AMSY-6 System Description

System Description

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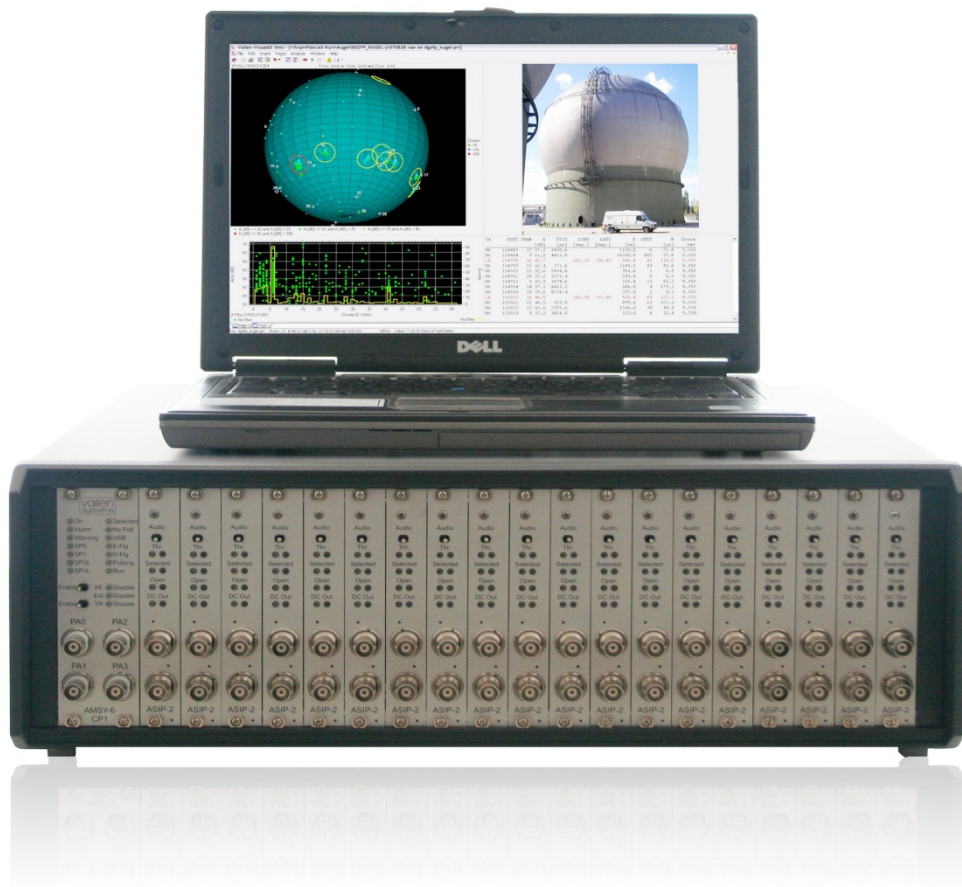
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Revision Record

Date	Changes
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Contents

1   Introduction to Acoustic Emission

Acoustic Emission (AE) is a phenomenon whereby transient elastic waves are generated because of plastic deformation, crack propagation, fiber breakage, de-bonding, corrosion, erosion, phase changes, impact, leakage, cavitation, partial discharge and friction. All these mechanisms and processes, in general *AE sources*, are accompanied by the emission of characteristic elastic waves and so these waves carry information of ongoing changes in the material. The AMSY-6 AE measurement system picks up the generated elastic waves and processes their information.

Each of these *AE sources* gives rise to a dedicated application for AE testing. E.g.:

- Above ground storage tanks (AST) are tested by use of AE for corrosion and leakage.

- Integrity testing by use of AE assesses the condition of the test object by judging the evolution of micro cracks.

- The structural damage of CFR polymer objects can be assessed by use of AE measurement technique.

- Leakage can be detected and located in pipelines or storage tanks by use of AE.

- Partial discharge can be located in transformers using AE.

- Material science and material development uses AE to learn about the failure mechanisms of materials and use this knowledge to design new, tougher materials.

Everyone is familiar with AE which can be heard when wood cracks and glass breaks. AMSY-6 is much more sensitive than the human hearing sense. It is sensitive enough to detect displacements of a surface in the order of a fraction of an atomic diameter. It is able to characterize non-audible acoustic emissions and their AE sources in a very detailed manner, e.g. strength of a source, position of it, frequency content, etc. The features of the acoustic emission signals may indicate the source mechanism (cracking, friction...) and help discriminating interesting AE signals from undesired noise.

With the help of the AMSY-6 measurement system the AE phenomenon can be used for 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.

Major advantages of AMSY-6 measurement technology are:

- Discovering hidden damage processes even at inaccessible locations of a structure.

- A cost-effective method to completely monitor a structure 24 hours a day, 7 days a week.

AMSY-6 AE measurement system complies with EN13477-1, "Non-destructive testing – Acoustic emission testing – Equipment characterization – Part 1: Equipment description" and that can be verified according to EN 13477-2, "Non-destructive testing – Acoustic emission testing – Equipment characterization – Part 2: Verification of operating characteristics".

2   AE Measurement and the AMSY-6 System

AE sources, such as micro cracks, emit transient elastic waves when they are stimulated. Elastic waves propagate through the test object. When they reach the surface, they are transformed into surface waves. Surface waves cause a displacement of the surface. The propagating displacement is detected once it reaches an AE sensor. AE is typically monitored above the audible frequency range (often 100 – 1000 kHz) with piezo-electric sensors. The AMSY-6 measurement system can work with many sensor types in a frequency range from 500 Hz to 2.4 MHz.
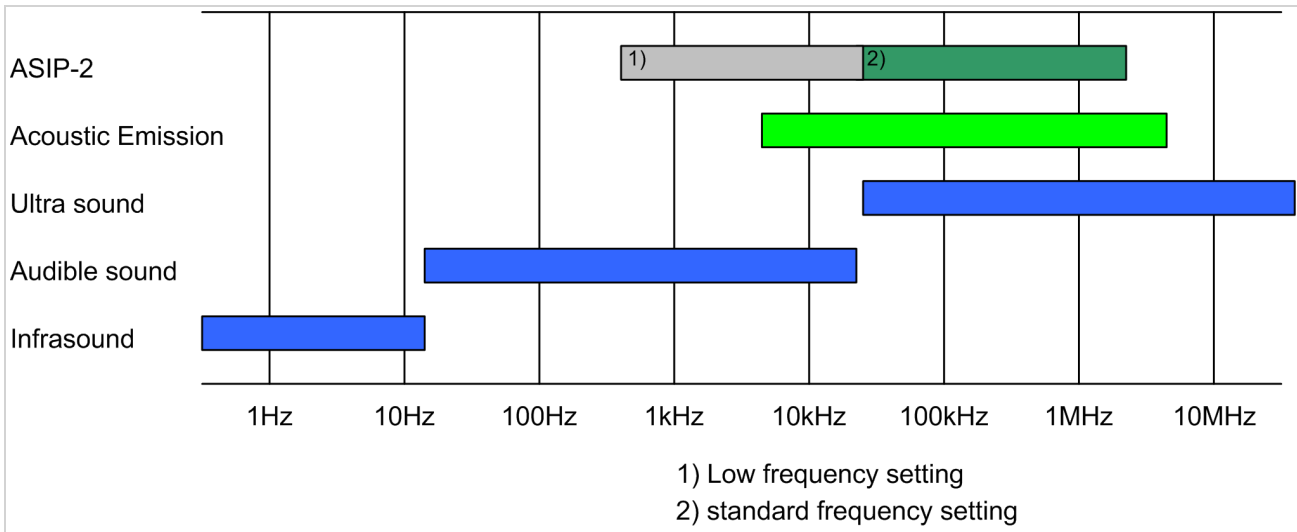
Figure 1: Frequency range of infra-, audible- and ultra sound. Frequency range of Acoustic Emission is between 5 kHz and 5 MHz. The frequency range of the ASIP-2 is between 500 Hz and 2.4 MHz.

