

Acoustic Emission System

AMS Y-5

System Description

AMS Y-5 = Acoustic Emission Measurement System,

high-speed ♦ user-friendly ♦ high performance ♦ very flexible



Figure 1: AMS Y-5 Master Unit M37-2

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1 Acoustic Emission Overview

Acoustic Emission (AE) testing is a powerful method for examining the behavior of materials deforming under stress. Materials 'talk' when they are in trouble and with the AMSY-5 AE-instrument you can listen to the sounds of crack growth, phase transitions, leakage, friction (both external and by crack surfaces), yielding, fiber-breakage, debonding, corrosion, wear, capacitive (or partial) discharge, cavitation, impact, etc.

Everyone is familiar with AE as heard from wood cracking and glass breaking, however AE equipment as the AMSY-5 can monitor many more useful non-audible emission phenomena. The AMSY-5 is an advanced AE system as it possesses the ability to detect all these AE sources but with improved sensitivity using state-of-the-art 32-bit software tools.

AE activity is detected when a mechanical wave propagates to an AE sensor. In contrast to audible AE, each measured AE signal appears as an electrical signal that can be seen on an oscilloscope or a transient recorder display. Typically AE appears as a wave packet (burst) that increases, reaches one or more peak amplitudes and then decreases. AE is typically monitored above the audible frequency range (often 100-1000 kHz) with a resonant piezo-electric sensor, but the AMSY-5 can work with many more sensor types and in a frequency range from 5 kHz to 3 MHz.

1.1 AE Measurement and the AMSY-5

The AMSY-5 is mainly used to measure and analyze discrete AE signals that cross a pre-defined fixed or floating threshold. In addition to discrete AE, the AMSY-5 can monitor and analyze continuous AE, produced by leaks and wear, for example.

The AMSY-5 converts each wave packet received by each channel into a set of numerical features describing the signal. Important signal features include: arrival time, peak amplitude, energy, rise time, counts and duration.

For the location of a defect in a structure, sensors can be mounted at many different positions on the tested object. The propagation times between the AE source and each sensor will give a series of time differences. By using these time differences, the AMSY-5 software can calculate the source location. The AMSY-5 also groups AE signals from a common source as "events" (each individual signal is called a "hit," regardless of how it is grouped).

Both hits and events can be filtered, classified, accumulated and clustered. Results are displayed graphically and/or numerically, either during the test (on-line) or during posttest analysis (off-line).

The AMSY-5 is the fourth generation of fully digital AE-systems developed by Vallen Systeme since 1985. It incorporates the experience and feedback received from users of the previous generations of digital AE-systems AMS2 (introduced 1986), AMS3 (introduced 1991), and AMSY4 (introduced 1996). AMSY-5 consists of very powerful hardware which includes: fast and accurate analogue to digital converters (40 Mega samples per second with ASIP-2), field programmable gate arrays, digital signal processing chips, the very fast ASyC (AE System Controller) PCI interface board, an external PC (e.g. desktop, lunchbox, panel,...), plus a very complete, flexible and easy-to-use software package. The software provides: system control, parameter management, data acquisition & recording, data analysis, source location, filtering, clustering, presentation and documentation of the measured data. Since this software is derived from the powerful and mature AMSY4 software package, the AMSY-5 offers a mature software package from the beginning.

1.2 Uses of AE

Each AE source listed in paragraph 1 of Acoustic Emission Overview represents one or more applications (uses) of an AE instrument. Some examples include integrity analysis that relies on detection of cracks and other defects, leak monitoring accomplished through leak detection and material process monitoring which can use phase transitions detection. Signal features may indicate the source mechanism (cracking, friction...) and help to distinguish the interesting AE signals from undesired noise.

With the help of the AMSY-5 system, the AE phenomenon can be used for the non-destructive inspection of small and large-sized structures, such as pressure vessels, pipelines, bridges, storage tanks, and for other components for which the early detection of reduced structural integrity is important.

By discovering hidden failures, even at inaccessible locations of a structure, damage can be prevented: this is one of the major achievements of the AMSY-5.

2 Hardware Overview

The AMSY-5 is a multi-channel AE system consisting of parallel measurement channels. Each channel combines an analogue measurement section, digital processing of the signal and communication to the systems front-end, which is a powerful PC with a complete set of peripherals.

The analogue measurement chain of each channel consists of an AE sensor, a preamplifier and one channel of an ASIP-2 (Dual channel AE Signal Processor), plugged into the system case. The AE-sensor picks up the stress wave from the structure, converts it into an electric signal that is then amplified by a preamplifier nearby. In the ASIP-2, the AE-signal received from the preamplifier is converted into a digital data stream.

AE-features such as time of the first threshold crossing (arrival time), risetime, duration, peak amplitude, energy and counts are extracted by the ASIP-2. In parallel to the feature extraction, the complete waveform can also be stored in an optional transient recorder module.

The AE-feature data as well as parametric data, such as load, strain temperature, etc. are temporarily stored in the memory of the ASyC (32MB) and then transferred to the PC.

In parallel to transferring the AE data the ASyC can read the waveform data from the ASIP-2's optional transient recorder and transfer it to a TRA-file (transient data file) on the PC hard disk. TR-Features can be extracted from the time or frequency domain of the waveform data and be analyzed in combination with the traditional AE-data (online as well as offline).

During data acquisition, or later, after the test, the data can be analyzed and displayed in various different plots on the screen of the PC.

Figure 1 shows the front of a 74-channel AMSY-5 system, illustrating its user-friendliness, compactness and comprehensiveness.

Each ASIP-2 front panel gives the user easy access to 2 BNC connectors for preamplifier connection and one switch to toggle audio-selection per channel on and off. ASIP-2 gives the following status information on 4 bi-color-LEDs:

- Threshold crossing detected
- Amplitude saturation detected
- Channel selected for audio or test-pulse-through
- Preamplifier connected
- Preamplifier supply overloaded
- Input mode DC@50R or AC@100K

More details about the front panel elements will be given later in this document.

On the left of the upper row of ASIP-2's the special feature plug-in AMSY-5-SF can be seen. There are 4 (isolated) BNC connectors for 4 isolated parametric inputs, each one with a range selection switch for 1 V or 10 V. There are also front panel controls for the audio output and the pulser amplitude. The SF-plug-in incorporates a pulser control that receives pulser commands from the PC and controls a pulse amplifier in the system to generate either single pulses or pulse trains up to 400V_{pp} in amplitude.

On the left of the SF-module, the Control Panel AMSY-5-CP can be seen. It provides additional status LED's; two switches for enabling/disabling the recording of AE and/or transient data and a speaker to make audio signals audible.

On the very left the front panel AMSY-5-SM (Supply Monitor) with the power switch shows LED's for AC on and DC ok.

An "Externals" connector providing access to various inputs and outputs is on the backside.

The built-in power supply is optimized for lowest possible noise.

Not seen in Figure 1 is the ASyC (AE System Controller) that is used to assemble data and send it to the PC for further data analysis.

The block-diagrams in the appendix will help in understanding the system concepts of the AMSY-5.

2.1 Acoustic Emission Preamplifier

The acoustic signal is received by the AE sensor and fed electrically to a preamplifier nearby. The amplified AE signal is transmitted along a coaxial cable to the ASIP-2 plug-in in the AMSY-5 system case. The coaxial cable can be several 100 m long. Vallen Systeme offers three preamplifier models: AEP3, AEP4 and integrated preamplifiers in some sensor models. A number of derivatives exist of AEP4 and the integrated preamplifiers. A block diagram of the AEP4 preamplifier is shown in Appendix 5.5.

In low-noise applications, the very first amplification stage of the measurement chain determines the quality of the complete measurement chain. Subsequent stages of the measurement chain amplify not only the desired signal, but also the noise from the first amplification stage. The best signal-to-noise ratio is achieved with a high gain of the very first amplification stage.

On the other hand, when high input voltages are expected, a high gain of the first stage would saturate the measurement chain, hence the gain of the first stage must be lowered for high-level applications.

AE applications are so diverse that a fixed gain of the very first stage of the measurement chain might not be the optimum for all applications.

The AEP3 preamplifier offers the most flexible and best possible solution for that requirement; the gain of the very first stage in the preamplifier is software programmable for a total gain of 34dB to 49dB.

The gain can be adapted to the current needs by software and is automatically taken into account when the amplitude, the threshold, the energy and the RMS-noise are calculated.

The AEP3 preamplifier's frequency range is 20kHz to 2MHz, normally limited by very sharp high-pass (54dB/octave) and low-pass plug-in filter modules as required by the application.

The model AEP4 preamplifier is a lower cost alternative that does not offer the programmable gain function or the sharp filtering. It has a wideband response from 3 kHz to 3 MHz that is suited under the assumption that the necessary filtering is done in the ASIP-2 board. The preamplifier's low noise, in combination with the high resolution of the ASIP-2, at fixed gain of 34 dB (can be jumpered to 40dB) it suits most of the applications. While the AEP3 offers connectors for single-ended and differential sensors, the AEP4 supports single ended sensors only.

The test-pulse-through capability is another unique feature of the preamplifiers AEP3 and AEP4: Test pulses can be passed through the preamplifier up to the sensor.

The AEP3/AEP4 preamplifier is connected to the ASIP-2 board in the system case by a single coaxial cable over which the preamplifier supply (28V_{DC}), the amplified AE signal, the gain control information and test pulses are transmitted.

Instead of a separate preamplifier, a sensor with integrated preamplifier can be used. The available integrated preamplifiers do not provide a programmable gain and the sharp frequency filtering. Most of them provide the test-pulse-through feature. The AEP4-IS combines a low-noise preamplifier with 400Vpp test-pulse-through capability with an integrated, spring-loaded sensor and a strong 3-point magnet holder.

2.2 AE Signal Processor ASIP-2

Two versions of ASIP-2 are offered: ASIP-2/S as standard version and ASIP-2/A as advanced version. The following describes the advanced version and notes which functions are not included in the standard version.

As the ASIP-2/A block diagram in the appendix 5.1 shows, each channel can be set to one of four possible input modes:

The normal input mode is "28V@50Ohm" what means that the BNC connector delivers 28V DC supply for the preamplifier and employs an input impedance of 50 Ohm.

Specifications are subject to change as product developments are made

When the input mode “**AC@100K**” is selected by software, the channel does not deliver any DC and employs an input impedance of 100kΩ. In this mode, several channels can be connected in parallel to one preamplifier and only one of them must be set to 28V@50Ohm. This is helpful, if one sensor signal shall be acquired using different thresholds and/or different filters.

With the input mode “**8-28V@200R**”, the DC voltage for preamplifier supply is programmable in the range 8 to 28V and the input impedance is 200 Ohm. (Available with ASIP-2/A).

With input mode “**8-28V@50Ohm**”, the DC voltage for preamplifier supply is programmable in the range 8 to 28V and the input impedance is 50 Ohm (Available with ASIP-2/A).

The preamplifier signal of each channel is fed over a programmable gain (x 1, 2, or 4), over an analogue high-pass and a 2.4MHz antialiasing low-pass filter to the Analog-Digital-Converter (ADC). ASIP-2/S offers gain 1 only, and that results in an input range of $5 V_P$ ($10 V_{PP}$).

The high-pass filter is switch-selectable to a corner frequency of 18kHz (normal) or 1.6kHz (for very special low-frequency applications).

The ADC converts the filtered signal at 40 MHz sample rate with 16 bit resolution. A 27-tap FIR filter behind the ADC reduces ADC-noise and expands the dynamic range to 18 bit.

Application specific frequency filtering is done in digital technology on the output of the ADC. This concept offers three main advantages:

1. For any kind of application, the optimum bandwidth can be selected without touching the hardware.
2. With low bandwidth applications, e.g. tank floor testing, the system noise can be drastically reduced compared to earlier models, since the ADC noise is filtered out as well.
3. With same filter setting, there is zero tolerance of filter behavior between the channels.

One of about 500 bandpass filters can be selected with ASIP-2/A at any time. ASIP-2/S comes with high-pass frequencies of 25, 50, 95 and 230 kHz and low-pass frequencies of 45, 300 and 850kHz. A bypass to the bandpass filter is also included. Any additional bandwidth option for ASIP-2/A can be purchased for ASIP-2/S.

Both, high-pass and low-pass filters are 8th order: they provide a roll-off attenuation of 48dB/octave.

Filters for 40 MHz AE-sample rate (feature extraction processing rate) are of 4th order providing a 24 dB/octave roll-off.

ASIP-2/A offers an additional filter stage which can be configured as a notch filter that blocks one, two or 4 user-defined frequencies, up to 2.5% of the AE sample rate.

The output of the digital filter goes to the AE-feature extraction. The routines for feature extraction are given by firmware and can be updated in the course of future developments.

The following features are processed: Arrival time, peak amplitude, risetime, duration, counts, true energy or signal strength, and background noise (before a hit) as true RMS or absolute average level. If true energy and true RMS mode is selected the AE signal is digitally squared, otherwise the digitally rectified value is further processed.

The resulting feature values are stored in the subsequent buffer memory from where it is read and processed by the ASyC.

Parallel to the feature extraction the digitally filtered AE signal goes to the optional transient recorder storage and to the audio-selection sub-system.

The optional transient recorder storage module is an add-on module for the ASIP-2. It has a very flexible choice of trigger configurations. It stores the waveform of AE-signals. Options for 8 or 256 MB or 1GB per channel are offered. Lots of waveforms can be temporarily buffered and are then transferred to the PC over the ASyC during data acquisition.

