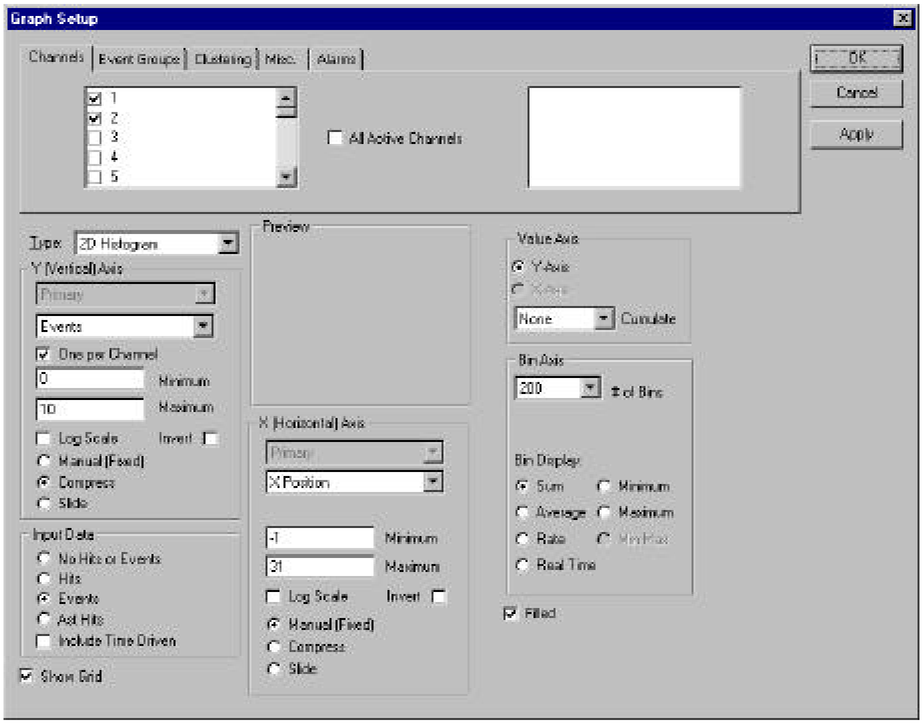


Figure 125. Graph Setup Dialog

This screen capture shows us how we have set up the Graph setup menu for a linear location. This gives us a lot of insight into how the graph setup menu works and how to set it up. Lets note first the layout of the menu. We see at the top of the menu, a selection area for Channels, Event Groups and Clustering. These settings allow us to select exactly those items. With the Channels Tab, we can select which channels will be displayed on the graph that we are setting up. In this case we are only selecting channels 1 and 2 for viewing in the graph. You can see that we have set group #1 in Event Groups if you select that tab. Clustering allows you to set up parameters that link closely spaced hits/events together.

The next menu area is the Graph Type selection box. This is located on the left just below the Channel, Event Group and Clustering selection area. Various graph types can be selected, but for this application we will use a 2D Histogram.

Below the Graph Type selection, is the <u>Y (Vertical) Axis</u> setup menu area. Going down one item at a time in this menu is the plot # selection within the graph. This selection normally allows you to display more than one plot on a graph, but it is disabled for this 2D Histogram type, because we have checked <u>the One per Channel</u> checkbox (see below). Basically the selection (Primary, Secondary-1, 2 etc.) controls which plot the Y Axis settings apply to.

Next is the Y-Axis parameter to be plotted on the graph. By clicking this, you can see many selections. However, we have selected Events. This will display the number of Events detected on the Y-Axis.

The checkbox <u>One per Channel</u> allows us to select a unique per channel plotting color that will give us a multiple color by channel plot. In our case for events and 2 channels, we will get a different color for the channel that was hit first if this is checked. If not we will only get one color plot.

The next two edit boxes allow us to set the starting Y-axis Minimum and Maximum settings.

The next checkbox Log Scale allows us to set a log or linear graph scale. Beside it is an Invert checkbox which allows the user to reverse the positive to negative direction on the axis.

The next 3 radio buttons are related, allowing you to select one type of graph scaling. Manual(Fixed) will force the graph limits as set above to remain fixed. Compress will compress the graph so that the minimum graph value remains but the maximum keeps changing as the graph limit is exceeded. And the Slide selection will allow both the minimum and maximum limits to change or slide as data is received that is beyond the current limits.

The next box allows us to select what type of Input Data we are plotting. In our case since we are plotting a location graph, we want to choose the Event data for plotting.

Below this is a Show Grid checkbox for displaying a grid on the graph background.

The next column to the right, shows the X (Horizontal) Axis settings. The X-axis settings have similar setup boxes as were described for the Y-Axis and will not be described here. Just note how they have been set up to display the X-Position for location and that we have set up the minimum and maximum graph values to include the sensor positions of 0 and 30 inches. Also note that we have selected fixed scaling on the X-axis because we do not expect the X axis position to change. If this were a time axis we would be using a “compression”, or sliding graph scaling.

The last column on the right changes according to the graph type being set up. If a 3-D graph were being set up, this would be the column for the Z-axis setting. However, since we have selected a graph type of 2-D Histogram, settings for the Value Axis and the Bin Axis appears. Again, for now just note the settings and you can get familiar with what they do by making a change and seeing how it affects the graph later.

At the bottom of the third column is a checkbox that allows you to decided whether the histogram shows unfilled, outlined bars or filled solid bars.

Please note and try to make sense of all the selected menu settings. Although it might look complex at the start, if you have gone through these settings, one at a time you will see that all is quite simple. Exit the graph menu by selecting the OK button at the top right of the Graph setup menu.

By looking at the top of the graph we see its graph title of “Events vs. X Position <1,2> Loc(1)”. This summarizes what is being displayed. First is the graph type “Events vs. X-Position”. Next we are displaying data from channels 1 and 2. Finally, we are displaying results from location group #1.

Now that we are finished, we see that we have set up a Linear location graph and are ready to test it. However, before we do, we have a second graph located below the first one. Lets take a look at it. By the title, we see that it is an Events vs. Channel graph, plotting channel 1 and 2 data and also working with data from location group #1. We can look further to see how this graph is set up by entering the graph set up menu (right clicking within the graph area and selecting the “graph menu” selection at the top of the submenu).

Take a look to see how this has been set up. The main difference is in the X-Axis graph parameter and the Bin Axis setting # of bins. This should help give a little insight into how you can set up different graphs.

Now we are ready to proceed with a test or a replay. As a reminder, as a precaution always save your Layout file before trying it out. It is not fun to have all your work disappear because power went down or something happened to lose the layout.

Step 9. The next step after setting up the graphs is to test the layout & verify that it functions properly during acquisition. We can do this by carrying out a trial acquisition and location test if we have setup our sensors or we can do this by replaying our test file called **Zonal_Linear.DTA** . To do this, refer to the sections on going into acquisition or replay (section 3.4 and 3.5). In our example we will replay the DTA file by going to the Replay function, selecting the file “Zonal_Linear.DTA and starting. Upon selecting, our data file is replayed and should look like the graphs shown below.

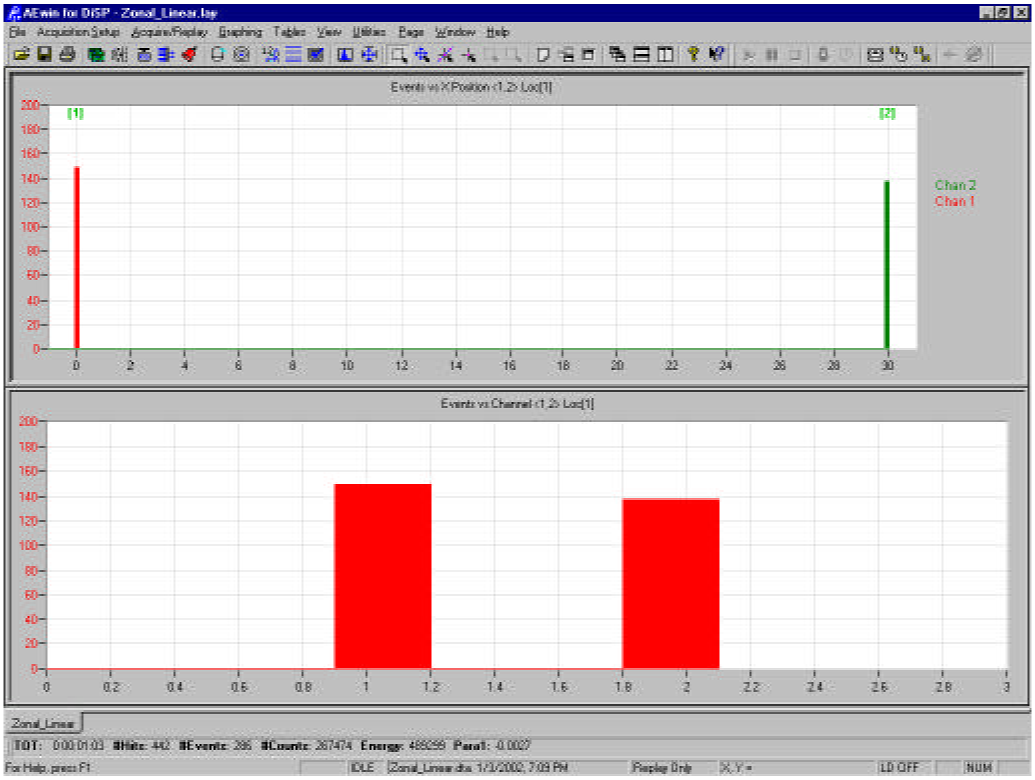


Figure 126. Zonal Location Graph

The top Events versus position graph shows that all the locations occurred at each of the sensor positions, even though in reality the events were distributed along the length between the two sensors. You can also see that there are fewer events on the right side, or from sensor #2. This is confirmed in the Events versus channel graph below the location graph. The reason for the events showing up at the channel of a Zonal location group is that again the zonal group provides information on which sensor was hit first.

From the above display it seems that our setup is good and we could proceed on to test with a setup like this. However, you can modify some of the settings in the graph setup menu & repeat the replay of the data to see how the graphs are affected by changes and to get familiar with the graphing capabilities.

To illustrate the ease with which changes can be made, we'll now modify the location setup & transform the Zonal location group into a Linear location group. Simple use F8 to bring up the Location Setup dialog & change the Location Type of group #1 from Zonal to Linear, Next use F10 to replay Zonal_Linear.DTA again. Note how the results on the location graph below compare with the results for the zonal location shown above using the same Zonal_Linear.dta data file. There are now locations along the length of the top graph indicating that some events have located in between the 2 sensors..

This example shows one of the very nice capabilities built into the software, the ability of changing a setup and visualizing a different result upon replay. Remember that simply by changing the Zonal setup to a Linear location setup we got two different graphical results. This is very useful when analyzing data.

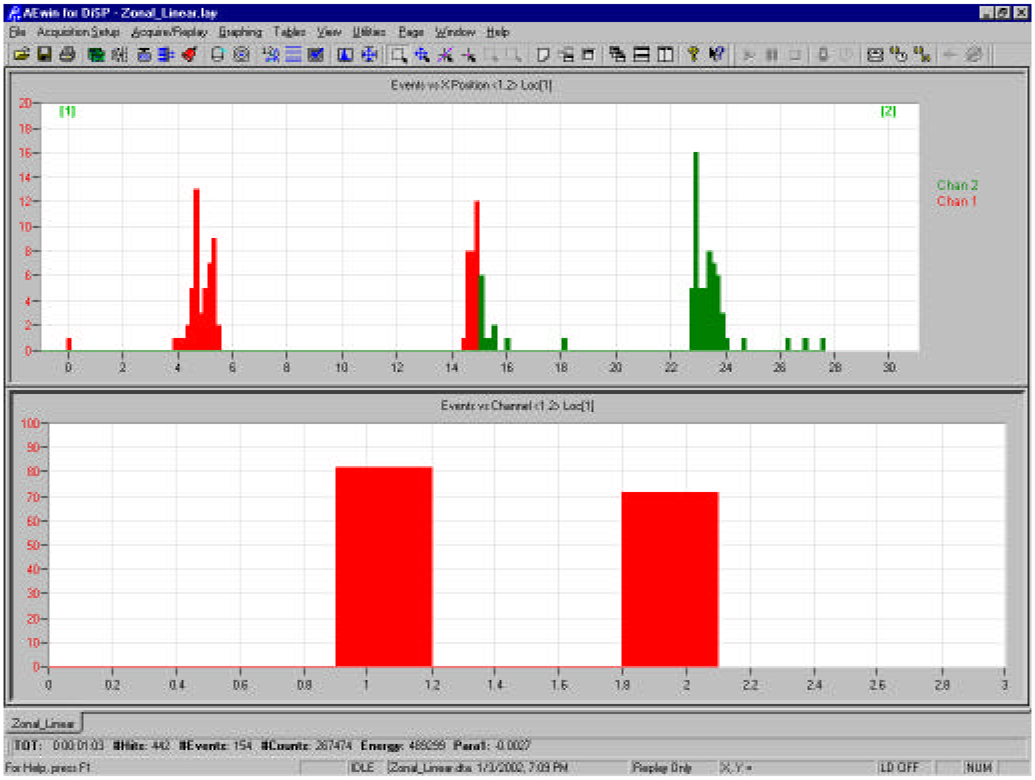


Figure 127. Linear Location Graph

4.5.2 Setup and Testing of a 2D Planar Location Group

As a detailed example, we will be setting up a 2D Planar location group with 4 sensors. We will be using the 2D-Planar.lay and chan24.dta example layout and data file and which are in the AEData directory by default. If you do not have these examples, we will be showing the setup screens so that you can duplicate the setup and conduct your own acquisition test.

As explained at the beginning of this chapter, 2D Planar location is part of the full location option. You can check for the full location option using the Options dialog available on the Help pulldown menu. Look for a checkmark next to Full Location. Alternatively you can just look for 2D Planar in the list of available location modes under the Location Type column in Location Setup.

2D Planar location lets you place multiple sensors anywhere on your test structure without restricting you to a fixed grid arrangement. This is convenient as many structures have pipes or valves that may make a fixed triangular or rectangular arrays of sensors impossible to set up. The position of the source event is calculated from the differences in arrival times between the first 3 (up to 8) valid hits (≥2 Δt values). The positions of the sensors for first 3 hits always determines a triangle. The ideal arrangement for 2D Planar would be a layout made up of equilateral triangles, but exact equality of the triangles & sides of the triangles is not an absolute requirement. You will get better results if you avoid creating sensor triangles where one side of the triangle is much larger or smaller than the other 2.

Setting up for 2D Planar location is very easy in the software and is similar to setting up zonal or linear location. The steps are identical to those outlined above, only some of the menu selections are changed for the 2D Planar location. Let's provide a quick run-through of setting up 2D Planar location using the same steps outlined above for the other location setups. We will be using the example layout file, 2D-Planar.lay.

Step 1. Use the File pulldown menu's Open Layout option (Ctrl-O) to recall 2D-Planar.lay.

Step 2. Enter the Location Setup dialog (F8 key) & use the Distance Units button to select Inches.

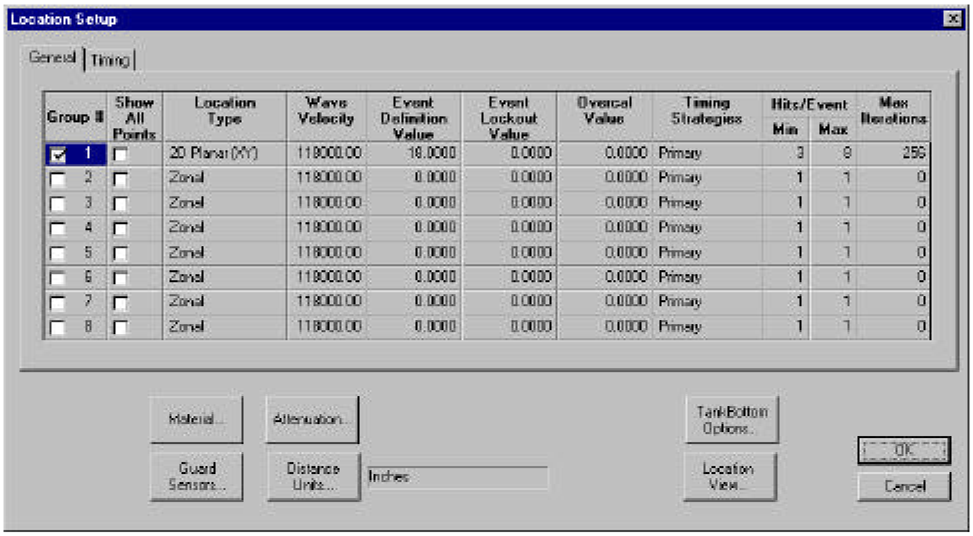


Figure 128. 2D Planar Location Setup

Step 3. Now configure the settings for location Group #1 as shown above. Enable the group by putting a check next to #1. Set the Location Type to 2D Planar. Enter 118,000 for Wave Velocity. Set the Event Definition Value to 18, Event Lockout to 0 & Overcal to 0. Leave the Timing Strategies, Min & Max Hits/Event, Max Iterations & all settings on the Timing page at the defaults.

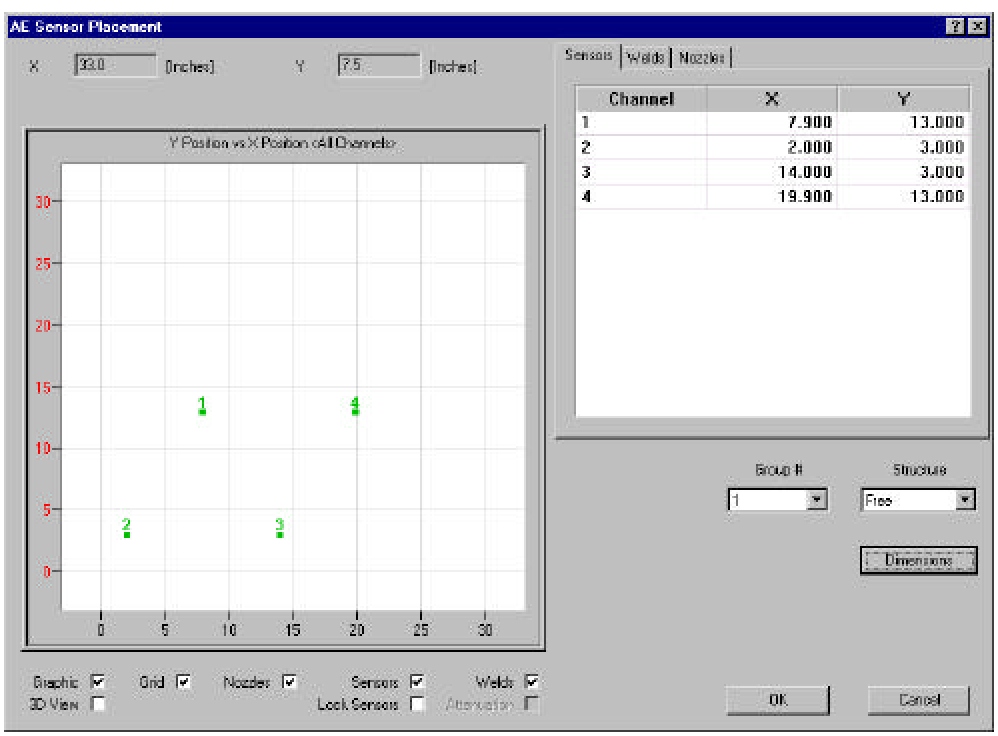


Figure 129. Sensor Placement for 2D-Planar.lay Location Setup

Steps 4-5. Click on Location View to bring up the Sensor Placement dialog. Make sure the Structure type is set to Free with the Dimensions set to 0 & 30 for Min & Max values.

Steps 6-7. Set up the sensor locations on the screen using the same procedure described in the previous section for zonal location. The only difference now is that you will set up 4 sensors in a 2 dimensional layout. An example is shown above along with the coordinates of the 4 sensors. Even though we are showing a triangular arrangement, 2D Planar is not restricted to a specific sensor pattern. When you are done placing sensors, click OK in Sensor Placement & Location Setup to return to the main menu.

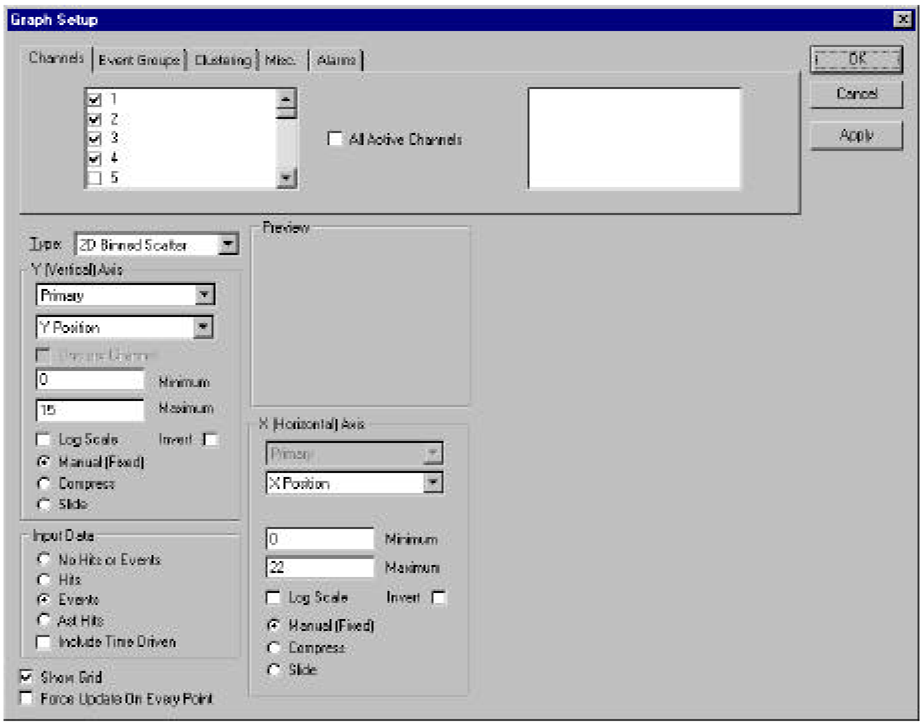


Figure 130. Graph Setup for 2D-Planar Location Plot

Step 8. Next, define a 2D X-Y location plot using the graphing menu following the procedure described in the section for zonal location . The screen capture above shows the graph setup menu for the location plot in 2D-Planar.lay while the one below shows the graph (top graph) for that layout. You can compare the differences between the setup above and the graph setup for the zonal and linear location graph shown earlier. First, you can see that we have enabled all 4 sensors for display that have been setup in the location view menu. Next, you can see that we have selected a 2D Binned Scatter (point plot) for the graph type. Next, you can see that we have changed the Y-Axis to plot "Y-Position" instead of Events. You can also see that we have changed the axis coordinates in both the X and Y axes. Finally, you can see that there is no "bin or value axis settings" to the right of the X axis setup as there was for the 2D Histogram graph setup. 2D Binned Scatter graphs don't require any user choices about the binning strategy. All 2D Binned Scatter graphs use a fixed 200x200 binned grid when plotting the data. The point of using a 2D Binned Scatter graph rather than a 2D Scatter graph is speed. It's binning strategy decreases the number of data points actually plotted, so that multiple point at one location graph as just one point. The 2D Colored Scatter graph is similar to the 2D Binned Scatter, but it will allow you to plot the points in different colors that reflect how many original data points are superimposed at any particular location.

The result of the graph setup is shown in top graph of the screen below. In this graph you can see the sensor locations, although your graph will be empty at this point.

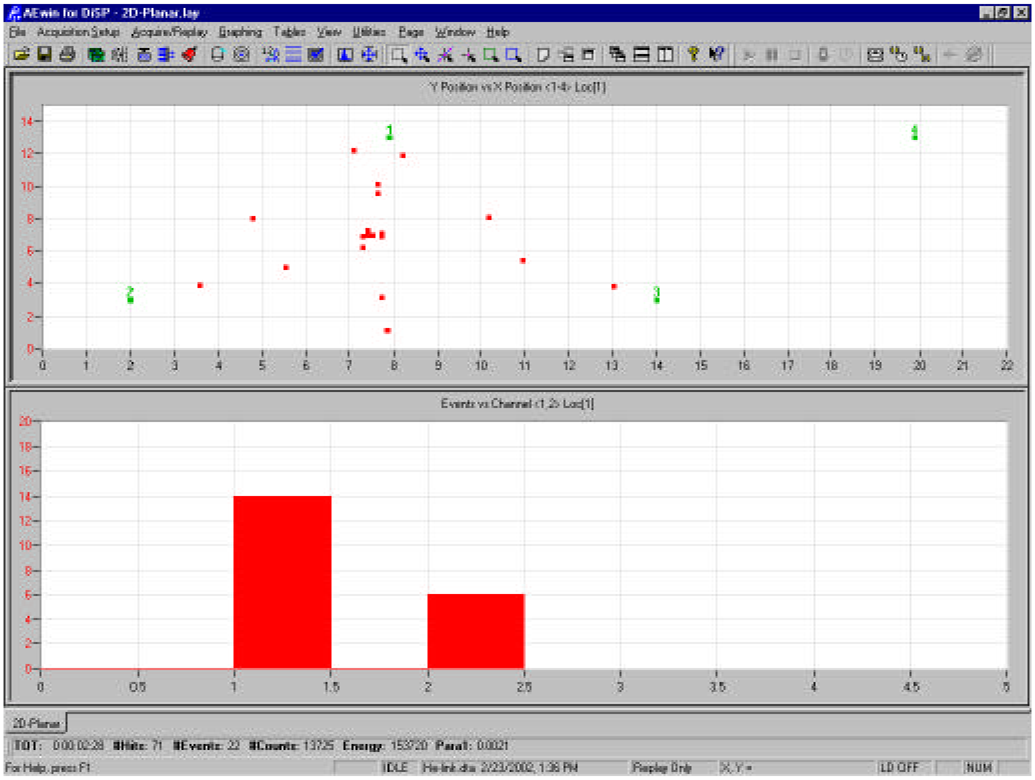


Figure 131. 2D-Planar Location Point Plot

Step 9. Now perform a test of the setup using the same procedure as described in the previous section for zonal location. Replay the data file HE-Link.dta. Results in a point plot will be plotted as dots on the screen where each dot represents the location of a detected event. Now your graphs should resemble those shown above. You can right click on the graph & look for the Large Scatter Graph Points for better visibility of the data points, if you prefer.

4.5.3 Setup and Testing of a Tank Bottom Location Group

Tank Bottom location is a specialized AE source location mode, developed specifically for monitoring the floors of large cylindrical vessels. The software assumes a tank with a circular bottom with sensors equally spaced around the circumference of the tank. Tank Bottom location should not be confused with TANKPAC. The difference between them is that Tank Bottom software performs a location calculation and projects the result of that location determination onto the tank floor graphic. In contrast, TANKPAC© is a knowledge & experienced based procedure for assessing and grading the integrity of tank floors.

If you have purchased the Tank Bottom location software option, this section will help you to setup for your first Tank Bottom test. Please first verify that you have the Tank Bottom software option by selecting the Options dialog from the Help pulldown menu. If you have this option, it will be checked. If the option is not present and you desire it, please contact the Customer Service Department at customerservice@pacndt.com.

Tank Bottom location follows along the same location setup, menus and setup procedure as do the other location modes. Setting up Tank-Bottom location is a simple 3 step process including;

1. Accessing the Location Setup menu (F8), from the "Acquisition Setup" main toolbar menu, and setting up a Tank Bottom location group.
2. Accessing the Location View menu to setup the Tank bottom structure, dimensions and sensor placement.

3. Setting up a Tank Bottom location graph in the Graph setup menu.
4. Acquiring and/or Replaying data.

Assuming one is familiar with the software, the following is a step by step procedure for setting up and running the Tank Bottom Location software.

4.5.3.1 Configuration of Location Setup

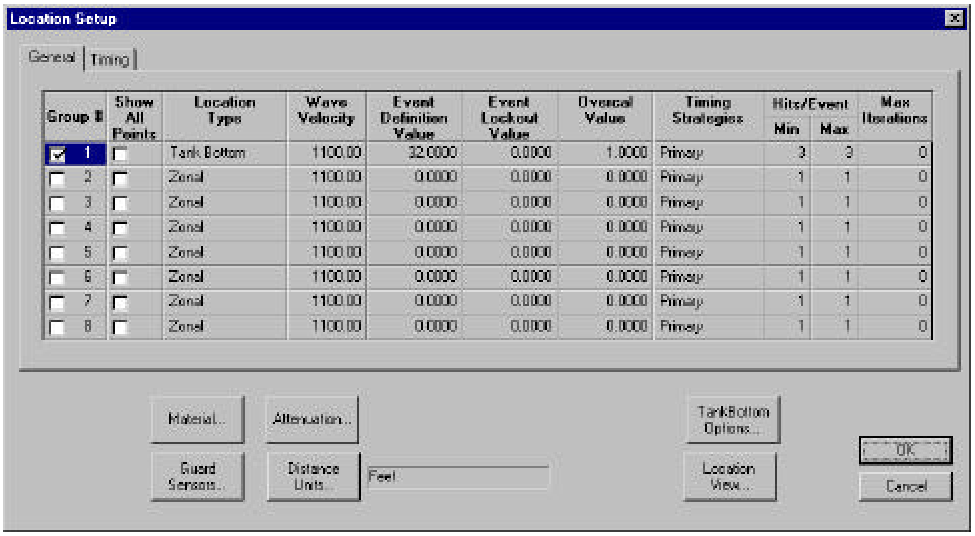


Figure 132. Location Setup Menu

The first step in setting up for a Tank Bottom location application is to access the Location setup menu. This is done by selecting Location from the Acquisition Setup pulldown menu (or by pressing the F8 key). The Location Setup menu appears as shown above. We have shown an example Tank Bottom location group as group number 1.

The first step in setting up a location group is to first select the distance units that you want to use for your work. You will know what distance units you are working in by viewing the textbox at the bottom center of the Location setup menu. In the example above, the current measurements are in feet. To change from the default distance units, left-click the "Distance Units" selection box at the bottom of the Location setup menu. Upon clicking this button, you will see the dialog shown to the right appear. Select whichever units you desire to work with and click "OK". Upon clicking OK, you will see the units textbox at the bottom of the location setup menu show these new values.

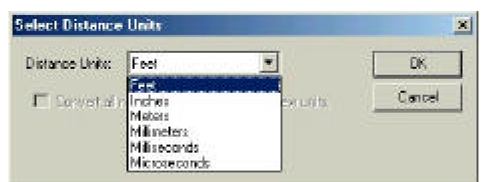


Figure 133. Distance Units Dialog

It is important to setup your distance units as early as possible into the location setup since all the location setup entries including "Wave Velocity", "Event Definition Value", "Event Lockout value", and "Overcal value" all use the units selected (of course in the case of velocity it will be units/second). By dealing in direct units, the user can think in terms of distance values when setting up these entries.

Returning to setting up the Group #1 (as shown by the first row of the Location setup menu), we will address each column entry below.

Group#: The first column shows that we have checkmarked the Group #1 Location group to be an active location group. Putting a check in this box activates that location group and tells the software to perform a location calculation on based on the setup data in this menu, the Location setup "Timing"menu (see the upper tabs) and the "Location View" and "Tank Bottom Options".

Show All Points: This allows the user to show all source results for events that this group can successfully locate. Independent of which groups have Show All Points checked, the software always allows all enabled groups to analyze a given event to get the best results for each group and then compares the results from all successful groups to come up with a best result. For example, linear location is always presumed to give a better result that zonal location, if there are enough hits(2) to produce a location. If no groups have Show All Points checked, the software will report one source location per event & it is the best result that is shown on graphs & in the line display. There are times when a side-by-side comparison of the results of 2 or more location groups are useful. In that case you can mark the groups as Show All Points & then whatever source locations they can calculate will be reported. The software will appear to sometimes produce more than one source location per event & if you look at the line display, you will see extra event listings with the same first hit times. The extra location results will also show up as extra points on your graphs too, but they only count as 1 event in the Statistics bar. In all cases you will see the software's best result as one of the points. There will be times when an event cannot be located by more than 1 group, so having Show All Points does not guarantee a result from a given location group. It is only a guarantee that you will see it, if it can produce a useful result.

Location Type: In the next column, we have selected "Tank Bottom location" as the location type. By left clicking your mouse in the Location type area on this first row, a selection box will appear with all the available location option choices that are enabled within the software. "Tank Bottom" will be one of the choices, select this.

Wave Velocity: For Wave Velocity, we suggest that you use the velocity of the fluid that is in the tank as a starting point. It is recommended you perform some tests to try to empirically determine what that actual velocity is once you get on the tank. This can be done by creating an impact signal near one sensor, that travels from one side of the tank to the other and monitoring the time it takes for the signal to travel the liquid path to the sensor on the opposite side. You can then measure the time it has taken to arrive and use that with the knowledge of the diameter to arrive at a velocity. However, you must be careful not to mistake the faster metal path arrival, traveling around the tank.

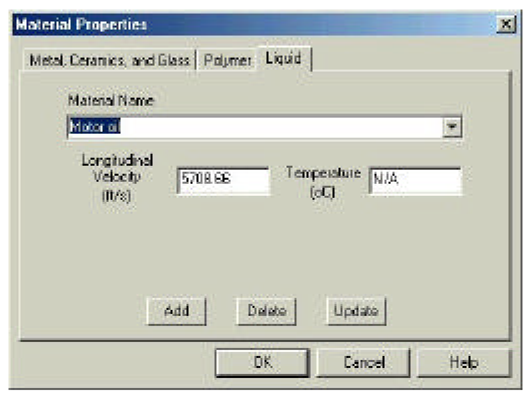


Figure 134. Material Properties Dialog

If you do not know the velocity of the fluid in the tank & cannot easily measure it, you can access a built in "Material" database within the software. To access the "Materials" database, simply click the "Materials" button at the bottom of the Location Setup menu. The Material Properties dialog box will appear as shown below. Along the top of the menu, you can select what type of materials group that you want. In our case, the "liquid" database has been selected. By clicking on the down-arrow in the Material Name text entry box, a list of materials (liquids) in our case will be shown. Simply scroll down and select the desired material (or liquid). In our case, we have selected Motor oil. You will note that the velocity will automatically read out in the distance units that you have selected in the Location setup menu. If the material selection you want is not in the database, you will be able to enter this into the material database by using the "Add" "Delete" and "Update" keys near the bottom of the Materials database menu. You will note that for the example of the Motor oil in the figure the velocity is 5708. We can make use of this velocity by entering it into the "Wave Velocity" column of the location group setup row. The direct way is to simply left-click the cell in Location Setup, type the appropriate value into it and hit the "Enter" key. Remember to enter the value in the same units as that listed at the bottom of the Location setup menu. As an alternative, you can Copy & Paste the value by highlighting it in the Material Properties dialog box & pressing Ctrl-C. In Location Setup, highlight the cell, press F2 to edit its contents & then press Shift-Ins

Event Definition Value: The Event Definition Value is the length of an event in the user's distance units. The Event Definition Value should be set to make sure that an AE source, from any point in the location array, will intersect a minimum desired number of sensors (3 is the minimum), forming an event. In our example of a 30 foot diameter tank, we have selected an Event Definition value of 32 which assures that all the sensors in the tank will have the capability of detecting an event regardless where it originates.

Event Lockout Value: The Event Lockout Value is also entered in the user's distance units. The Event Lockout Value controls the interval between consecutive events. Enter an Event lockout Value starting from the beginning of the Event and long enough to assure that the there is enough time (or distance) for all additional hits and reflections related to that event, to have had a chance to die down. In order for the Event Lockout Value to be effective, it needs to be set longer than the Event Definition Value, since they both start at the same time. There are no rules of thumb for setting Event Lockout Value, since the event related activity is dependent on the structure and sensitivity settings of the system. It is best to experiment to find the best selection.

Overcal Value: The Overcal value is also set in the selected distance units and is usually set at an amount of approximately 10% of the Event Definition Value. This is to assure that the location algorithm does not ignore minor variations in the wavepath velocity.

Timing Strategies: The user can select from some different timing strategies as set up in the "Timing" tab located at the top of the Location Setup menu. Please note that although the user can select a different timing strategy, that the Tank Bottom location algorithm cannot support using multiple timing strategies as the other advanced location modes can.

Hits/Event (min/max): This entry is to be used with iterative location determination strategies that are able to process more than 3 hits for a given location. However, Tank Bottom location only uses 3 arrivals to determine location and therefore, these fields are not adjustable.

Max Iterations: The Tank Bottom Location algorithm does not use an iterative location algorithm and therefore you cannot enter a value in this textbox area.
Once you fill out all this information, you should proceed to the "Location View" menu where you can setup up the Tank Bottom "Structure" and dimensions and set sensors around the tank. Meanwhile, you may change any of the above entries at any time you want to improve the location accuracy.

4.5.3.2 Configuration of Sensor Placement

The Sensor Placement dialog is entered from the Location Setup by selecting the "Location View" button. Upon selecting this option, the dialog box shown in figure 132 will appear. This menu is the base starting point for setting up the Tank bottom (and other location based) structures. The Tank Bottom is one of the easiest location setups to perform since the sensors can be placed quickly and automatically. Please perform the following steps to set up all the aspects required in the Sensor Placement dialog shown below.