An AE sensor converts the surface displacement into an electrical signal (AE signal). An AE signal can be displayed on an oscilloscope or a transient recorder display or can be processed by the hard- and software of the AMSY-6 measurement system.
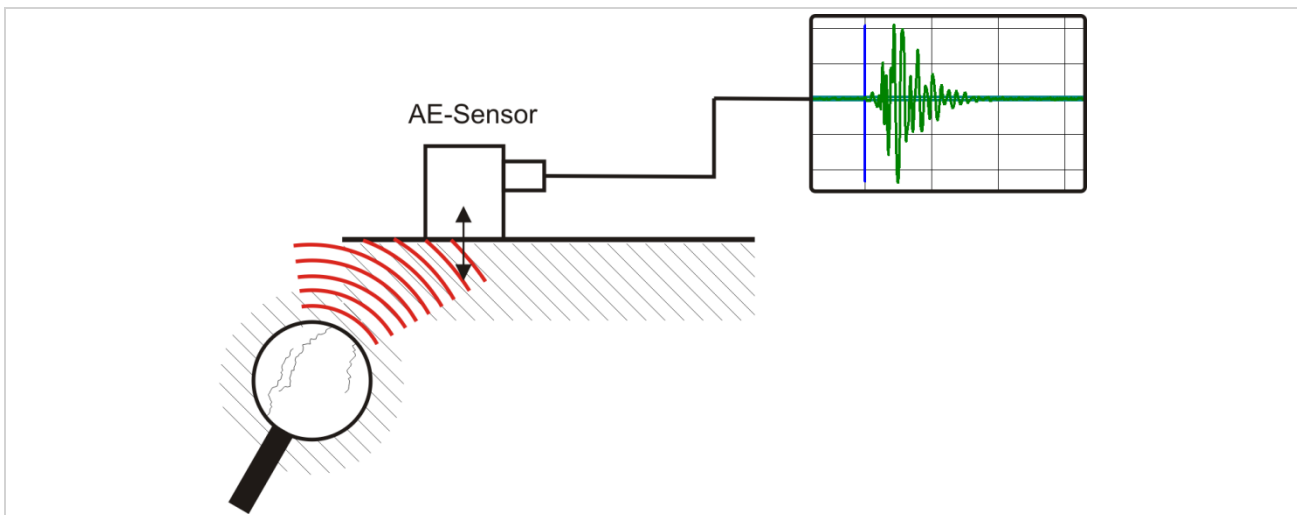
Figure 2: Schematic drawing of cracks emitting an elastic wave (wave fronts are indicated as curved red lines) which is picked up by a sensor and displayed as transient

Typically, one is interested in burst emissions since crack formation and crack propagation cause short bursts of elastic waves. A burst emission is characterized by a sharp increase of wave energy. The

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amplitudes of a burst emission reach one or more peaks and then decrease (see figure 3). The AMSY-6 system processes burst emissions if they cross a pre-defined fixed or floating threshold. Once a burst emission crosses the threshold it is called a hit and will be processed by the hard- and software. In addition, the AMSY-6 system can monitor and analyze continuous emission as produced by leaks or wear as well.
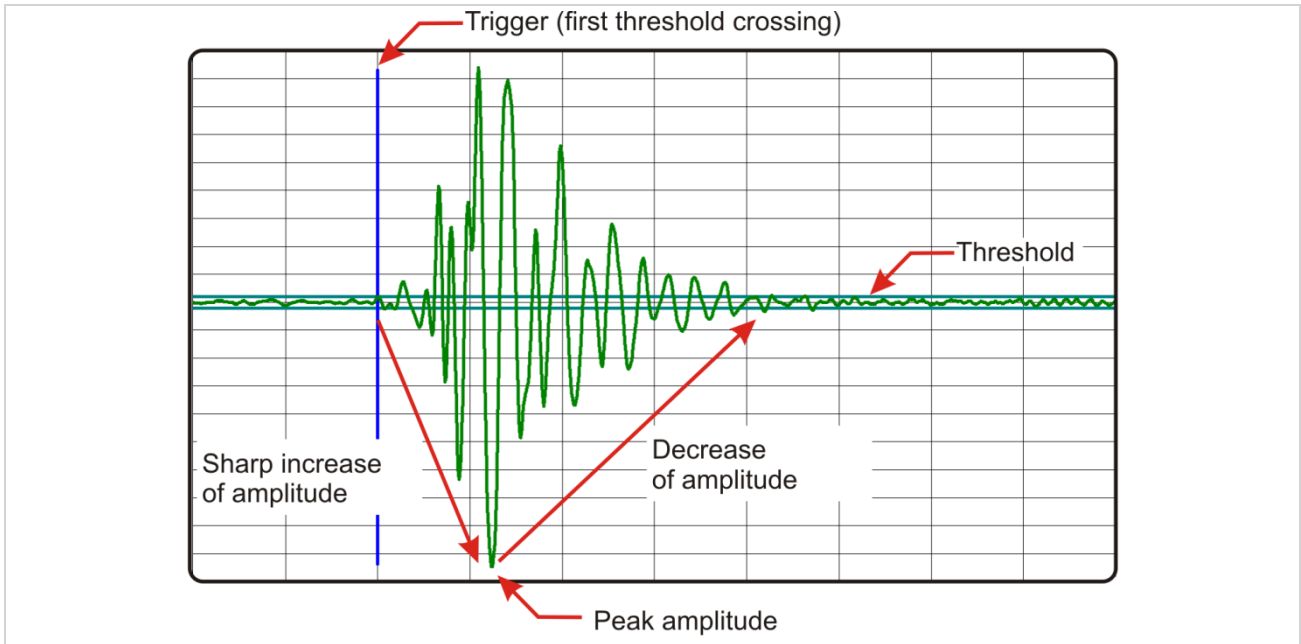
Figure 3: Schematic of a burst emission that is a hit because it exceeds the threshold.

An AMSY-6 system extracts a set of features from a hit. This set of numerical features is suitable for describing the raw AE burst signal. Important hit features include: arrival time, peak amplitude, energy, rise time, counts and duration. In addition, an AMSY-6 system has the capability to record the waveform of the hit (transient recorder) and to analyze its frequency content.
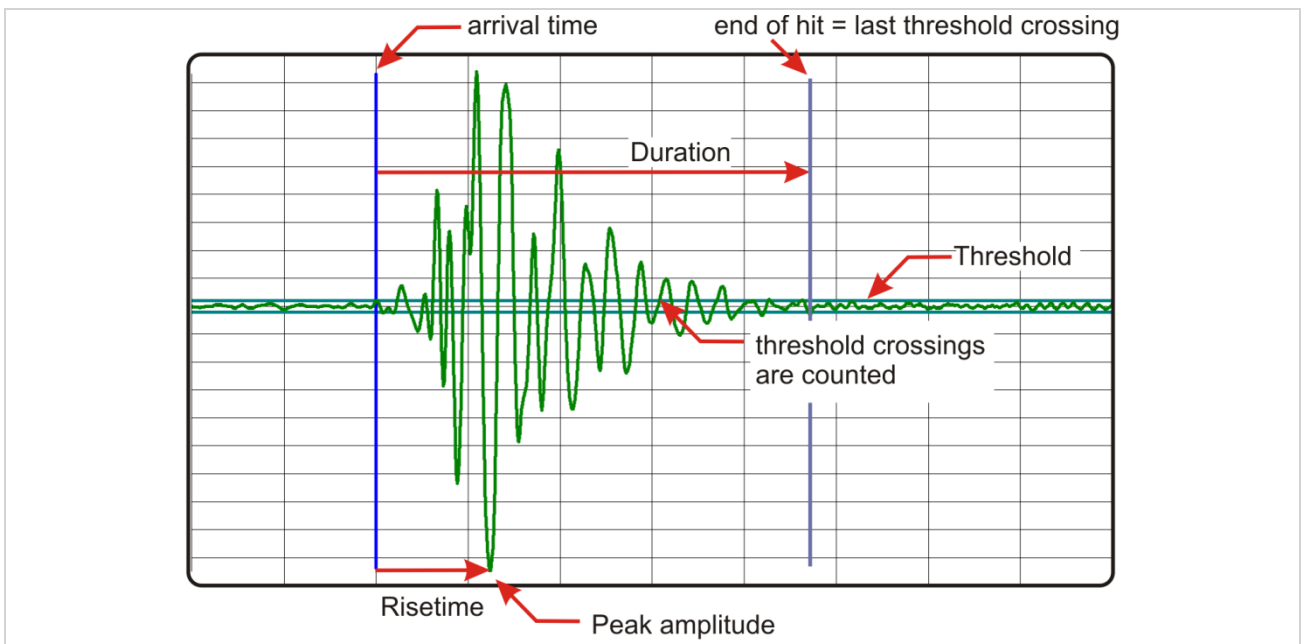
Figure 4: Selection of hit features that are extracted for every hit. Additionally, hit energy and RMS before hit is measured by the ASIP-2 signal processor