When the audio-selection LED at the ASIP-2's front panel is lighting green, the filter output is sent over a separate bus to the audio DAC on the SF-module. There the signal envelope of all selected channels is converted to an analogue signal which is made audible by the speaker in the control panel AMSY-5-CP.

2.3 Special Feature Unit AMSY-5-SF

The block diagram of the AMSY-5-SF special feature board (see appendix 5.3) shows the functions implemented on the SF-unit:

- Measurement of 0, 2, 4 or 8 parametric inputs, such as for load, temperature, crack opening, etc. (a PBx option must be chosen for this)
- Generating pulses for the sensor coupling test or acoustic ultrasonic applications via a pulse amplifier in the master unit.
- Receiving the maximum AE-signal of selected channels and converting it into an audible signal played over the speaker in the control panel AMSY-5-CP.
- The SF-boards of interconnected AMSY-5 Master Units can be used up to 8 PAX inputs.

The SF module, like the ASIP-2 plug-in, is a Eurocard module plugged into the front of the AMSY-5 system box.

It can provide 0 (no PBx option), 2 (with option PB2) or 4 (option PB4) parametric inputs. For needs of more than 4 parametric inputs the option PB8 can be delivered. It provides 8 inputs but occupies the space of one ASIP-2 on the right of the SF-panel. The master case can then house two channels less.

Each parametric input is isolated against ground to avoid ground loop problems. Each parametric input has a strong, user-friendly BNC connector at the front panel, a 1V / 10V-range selection switch, a differential input, an input filter with a jumper-selectable 3dB-frequency limit (16 Hz or 180 Hz), and a 16-bit 100 ksample/s ADC.

Each parametric input is protected by a 100 V-varistor against common mode over-voltages and by a 33 V-varistor against normal mode over-voltage.

A FPGA controls the ADC's of the parametric inputs and stores the data in an ASyC-readable FIFO buffer.

The parametric values can be displayed versus time, and/or in any combination with AE data, and can be used for filtering of AE data. Parametric data sets are created at an adjustable rate (100 Hz to 5 kHz) and added to hit data sets. While AE signals are not arriving, parametric data sets are generated at user-defined time intervals, e.g. once every second, to ensure that plots, such as Load versus Time, show data in sufficient time resolution even when there are no hits detected.

Beside of the parametric inputs, the parametric data set contains the parametric counters PCTA, PCTD and PCTE and the CYSL flag as described later in this chapter.

In the software, the analog inputs are identified by the abbreviations "PA0" to "PA7". The corresponding BNC inputs on the front panel of the parametric unit are labeled accordingly.

The parametric input PA0 can be selected for counting load cycles. The parametric counter "PCTA" (parametric counter, analog controlled) is incremented, when the PA0 input voltage crosses a user-defined trigger-level. A user-defined hysteresis prevents counter-triggering by noise. Instead of the 16-bit counter PCTA, a 32-bit counter PCTE can be used for load cycle counting.

If PCTE is not used, an additional 16-bit parametric counter with 4 digital inputs is provided as described later. The values of either parametric counters, PCTA (16 bit) and PCTD (16 bit), or PCTE (32 bit) are included in the parametric data set.

A flag called "CYSL" (cyclic load's slope) reflects the direction of the movement of the analog input voltage at PA0. CYSL can be used as filter criterion distinguishing events, generated during increasing load, from events, generated during decreasing load.

PA0 can also be used to control the data recording: When the voltage at the selected input is outside the user-defined limits, data recording is disabled.

The control for sensor coupling test pulser is also part of the special feature unit. Pulser commands from the PC are converted into pulses, amplified over the system internal pulse amplifier and fed out either at a BNC connector at the rear panel or sent to a sensor via the pulse-through feature of a selected AE-channel. The pulses are adjustable in amplitude (manually in local mode, or software selectable in remote mode) from 4 to 400V_{pp}. Two frequency ranges for the pulses can be software selected. Normal: 90-210kHz and Low: 30-210kHz (-12dB points).

Specifications are subject to change as product developments are made

To inject as much energy as possible into the structure, the SF-PU can generate a programmable number of pulses (1 to 15) in a single pulse train (burst).

2.4 Control Panel AMSY-5-CP

This panel has an internal speaker for audio output, 2 record enable/disable switches and LED's for: AE-disable, TR-disable, External disable, Running, Warning, Alarm, and 2 spare LEDs for future developments.

2.5 Externals Connector

The "Externals" connector is a 15-pole male D-connector which allows for external record control and control of the parametric counter PCTD. One can also connect an external speaker (in parallel to the internal speaker in the unit). This connector inputs and outputs the following signals over the following pin numbers:

Pin	Signal	Pin	Signal	Meaning
1	Return line for pin 9	9	Speaker	External speaker amplifier, connected to internal speaker over 100R. Voltage limited to range 0..5V by internal ESD-protection circuit
2	Return line for pin 10	10	CAL-DAC	Outputs the DA-converted pulse amplitude control signal (only for system checkout, 0...+5V)
3	GND	11	PCTD-Clock	Any transition (H->L or L->H) increments or decrements the parametric counter PCTD, depending on the other inputs of the PCTD. Operates only, if the system is running.
4	GND	12	PCTD-up/down	High or open: causes that PCTD increments, Low: causes that PCTD decrements, when PCTD-clock changes H-L or L-H
5	GND	13	PCTD-enable	High or open: enables incrementing/decrementing of PCTD, Low: a transition at PCTD-clock does not change PCTD
6	GND	14	PCTD-reset	High or open: PCTD is set to 0 Low: PCTD stores the current value
7	GND	15	ETRIG	Spare for future use
8	/DISABLE			Low disables AE- and TR-recording and lets the LED "Ext. Dis" shine

Note: Pin 1,2,9,10: are outputs, no external voltage shall be applied at these pins.

Pin 8, 11 to 15: are TTL inputs. Only voltages between 0 and +5V against pins 3 to 7 (ground) are allowed at these pins, and only when the unit is powered and switched on, otherwise permanent damage might occur. Open pins are high. All signals are limited to the voltage range 0...5V by internal ESD protection circuit that protects internal electronics against electrostatic discharge transients up to 15kV (human body model)

2.6 Alarm/Warning Connector

This is a 9-pole female D-connector. It grants access to the following signals over the following pin numbers:

Pin	Signal	Pin	Signal	Meaning
1	+5V			to supply external logic. CAUTION: permanent DAMAGE may occur if a) pin 1 is connected to ground or b) pin 1 is connected to pins 6-9 over less than 333Ohm
2	GND	6	ALARM	low when ALARM LED is on, otherwise pulled up to 5V by 10 kΩ
3	GND	7	WARN	low when WARNING LED is on, otherwise pulled up to 5V by 10 kΩ
4	GND	8	SP0	low when SP0 LED is on, otherwise pulled up to 5V by 10 kΩ
5	GND	9	SP1	low when SP1 LED is on, otherwise pulled up to 5V by 10 kΩ

Note: Pin 6 to 9: each drives up to 15mA to +5V, means minimum allowed resistance between Pin 1 and each of the pins 6 to 9 is 333Ohm. A lower resistance, or a short cut, may cause permanent damage. All signals are protected against electrostatic discharge of up to 15kV (human body model)

2.7 Switch (SW)

At this switch the address of the AMSY-5 unit is defined. In addition, it lets the user disconnect the internal pulser from the pulsing bus. (The BNC cables that connect all BNC connectors "Pulse out /in")

Sw		ON	OFF	Meaning
6	Pulse	out	in	Both switches (5 and 6) must be either ON or OFF. If ON, the internal pulser output is connected to the BNC connector "Pulse out/in" and makes that connector an output.
5	Pulse	out	in	At extension units these switches must be OFF. At the master unit with the lowest address (defined by switches 1-4), the switches 5 and 6 must both be set to ON, if the internal pulse shall be used. At all other units, switches 5 and 6 must be set to OFF.
4	Addr 3	0	8	Define any address (1 to 14) of an AMSY-5 unit as sum of the weight of each switch set to OFF. Example: Switch 4:ON (0), 3:OFF (4), 2:OFF (2), 1:ON (0) defines Addr = 0+4+2+0 = 6. Each unit must have a unique address. The master unit with the lowest address acts as master unit, the others as extension units. Address = 0 and 15 are not allowed.
3	Addr 2	0	4	
2	Addr 1	0	2	
1	Addr 0	0	1	

Note: AMSY-5 software automatically detects address duplicates and illegal address settings.

2.8 AMSY-5 Rack Driver

As shown in the AMSY-5 block diagram (see appendix), the AMSY-5 Rack Driver links the ASIP- bus (at the rear of the AMSY-5 unit), in which one or more ASIP-2s and an AMSY-5-SF unit is installed, with the external ASyC-Bus and the control panel AMSY-5-CP.

The Rack Driver supports multiple AMSY-5 Master Units and/or Extension Units. These are then fully synchronized so that location calculation can be made between channels of different units.

The Rack Driver also provides a special trigger function for the transient recorders, the Pool Trigger: The first threshold crossing of any channel in the pool immediately triggers all transient recorders of the pool. The Pool Trigger function supports multiple Master-/Extension Units. This feature helps to evaluate delta-t's between channels in noisy environments by using cross correlation techniques.

2.9 ASyC – AE System Controller

The ASyC is a half size PCI interface board to be mounted in an external PC. The ASyC comprises a PowerPC processor and large (32MB) memory for intermediate data storage prior to transfer to the PC.

Since the PC runs under Windows 2000®/XP® which are no real time operation systems; it is very important that the ASyC has enough temporary storage space to cover time periods when the CPU is not available for data transfer. However, the AMSY-5 data processing scheme is designed such that data can never go lost.

Before any buffer fills up, the channel group is set into a so-called “long rearm mode” during which only the most important data will be acquired until enough data is transferred and buffer space is again available.

During signal pauses, the ASyC calculates the floating threshold by multiplying the RMS value of the background noise by a user-defined factor. The user can define a minimum value for the floating threshold. The ASyC is mounted to the PCI bus like any other standard board.

2.10 External PC

The AMSY-5 requires an external PC to which it can easily be connected by cables CBL1-x.x, using a rugged plug.

Any kind of PC, e.g. desktop, lunchbox, 19” rack industry standard PC can be used. Thereby the system can easily be upgraded to latest PC technology. A notebook can be used in combination with either a docking station or a Cardbus-to-PCI-Extender.

Please find the minimum PC requirements in the AMSY-5 System Specification (section External PC).

2.11 AMSY-5 Units

Three different Master Units M6-2, M16-2, and M37-2, for up to 6, up to 16, or up to 37 ASIP-2s, are available. Additionally an Extension Unit E20-2 for up to 20 ASIP-2 boards is available.

The AMSY-5 units are described in detail in the AMSY-5 System Specification document.

3 Software Overview

The AMSY-5 software is well-proven native 32 bit software designed for the Windows 2000® or XP® operating system. Its multitasking capabilities allow for running several tasks in parallel. Its reliability secures safe data recording.

The Vallen Control Panel is the central control unit of Vallen Systeme software. From here the user starts the data acquisition and analysis software.

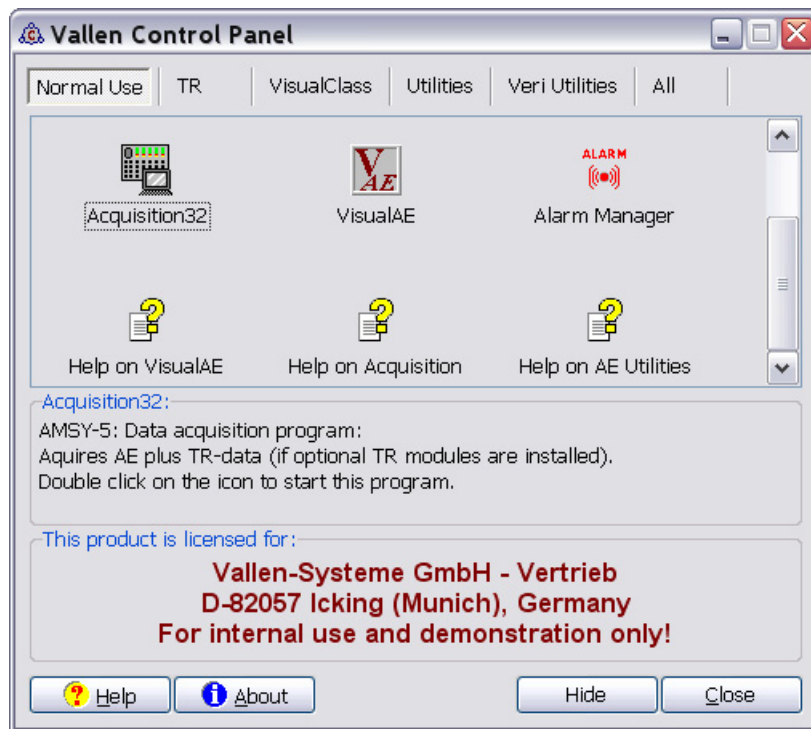


Figure 2: Vallen Control Panel.

Data acquisition is completely independent of analysis and data display. During data acquisition as well as for post test analysis, the operator can choose one or more of the following analysis programs from the Control Panel:

- VisualAETM
- VisualTRTM or TR-Viewer under the TR section of the control panel.
- VisualClassTM and/or a Classifier
- Various utilities

Note: Some programs, such as VisualTRTM, are optional components of the software package.

3.1 Data Acquisition

The 32-bit AMSY-5 acquisition program acquires AE data only or AE and TR data simultaneously (TR modules needed) and stores them on hard disk. In parallel, the data can be analyzed by e.g. VisualAE.