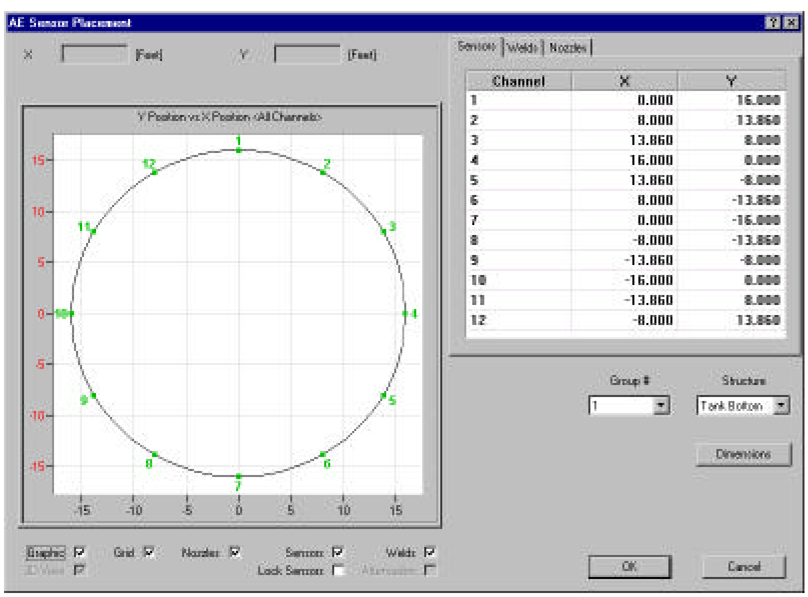


Figure 135. Tank Bottom Sensor Placement

1. First, make sure that you have selected the location group that you wish to work with. In our case, we had set up location group #1 in the Location Setup menu, so make sure Group #1 is selected in the Group selection text entry box.
2. Next, we go to the "Structure" menu and select the "Tank Bottom" structure as the desired structure. This gives us a chance to talk about our "structure" based location capability. Since the user is setting up his application on a particular type of structure (such as a plate, a pipe, a vessel, a sphere, a tank bottom, etc., etc., it is important for the location to think in terms of structures as well. This is what has been implemented in the software and is an extremely advanced concept that only PAC is doing.
3. Once you have selected the Tank Bottom as your Structure type, you should then click the "Dimensions" button. The dialog box shown to the right will appear. This menu is a customized user configuration menu for the type of structure you have selected and allows the customer to set up certain aspects of that structure. In the case of a Tank Bottom, the menu allows the user to enter the Tank diameter (which we have set to 30 feet in our example, allows you to set alternate units and also allows you to enter information about the automatic sensor placement. First it lets you select the starting sensor number as well as the total number of sensors that will be equally spaced around the tank and the starting phase, assuming that 0 degrees is that the top of the tank bottom (or North). In our example, we have set up for our sensors to start at sensor #1, starting at the top or 0 degrees and the placement of 12 sensors. When accepted (by clicking the OK button), the sensors will be automatically placed in a clockwise fashion at equal angular spacing, on a circular tank bottom in the Location View area. This allows the user to view the spacing. Please note the table of sensor positions that is automatically generated. This table can be exported to the clipboard (by right clicking on the grid and selecting 'copy to clipboard') for insertion into a report file.
4. After the sensor placement step, the user should then go and set up the sensors on the tank in the locations indicated by the Location view menu. Once done and the sensors have been connected to the appropriate AE channel number, you are ready to proceed to the setting up the Location graph and begin acquisition.

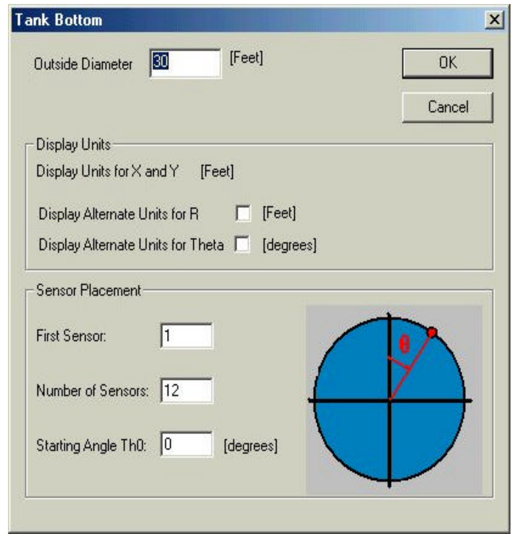


Figure 136. Tankbottom

4.5.3.3 Setting Up a Tank Bottom Location Graph

The next step in the process of getting ready for carrying out a Tank Bottom location test is to set up the Tank Bottom Location screen. This is a straightforward process which is carried out in conjunction with the Graph Setup menu. The following are the steps in setting up a Tank Bottom Location Graph.

1. First, exit the Sensor Placement dialog and the Location Setup menu by clicking the OK button. Please note that if you click "Cancel" that you will lose all the setup changes that you have entered. Make sure you click the OK button before proceeding. Upon getting out of the Location setup menu, you will be back to the main screen showing some graph setups.

2. First, lets add a graph page by either right-clicking on one of the graph tabs at the bottom of the screen or by clicking on the "New Page" icon on the icon toolbar (the icon looks like a sheet of paper). This action will add a new tab to the bottom of the graph selection tabs and will create a blank screen. Next, lets name the new Graph Tab, "Tank Bottom" by right-clicking on the tab and selecting the "Rename Page" selection.

3. Next, lets add a graph to the page by either right-clicking on the new "Tank Bottom" tab or selecting the "New Graph" icon on the icon toolbar menu at the top of the screen (its next to the "new page" icon). Once you do this, a graph window will pop up. Maximize the graph to be full screen by clicking on the "Tile

Horizontal" or "Tile Vertically" icons on the top icon toolbar. You are now ready to create your Tank Bottom Location graph.

4. To setup for a Tank Bottom Location graph, first you need to enter the Graph Setup menu by right-clicking in the Graph area of the graph you want to setup. This is the topmost selection in the context menu that comes up when you right-click. Please note the Graph setup dialog box to the right.

5. Next, select the "Event Groups" Tab at the top of the Graph setup menu and Check the location group #1 which is identified as a Tank Bottom location group (if you have properly followed all previous steps).

6. Next, select the type of Graph. In the case of a location graph, you want to select a 2D Binned Scatter Plot. This text entry box is just above the Y-vertical axis settings.

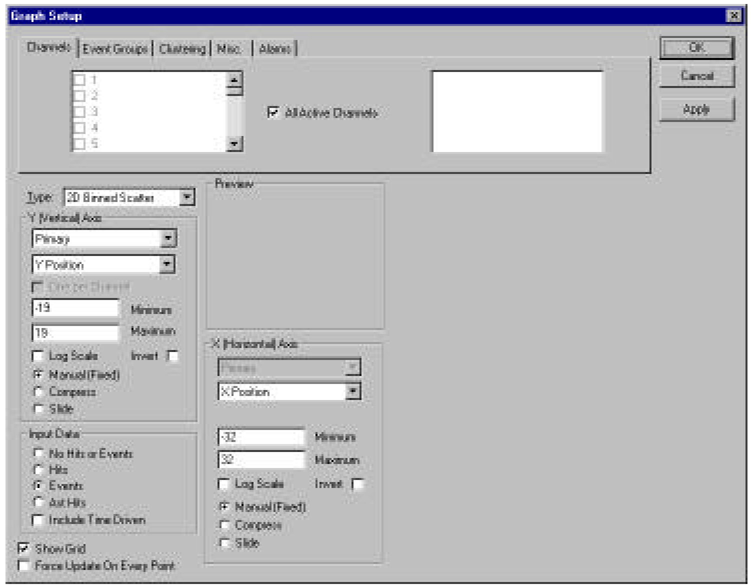


Figure 137. Tank Bottom Graph Setup

7. Next, setup the Y-(vertical axis) and X-(horizontal axis) for display. First set the Y vertical axis to be a Primary graph (this means that you will only be plotting one graph on this screen plot. The next scrolling textbox allows you to select the feature or value that you want to plot. Since this is a location plot you want to plot the Y position versus the X position, so select these for your Y and X settings.

8. Next, you need to select the graph scale. Since Tank Bottom location always assumes that the center of the tank is the 0,0 position, you need to take this into account and select a negative value for the minimum graph scale and the equal positive number as the maximum if you want the displayed in the center. Also since you want the graph to not change, please select the Manual (Fixed) axis scaling. Do the same for X. Please note the values that we have set to center the tank bottom display in the screen and have it show up perfectly round. Due to different screen resolutions you may have to vary your X and Y axis scale settings to get your image perfectly round.

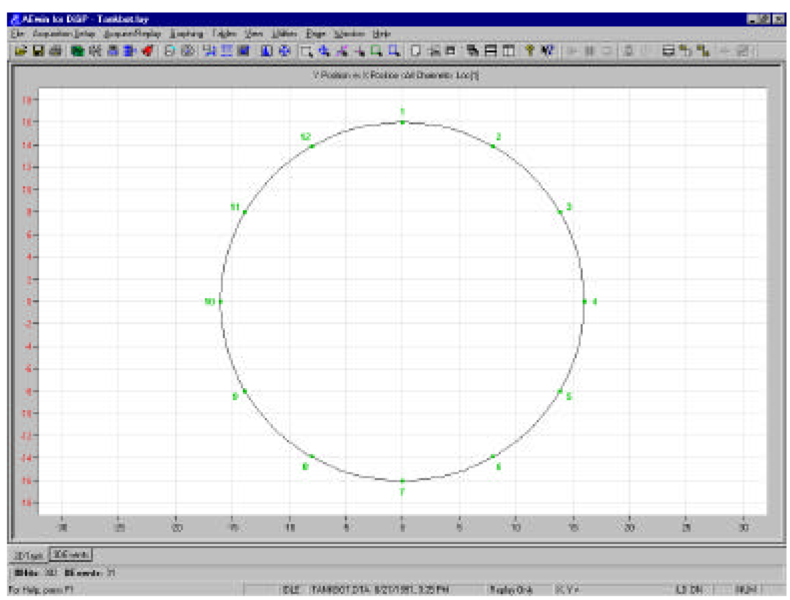


Figure 138. Tank Bottom Graph

9. The last important setting is to select Events as your Input data to the graph. Events will show the result of the location determination on the incoming AE data.

10. With all these settings done, we can exit the graph setup menu by clicking the OK button. If you did everything correctly, you will get a nice looking tank bottom screen like that shown here. If you do not have such a nice looking screen, you should go back to the graph setup menu and make some corrections until it is as nice looking as this one. Also note that you can have other graphs on this same screen, you are not limited to just the one graph.

11. Note that the structure and the sensors were automatically plotted on the screen. This is because the software was instructed that the structure of the Location group #1 was a Tank Bottom location and was automatically able to draw this structure as soon as it saw that the graph which was being set up was an X versus Y position location graph.

You have now totally completed the setup of a Tank Bottom location test and are ready to acquire or replay data.

4.5.3.4 Acquiring and Replaying and Displaying Data

Now that the entire setup is complete, you are ready to acquire or replay data from your Tank bottom test. To acquire data, simply enter data acquisition and begin recording data. You should always perform a test to determine if the location algorithm is operating properly before actually performing the true acquisition test. Verify that the location is performing properly and the AE hardware and software settings are all correct to minimize noise and maximize the types of signals you want to record. Once satisfied, start acquiring test data.

Once acquisition is completed you can start replaying and analyzing data. There should be a Tank bottom data file in your directory for you to experiment with. If you have this file, it should be called TankBot.dta. There might also be a Tank Bottom Layout file called TankBot.lay. If you have these you can use them to test Tank Bottom location. If you do a replay of TankBot.dta using the TankBot.lay layout file, you should see results like that shown here.

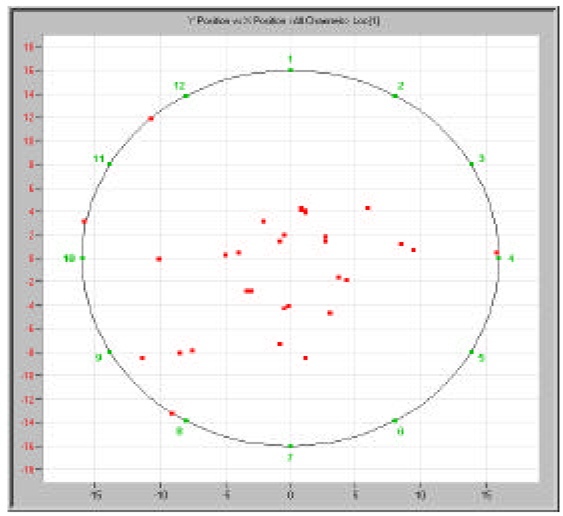


Figure 139. Tank Bottom Data

All standard analysis and filtering tools can be used on this data to weed out noise and assure that you have the most relevant data.

There is one other mode that has been built into the Tank Bottom Software that allows multiple location calculations and plots to be displayed on the Tank Bottom location screen. To access this processing selection please select the **Acquisition Setup → Location → Tank Bottom Options** selection. You will see this selection box just above the "Location View" menu selection as shown on figure 137. The resulting Tank Bottom Options dialog box is shown here.

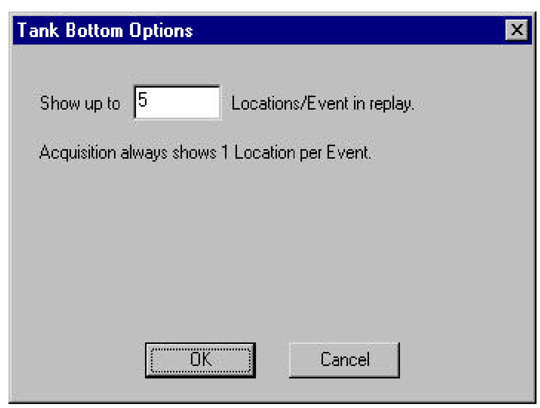


Figure 140. Tank Bottom Option

This option allows you to choose to display more than 1 location per event. Normally, the number is set to 1 as a default but we have set it to 5 to allow up to 5 location calculations per event to process and display on the screen.

This uses other hits in the event in order to calculate location in case the first hits of the events have some problems. Note that this option will only be displayed in replay to keep acquisition at its highest speeds. Once this is selected and the file is replayed, you can see the difference by comparing the graph at the right with the one above. As can be seen, there are more events displayed the one to the right, as there should be. What we learn by this is that the location is pretty good and matches pretty closely telling us that the original location data in figure is valid. This completes the setup and operation of the Tank Bottom location.

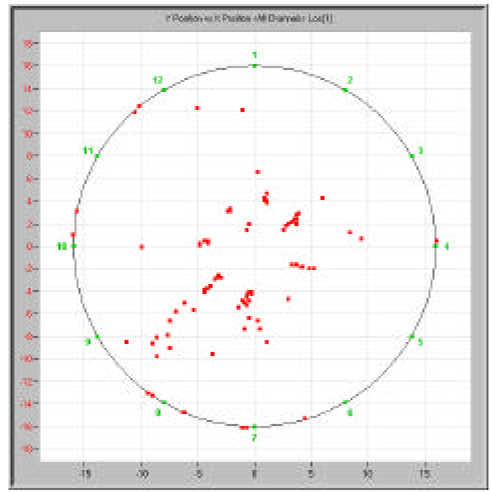


Figure 141. TankBottom Data

5. OPTIONS FOR AEwin

5.1 Supervisor Option

The 'Supervisor Option' allows the user to restrict access to the software by the use of a password. With this option installed the software will start up in ***Operator Mode*** by default.

In ***Operator Mode*** the user has limited access to the system. He can:

- Load a layout file.
- Print/Export graphs or copy them to the clipboard.
- Change the Test Title.
- Edit the Logistics Information.
- Setup the Audio Monitor (if present).
- Perform a test or AST.
- Replay an existing data file.
- Toggle the Line Listing Display on/off.

The user can switch to supervisor mode by clicking 'Switch to Supervisor Mode' from the File menu and entering the password.

In ***Supervisor Mode*** the user has full access to the system. He can perform all the functions possible in operator mode plus he can:

- Change the password.
- Create and save layout files.
- Access the various Test Setup menus.
- Create, modify and delete graphs.
- Modify the arrangement of the graphs, create and delete pages, etc.

How to set the password the first time. The first time the user tries to switch to supervisor mode the software will ask for an initial password. Enter a password of your choice which must be 4-8 alphanumeric characters in length. It is not case sensitive. From this point on the user must enter this password to switch to supervisor mode.

Note: If your system came with AEwin pre-installed and the program doesn't request an initial password, this means that the initial password was set at the factory. The password in this case is 'AEwin'.

How to change the password: The user can change the password by switching to supervisor mode and clicking 'Change Password' from the file menu.

What to do if you forget the password: If you forget the password the only way to recover is to uninstall the software and reinstall it. This will allow you to enter a new password.

5.2 LeakTEC Alarms

LeakTEC Alarms (part of the 'LeakTEC/On-Line-Crack Alarm' Option) are used to monitor ASL or RMS levels (using Time Data) during acquisition and alert the user if they stray beyond certain pre-set lower and upper limits. If ASL or RMS levels stray beyond these limits for a certain period of time an Alarm is generated.

5.2.1 Setup

If you have the 'LeakTEC/On-Line-Crack Alarm' Option installed then you can enable and customize these alarms by using the LeakTEC Alarm Setup dialog box located on the Acquisition Setup menu. It's controls are described below.

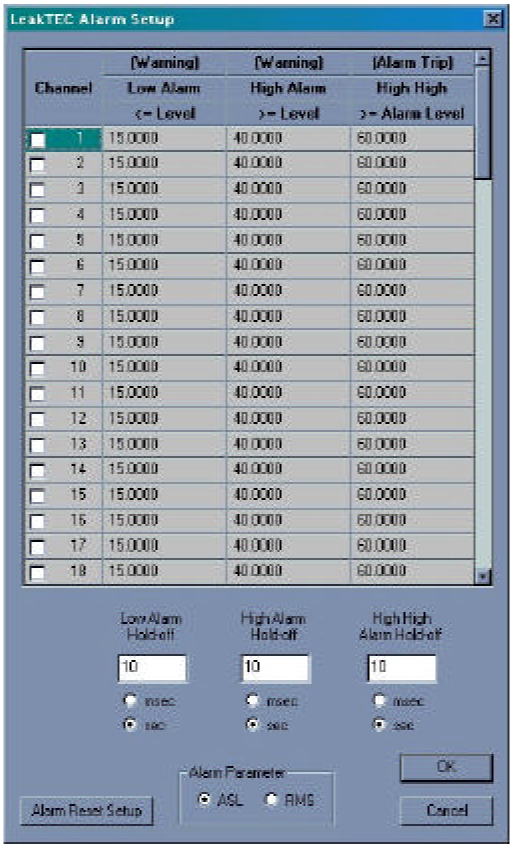


Figure 142. LeakTEC Alarm Setup

Channel – Each channel can be enabled/disabled and customized independently. Click a channel's checkbox to enable that channel.

Low Alarm – Set the Low Alarm Level for a channel in this cell. An alarm 'warning' is triggered if ASL/RMS levels drop to this level or below for a duration of time equal to the 'Low Alarm Hold-off' period.

High Alarm – Set the High Alarm Level for a channel in this cell. An alarm 'trip' is triggered if ASL/RMS levels equal or exceed this level for a duration of time equal to the 'High Alarm Hold-off' period.

High High Alarm – Set the High High Alarm Level for a channel in this cell. An alarm 'trip' is triggered if ASL/RMS levels equal or exceed this level for a duration of time equal to the 'High High Alarm Hold-off' period.

Low Alarm Hold-off – This is the period of time that a channel's ASL/RMS must remain at or below the Low Alarm Level before a Low alarm 'warning' is triggered.

High Alarm Hold-off – This is the period of time that a channel's ASL/RMS must remain at or above the High Alarm Level before a High alarm 'trip' is triggered.

High High Alarm Hold-off – This is the period of time that a channel's ASL/RMS must remain at or above the High High Alarm Level before a High High alarm 'trip' is triggered.

ASL/RMS – Select which Time Dataset feature to monitor using this control.

Alarm Reset Setup – Click this button to enter the Auto Alarm-Reset dialog box. This can be used to set the system to automatically clear the alarms periodically.

5.2.2 Operation

If the ASL/RMS for a particular channel violates an alarm level (low, high or high high) and remains continuously in violation of that level for a duration of time equal to the appropriate 'Hold-Off' then an alarm is triggered.

5.2.3 What happens when an alarm is triggered

1) An alarm message (16) is generated. If autodump is on then this message is saved to the datafile. If the line display is active then it will be displayed there with the time was triggered and the conditions that triggered it.
2) The Alarm Display dialog box is opened (or updated if already open). The details of the alarm and the conditions that triggered it are shown. The alarm can be cleared by clicking the 'Clear Alarms' button.
3) If the alarm is an alarm 'warning' then the Alarm Warning output line is set high. If the alarm is an alarm 'trip' then both the Alarm Warning and Alarm Trip lines are set high.
4) An audible alarm is triggered if you have an audio board installed and enabled.

5.3 On-Line Crack Alarms

On-Line Crack Alarms (part of the 'LeakTEC/On-Line-Crack Alarm' Option) are used to monitor hits or events during acquisition and alert the user if the hit/event or energy rates exceed certain pre-set levels. If these rates exceed these limits within a certain period of time an Alarm is generated.

5.3.1 Setup

If you have the 'LeakTEC/On-Line Crack Alarm' Option installed then you can enable and customize these alarms by using the On-Line Crack Alarm Setup dialog box located on the Acquisition Setup menu. It's controls are described below.

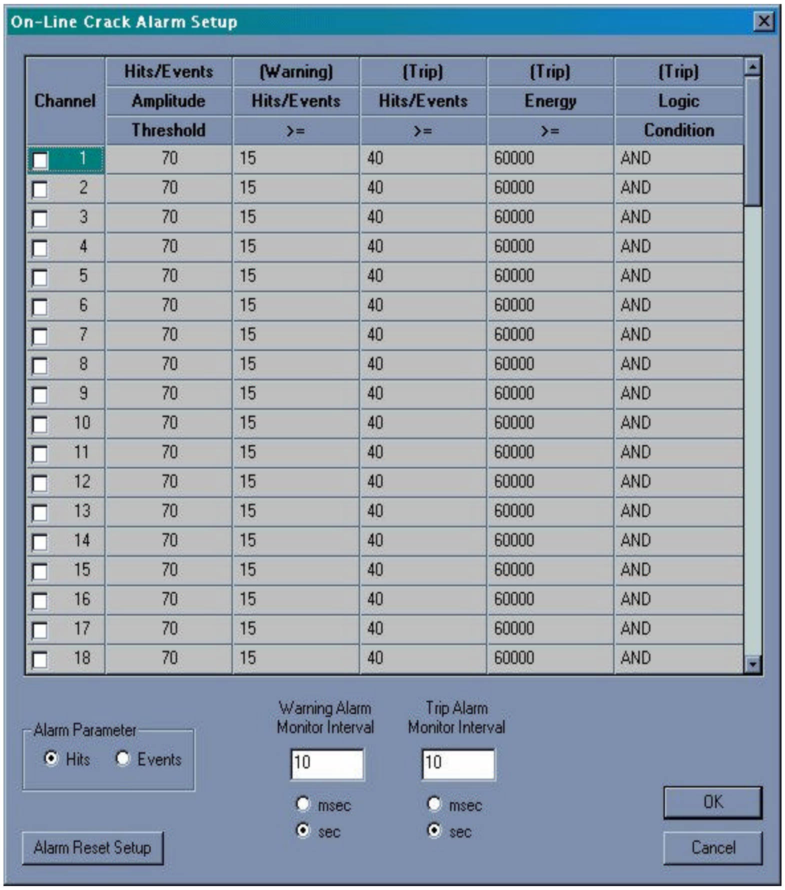


Figure 143. On-Line Crack Alarm Setup

Channel – Each channel can be enabled/disabled and customized independently. Click a channel's checkbox to enable that channel.

Hits/Events Amplitude Threshold – This is the amplitude that a hit (or first hit of an event) must equal or exceed in order to be counted towards a 'Warning Hit/Events' or 'Trip Hit/Events' alarm. This does not affect energy alarms.

[Warning] Hits/Events – A 'Hits/Events Warning' alarm will be triggered if at least this many hits/events that meet the Amplitude Threshold are acquired within a period of time not exceeding the Warning Alarm Monitor Interval.

[Trip] Hits/Events – A 'Trip Hits/Events' alarm will be triggered if at least this many hits/events that meet the amplitude threshold are acquired within a period of time not exceeding the Trip Alarm Monitor Interval. If the logic condition is 'ENERGY' then this alarm type is disabled and will not trigger. If the logic condition is 'AND' then the Trip Energy condition must be met as well before an alarm will be triggered.

[Trip] Energy – A 'Trip Energy' alarm will be triggered if the total energy of any number of hits/events (with any amplitude) are acquired within a period of time not exceeding the Trip Alarm Monitor Interval meets or exceeds this value. If the logic condition is 'Hits/Events' then this alarm type is disabled and will not trigger. If the logic condition is 'AND' then the 'Trip Hits/Events' condition must be met as well before an alarm will be triggered.

[Trip] Logic Condition – The logic condition controls how the Trip alarms are calculated. If it is set to 'Hits/Events' then the 'Trip Energy' condition is ignored and no alarms will be triggered using it. If it is set to 'Energy' then the 'Trip Hits/Events' condition is ignored and no alarms will be triggered using it. If it is set to AND then both the 'Trip Hits/Events' and 'Trip Energy' conditions must be met before an alarm is triggered. If it is set to OR then meeting either condition will trigger a Trip alarm.

Warning Alarm Monitor Interval – This is the period of time in which hits/events (passing the threshold) are accumulated towards a Warning alarm.

Trip Alarm Monitor Interval – This is the period of time in which hits/events (passing the threshold) and energy are accumulated towards a Trip alarm.

Alarm Parameter – Select whether to use hits or the first hit of events for alarm determination.

Alarm Reset Setup – Click this button to enter the Auto Alarm-Reset dialog box. This can be used to set the system to automatically clear the alarms periodically.

5.3.2 Operation

Four kinds of alarms can be generated by this option.

- Warning Hits/Event – A number of hits/events that met the Amplitude Threshold were acquired within a period of time not exceeding the Warning Alarm Monitor Interval. The number of hits/events met or exceeded the [Warning] Hits/Events value.
- Trip Hits/Event – A number of hits/events that met the Amplitude Threshold were acquired within a period of time not exceeding the Trip Alarm Monitor Interval. The number of hits/events met or exceeded the [Trip] Hits/Events value.
- Trip Energy – The total energy of all hits/events (with any amplitude) that were acquired within a period of time not exceeding the Trip Alarm Monitor Interval met or exceeded the [Trip] Energy value.
- Trip Hits/Event and Energy – Both the 'Trip Hits/Event' and 'Trip Energy' conditions were met.

5.3.3 What happens when an alarm is triggered

1) An alarm message (16) is generated. If autodump is on then this message is saved to the datafile. If the line display is active then it will be displayed there with the time was triggered and the conditions that triggered it.
2) The Alarm Display dialog box is opened (or updated if already open). The details of the alarm and the conditions that triggered it are shown. The alarm can be cleared by clicking the 'Clear Alarms' button.
3) If the alarm is an alarm 'warning' then the Alarm Warning output line is set high. If the alarm is an alarm 'trip' then both the Alarm Warning and Alarm Trip lines are set high.
4) An audible alarm is triggered if you have an audio board installed and enabled.

APPENDIX

UTILITIES MENU AEwin ä SOFTWARE

Utilities Menu
AEwin Software

UTILITIES MENU

AEwin SOFTWARE

TABLE OF CONTENTS

1 UTILITIES MENU

The utilities Submenu show the list of utility programs to help the user perform post-test analysis.

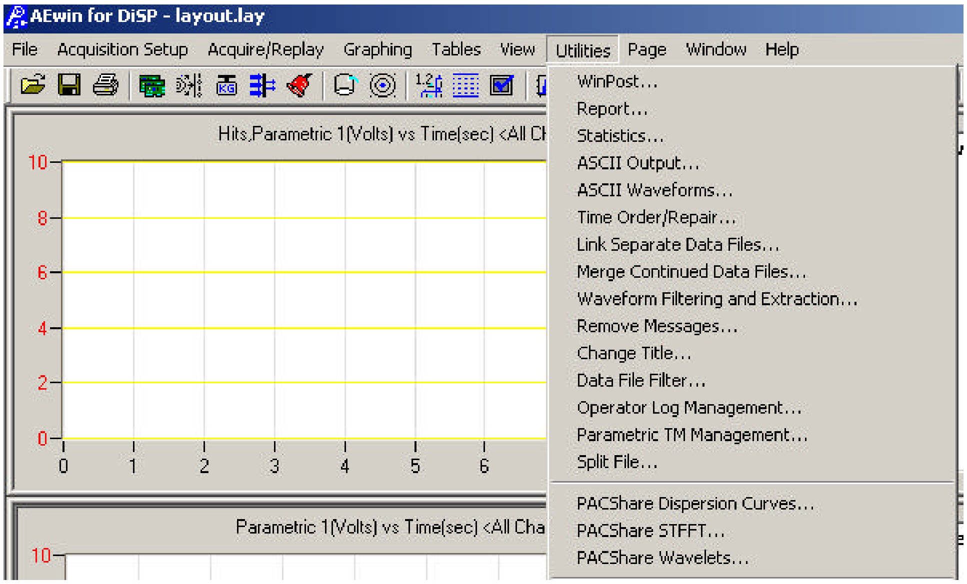


Figure 1. AEwin Utilities Menu

The utility programs and their functions are:

- **WinPOST:** AEwinPOST is an optional graphical data visualization post-acquisition tool that provides useful insight into your AE data. In addition, there are some fantastic data manipulation and filtering tools available in this optional utility that are not available in AEwin. Please note that this utility is an option. A brochure for AEwinPOST can be found in your AEwin directory in a file called AEwinPOST Brochure. PDF. Also, a separate manual exists in PDF form in your AEwin directory called AEwinPOST_v1_Manual.pdf.

- **Report:** Reads a Data file and creates a report containing: System Information, Test Information, Hardware Setup as well as Alarm and Filter setup information. This is useful when making reports of AE tests to provide full Test Setup documentation.

- **Statistics:** Provides minimum, maximum, average and standard deviation of all features in a DTA file.

- **ASCII Output:** Extracts AE Feature data from a DTA file and writes it into a new ASCII format text file.

- **Waveform to ASCII**: Converts each waveform found in a DTA or TDA file into an ASCII text file.

- **Time Order/Repair:** Performs a time ordering of all messages in a DTA file and checks the file for proper file close messages.

- **Link Separate Data Files:** Puts together at least two data files with the header information of the first one.

- **Merge Continued Data Files:** Puts together at least two continued data files.
- **Waveform Filtering and Extraction**: Filters waveforms and extracts hits based on a user-specified dataset.
- **Remove Messages**: Removes the selected types of messages from a DTA file
- **Change Title:** Lets the user change the title from a given DTA file.
- **Data File Filter:** Filters a DTA files based on based on a user-defined filter.
- **Operators Log Management:** Allows the user to view, modify, add and manipulate comment user time marks, in a DTA file.
- **Time Mark and Parametric**: Allows the user to view, modify, add and manipulate parametric time marks, in a DTA file.
- **Split File:** Lets the user to split a given DTA file into smaller DTA files.

Each of these utilities is described more comprehensively in the following sections.

2 REPORT

REPORT is utility program that reads PAC, AE Multi-channel system Data (DTA) files, extracts the file "header" contents, and creates a report containing; System Information, Test Information, Hardware setup, as well as Alarm and Filter setup information. This file can be displayed on screen, saved as a text (ASCII) file, copied or imported into a word processor file.

The Data (DTA) file includes hardware setup information and also includes Test Information as shown below;

- Filename of file being processed
- Software Product Name and software Version Number (which was used to generate the file)
- Test Title
- Test Duration
- Date & Time of Test
- Complete logistics table
- Version Number of the software where the file was created.
- Status of the waveforms (ON/OFF)
- Number of channels
- List of channels (Channel number, gain, HDT, HLT, PDT, THR and THRTYPE)
- Smart Threshold (Channel, Low Hits, High Hits, Internal, Step, Low Limit and Duration Limit)
- Front End Filters (Filter ID, Channel, Characteristic, Type, Lower Level, High Level)
- Front End Alarms (Alarm ID, Channel, Characteristic, Type, Warning, Trigger)
- Waveform Front End Filters (Waveform Filter ID, Channel, Characteristic, Type, Lower Level, High Level)

This utility program is very easy to use and is a very convenient way of documenting and archiving a test setup as part of a test report or as a standalone file for later access.

Don't expect to see all the above information because not all the files have this information. In other words, the "report" is able to read all information but the user only will see what has been saved in the file under examination.

When the user runs this utility, the program will ask him to select the input file:

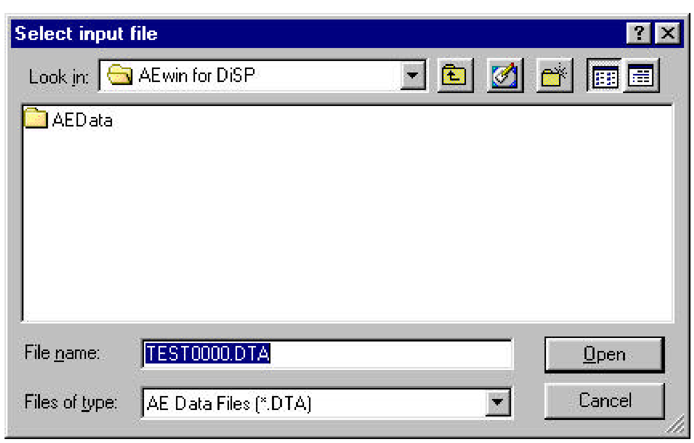


Figure 2. Select Input File

If the user selects "Open" the report program immediately will begin to process the selected file, meanwhile the user can see the progress bar at the right bottom in the main window. When the program finishes the user will see the information about the file displayed in the report results window as shown in the following image.

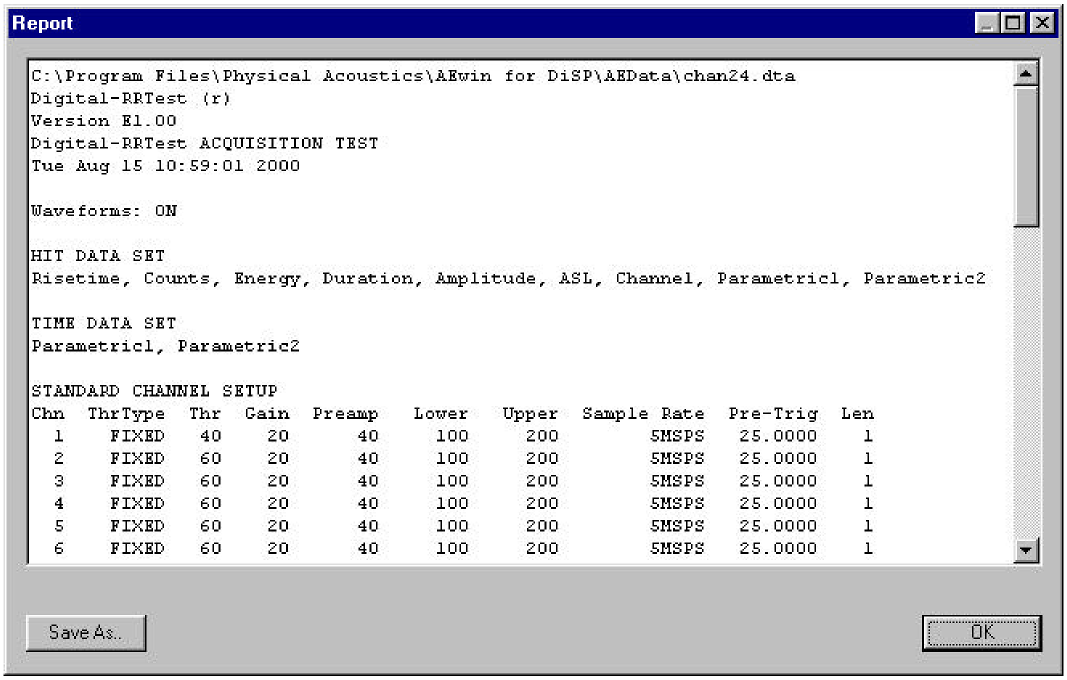


Figure 3. Report Utility, Result Window

The user has the option to copy this information to the clipboard for inserting in other documents, directly save the information in an ASCII format text file by clicking on the "Save As.." button. Or simply view the information in the screen.

3 STATISTICS

STATISTICS is a utility program that reads an AE multi-channel Data (DTA) file and processes the file to provide a summary report of the AE data inside the data file in terms of number of hits for each channel, total hits, total waveforms and time based records as well as the maximum, minimum average and standard deviation per feature per channel.

When the user selects the option in the menu the program asks to select the input name for the data file.