One of the most important requirements of the AMSY-6 system is the location of AE sources since operators are not only interested in the existence of defects but also in their location. For the location of an AE source, AE sensors have to be mounted at different positions on the test object. The transient wave emitted by the AE source will arrive at the sensors at different times. The AMSY-6 software automatically groups hits from the same AE source into an event set. The arrival times of the hits of an event set lead to a series of arrival time differences. These time differences are processed by the AMSY-6 software and produce a location result of the AE source. The calculated locations can be plotted in diagrams and assigned to coordinates in the drawings of the object.
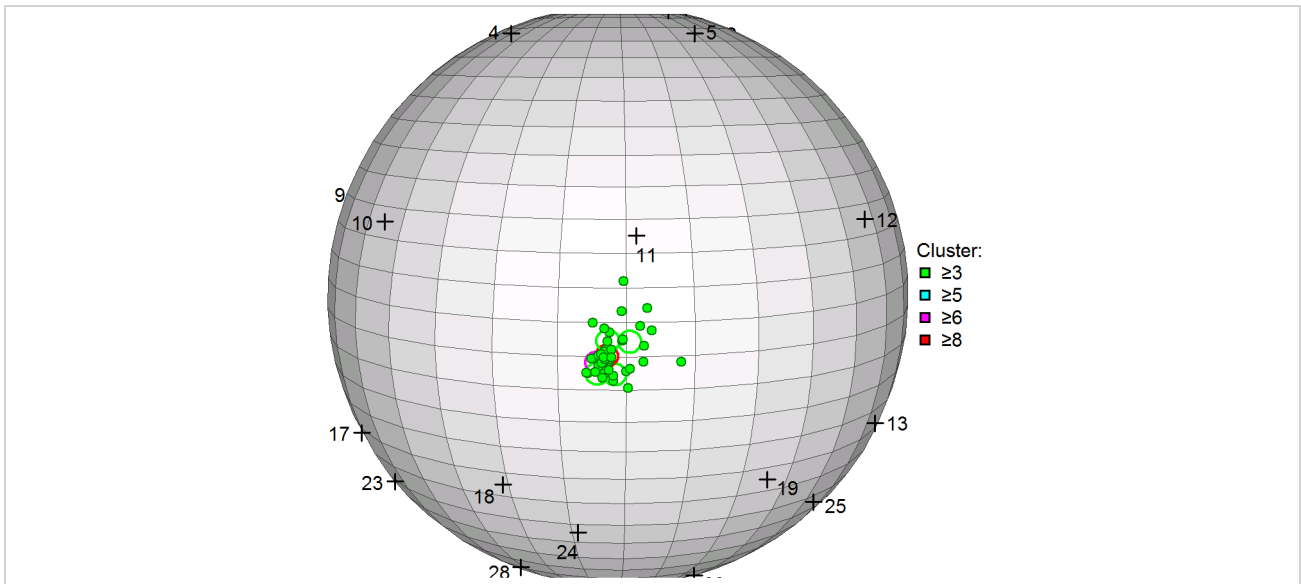
Figure 5: Example of AE source locations on a spherical storage tank.

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).

3 Hardware Description

The AMSY-6 system is a multi-channel Acoustic Emission (AE) measurement system consisting of parallel measurement channels and system front end software running on an external PC.

On an abstract level an AMSY-6 system combines up to 254 parallel measurement channels with a data storage device and a software for data analysis. Each channel consists of a sensing element, a subsequent analogue signal conditioning path and a digital signal processing unit. AE features, such as time of the first threshold crossing (arrival time), rise-time, duration, peak amplitude, energy and counts, are extracted by a measurement channel. Optionally, the complete waveform can be stored and its frequency content analyzed.

On a physical level an AMSY-6 system consists of AE sensors (see section 3.1), preamplifiers (see section 3.2) ASIP-2 (dual channel) acoustic emission signal processors (see section 3.3), a chassis into which the ASIP-2 boards are plugged into, a PC for data storage and running the Vallen AE Suite software. The chassis communicates over an USB 3.1 Gen 1 interface with the PC.
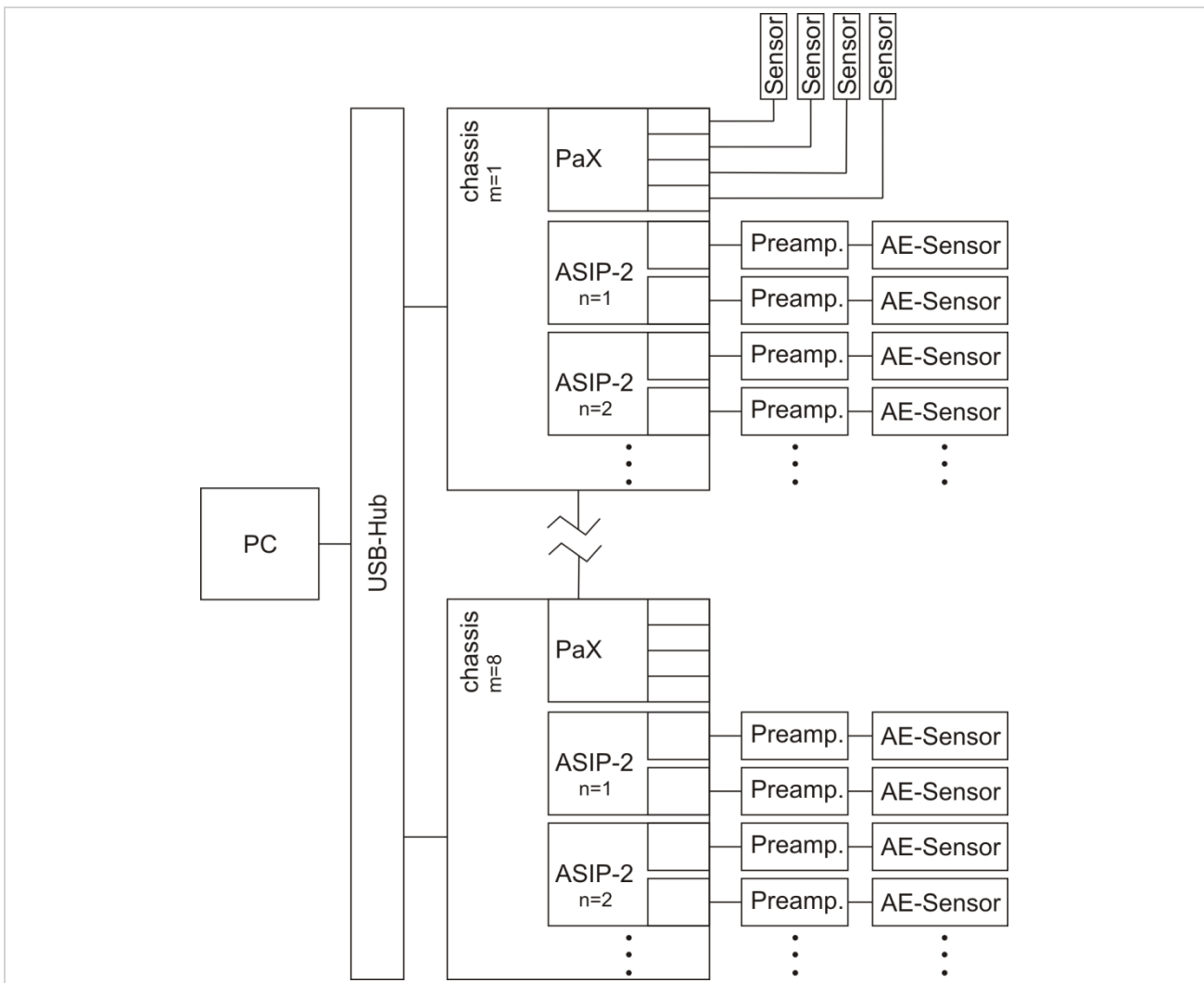
Figure 6: Block diagram of an AMSY-6 system consisting of AE sensors, preamplifiers, ASIP-2 cards mounted in one or more chassis and the PC. Additionally, up to a total of 16 parametric inputs can be used.

The Vallen AE Suite software is roughly divided into acquisition- and analysis software. The acquisition software controls every aspect of the measurement hardware while the analysis software processes and displays the measurement data.

Analysis software runs in parallel but independent of acquisition software. Hence it is possible to stop analysis software, change parameters and restart it again. Acquisition software will be unaffected and continues recording data.

The AMSY-6 system provides 4 types of measurement data:

- hit data: data generated when hits occur

- status data: data generated in regular time intervals

- parametric data: data of external parametric sensors which are measured at regular time intervals. Parametric data are stored with every hit or at user specified time intervals.

- waveform data: sampled AE sensor signal.