Double clicking on 'Acquisition32' in the Vallen Control Panel starts the program. The hardware detection sequence evaluates and tests all installed hardware components and their revisions.

Note: Vallen software has always been compatible with many years old hardware.

Menus in Acquisition32 let the user

- specify the storage file,
- specify all acquisition parameters,
- activate and deactivate data acquisition,
- start and stop pulse through mode, and
- insert labels.

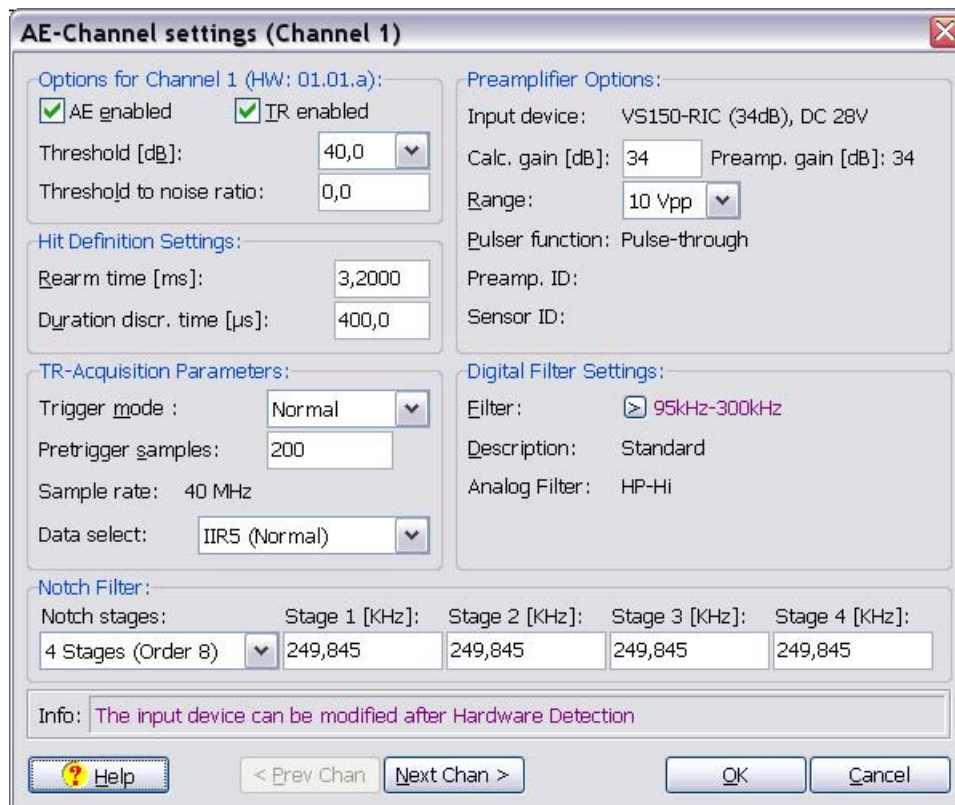


Figure 3: dialog to specify the channel settings.

The acquisition settings are stored in a separate file (*.vac). Those can be copied and their names changed for use with a new measurement.

Different file-types exist:

- Primary data file (extension .pri)
- TR-data files (extension .tra)
- Transient Record Feature files (extension .trf)
- VisualAE set-up files (extension .vae)
- VisualTR set-up files (extension .vtr)

3.2 Acquisition Dialogs

As already mentioned the hardware detection sequence first evaluates and shows the individual hardware components of the system and their revision. There are many more dialogs available. Among them are:

3.2.1 Parameter Settings

Different menus let the user define different kind of acquisition parameters.

The dialog below (see Figure 4) displays the AE-channel parameters. By double clicking on a channel the AE channel settings dialog is opened (see Figure 3), which gives access to the settings of a single channel.

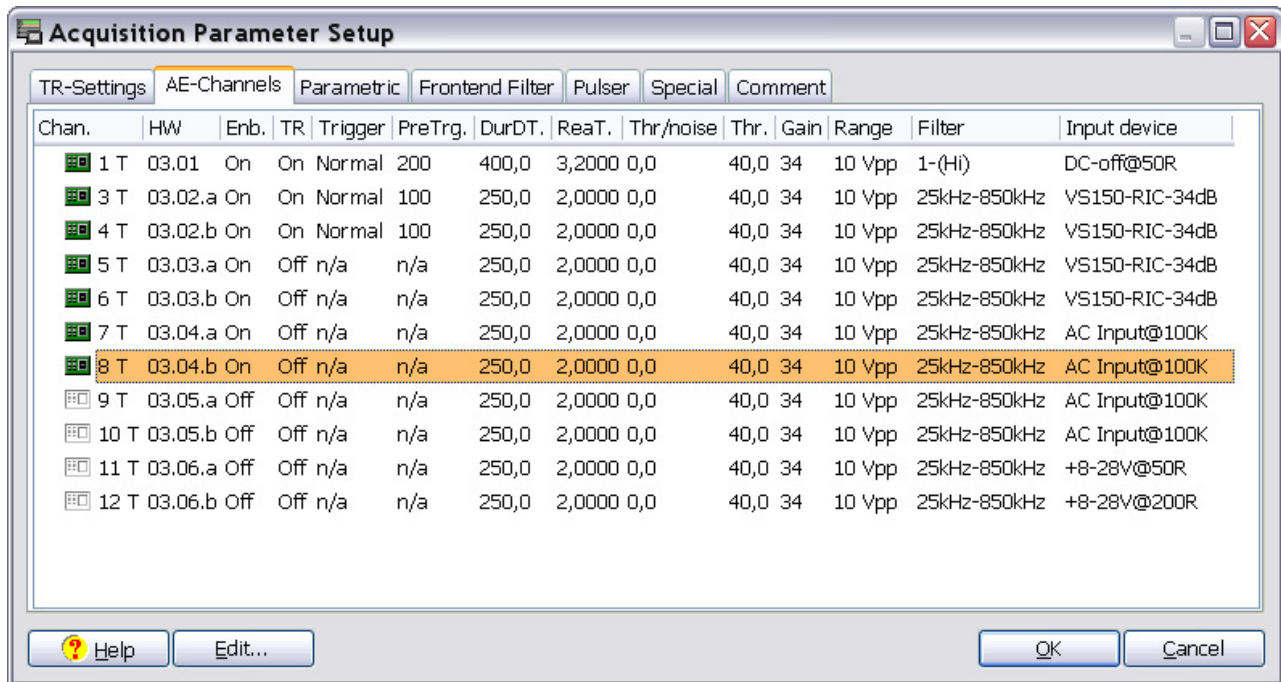


Figure 4: AE-Channels tab of the Acquisition Parameter Setup menu.

There are seven dialog tabs that can be accessed from the Acquisition Parameter Setup dialog:

- **TR-Settings** for the acquisition of digital waveforms (sample rate, size of page). Faster sample rates and larger samples per waveform increase the resolution of the waveforms, while slower sample rate and smaller samples per waveform minimize the needed disk space and TR-data transfer. The sample rate of AE-data can be selected here as well.
- **AE-Channels** for the traditional settings (threshold, gain, hit-timing, etc.) and waveform settings (pre-trigger, trigger mode) as well as filter and notch filter (ASIP-2/A only) settings.
- **Parametric** for the parametric settings, such as acquisition clock, storage interval, cycle counter threshold and more.
- **Frontend Filter** to reject hits / waveforms before these are stored, if desired.
- **Pulser** for the settings of the test-pulse, such as pulse amplitude, pulses per burst, burst interval, and more.
- **Special** for other settings, such as the energy mode (true energy or signal strength measurement), Continuous Mode, External Threshold Mode, and more.
- **Comment** for free text entered by the user, to be stored with the AE data.

3.2.2 TR Data Select Settings (ASIP-2/A only)

The Data Select setting (see Figure 3, TR-Acquisition Parameter group), available for ASIP-2/A, specifies after which filter the TR data is recorded. Possible settings are

- FIR: after the anti-aliasing filter (FIR) and before the bandpass filter.
- IIR4: after the bandpass filter (IIR4) and before the notch filter.
- IIR5: after the notch filter, the last filter in the filter chain. (Normal, ASIP-2/S)

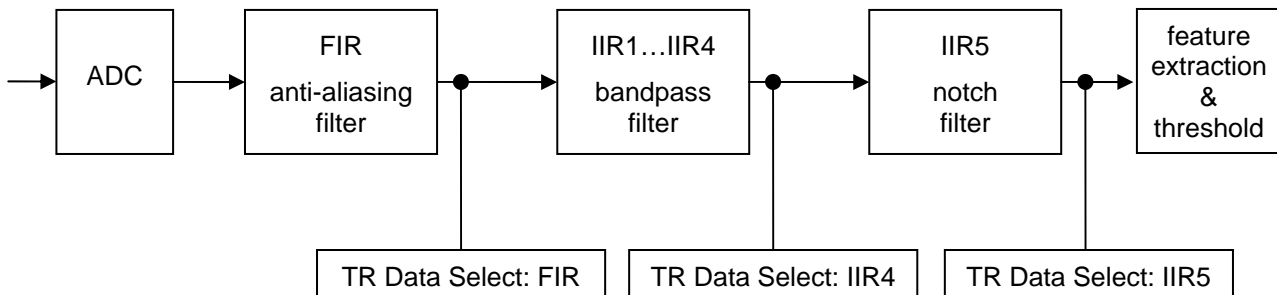


Figure 5: filter chain from ADC (analog to digital conversion) to feature extraction.

While the AE features are always extracted behind filter IIR5, waveform data can be optionally taken after FIR or IIR4 with ASIP-2/A. This allows for narrow band triggering but wide band waveform capture.

3.2.3 TR-Settings: Choosing the TR- and AE sample rate (ASIP-2/A only)

The TR-Settings tab is used for selection of the sample rate of TR-data (waveform capture) and AE-data (feature extraction). With ASIP-2/S AE-data sample rate is 10 MHz. With ASIP-2/A, 10, 20, or 40 MHz AE sample rate can be selected. This influences the range of available bandpass filters:

Any standard filter (about 500), can be used with AE sample rates up to 20 MHz. Each bandpass consists of an 8th order high-pass and an 8th order low-pass, each providing a filter roll-off of 48dB/octave.

At 40MHz AE sample rate, 100kHz or bypass can be selected for high-pass, and 1.8, 2.0, 2.2 MHz, and bypass for low-pass. Such a bandpass consists of a 4th order high-pass and a 4th order low-pass.

The performance of AMSY-5 is optimized for 10 MHz AE sample rate. Higher sample rates decrease the maximum acquisition speed, when a large number of channels is in use.

3.2.4 Notch Filter Settings (ASIP-2/A only)

Using the AE channels settings dialog (see Figure 3) the notch filter settings can be specified. The notch filter can be used to filter out certain frequencies of the AE-spectrum. The notch filter can consist of 1, 2 or 4 stages, for AE-sample rates of 40, 20 or 10 MHz respectively. Each stage resembles an infinite impulse response (IIR) filter of 2nd order. For each stage one frequency to be filtered out can be specified in kHz, up to 2.5% of the selected AE-sample rate. Entering 0 kHz switches a notch filter stage off.

A one stage notch filter provides approximately 26dB attenuation at the notch frequency. For higher attenuation, a second stage can be set to the same frequency. Sometimes the 2nd, 3rd and 4th stage are used to reject harmonics of the lowest notch frequency.

3.2.5 Disk Space Allocation Dialog

This menu recommends the file size (up to 64GB for TR data and up to 4GB for AE data) to be allocated, which the user can simply accept with "Okay." If the user desires, this menu lets the user limit the available size for data acquisition.

Vallen AE systems have always provided a strategy for protecting data files against power loss and system crashes. Even after a power loss, data acquisition can be continued at the interrupted point - without remarkable data loss. This can be achieved due to Vallen's Disk Space Allocation mechanism.

3.2.6 Record Control Dialog

This menu controls on-line communication between the user and both the data file and the AE-acquisition hardware. The "Record" button begins acquisition.

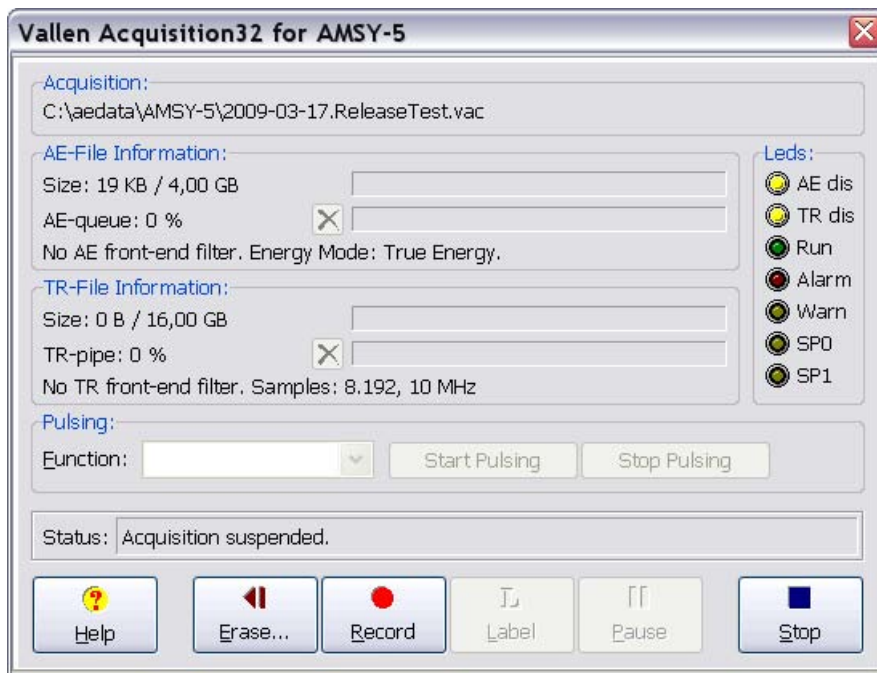


Figure 6: record control dialog

At any time, the user can insert text labels (comments) into the data stream. Such labels can be used as start and termination criteria for the analysis process. Using the label feature, the data file can be conveniently subdivided into an unlimited number of easily addressable sections.