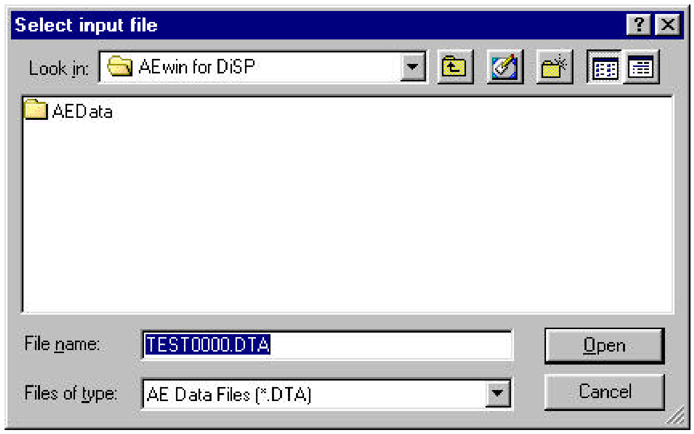


Figure 4. Select Input File

The Statistics process begins when the user clicks on the "Open" button over a file (if the user clicks Open over a folder the Open button expands the folder).
When the process finishes the user can see the statistics result window as shown below:

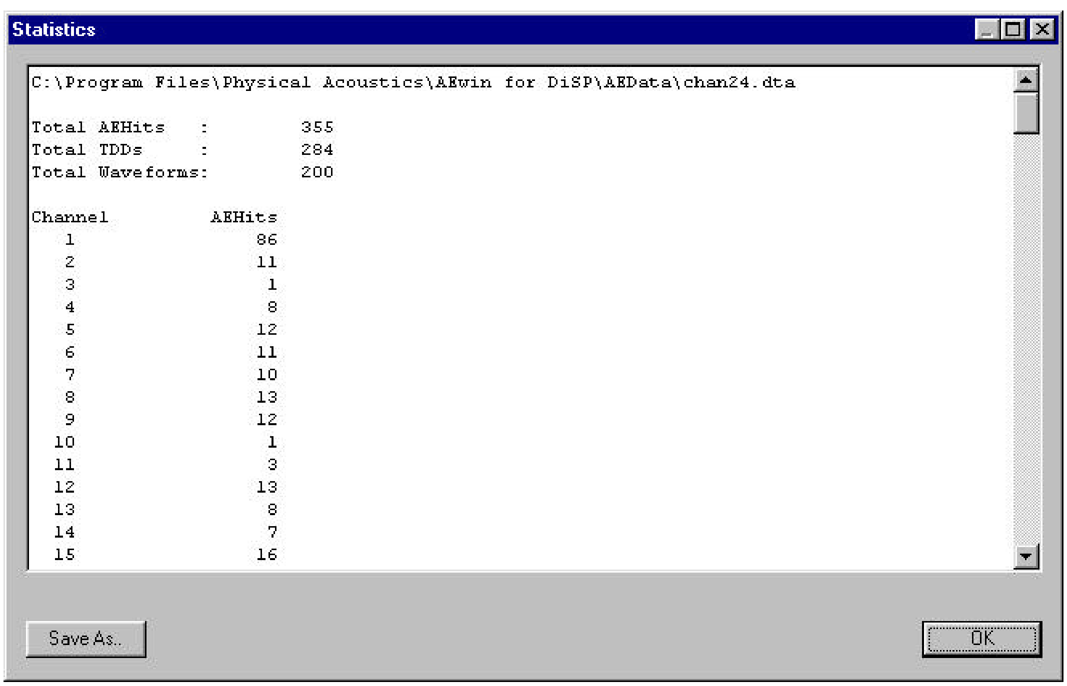
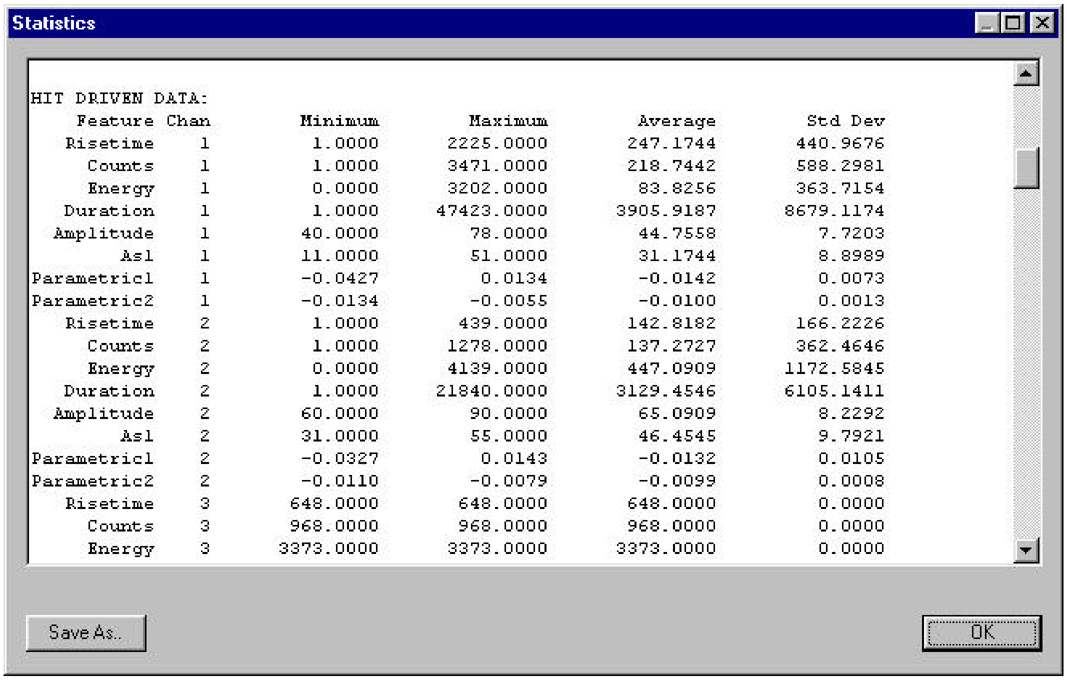


Figure 5. Statistics Utility, Result Window


Statistics

HIT DRIVEN DATA:

Feature	Chan	Minimum	Maximum	Average	Std Dev
Risetime	1	1.0000	2225.0000	247.1744	440.9676
Counts	1	1.0000	3471.0000	218.7442	588.2981
Energy	1	0.0000	3202.0000	83.8256	363.7154
Duration	1	1.0000	47423.0000	3905.9187	8679.1174
Amplitude	1	40.0000	78.0000	44.7558	7.7203
Asl	1	11.0000	51.0000	31.1744	8.8989
Parametric1	1	-0.0427	0.0134	-0.0142	0.0073
Parametric2	1	-0.0134	-0.0055	-0.0100	0.0013
Risetime	2	1.0000	439.0000	142.8182	166.2226
Counts	2	1.0000	1278.0000	137.2727	362.4646
Energy	2	0.0000	4139.0000	447.0909	1172.5845
Duration	2	1.0000	21840.0000	3129.4546	6105.1411
Amplitude	2	60.0000	90.0000	65.0909	8.2292
Asl	2	31.0000	55.0000	46.4545	9.7921
Parametric1	2	-0.0327	0.0143	-0.0132	0.0105
Parametric2	2	-0.0110	-0.0079	-0.0099	0.0008
Risetime	3	648.0000	648.0000	648.0000	0.0000
Counts	3	968.0000	968.0000	968.0000	0.0000
Energy	3	3373.0000	3373.0000	3373.0000	0.0000

Save As..

OK

Figure 6. Statistics Utility Result Window

The user has the option to copy this information to the clipboard for inserting in other documents, directly save the information in an ASCII format text file by clicking on the "Save As.." button. Or simply view the information on the screen.

4 ASCII OUTPUT

The ASCII Output utility will convert an AE data file (.DTA) into an ASCII format text file that can be read in word processors and spreadsheets. The program requires the user to input the file name to be processed, the output file name and the selection of messages and data content the user is interested in saving to the ASCII output file.

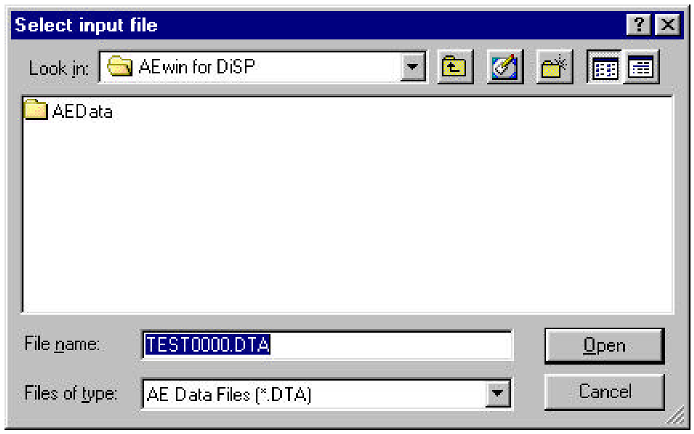


Figure 7. Select Input File

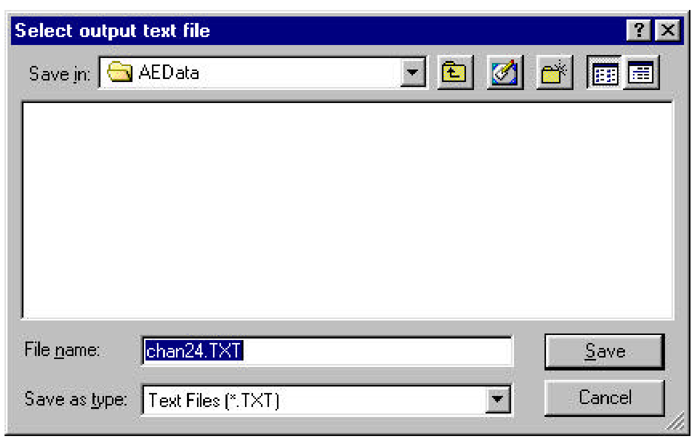


Figure 8. Select Output Text File

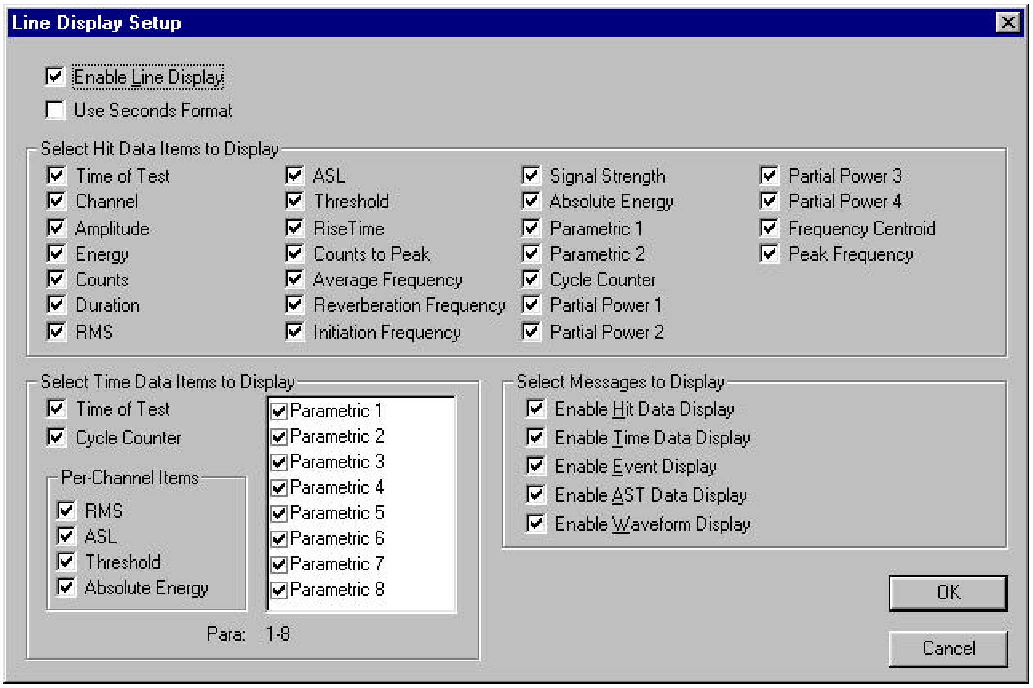


Figure 9. Options to Include in the Text File Output

This Dialog box (shown above) lets the user select which should be recorded to the resultant text file (if existing on the file)

The user will know that the program has finished when the following message appears:

Figure 10. ASCII Output Utility, Final Message

5 ASCII WAVEFORMS

The waveform to ASCII utility processes a DTA file or a TDA file containing waveforms , takes each waveform found in the file and saves each of them into a separate ASCII text file (Excel compatible). The program offers the user two types of conversion: simple and complete. Simple is when the output files only contain one column of data without any information header, meanwhile complete contains the information header and the data column.

When the user selects to run this utility, the program will ask him the name for the input file.

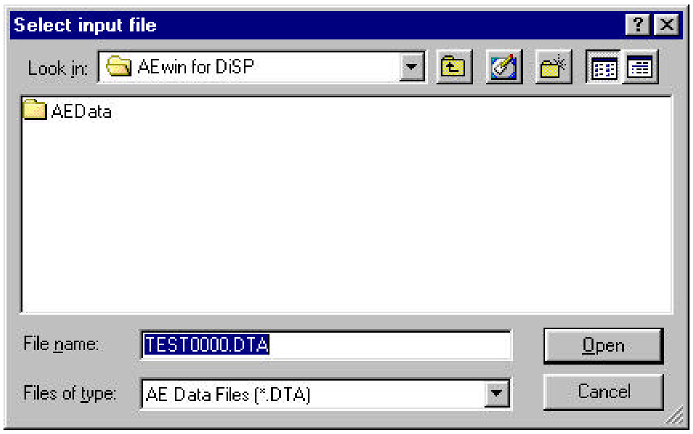


Figure 11. Select Input File

After selecting the input file, a dialog is displayed for selecting the output folder name. Notice that this is not the common window to select a file, because in this case you need to provide a folder for the multiple waveform files to reside, so you are going to see the window "Browse for Folder". As a default, the same folder as the input file is displayed, but the user has the option to change it.

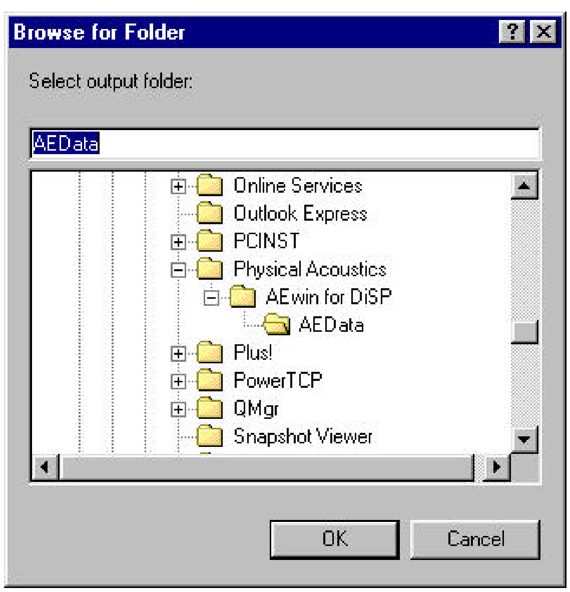


Figure 12. Browse for Output Folder

Now the program will ask the user to select some options for the output file.

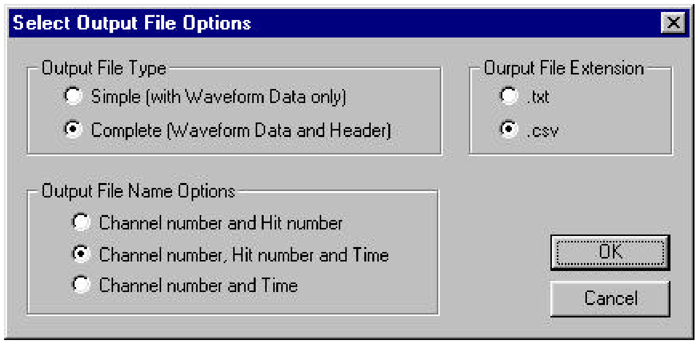


Figure 13. Select Output File Options

The user can choose the Type, the file extension and the name for the output files. Type has two choices: simple, with waveform data only and complete with waveform data and header. Complete is the default option. The information header lists the following information:

- Input file name
- Date
- Time
- Sample Interval
- Units
- Channel number
- Hit number
- Time of Test

Another option for the user is the output file extension. If he wants to analyze the data using EXCEL he should select the "csv" extension to open directly in EXCEL without being asked to convert the file in EXCEL. The "csv" option is the default. The "txt" output should be selected for non-EXCEL applications and is more generic.

The last question to answer is the file name options, there are three of them: (1) channel number and hit number, (2) channel number, hit number and time and (3) channel number and time. The second one is the default option. These allow an automatic file naming convention for recognition and identification of the waveform file after conversion. The user should choose the option that he feels is best.

When the program is processing the input file, the user will see the progress bar located at the right bottom in the main window. As soon as the program finishes, the summary window will show the input file name, the output folder with the base name and a list with the number of processed waveforms per channel.

The user can go to the output folder he selected to find the created files, one file per waveform.

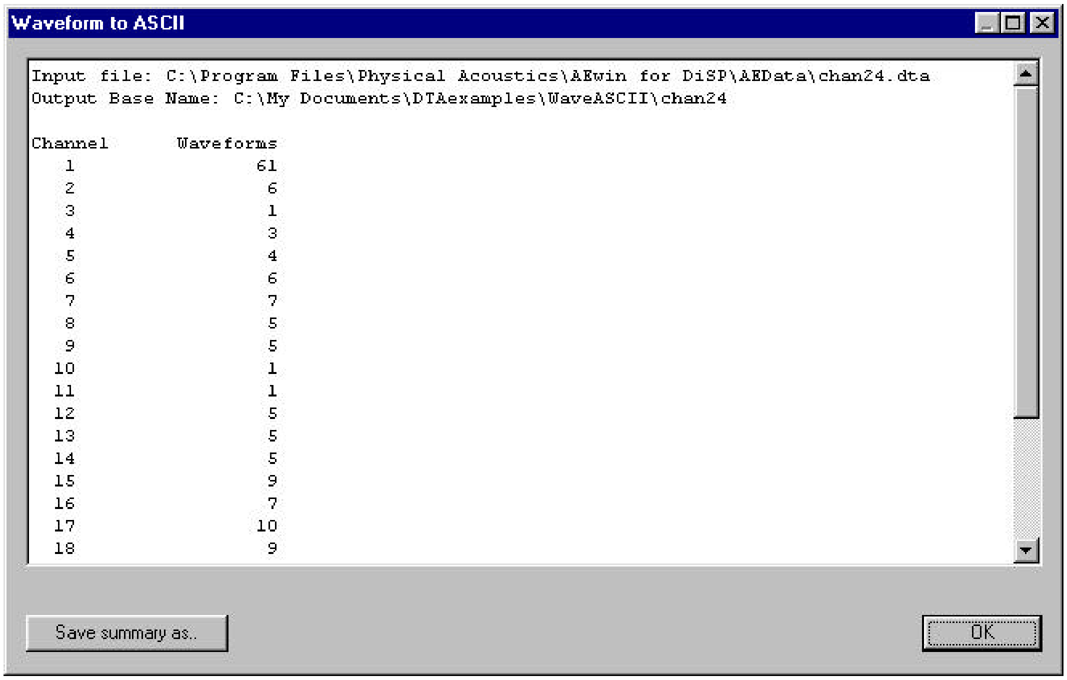


Figure 14. ASCII Waveform Utility Summary Window

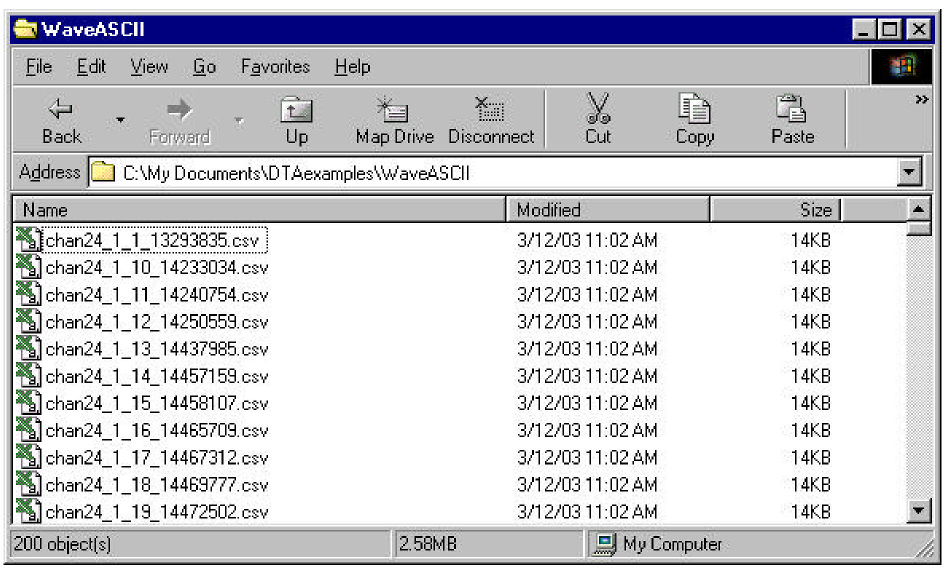


Figure 15. Output Folder Showing the Text Files Created by ASCII Waveform Utility

6 TIME ORDER/REPAIR

It should be noted that in AEwin, data is already saved in a Time Ordered sequence, so time ordering is not a necessity for data collected by AEwin. However, all DTA data files generated outside of AEwin (all DOS based AE programs) should be processed by this utility before being replayed into AEwin.

Time Order as its name suggests is a utility to time order the messages in AE Data files. The data file "header" is transferred to the output file unchanged. The remaining messages, which constitute the actual data, are transferred to the output file in time order. That is, the data is sorted into order of increasing time.

Extensive error checking of the messages in the data file is provided in the process and, when possible corrections are made.

To run Time order over a file the user will need to provide the input file name and the output file name.

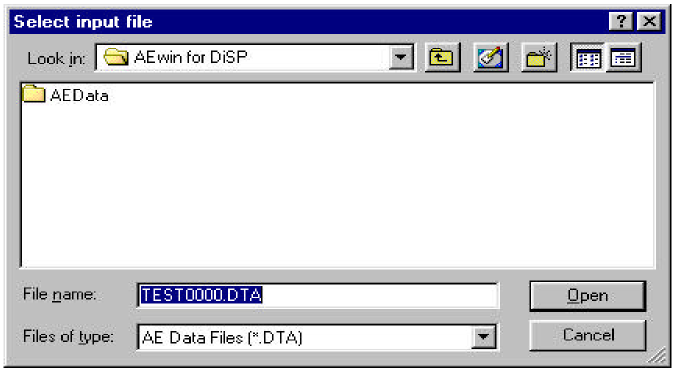


Figure 16. Select Input File

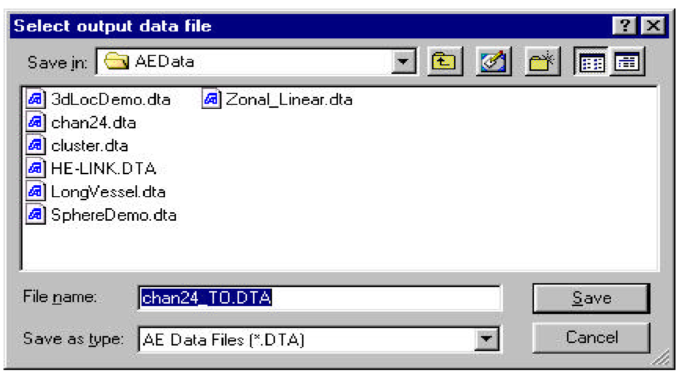


Figure 17. Select Output DTA File

Once the output file name is provided then the process for time ordering begins. When it finishes, the user will see the following message:

Figure 18. Time Order Final Message

7 LINK SEPARATE DATA FILES

Link is a utility that allows the user to combine files from different tests into one file so that for all other purposes the data will appear as if they came from a single test. A typical case where this may be desirable might be: if for some reason a test had to be aborted and was resumed at a later time, the user will then have two separate files, but for analysis purposes the user will need to have just one file.

When the user selects to run Link Utility from the Utilities Menu in AEwin the first window that will appear is the one asking him about the time between files. The default value is 1 second. This time becomes the time gap between the ending of the first data file and the beginning time of the second when the files get linked into one.

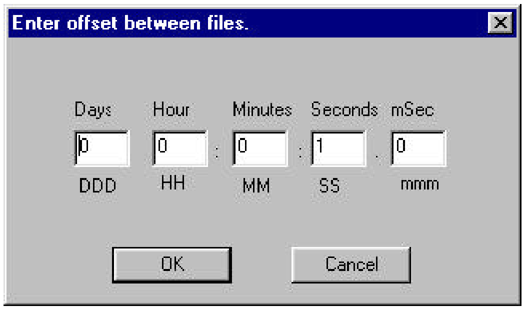


Figure 19. Dialog for Entering Offset Time Between Files

There is one restriction in the way to use this utility. If the user needs to link more than two files with different time gaps between them, then the user should run twice the program, the first time with file1 and file2 with a time gap of time1 with an output file to file12, and the second with file12 and file3 with a time gap of time2 with an output of file123. Notice that this is not necessary for linking more than two files with the same time gaps in between them.

After the user selects the offset time between files then he should select and provide an order for the files to combine. This allows linking of two or more files into one.

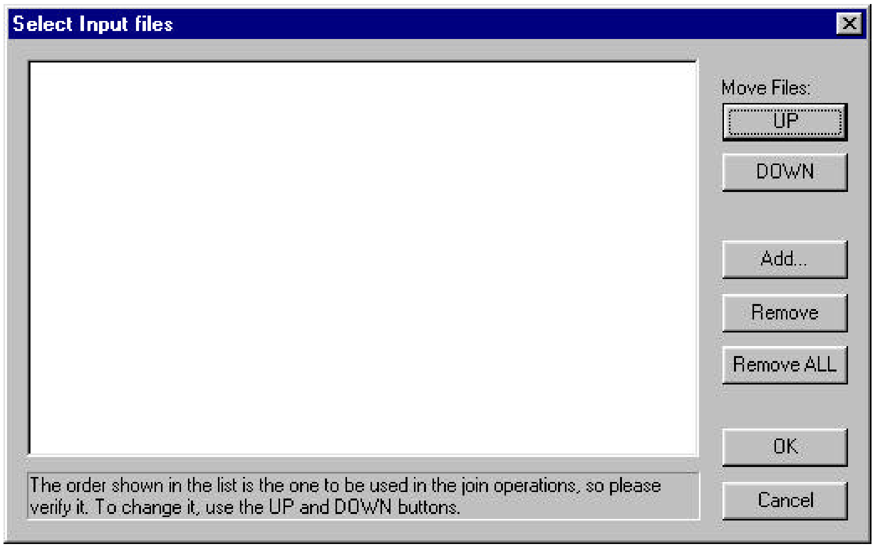


Figure 20. Select and Order Multiple Input Files

Button Actions:

- Add: Use this button to select the files to be linked.
- Remove: Select a file and then press this button to remove the selected file.
- Remove ALL: With this one the user can remove in one step all the files. Doesn't have to select them.
- Up: Select the file you want to move one position before and press this button.
- Down: Select the file you want to move one position after and click on this button.
- OK: To proceed with the process
- CANCEL: To stop the selected process.

After selecting the files to link and establishing the order, the user has to provide the program with an Output file name. This file is going to be approximately, actually less than the sum of the sizes of the files selected as input files. So when selecting the output file take this fact into account.

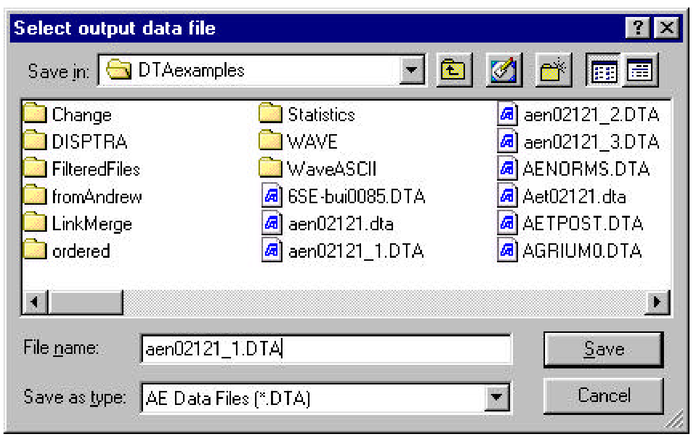


Figure 21. Select Output Data File

When the program finishes the linking, it will show the next dialog message to the user:

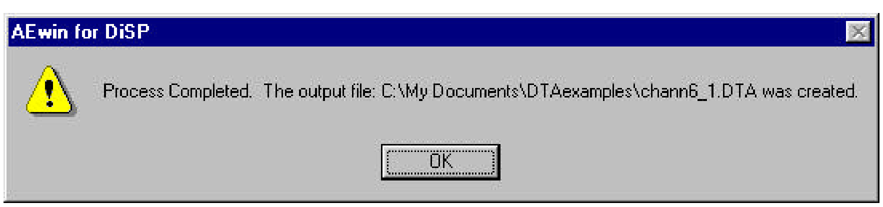


Figure 22. Link Utility, Final Message

8 MERGE CONTINUED DATA FILES

Continued files are an option in the AEwin software which allows the user to close a DTA file based on an elapsed time, number of hits or file size, and immediately re-open a new "continued" file with links in the filename and data header to the previous file.

Merge is the utility that allows the user to merge multiple continued files into one large data file. The user has to provide the input files names and order for merging them in the following window:

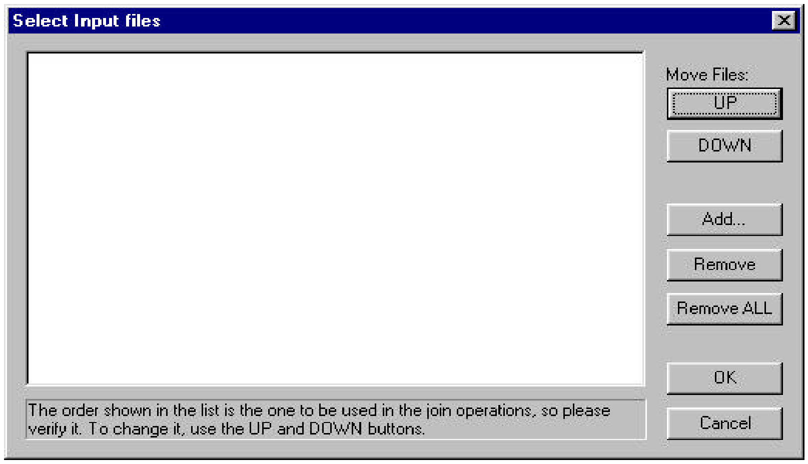


Figure 23. Select and Order Multiple Input Files

Then has to provide also the name for the output file:

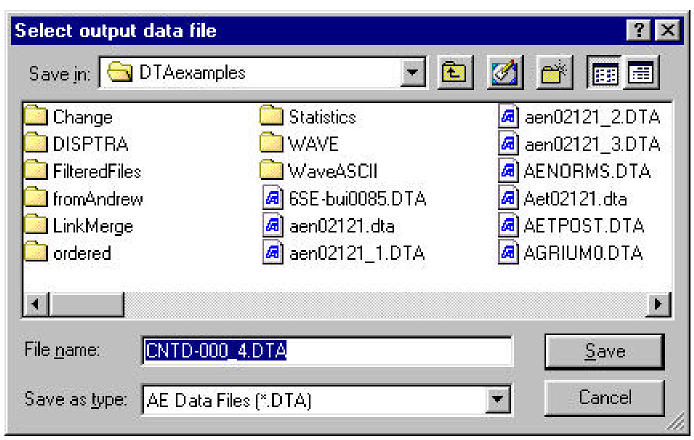


Figure 24. Select Output Data File

When the process finishes will show the next dialog message to the user:

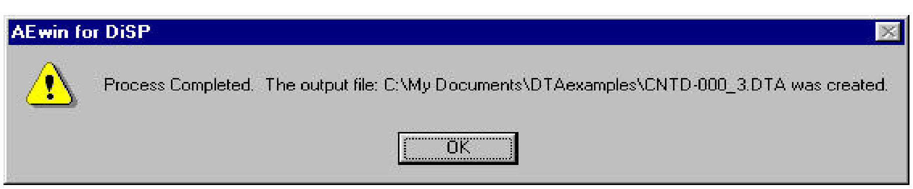


Figure 25. Merge Utility, Final Message

9. WAVEFORM FILTERING AND FEATURE EXTRACTION

9.1 Overview

"Waveform Filter and Extraction" is a 'built-in' utility within AEwin used in post-test, to filter waveforms and extract hits based on a user-specified dataset. This utility can be run by clicking on "Waveform Filter and Extraction" on the 'Utility' menu.

9.2 Setup

On startup the user is prompted to enter an input data file. Be sure that this data file was created by the same data acquisition board type (AEDSP, PCI-DSP4, etc) used by your version of AEwin. The input data file is then read and the Setup screen displayed. The information displayed reflects the setup information of the input data file.

Waveform & Hit Output:
Choose which output mode to use. The utility can save either:

- Original Waveforms and Original Hits.
- Filtered Waveforms and Extracted Hits.

In both cases the waveforms/hits are only saved if the filtered waveform (or original if no filter defined) passes the new threshold. Note that Feature Extraction is disabled if "Save Original" is selected.

General Setup:
Here the user can set a new threshold and pre-amp gain if desired.

Waveform Modification: Here the user can specify a High, Low or Band Pass waveform filter.

Feature Extraction:
This is enabled only if 'Saving Filtered Waveform' is selected. It replaces every hit with a new one based on its associated waveform.

The user can select or remove hit data set features and change HDT and PDT at this time. Certain hit dataset features (RMS, ASL, Parametrics, Cycle Counter) cannot be 'extracted' from the waveform and are copied directly from the original hit. Therefore these features can't be enabled if they were not present in the original hit dataset.

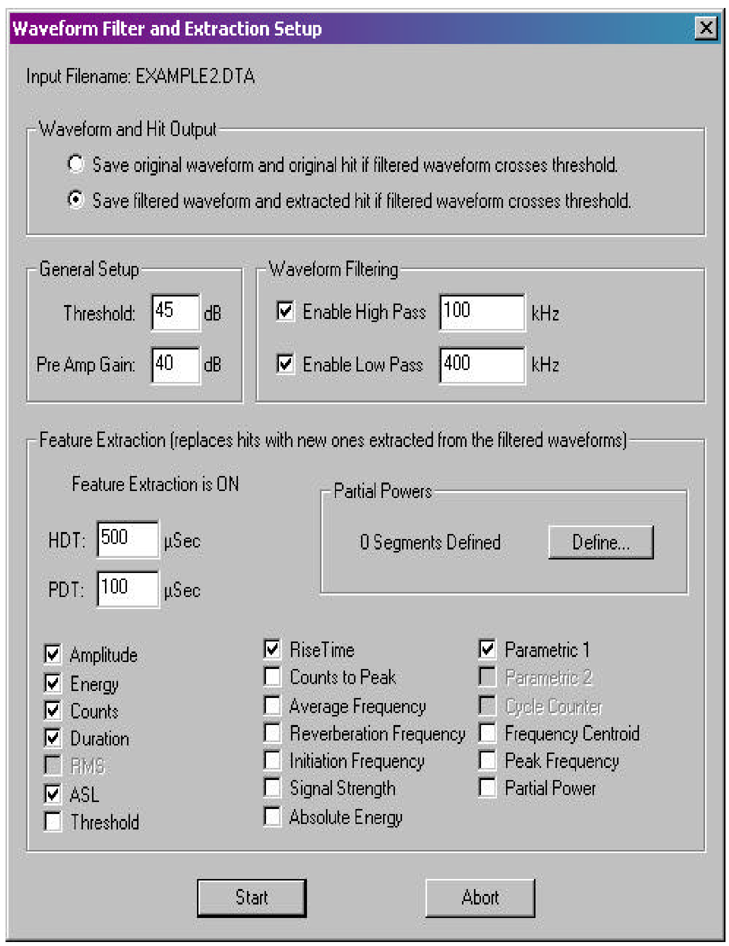


Figure 26. Waveform filter and extraction setup dialog

9.3 Program Process

Once the 'Start' button is clicked and an output filename is entered the main process begins. Each waveform and its associated hit is read from the input data file and processed as follows:

1) The filter (if enabled) is applied to the waveform. This may alter its arrival time and that of any hit extracted from it.

2) If the filtered waveform (or original if no filter is enabled) does not reach or exceed the threshold then it and it's associated hit are NOT written to the output file and the process begins again with the next waveform and associated hit.

3) If the filtered waveform (or original if no filter is enabled) does reach or exceed the threshold then:
    - If 'Saving Original Waveform…' is selected then the original waveform and associated hit are written to the output data file. The process begins again with the next waveform and associated hit.
    - If 'Saving Filtered Waveform…' is selected then the filtered waveform is saved to the output data file and the process continues to step 4.

4) A new hit is extracted from the filtered waveform and is saved to the output data file. If for some reason no hit is associated with the waveform than a new hit is NOT extracted and written.

9.4 Tips and Considerations

1) The input data file must have been collected using the same data acquisition board type (AEDSP, PCI-DSP4, etc) as the version of AEwin this utility is running on. I.E. If the user is running AEwin for DiSP then this utility can use data files created by AEwin for DiSP, DiSP and DiSP-LOC. If the user tries to filter/extract a data file created by a different data acquisition board type then the setup may be incompatible. If it is then an error message "Error Reading Hardware Setup, Aborted" will be shown and the utility will abort.

2) Unassociated hits (hits not associated with a waveform) are NOT copied to the output data file.

3) The arrival times of filtered waveforms and their associated extracted hits may change during the filter process.

4) In order for the extracted features to be the same as the original features the waveforms must be equal to a length defined as Pre-Trigger + Duration + HDT. If the waveform length is shorter than this then the calculation of the features may terminate prematurely.

10. REMOVE MESSAGES

"Remove Messages" is a utility that lets the user remove some messages from a given DTA file and saves the result in a new DTA file. The user has to provide the input and output name for the files. The default name for the output file is the input file + the suffix QF (for quick filter).