3.1 Acoustic Emission Sensors

The purpose of an acoustic emission sensor is to convert a surface displacement into an electrical signal. Vallen Systeme manufactures piezoelectric AE sensors. Such piezoelectric elements have many advantages upon the most important are:

- No saturation behaviour even for large excitations

- Highest possible sensitivity compared to other sensor designs

- Cost efficient

An AMSY-6 system allows using different sensor designs or different brands of sensors as long as the sensor output meets the specified input requirement of the pre-amplifier or the ASIP-2.

Using Vallen AE sensors ensures compatibility with the remaining measurement equipment of Vallen (plug & measure).

More information about AE sensors can be found in the according document "Acoustic Emission Sensors".

3.2 Acoustic Emission Pre-amplifier

AE Pre-amplifiers are used to transform the high impedance signal of a sensor to a low impedance signal suitable for long cable transmission. It amplifies the AE sensor output to match the input requirements of the ASIP-2. All Vallen preamplifiers are designed to achieve the highest possible signal-to-noise ratio and therefore help raising even weak AE signals above the background noise For more information about pre-amplifiers see the according document "Acoustic Emission Preamplifiers"

Preamplifiers of different brand can be used. However, using Vallen pre-amplifiers ensures that the pre-amplifier output matches ASIP-2 input optimally.

3.3 AE Signal Processor ASIP-2

The ASIP-2 signal processor can process AE signals in two channels. It has to be plugged into a chassis. The ASIP-2 signal processor is available in a standard version (ASIP-2/S) or in an advanced version (ASIP-2/A).

Both versions have in common that they

- Supply power to the preamplifier by choosing the appropriate input device (see section 3.3.1).

- Condition the analogue signal for optimum signal-to-noise ratio in the measurement range, to avoid aliasing effects (see section 3.3.3) and to avoid saturation of ADC by unwanted (low) frequencies.

- Convert the analogue sensor signal to a digital stream (see section 3.3.3).

- Apply a dedicated filter for ADC noise reduction.

- Apply application specific digital band pass filters to the digitized AE signal (see section 3.3.4) for further reduction of unwanted noise.

- Extract features from the digitized AE signal (see section 3.3.6).

- Store waveforms to a dedicated memory if it is available (see section 3.3.7) and transient recording is enabled. The waveform data can be used for frequency domain feature extraction and in-depth analysis of source mechanisms.

- Provide a digital audio signal (see section 3.3.8).

- Provide a loop-through for a test pulse (see section 3.3.9) that enables monitoring the coupling state of AE sensors.

Beyond that, the ASIP-2/A signal processor offers:

- Two more generic input devices with user selectable supply voltage for preamplifiers (see section 3.3.1) enabling the operator to use a wide variety of preamplifiers and sensors.

- A programmable gain (see section 3.3.2) for additional amplification (in addition to pre-amplifier) of small signals increasing the signal resolution.

- About 500 application specific filters (see section 3.3.4) for noise reduction and improving signal to noise ratio in every testing situation.

- A notch filter stage (see section 3.3.5) for rejecting up to four unwanted frequencies.

- Feature extraction at higher sample rates (see section 3.3.6) for a higher time resolution of AE features which improves location accuracy in small samples.

- Transient recording from different data sources (see section 3.3.7), e.g. the unfiltered signal right after ADC for unbiased analysis of AE wave modes.

- Transient recording at higher sample rates (see section 3.3.7).
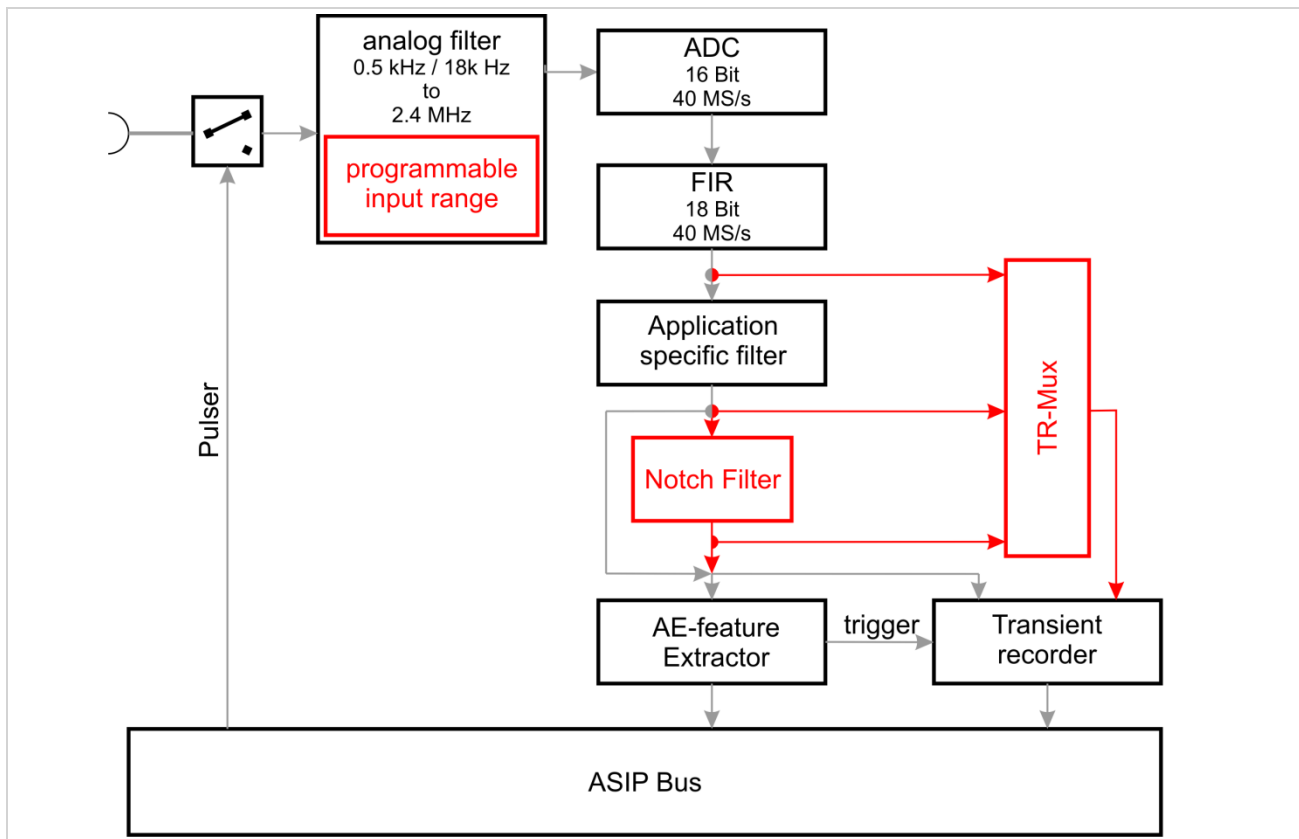
Figure 7: Simple block diagram of an ASIP-2 signal processor. Black blocks and grey arrows indicate functions and data paths of the ASIP-2/S. Red blocks and data paths indicate additional features of the ASIP-2/A.

3.3.1 Input devices

An input device ensures that a correct power supply and gain is initiated for the pre-amplifier that is connected to the channel. This eases a correct setup and avoids mistakes during gain and supply voltage settings.

A separate input device exists for each Vallen preamplifier and sensor with integrated preamplifier. Additionally, an ASIP-2/S signal processor offers two more input devices:

- 28V@50Ohm: input device that supplies 28 V_{DC} and has input impedance of 50 Ohm. This device can be used if non-Vallen preamplifiers that utilize 28 V and match the 50 Ohm impedance are used.

- AC@100K: input device that does not supply power and has an input impedance of 100 kOhm. This device can be used to parallel measurement channels (e.g. measure the same signal at different channels each with its own threshold setting), when only one of them provides power to a preamplifier.

An ASIP-2/A signal processor provides two more generic input devices for higher flexibility in using non Vallen preamplifiers:

- 4-28V@200R: the DC voltage for preamplifier power supply is programmable in the range of (4-28) V and the input impedance is 200 Ohm

- 4-28V@50Ohm: the DC voltage for preamplifier power supply is programmable in the range if (4-28) V and the input impedance is 50 Ohm.

3.3.2 Programmable input range (ASIP-2/A only)

The preamplifier output signal is fed over a software selectable gain (0 dB, 6 dB or 12 dB). The extra gain can be used to optimally utilize the measurement range of the AE channel in case of weak signals. The extra gain increases the resolution for low level signals.