Labels are automatically inserted, when the acquisition process is resumed after a stop, when parameters, such as gain, threshold etc. are changed and reloaded into the AMSY-5 hardware, and when a sensor coupling test sequence is started or terminated.

The record control dialog also informs whether front-end filtering is activated and whether True Energy or Signal Strength has been selected.

3.2.7 Online Threshold Control

The Online Threshold Control is accessed via the record control dialog. A right click on the record control dialog opens a pop up menu from which one can choose **Threshold Control** (<Ctr>+<t>).

The Online Threshold Control gives the user access to the threshold settings of every single channel. By use of this dialog the user can change the threshold settings of a channel while the acquisition is still running. Changes to the threshold are instantly applied.

The altered settings for the threshold are written to VAC file when the acquisition is paused or stopped.

A vertical bar indicates the current amplitude of an AE-hit. The dimmed bar indicates the largest amplitude of the last two seconds. The red marker indicates the current threshold setting. A channel is selected either by a double click on the according bar or by selecting it from the drop down list.

The Help button lets one access context sensitive help information for accelerated learning.

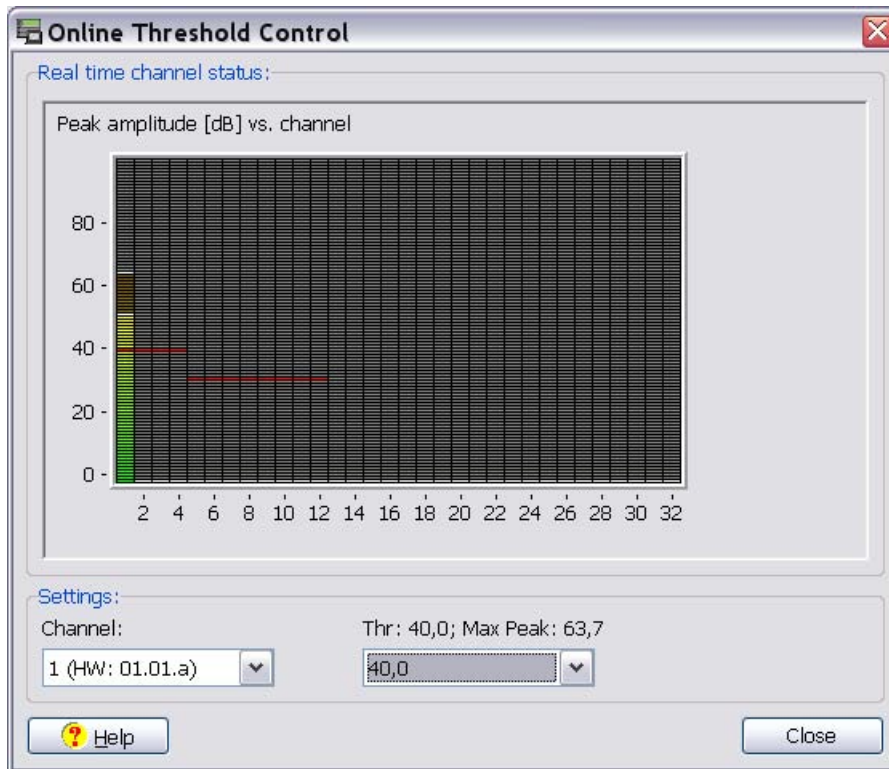


Figure 7: Online Threshold Control dialog

3.2.8 Pulsing

The pulsing function shall be used to verify that the sensor coupling does not degrade with time. Pulsing functions are available as soon as the recording is started (pushing the Record button, see Figure 6). There are three pulsing options:

1. Single Cycle: pulses are sent consecutively to each channel only once.
2. Iterative Cycle: pulses are sent consecutively to each channel until the user stops pulsing manually.
3. Single channel: a single channel pulses until the user stops pulsing manually.

Pulses are fed out either at a BNC connector at the rear panel of the AMSY-5 or sent to a sensor via the pulse-through feature of a selected AE-channel.

3.2.8.1 Pulsing via ASIP-2

Pulses can be fed to the sensor via ASIP-2 and preamplifier (caution: preamplifier must have pulse-through feature). The pulse-through feature of the ASIP-2 transfers the pulse over relays to the BNC connector of the pulsing channel (see block diagram of ASIP-2, Appendix: 5.1 and 5.2). Additionally the pulse is also fed via an attenuator (see block diagram of ASIP-2, Appendix: 5.1 and 5.2) into the AE-signal processing unit of the pulsing channel itself. An exact time stamp is produced of the pulse this way.

3.2.8.2 Verifying constant sensor coupling with time

Pulsing shall be used to verify that the sensor coupling is constant with time. At least at the beginning and end of a test a sensor coupling verification shall be performed.

During pulsing (iterative cycle, singly cycle or single channel), pulses are generated and sent to a software selected channel which is set to "pulse-through mode" to pass the pulses through to the preamplifier and to the sensor.

The sensor injects acoustic waves into the structure. The waves propagate through, or along the surface of, the structure being tested, and the other AE channels receive these waves and convert them into AE data.

After 4 or 5 pulses, the software automatically selects (in single cycle or iterative cycle pulsing) the next channel for sending pulses.

From this data, the AMSY-5 software can calculate and list the velocity of sound. The calculation is based on sensor positions and the time difference of the first threshold crossing of two channels.

Coupling tables (formerly called auto calibration tables) let the user quickly and easily observe the operation of all the sensors and helps to identify any reduced efficiency in sensor coupling.

3.3 External Control of Acquisition32

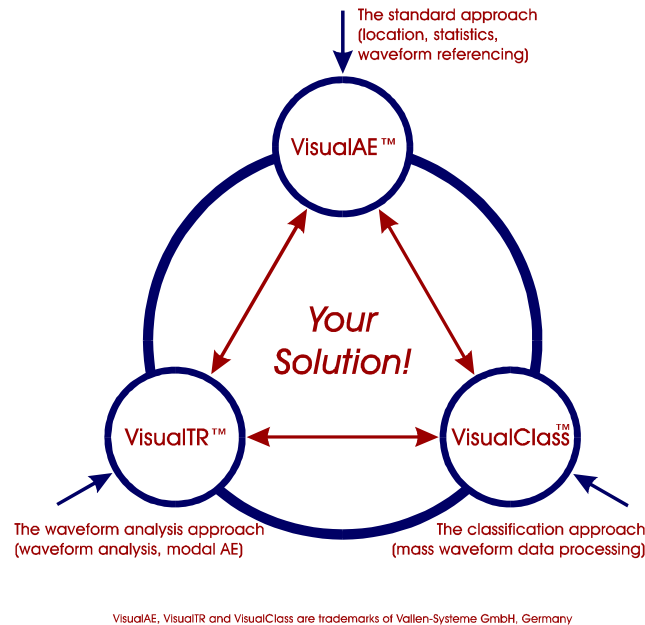
Acquisition32 can be controlled externally by use of the command line tool AcqCmd.exe or by use of the ActiveX interface AcqCmdAPI. A detailed description can be found in the online help.

The AcqCmd.exe can be used to perform routine checks of sensor coupling as a scheduled task in Windows. See the online help, scheduled pulsing, for further information.

The AcqCmdAPI can be used to integrate the Acquisition32 into external software projects for automated control of the acquisition.

3.4 Analysis Programs – the VisualCircle

VisualAE, **VisualTR** and **VisualClass** establish a powerful set of AE-analysis software, the so-called Vallen **VisualCircle**:



VisualAE supports an unlimited number of 2D and 3D graphs on multiple pages, any combination of results, in-line filtering, many location algorithms, clustering, and more.

VisualTR is the ideal tool for a closer look at waveform data, with digital filtering, mode-selection using Gaussian cross-correlations, digital filtering, and includes a set of tools to manage learning data for signal classification.

VisualClass is a powerful tool for the development of a waveform classifier. The classification process assigns a class number and class-distance to each hit which are then stored on a so-called feature file. **VisualAE** can read that feature file and correlate the classification results with AE-parameters, external parameters, location results etc. This closes the circle **VisualAE * VisualTR * VisualClass * VisualAE**.

In addition, ActiveX-routines are now available through which a user-written program can read waveform data and write feature data that can be processed by VisualAE. This helps the user to concentrate on the feature extraction development using the programming language he likes, because ActiveX-routines can be used with any 32-bit Windows programming environment.

3.4.1 VisualAE

VisualAE represents newest generation 32-bit Windows software for the analysis of AE data. It offers unique functionality and outstanding user-friendliness. Never before has the analysis of AE data been such powerful, transparent and flexible.

Because AE analysis is a complex topic, the new dimension in AE analysis achieved with VisualAE will quickly become an important factor. The many features available with VisualAE require some learning efforts. The scope of this document is to reduce these efforts to a minimum. An introduction to the internal data processing structure will be given that enables the user to draw optimum benefit from the use of VisualAE.

The control panel can launch the VisualAE program; this will request the data file (.PRI file) for analysis. When the acquisition program is already on-line the control panel suggests the on-line file in the file requester menu or most recently used files. For new files there will be a default set of graphs, the reset and run commands are used to analyze the data.

3.4.2 Relation of VisualAE to Acquisition32

The program "Acquisition32" performs high-speed data acquisition at very high reliability. Data is stored to hard disk in a very efficient format. The analysis software VisualAE or VisualTR can immediately read any single data set that is written to disk. Acquisition32 and VisualAE or VisualTR are separate applications and can run independently from each other. As data is time sorted before it is stored to disk, location calculation is possible online and without any restrictions. A special communication module, the Scheduler, takes care that each analysis program is aware of data sets that have just been acquired. Of course offline analysis can be performed as well, even during the acquisition of another data file.

3.5 Analysis using VisualAE

During analysis data is read by VisualAE from the HDD (hard disk drive) and then processed in a processing tree. Analysis with VisualAE may contain 3 types of elements:

- **Data Source** (the file from where the program reads the data)
- **Data Processing** (more or less intense)
- **Data Presentation** (graphically or numerically)

The "**Data Source**" is usually a primary file that contains the binary AE-data with references into the waveform data file, plus the waveform data file, if one or more transient data diagrams are activated.

The "**Data Processing**" performs operations on data, such as location calculation, filtering, clustering and the evaluation of user-defined results. The user can define which of these processes shall take place and in which sequence. Multiple parallel processing paths can be linked to a previous processing element and form a more or less complex data processing tree.

Data Presentation is done by so-called "AE-Visuals". Each "AE-Visual" displays selected results in graphical or numerical form. The term AE-Visual includes AE-diagrams, AE-Listings and waveform diagrams, also called TR-diagrams (TR: transient recorder).

3.6 Data Processing

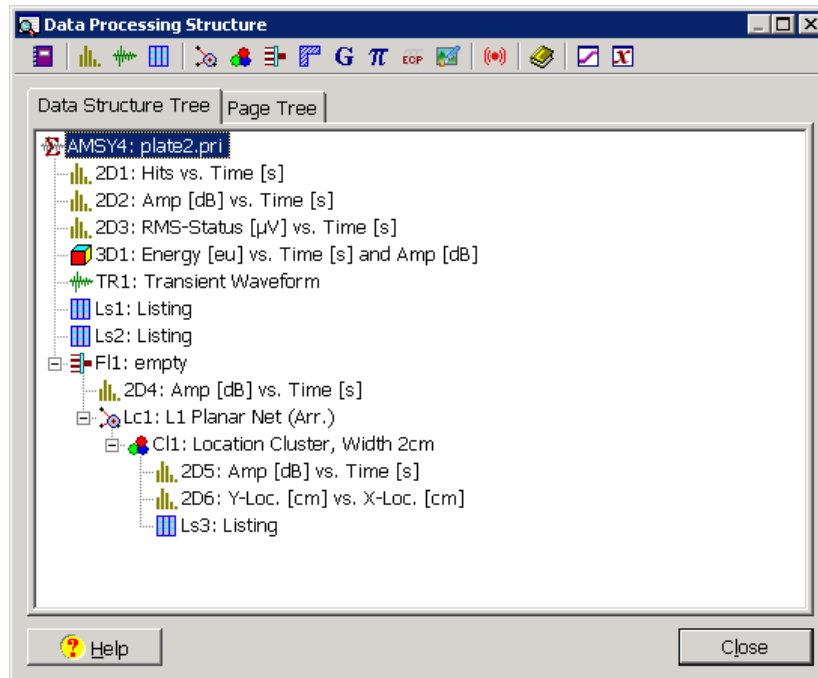


Figure 8: data processing – Data Structure Tree

The data-flow can be directed through several stages for calculations and/or decisions, the so-called “processors”. The data read from the HDD are directed through the first processor. Its’ output can be used as input for the next, subsequent processor stage(s) and so on.

A tree-structure can be created, starting from the data source (the “root” on top) and splitting up into several branches if required. The sequence of the processors is not fixed, but depends on the requirements of the analysis. To make the results accessible each “branch” requires a Visual (see section 3.7). This structure allows one to easily perform complex and powerful data processing.