The following figure shows the options for removing.

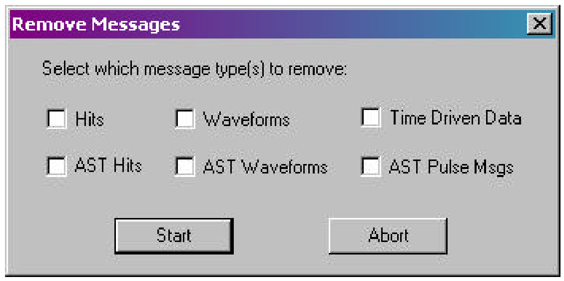


Figure 27. Remove Messages Dialog

11. CHANGE TITLE

"Change Title" is a utility that lets the user change the title from a given DTA file and saves the result in a new DTA file. The user has to provide the input and output file names. The default name of the output file is the name of the input file + the suffix "title".

The only restriction for the new title is the length, currently is 40 characters.

The following figure shows the change title dialog.

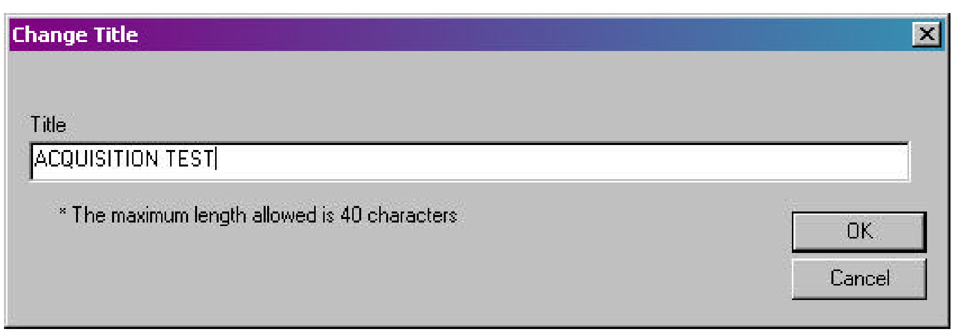


Figure 28. Change Title Dialog

12. DATA FILE FILTER

"Data File Filter" is a very helpful utility in AEwin that lets the user filter data files based on a user-defined filter. Clicking on "Data File Filter" submenu at the 'Utility' menu can run this utility.

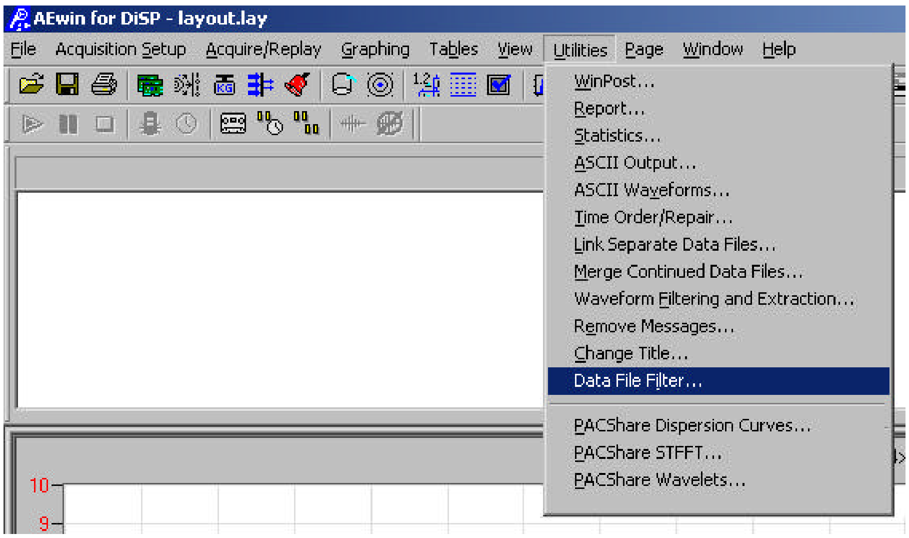


Figure 29. Utilities Menu

The user will be prompted to select an input data file for filtering. This utility program assumes the file is in time order. This is a valid assumption for any "DTA" data file collected under AEwin acquisition software.

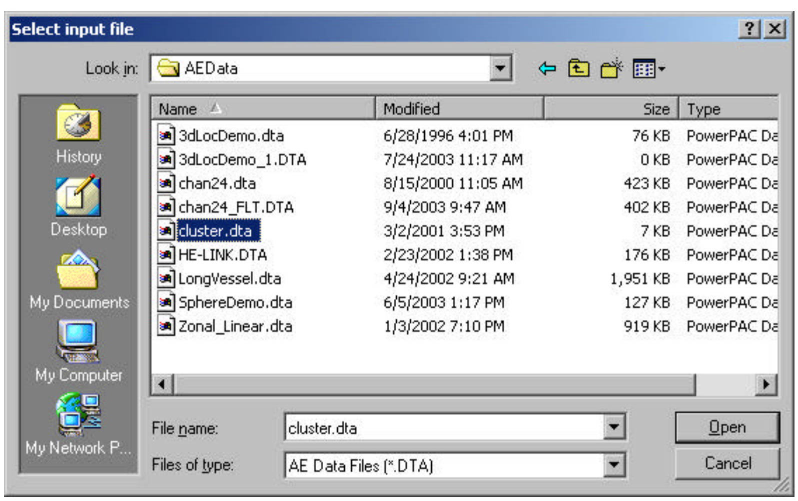


Figure 30. Select Input File

When the user opens the input file, the “Filter Setup Dialog” is shown. (Figure 31)

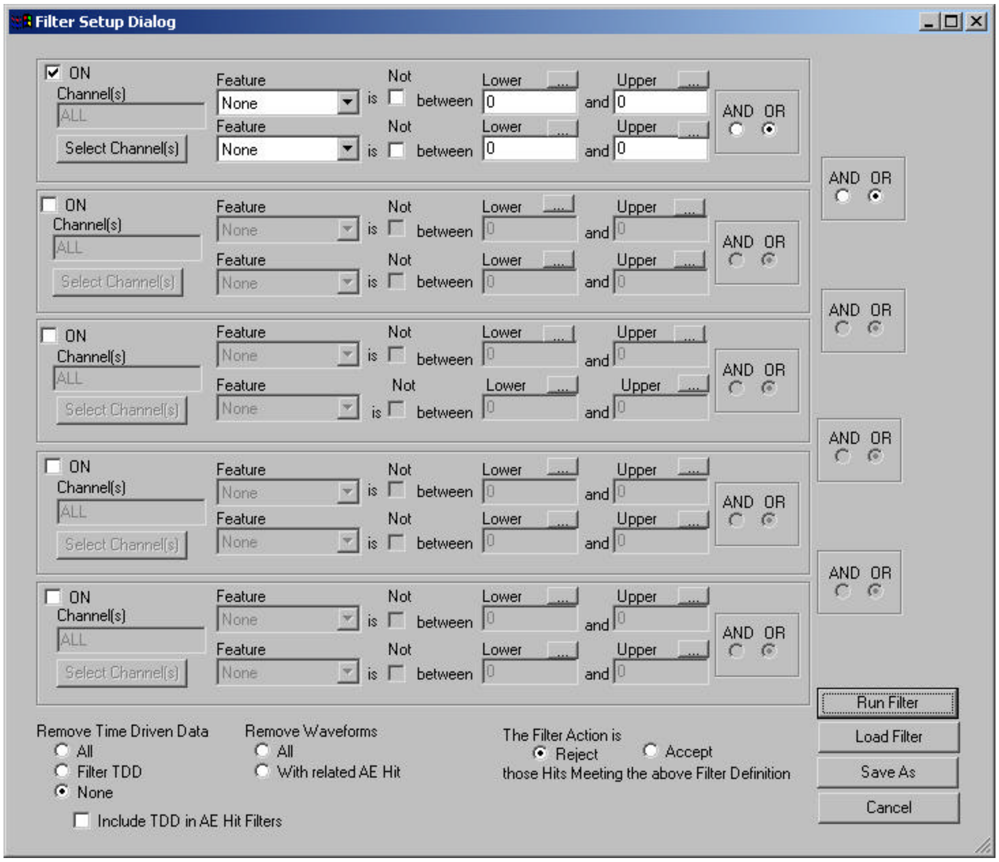


Figure 31. Filter Setup Dialog

The filter definition menu consists of five (5) groups, each of them linked by a logical condition (AND/OR). Each group operates on a pair of conditions, linked also by a logical condition, and a set of channels to which those conditions apply. The user can set the group ON or OFF.

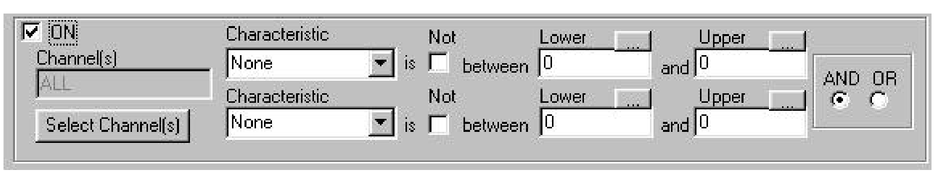


Figure 32. Group.

To set a condition, the user selects a characteristic to look for from the drop down list, then specifies a range by typing a lower and an upper value and also can check the "NOT" box if he wants to select the values out of the range.

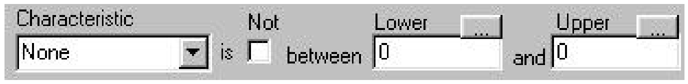


Figure 33. Condition.

When the characteristic selected is "Time", the lower and upper values should be given in seconds, but the software provides a time converter by clicking the little button at the right top of the edit box.

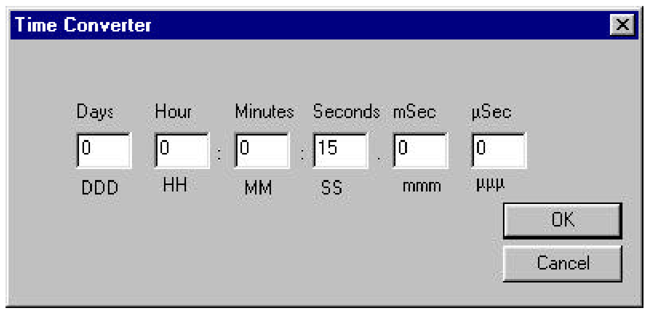


Figure 34. Time converter user interface.

To specify the channels to filter or the condition based in certain channels the user needs to click on the "Select Channel(s)" button of the specified condition. The interface that he will see is shown in Figure 35.

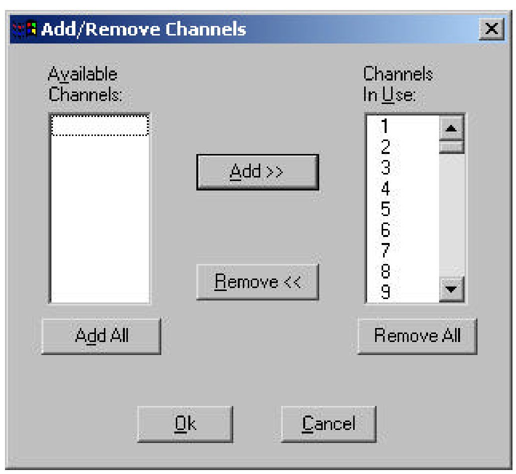


Figure 35. Select Channels user interface.

At the bottom part of the filter definition menu window, the user has other options applicable to the Waveforms and the Time Driven Data messages. Also in this section is the definition of the Filter Action. By selecting "Reject", all the values that fulfill the condition are going to be rejected, while selecting "Accept", all the values that fulfill the condition are going to be saved to the output file.

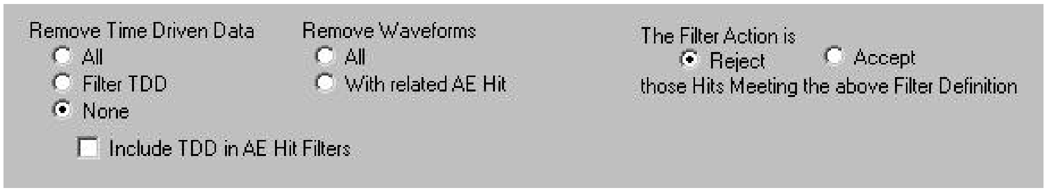


Figure 36. Other options in filter definition interface.

Options to “Remove Time Driven Data”.

- **All.** Removes all TDD messages without checking anything.
- **None**. Keep all TDD messages without checking anything.
- **Filter TDD.** Checks the value of the TDD and filtered if the characteristic selected is Time or any parametric.

If the check box for "Include TDD in AE Hit Filters" is checked this means that the user wants to look at TDD values and filtering AE hits. In order to enable this you have to choose the Filter TDD option.

Options to “Remove Waveforms”.

- **All.** Removes all Waveforms.
- **With related AE Hit.** Keep the waveform if the related AE Hit is saved or remove it when the AE Hit is removed.

Filter Definition Filter User Interface the user has four option buttons at the right bottom:

- **<u>Run Filter</u>.** This option prompts the user for an output file name for the filtered file. Once the user selects the file then the program runs the filter definition file to filter the input data file. While this action is being carried out, the progress bar will indicate how much of the file has been processed; also the name of the file in process is shown below the progress bar. This is helpful when working with big files. A message box will appear when the process is finished.

- **<u>Load Filter</u>.** This option prompts the user to recall a saved filter definition file (*.flt) to load and use in the filter for using directly or to use it as a base to create a new filter definition.

- **<u>Save as..</u>** This option prompts the user for a name for the filter definition file (*.flt) for future use/archiving.

- **<u>Cancel.</u>** This option lets the user exit the utility without saving any changes to the filter since the last time it was saved.

Note: The Report Utility can be used to view the history of filters applied to a data file.

13. OPERATORS LOG MANAGEMENT

The Operators Log Management is a utility tool in AEwin that allows the user to view, modify and manipulate time mark data in a file during post-test analysis. It is accessible by selecting 'Operators Log Management…' from the Utilities menu.

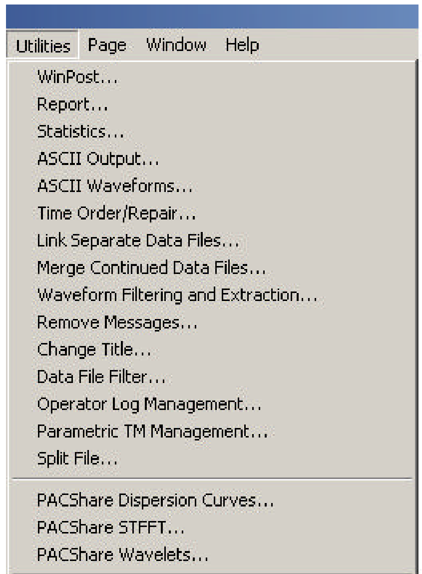


Figure 37. Utilities Menu

You will be prompted to select a data file for analysis. This utility program assumes that the file is in time-order. Perform time ordering only if the data file was generated by an acquisition program other than AEwin.

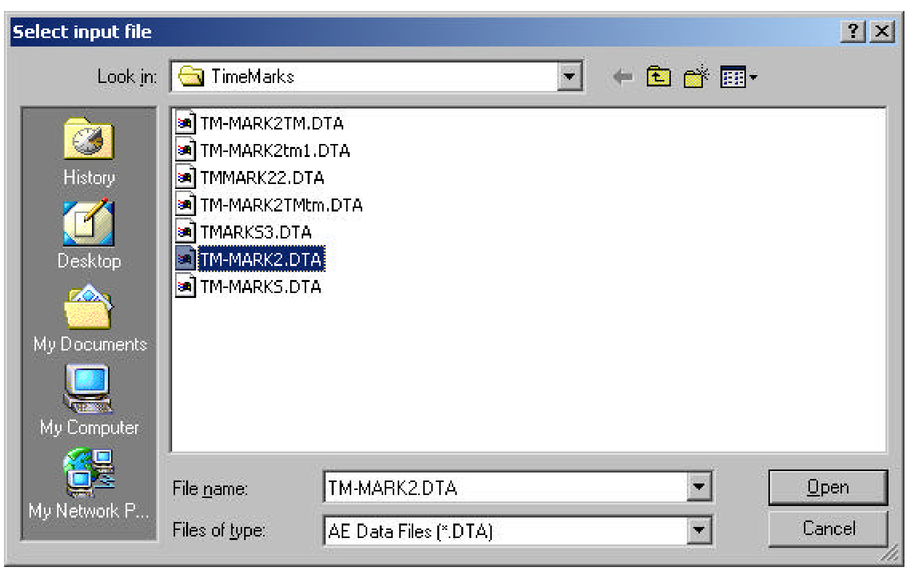


Figure 38. Select Input File

Once loaded, a list of existing comment user time marks will appear on the Operators Log Management screen (shown below).

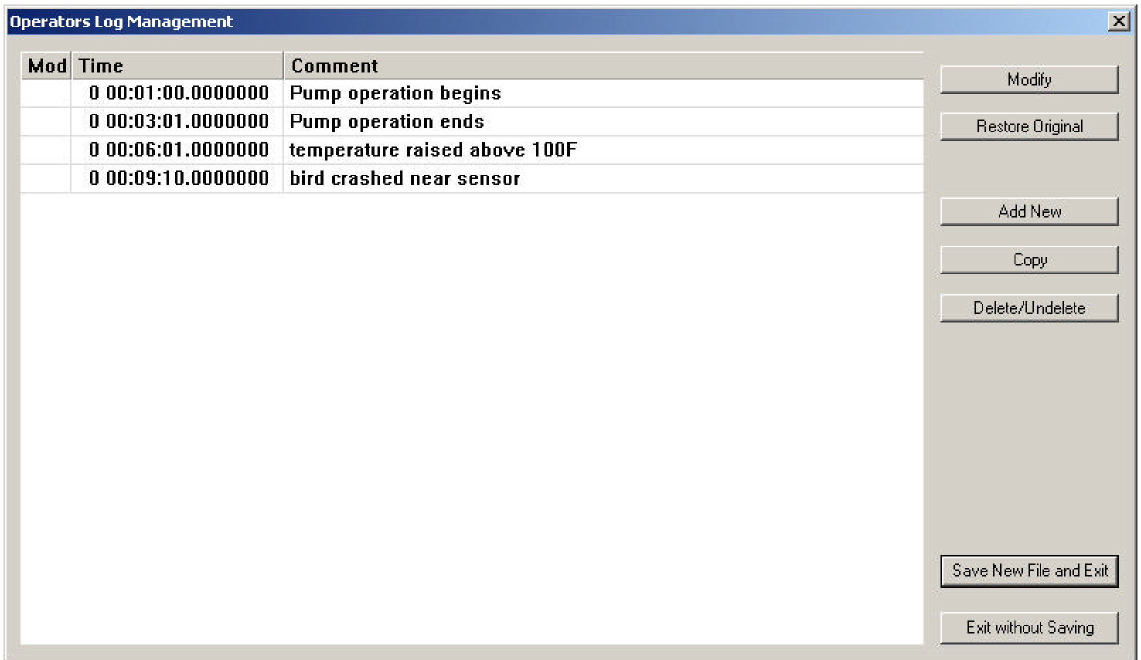


Figure 39. Operators Log Management

Each row in the grid pertains to a single comment time mark. There are three columns.
'**Mod**' shows an indication of any changes the user has made to the time-mark.

- '**N**' means that the comment time mark was just created.
- '**M**' means that the comment time mark is an existing one that was just modified.
- '**D**' means that the comment time mark is an existing one to be deleted.
- '**DM**' means that the comment time mark is an existing one, modified and to be deleted.

'**Time**' is the time of test of the comment time mark.

'**Comment**' is the label/comment (if any) of the time mark. The maximum length of the comment is 40 characters.

13.1 Modify

To change the time of test or comment of a comment time mark, select it by clicking on the row and press "Modify" button. This will bring up the dialog box shown:

The "Set Comment Time Mark Information" dialog box displays the original comment (if any) and time of test. A new comment can be entered by selecting one of the standard comments from its drop down box or by typing a new one. You can enter a new time in the 'Time of Test' fields. You can see the end time of test at the bottom of the dialog, you should be aware of this time because the time of test for any time mark should be less than the end time of test. When your changes are complete press 'Ok' to keep your changes or 'Cancel' to discard them. A modified (but non-new) time-mark will have an '**M**' in it's '**Mod**' column.

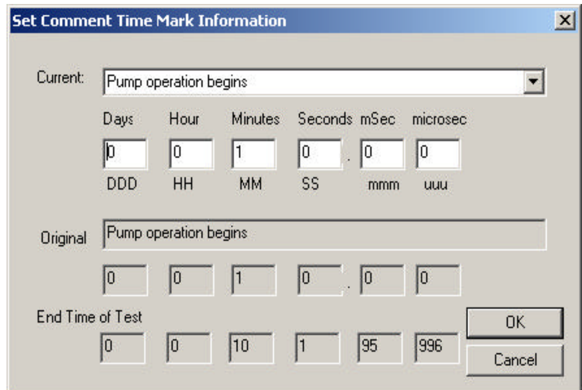


Figure 40. Modify

13.2 Restore Original

To undo a modification of a comment time mark, select the time mark row from the grid and press "Restore Original". This will remove the '**M**' from its '**Mod**' column and prevent it from being modified in a future file update.

13.3 Add New

To add a new comment time mark to the grid press "Add New". This will open the "Set Comment Time Mark Information" dialog box (shown previously). Once you have set the comment and time, press 'Ok' to keep your changes or 'Cancel' to discard them. The new comment time mark will be inserted in time order to the grid, marked by an '**N**' in the '**Mod**' column. It will be added to the new file during a file update.

13.4 Copy

A quick way to create a comment time mark is to make a copy of an existing one and modify it as desired. To do this select a time mark row from the grid and press "Copy". This makes a copy of the selected comment time mark and opens the "Set Comment Time Mark Information" dialog box (shown previously). Once you have completed your changes, select 'Ok' to keep the new time mark or 'Cancel' to discard it. The new comment time mark will be inserted in time order to the grid, marked by an '**N**' in the '**Mod**' column.

13.5 Delete/Undelete

To delete a comment time mark, select the row from the grid and press "Delete/Undelete". If the time mark is a new one (marked by 'N') it is immediately and permanently removed from the grid. If not then a 'D' will appear in the 'Mod' column, except when the time mark is a modified one (with an 'M' in the 'Mod' column), for this case a 'DM' will appear in the 'Mod' column. This action can be undone at any time prior to a file update. During a file update any comment time marks designated for deletion will be removed from the new file.

To undelete a comment time mark, select it from the grid and press "Delete/Undelete". This will remove the '**D**' or '**DM**' mark from the '**Mod**' column and will prevent the comment time mark from being deleted during a future file update.

13.6 Save New File and Exit

To create a new modified file from your old one, press “Save New File and Exit”. You will be prompted to enter a new output file name (See image below), by default you will have the input file name and the suffix tm’.

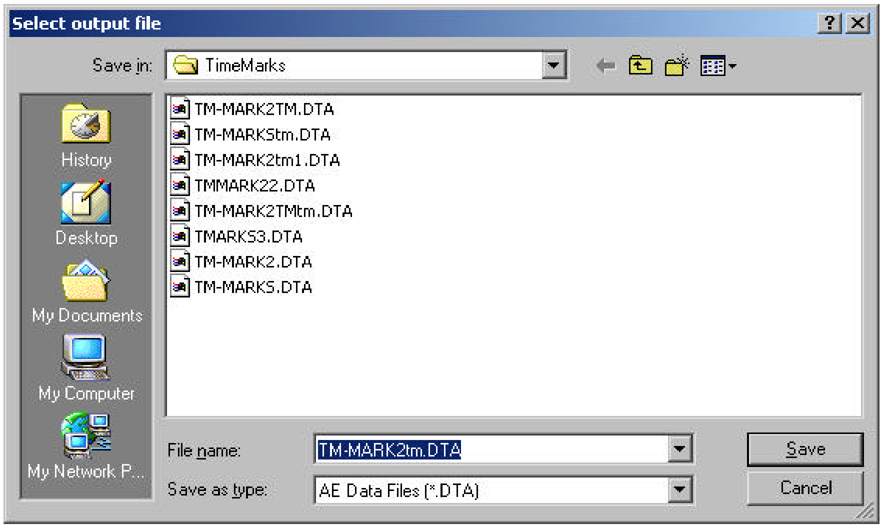


Figure 41. Select Input File

If you select the “Save” button, it will then copy your original file, modifying or deleting existing time marks and adding new ones as needed based on the changes you made. The original file is left unmodified.

13.7 Exit without Saving

To exit without saving changes to a file, press “Exit without Saving” button.

14. PARAMETRIC TM MANAGEMENT

Parametric TM Management is a utility tool in AEwin that allows the user to view, modify, add and manipulate parametric time marks, in a file during post-test analysis. Many times a user is not able to connect to a parametric source for input into the AE system. This feature allows the user to enter and record parametric information (as might be read and recorded from a meter or CRT screen) and add it to the existing AE data file in Post Test. This is accomplished through the use of ‘parametric’ time marks. These are created by the user and hold a (user specified) value for parametric 1 and comment. Once setup is complete these are written to the file, and the parametric 1 value for all hit and time-based messages are changed to the value of the most recent parametric time mark.

It is accessible by selecting ‘Parametric TM Management…’ from the Utilities menu.

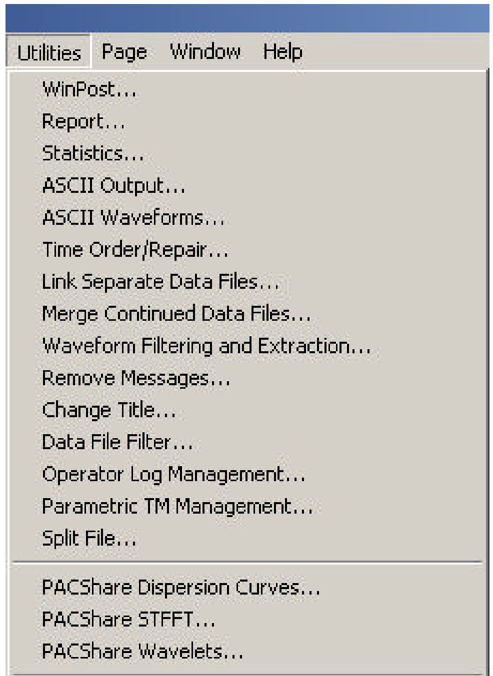


Figure 42. Utilities Menu

You will be prompted to select a data file for analysis. This utility program assumes that the file is in time-order. Perform time ordering only if the data file was generated by an acquisition program other than AEwin.

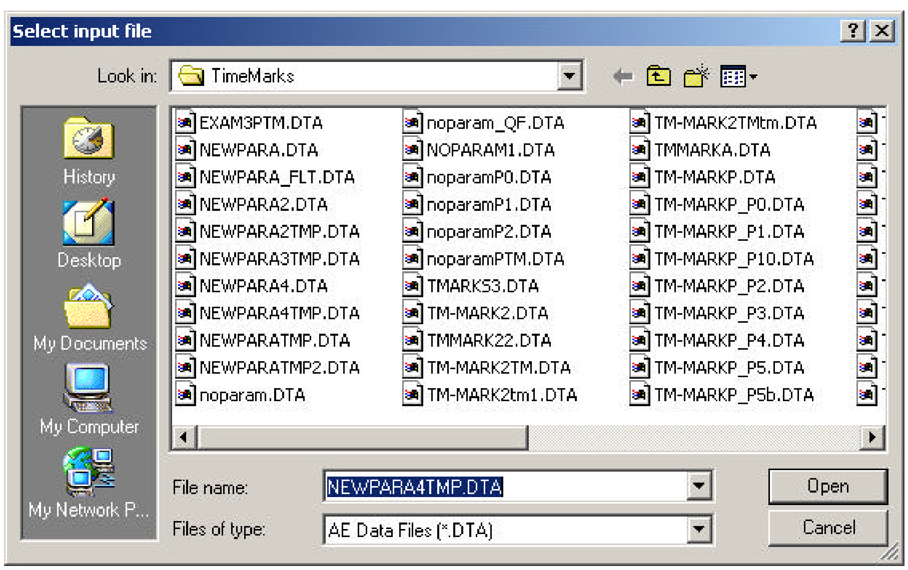


Figure 43. Select Input File

Once loaded, a list of existing time marks will appear on the Parametric TM Management screen (shown below).

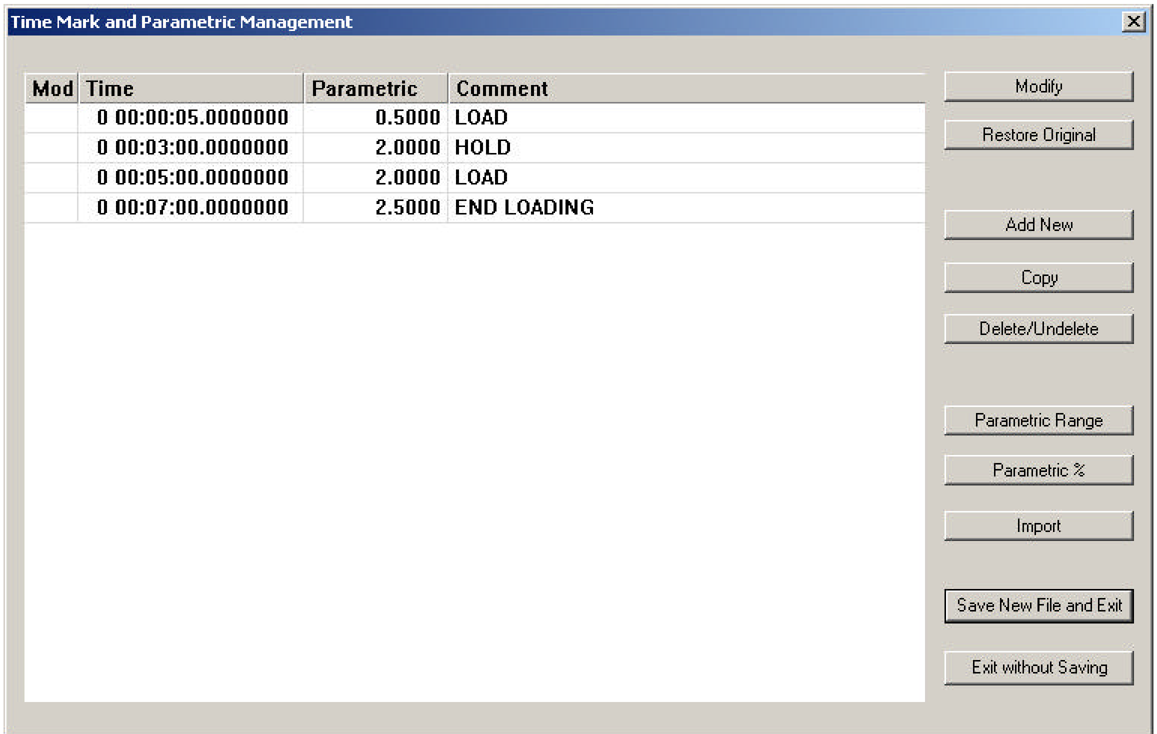


Figure 44. Parametric FM Management

Each row in the grid pertains to a single time mark. There are four columns.

1. '**Mod**' shows an indication of any changes the user has made to the time-mark.
   - '**N**' means that the time mark was just created.
   - '**M**' means that the time mark is an existing one that was just modified.
   - '**D**' means that the time mark is an existing one to be deleted.
   - '**DM**' means that the time mark is an existing one, modified and to be deleted.
2. '**Time**' is the time of test of the time mark.
3. '**Parametric**' displays the value of parametric 1 archived with the time mark.. This number is scaled in the same units as the user defines in the 'Scaling' dialog box in hardware setup (F2). **Or** it may display this same value as a percentage of the user-defined range. See the section on 'Changing the Parametric Range' for more on this.
4. '**Comment**' is the label/comment (if any) of the time mark. The maximum length of a time mark message is 40 characters.

14.1 Modify

To change the time of test, comment or parametric value of a time mark, select it by clicking on the row and press “Modify” button. This will bring up the dialog box shown below:

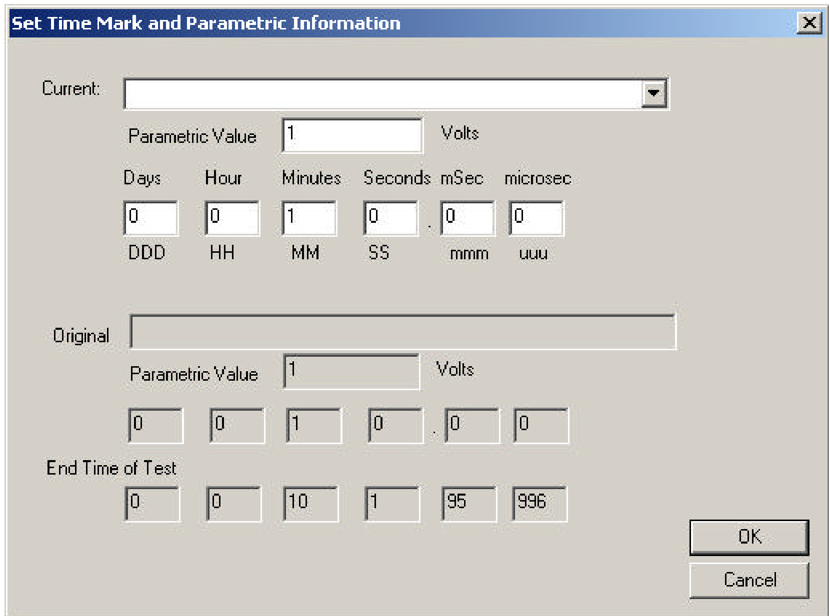


Figure 45. Set Information

The “Set Time Mark and Parametric Information” dialog box displays the original comment (if any), the parametric value and time of test. A new comment can be entered by selecting one of the standard comments from its drop down box or by typing a new one. You can enter a new parametric value as well as a new time in the ‘Time of Test’ fields. You can see the end time of test at the bottom of the dialog, you should be aware of this time because the time of test for any time mark should be less than the end time of test. When your changes are complete press ‘Ok’ to keep your changes or ‘Cancel’ to discard them. A modified (but non-new) time-mark will have an ‘**M**’ in it’s ‘**Mod**’ column.

14.2 Restore Original

To undo a modification of a time mark, select the time mark row from the grid and press “Restore Original”. This will remove the ‘**M**’ from its ‘**Mod**’ column and prevent it from being modified in a future file update.

14.3 Add New

To add a new time mark to the grid press “Add New”. This will open the “Set Time Mark and Parametric Information” dialog box (shown previously). Once you have set the comment and time, press ‘Ok’ to keep your changes or ‘Cancel’ to discard them. The new time mark will be inserted in time order to the grid, marked by an ‘**N**’ in the ‘**Mod**’ column. It will be added to the new file during a file update.

14.4 Copy

A quick way to create a time mark is to make a copy of an existing one and modify it as desired. To do this select a time mark row from the grid and press “Copy”. This makes a copy of the selected time mark and opens the “Set Time Mark and Parametric Information” dialog box (shown previously). Once you have completed your changes, select 'Ok' to keep the new time mark or 'Cancel' to discard it. The new time mark will be inserted in time order to the grid, marked by an '**N**' in the '**Mod**' column.

14.5 Delete/Undelete

To delete a time mark, select the row from the grid and press "Delete/Undelete". If the time mark is a new one (marked by 'N') it is immediately and permanently removed from the grid. If not then a 'D' will appear in the 'Mod' column, except when the time mark is a modified one (with an 'M' in the 'Mod' column), for this case a 'DM' will appear in the 'Mod' column. This action can be undone at any time prior to a file update. During a file update any time marks designated for deletion will be removed from the new file.

To undelete a time mark, select it from the grid and press "Delete/Undelete". This will remove the '**D**' or '**DM**' mark from the '**Mod**' column and will prevent the time mark from being deleted during a future file update.

14.6 Parametric Range

In order to display parametric 1 in percent form, you need to set a valid parametric range. Pressing "Parametric Range" will open the 'Set Parametric Range' dialog box (shown below).

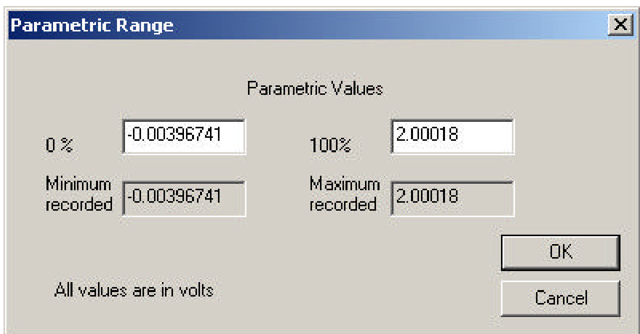


Figure 46. Parametric Range

Here you can set the values for 0% and 100% of range. There are also shown the minimum and maximum, recorded parametric 1 values. When you are done, press 'Ok' to apply your changes or 'Cancel' to discard them.

14.7 Displaying Parametric % or Value

To toggle the parametric display between Value and % (percent), press the button "Parametric % / Value" on the Time Mark and Parametric Management Dialog. This is labeled as either "Parametric %" or "Parametric value" depending on what is currently being displayed.

14.8 Import

This option lets the user to write a txt file with the information instead to modify or add one by one the parametric time marks to the grid. The file needs to have two columns, the first one is the time in seconds and the second one the parametric value.