3.3.3 Analogue filtering and digital conversion

An analogue band-pass filter stage is applied to the signal before analogue to digital conversion. This ensures that the signal will not suffer from aliasing effects or from low frequency noise.

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.

3.3.4 Application specific filters

After ADC an application specific band pass filter is applied to the signal. The filter works fully digital and is programmed to resemble the characteristic of analogue filters. This concept offers four main advantages:

- For any kind of application, the optimum bandwidth can be selected without interfering with the hardware.

- The ADC noise is filtered out. For low bandwidth applications, e.g. tank floor testing, the system noise can be drastically reduced compared to earlier models.

- With same filter setting, there is zero tolerance of filter behaviour between the channels.

- Filters can be added any time by simply importing a new firmware file.

Over 500 band pass filters are available with the ASIP-2/A. 8 band pass frequencies are selectable with the ASIP-2/S (see AMSY-6 specification for details). Any available filter configuration can be added to the ASIP-2/S standard filters.

A bypass to the band pass filter is also included. This filter shall be used to verify analog band pass filters or for sensor verification by using the Vallen Sensor Tester.

3.3.5 Notch filter (ASIP-2/A only)

An ASIP-2/A signal processor 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 selected AE sample rate. This is especially useful to block an ultrasonic signal such as from a liquid level sensor in an above-ground storage tank that would otherwise disturb the measurement.

3.3.6 AE Feature extraction

The output of the digital filter is fed into the AE feature extraction. The routines for feature extraction are defined in the firmware and can be updated in the course of future developments.

Feature extraction is conducted at 20 MHz sample rate (ASIP-2/S). In a sequential step the sample rate is reduced to 10 MHz relieving the data transfer on the internal bus. The reduction of sample rate also reduces the resolution of arrival time to 100ns.

In case of an ASIP-2/A feature extraction can also be done at 20 MHz and 40 MHz with a time resolution of 50 ns and 25 ns, respectively. A higher sample rate puts a higher load on the internal bus but may increase accuracy of location in small samples.

The following features are measured compliant to EN 13477-1: arrival time, peak amplitude, rise time, duration, counts, true energy and signal strength, as well as background noise (before a hit) as true RMS and absolute average level.

3.3.7 Transient Recorder

For transient recording the ASIP-2 signal processor has to be equipped with an optional TR-memory module. If it is available and TR is enabled the digitized AE signal will be fed to the transient recorder stage in parallel to the feature extraction. Transient recording is useful for in-depth analysis of AE signals e.g. to classify the source mechanism.

Waveforms are buffered in a fast TR-memory. This ensures that a sudden high activity does not cause data loss because of high data rates. Data from TR-memory is continuously transferred to PC.

3.3.8 Audio signal

If the ASIP-2 signal processor's audio output is selected the AE signal will be passed to the audio-selection sub-system. The filtered signal is sent by a separate bus to the audio DAC. The signal envelope of all selected channels of a chassis is converted to an analogue signal which is output to the speaker. This function is useful if the operator desires to have an audio indication of hit activity. The speaker signal is externally available at the audio jack (see section 3.4.2.6).

3.3.9 Pulse through

Pulse through describes a functionality where voltage pulses are produced by the chassis' own pulser module and connected through the ASIP-2 and preamplifier to the AE sensor. An AE sensor converts the electrical pulse into a mechanical impulse. As a result, the object's surface is mechanically excited and an elastic wave propagates through the material or along its surface. The so generated elastic wave will be picked up by other AE sensors. If this is done regularly, comparison of AE sensor responses can be used to verify constant coupling quality.

One or more voltage pulses can be produced by the chassis' own pulser module. Voltage pulses can be up to 450 V_{PP}. The pulse is also fed into the signal processing path of the pulsing AE channel. This produces an accurate time stamp of the pulse.

High pulsing amplitude (up to 450 V_{PP}) is useful for materials with high attenuation or wide sensor spacing. This ensures that receiving sensors will pick up the acoustic wave emitted by the pulsing AE sensor.

Additionally, the ASIP-2/A signal processor also supports the automatic sensor test (AST) function.

3.4 Chassis types
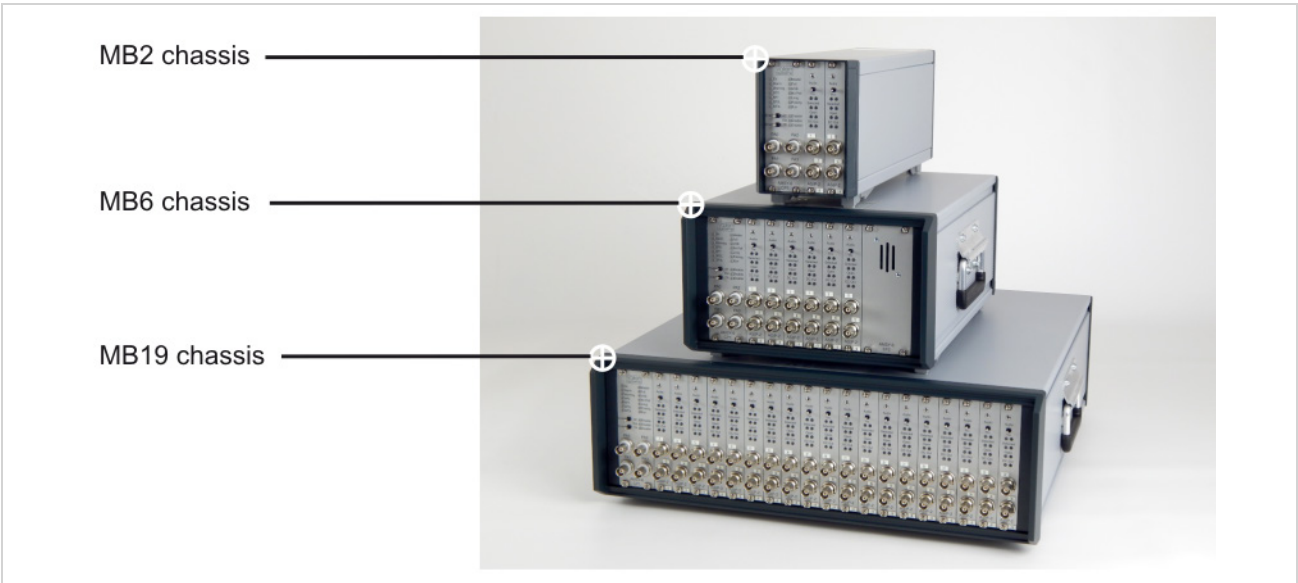
Figure 8: MB2, 4 channel AE measurement system; MB6, 12 channel AE measurement system; MB19, 38 channel AE measurement system

The chassis is container for ASIP-2 boards. It also contains the Control Panel with the parametric channels (see section 3.4.1). The chassis provides an interface to the PC over a USB 3.1 Gen 1 interface and interfaces for various other applications (see section 3.4.2). An integrated speaker (see section 3.4.3) and the pulser module are also part of the chassis.

The chassis are available in different sizes:

- MB2: can hold max. 4 AE channels (no internal speaker)

- MB6: can hold max. 12 AE channels

- MB19 or MR19: can hold max. 38 AE channels

- EB21 or ER21: can hold max. 42 AE channels and are extension chassis to a MBx or MR19 chassis.

MR19 and ER21 refer to rack mountable versions of the MB19 and EB21, respectively. A subsequent suffix, -*V1* or -*V2*, to the chassis designator indicates the version of a chassis. AMSY-6 chassis of different versions can be used in the same multi chassis setup, but require different/special cables for connecting it amongst each other and to the PC. Apart from the chassis, rack mountable versions MR19 and ER21 are identical to their counterparts MB19 and EB21, respectively. Everything that applies to an MB19 or EB21 applies to an MR19 or ER21 without explicitly stating it, as well.

3.4.1 Control Panel (CP)

The control panel provides various control elements (see section 3.4.1.2 and 3.4.1.3) as well as inputs for parametric channels (see section 3.4.1.1).