3.6.1 Location Processor

The location processor assembles hits into events (hits determined to be generated by a single source), calculates the location of the source, and adds results, such as X, Y, LUCY (location uncertainty), time-differences, number of hits of the event, and more, to the event's data for further processing by subsequent processors or Visuals. Behind a location processor, AE parameters, such as amplitude, counts, etc., are taken from the first-hit of the event. The calculated kind of location results depend on the kind of location algorithm and can be x-, x-y-, x-y-z-coordinates or latitude and longitude, for example. The set-up for the location processor can be made according to the requirements of your application, for details see below (or online help).

3.6.1.1 Event builder

The event builder groups hits into events. The corresponding set-up parameters are found in the Event Builder Tab of the location setup. The "channels" portion of the dialog identifies which channels belong to the location set and whether it has a "normal", "guard" or "combined" function. The event assembly time criteria define how long the time differences can be for one event within a location set. If there are more hits than required to calculate the location, a location uncertainty result (LUCY) is available with most of the algorithms. Finally, general location setting, such as speed of sound, velocity units, maximum distance between sensors, etc. are also to be specified. These general settings are independent of the selected location algorithm.

3.6.1.2 Channel group

There may be one or more groups inside a location set. With multiple channel groups more complex structures can be covered. Each group may be assigned to a different location algorithm. If sensors are located around a cylindrical vessel, the cylindrical part and the end caps can be combined in one location set by using multiple groups. This channel grouping includes but is not limited to the former Multi-Triplet location algorithm known from the Vallen MultiPlot program.

3.6.1.3 Location and Location Set

To calculate the location of a source from measured data, an algorithm can be assigned to each channel group individually. The kind of algorithm is based on a structure's geometry and how sensors are arranged on the structure. Location algorithms are options in the software and only the purchased algorithms can be used. The algorithms usually place some restrictions on number and position of sensors. For instance the algorithm "Solid 3D" requires at least 4 sensors.

Sensor and source locations are relative to a co-ordinate system defined by the user. If the sensors are not exactly at the position as entered in the software, this will influence the location accuracy.

3.6.2 Cluster Processor

While the cluster processor passes through all data, it adds density levels as defined by thresholds and provides additional statistics about these regions. In the past, clustering has been performed on location results (indicating the location density). In VisualAE the process has been generalized and clustering can be performed on any number and kind of results, such as location results, AE parameters, time, external parameters, and user-defined results.

The user specifies the results to be used for clustering (any number), size, shape (circle/rectangle) and minimum number of elements that shall establish a valid cluster. Graphs linked to the cluster processor and showing the cluster results will display color-coded clusters along with a cluster-legend explaining the color's meaning.

The clustering process is not limited to one or two dimensions: Any number of dimensions can be clustered. Any number of cluster processors can be defined in a processing tree.

3.6.3 Filter Processor

A filter processor passes or rejects AE-data sets based on user specified criteria. The filter processor considers AE-data and external parameters, if it is linked directly to the data file. Behind a location processor, it also considers location results. Behind a user-processor, it also considers the user-defined results. If the filter processor is placed behind a location set, it considers only hit-data of the first-hit per event.

3.6.4 Polygon Processor

This user processor is a kind of graphic filter: it allows the user to define arbitrary polygons on any kind of diagram. Each hit data set will be either inside or outside the defined area and can be filtered accordingly. Example: only data inside the polygon may pass for further analysis/display.

3.6.5 Grading Processor

Provides the formulae for Historic Index and Severity Index published by Professor Tim Fowler. These results can then be displayed graphically and also the maximum numerical values per channel can be obtained provided.

3.6.6 User Processor

User processors can extend the range of results by mathematical operations on all kind of incoming data. The user can choose from a list of predefined mathematical operations, supply one or more parameters or constants (depending on the operation) and give the new parameter both, name and units. User-defined results are available to any process and visual behind the user processor. For example: To produce a plot

"Cumulative Hits vs. Load", one can define a user-processor which gives the sum of hits (the value of "Hits" is always one for a hit), name it e.g. CumHITS, and then create a X/Y-history showing CumHits at the vertical axis and the parametric input for the load at the horizontal axis. In addition, combination of AE-parameters can easily be defined with user-processors, e.g. Risetime/Amplitude or Counts/Duration.

3.6.7 ECP Embedded Code Processor

It allows the user to write his own code to be executed inside VisualAE online as well as offline. With this advanced tool one can take any available result(s) and process them according to the specific needs. This is very powerful to support routine testing according to a well defined procedure.

3.6.8 Image Processor

With an image processor digital pictures can be stored and displayed inside VisualAE: with that one can keep measured data and digital photos together without further hassle.

3.6.9 Alarm Processor

Within the alarm processor the user can define a warning and an alarm level for any result. As soon as this level is reached or exceeded the software fires a signal to the Alarm Manager who in turn alerts the user: either by sound, blinking LED, sending a network message or even an email. Perfect to support monitoring of safety related tests where various criteria may trigger to halt or even abort the test.

3.6.10 Summary

A structure menu provides an overview about the current data processing structure. It shows the complete data processing tree including data source, processors, and visuals. From this menu the properties of all processors and visuals can be accessed and modified. The elements can be rearranged by drag-and-drop as well. Thereby you have complete and very convenient control of your data processing structure. You also can show the Visuals ordered by the page number and shift a visual from one page to another.

3.7 AE Visuals

For data presentation, VisualAE offers so-called AE-Visuals, which can be diagrams (AE and TR) and listings. Any number of visuals can be arranged to any point in the data tree. Of course, the results to be displayed have to be available at the linked point. For instance, a user-defined result can only be presented if the Visual is linked directly or indirectly behind the user-processor that evaluates this result.

3.7.1 TR Diagrams

TR-diagrams show waveforms (transient data) in time and/or frequency domain. If VisualTR has been purchased, the corresponding extra functions (e.g. digital filtering and more) are available for the TR Diagrams in VisualAE.

3.7.2 AE Diagrams

2D and 3D-diagrams show AE parameters versus other AE parameters, or the time, or external parameters.

Many properties of those graphs can be adjusted: the results (attributes) to be shown (e.g. Amplitude vs. Time, or Duration vs. Energy...), left and right axis legend, caption (top) and comment text (bottom).

Legends can be edited or made invisible, printable or not printable, and more.

Diagrams can show distributions, correlations (point plots), histories, etc. Each diagram can show several planes. Data represented on a plane can be filtered (e.g. show a certain amplitude range or a certain channel), the color and shape of symbols can be selected, and more.

3D-diagrams can be rotated around each axis and each axis can be stretched.

3.7.3 Listing

A listing presents data in columns of numbers. The results to be listed and their ordering can be selected in the property menu where you also can define which kind of listing lines you want, such as first-hits only, subsequent hits, time driven external parameters and/or time driven status sets.

Listings can be exported via the clipboard.

3.7.4 Coupling Table

(Formerly called calibration table) The coupling table presents the results of a sensor coupling test run and is a powerful tool for checking sensor coupling and determining the speed of sound. If there are multiple such runs on a file, each run can be selected and differences between the runs can be shown.

3.8 Reporting

At the end of each data analysis task, usually a report has to be created. This part of your work, the representation of your results, is very important, can be quite time consuming and puzzling. VisualAE accelerates these important tasks tremendously. VisualAE offers numerous features for the generation of perfectly looking reports in a minimum of time.

3.8.1 Exporting Diagrams

Complete VisualAE-pages or single diagrams can be exported as graphic to clipboard (if the corresponding option is enabled) and transferred to your word processor or saved to file. Optional packages are available that include tools to copy only an individual AE-Visual. Powerful tools for adjusting the appearance of the graphs, such as the resolution, the inclusion of certain legends, and more, are included.

Another possibility is to export a diagram's data table via clipboard to e.g. a spreadsheet for further processing.

3.8.2 Printing

Creating high-resolution hardcopies from VisualAE is simple and convenient. Any Windows-supported printer can be used. A dialog window offers a printer-preview and many possibilities for adjusting the appearance of the printed page (landscape or portrait, size, position on page...).

3.9 User-Data-Access

Getting ASCII-data from the system is easy and important for a user who wants to use, for example, a spreadsheet program with AE data or transient data.

There are several possibilities to obtain stored AE data or transient data for further processing by other programs, either in ASCII form, or, directly read by user-programs (on-line as well as off-line).

One of them is exporting a listing via the clipboard; another is using the ActiveX interface XTR to read TR-data directly with user-designed software.

The above-mentioned details do not completely describe all features of VisualAE. This description shall prove that VisualAE offers you much more functionality than any other AE-software on the market today.

3.10 More Analysis Software

3.10.1 TR-Viewer

TR-Viewer is part of the basic package and offers reduced functionality (compared to VisualTR). It displays waveforms (fix/autoscaling), client diagrams and calculation of the FFT of a selected part of a waveform.

3.10.2 VisualTR

This Windows program is the top tool for waveform data analysis.

It shows one or multiple graphs of transient recorder data (TR data) on one screen. Each graph contains the data around the corresponding trigger event, usually the first threshold crossing of a hit (or a hit-cascade).

The labels shown at the vertical scaling are always round numbers and refer to the preamplifier input.

A "Next", a "Previous" and a "Go to..." item in the context menu allow for navigating through the file. A "Run" mode is for stepping through the file without user intervention. A link to the acquisition task causes that new on-line data are shown in the Run mode automatically.

The user can call a context menu of a signal by clicking on the right mouse button. The vertical or horizontal scaling can be changed to zoom in any interesting part of the waveform.

A client-graph can be opened for each waveform diagram showing a selected part of the signal in time or frequency domain.

VisualTR (request separate brochure) supports selectable FFT window functions (Hamming, Hanning...), digital frequency filtering, Gaussian cross-correlation, editing of legend text, multiple pages and more. It also provides helpful utilities for feature extraction, filtering of TR data, combining TR-data from different files to e.g. learning data files and more.

3.10.2.1 Filtering of Transient Recorder Data

Since the selection of the interesting signals is a very important requirement when transient recorder data are to be analyzed, various TR-filter possibilities have been implemented in the AMSY-5 software:

The **front-end filter** rejects data according to the selected criteria before they are transferred and stored (e.g. if the AE data of the hit does not exceed selected minimum peak amplitude or the minimum duration).

The user can generate a correlation plot in VisualAE that contains the TRAI of filtered AE data. A utility (belongs to optional VisualTR) can then be used to copy only TR data belonging to the TRAI(s) of such a plot.

The following items are only available with the optional VisualTR package:

3.10.2.2 Feature Extractor

This is another VisualTR utility program to extract features from TRA data and to write them to a feature file. The AE analysis program can read this file. The TR-features are then handled like AE features (hit data), which means they can be plotted, listed, or used for filtering in the multi-plot program like AE results. The following results are calculated: Center of Gravity of the frequency spectrum (FCOG), Frequency of the spectrums' maximum (FMXA), initiation and reverberation frequency, spectral ratios (energy content ratio for up to 20 time-frequency windows) and some more are currently the most important TR-features.

3.10.2.3 FFT Averager

This application calculates and displays the average spectrum of all waveforms in a TRA file. From all FFTs, for each frequency bin, 3 averaging methods are calculated and shown in 3 curves:

- RMS: Root mean square, result converted to dB above $1 \mu V_{RMS}$
- AVG: Mean value of all bins, result converted to dB above $1 \mu V_{AVG}$
- AVG[dB]: Mean value of all bins, converted to dB above $1 \mu V$ prior to averaging, and a
- curve RMS subtracted by AVG[dB]. This curves gives an indication which frequencies are equally distributed on the analyzed data, (difference is very small) and, vice versa, at which frequencies the waveforms differ.

This application is useful for discovering the lowest level spectral compositions out of the white noise. Additionally the spectra reduces the white noise level shown and pronounces other spectral components.

3.10.2.4 TR-Combi, TR-Copy, TR-Indexer

These Windows programs are utilities to copy selected TR data from one file to other file(s) and to renumber the TR-Index, where needed. They support the efficient generation of learning databases for signal classification by VisualClass.

3.10.2.5 Transient Data Listings

The waveform currently displayed by the waveform display program (TR-View) can be stored to an ASCII file, one sample per line, also over the "copy ASCII table to Clipboard" function in the TR-View and VisualTR programs.

3.10.2.6 TR-Filter, TR-Unifier

TR-Filter allows one to apply a digital (software) filter to already recorded data and store the result. Thereby TR-data recorded with different hardware filters can be unified.

TR-Unifier is a tool to change sample rate and page length (number of samples per waveform) after recording. This is very useful if data acquired with different settings shall be analyzed with VisualClass.

3.11 Online-Help

Online help is available in the help menu or by pressing F1 for further features. The user will probably wish to familiarize with some more of the features including sensor coupling test, labeling, PC configuration and on- and off-line analysis modes.

3.12 Modify PAX Input

This Windows program modifies parametric data on a primary file. The user can define the parametric input (PA0...PA7) to be modified and a list of data sets and the corresponding input voltages. The program calculates a voltage ramp for the parametric data between two specified data sets. This program enables the user to enter the load curve after a test, especially in the case when no analog signal of the load was available during the test.

In combination with a filter operation, such as "PA7 > -9.000", and setting PA7 to e.g. -10.000mV for a certain range of data sets, the user can exclude undesired hit-data from the data analysis.

3.13 PCTA-Counter Extender

This Windows program is a utility that extends the data from the 16-bit parametric counter PCTA to the 32-bit counter PCTE on already acquired data files. Helpful, when the user has forgotten to switch on PCTE before the data acquisition.