14.9 Save New File and Exit

To create a new modified file from your old one, press “Save New File and Exit”. You will be prompted to enter a new output file name (See image below), by default you will have the input file name and the suffix ‘tmp’.

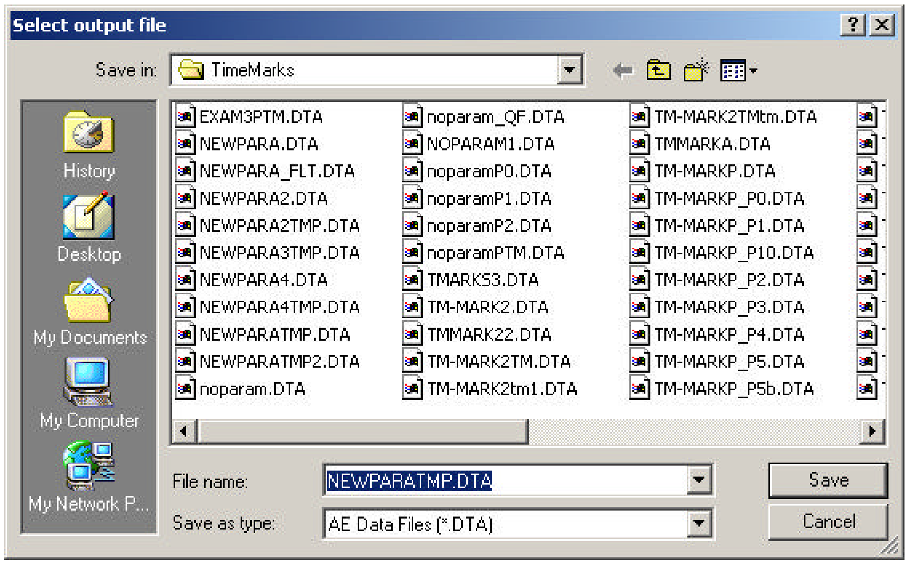


Figure 47. Select Output File

If you select the “Save” button, it will then copy your original file, modifying or deleting existing time marks and adding new ones as needed based on the changes you made. The original file is left unmodified.

14.10 Exit without Saving

To exit without saving changes to a file, press “Exit without Saving” button.

15. SPLIT FILE

Split File Utility is a tool in AEwin that allows the user to split a given file into smaller files. It is accessible by selecting 'Split File…' from the Utilities menu.

The user will be prompted to select an input data file. This utility program assumes the file is in time order. This is a valid assumption for any "DTA" data file collected under AEwin acquisition software.

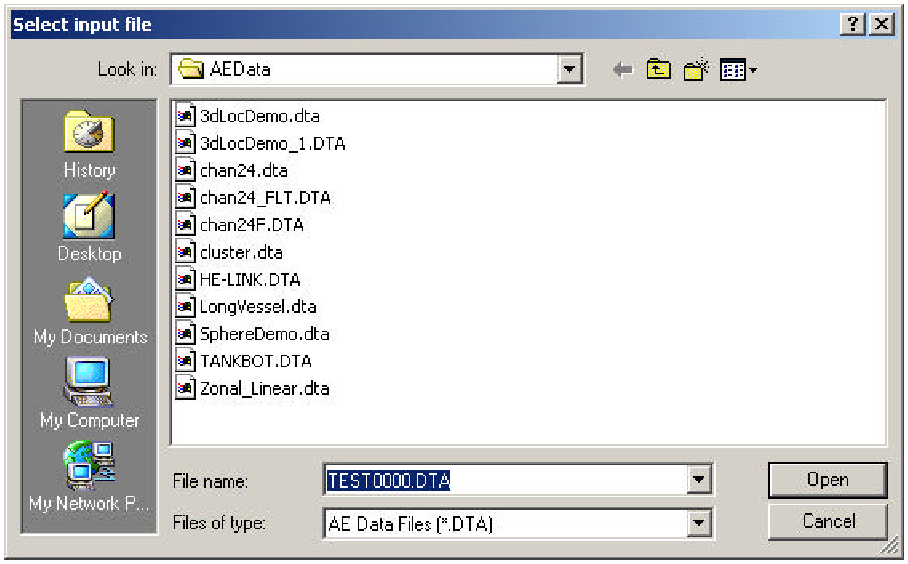


Figure 48. Select Input File

Once the user selects the name of the input file then the utility will prompt for the base name for the output files. The program will take the base name the user selected and will add to it a consecutive number as a suffix.

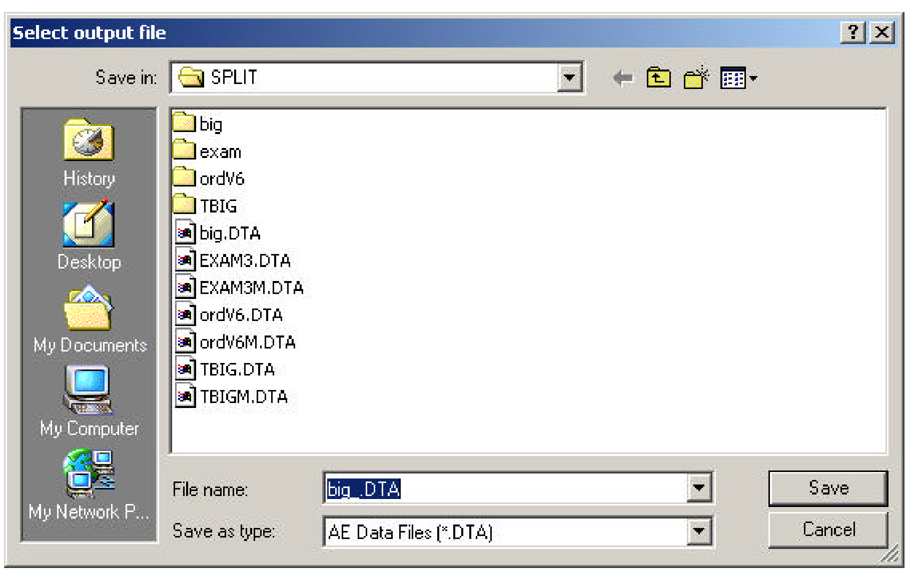


Figure 49. Output Type

Then the utility is going to ask the user to type the desired size for the resultant files, which has to be specified in Kb (and for the program is taking 1 Kb equal to 1000 bytes).

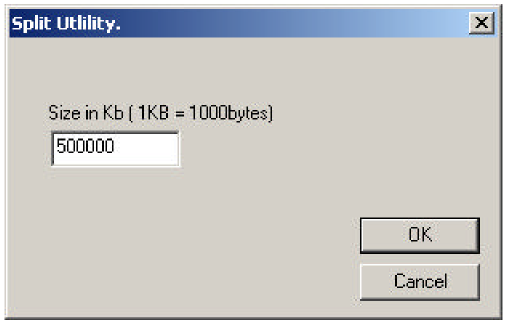


Figure 50. Split Utility

AE GENERAL PRACTICES

PHYSICAL ACOUSTICS CORPORATION

A Member of MISTRAS Holdings Group

Acoustic Emission Inspection

Dr. Adrian A. Pollock
Physical Acoustics Corporation

TECHNICAL REPORT

TR-103-96-12/89

Acoustic Emission Inspection

Adrian A. Pollock, Physical Acoustics Corporation

ACOUSTIC EMISSIONS are stress waves produced by sudden movement in stressed materials. The classic sources of acoustic emissions are defect-related deformation processes such as crack growth and plastic deformation. The process of generation and detection is illustrated in Figure 1. Sudden movement at the source produces a stress wave, which radiates out into the structure and excites a sensitive piezoelectric transducer. As the stress in the material is raised, many of these emissions are generated. The signals from one or more sensors are amplified and measured to produce data for display and interpretation.

The source of the acoustic emission energy is the elastic stress field in the material. Without stress, there is no emission. Therefore, an acoustic emission (AE) inspection is usually carried out during a controlled loading of the structure. This can be a proof load before service, a controlled variation of load while the structure is in service, a fatigue test, a creep test, or a complex loading program. Often, a structure is going to be loaded anyway, and AE inspection is used because it gives valuable additional information about the performance of the structure under load. Other times, AE inspection is selected for reasons of economy or safety, and a special loading procedure is arranged to meet the needs of the AE test.

Relationship to Other Test Methods

Acoustic emission differs from most other nondestructive testing (NDT) methods in two key respects. First, the signal has its origin in the material itself, not in an external source. Second, acoustic emission detects movement, while most other methods detect existing geometrical discontinuities. The consequences of these fundamental differences are summarized in Table 1.

Often in NDT, there is no one method that can provide the whole solution; for cost effectiveness, technical adequacy, or both, it is best to use a combination of methods. Because acoustic emission has features that distinguish it so sharply from other methods, it is particularly useful when used in combination with them.

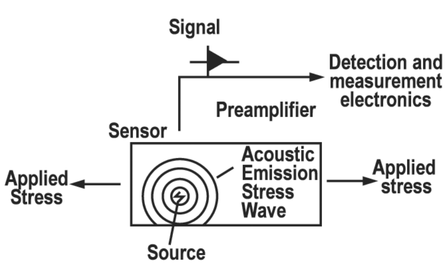


Figure 1: Basic principle of the acoustic emission method.

A major benefit of AE inspection is that it allows the whole volume of the structure to be inspected nonintrusively in a single loading operation. It is not necessary to scan the structure looking for local defects; it is only necessary to connect a suitable number of fixed sensors, which are typically placed 1 to 6 m (4 to 20 ft.) apart. This leads to major savings in testing large structures, for which other methods require removal of insulation, decontamination for entry to vessel interiors, or scanning of very large areas.

Typically, the global AE inspection is used to identify areas with structural problems, and other NDT methods are then used to identify more precisely the nature of the emitting defects. Depending on the case, acceptance or rejection can be based on AE inspection alone, other methods alone, or both together.

Acoustic Emission	Other Methods
Detects movement of defects	Detect geometric form of defects
Requires stress	Do not require stress
Each loading is unique	Inspection is directly repeatable
More material-sensitive	Less material-sensitive
Less geometry-sensitive	More geometry-sensitive
Less intrusive on plant/ process	More intrusive on plant/ process
Requires access only at sensors	Requires access to whole area of inspection
Tests whole structure at once	Scan local regions in sequence
Main problems: noise related	Main problems: geometry related

Table 1: Characteristics of acoustic emission inspection compared with other inspection methods

Range of Applicability

Acoustic emission is a natural phenomenon occurring in the widest range of materials, structures and processes. The largest-scale acoustic emissions are seismic events, while the smallest-scale processes that have been observed with AE inspection are the movements of small numbers of dislocations in stressed metals. In between, there is a wide range of laboratory studies and industrial testing.

In the laboratory, AE inspection is a powerful aid to materials testing and the study of deformation and fracture. It gives an immediate indication of the response and behavior of a material under stress, intimately connected with strength, damage and failure. Because the AE response of a material depends on its microstructure and deformation mode, materials differ widely in their AE response. Brittleness and heterogeneity are two major factors conducive to high emissivity. Ductile deformation mechanisms, such as microvoid coalescence in soft steels, are associated with low emissivity.

In production testing, AE inspection is used for checking and controlling welds (Ref 1), brazed joints (Ref 2), thermocompression bonding (Ref 3), and forming operations such as shaft straightening (Ref 4) and punch press operations. In general, AE inspection can be considered whenever the process stresses the material and produces permanent deformation.

In structural testing, AE inspection is used on pressure vessels (Ref 5), storage tanks (Ref 5) pipelines and piping (Ref 6), aircraft and space vehicles (Ref 7), electric utility plants (Ref 7), bridges (Ref 7), railroad tank cars (Ref 8), bucket trucks (Ref 7), and a range of other equipment items. Acoustic emission tests are performed on both new and in-service equipment. Typical uses include the detection of cracks, corrosion, weld defects and material embrittlement.

Procedures for AE structural testing have been published by The American Society of Mechanical Engineers (ASME), the American Society for Testing and Materials (ASTM) and other organizations. Successful structural testing comes about when the capabilities and benefits of AE inspection are correctly identified in the context of overall inspection needs and when the correct techniques and instruments are used in developing and performing the test procedure (Ref 9).

Acoustic emission equipment is highly sensitive to any kind of movement in its operating frequency range (typically 20 to 1200 kHz). The equipment can detect not only crack growth and material deformation, but also such processes as solidification, friction, impact, flow and phase transformations. Therefore, AE techniques are also valuable for:

- In-process weld monitoring (Ref 10)
- Detecting tool touch and tool wear during automatic machining (Ref 10)
- Detecting wear and loss of lubrication in rotating equipment (Ref 10) and tribological studies (Ref 11)
- Detecting loose parts and loose particles (Ref 12)
- Detecting and monitoring leaks, cavitation and flow (Ref 12, 13)
- Monitoring chemical reactions, including corrosion processes (Ref 14), liquid-solid transformations and phase transformations (Ref 14)

When these same processes of impact, friction, flow, and so on, occur during a typical AE inspection for cracks or corrosion, they constitute a source of unwanted noise. Many techniques have been developed for eliminating or

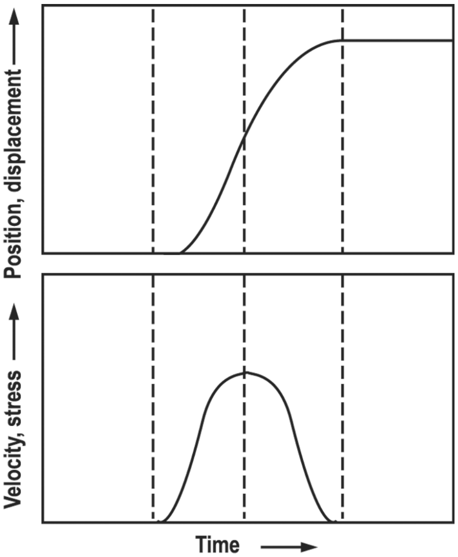


Figure 2: Primitive AE wave released at a source. The primitive wave is essentially a stress pulse corresponding to a permanent displacement of the material.

discriminating against these and other noise sources. Noise has always been a potential barrier to AE applicability. This barrier is constantly being explored and pushed outward, bringing previously impractical projects into the realm of feasibility.

Acoustic Emission Waves and Propagation

The primitive wave released at the AE source is illustrated in Figure 2. The displacement waveform is basically a steplike function corresponding to the permanent change associated with the source process. The corresponding velocity and stress waveforms are basically pulselike. The width and height of the primitive pulse depend on the dynamics of the source process. Source processes, such as microscopic crack jumps and precipitate fractures, are often completed in a few microseconds or fractions of a microsecond, so the primitive pulse has a correspondingly short duration. The amplitude and energy of the primitive pulse vary over an enormous range from submicroscopic dislocation movements to gross crack jumps. The primitive wave radiates from the source in all directions, often having a strong directionality depending on the nature of the source process, as shown in Figure 3. Rapid movement is necessary if a significant amount of the elastic energy liberated during deformation is to appear as an acoustic emission.

The form of the primitive wave is profoundly changed during propagation through the medium, and the signal emerging from the sensor has little resemblance to the original pulse. This transformation of the AE waveform is important, both to the researcher interested in source function analysis and to the practical NDT inspector interested in testing structures. The researcher who wants to determine the original source waveform uses broadband sensors and performs a detailed analysis of the early part of

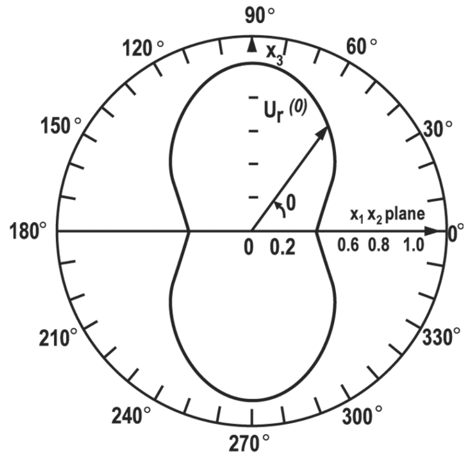


Figure 3: Angular dependence of acoustic emission radiated from a growing microcrack. Most of the energy is directed in the 90 and 270° directions, perpendicular to the crack surfaces.

the received signal. This is an important but very demanding line of inquiry. It may take an hour of computer time to process a single waveform. Most materials-oriented researchers, along with NDT inspectors, are interested in broader statistical features of the AE activity and do not need to know the precise details of each source event. They use narrowband sensors and electronic equipment that measures only a few features of the received waveform but is able to process hundreds of signals per second. The salient wave propagation factors are different for these two lines of work, as discussed below.

Factors in Source Function Analysis. The relationship between the source pulse and the resulting movement at the point of detection has been intensively studied during the last 10 to 15 years. Research groups at the NDT Centre at Harwell, UK (Ref 15), the National Bureau of Standards (Ref 16), Cornell University (Ref 17), and the University of Tokyo (Ref 18) have led the attack on this surprisingly difficult problem. A long-term goal of these studies has been to learn how to calculate a description of the source event from observation of the output of a distant sensor.

The difficulty of the problem is indicated in Figure 4, which shows the vertical component of the surface movement at point B, resulting from the abrupt application of a vertical force at point A on a semi-infinite body. Even with this simple geometry and source function, the resulting waveform is quite complicated. In the case of a plate, it is more complicated yet, because the second surface also plays its role in the elastodynamics of the wave propagation process. In plates, the motion at the point of detection depends strongly on the ratio of source distance to plate thickness.

In addition, the source function is not instantaneous, it will in fact be a force dipole and/or double couple rather than a point force, its orientation is in general unknown, and horizontal as well as vertical components of motion need to be considered. With these complications, it has understandably taken many years of effort to de-

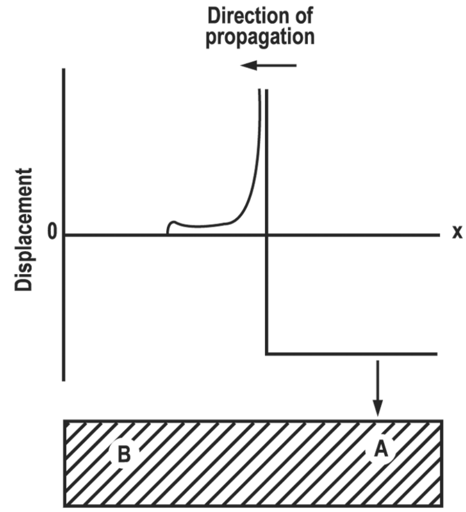


Figure 4: Displacement waveform produced by an abrupt application of a downward force at point A. The waveform can be viewed as either a "snapshot" of surface displacement (in which case *x* = position) or as a graph of the displacement at point B as a function of time (*x* = time).

velop mathematical theory, computational tools, and experimental techniques equal to the task of calculating the source function.

In recent years, the leading laboratories have attained the ability to quantify crack growth increments, orientations and time characteristics in some of the simpler specimen geometries ordinarily encountered (Ref 19). High-fidelity sensors must be used, and the analysis involves only the first part of the AE waveform, which is recorded in full detail with a high-performance transient recorder. This effort in the characterization of the source pulse has been one of the leading areas of AE research, and it can be expected eventually to yield returns in applied NDT.

Factors in Source Location and Typical AE Measurements. Whereas source function analysis utilizes only the first part of the AE waveform, mainstream AE technology accepts the waveform in its entirety. The later part of this waveform is made up of many components reaching the sensor by a variety of paths. Figure 5 illustrates this principle, but shows only a few of the indefinitely large number of possible paths by which the wave can reach the sensor. Typically, the highest peak in the waveform is produced, not by the first component, but by the constructive interference of several of the later components. The AE wave bounces around the testpiece, repeatedly exciting the sensor until it finally decays away. This decay process may

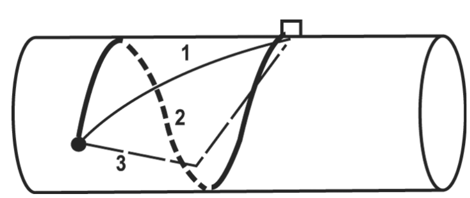


Figure 5: Three possible paths from source to sensor in a water-filled pipe. 1, direct path; 2, spiral path; 3, waterborne path

take 100 m s in a highly damped, nonmetallic material or tens of milliseconds in a lightly damped, metallic material-much longer than the source event, which is usually finished in a few microseconds or less.

It is important to understand that the shape of the received waveform is fundamentally the result of these wave propagation processes. Other important aspects of wave propagation in typical AE testing are attenuation and wave velocity. Attenuation is the loss of signal amplitude due to geometric factors and material damping as the wave travels through the material (Ref 20). Attenuation governs detectability at a distance and is therefore an important factor in choosing sensor positions and spacing. Acoustic emission procedures typically call for attenuation measurements to be made before a test and specify permissible sensor spacing based on these measurements.

Wave velocity is an additional factor to be considered when AE technology is used for source location. Source location is an important technique that is widely used both in laboratory studies and in structural testing. It is particularly significant in testing large structures, for which AE inspection is used to identify active regions for conclusive follow-up inspection with other NDT methods. Large cost savings have been realized through this combination of global AE inspection and focused inspection by other methods.

There are several strategies for source location. Zone location places the source within a broad area. Point location places the source precisely, by calculating from the relative arrival times of the AE wave at several sensors. Wave velocity is involved in these calculations. The attainable accuracy is governed by wave propagation processes and depends on such factors as geometry, plate thickness, and contained fluids. In effect, these factors render the wave velocity uncertain and this leads to errors in source location. In favorable cases, the attainable accuracy is better than 1% of the sensor spacing; in unfavorable cases, worse than 10%. The wave propagation effects underlying these variations are reviewed in Ref 20.

Acoustic Emission Sensors and Preamplifiers*

The key element in an AE resonant sensor is a piezoelectric crystal (transducer) that converts movement into an electrical voltage. The crystal is housed in a suitable enclosure with a wear plate and a connector, as shown in Fig. 6. The sensor is excited by the stress waves impinging on its face, and it delivers an electrical signal to a nearby preamplifier and then to the main signal-processing equipment. The preamplifier can be miniaturized and housed inside the sensor enclosure, facilitating setup and reducing vulnerability to electromagnetic noise.

Sensor Response. One of the most sought-after properties in an AE sensor is high sensitivity. Although high-fidelity, flat frequency response sensors are available, most practical AE testing employs resonant-type sensors that are more sensitive, as well as less costly, than the fiat frequency response type. These sensors have one or more preferred frequencies of oscillation, governed by crystal size and shape. These preferred frequencies actually dominate the waveform and spectrum of the observed signal in typical AE testing.

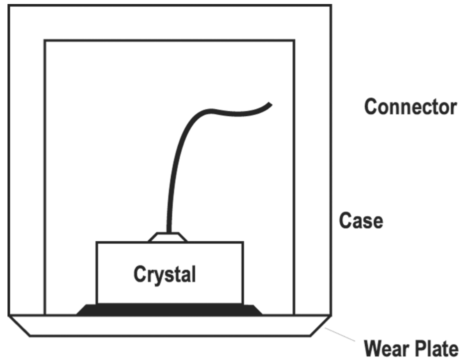


Figure 6: Typical construction of an AE resonant sensor

The sensitivity calibration of AE sensors was the subject of a substantial developmental program at the National Bureau of Standards (NBS) through the late 1970s. This program has led to the routine availability of NBS-traceable plots showing the absolute sensitivity of AE sensors in volts per unit velocity as a function of frequency (Ref 21).

Acoustic Emission Waveform Transformation. In addition to the wave propagation factors discussed earlier, the transformation of a single AE waveform is further compounded by the sensor response. When a resonant sensor is excited by a broadband transient pulse, it rings like a bell at its own natural frequencies of oscillation. Therefore, the electrical signal at the sensor output is the product of this ringing, thus compounding the effects of multiple paths and multiple wave modes by which the wave travels from source to sensor. A typical AE signal from a piezoelectric sensor is shown in Fig. 7; the radical difference between this observed signal and the simple waveform at the source (Fig. 2) cannot be overemphasized.

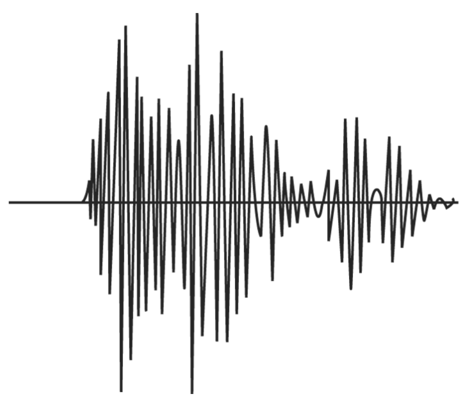


Figure 7: Typical AE burst-Type waveform recorded from a flat-bottom storage tank with a transient recorder

Frequency Response. By selecting a resonant sensor from the wide range available, one can effectively choose the monitoring frequency. This is a useful feature that allows the inspector to make a suitable trade-off between the desired detection range and the prevailing noise environment. In practice, the vast majority of AE testing is well performed with sensors that are resonant at about 150 kHz.

Preamplifier Response. The signals generated by the sensor are amplified to provide a higher, more usable voltage. This is accomplished with a preamplifier, which is placed close to (or even inside) the sensor so as to minimize pickup of electromagnetic interference. The preamplifier has a wide dynamic range and can drive the signal over a long length of cable so that the main instrumentation can be placed hundreds of meters from the testpiece if necessary.

The preamplifier typically provides a gain of 100 (40 dB) and includes a high-pass or bandpass filter to eliminate the mechanical and acoustical background noise that prevails at low frequencies. The most common bandpass is 100 to 300 kHz, encompassing the 150 kHz resonant frequency of the most commonly used sensor. Other operating frequencies can be used, but there are limitations. At lower frequencies, there are increasing problems with mechanical background noise. At higher frequencies, the wave attenuates (damps out) more rapidly, and the detection range of the sensor will be smaller. Choice of operating frequency is therefore a trade-off between noise and detection range. Lower frequencies are used on pipelines, where detection range is at a premium, and in geological work because rocks and soils are highly attenuating. Higher frequencies are used to test steam lines in electricity generating stations, where background noise is unusually high.

Attainable Sensitivity. Preamplifiers inevitably generate electronic noise, and it is this noise that sets the ultimate limit to the smallest movement detectable with AE equipment. The smallest signal that can be detected is about 10 mV at the transducer output, corresponding to a surface displacement of about 25 pm (1 x 10^{-6} min.) for a typical high-sensitivity sensor. This sensitivity is more than enough for most practical NDT applications.

Installation. Typically, the sensor is coupled to the testpiece with a fluid couplant and is secured with tape, an adhesive bond, or a magnetic hold-down device. In some applications, however, the AE sensor may be mounted on a waveguide, as in Example 1.

After the sensor is installed and connected to the monitoring equipment, system performance is checked by "lead break" before monitoring begins. This involves the breaking of a lead pencil near the sensor to verify the response from an acoustic signal. Properly performed, the lead break delivers a remarkably reproducible signal that closely matches the "point impulse loading" source discussed above (see the section "Factors in Source Function Analysis” in this article).

Example 1: Acoustic Waveguide Sensors Used in Monitoring the Cooling of Molten Vitrified Nuclear Waste. Acoustic emission monitoring was used to help correlate cracking in vitrified high-level waste with cooling procedures. There was a need for a method capable of performing in an environment consisting of approximately 900° C (1650° F) temperatures and 500 Gy/h (50 000 rad/h) gamma radiation for the continuous monitoring of vitrified waste in canisters during cooling to detect glass cracking. Waveguide sensors about 4.6 m (15 ft) long were used; one end was submerged in the glass, and a sensing crystal and preamplifier were positioned on the other end. The signal from the sensor was passed through coaxial cables to the outside of the hot cell, where it was received by an AE monitor system for analysis. At the end of the testing, the AE sensors had been in the environment for 120 days, and the accumulated dose of gamma radiation had reached 14×10^5 Gy (14×10^7 rad). The sensors were still functioning properly.

Instrumentation Principles

During an AE test, the sensors on the testpiece produce any number of transient signals. A signal from a single, discrete deformation event is known as a burst-type signal This type of signal has a fast rise time and a slower decay, as illustrated in Fig. 7. Burst-type signals vary widely in shape, size, and rate of occurrence, depending on the structure and the test conditions. If there is a high rate of occurrence, the individual burst-type signals combine to form a continuous emission. In some cases, AE inspection relies on the detection of continuous emission (see the sections “Mechanisms of AE Sources” and “Leak Testing” in this article).

The instrumentation of an AE inspection provides the necessary detection of continuous emissions or detectable burst-type emissions. Typically, AE instrumentation must fulfill several other requirements:

- The instrumentation must provide some measure of the total quantity of detected emission for correlation with time and/or load and for assessment of the condition of the testpiece
- The system usually needs to provide some statistical information on the detected AE signals for more detailed diagnosis of source mechanisms or for assessing the significance of the detected signals
- Many systems can locate the source of detectable burst-type emissions by comparing the arrival times of the wave at different sensors. This is an important capability of great value in testing both large and small structures
- The systems should provide a means for discriminating between signals of interest and noise signals from background noise sources such as friction, impact, and electromagnetic interference

Instruments vary widely in form, function, and price. Some are designed to function automatically in automated production environments. Others are designed to perform comprehensive data acquisition and extensive analysis at the hands of skilled researchers. Still others are designed for use by technicians and NDT inspectors performing routine tests defined by ASME codes or ASTM standards.

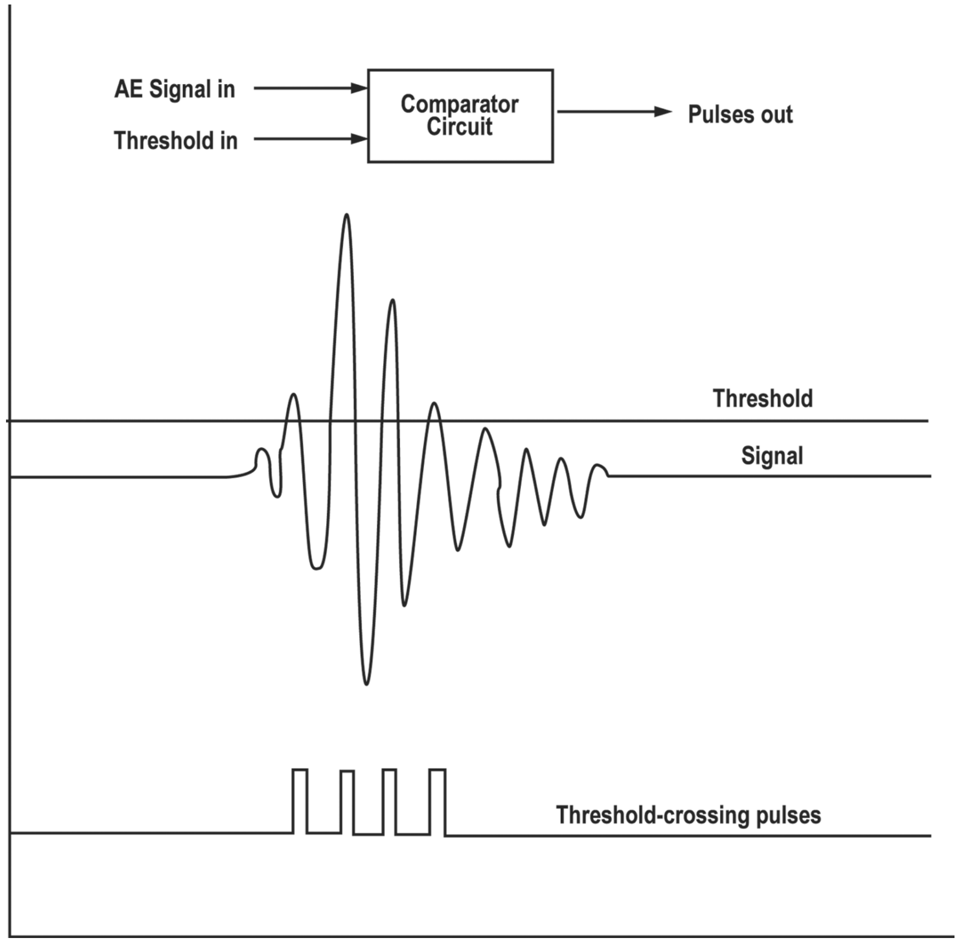


Figure 8: Principle of AE signal detection and threshold-crossing counts

Signal Detection and Emission Counts. After sensing and preamplification, the signal is transmitted to the main instrument, where it is further amplified and filtered. Next is the critical step of detecting the signal. This is accomplished with a comparator circuit, which generates a digital output pulse whenever the AE signal exceeds a fixed threshold voltage. The relationship between signal, threshold, and threshold-crossing pulses is shown in Fig. 8. The threshold level is usually set by the operator; this is a key variable that determines test sensitivity. Depending on instrument design, sensitivity may also be controlled by adjusting the amplifier gain.

One of the oldest and simplest ways to quantify AE activity is to count the threshold crossing pulses generated by the comparator (Fig. 8). These acoustic emission counts are plotted as a function of time or load, either as an accumulating total or in the form of a count rate histogram. The all-hardware AE systems of the early 1970s could draw these count and count rate displays on *x-y* recorders as the test proceeded, and much of the early AE literature presents results in this form. Figure 9, a typical plot of this type, shows cumulative counts as a function of applied load during a rising-load test on a precracked specimen of high-strength steel. The vertical scale is 10 000 counts full-scale. The vertical steps on the first parts of the plot are individual AE events. The larger events score several hundred counts each. By 35 kN (8000 lbf), 10 000 counts have been accumulated. The pen resets to the bottom of the graph, and resumes plotting. As

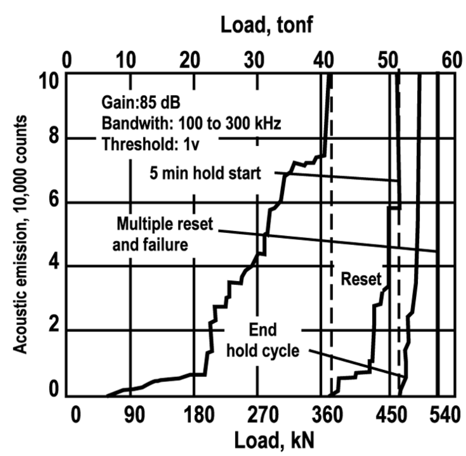


Figure 9: Acoustic emission from a welded three-point bend specimen of 12% Ni maraging steel. Steps in the curve are discrete, burst-type emissions caused by plastic zone growth and later, crack front movement.

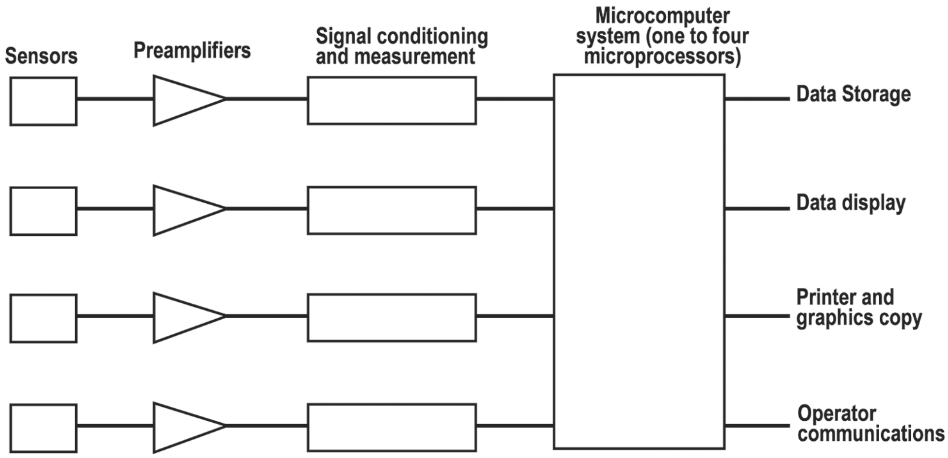


Figure 10: Generic block diagram of a four-channel acoustic emission system

the load rises, the AE rate increases, and the individual events are no longer discernible on the plot. As the specimen approaches failure, there are multiple resets of the pen corresponding to the generation of hundreds of thousands of AE counts.

Hit-Driven AE Systems. All-hardware systems reached an apex of development in the late 1970s, but they were eventually superseded by computer-based systems. The development of AE technology coincided with the development of computers, and computers were probably used earlier for AE inspection than for any other NDT method. Computers were first used for AE multichannel source location systems around 1970. Although source location was the first task (and a very advanced one), computers soon came into use for the more general purposes of AE data storage, analysis, and display. At the same time, personnel involved in AE inspection became interested in other signal features of burst-type emissions beyond the threshold-crossing counts (see the section “Signal Measurement Parameters” in this article).

These trends led to a new principle of AE instrumentation that has dominated the technology ever since. This principle involves the measurement of key parameters of each hit, that is, each AE signal that crosses the threshold. A digital description of each hit is generated by the front-end hardware and is passed in sequence with other hit descriptions through a computer system, which provides data storage, a variety of graphical displays, and replay for posttest analysis.

A generic block diagram is shown in Fig. 10, and a typical modern system is shown in Fig. 11. The larger, multichannel systems divide the data-processing tasks among many microprocessors. In the system shown in Fig. 11, for example, a separate microprocessor serves each pair of signal measurement channels. The highest priority for this microprocessor is to read the results of each signal measurement as soon as the measurement process is completed, so that the measurement circuitry can be reset for the next event. The front-end microprocessor can rapidly store several hundred hit descriptions in its buffer, pending further processing. With this parallel processing architecture, added channels will automatically bring added data processing power. With the front-end buffers supplemented by other, even larger buffers in the later stages of the microcomputer network, the system has the versatility to absorb sudden surges of AE activity and to handle widely varying data rates in an optimum manner (Ref 22).