Note:

An extension chassis does not have a CP module and cannot be operated standalone.
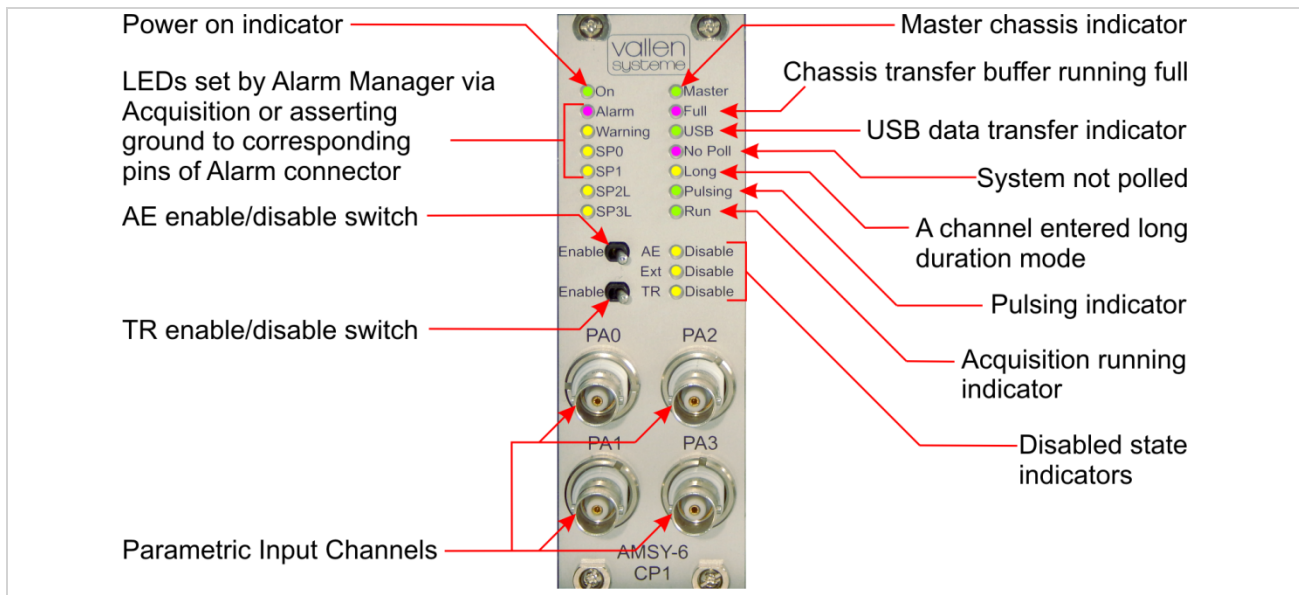
Figure 9: control panel.

3.4.1.1 Parametric inputs

The parametric input channels can be used to monitor environmental conditions such as temperature, load, etc. and correlate it to AE data. Parametric data sets are generated at a user defined time interval and automatically with every hit.

By default, there are four parametric input channels labeled PA0 to PA3. Up to a maximum of 16 parametric channels can be used in a multi chassis setup (see section 3.5). A maximum of 8 parametric channels is supported per chassis. In case of an MB19 the additional 4 parametric input channels occupy 2 ASIP-2 slots (see section 3.4.5).

The parametric data set also contains the parametric counters PCTA (up to 63 bit analogue controlled) and PCTD (16 bit digital controlled) as well as the CYSL (cycle counter slope) and CAL flags.

PCTD counter can be controlled via input pins of the external connector (see section 3.4.2.3).

PCTA counter is controlled by PA0 and can be used to count load cycles.

CYSL (cycle counter 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.

CAL flag can be used to filter data generated while test pulse sequence was either on or off.

Any of the parametric input channels can be used to control the data recording. Data recording is disabled when the voltage at the selected parametric input channel is outside the user-defined limits.

3.4.1.2 Record control switches

There are two record control switches at the Control Panel, "AE disable" and "TR-disable". Both switches trigger the according LED next to them.

AE enable switch

This switch is located left of the "AE Disable" LED. Pushed to the right (towards the LED), the switch disables data acquisition (AE and TR). It is recommended to disable data acquisition before someone works on the test object e.g. if sensors need to be remounted.

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TR enable switch

This switch is located left of the "TR Disable" LED. Pushed to the right, it disables TR-data (waveform) acquisition only, but AE data will still be recorded. This can be used to reduce the amount of data stored to disk: e.g. enable TR recording only from time to time still provides useful information but reduces the data volume considerably.

3.4.1.3   LEDs

Various LEDs indicate the operating status of the AMSY-6 (see figure 9). A description of LEDs is found in the AMSY-6 System Specification document.

3.4.2   Back panel elements

The back panel contains various interfaces for data transfer and chassis control.

Figure 10: Back panel elements in case of an MB6 chassis. Back panel elements of an MB2, MB19 or EB21 chassis are analogue to the depicted ones.

3.4.2.1   USB Interface

The USB Interface is the data transfer and control port of the chassis. The USB interface allows for easy connectivity. The chassis can be connected to a PC or laptop which supports USB 3.1 Gen 1. USB connectivity is downward compatible. Data throughput rate is slower then.

AE , TR-, parametric- and status data sets are transferred to the PC via USB interface. Acquisition software running on the PC controls the functions that the chassis and its components provide.

3.4.2.2   Alarm Connector

The alarm connector provides an interface to read out the status of Warning, Alarm, SP0 and SP1 LEDs. These LEDs can be set by the Alarm Manager software indicating certain states (e.g. alarm, warning, etc.) of the analysis or the PC.

Additionally, these LEDs can be set by externally applied digital inputs.

Note:

The Alarm connector should be used in a master chassis only. In a slave chassis the outputs are undefined and the inputs will only enable the corresponding LEDs.

3.4.2.3 Externals Connector

The external connector provides digital input to enable or disable recording (both AE and TR), and four other inputs to manipulate digital counter PCTD.

Note:

The Externals connector should be used in a master chassis only. In a slave chassis the signals at the Externals connector are undefined.

3.4.2.4 Previous Port / Next Port

If more than one chassis is used (multiple chassis setup) the chassis have to be daisy chained by use of a special sync-cable. The interconnection of chassis enables time synchronization across multiple chassis.

3.4.2.5 Address selector

In a multi-chassis setup, each chassis has to have a unique address. The chassis address is set by the rotary selector.

3.4.2.6 Audio jack

The Audio jack provides an audio output to a passive speaker of 8 Ω impedance. The peak envelope of waveforms of all audio enabled channels will be output. In case a speaker is connected the internal speaker of the chassis will be disabled.

3.4.2.7 Pulser Output

The pulser output is a BNC socket to which the internally generated pulse will be put out apart from being fed to the selected ASIP-2. It is a test output, only.

3.4.3 Speaker

The panel speaker is used for audio output. The audio signal is the envelope over all signals that are selected for audio output (see section 3.3.8).

There are three versions of the speaker:

- Rear panel speaker: used in MB19 and EB21 at the rear of the chassis.
- Front panel speaker: used in MB6 at the front of the chassis.
- Front panel speaker in combination with PA472 (see section 3.4.5).

3.4.4 Power Supply

An MBx chassis needs a 24 V_{DC} power supply. An external power supply converts the typical line voltage to the required DC voltage. The status of the power is indicated by three LEDs which are described in the AMSY-6 System Specification document.

3.4.5 Optional parametric inputs (PA47x)

PA47x designates a module that provides four additional parametric input channels. There are two different versions of this module:

- PA471: four parametric inputs with additional speaker, used in MB19 chassis. A PA471 module will occupy two ASIP-2 slots.
- PA472: four parametric inputs with speaker, used in MB6 chassis instead of standard front panel speaker.

3.5 Multi Chassis setup

Up to 9 chassis can be interconnected to form one large AMSY-6 for a total of 254 AE channels. In a multi chassis setup each chassis has to be connected in parallel to the USB interface. External USB hubs can be used. Additionally, for time synchronisation purposes the chassis have to be daisy chained by use of special sync-cables (see section 3.4.2.4).

In a multi chassis setup each chassis has to have a unique address. The chassis with the lowest address acts as master while all other chassis are considered slaves.

Because of paralleling the chassis on the USB hub, the full bandwidth of the USB can be used with multiple chassis. The maximum number of hits that can be processed is not a function of the number of channels. It is only limited by the chassis itself, each chassis being able to process about 100.000 hits per second.

3.6 External PC

The external PC is used to configure the hardware, control it during data acquisition, display and analyze measurement results and store measurement data.

The system front-end provides access to hardware settings and its configuration. It provides means to analyze the data and manage data storage.

Any kind of PC, e.g. laptop, desktop, lunchbox, 19" rack industry or standard PC can be used. As PC and MBx chassis are separate items it is possible utilizing always state of the art PC technology. The minimum PC requirements can be found in the System Specification.