4 Results

The AMSY-5 system offers various results which are either directly measured, such as Arrival-time, Peak amplitude, Parametric Input, etc., or calculated, such as location results, delta-t, or signal slope. In addition, there are logical results (flags) that indicate special situations, such as multi-peak, hit-time-out, etc.

Each result has an identifier used in the filter editor, in plot legends, in listing headers, etc. This identifier is also used in the menu in which the user selects the desired result for plotting or listing. An extensive help text is provided in which the user quickly finds the description of each of the offered results.

Any numerical result can be selected as an axis attribute of a graph.

Most of the numerical and logical results are available for listing as well as for filtering.

The term "hit" means the AE signal of one event received by an independent channel. Several channels can receive hits from one and the same event. Those hits are collected to an event data set by the analysis software.

In the following description of the AMSY-5 results, the abbreviation of each result is shown:

4.1 Hit Data

Hit data are generated by each AE channel independently, and describe usually one or a series of discrete AE signals with a clear beginning and end. The beginning of a hit is defined by its first threshold crossing, the end, by the absence of threshold crossings for a user-defined period of time, (the Duration Discrimination Time). A hit cascade is a series of discrete hits. The end of a hit-cascade is defined by the absence of threshold crossings for the selected Rearm Time.

Hit data sets contain the following information:

4.1.1 HITS Hits

This returns the value 1 for each hit data set, to be used in cumulative plots.

If location set zero is selected, all hits of all channels are considered. If a location set >0 is selected only hits from channels belonging to the selected location set are considered. Depending on the parameters of the plot currently being processed, either the hits of all considered channels are cumulated in one counter or only the first-hits are considered, or separate counters per channel are used.

HITS-histories as well as histories of CNTS, CCNT, E, CENY, and CHIT are automatically initiated as cumulative plots.

4.1.2 CHAN Channel Number

This is the number of the channel that has produced the data set.

4.1.3 TS Arrival Time

This is the absolute time of the first threshold crossing of a hit. It is measured and stored by each channel individually in steps of 100ns (200ns with AMS3). It is used to identify a hit (in combination with the channel number) and to calculate the event's source location (in combination with the arrival times of other hits).

In listings, the arrival time appears in long format:

"dd hh:mm:ss xxx.xxxx"

dd = day 0,1,2...n

hh = hour

mm = minute

ss = second

xxx.xxxx = ms, with a resolution of 0.1µs.

For graphs, the arrival time can be selected as:

TS (time in seconds) or as TH (time in hours).

TS and TH start with zero at the left-hand margin of the plot. The absolute time belonging to that zero-point is shown in long format in the legend of the graph.

For longtime tests that go over the end of a month, the day is not reset to 1; instead, it is incremented each day until the test ends. This ensures that the internal time is always incremental.

4.1.4 A Peak Amplitude

This is defined as the peak amplitude of a hit. The peak amplitude (A) is given in dB above 1µV referring to the preamplifier input (0dB = 1µV, 20dB = 10µV, 40dB = 100µV, etc.). Maximum is 99.9dB (98.9mV_{PK}) at 34dB preamplifier gain. The peak amplitude is extracted from a stream of 16 bit samples (resolution of 3µV at ±100mV range) and then converted to and stored as an 8 bit value with a resolution of 0.3763dB (20 * log(2)

/ 16) and an offset of 9.9dB.. The software takes the chosen preamplifier gain into account when displaying amplitude results.

4.1.5 ALIN linear Peak Amplitude

Peak Amplitude in μV . (Derived from the Peak Amplitude in dB)

4.1.6 THR Threshold

The first crossing of the threshold level is the start of a hit. The end of the hit is reached when the input voltage does not cross the threshold for a specified period of time (called the duration discrimination time). The threshold is a dB-value of same range and resolution as the peak amplitude.

In case of a floating threshold, the threshold can vary during a test. Because of this, the threshold is not only a parameter but also a result.

4.1.7 E Energy

The Energy is processed in either a so-called true energy mode, or a signal strength mode. In both modes, the energy is given in Energy Units (eu) and the software takes the selected gain into account, when calculating and displaying the energy. The energy is stored in a logarithm format with a resolution of 0.1%. The scaling below is given at 34dB gain.

True Energy Mode:

Energy is calculated by squaring the digitized AE signal and integrating the results during the hit. (Squarer option ASP-SQ needed)

1 eu corresponds to $10^{-14}\text{V}^2\text{sec}$ at the sensor output (preamplifier input). The internal resolution is $0.18 * 10^{-3}$ eu; the maximum is $25 * 10^9$ eu (48 bit).

Signal Strength Mode:

Energy is calculated by integrating the absolute value of the AE signal during the hit.

1 eu corresponds to 1nVs at the preamplifier input. (The linear energy value is required by some standard procedures.)

The internal resolution is $0.3 * 10^{-3}$ eu, the maximum is $1.2885 * 10^6$ eu (32 bit).

4.1.8 CENY Cascaded Energy

The Cascaded Energy is the sum of the energies of the first-hit and all subsequent hits in a hit-cascade. For resolution and range see Energy.

4.1.9 R Risetime

The Risetime is the time between the first threshold crossing and the first peak detected in a hit.

The resolution is 200ns if $R < 800\mu\text{s}$ else 0.025% of the value. Maximum value supported by the internal representation is 50s, limited to the value of the duration.

4.1.10 D Duration

The Duration is the time between the first and last threshold crossing of a hit.

The resolution is 200ns if $D < 800\mu\text{s}$ else 0.025% of the value. Maximum value in the internal representation is 50s. Limited to about 100ms by the time-out feature of the AMSY-5.

4.1.11 CNTS Counts

Counts are the number of positive threshold crossings of a hit. Range is limited to the maximum of 65535 (per hit).

4.1.12 CCNT Cascaded Counts

Cascaded Counts are the total number of positive threshold crossings during a hit-cascade. Range is 1 to 65535 (per hit-cascade).

4.1.13 RMS Background Noise

The RMS Background noise is the root-mean square value of the noise on each channel during pauses of threshold crossings. It is derived from the energy measurement. If no hits arrive, the energy is accumulated in time slices of 13ms. The energy rate per 13ms time interval is fed over a variable digital low-pass filter to achieve the user-selected time constant.

The RMS is presented in μV related to the sensor output (preamplifier input). The software takes the selected gain into account.

The result "RMS", included in the hit data set, is a measure of the noise before the hit. The result "RMSS" is part of the status set (see below).

When True Energy is selected, a true RMS value is evaluated. When Signal Strength is selected, the linear average of the absolute voltage is evaluated. This conversion from energy rate to RMS is done in the analysis program.

Due to the averaging effect, the resolution is very fine. Reasonable accuracies cannot be expected from values lower than half the ADC resolution.

4.1.14 CHITS Cascaded Hits

Cascaded hits are the total number of hits in a hit-cascade.

4.1.15 TRAI Transient Recorder Index

The Transient Recorder Index is a unique number that identifies the transient recorder data belonging to the hit. This can be used to filter TR data according to filtered AE data.

4.1.16 Hit Data Flags

Hit Data Flags are used to indicate special conditions during a hit. These can be shown in a listing and they can be used as filter criteria.

0 means false, 1 means true.

The following flags are provided:

4.1.16.1 TOAB Time-out aborted Signal

This indicates a very long hit or hit-cascade ($>100\text{ms}$) which has been terminated by a time-out process. In the case of suddenly increasing noise (caused by a leakage for example), the hit evaluation is terminated by a time-out function to keep the time sorting process running.

In the listing, this flag is indicated by a "T".

4.1.16.2 ATOA After Timeout Signal

This indicates an artificially started hit after hit time-out (see above). Arrival time, risetime and duration of this hit are not meaningful. Meaningful are the results Cascaded Counts, Cascaded Energy, Amplitude. This hit is not suitable for location calculation.

In the listing, this flag is indicated by an "A".

4.1.16.3 EXTC **Extended Cascading**

This indicates a temporary "long-rearm mode" which prevents buffer overflow, because the PC was not able to read out data fast enough.

In the listing, this flag is indicated by an "E".

4.1.16.4 DTOS **DDT too short**

This indicates a temporary "long duration discrimination mode": At the user-defined DDT, the detected hit rate is too fast to be processed.

In the listing, this flag is indicated by a "D".

4.1.16.5 ROVL **Rearming Overlap**

This indicates that at least one hit has been detected during rearming. It has the same meaning as "CHIT > 1".

Hardware rearming means waiting for a pause of threshold crossings for a user-defined period of time (the rearm time) before the channel is enabled to trigger a new evaluation of a hit-cascade.

In the listing, this flag is indicated by an "R".

4.1.16.6 CAL **Coupling Pulse**

(Formerly called Calibration pulse) This indicates a signal that has been generated by the test pulse through feature of the AMSY-5; which is to be used for the determination of the velocity of sound and for the confirmation of proper sensor coupling.

The amplitude of such a pulse is indicated approximately 60dB below the real amplitude at the emitting channel.

The flag is set in the signal data set of the emitting channel. When the software finds that flag set, it sets the flag internally for all hits generated within the "hit tracking time", a user controlled parameter.

The filter operation "CAL =1" allows only the transmitted and received test pulses to pass the filter. The filter condition "CAL =0" excludes such signals from an analysis process. Note: To eliminate test pulse data from a plot, you can also use a label filter.

4.1.16.7 CAL1 **Coupling Pulse (sent)**

CAL1 indicates hit data sets generated by the test pulse in the sending channel.

CAL1 is shown in the listing as upper case "C".

4.1.16.8 CAL2 **Coupling Pulse (received)**

CAL2 indicates a hit with a delta-t to the previous CAL1-flagged hit of less than the hit tracking time set in VisualAE/Edit/Project Settings/other.

CAL2 is shown in the listing by a lower-case "c".

4.1.16.9 SATR **Saturation of Measurement Chain**

SATR indicates when the amplitude of a hit exceeds 95% of the input range ($5V_p$). If hit amplitude exceeds 95% of the input range this is also indicated by a yellow flashing THR LED at the ASIP-2 front panel.

If a saturation occurred for a hit, this is indicated by a "S" flag in the listing.

4.2 Status Data

Each channel generates status data sets in a time driven manner according to the user-defined status interval. Status data sets are also generated every time the transient recorder of a channel is triggered externally. Status data sets contain mainly the following results:

4.2.1 CHAN Channel Number

The number of the channel that has produced the status data set.

4.2.2 RMSS Background noise

This has the same meaning as RMS in hit data. It characterizes the background noise.

4.2.3 ENYS Energy between two status data sets

The energy (true energy or signal strength mode as described for E), including the energy of background noise and energy of hits during the time period between two status data sets.

4.3 Parametric Data

Parametric inputs (PA0-PA7) are measured in the time interval defined by Parametric Clock (0.2...10ms). The latest measurement is stored in a parametric data set, before the next hit data set. When hits arrive in shorter time distance than Parametric Clock, only one parametric data set is stored. When no hits arrive, parametric data sets are written at user-defined Parametric Interval (10 ms...600 s). Parametric results can be used to analyze AE data versus parametric information, e.g. load, pressure, temperature, etc., in correlation and distribution plots. Parametric data can be plotted independently from AE data in history plots.

4.3.1 PA0...7 Parametric Analog Inputs

All analog inputs, in the range -10240mV to +10235mV, are digitized with 0,315mV resolution, in the menu-selected time interval: range 200 μ s to 10ms.

Each measurement of these inputs is addressed by "PAX" whereby "x" identifies the channel number between 0 and 7. The peak to peak noise of the internal ADC is 2mV maximum.

4.3.2 PA0...7U Parametric Analog Inputs

In addition to PA0 to PA7 that are always presented in mV, PA0U to PA7U can be presented in any linear converted engineering unit, such as N, bar, etc.

To convert the mV into other engineering units, the measured values can be subtracted by an offset and multiplied by a factor. Offset and factor can be entered in the parametric conversion menu (via structure menu).

4.3.3 PCTA Analog-Controlled Counter

This means a 16-bit-counter, incremented when the voltage at PA0 crosses a user-defined trigger level in a certain direction.

A tunable hysteresis band avoids triggering by noise.

See PCTE for the 32-bit equivalent.

4.3.4 PCTE Extended PCTA

This identifies a parametric 32-bit counter like the PCTA. It can only be used if PCTD is not used. It must be selected in the Acquisition Parameter Setup.

4.3.5 PCTD Dig. Controlled Counter

This identifies an additional 16-bit-counter. PCTD is incremented by the leading and the trailing edges of an external clock pulse, if enabled by an external enable input. This counter can be cleared by an external reset input (TTL-inputs, externals connector). If PCTD is to be used PCTA (but not PCTE) can be used simultaneously.

4.3.6 CYSL Cycle Slope Flag

This indicates the direction of the voltage change of the analog input that is selected as the PCTA-counter-input, normally measuring a cyclic load.

This flag can be used as a filter criterion to separate AE measured during increasing load, from AE measured during decreasing load.

Zero means a negative change.

One means a positive change.

If there is no change, the flag remains in its previous state.

Note: If noise is added to the input signal, this noise may influence the CYSL flag, too.

4.4 Location Results

A location processor generates location results. The setup is independent from the data acquisition and can be changed at any time during or after data acquisition. The program always uses the most recent version of that setup. The setup is stored on the .vae file.

4.4.1 EV Events

This identifies a counter in the analysis program that counts the number of events detected by the channels of the selected location processor. All hits coming from a common acoustic source are collected and only the first-hit of an event increments that counter.