Signal Measurement Parameters. The five most widely used signal measurement parameters are counts (Fig. 8), amplitude, duration, rise time, and the measured area under the rectified signal envelope (MARSE) (Fig. 12). Some tests make do with fewer parameters, and some tests use others, such as true energy, counts-to-peak, average frequency, or spectral moment.

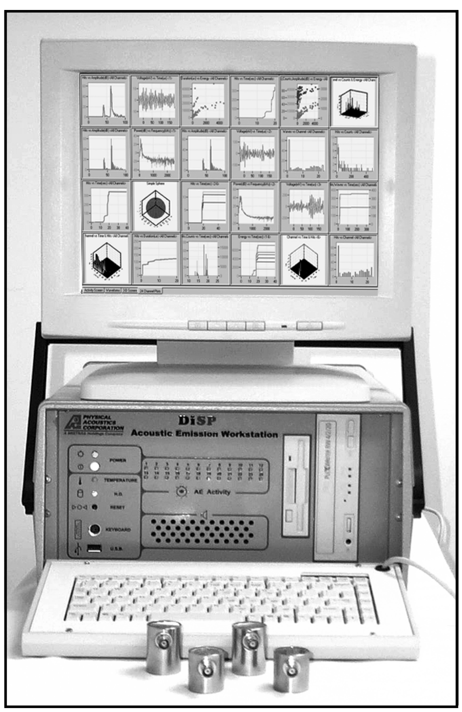


Figure 11: Typical general purpose AE intstrument - a 24-channel data acquisition system with computer for data display, storage, and analysis. Courtesy of Physical Acoustics Corporation

However, the five principal parameters have become well standardized and accepted through the market processes of the last 10 years.

Along with these signal parameters, the hit description passed to the computer typically includes important external variables, such as the time of detection, the current value of the applied load, the cycle count (if it is a cyclic fatigue test), and the current level of continuous background noise. The length of the total hit description is usually between 20 and 40 bytes.

Amplitude, A, is the highest peak voltage attained by an AE waveform. This is a very important parameter because it directly determines the detectability of the AE event. Acoustic emission amplitudes are directly related to the magnitude of the source event, and they vary over an extremely wide range from microvolts to volts. Of all the conventionally measured parameters, amplitude is the one best suited to developing statistical information in the form of distribution functions (Ref 23). The amplitudes of acoustic emissions are customarily expressed on a decibel (logarithmic) scale, in which 1 mV at the transducer is defined as 0dBae, 10 mV is 20dBae, 100 mV is 40dBae, and so on.

Counts, N, are the threshold-crossing pulses (sometimes called ringdown counts) discussed above. This is one of the oldest and easiest ways of quantifying the AE signal. Counts depend on the magnitude of the source event, but they also depend strongly on the acoustic properties and reverberant nature of the specimen and the sensor.

MARSE, sometimes known as energy counts, *E,* is the measured area under the rectified signal envelope. As a measure of the AE signal magnitude, this quantity has gained acceptance and is replacing counts for many purposes, even though the required circuitry is relatively complex. MARSE is preferred over counts because it is sensitive to amplitude as well as duration, and it is less dependent on threshold setting and operating frequency. Total AE activity must often be measured by summing the magnitudes of all the detected events; of all the measured parameters, MARSE is the one best suited to this purpose.

Duration, D, is the elapsed time from the first threshold crossing to the last. Directly measured in microseconds, this parameter depends on source magnitude, structural acoustics, and reverberation in much the same way as counts. It is valuable for recognizing certain long-duration source processes such as delamination in composite materials (Ref 24), and it can be useful for noise filtering and other types of signal qualification.

Rise time, R, is the elapsed time from the first threshold crossing to the signal peak. Governed by wave propagation processes between source and sensor, this parameter can be used for several types of signal qualification and noise rejection.

Multichannel Considerations. Measure-

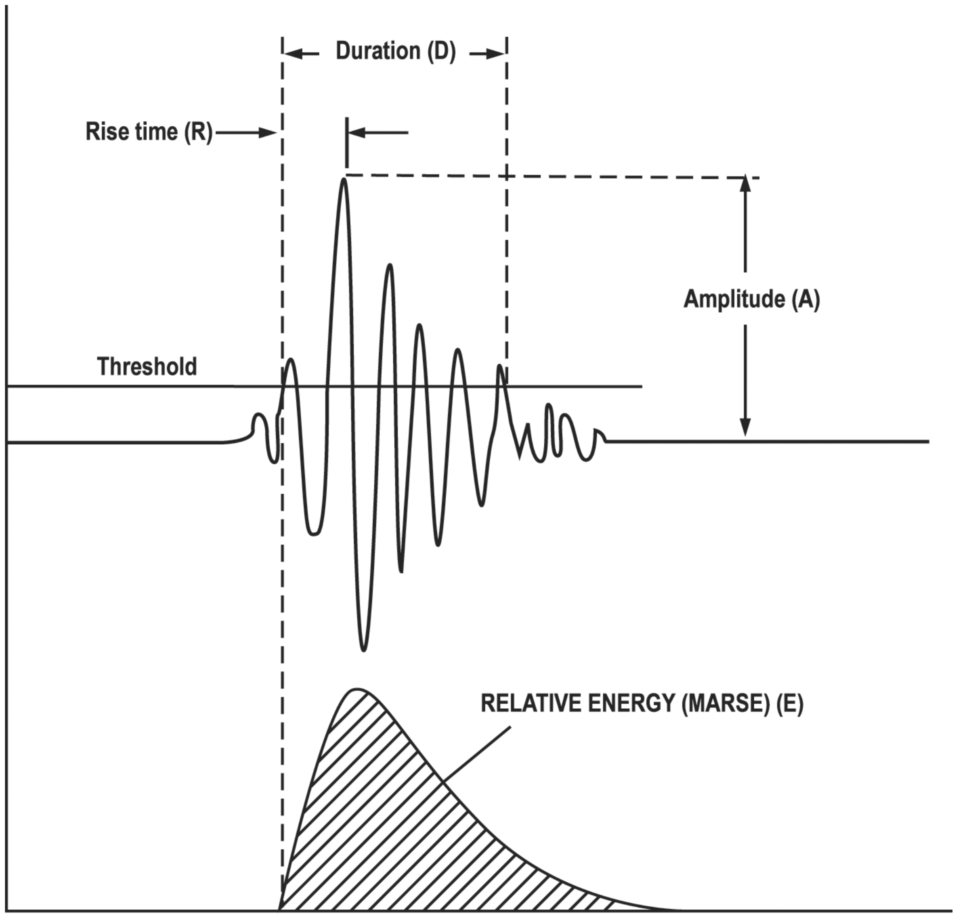


Figure 12: Commonly measured parameters of a burst-type acoustic emission signal

ment of the signal proceeds simultaneously on every channel that detects (is hit by) the AE wave. Acoustic emission systems are available in sizes from 1 channel to over 100 channels, depending on the size and complexity of the structure to be tested. Typical laboratory systems have 2 to 6 channels, while most structural tests are accomplished with 12 to 32 channels.

An individual AE event may hit just one channel or it may hit many channels, depending on the strength of the event, the wave attenuation in the structure, and the sensor spacing. Therefore, an early task for the multichannel system is to determine whether a group of closely spaced hits on different channels is from the same source event. Depending on the system design, this can be accomplished either in hardware or in software. The second, third, and later hits from a source event can be either retained for the purposes of source location or discarded to keep the data clean and simple. After this task of event/hit identification has been performed, the system can deal in event descriptions as well as hit descriptions. The event description usually includes channel identification and relative timing information for all the channels involved, along with the signal characteristics of the first hit and perhaps the other hits as well.

The stream of hit (or event) descriptions is passed through a central processor that coordinates the tasks of data storage, display, and operator communications. In larger systems, these tasks can be divided among several processors. In many systems, the entire stream of hit descriptions is stored to disk; this provides unlimited posttest analysis capability. Full data storage is a vital aspect of applied AE technology. It reduces dependence on the on-site operator for ultimate test results, allowing him to concentrate on the vital task of correct data collection (Ref 11).

Data Displays. A software-based, hit-driven AE system can produce many types of graphic displays. The operator is not limited to what can be observed during the test, because the results can be refined, filtered, and redisplayed in any manner during the posttest analysis.

Broadly, AE data displays can be classed as:

- History plots that show the course of the test from start to finish
- Distribution functions that show statistical properties of the emission
- Channel plots showing the distribution of detected emissions by channel
- Location displays that show the position of the AE source
- Point plots showing the correlation between different AE parameters
- Diagnostic plots showing the severity of AE indications from different parts of the structure

Some of these generic display types are illustrated in Fig. 13.

Figures 13(a) and (b) show history plots of AE data versus time in cumulative and rate form, respectively. A cumulative plot is the more convenient format for reading off a total emission quantity, while a rate plot highlights the changes in activity that occur during the test.

Figure 13(c) is a history plot of AE data versus load. This is the most fundamental plot because it directly relates cause to effect. This type of plot is especially useful for separating good parts from bad; bad parts characteristically begin to emit at lower loads and give more emission than good parts at all load levels. This basic plot of AE data versus load is also the best way to display the Kaiser and Felicity effects, as shown in Fig. 14.

Figures 13(d) and (e) show the cumulative and differential forms, respectively, of the amplitude distribution function. The x-axis shows amplitude, and the y-axis shows how many hits had that amplitude (differential form) or exceeded it (cumulative form). The differential amplitude distribution (Fig. 13e) is useful for distinguishing between deformation mechanisms and for observing changes in AE intensity as the test proceeds. The cumulative form (Fig. 13d) is more useful for quantitative modeling and for assessing how the detectability of AE will be affected by changes in test sensitivity. The amplitude distribution is a standard AE display, and the underlying theory is well developed (Ref 23). Distribution functions using the other signal measurement parameters are also employed for special purposes.

Figure 13(f) is a planar source location display. This display is basically a map of the structure, with the computed location of each emission event shown as a single point in the appropriate position. Sensor locations are shown as large dots, providing a reference frame. The eye is drawn to clusters of located events, which correspond to the most active sources, typically structurally significant defects.

Figure 13(g) is a point plot of counts (or duration) versus amplitude. Each hit is shown as one point on the display, and its position shows information about the size and shape of the waveform. This type of display is used for data quality evaluation, specifically for identifying some commonly encountered types of unwanted noise (Ref 25). Acoustic emission signals from impulsive sources typically form a diagonal band running across this display. Noise signals from electromagnetic interference fall below the main band (circled area, lower right, Fig. 13g) because they are not prolonged by acoustic reverberation. Noise signals from friction and leaks fall above the main band (circled area, upper left, Fig. 13g) because the source process is extended in time, not a short impulse. This is only one of the many point plots that have proved useful in practical AE testing.

The typical software-based system can generate many displays simultaneously in memory while the test is running, presenting them to the

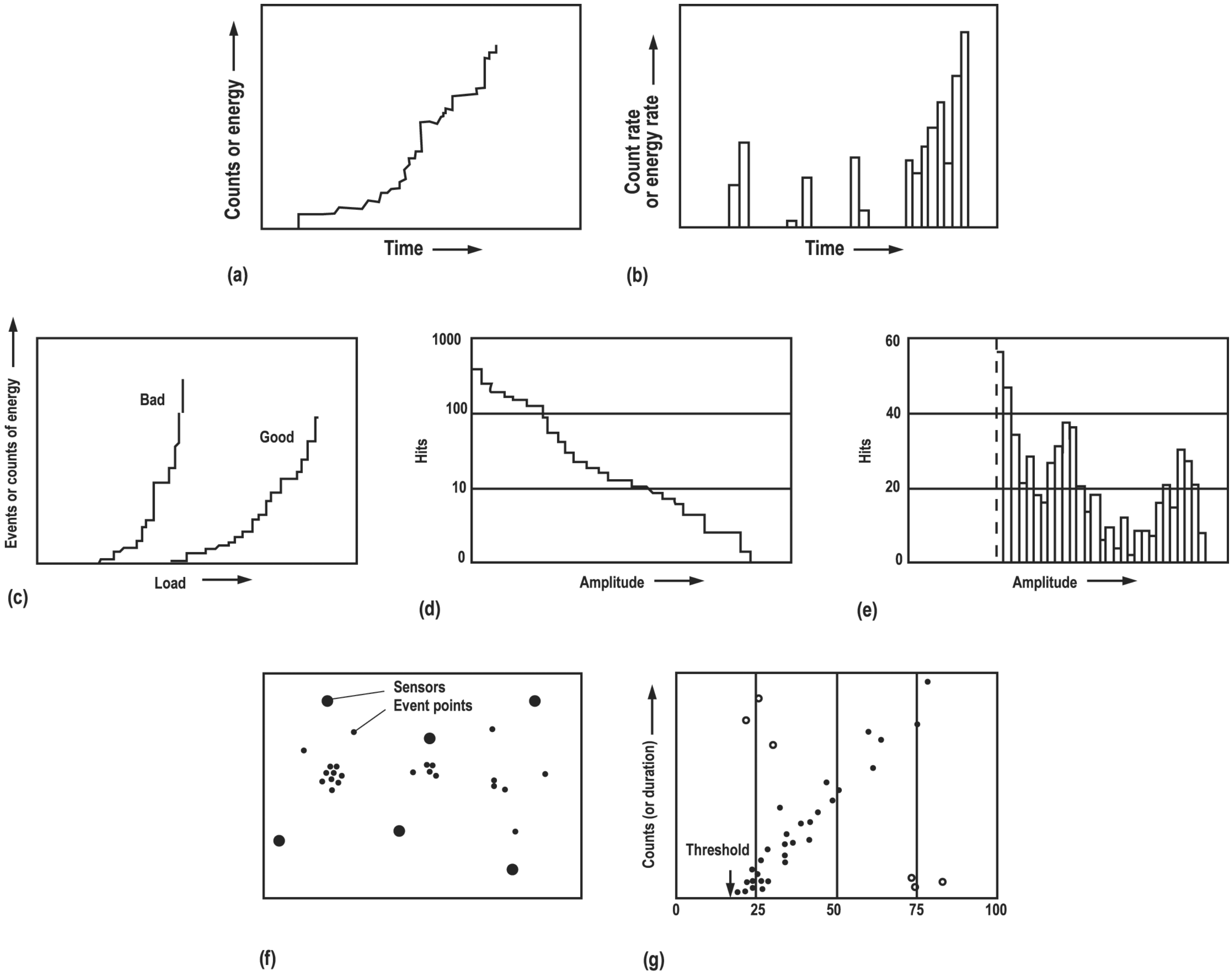


Figure 13: Typical AE data displays. (a) History plot of the cumulative count or energy. (b) History plot of the count rate or energy rate. (c) History plot of AE data versus load. (d) Cumulative amplitude distribution showing the number of hits that exceeded an amplitude. (e) Differential amplitude distribution showing the number of hits of a particular amplitude. (f) Planar source location display. (g) Point plot of counts (or duration) versus amplitude

operator upon demand. In addition to these graphic displays, the system may present tabulated data and/or listings of the individual event or hit descriptions.

Special-Purpose AE Systems. The software-based, hit-driven AE system has the architecture of choice for application development and general-purpose laboratory and structural testing, but not all AE systems require this kind of computational power and versatility of display. Once the needs of the test have been defined, simpler equipment is often appropriate for routine application.

Production testing can often be done with a basic, all-hardware instrument that simply measures counts or energy and trips an alarm when the emission exceeds a predetermined quantity. Automatic self-checking for good sensor contact can be incorporated into the function of such an instrument.

Resistance weld monitoring and feedback control is accomplished with all-hardware systems that have special gates, timers, and interfaces to synchronize the AE monitoring with the operation of the weld controller. Other types of weld monitoring instruments incorporate pattern-recognition algorithms for automatically recognizing and classifying specific kinds of weld defects.

Leak testing is a major and relatively simple application of AE instrumentation (see the section "Structural Test Applications" in this article). Leak testing can be performed with instruments that measure only the root mean square (rms) voltage of the continuous emission from a leak. Sometimes, detect ability is enhanced by the occurrence of burst-type signals from particle impact or structural degradation of the local material. Small size is a major advantage when the instrument has to be carried around an industrial complex or power generating plant.

Specific Applications. Instrument manufacturers have also developed special instruments for specific, well-established applications, such as bucket truck testing and tank car testing. These instruments are based on the applicable codes or standard procedures for performing the test. Simplification of hardware and software leads to a lower-cost instrument. Customized software provides more positive guidance and fewer operator choices, so that a lower level of skill can be used on-site and the test can be performed reliably and economically.

Noise

Precautions against interfering noise are an integral part of AE technology. Enormous progress has been made since the early days when students worked at night, using specially constructed loading machines in underground laboratories to avoid disruption of their experiments by street traffic and people moving nearby. With current technology, many tests can be performed without special measures, and a wide range of techniques have been developed to make AE inspection applicable in extremely noisy environments.

A basic starting point is the selection of an appropriate frequency range for AE monitoring. The acoustic noise background is highest at low frequencies. The 100 to 300 kHz range has proved suitable for perhaps 90% of all AE testing. In noisy environments (an electric power plant, for example), higher frequencies, such as 500 kHz, have been necessary to reduce the noise detected from fluid flow. Because higher frequencies bring reduced detection range, there is an inherent trade-off between detection range and noise elimination.

Acoustic noise sources include fluid flow in pumps and valves, friction processes such as the movement of structures on their supports, and impact processes such as rain and windblown cables striking the structure. Electrical and electromagnetic noise sources include ground loops, power switching circuits, radio and navigation transmitters, and electrical storms.

Noise problems can be addressed in many ways. First, it may be possible to stop the noise at the source. Second, it may be possible to eliminate an acoustic source by applying impedance-mismatch barriers or damping materials at strategic points on the structure. Electrical noise problems, which are often the result of poor grounding and shielding practices, can be eliminated by proper technique or by using differential sensors or sensors with built-in preamplifiers. If these measures are inadequate, the problem must be dealt with by hardware or software in the AE instrument itself.

Sensitivity adjustments, including floating-threshold techniques, can be very effective as long as they do not also cause the loss of essential AE data. Methods for selective acceptance and recording of data based on time, load, or spatial origin are well developed. Beyond this, because noise sources often give characteristically different waveforms, they can often be separated from true acoustic emissions by computer inspection of the measured signal characteristics (Ref 25). This can be accomplished immediately after measurement (front-end filtering), during the display process (graphical filtering), or after the test by playing the data through a posttest filtering program or advanced waveform analysis package.

Through the development and application of these techniques, AE inspection has been brought into service in increasingly demanding environments, and this trend is expected to continue. Examples of difficult applications in which noise elimination was key to the successful use of AE inspection include the on-line monitoring of welding (Ref 1, 26) and the detection of fatigue crack growth in flying aircraft (Ref 7).

Load Control and Repeated Loadings

Because acoustic emission is produced by stress-induced deformation of the material, it is highly dependent on the stress history of the structure. Emission/stress/ time relationships also depend on the material and on the type of deformation producing the emission. Some materials respond almost instantly to applied stress, emitting and then quickly stabilizing. Other materials take some time to settle down after a load is applied; this is readily observed in materials that show viscoelastic properties, such as resin-matrix composites. In other cases, a constant load may produce ongoing damage, and the structure may never stabilize. An example of this is hydrogen-induced cracking, which may proceed under constant load to failure, with continual emission.

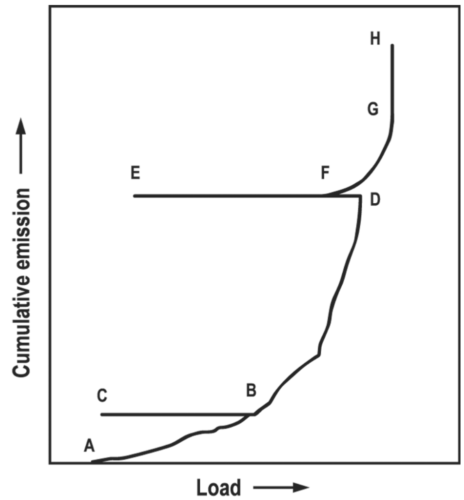


Figure 14: Basic AE history plot showing Kaiser effect (BCB), Felicity effect (DEF), and emission during hold (GH)

Acoustic emission testing is often carried out under conditions of rising load. The first load application will typically produce much more emission than subsequent loadings. In fact, for instantaneously plastic materials, subsequent loadings should produce no emissions at all until the previous maximum load is exceeded. This behavior was first reported by Kaiser in 1950 (Ref 27) and has been a leading influence in the development of AE test methodology. Dunegan (Ref 28) showed that for materials that obey the Kaiser effect, emission on a repeat loading will indicate that structural damage occurred between the first loading and the repeat. This became the conceptual basis of much of the AE testing of the 1970s, when the first AE field test organizations undertook periodic inspection of pressure vessels and other structures.

Recent test strategies pay much attention to emission that occurs at loads below the previous maximum and to emission that continues when the load is held at a constant level. The evidence is that structurally significant defects will tend to exhibit these behaviors, while emission related to stabilization of the structure, such as the relief of residual stress, will tend not to recur when the structure is loaded again.

Figure 14 is a generic illustration of these contrasting behaviors. Emission is observed upon initial loading from A to B, but not upon unloading (B to C). Upon reapplying the load, there is no emission (line is horizontal) until B is reached again; this is the Kaiser effect. The load is increased to D, with more emission, and another unload-reload cycle is applied. This time, because of the higher stress levels, significant defects begin to emit at point F, below the previous maximum load. This behavior is known as the Felicity effect. It can be quantified with the Felicity Ratio (FR):

$$\text{FR} = \frac{\text{Load at which emission begins again}}{\text{Previous maximum load}}$$

Technically, the Kaiser effect can be construed as a Felicity Ratio of 1.0 or greater. Systematic decreases in the Felicity Ratio as material approaches failure have been well documented for fiber-reinforced plastics (Ref 29) and a Felicity Ratio less than 0.95 is cause for rejection of an FRP tank or pressure vessel tested by AE inspection according to ASME Article II (Ref 30). Under ASME Article 12 (Ref 3l) for the AE testing of metal pressure vessels, it is in some cases admissible to ignore AE data from the first loading of a vessel and to consider only AE data from a second loading. The basis for this is that much emission on the first loading comes from local yielding (structurally insignificant), while only the significant defects will emit on the second loading (Felicity Ratio < I).

Figure 14 also illustrates the graphical appearance of emission continuing during a load-hold period (G to H). The Felicity effect and the occurrence of emission during load holds may share a common underlying explanation; both are associated with the unstable nature of structurally significant defects. Emission during load holds has been known since the early years of AE inspection (Ref 28) and was incorporated in FRP evaluation criteria in the mid 1970s. In the late 1980s, emission during hold has been made the entire basis of Monsanto's successful procedure for the AE testing of railroad tank cars (Ref 8). In this interesting development, data analysis is greatly simplified because the background noise sources present during rising load are much less obtrusive during the load-hold periods.

Careful attention must be paid to the loading schedule if AE testing is to be successful. Procedures for an AE test typically specify the loads that must be applied (relative to the working load or design load) and the upper and lower limits on the loading rate. Fiber-reinforced plastic tanks and vessels must be conditioned by a period at reduced load before the AE test is conducted (Ref 30). An AE test can be invalidated if the structure is inadvertently loaded beforehand to the AE test pressure. For success in dealing with these points, there must be good communication and coordination between the personnel loading the structure and those collecting the AE data.

Acoustic Emission in Materials Studies*

Acoustic emission is a remarkable tool for studying material deformation because the information it provides is both detailed and immediate. With its sensitivity to microstructure and its intimate connection with failure processes, AE inspection can give unique insights into the response of material to applied stress. Acoustic emission analysis is most useful when used in conjunction with other diagnostic techniques, such as stress-strain measurements, microscopy, crack-opening-displacement measurements and potential drop (for crack growth), or ultrasonic damping measurements (for dislocation studies). Acoustic emission complements these techniques and offers additional information on the dynamics of the underlying deformation processes, their interplay, and the transitions from one type of deformation to another.

Many materials studies involve the development of a test approach for eventual field application. Such work can be valuable, but it is subject to the difficulty of simulating defect emissivities and other field conditions in the laboratory. Laboratory tests are often done with simple uniaxial stresses applied parallel to the rolling direction, while materials in industrial service are often subjected to complex biaxial or triaxial stress fields. In such cases, the acoustic emissions from the laboratory tests will not be a good model of the acoustic emissions from materials in industrial service.

Mechanisms of AE Sources. Needless to say, acoustic emissions are not generated by the reversible, homogeneous alteration of interatomic spacings that constitutes elastic deformation. Acoustic emissions are only generated when some abrupt and permanent change takes place somewhere in the material. Mechanisms that produce acoustic emissions in metals include the movement and multiplication of dislocations; slip; twinning; fracture and debonding of precipitates, inclusions, and surface layers; some corrosion processes; microcrack formation and growth; small and large crack jumps; and frictional processes during crack closure and opening.

The amount of AE energy released depends primarily on the size and speed of the local deformation process. The formation and movement of a single dislocation does produce an AE stress wave, but it is not a large enough process to be detected in isolation. However, when millions of dislocations are forming and moving at the same time during yielding of a tensile specimen, the individual stress waves overlap and superimpose to give a detectable result. The result is a continuous excitation of the specimen and sensor that is detectable as soon as the voltage it produces becomes comparable with the background noise. The higher the strain rate and the larger the specimen, the larger this signal becomes. This so-called continuous emission is different from burst-type emission in that the individual source events are not discernible. Continuous emission

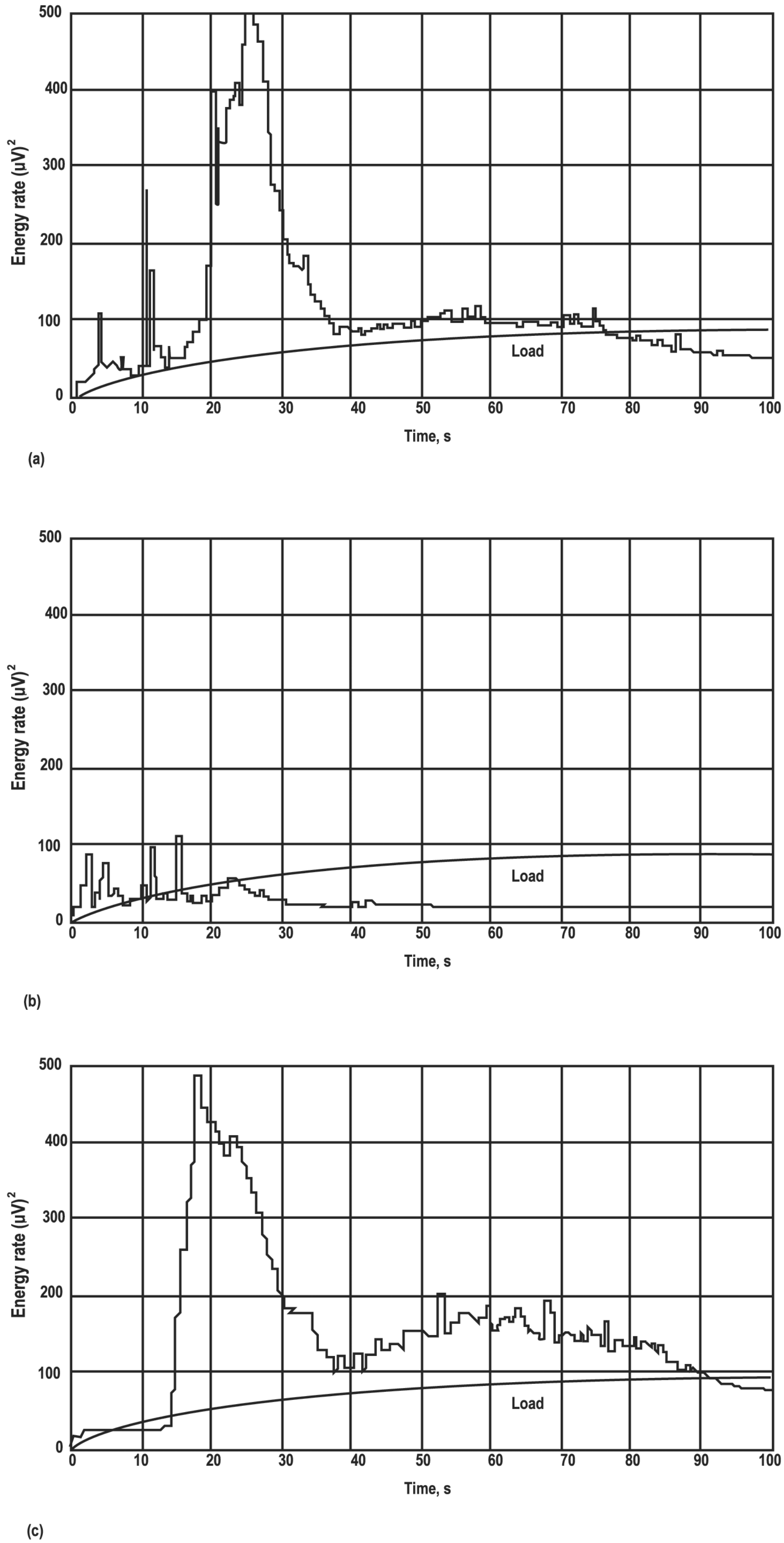


Figure 15: Acoustic emission energy rate (expressed as the mean square of sensor voltage) and load versus time. Optimum formability corresponds to the lowest emissivity in a deep-drawing steel subjected to spheroidization heat treatment. (a) Underannealed: 80% pearlite, 20% spheroids. (b) Optimally annealed: 100% spheroids. (c) Overannealed: 30% elongated spheroids and doglegs.

is best measured with rms or energy rate measuring circuitry.

Continuous emission from the plastic deformation of steels, aluminum alloys, and many other metals has been extensively studied, and there have been many detailed findings relating acoustic emissions to dislocation activity and precipitates, microstructure, and materials properties (Ref 32). Such studies can yield valuable insights for alloy and material development. Most studies have focused primarily on continuous emission during and after yield; burst-type emissions sometimes observed in the nominally elastic region are less well explained.

The following example illustrates the dependence of continuous emission on microstructure. The fracture of small-scale precipitates (in this case, pearlite lamellae) generates continuous emission, which can be related to the microstructure that results from heat treating.

Example 2: Relation of Acoustic Emissions With the Optimum Heat Treating of Ferritic/ Pearlitic Steel. Figure 15 illustrates the dependence of continuous acoustic emissions on the microstructure of a deep-drawing ferritic/pearlitic steel subjected to a spheroidizing heat treatment to improve its formability. Data are shown from representative underannealed, optimally annealed, and overannealed conditions. Figure 15 shows AE energy rate as a function of time from dog-bone tensile specimens pulled to failure in a screw-driven test machine. All the graphs display peaks around the yield region, a common feature in the high-sensitivity tensile testing of unflawed specimens. Figure 15 also shows a second, shallow peak at higher strain levels.

The interesting result is that the optimally annealed specimen shows a much smaller peak (gives much less emission) than the other two specimens. The explanation is found by carefully relating AE behavior to microstructural deformation processes. It is known that dislocations can pile up against pearlite lamellae during plastic deformation, eventually causing the lamellae to fracture. This fracture of pearlite lamellae is believed to be the cause of the first peaks in Fig. 15.

With the test material in the underannealed condition, microscopy reveals the presence of many untransformed pearlite lamellae that can intercept the moving dislocations, so the peak is high. With the test material in the optimally annealed condition, microscopy shows that virtually all the lamellae have been transformed to spheroids. These have a smaller cross-sectional area and present less of an obstacle to the moving dislocations, so deformation can proceed without breaking pearlite. Ductility is enhanced, and there is very little emission from this optimally annealed material.

With the test material in the overannealed condition, microscopy shows that additional carbon has come out of solution, growing the spheroids and forming doglegs at the grain boundaries. These larger particles interfere more strongly with dislocation motion and produce larger emissions when fractured, so the emission peak is strong again. It is an interesting result that the optimum material condition is the condition of lowest emissivity, suggesting that AE inspection could be used for inspection and quality control of this material as well as for research.

Acoustic emission from crack growth is of the greatest interest for practical NDT applications of the AE phenomenon. By virtue of the stress concentrations in their vicinity, cracks and other defects will emit during rising load, while unflawed material elsewhere is still silent. Acoustic emissions from crack initiation and growth have been extensively reported in the literature. Many of these reports deal with specialized forms of crack growth, such as fatigue, stress-corrosion cracking, and hydrogen embrittlement (Ref 33).

It is useful to distinguish between AE signals from the plastic zone at the crack tip and AE signals from movement of the crack front itself. Growth of the plastic zone typically produces many emissions of rather low amplitude. These emissions are typically ascribed to the fracture of precipitates and inclusions (for example, manganese sulfide stringers in steels), and the triaxial nature of the stress field is implicated in the emissivity of these sources.

Acoustic emissions from crack front movement depend critically on the nature of the crack growth process. Microscopically rapid mechanisms such as brittle intergranular fracture and transgranular cleavage are readily detectable, even when the crack front is only advancing one grain at a time at subcritical stress levels. Slow, continuous crack growth mechanisms such as microvoid coalescence (ductile tearing) and active path corrosion are not detectable in themselves, but if general yield has not occurred, they may be detectable through associated plastic zone growth. Quantitative theory, which explains why some processes are detectable and others are not, was developed by Wodley and Scruby (Ref 33). The possibility of silent crack growth in ductile materials caused much consternation when it was first recognized in laboratory conditions, but it has not been a deterrent in real-life NDT, in which emission from defects is characteristically enhanced by environmental embrittlement, emissive corrosion products, crack face friction, or emissive nonmetallic materials entrained in the defect during the fabrication process.

Many fracture mechanics models have been developed to relate acoustic emissions to crack growth parameters. An important early approach was to relate acoustic emissions to the plastic zone size with the hope of estimating directly the stress intensity factor at defects found in the field (Ref 34, 35). Other models relate acoustic emissions to crack tip movement in situations of cyclic fatigue (Ref 33) or stress-corrosion cracking (Ref 36) for various materials. These models are commonly framed as power-law relationships, with the acoustic emission described by conventional parameters such as threshold-crossing counts, *N*. In the more recent but difficult technique of source function analysis discussed in the section "Wave Propagation Effects" in this article, individual crack growth increments can be quantified in absolute terms by computer-intensive analysis of the early portion of the AE waveform.

Nonmetallic layers on metal surfaces also exhibit acoustic emissions for potential NDT applications. Examples of acoustic emissions from nonmetallic layers include:

- The acoustic emission from high-temperature oxidation (Ref 37)
- The extensive study of acoustic emissions from room-temperature corrosion processes (Ref 38, 39)
- The use of acoustic emissions to optimize the performance of ceramic coatings used in high-temperature components (Ref 40)

Metal-Matrix Composites. The following example illustrates one application involving the testing of a metal-matrix composite.

Example 3: Acoustic Emissions From the Microcracking of the Brittle Reaction Zones of Two Metal-Matrix Composites.

During the tensile testing of two metal-matrix composites, microcracking of the brittle interphase between the fibers and the matrix produced distinguishable peaks in AE count rates well before ultimate failure from ductile failure of the matrix. This may suggest a potential application of AE inspection for the real-time monitoring of structures made of these or similar metal-matrix composites to provide indications of structural problems before critical damage occurs.

The materials tested were metal-matrix composites that consisted of a titanium (Ti-6A-l4V) matrix reinforced with continuous, large-diameter silicon carbide (SiC, » 0.142 mm, or 0.0056 in., in diameter) or boron carbide coated boron ($B(B_4C)$, »0.145 mm, or 0.0057 in., in diameter) fibers (with fiber volume fractions of 0.205 and 0.224, respectively). Standard straightedge tensile test coupons were used. Specimens were cut with the fibers either parallel or perpendicular to the load axis (longitudinal or transverse tension specimens, respectively). Steel end tabs were used, and all surfaces were sanded and cleaned.

Specimens were tested to failure in a servohydraulic testing machine operated at constant crosshead displacement. For each test, a single AE transducer was coupled to the midpoint of the specimen (within the gage section) with vacuum grease, and the acoustic count rate was measured as a function of the longitudinal displacement (strain). After each test, the fracture surface was examined with optical and scanning electron microscopes to determine the fracture processes that occurred.

The values given in Table 2 for rupture or fail-

Metal-matrix composite	Brittle compound	Failure strain, %
$B(B_4C)/Ti\text{-}4V$	Titanium diboride	0.25
	Boron carbide	0.57
	Boron	0.80
$SiC/Ti\text{-}6Al\text{-}4V$	Titanium carbide	0.28
	Titanium silicide	0.66
	Silicon carbide	0.91

Table 2: Brittle phase mechanical properties

ure strains of the fibers and the brittle reaction compounds formed at the fiber/matrix interface during the hot pressing process were used to find the correlations between fracture processes and AE count rates, with differences in the AE count rates between the two materials related to the differences in their brittle components. As shown in Fig. 16(a), for longitudinal tension specimens of $B(B_4C)/Ti\text{-}6Al\text{-}4V$, there was a distinguishable rise in the AE count rate near the rupture strain of titanium diboride and a peak near the rupture strain for boron carbide. The final peak resulted from ultimate fiber failure. For transverse tension specimens, Fig. 16(b) and (c) show large peaks in AE count rate near the rupture strains of the major brittle components (titanium diboride in $B(B_4C)/Ti\text{-}6Al\text{-}4V$ and titanium carbide in $SiC/Ti\text{-}6Al\text{-}4V$). There were also minor peaks near the rupture strains of the other brittle components. The larger brittle reaction zone in $B(B_4C)/Ti\text{-}6A1\text{-}4V$ relative to $SiC/Ti\text{-}6AI\text{-}4V$ results in the larger area for the AE count rate plot.