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4 Software Description

The Vallen AE-Suite software suite is composed of a number of programs that can be roughly separated into data acquisition, data analysis, hardware verification and utility programs. The block diagram in figure 11 gives an overview.
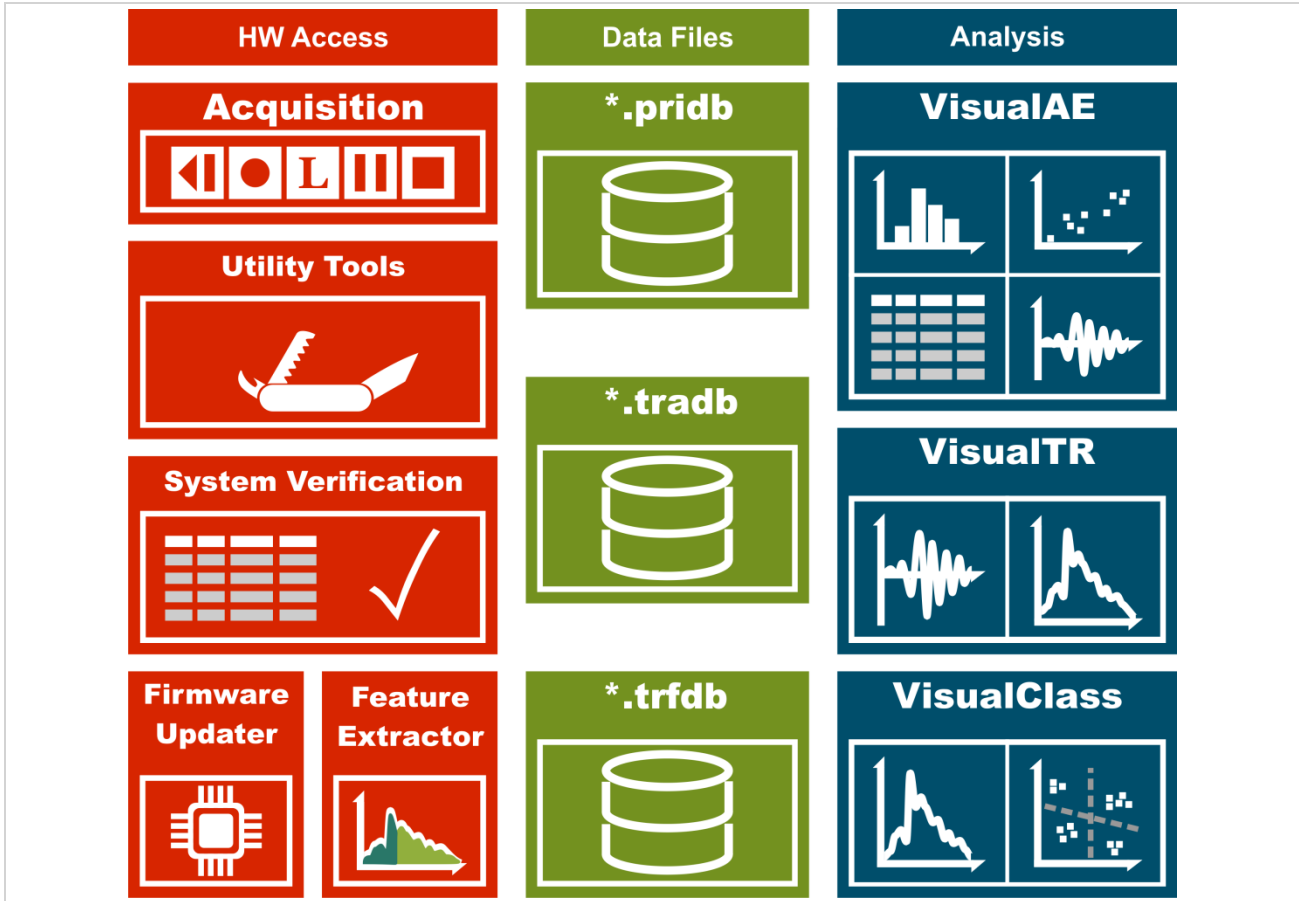
Figure 11: Simplified block diagram of the Vallen AE Suite software architecture.

In a standard work flow of an Acoustic Emission test the data acquisition program, *Acquisition*, writes the measurement data to the data files, **.pridb* and **.tradb*. The analysis program, *VisualAE*, is used to read the data from these data files. The operator uses *VisualAE* to extract the relevant information from the measurement data and conclude about the test object, e.g. a pressure vessel is safe or it is not.

For data analysis purposes *VisualAE* (see section 4.4), *VisualTR* (see section 4.5) and *VisualClass* (see section 4.7) establish a powerful set of tools.

VisualAE is a modular framework for complete data analysis and presentation. It processes and displays data. VisualAE can be configured to fit various applications (e.g. above-ground tank floor test, integrity tests of pressure vessels, etc.)

VisualTR is a tool for investigating waveform data in detail and provides helpful tools for generating training data sets for VisualClass.

VisualClass is a machine learning tool for statistical analysis of waveforms based on classification.

4.1 Acquisition

An acoustic emission test detects the presence of acoustic emission sources and provides as much information as possible about them. The first step to successful data analysis is obtaining unbiased raw data. The *Acquisition* program provides a front-end which controls and configures the measurement hardware and manages data storage. The operator is guided by graphical user interfaces through the correct hardware and measurement set-up.

Acquisition generates 5 types of data: (i) AE feature data, (ii) transient recorder data, (iii) parametric data, (iv) status data and (v) user input data.

Data type	What	Way of generation
AE feature data	Burst signal energy, - peak amplitude, - duration, - risetime, -ring down counts	Event - or time triggered
Transient recorder data	Sampled signal of a certain time period	Event - or time triggered
Parametric data	e.g. pressure, strain, force, temperature, etc.	Event - and time triggered
Status data	RMS and signal energy	Time triggered
User input data	User text	User triggered

4.1.1 Hardware control during a measurement

Usually the Acquisition software controls every aspect of the hardware automatically and the user is not bothered with it. In few circumstances the user can directly control the measurement hardware during acquisition:

- Start pulsing of AE channels via software in single cycle-, single channel- or iterative cycle mode.
- Changing pulse amplitude
- Online threshold control: change the acquisition threshold of each channel separately while data acquisition is running.
- Enabling and setting volume of audio output

4.1.2 External control of Acquisition

An application programming interface (API) is provided for Acquisition (ACQCmdAPI). This enables control of Acquisition from external programs such as LabVIEW or Matlab. Acquisition API provides a subset of acquisition program functionality that is: start/stop/pause recording, insert label, start pulsing and change of data files.

Note:
ACQCmdAPI (ACQuisition Command Application Programming Interface) comes together with the Acquisition and is part of the SWACQ module.

4.1.3 AE Feature Data

AE feature data is defined in EN 13554. An AMSY-6 system generates the following set of AE feature data:

1. Burst signal energy: the energy of the electrical signal caused by a detected burst
2. Burst signal peak amplitude: the highest voltage excursion of the detected burst signal
3. Rise time: the time difference of the peak occurrence to the start of hit
4. Duration: the time difference between end of hit and start of hit
5. Counts: the number of positive threshold crossings in the time period between start of hit and end of hit.

AE feature data can be generated by the *Acquisition* in two ways: hit based data acquisition and continuous mode data acquisition.

4.1.3.1 Hit Based Data Acquisition of AE Feature Data

This measurement mode identifies individual burst signals and extracts features from them. These features are a reduced set of data that describe the burst signal. Measuring in hit based mode is a way of reducing data that is recorded. It allows locating AE sources by the use of VisualAE's add-on location algorithms.

A transient data set is generated with every hit in case transient data recording is enabled.

4.1.3.2 Continuous Mode Data Acquisition – Streaming of Data

The continuous time stream of data is divided into equally long time slices. For each time slice a set of AE features is extracted:

1. Signal energy: the energy of the electrical signal of a time slice
2. Peak amplitude: the highest voltage excursion within a time slice
3. Counts: the number of positive threshold crossing within a time slice (a measure for the intensity of AE)

The results duration and rise time are also generated, but not useful in the analysis.

In parallel, TR data can be acquired continuously and seamless as long as the on board memory module is not full.

Dedicated onboard TR-memory plays an important role in streaming applications of large channel systems and at high sample rates. In such cases all available and active AE channels (up to 254) can stream TR-data in parallel at up to 10 MHz (40 MHz in case of ASIP-2/A) sample rate until onboard memory is full. By applying a TR frontend filter the amount of TR data to be transferred and stored can be tremendously reduced. As a result continuous data of important time periods will be available while data from unimportant time periods is simply discarded.

Note:
A frontend filter rejects AE- and TR-data or TR-data only. The logical filter conditions are based on an AE feature set. Employing the TR front end filter requires at least TR-2/512MB memory modules.