Selecting EV makes only sense in distributions or cumulative histories. In correlations, the value "1" would be shown for each event.

4.4.2 SIGS Signals of Event

It gives the number of processed hits for the current event.

4.4.3 1.CH...7.CH Channel Sequence

This means the sequence number of a hit.

Example: An event hits first channel 2 then 4 and then 3. Then:

1.CH would be 2,

2.CH would be 4,

3.CH would be 3.

4.4.4 DT12...17 Time Difference

Each of these results reflects the time distance between the first-hit and the n^{th} hit of an event. Mainly provided for filtering. For listing use DT1X.

4.4.5 DT1X Time Difference

This is the time difference between the first-hit of an event and the subsequent-hit currently being processed. It is mainly used in listings.

4.4.6 X X-Coordinate

This is the location result in the X direction. All location algorithms calculate X.

At circular test structures, the valid range for X is $(-0.5...+0.5) * \text{circumference}$.

For spherical results, X corresponds to the projection of the radius vector onto the x-axis.

4.4.7 Y Y-Coordinate

This is the location result in the Y direction. All except the linear location algorithms calculates Y.

For spherical results, Y corresponds to the projection of the radius vector onto the y-axis.

4.4.8 Z Z-Coordinate

This means the location result in the Z direction in cm. Z is calculated by the 3D and spherical location algorithm.

For spherical results, Z corresponds to the projection of the radius vector onto the z-axis.

4.4.9 LONG Longitude

This means the degree longitude of a sphere. LONG is available for spherical location, only.

4.4.10 LATI Latitude

This means the degree latitude of a sphere. LATI is available for spherical location, only. 0 means equator, +90 means North Pole, -90 means South Pole.

4.4.11 LUCY Location Uncertainty

LUCY represents the location uncertainty of an event in cm.

The calculation of LUCY requires that more channels have been hit than needed for the location calculation. For example: 3 hits are needed to calculate a planar location. 4 hits would be needed to calculate the location uncertainty for a planar location.

As a filter criterion, LUCY can separate location results by its uncertainty and show only the more trustworthy locations.

4.4.12 CGRP Channel Group Number

Number of the channel group of the location processor. Using this in a plane filter of a location diagram lets one easily see which location set in a channel group has lead to which result.

4.4.13 RANK Location Ranking

This result gives a ranking of multiple location results per event in a location group that lets one easily select the result with the lowest LUCY (location uncertainty).

4.5 Administrative Results

4.5.1 LABL Label Number

This means the number of a text label inserted into the data stream either automatically by the system or by the operator. It can be used for filtering and as start and termination criterion for the analysis process.

4.5.2 DSET Data Set

This means a sequential number assigned to each data set in the .PRI file at the time of the data analysis. For example, DSET can be used in a plot to find out the data set no. of a particular data range for using it as a start and/or termination criterion of the analysis process.

4.6 TR-Feature Extractor Results

These results are extracted from transient recorder data by the Feature Extractor Utility (part of VisualTR), stored on the Feature File and read by the analysis program (e.g. VisualAE).

4.6.1 FCOG Center of Gravity of Frequency Spectrum

This gives the frequency in kHz at which the spectrum has its center of gravity.

4.6.2 FMXA Frequency at max. Amplitude of Spectrum

This gives the frequency in kHz at which the spectrum shows the maximum amplitude.

4.6.3 FExYY User-assignable Results

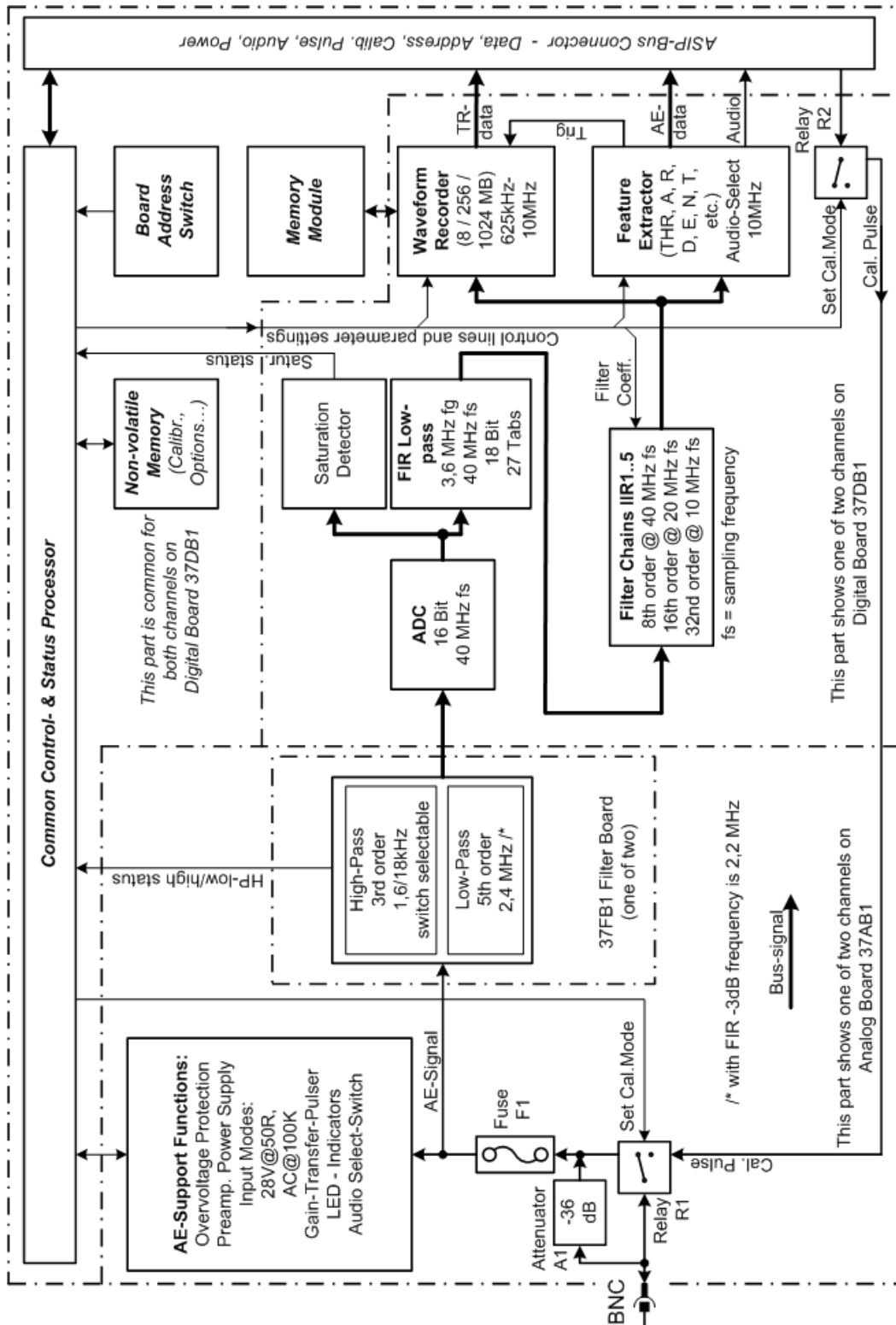
There are 9 results FEx08 to FEx16 provided. To each of them the user can assign a certain feature that shall be extracted from transient recorder data.

There are general features, like Counts to Peak, Initiation Frequency and Reverberation Frequency, and features that are extracted from user-defined time and frequency segments. Spectral densities may allow for the separation of source mechanisms or wave modes.

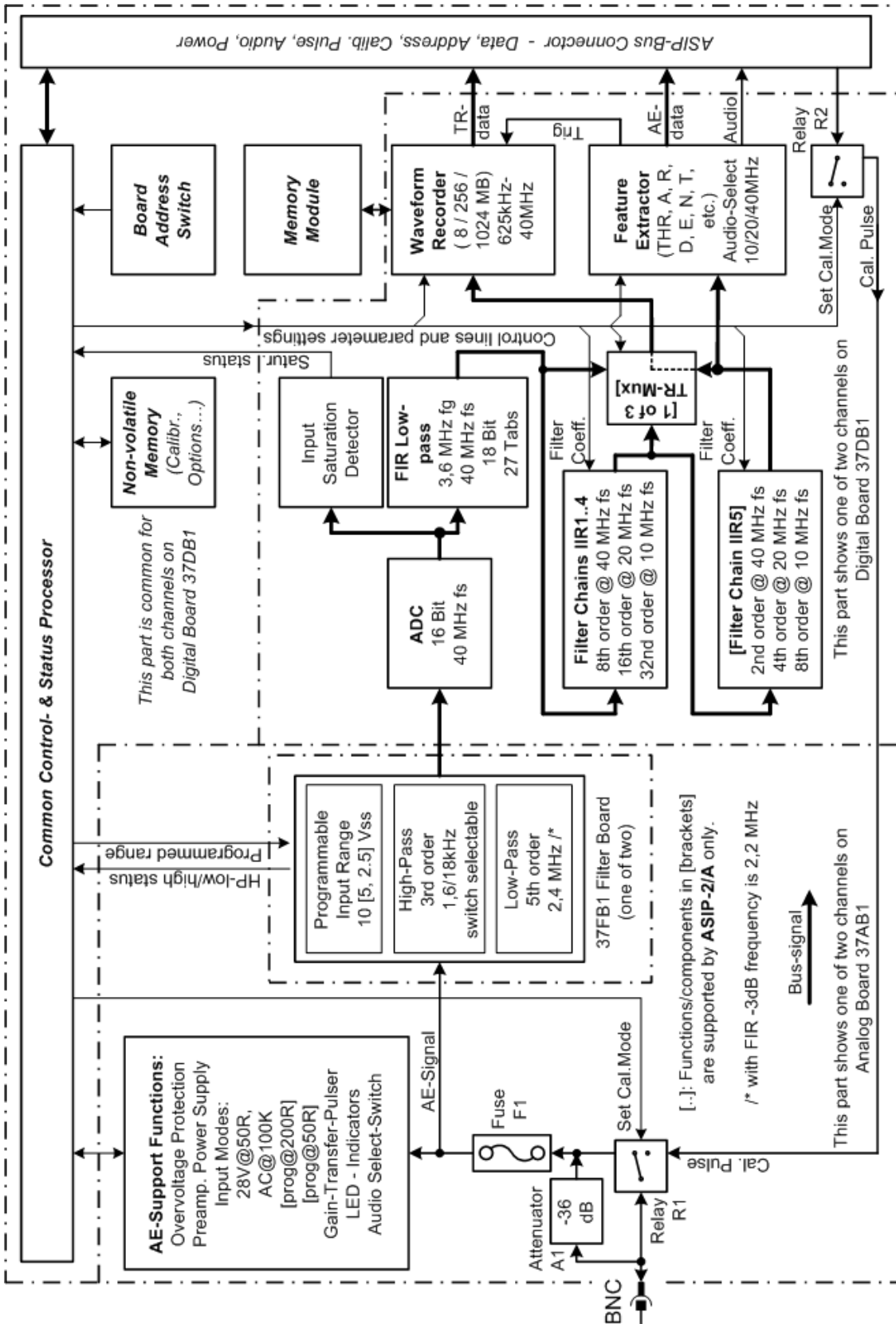
A detailed description is available in the online help system.