The ultimate failure in the transverse specimens consisted largely of ductile matrix failure with lower AE count rates (relative to the microcracking).

Use of AE Inspection in Production Quality Control

In a small but important class of applications, AE inspection is applied during a manufacturing process to check the quality of the product or one of its components before final assembly and/or delivery. Of the production testing applications discussed in the section "Range of Applicability" in this article, common application of AE inspection in production quality control is the monitoring of welding and shaft straightening processes. Other efforts have been directed toward the inspection of integrated circuits. In the early 1970s, for example, an entire satellite launch mission failed because of a loose particle inside the cavity of a single integrated circuit. As a result, integrated circuits for critical applications are now routinely tested by particle impact noise detection technology, an inexpensive derivative of AE testing (Ref 12). During the manufacturing process, other types of flaws in integrated circuits can also be effectively controlled with AE inspection. Acoustic emissions from bonding processes and from ceramic substrate cracking were investigated by Western Electric researchers during the 1970s and were used as accept/reject criteria for parts on automated assembly lines (Ref 3).

The AE monitoring of welding processes has been part of the technology since its early days. Slag-free, more-automated weld techniques such as resistance welding, laser and electron beam welding, and gas tungsten arc and gas metal arc welding are the easiest to monitor. In the case of resistance welding, AE monitoring is carefully synchronized to the weld cycle, and the various phases of the weld process are treated separately. Emission during solidification and cooling is correlated with nugget size and therefore with weld strength, while high-amplitude signals from expulsions can be used to switch off the weld current at the optimum time to avoid overwelding and to save power and electrode life. In the case of gas tungsten arc and gas metal arc welding, real-time computer algorithms have been developed to recognize the characteristic AE signatures of particular types of defects and to report these defects while the weld is being made. These procedures are effective even in the presence of substantial background noise. Gas tungsten arc welded injector tubes for the space shuttle are among the welded components routinely monitored by AE inspection in the production environment.

Shaft straightening is another production process that lends itself to quality control by AE monitoring. Forged shafts are routinely straightened in special machinery that detects any imperfections in alignment and applies suitable bending forces to correct them. The quality of the product is threatened by microcracking of the hardened surface of the shaft during the bending process. Acoustic emission inspection detects this very effectively and is incorporated into the machinery to warn personnel and to halt the process when potentially damaging microcracking occurs (Ref 4).

In welding and shaft straightening, the stresses that activate acoustic emissions are already present in the normal production processes (in welding, they are thermal stresses). In other cases, the stress is applied for the express purpose of AE testing. This is akin to the loadings routinely applied for the AE inspection of new and in-service pressure vessels and other large structures. Examples include the production testing of brazed joints (Ref 2), and the proof testing of welds in steel ammunition-belt links described in the following example.

Example 4: Acoustic Emission Inspection of Projection Welds in 1050 Steel Ammunition-Belt Links. The ammunition-belt link shown in Fig. 17(a) was made of 0.81 mm (0.032 in.) thick 1050 steel strip. The steel was preformed into link halves that were joined by two projection welds on each side where the sections overlapped. Although the welding schedules were carefully controlled to produce good resistance welds, there was a significant potential for producing some faulty welds in the mass-produced links. In a good weld, a weld nugget is formed that is usually stronger than the base metal in tension; that is, the base metal will tear before the weld will break. In a poor weld, the joint interface is literally just stuck together, and a moderate force, particularly one imposed by impact, will cause the joint to fracture at the interface. A preliminary feasibility investigation showed that poor welds produced more acoustic emission under load than good welds, even though the load was insufficient to break a poor weld.

Proof-Testing Equipment. A mechanical link tester (Fig. 17b) was designed to apply both a shear load and a bending load to the ammunition-belt link at the welded joints. This simulated the service load that would be imposed on the link.

Initially, piezoelectric sensors were attached to each link before testing to monitor acoustic emissions. This was the simplest and most direct method of confirming feasibility. Because attaching sensors directly to the link was not feasible for production testing, piezoelectric sen-

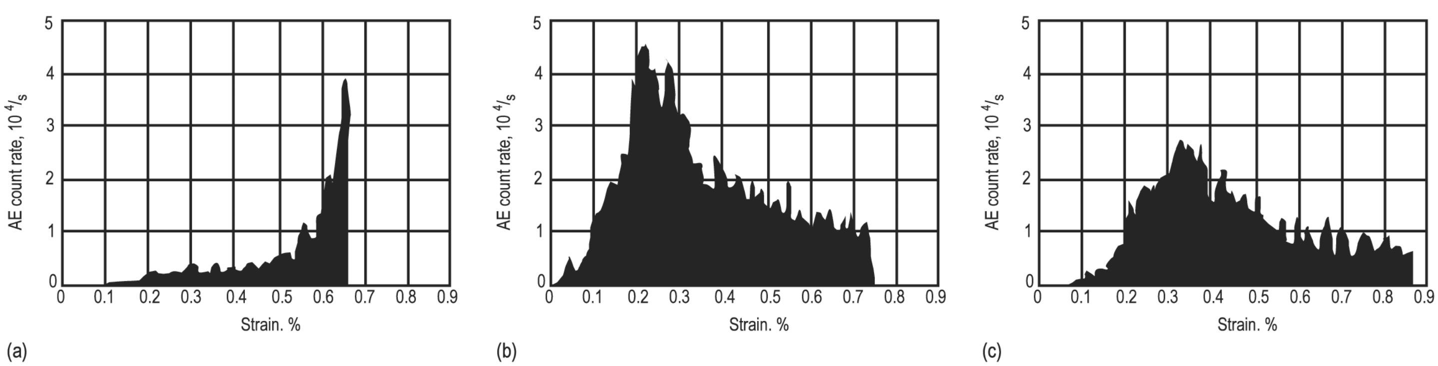


Figure 16: Area plot of AE count rate versus strain. (a) Longitudinal tension test of a $B(B_4C)/Ti\text{-}6Al\text{-}4V$ specimen. (b) Transverse tension test of a $B(B_4C)/Ti\text{-}6Al\text{-}4V$ specimen. (c) Transverse tension test of a $SiC/Ti\text{-}6Al\text{-}4V$ specimen

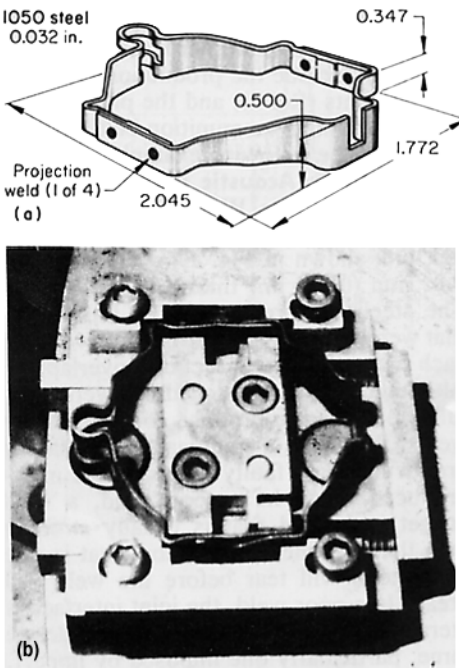


Figure 17: Ammunition-belt link, of 1050 steel, joined by four projection welds that were inspected by AE monitoring during proof testing in the fixture shown. Dimensions given in inches. Source: Ref 41

sors were embedded in the spreader arms of the link-test fixtures in an area adjacent to the welded joints in the link.

A spreader force of 270 N (60 lbf) on the link provided a link-spreader-arm interface pressure of about 35 MPa (5 ksi), which provided good coupling of acoustic information across the interface. The sliding action of the spreader mechanism produced a wide-frequency noise range that could not be electronically filtered without also filtering the acoustic emission. This problem was overcome by gating out the noise from moving parts of the link-stressing mechanism and monitoring for acoustic emission during static stressing of the link after the spreader arms had reached full displacement. A microswitch was installed in the fixture to turn on the AE monitoring system in proper relation to operation of the spreader arm.

Acceptance Levels. The form of signal energy analysis that produced the best results consisted of electronically integrating for the area under the half wave rectified envelope of the emission signal in terms of volts amplitude and time duration. The analyzer used for the production application produced a dc voltage proportional to the total AE energy measured. The system sensitivity was adjusted so that an energy analog output voltage of 10 V represented the division point between a good and a bad projection weld in a link. If the welded joint generated enough acoustic emission to produce a 10-V energy output, the link was rejected. If the value was less than 10 V, the link was accepted. The selective ejection function of the mechanical tester was designed to eject the links into the accept or reject container based on an electronic switching function that was controlled by the output voltage of the emission analyzer.

The monitoring system was calibrated by introducing an artificial signal into sensors in the spreader arms, where it was detected and processed by the monitoring system. A l0-V, 10-μs pulse was fed into these sensors from a pulse generator. The resulting signal was reproducible, was a reasonable simulation of the real data, and was simple to generate. Monitoring by acoustic emission was the only available nondestructive method that could perform the necessary 100% inspection of these projection resistance welds.

Structural Test Applications

Acoustic emission inspection has been successfully applied in the structural testing of aircraft, spacecraft, bridges, bucket trucks, buildings, dams, military vehicles, mines, piping systems, pipelines, pressure vessels, railroad tank cars, rotating machinery, storage tanks, and other structures. The typical goal of an AE structural test is to find defects and to assess or ensure structural integrity. Acoustic emission inspection has been described as condition monitoring of static plant (Ref 42), which is parallel to the vibration monitoring techniques that are effectively used to monitor the condition of rotating plant. Both of these methods are useful for predicting failures (Ref 43) and reducing maintenance costs.

Key to structural testing with AE inspection are the stress concentrations that cause defects and other areas of weakness to emit while the rest of the structure is silent. Acoustic emission inspection thus highlights the regions that threaten the integrity of the structure. As a whole-structure test using fixed sensors, AE inspection is normally complemented by other NDT methods that are used to follow up the AE findings and to assist in determining the type, severity, and acceptability of the AE sources.

A major advantage of AE inspection is that it does not require access to the whole examination area. Removal of external insulation or internal process fluids, typically a major expense associated with other NDT methods, is not required for the AE test. In fact, this procedure can be avoided altogether if the AE test indicates that the structure is in good condition.

For AE inspection to function reliably as a whole-structure test, the structure must be loaded in such a way as to stimulate emission from all structurally significant defects. Continuous monitoring in service is a possible test approach that has been applied, for example, to aircraft (Ref 7) and nuclear reactors. This approach guarantees appropriate stressing, but it is difficult because a small amount of emission from defect growth must be separated from a large amount of noise over a long time period. More commonly, the AE test is conducted over the course of a few minutes or hours, during which the structure is stimulated by applying a controlled stress (Ref 44). In most cases, this is satisfactorily accomplished by going somewhat above the normally apparent service loads (for example, 110% of the working pressure for an in-service pressure vessel, 200% of the rated load for an aerial manlift device). However, there are cases in which this approach will not work. For example, if defects are being induced in service by thermal stresses rather than mechanical stresses, an applied mechanical loading may not give a good match to the stress field that is causing the defects to grow in service. The defects, effectively unstressed, may not emit. To overcome this problem, inspectors testing steam lines in electric power plants have conducted AE monitoring during thermal overloads and cool-downs and have reported better success from this type of stressing.

In performing a successful AE test, careful attention must be paid to the type, magnitude, and rate of the applied stimulation (loading). Previously applied stresses will have a very strong influence on the emission that will be observed, as discussed in the section “Load Control and Repeated Loadings” in this article. Precautions must be taken to avoid inadvertent loadings of the structure. Many tests have been spoiled when site personnel, eager to ensure that the pressure system is leaktight, have taken the vessel up to the test pressure before the arrival of the AE inspectors. Accurate load measurement and the ability to hold load at a constant value are other requirements that may demand special attention from site personnel.

Load history is less important for leak testing because leak testing relies primarily on the detection of turbulent flow through the leak orifice. Major structural test applications of acoustic leak testing include flat-bottom storage tanks and nuclear reactor components. In the case of nuclear reactor components, millions of dollars have been saved through the selected use of AE instrumented inspection technology as an alternative to hydrotesting (Ref 45).

Data evaluation procedures depend on the context and content of the test. In one-of-a-kind and developmental testing, the skill and experience of the investigator are of prime importance. This fact inhibited the widespread use of AE inspection until standard test procedures started to become available in the late 1970s. The development of standard test procedures made it possible for AE tests to be efficiently conducted by regular NDT inspectors (given the proper training), while the more innovative investigators moved on to the development of new application areas. Some of the well developed and standardized structural test applications of AE inspection will be briefly summarized below.

Bucket Trucks. The AE inspection of aerial manlift devices (bucket trucks) was pioneered by the author for Georgia Power Company in 1976 and was carried forward into routine practice by independent testing laboratories and several electric utilities in the years that followed. The ASTM F-18 Committee on Electrical Protective Equipment for Workers published the Standard Practice on the subject in 1985 (Ref 46).

First intended for use on the fiberglass boom sections of insulated bucket trucks, the method was soon extended to cover the pedestal, pins, and other metal components. An estimated 70 000 to 100 000 AE tests have been conducted up to 1988. Bucket trucks can develop problems through accidents, overloads, and fatigue in service. A thorough, regular inspection and test program can identify potential problems before they cause injuries or downtime (Ref 47).

Acoustic emission inspection is a major part of the structural integrity evaluation that complements functional tests of the bucket truck. Of all inspection methods, it is the most effective for detecting problems in fiberglass components, while for metal parts and 100% structural coverage, it serves as a cost-saving screening test that directs the inspector's attention to problem areas. The AE test is preceded by a visual inspection, and any AE indications are normally followed up with magnetic particle, dye penetrant, or ultrasonic inspection.

The AE test typically requires 12 to 16 sensors. System performance is checked by lead break before monitoring begins (see the section "Installation" in this article). Monitoring begins with a noise-check period, followed by two loadings to a predetermined proof load. Emissions during rising load, load hold and load release are separately recorded.

Data evaluation procedures are difficult to spell out because of the wide variety of possible noise and AE sources and the wide range of bucket truck constructions. The experienced inspector uses his knowledge of the truck as he evaluates high- and low-amplitude emission on the different channels during the different stages of the test. Aware of possible noise sources, he looks for indications that may lead to confirmation of damaged fiberglass, cracked metal components, or maintenance problems such as lack of lubrication in visually inaccessible areas.

Using an AE instrument specially designed for economical bucket truck testing, an experienced test crew can perform five to ten AE tests in a single day. When the required visual, operational, ultrasonic, magnetic particle, and dye penetrant testing operations, are also performed, typically two to three trucks can be inspected per day.

Jumbo Tube Trailers. Acoustic emission inspection for testing jumbo tube trailers was developed by Blackburn and legitimized in lieu of hydrotest by a Department of Transportation exemption granted in 1983 (Ref 48). These tube trailers carry large volumes of industrial gases on the public highways, typically at a pressure of 18 200 kPa (2640 psi). Fatigue cracks can grow in service, but the hydrotest will not detect these cracks unless they actually cause rupture of the tube. The AE test will detect the cracks while they are still subcritical, during a 10% overpressure applied during the normal filling operation. The AE test is therefore more meaningful than the hydrotest. The AE test is also less expensive and avoids disassembly of the trailer and contamination of the internals with water.

The trailer typically holds 12 tubes, which are all tested at the same time. The AE test requires just two sensors on each 10 m (34 ft) long tube; wave propagation and attenuation characteristics are very favorable in this structure, and AE sources can be accurately located. If ten or more valid events are located within a 200 mm (8 in.) axial distance on the cylindrical portion of the tube, ultrasonic inspection is carried out and the tube is accepted or rejected based on the ultrasonic evaluation of flaw depth. The accept/reject criteria are based on a conservative fracture mechanics analysis of in-service fatigue crack growth. Between March 1983 and March 1988 about 1700 jumbo tubes were AE tested, and the method has been further extended to other shippers of compressed gas and other tube types.

Fiberglass Tanks, Pressure Vessels, and Piping. In the 1970s, the chemical industry was experiencing worldwide failures of fiberglass storage tanks and pressure vessels. Causes included inadequate design and fabrication, mishandling during transportation, and misuse of this relatively unfamiliar material. The situation was aggravated by the lack of a viable inspection method.

An AE test methodology was pioneered by Monsanto, resulting in elimination of the tank failure problem (Fig. 18). The method came into widespread acceptance through the formation and activities of the Committee for Acoustic Emission in Reinforced Plastics (CARP), which is currently affiliated with the American Society for Nondestructive Testing. The written procedure developed by CARP and first published by the Society for the Plastics Industry in 1982 was the basis for the introduction of AE inspection into the ASME Boiler and Pressure Vessel Code in 1983 (Ref 30, 49). An estimated 5000 tests have been carried out using this procedure as of 1988. The work of CARP was also extended to cover methodology for testing fiberglass piping (Ref 50).

The AE test typically requires 8 to 30 sensors, depending on the size of the vessel or tank. High-frequency (typically 150 kHz) channels are used to cover regions of known high stress, such as knuckles, nozzles, and manways; low-frequency (typically 30 kHz) channels having a larger detection range are used to complete the coverage of less critical regions. In the case of a storage vessel, the test is typically conducted during filling with process fluid after an appropriate conditioning period with the contents at a reduced level. In the case of a pressure vessel, appropriate overpressure is applied. The loading is conducted in several stages, with load-hold emission, Felicity Ratio, and other accept/reject criteria evaluated at each stage. System performance checks and background noise checks are part of the test procedure.

Metal Pressure Vessels and Storage Tanks. In the 1970s, many research and engineering organizations and test companies were active in the AE testing of metal pressure vessels. A 1979 survey estimated that about 600 pressure vessels had been tested by AE inspection on a production basis up to that time, mostly in the petroleum, chemical, and nuclear industries (Ref 51). (Although tests on pipes, heat exchanger tubing, and miscellaneous components were much more numerous, pressure vessels have always been a focal point for AE testing.) Much of this testing was done with *ad hoc,* undocumented procedures that relied heavily on the individual experience of the teams performing the work. The main emphasis was usually placed on source location, technically a most attractive feature of AE testing. Located sources would be graded according to their AE activity and/or intensity, and the vessel owner would be advised regarding which areas to inspect with other NDT methods. Many structural defects were successfully identified with these methods.

A significant maturing of the technology took place when Fowler at Monsanto engaged on a systematic program of methods development, using the results of follow-up inspection to refine and improve the AE data analysis procedures. Starting in 1979, this program included destructive tests on decommissioned vessels, field tests on many hundreds of in-service vessels and tanks, and development of analytical procedures for recognizing and eliminating extraneous noise (Ref 25). The program de-emphasized the calculation of source location (which requires several sensors to be hit) because in practice many AE events hit only one sensor. To use all the AE hits, zone location was employed instead of point location. The outcome of this program was a comprehensive test procedure backed by detailed case histories and available to licensees under the trademark MONPAC. This procedure has been applied to approximately 2000 metal vessels and storage tanks as of 1988 (Ref 8).

A typical MONPAC test result is shown in Fig. 19. Here a 30-year old ethylene storage bullet was AE tested on-line, raising the pressure by turning off a compressor. Results are presented in the form of an unfolded map of the vessel, with the evaluation of appropriate zones on the map being displayed in color codes (Fig. 19 only shows the color as a dark region). The zone evaluations indicated "no significant emissions," so a hazardous and possibly deleterious internal inspection was avoided (Ref 42).

Other MONPAC tests have found external and internal corrosion, stress-corrosion cracking, weld cracking, lack of fusion, lack of penetration, and embrittled material. Plant shutdowns have been shortened through early diagnosis of major problems, or have been eliminated through positive demonstration of structural integrity. Savings achieved through this method run to tens of millions of dollars.

An AE methodology for metal vessel testing has also been introduced into the ASME Boiler and Pressure Vessel Code as of the December 1988 Addendum (Ref 31). The article states requirements for written test procedure, personnel qualification, equipment, system calibration, pre-examination measurements, background noise check, and vessel pressurization. An illustrative loading schedule and sensor layouts are included. Evaluation criteria are to be supplied, class by class, by the referencing code section; they will be based on emission during load hold, count rate, number of hits, large amplitude hits, MARSE, and activity trends. This entry into the ASME Code represents a major milestone in the establishment and maturity of AE technology.

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APPENDICES

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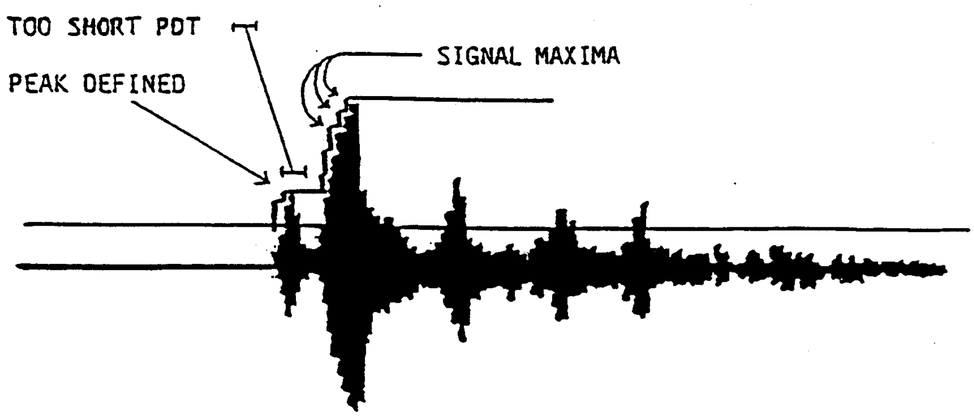
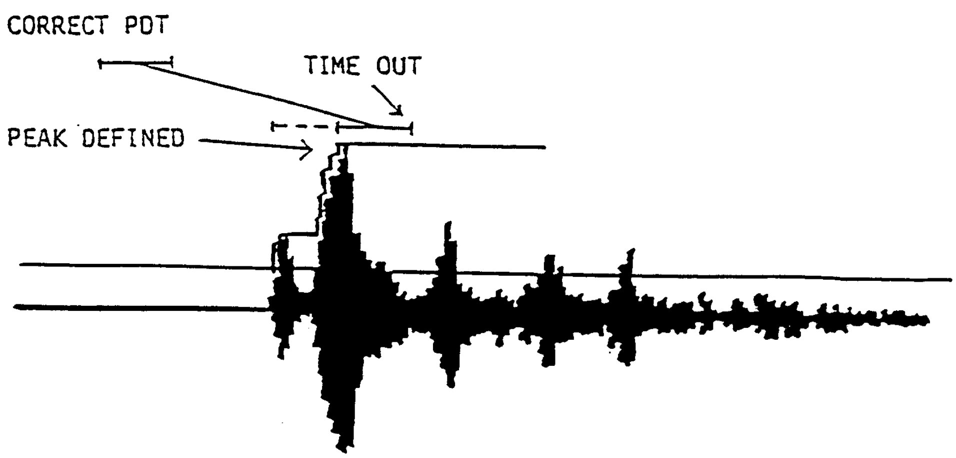
APPENDIX I

System Timing Parameters (PDT, HDT, HLT)

PEAK DEFINITION TIME (PDT)
Also known as RISE TIME OUT (RTTO)

The function of Peak Definition Time is to enable determination of the time of the true peak of the AE waveform. The PDT circuitry is a retriggerable one-shot, triggered by new signal maxima.

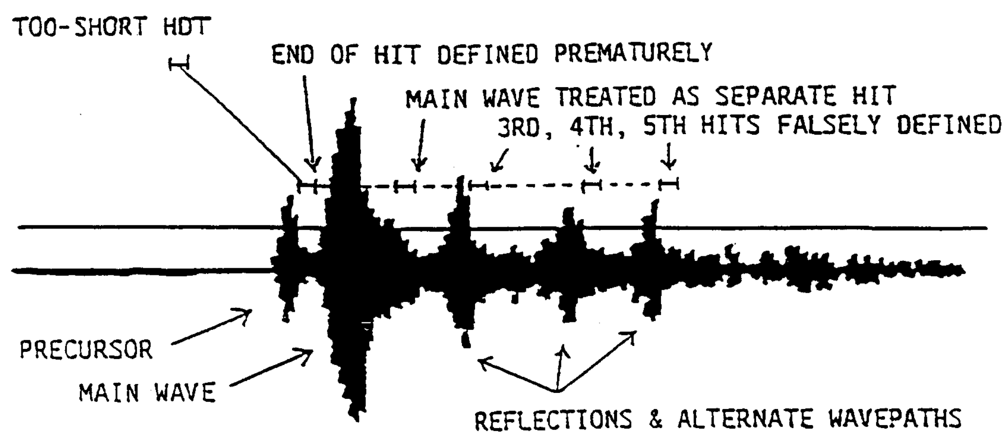




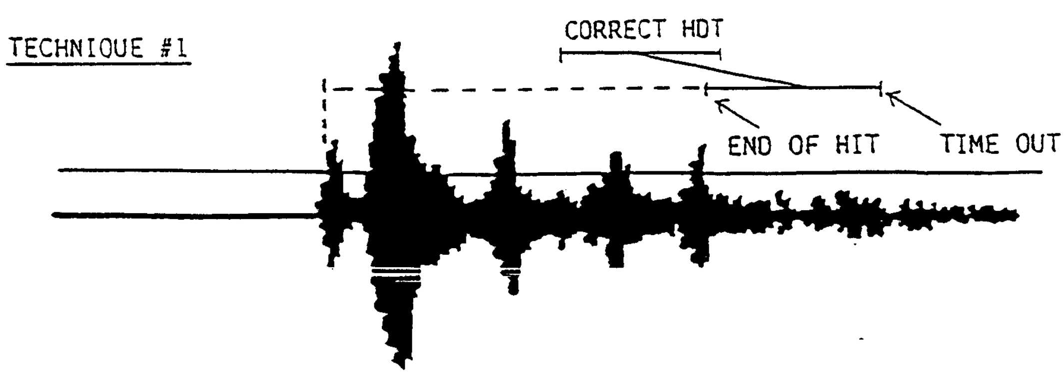
The main requirement is to avoid false measurements being made on a high-velocity, low-amplitude precursor. subject to this, PDT should be set as short as possible. A reasonable value to pick for PDT is D/C where D is the sensor spacing and C is the speed of the <u>fastest</u> wave, say 6mm/us.

HIT DEFINITION TIME (HDT)
Also known as Single Channel Event Time Out (SCETO)

The function of Hit Definition Time is to enable the system to determine the end of the hit, close out the measurement processes and store the measured attributes of the signal. The HDT circuitry is a retriggerable one-shot, triggered by the threshold crossings. In most PAC systems the HDT must be at least twice as long as the PDT.



The goal is to identify and describe events realistically. The HDT must be long enough to span over an intervals in which the signal to be measured falls below the threshold. Subject to this, the HDT should be set as short as possible, in order to permit high data throughput rates and reduce the risk that two separate events will be treated as a single hit.



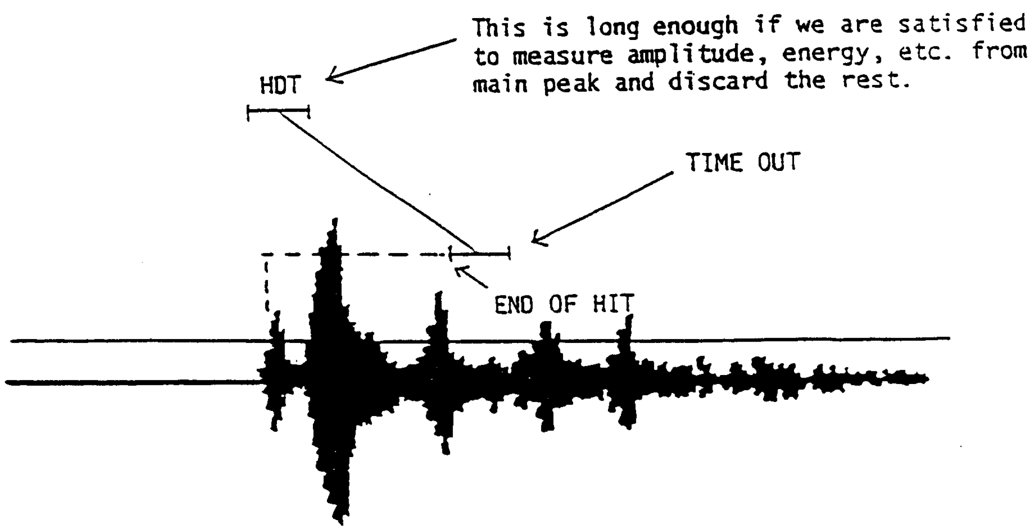
HIT DEFINITION TIME (Continued)

The idea of TECHNIQUE #1 is to include, in the hit description, all consequences (reflections, alternate paths, etc.) of the source event. This is the straightforward approach, using a relatively long HDT.

The reasonable value to pick for HDT is L/C where L is a characteristic length of the structure (e.g. circumference of a vessel) and C is the speed of a typical main wave (say 3mm/us); or 20/AC where A is measured attenuation coefficient (dB/mm); whichever is smaller.

The idea of TECHNIQUE #2 is that the system throughput can be improved by discarding "irrelevant" reflections, etc. and measuring only the main part of the wave.

TECHNIQUE #2

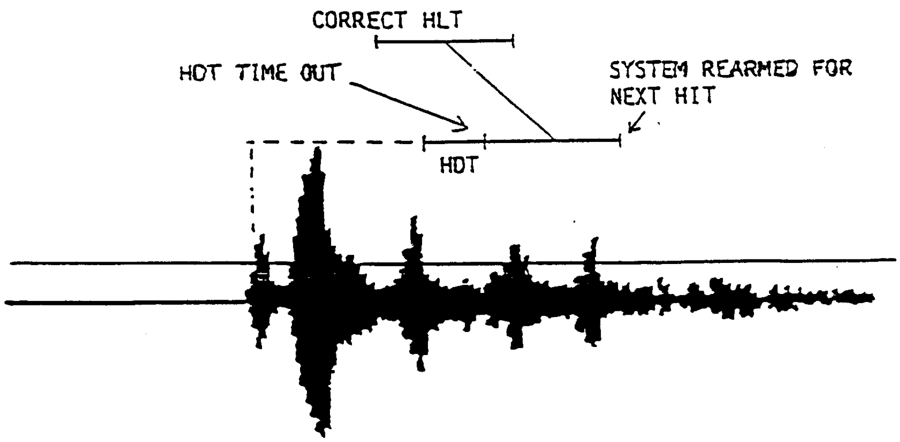


With TECHNIQUE #2, the system can clear buffers and get ready for a second hit while the reflections from the first hit are locked out by the HLT (next page). So the system is ready earlier for a second hit.

A reasonable value for HLT using TECHNIQUE #2 is 20/F where F is the sensor resonant frequency in MHz.

HIT LOCKOUT TIME (HLT)
Also known as REARM TIME OUT (RTO)

The function of Hit Lockout Time is to inhibit the measurement of reflections and late-arriving parts of the AE signal, so that data from wave arrivals can be acquired at a faster rate. The HLT circuitry is a non-triggerable one-shot, triggered by the time out of the HDT.



HLT is important only when using TECHNIQUE #2 for HDT selection. When TECHNIQUE #1 is used for HDT selection, HLT may be conveniently set to the smallest value permitted by the system.

When using TECHNIQUE #2, the HLT should be long enough to span any gaps between threshold crossings, especially the longer gaps that tend to occur in the tail end of signals from reverberant structures. A reasonable value may be picked using the same methods as for HDT (TECHNIQUE #1). HLT's shorter than about 300us will not be meaningful since it takes this time for the ICC to complete data measurements and transfer the results to its output buffer.

APPENDIX II

Data File Definition for AEwin

APPENDIX II

DATA FILE DEFINITION FOR AEwin

This document gives the format of the AEwin data files. These files are created by the AEwin when acquiring data in AUTODUMP mode. When data is dumped to disk, a file specified by the user, with the extension .DTA (e.g., TEST0000.DTA) is created.

The data file consists of three basic types of variable length messages. These messages are (I) Products Definition Messages (II) Test Setup Messages and (III) Messages from the test. Each message has two bytes for length, 1 byte for ID (2 bytes for ID followed by 2 bytes for format version number in messages with ID41 to 44 only) and a variable length body. The messages 41-44 are special messages in that they are also included in the INI files.

PAC MESSAGE DEFINITIONS

1. INTRODUCTION

This document describes the messages used to communicate between various processes within the data acquisition and replay environment of PAC products. These messages may be commands and/or data depending on where they are generated within the system and where they are sent. The same types of messages are saved in the data files.

The message structure was developed for the first SPARTAN implementation to allow communication between the SPARTAN main chassis (GCC) and High End (HE) but it has been extended in other contexts to (a) program to program communication (files), (b) Slaved Graphics processors (S100 Color Slave Board) and (c)indirect subroutime communication (pseudo GCC in the Locan-AT, User output, User Hardware Setup (and the file) share/communicate via recently defined message which is based on the 3000 SPARTAN "488" file (i.e., the test setup information sent from a 3000 file to the SPARTAN GCC chassis). Other general principals have been applied when assigning message ID numbers: the IDs from 200 to 255 were reserved for applications, ID = 0 is illegal, once an ID assigned a meaning and implemented for some product, it can only be used by a different product for the same function. By the time the second application program was designed it seemed that the 55 message ID values would quickly be used up, and therefore later application messages have added structure by using a message "subfunction" byte (e.t., 172, 42 for MI-TRA.

Once assigned, we try to avoid changing the meaning of a message ID according to where it is at a given time or which direction it is going. Thus, AE data messages always have a message ID of 1 and the Resume message has an ID of 128. Commands and messages may be built up using other messages by "sequence" or by using an new id to combine a series of messages into a "single" block. The "Start" command is actually 2 commands; a Clear Time of Test Clock command and a "Resume" command. The "Resume" command and the "Resume" message share the same message ID; user commands are sent to the GCC as 1 byte versions of message and the returned (data) message with the Time of Test confirms that the GCC has completed the requested action. So the "command" message is "hidden" from the rest of the world. Any subsequent use of the message may or may not use the time of test attached to it depending to the application. The "Resume" which is a start, normally has its time of test IGNORED (the program treats it as 0 since it follows a Clear Clock) but subsequent "Resume" messages have a new time of test which the programs can use.

This structure has been extended for the TRA products and the AEDSP software.

2. GENERAL MESSAGE INFORMATION

Classes of Messages

(I) HARDWARE STATUS AND CONTROL Messages [[NOT IN THE DATA FILES]]

(II) PRODUCT SPECIFIC Messages

These are messages, only found in the data files, which have a general form but their details will vary with the products.

Product Identification Message: Identifies a the Product and its Version.

Product Special Message: Test, Product specific information PRIMARILY for post test report generation but may contain configuration information.

Product Post Test Filter Description Message: While the form of this message should be the same for all the products, the details of the filter process are product specific. Similar to the setup message, THIS OUGHT TO CONTAIN ALL THE INFORMATION FOR THE FILTER AND ALSO SERVE AS THE BASE FOR ANY CODE TO SAVE OR RESTORE FILTERS FOR FUTURE USE.

(III) TEST SETUP Messages

These messages are used to set up the system hardware and the test parameters. The Test Setup messages include Test Label, Date and Time, Location Setup and the Hardware Setup Messages.

Test Label: Title or Name of the test.

Date and Time: Date and Time of Day (ASCII string) of start of test.

Location Setup: Defined in Location version data file only.

Hardware Setup: The Hardware setup message is group of setup messages.

(IV) Messages from the TEST

(A) DATA Messages: DATA messages include AE Hit Data, Time Driven Data, Sample Data, Alarm Data and User Comment Messages.

(B) CONTROL Messages: PAUSE, RESUME, STOP, and ABORT.

(V) Synchronization and Control Messages for "external" tasks

These include commands sent to the mGCC or AEDSP processors.

(VI) Data File Messages

Typical raw data (.DTA) files contain the following messages:

Type	Id	Description of Message Body
II	41	Product Definition
III	7	Test Label
III	99	Time of Day of start of test
III	44	Location setup message
III	42	Hardware setup message
V	128	Start/Resume test
IV	1	AE hit data
IV	2	Time Driven data
IV	3	Sample data
IV	7	User Comment
IV	130	Test Pause
IV	129	Test Stop
IV	15	Test Abort message

Message Format

Each message has two bytes for length and a body of that length of bytes. Thus the total length of the "transmission" is Length+2 bytes. The body of the message starts with a message id byte. Unfortunately it was felt that the software would be easier if the messages which "define" the file (Presently they have ID values from 40 to 49) if the ID space was an integer quantity. In fact, because the files contain messages with 1 byte id values, all the message IDs should be identified by the byte value. The legal range for an ID is 1 to 255.

Special setup files would contain only (primary) messages with 2 byte ID values for example the ".INI" files for setup of LOCAN 420, MISTRAS or SPARTAN 2000 data acquisition and replay. I would expect that we will expand this concept to at least the post test filtering programs when they have to be coded to save and restore user setup information.

The INI file contains the messages:

41 Product Definition
42 Hardware Setup
43 Graph Setup
44 Location Group Setup (even in non-location versions)
45 Acquisition Control
46 Auto Run
7 Test Title

and possibly:

49 Product Specific Information

In order to help the user to understand the structure of various types of messages, a set of them from the data file header will be briefly described. This should help to explain the message concept and give a good idea of the structure of a DTA or INI file.

ID 41 — ASCII Product Definition
(With example values)

LEN	b1, b2	2 bytes
ID	b1= 4 (29H) b2= 00	Product Definition Message ID high byte of ID (2 bytes)
PVERN	b1= 200 (C8H) b2= 00	Product version number (200) (2 bytes)
Prod_string	"LOCAN-AT",CR,LF ,"VERSION 2.00",CR,LF number, CR,LF	ASCII Product name, Carriage Return, Line Feed, Version

ID 7 — User Comments/Test Label

LEN	b1, b2	2 bytes
ID	b1=7 (07H)	User Comments or Test Label
	b1 | | bn	Text in ASCII

ID 99 — Time and Date Of Test Start

EN	b1, b2	2 bytes
ID	b1= 99 (63H)	Time and date of test start ID
"Sun Jul 03, " "08:49:55 1988"	(For Example)	ASCII date string, ASCII time and year string.

ID 44 — Location Definition
(Dummy message in Non-Location version)

LEN	b1, b2	2 bytes
ID	b1= 44 (2CH) b2= 00	Location Definition ID high byte of ID (2 bytes)

The MISTRAS DTA file also includes two TRA setup messages when the wave forms are being recorded.

ID 173,42 — Hardware Setup

ID 172,29 — Digital Filter Setup

ID 42 — Hardware Setup

LEN	b1, b2	2 bytes
ID	b1= 42 (2AH)	Hardware Setup ID

```
                     b2= 00            high byte of ID (2 bytes)
 MVERN               b1= 200 (C8H)     Message version number
 b2= 00               (0 filled)

 LSUB 1                                length of submessage 1 (2 bytes)
 SUBID 1                               submessage 1 ID ( 1 bytes),
 SUBMSG 1                              submessage 1 body.
     |
     |
 LSUB I                                length of submessage I (2 bytes),
 SUBID I                               submessage I ID ( 1 bytes),
 SUBMSG I                              submessage I body.
     |
     |
 LSUB n                                length of submessage n ( 2 bytes),
 SUBID n                               submessage n ID ( 1 bytes),
 SUBMSG n                              submessage n body
```

```
Note: Submessages are:
  Start of Test Setup                   ID = 100 ( 64H )
  Set Sampling Interval                 ID = 27  ( 1BH )
  Set Demand Sampling Rate              ID = 102 ( 66H )
  Pulser Rate                           ID = 133 ( 85H )
  Event Data Set Definition             ID = 5   ( 05H )
  Demand Data Set Definition            ID = 6   ( 06H )
  Group Definition                      ID = 106 ( 6AH )
  Alarm Definition                      ID = 28  ( 1CH )
  AE Filter Definition                  ID = 29  ( 1DH )
  Group Parametric Assignment           ID = 110 ( 6EH )
  Group Settings                        ID = 111 ( 6FH )
  End of Group Settings                 ID = 124 ( 7CH )
  End of Setup                          ID = 101 ( 65H )
```

3. DETAILED MESSAGE DESCRIPTIONS

The following is a list in numeric order of the messages. Each message has the two bytes for length explicitly shown, 1 byte for ID. (Remember there are a few messages with 2 bytes for the ID field EVEN THOUGH the ID is 1 byte long. They are shown with the O BYTE in the ID field.

Notation:

AM	-	Acquisition Module
#	-	'the number (of)'
PID	-	the Parametric Channel ID
CID	-	an AE channel ID
CHID	-	the AE characteristic ID number (List after Message #5) b1,b2,b3,b4,…
	-	bytes (least significant first)
V	-	value
RTOT	-	Time of test relative to the start of test
PVERN	-	Product version number
MVERN	-	Message version number
LEN	-	length of a message
Internal	-	Defined but never appear in the data file
Defined	-	Assigned for some product(s) may appear in a data file at some later date
Not Used	-	Reserved by PAC for future use

Setup Message Units

Threshold and Gain Units:	dB
HDT, Rearm Time:	2 µsec
PDT	1 µsec.
Sampling Interval	1 msec.

[Also MID 102 is in msec steps]
msec == milliseconds
µsec == microseconds

Front End Filter Types (ICC filtering)

SCSH Single Channel, Single Hit

GCC or Parametric Voltage Filtering

Alarms

SCSH Single Channel, Single Hit
SCTC Single Channel, Test Cumulative
GTC All Channels (Group), Test Cumulative
Parametric

ID 1 — AE Hit or Event Data

```
LEN                b1, b2          2 bytes
ID                 b1=1 (01H)      AE Hit ID

RTOT               b1              Relative time of test
                   b2
                 |
                 |
                   b6

CID                b1              AE Channel Number

   V1               b1             Value of First AE Characteristic
   |                |
   V1               bn
   |                |              as many as defined
   |                |
   Vm               b1             Value of Last AE Characteristic
   |                |
   Vm               bx

PID1               b1              Hit Parametric Channel ID
V1                 b2              Parametric value (low byte)
V2                 b3              Parametric value (high byte)
V3                 (b4)            Cycle Counter MSB byte
                 |
                 |
PIDj               b1              Last Hit Parametric Channel ID
V1                 b2
V2                 b3
V3                 (b4)
```

ID 2 — "Time Driven" Sample Data

LEN	b1, b2	2 bytes
ID	b1 = 2 (02H)	Time Driven ID
RTOT	b1	Relative time of test
	b2	
	|	
	|	
	b6	
PID1	b1	First Parametric Channel ID
V1	b2	Parametric value (low byte)
V2	b3	Parametric value (high byte
(V3)	(b4)	(Cycle Counter MSB byte)
	|	
	|	
PIDj	b1	Last Parametric Channel ID
V1	b2	
V2	b3	
V3	(b4)	
CID	b1	ID of the first channel in use
V1	b1	Value of first AE Characteristic
.	.	
V1	bn	|
|	|	
|	|	
Vm	b1	Value of Last AE Characteristic
.	.	
Vm	bx	end of first channel
|	|	
|	|	
CID	b1	ID of the last channel in use
V1	b1	Value of First AE Characteristic
|	|	
V1	bn	|
|	|	
|	|	
Vm	B1	Value of Last AE Characteristic
|	|	
|	|	
Vm	bx	end of last channet
		end of Time data set

ID 3 — "User Forced" Sample Data — Now also a GCC Command

ID 4 - GCC Module Detection of Error

Defined for mGCC Ver. 1.53 and later.
(V1.8+ planned to have control from H.E.)

LEN	b1, b2	2 bytes
ID	b1 = 4 (04H)	GCC detection of error
Error Code	b1	Error identification
Error Bytes	eb1 | ebX	Error information. May be text or garbled message from ICC.

Error Codes

b1 = 1	This is ICC-GCC transmission error. Bad CID, bad MID or bad message length. MID is part of the fifo information (1,2...). Also the fifo presents a total byte count = 2 + message length. The CID can only be the ICC's low or high channel.
eb1...ebX	The message that was not received correctly
b1 = 2	Internal GCC error detection: Error message displayed on LCD. {May be only in debug version.} and saved in error bytes field.
eb1...ebX	The text of the front panel error message.
b1 = 100 and 200-203	Used by the Combustion Engineering special software.

ID 5 — Event Data Set Definition

LEN	b1, b2	2 bytes
ID	b1=5 (05H)	Event Data set definition ID
# CHID	b1	Number of AE characteristics
V1	b1	Value of CHID 1
|	|	Value of CHID m (last one)
Vm	b1	Value of CHID m (last one)
# PID	b1	Maximum number of Hit parametric

AE Characteristics Presently Defined or Planned

CHID Value	Size	Item
1	2	Rise Time of AE signal
2	2	AE Counts to Rise Time (or "Counts to peak")
3	2	Total AE counts
4	2	Energy counts (ASTM has another name for this)
5	4	Duration
6	1	Amplitude
7	1	RMS (volts) - After both were defined, the H/W
8	1	ASL (dB) - design allowed only 1 at a time.
9	1	Gain
10	1	Threshold
11	1	Pre-Amp Current
12	4	Lost Hits (per channel) WAS Overlap flag
13	2	Average Frequency (kHz) (1000* [3]/[5])

Tentative Assignments

14	2	Reserved (2 byte duration)
15	6	Reserved (6 byte TOT)
16	(4)	Reserved (Vari. length TOT with Message 12) (Example: Msg12 used in TI for 4 byte TOT.)

This is clearly a system with expansion capability, but we will need to try to do the expansion in an intelligent manner.

ID 6 — Time Driven/Demand Data Set Definition

LEN	b1, b2	2 bytes
	b2	High byte value
ID	b1=6 (06H)	Demand Data Set Definition ID
# CHID	b1	Number of AE char. in the demand data set
V1	b1	First CHID
|	|	
|	|	
Vn	b1	Last CHID
# PID	b1	Number of Parametric in user
V1	b1	First PID
|	|	
|	|	
Vn	b1	Last PID

ID 7 — User Comments/Test Label

LEN	b1, b2	2 bytes
ID	b1=7 (07H)	User Comments or Test Label
	b1 | | bn	Text in ASCII

ID 8 — Message for Continued File TYPE A
This one is at the END of the file and indicates that there was more data when space ran out on the disk.

LEN	b1, b2	2 bytes
ID	b1=8 (08H)	File continuation
	b1 | | b8	Time & Date of continuation in DOS format so that 'gaps' in time in the continuation can be detected. {CX,DX of DOS Time, CX,DX of DOS Date INT 21 DOS calls.}

ID 8 — Message for Continued File TYPE B
Appears only at the beginning of a file and indicates that the file is NOT the start of a test.

LEN	b1, b2	2 bytes
ID	b1=8 (08H)	File continuation
	b1 | | b8	Time of continuation in DOS format exactly the same as written at the end of the preceding file.
{complete setup record from the first file of the test}		

This is all the messages up to the "Start Test Command" which were written at the beginning of the first file. If that file were to be unavailable, then this allows this file to be analyzed.

ID 9/ID 10 — Not Used

ID 11 — Reset Absolute Time Clock

LEN	b1, b2	2 bytes
ID	b1=11 (0BH)	Reset Absolute Time Clock

ID 12 — Define the Size of the Clock Base ("Tick") Reserved

ID 13/ID 14 — Not Defined

ID 15 — Abort Data Acquisition

LEN	b1, b2	2 bytes
ID	b1=15(0FH)	Abort data acquisition/transfer ID
RTOT	b1 b2 | | b6y	Relative time of test

ID 16 — Alarm Data

LEN	b1, b2	2 bytes
ID	b1=16(10H)	Alarm message ID
RTOT	b1 b2 | | b6	Relative time of test
Level	b1	0 = warning, 1 = trip [C.E. 16,17]
AID	b1	Slarm ID
CID	b1	Channel number that generated the alarm
		0 if time alarm (C.E.)]
V	b1 b2 b3 b4	Value of the alarm (LSB)

ID 17 — Reserved

ID 18 — Reserved

ID 19 — Reserved

ID 20 — Reserved for Recording Pre-amp Gain
TRA 212 uses this as a sub-function code.

ID 21 — Reserved

ID 22 — Set Threshold

LEN	b1, b2	2 bytes
ID ID	b1= 22 (16H)	Set threshold value (dB) ID
CID	b1	Which channel
V	b1	byte value for threshold (MSBit = 1 float, = 0 fix)

ID 23 — Set Gain

LEN	b1, b2	2 bytes
ID ID	b1= 23 (17H)	Set gain value (dB) ID
CID	b1	Which channel
V	b1	1 byte value for gain

ID 24 — Set Hit Definition Time

LEN	b1, b2	2 bytes
ID	b1= 24 (18H)	Set Hit Definition Time (mS) ID
CID	b1	Which channel
V	b	low byte value
V	b2	high byte value in steps of 2 mS

ID 25 — Set Hit Lockout Time

LEN	b1, b2	2 bytes
ID ID	b1= 25 (19H)	Set Hit Lockout Time (mS) ID
CID	b1	Which channel
V	b1	low byte value
V	b2	high byte value in steps of 2 mS

ID 26 — Set Peak Definition Time

LEN	b1, b2	2 bytes
ID	b1= 26 (1AH)	Set Peak Definition Time (mS) ID
CID	b1	Which channel
V	b1	low byte value
	b2	high byte value in steps of 1 mS

ID 27 — Set the Sampling Interval

LEN	b1, b2	2 bytes
ID	b1= 27 (1BH)	Set the sampling interval (mS) ID
V	b1	low byte value
V	b2	high byte value in steps of 1 mS

ID 28 — Alarm Definition

LEN	b1, b2	2 bytes
ID	b1= 28 (1CH)	Alarm definition ID
j	b1	Number of alarm definition sent
Alarm #	b1	Which one is being defined
CID	b1	Which channel
Type code	b1	Type of alarm
CHID #	b1	AE characteristic used
Level 1	b1	Warning level
	b2	
	b3	|
	b4	
Level 2	b1	Trip level
	b2	
	b3	
	b4	j times

ID 29 — AE Filter Definition

LEN	b1, b2	2 bytes
ID	b1= 29 (1DH)	AE filter definition ID
k	b1	Number of filter definitions sent
Filter #	b1	Which one is being defined
CID	b1	Which channel
Type code	b1	Type of filter (scsh only)
CHID #	b1	AE characteristic used
Level 1	b1	Low level
	b2	
	b3	
	b4	
Level 2	b1	High level
	b2	
	b3	
	b4	k times

ID 30 — Delta-T AE Filter Definition
(INI and DTA, AEDSP board)

LEN	b1, b2	2 bytes
ID	b1 = 30	Location definition ID
FS		1 byte # of filter definitions to follow
FID		1 byte Delta-T filter ID number
BDID		1 byte Board number (2 channels per board) 0 = all boards 1 = first board (channels 1,2) 2 = second board (channels 3,4),etc
TYPE		1 byte type of delta-T operation = accept events (hit pairs) with delta-T between LOW and HIGH reject other events Only one type presently defined
INDHITS		1 byte independent hit control 0 = reject independent hits delta-T over CAL) 1 = accept independent hits
LOW HIGH EDT		4 bytes Low level in usec (signed long integer) 4 bytes High level in usec (signed long integer) 4 bytes Calibration time in usec (unsigned long) FS times

ID 31 — Reserved

ID 32 — Reserved

ID 33 — Reserved

ID 34 — Reserved

ID 35 — Reserved

ID 36 — Reserved

ID 37 - INI Write Protect Password
(INI file)

LEN	b1, b2	2 bytes
ID	b1 = 37	Location definition ID

MVERN		1 byte = Message version*100 e.g., V1.00=100
TOT		6 bytes (least significant first) Time of hit
SZPW		n bytes Zero terminated string

ID 38 - Test Information
(INI and DTA files)

LEN	1, b2	2 bytes
ID	1 = 38	Location definition ID
MVERN		1 byte = Message version*100 e.g., V1.00=100
ENEDIT		1 byte Enable edit of title fields
EDISPF9		1 byte Enable display of test info.at start of test
ZTITLE		n bytes Zero terminated string title
SZFIELD		n bytes Zero terminated string field

These two fields repeat for the duration of the message.
If there is no entry, the field will be 1 '0' byte as a placeholder.

ID 39 — Reserved (Not Implemented)

ID 40 — Reserved (Not Implemented)

ID 41 — Product Definition Message

LEN	b1, b2	2 bytes
ID	b1= 41 (29H) b2= 00	ASCII Product Definition ID high byte of ID (2 bytes)
PVERN	b1= pv# b2= 00	Product version number (2 bytes) MESSAGE FORMAT=100*Product ID ONLY FOR THIS ONE
TEXT	a1 a2 a3 | | an	SCII Product name, Carriage return, Line feed, Version number, Carriage return, Line feed

ID 42 — Hardware Setup

LEN	b1, b2	2 bytes
ID	b1= 42 (2AH) b2= 00	Hardware Setup ID high byte of ID (2 bytes)
MVERN	b1= fv# b2= 00	Message version number (2 bytes) (200. at the present)
LSUB 1 SUBID 1 SUBMSG 1		length of submessage 1 (2 bytes), submessage 1 ID (1 bytes), submessage 1 body

|

```
    |
LSUB I                              length of submessage I (2 bytes),
SUBID I                             submessage I ID ( 1 bytes),
SUBMSG I                            submessage I body
    |
    |
LSUB n                              length of submessage n (2 bytes),
SUBID n                             submessage n ID ( 1 bytes),
SUBMSG n                             submessage n body.
```

```
Note: Submessages are:
      Start of Test                         ID = 100 ( 64H )
      Set Sampling Interval                 ID = 27  ( 1BH )
      Set Demand Sampling Rate              ID = 102 ( 66H )
      Pulser Rate                           ID = 133 ( 85H )
      Event Data Set Definition             ID = 5   ( 05H )
      Demand Data Set Definition            ID = 6   ( 06H )
      Group Definition                      ID = 106 ( 6AH )
      Alarm Definition                      ID = 28  ( 1CH )
      AE Filter Definition                  ID = 29  ( 1DH )
      Group Parametric Assignment           ID = 110 ( 6EH )
      Group Settings                        ID = 111 ( 6FH )
      End of Group Settings                 ID = 124 ( 7CH )
      End of Setup                          ID = 101 ( 65H )
```

ID 43 — Graph Definition (*.INI file only)

```
LEN                 b1, b2              2 bytes
ID                  b1= 43 (2BH)        Graph Definition ID
                    b2= 00              high byte of ID (2 bytes)
MVERN               b1= fv#             Message version number (2 bytes )
                    b2= 00
Product Specific Information
```

ID 44 — Location Definition
(if found in a non-location data file, length is 1 or 2).

```
LEN                 b1, b2              2 bytes
ID                  b1= 44 (2CH)        ocation Definition ID
                    b2= 00              high byte of ID (2 bytes)
MVERN               b1= 200 (C8H)       Message version number (2 bytes )
                    b2= 00
Product Specific Information
```

ID 45 — Acquisition Control Information Product specific information (in the Multichannel AT products, "F8" information)

```
LEN                 b1, b2              2 bytes
ID                  b1= 45 (2DH)        Location Definition ID
                    b2= 00              high byte of ID (2 bytes)
MVERN               b1= fv#             Message version number (2 bytes)
```

	b2= 00
Product Specific Information	

ID 46 — Autorun Message — "Command" for Acquisition Program — Product specific information

LEN	b1, b2	2 bytes
ID	b1= 46 (2EH)	Location Definition ID
	b2= 00	high byte of ID (2 bytes)
MVERN	b1= fv#	Message version number (2 bytes)
	b2= 00	
Product Specific Information		

ID 47 — Reserved

ID 48 — Filtered File Information

LEN	b1, b2	2 bytes
ID	b1= 48 (30H)	Location Definition ID
	b2= 00	high byte of ID (2 bytes)
MVERN	b1= fv#	Message version number (2 bytes)
	b2= 00	
Text follows		Product specific subkeys & maybe some product specific keys (see Appendix A, Part 1)

ID 49 — Special Product Specific Information

LEN	b1, b2	2 bytes
ID	b1= 49 (31H)	Location Definition ID
	b2= 00	high byte of ID (2 bytes)
MVERN	b1= fv#	Message version number (2 bytes)
	b2= 00	
Product Specific Information		

Note: Messages from 50 to 53 are defined in some versions of LOCAN AT software. These messages will not be supported in LOCAN AT version 2.00 and higher.

ID 50 — Reserved

ID 51 — Reserved

ID 52 — Reserved

ID 53 — Reserved

ID 54 to ID 98 — Not Used

See 59 (V1.8) and C.E. specific MIDs

ID 59 — Turn Off Alarm Command from HE to mGCC

Version 1.8 supports this.

LEN	b1, b2	2 bytes
ID	b1= 59 (3BH)	Turn off alarm

ID 99 — Time and Date of Test Start

LEN	b1, b2	2 bytes
ID	b1= 99 (63H)	Time and date of test start ID
"Sun Jul 03, " (For Example)		ASCII date string,
"08:49:55 1988"		ASCII time and year string.

ID 100 — Begin Setup

LEN	b1, b2	2 bytes
ID	b1= 100 (64H)	Begin Setup ID

ID 101 — End of Setup

LEN	b1, b2	2 bytes
ID	b1= 101 (65H)	End of Setup ID

ID 102 — Set Demand Sampling Rate

LEN	, b2	2 bytes
ID	= 102 (66H)	Set Demand Sampling Rate ID
V		Multiple of Parametric Sampling Rate)
V		

ID 103 to ID 105 (Not Used)

ID 106 — Define a Group

LEN	b1, b2	2 bytes

ID	b1= 106 (6AH)	Define a group ID
Grp #	b1	Which group
# CHNs	b1	How many channels IDs in list
CHID1	b1	First channel id
CHID2	b1	
|		
|		
CHIDn	b1	Last channel

ID 107 — Reserved

ID 108 and 109 Not Used

(110) Group Parametrics Assignment

LEN	b1, b2	2 bytes
ID	b1= 110 (6EH)	Group parametrics assignment ID
# PIDs		Number of PIDs to follow
PID1	b1	First PID
|		
|		
PIDm	b1	Last PID

ID 111 — Group Settings

LEN	b1, b2	2 bytes
ID	b1= 111	Group settings ID
j		Number of group messages
[body 1]		Body of first message (ID # = 22-26)
[body 2]		Body of second message
[body j]		Last body

ID 112 to ID 123 — Not Used

ID 124 — End of Group Setting

LEN	b1, b2	2 bytes
ID	b1= 124 (7CH)	End of group message ID

ID 125 — Internal

ID 126 — Internal

ID 127 — Internal

ID 128 — Resume Test or Start Of Test

Test Start only when the Clear Clock was sent after Legal Setup and no intervening Resume, Stop nor Pause was sent. Normally the HE sends the messages sequentially.

LEN	b1, b2	2 bytes
ID	b1= 128 (80H)	Resume/start a test ID
(End of command)		
RTOT	b1 b2 | | b6	Relative time of test Added when message is built from the command. ALSO FOR STOP AND PAUSE messages

ID 129 — Stop the Test

len	b1, b2	2 bytes
ID	b1= 129 (81H)	Stop the test ID
{End of Command}		
RTOT	b1 b2 | | b6	Relative time of test

ID 130 — Pause the Test

LEN	b1, b2	2 bytes
ID	b1= 130 (82H)	Pause the test ID
{End of Command}		
RTOT	b1 b2 | | b6	Relative time of test

ID 131 — Configuration Status/Report (Response to Command Mess. 132)
NEW definition for PAC Bus 488 Inquire/Report (BOEING)

Len	b1 b2	Length of body
Message ID	131 (H)	MID byte
Prod ID or version.	a1 a2 a3 a4	ASCII Prod ID code (byte 1) byte 2 byte 3 byte 4
Prod Ver	b1 b2	Product Version Number (16 bits)

Product specific information follows

SPARTAN mGCC Response in version 1.8 is shown below

LEN	b1, b2	2 bytes
ID	b1=131	Status report message ID
	b1 b2 b3 b4	GCC version string (e.g., V1.8)
	b1 b2	GCC version number (e.g., 180)
	b1 b2 b3 b4	ICC version string (e.g., 2.11 or MIX)
STAT	b1	Test state code
AECH	b1 b1 | | bn	Number of active AE channels(=number of bytes to follow) number of first active channel number of last active channel
PCH	b1	Number of active parametric channels (= 4 for mGCC, 8 for PACbus)

The GCC valid states are 0 through 7.

0 Power Up	1 In Setup	2 Setup Done	3 T.O.T cleared
4 Active(Acq.)	5 Waiting	6 Test Paused	7 Stopped

ID 132 — Status Report (Command HE ® GCC) {C.E. only}

ID 133 — Pulser Rate

LEN	b1, b2	2 bytes
ID	b1= 133 (85H)	Pulser rate in milliseconds ID
v	b1	low byte of rate
	b2	high byte of rate

ID 134 — Reserved

ID 135 — Reserved

ID 136 — Analog Filter Definition
(INI and DTA files only, AEDSP software)

LEN	b1, b2	2 bytes
ID	b1= 136	
AFID	b1	First analog multi-filter ID number
HFS	b1	k = # of highpass filters to follow
HPF1	b2	First highpass cutoff frequency, in kHz
HPF2	b2	
|		
|		
HPFk	b2	Last highpass cutoff frequency, in kHz
LFS	b1	n = # of lowpass filters to follow
LPF1	b2	First lowpass cutoff frequency, in kHz
LPF2	b2	
|		
LPFn	b2	Last lowpass cutoff frequency, in kHz

Repeat above for as many different multi-filters as need to be defined

NOTE: one multi-filter is produced by the combination of available filters on a plug-in filter module with the fixed filters on the underlying board (e.g., AEDSP-32/16), if selections exist to bypass the plug-in filter.

Presently, only one combination is available. In the future, different options for plug-in and on-board filters may become available and will be described, per channel, in a modified configuration report message. At that point, the software will process the configuration report, determine all possible combinations, and generate this message.

EXAMPLE: Use this for first version of the code	
LEN	20
ID	136
AFID	1
HFS	4
HPF1	10 kHz
HPF2	20 kHz
HPF3	100 kHz
HPF4	200 kHz
LFS	4
LPF1	1200 kHz
LPF2	100 kHz
LPF3	200 kHz
LPF4	400 kHz

ID 137 - Analog Filter Selection
(INI and DTA files, AEDSP board)

LEN	b1, b2	2 bytes	
ID	b1 = 137		
CID		1 byte	Channel number, if 0 then all channels
AFID +		1 byte	Multi-filter ID type number, must be one defined with message 136
Highpass code		1 byte	0-15, in the order that is defined for the plug-in filter
Lowpass code		1 byte	0-15, in the order that is defined for the plug-in filter

NOTE: the AFID number is ignored by the AEDSP board, which will just take the highpass and lowpass selection codes and set the plug-in filter control lines to these codes.

ID 138 — Analog Parametric Setup
(INI and DTA files, AEDSP board)

LEN	b1, b2	2 bytes	
CID		1 byte	Channel number, if 0 then all channels
Gain code	0 = x 1 1 = x 10 2 = x 100 3 = x 1000	1 byte	
Filter code	0 = no filter 1 = filter ON	1 byte	

ID 139 — Cycle Counter Analog Setup
(INI and DTA files, AEDSP board)

```
LEN             b1, b2            2 bytes
CID                               1 byte   Channel number, for future expansion
Threshold                         2 bytes  Threshold in millivolts
      Range : -5080 to 5120
Source                            1 byte
   0 = parametric 1
   1 = filtered parametric 1
   2 = parametric 2
   3 = filtered parametric 2
```

ID 140–ID 170 (Not defined)

ID 171 — TRA Messages (TRA2.5)

ID 171 — TRA Messages 1(TRA212)

ID 172,29 — Digital AE Data Filter Definition
(INI and DTA, AEDSP board)

```
LEN                b1, b2            2 bytes
ID                 b1 = 173          Message ID
Sub-ID           b1 = 29             Submessage ID
```

Exact copy of the body of ID 29 message (AE filter definition):

```
FS                     1 byte   # of filter definitions to follow
FID                    1 byte   Waveform filter ID number
CID                    1 byte   Channel number
TYPE                   1 byte   Type of filter operation
                                1 = SCSH (single channel, single hit)
                       Only one type presently defined
CHID                   1 byte   AE characteristic
                                0 = none (reject all waveforms)
                                1 = risetime, 2 = counts to peak,
                                3 = counts,   4 = ICC energy
                                5 = duration, 6 = amplitude
                                13 = average frequency
LOW                    4 bytes  Low level in msec (signed long integer)
HIGH                   4 bytes  High level in msec (signed long integer)
                                                         FS times
```

Will determine which hits are eligible to be recorded as waveforms

To block all waveforms, the AE characteristic (CHID) is set to 0 and the LOW and HIGH limits are also set to 0.

172, 42 Hardware setup

LEN	b1, b2	2 bytes
ID	b1 = 172 (ACH)	Message ID
Sub-ID	b1 = 42 (2AH)	Message sub-ID
MVERN	b1 = 100 b2 = 0	Message version number, 100 is V 1.00
ADT	b1	A/D converter data type 2 = 16 bit signed (only type currently defined for MI-TRA)
SETS	b1 = n b2	Number of TRA channels (setups)
SLEN	b1 b2	Size of hardware setup, in bytes
TRA setup 1		
CHID	b1	Channel ID. If 0, setup for all channels
HLK	b1 b2	Hit length, in K samples (K = 1024)
HITS	b1 b2	Not used for MI-TRA.
SRATE	b1 b2	Sampling rate, in kHz (8000, 4000, 2000, 1000, 500, 200, 100)
TMODE	b1 b2	Trigger mode 0 = individual
TSRC	b1 b2	Trigger source 1 = digital
TDLY	b1 b2	Trigger delay in samples (negative is pretrigger)
MXIN	b1 b2	Maximum input voltage 10 = 10 Volts, only one for AEDSP
THRD	b1 b2	Trigger threshold in dBae
TRA setup 2		
|		As many setups as necessary
TRA setup n		

ID 172,134 - Reserved

ID 173,1 — Digital AE Waveform Data
(DTA file, AEDSP board)

LEN	b1, b2	2 bytes
ID	b1 = 173	Message ID
Sub-ID	b1 = 1	Submessage ID
TOT		6 bytes (least significant first) time of hit
CID		1 byte Channel number
ALB		1 byte Alignment byte (dummy)
N		2 bytes Number of 16-bit samples following

s1	2 bytes First sample of waveform
s2	2 bytes Second sample
|	
sN	2 bytes Last sample
AEF	Many bytes Copy of part of message 1 after CID (AE features and TD data)

ID 173,3 — Digital AE Power Spectrum Data (AEDSP board)
Reserved for external use

ID 174 to ID 196 — Not defined

ID 197 IDIBVALSCRN — Screen Template for Display of Improved b-Value data

LEN	b1, b2	2 bytes
ID	b1	Message ID byte
VID	b1	Version of the current message
b1		TRUE/FALSE flag Controls which event plot is shown
b2		not used
|		struct graph_def array defines the special graphs
|		
bn		

ID 198 IBVALCALC — Improved b-Value Calculation Definition

LEN	b1, b2	2 bytes
ID	b1	Message ID byte
VID	b1	Version of the current message
b1		First byte of the information which contains
|		the user setting to control the b-value
|		calculations.
bn		

ID 199 — Internal

ID 200–ID 254 — Reserved for Application Programs
(See MID = 211)

ID 211 — Time Mark [Command] ® mGCC
(Lets the user make a time mark in the data set to indicate when some special

action or external event occurs.)

ID 211 — (Extended) Time Mark Message(s) (Time Stamp)

```
LEN              b1, b2              2 bytes
ID               b1= 211 (D3H)       Time mark ID
RTOT             b1                  Relative time of test
                 b2
                 |
                 |
                 bn                  (n = 6 if MONPAC, SPARTAN, ...
                                     (n = 4 if TRANSPORTATION)*
```

```
IF LEN = (5 or) 7, then the 211 message is a plain time mark message.

IF LEN >7, then it is a SPARTAN-AT style Extended time mark.  Version
  1.54 and higher of the mGCC will send to the high end gain and threshold
  changes with the Time Of Test stamp.

Extended message:  Len = 7 + total length of the appended message.
                   Body of 211 message                   (7 bytes)
                   Len of appended message   Body length (2 bytes)
                   Body of appended message  {Total is 2+Body}

The "unnecessary" length of the appended message is so that appended
message can be processed as though it didn't have a time stamp (i.e.
skip the first 9 bytes and pass the rest onto the message processing
for appropriate message type).

*NOTE:  The Transportation Instrument does not have extended messages.
```

ID 220 & ID 221 — Reserved for Boeing Programs

```
NOTE:  Short Hand   W == Word, DW == Double Word, TW == Triple Word

    W1      Length of Message
    B       Message ID      = 206
    W       SubFunction Code [0-8]
    X       subfunction body
           ______________________________
            SubFunction 0:          Velocity conversion Factor
            DW                      Value

            SubFunction 1:          Display Limits
            DW                      Value {Horiz. Low Lim}
            DW                      Value {Horiz. High Lim}
            DW                      Value {Vert. Low Lim}
            DW                      Value {Vert. High Lim}
    Opt.[   DW                      Value {Depth Low Lim}
            DW                      Value {Depth High Lim}
           ]
            SubFunction 2:          Sensor Position
            DW                      Horiz. Value
            DW                      Vert. Value
    Opt.[   DW                      Depth Value
           ]
           SubFunction 3:           Event Data
           W                        +1 Start  -1 Stop
           SubFunction 4:           Channel Timing
           W                        CID (Channel ID)
           TW                       6 byte Time
           W                        Time to Peak
           SubFunction 5:           Turns ON/OFF S100 Data Display
           W                        1 == ON , else OFF
           SubFunction 6:           Special 3-D algorithm control values
           SubFunction 7:           Special 3-D setup Command to Draw
                                    Either (1) All Sensors or (2) Last one
           SubFunction 8:           Use Rise Time in 3-D location calculate
           W                        1==Yes, 0==No
```

ID 255 — Reserved

ID 255 — Reserved

4. SUMMARY:

Condensed System Messages & Commands

Id	Description
1	AE hit/Event Data
2	Time Demand Data
3	Sample/Last Time Demand Data
4	GCC detected an error condition.
5	Hit Data Set Definition
6	Time driven/Demand Data Set Definition
7	User Comments/Test Label
8	Continued File Mark
9–10	Not Used
11	Reset Real Time Clock
12	Reserved
13–14	Not Used
15	Abort acquisition/transfer
16	Alarm Data
17	Reserved
18	ICC self test (Internal)
19	Single ICC Reset (Internal)
20	{Reserved for pre-amp gain}
21	(AST messages)
22	Set Threshold
23	Set Gain
24	Set Hit Definition Time
25	Set Hit Lockout Time
26	Set Peak Definition Time
27	Set Parametric Sampling Time
28	Alarm Definition
29	Filter Definition
30	AEDSP Delta-T AE Filter Definition
31	Reserved
32	High end Alarm Detected (Internal)
33–36	Reserved
37	INI Write-Protect Password
38	Test Info
39–40	Reserved
41	ASCII Product Definition
42	Hardware Setup
43	Graph setup (*.ini file Only)
44	Location Setup
45	Acquisition Control Information
46	Auto Run Message
47	Reserved
48	Post Filter Definition and Information
49	Product Specific Setup & Configuration Information
50	Reserved
51	Reserved

Id	Description
52	Reserved
53	Reserved
54–58	Not Used
59	Ignore Alarm" - HE command to mGCC
60–98	Not Used
99	Time and Date of Test Start
100	Begin setup
101	End Setup
102	Set Demand Data Sampling Rate
103–105	Not Used
106	Begin a Group Setup
107	Reserved
108–109	Not Used
110	Define Group Parametric Channels
111	Group Parametric Settings (msgs 22-26)
112–123	Not Used
124	End of Current Group Setup
125	Internal
126	Internal
127	Internal
128	Begin Test
129	Stop Test
130	Pause Test
131	Configuration report [PRODUCT SPECIFIC]
132	Status report [PRODUCT SPECIFIC]
133	Pulser Rate
134	Reserved
135	Reserved
136	Analog Filter Definition (INI and DTA Files only, AEDSP software)
137	Analog Filter Selection (INI and DTA Files only, AEDSP board)
138	Analog Parametric Setup (INI and DTA Files only, AEDSP board)
139	Cycle Counter Analog Setup (INI and DTA Files only, AEDSP board)
140–170	Not Used
171	TRA2.5
172	TRA212
173	AEDSP waveform recording
174–196	Not Used
197	Screen template for display of improved b-value data
198	Improved b-value calculation definition
199	Internal
200–203	Not Used
204–210	Reserved
211	Time Mark (also in the MONPAC and Transportion Instrument)
220-221	Reserved {Boeing}
222-254	Not defined
255	Reserved

APPENDIX III

System Defect Report

Group Headquarters:
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Princeton Junction, NJ 08550
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Group Offices Worldwide:
• Athens • Paris • Cambridge • Moscow
• Rotterdam • Tokyo • Beijing • Navi Mumbai
• Kuala Lumpur • São Paulo • Buenos Aires•
Philadelphia • Houston

3/12/07 MISTRAS GROUP Inc.

SYSTEM DEFECT REPORT and PRODUCT ENHANCEMENT REQUEST

Physical Acoustics Corporation (PAC), NDT Automation (NDTA) and Vibra•Metrics are member companies of MISTRAS Group Inc (MISTRAS). In an effort to provide continuous improvement on our products (including hardware and software) and to solicit your idea's regarding product enhancements that will help make your use of our product easier and more enjoyable, we provide this "System Defect and Product Enhancement Request Report" for you. We appreciate your comments, suggestions and concerns and promise to evaluate all of your requests. We ask you to use this form whenever you feel the need. Additionally, we have included our email and web page addresses for correspondence and information over the internet.

Hardware ____ Software ____ (Check One)

Name:______________________________ Date:____________

Company:____

Address:____

____

____

Phone:_____________________________ Fax:_____________________________

System Name/Model #:__________________________ System S/N #:_______________

Software Title:_______________________________ Version #:_________________

Software Release Date:__________________________

Defect Description:____

____

Please send attention to: **Customer Service Manager**

MISTRAS Group Inc.
195 Clarksville Road
Princeton Junction, NJ 08550-5303

Or:

E-mail report to: Customerservice@pacndt.com
Fax # : (609)716-0706
Web pages: www.ndtautomation.com, www.pacndt.com and www.Vibrametrics.com

This area to be filled in by MISTRAS Group Inc.

Verified by:___________________________ Date:_________________________

Additional MISTRAS Comments:

ADDENDA TO THIS MANUAL

From time to time PAC may send out addenda to this manual to keep you informed of the latest changes. Please place the addenda in this section.