5 Appendix

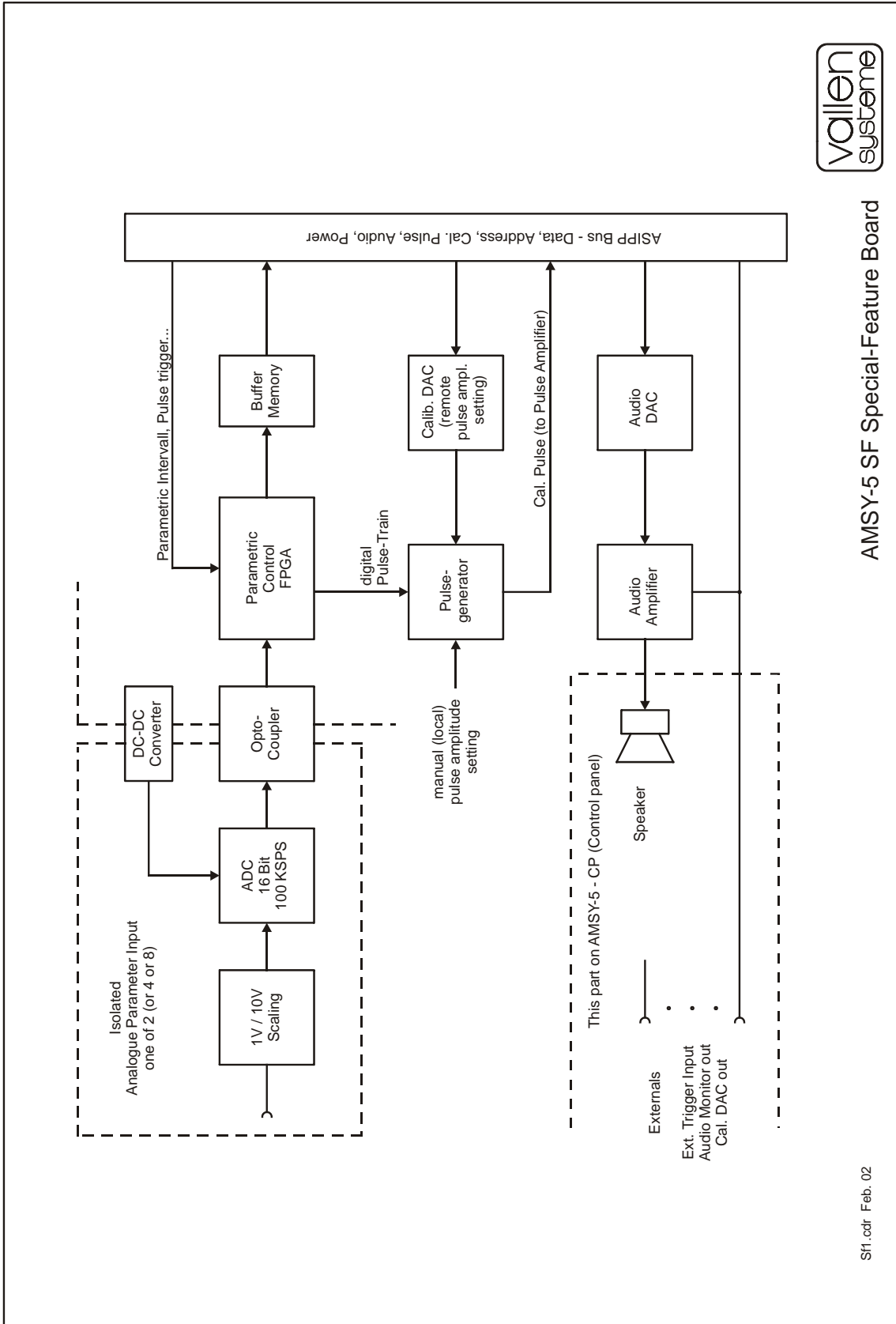
5.1 ASIP-2/S (Standard) Block Diagram



5.2 ASIP-2/A (Advanced) Block Diagram



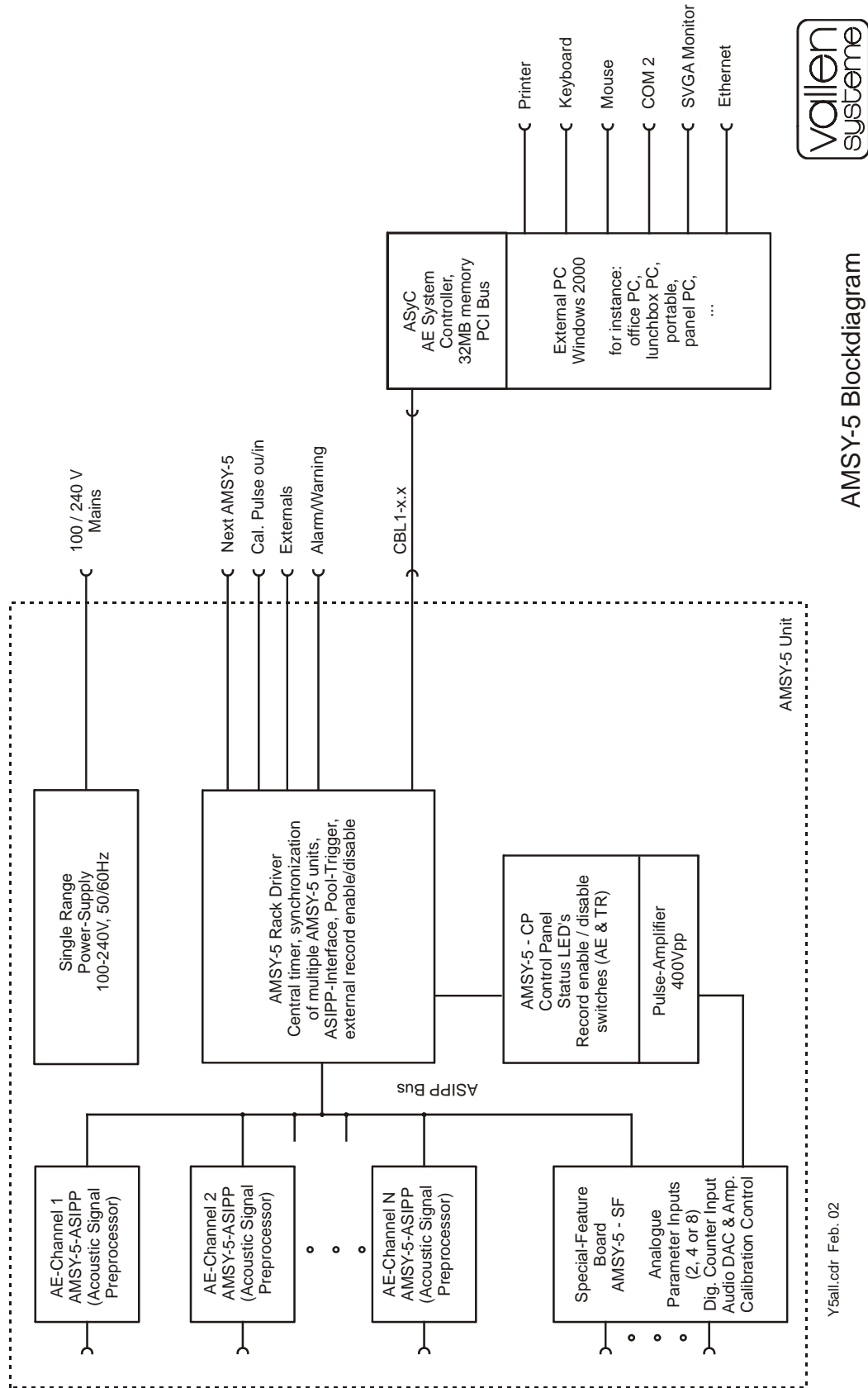
5.3 Special Feature Board - Block Diagram



AMSY-5 SF Special-Feature Board

Sf1.cdr Feb. 02

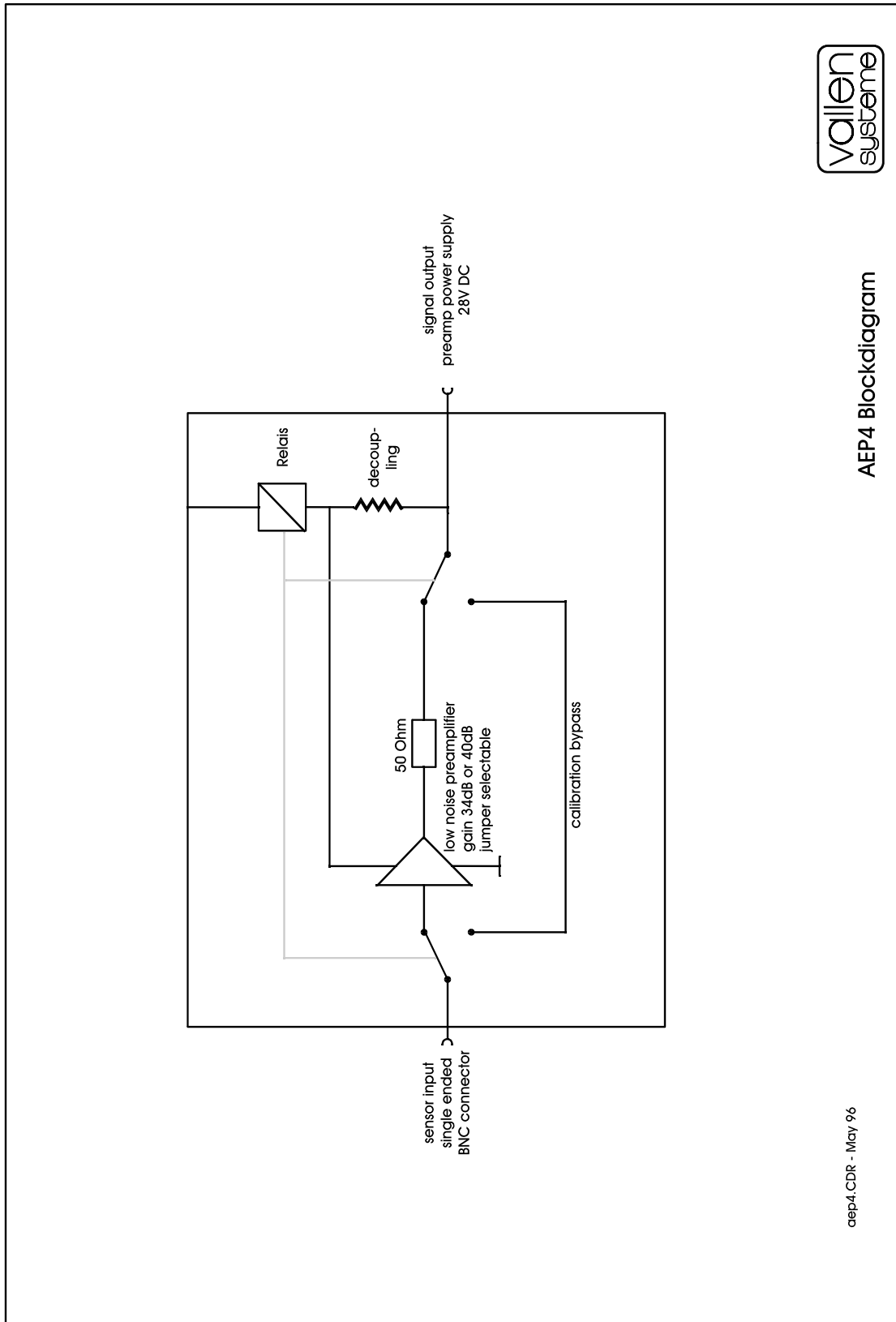
5.4 AMSY-5 System Block Diagram



Y5all.cdr Feb. 02

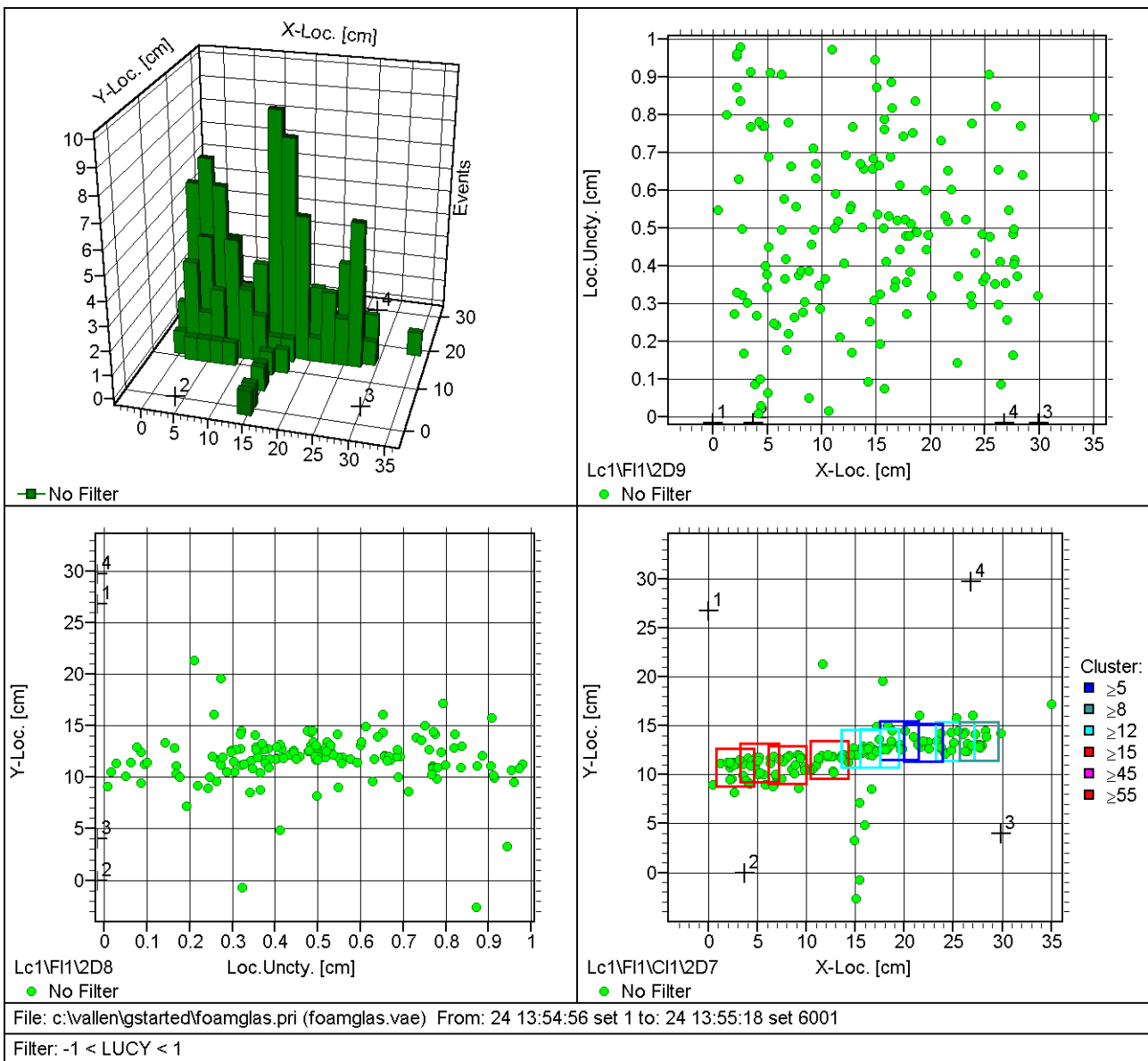
AMSY-5 Blockdiagram

5.5 AEP4 Preamplifier Block Diagram



Note: The terms "calibration bypass" and "pulse-through-capability" mean the same.

5.6 Example of VisualAE data presentation from a foam glass test under compressive load



With so many unique features, the AMSY-5 is the most “state of the art“ AE system today available.