4.1.4 Transient Recorder Data

Samples of a burst signal, the *waveform*, can be recorded upon a trigger event. Four ways of triggering the transient recorder, so called *trigger modes*, are possible:

1. Normal: the recording is triggered with the start of hit in the same channel
2. Slave: the recording is triggered if the master channel triggers.
3. Master: the recording is triggered with a start of hit. The *Master* triggers its own transient recorder and all slave transient recorders.

4. Combined: The first *Combined* channel that detects a start of hit acts as a *Master* else it becomes a *Slave*.

A subset of channels, even across different chassis, can be assigned to a *trigger group*. Trigger modes are applied per *trigger group*. The first hit channel of a *trigger group* triggers the other channels according to the selected modes. Each channel can be assigned to one *trigger group*, only.

Three data sources can be defined for the transient recorder: (i) the last filter block of the filter chain (default), (ii) the unfiltered output of the ADC or (iii) after the band pass filter and before the notch filter.

Recording the unfiltered signal is useful for frequency content analysis or analysis of AE wave modes.

The *waveform* can be recorded in one of two ways: duration adapted or with a fixed page.

4.1.4.1 Duration Adapted Transient Recording

Duration adapted transient recording describes a recording mode in which the burst signal is recorded starting from a defined number of samples before the first threshold crossing ("PreTrg") up to a defined number of samples after the last threshold crossing ("PostDur"). "PreTrg" is the number of pre-trigger samples, "PostDur" the number of post duration samples, both are user-defined parameters. Duration adapted transient recording ensures that the whole burst signal is recorded on a single TR-page. Even when hits of short and long durations occur in a high rate, each hit gets its own TR-page and its own TR-Index. TR-pages will be of different size, depending on the duration of each burst signal.

This recording mode can substitute the continuous TR streaming mode and thereby save resources of the bus system and hard disk drive.

4.1.4.2 Fixed Page Length Transient Recording

Fixed page length recording refers to recording a fixed number of samples per trigger. The number of samples that are recorded have to be defined during Acquisition setup. As a result, a page may contain only the begin of a burst signal. On the other hand a page can contain a lot of noise after a short burst signal. Even worse for data analysis would be the case where a TR-page contains the samples of more than one burst signal.

4.1.5 Parametric Data

In parallel to the AE and TR-data parametric data from e.g. pressure sensors, temperature sensors, etc. can be recorded. These physical quantities change only slowly with time compared to an AE signal. This type of data is used to correlate the AE results to certain environmental conditions. Parametric data sets are stored at certain time intervals (time triggered). In case of AE activity, parametric data sets are stored in an event-based mode.

4.1.6 Status Data

Status data sets are purely time triggered. Status data sets are collected for each AE channel and provide the status (energy and RMS) of the AE channel for certain time intervals. Burst signals that are measured do not contribute to the energy or RMS of status data.

4.1.7 User Input Data

The user can store information in the time stream of data, so called *labels*, at his convenience. This kind of information is extremely helpful if it describes the test steps and settings or characteristics that cannot be concluded from the Acquisition settings. Each label generates a data set with a time stamp derived from the PC timer. Labels can be used as start- and termination criteria for analysis.

4.2 Data Files

AE feature data is stored to the primary data base file, *.pridb. Parametric data, status data and user input data is also stored to this file. Transient data is stored to a *.tradb file. Acquisition time sorts the data before it is written to the hard disk.

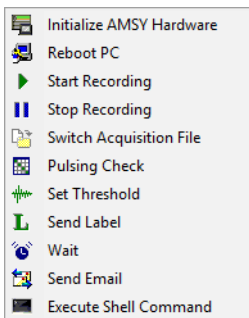Especially time sorting of hits is important since it enables a fast on-line location calculation.

AE feature data and transient data are stored to a database that complies with SQLite3 standard. Data stored to *.pridb and *.tradb files can be accessed by any external application that supports SQLite3, e.g.: LabVIEW, Matlab, Python, etc.

Acquisition manages data within a primary data file in sections. A section contains data recorded with same acquisition settings. Every time acquisition parameters are changed, Acquisition introduces a new section. The tracking of acquisition settings is possible in a post analysis.

4.3 Automation Manager

The Vallen Automation Manager can be used in tasks of continuous monitoring and automation using Vallen Systeme acoustic emission equipment. The program runs on the acquisition PC. It is the central instance which controls and supervises other programs, including the Acquisition and VisualAE analysis program.

Initialize AMSY Hardware
Reboot PC
Start Recording
Stop Recording
Switch Acquisition File
Pulsing Check
Set Threshold
Send Label
Wait
Send Email
Execute Shell Command

The Vallen Automation Manager uses the concepts of events, tasks, and actions to perform its duties.

The available actions are shown in the screenshot to the left. A task has to be defined by the user or operator and can consist of one or more actions.

A task is executed when the Automation Manager program identifies an event that has been defined in its context. There are four categories of Events: Manual Triggers, Timers, Alarm Signals and Watchdogs. When an event occurs, the Automation Manager executes a user-defined task that consists of one or several actions.

Predefined actions are continuously added to the portfolio for an ever increasing scope of tasks that can be defined with the automation Manager.

4.4 VisualAE

VisualAE provides a framework for all data analysis tasks in online - or in post process mode (offline). VisualAE can be configured on a modular basis to fit a certain analysis task. The individual configuration is based on the selection of software modules. Software modules can be added any time for extending the functionality.

The basic functionality of VisualAE is governed by two software options called SWBN and BDSWB. The difference between these two software options are the modules VAE1 and VAE2 as well as a few *Processors* which are included in BDSWB.

Note:

We recommend using VisualAE with the option BDWSB because many useful functions and processors are included in this option.

VisualAE provides tools for processing and displaying data. *Processors* allow the manipulation of data, while *Visuals* display data in diagrams or tabular form. Any number of *processors* or *visuals* can be defined and used to even enable the most complex analysis.
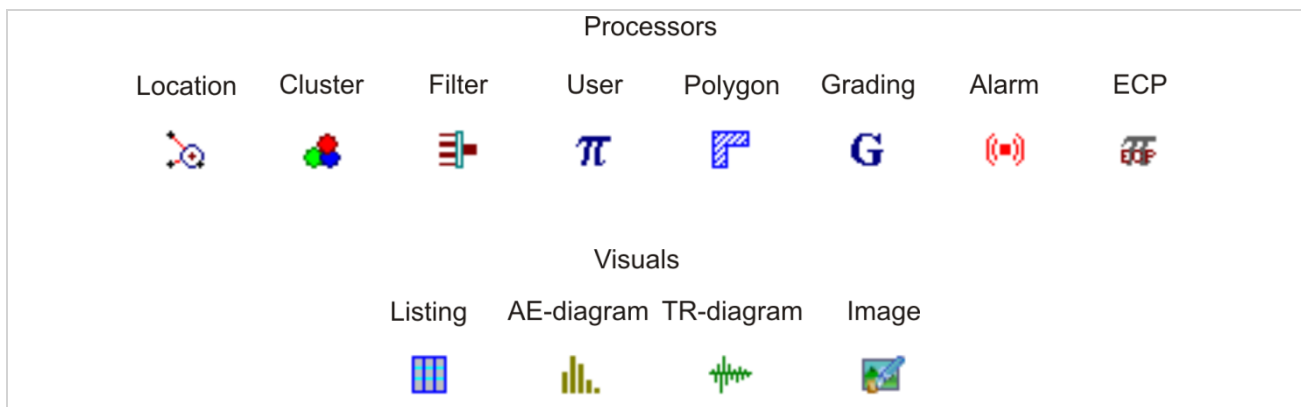
Figure 12: Overview of processors, visuals and their according symbols

4.4.1 Basic Functionality of VisualAE

Next to *Visuals* and *Processors*, VisualAE offers also methods for organizing and configuring the processing of data and managing the portion of data that is processed.

4.4.1.1 Data Processing Structure

Visuals and *Processors* are organized in a tree like processing structure. Each processor introduces a new branch and adds or removes temporarily (as long as the analysis is running) data to/from the data stream of the branch. VisualAE has only read access to the raw data so raw data remains unaffected by *Processors*.

Each branch of the processing structure can have an arbitrary number of *Visuals* attached to it. *Visuals* can be arranged on one or multiple pages. Furthermore, *Visuals* and *Processors*, even whole branches, can be rearranged by drag and drop in the processing structure. As *Processors* and *Visuals* can be rearranged easily the analysis can be changed or adopted quickly.
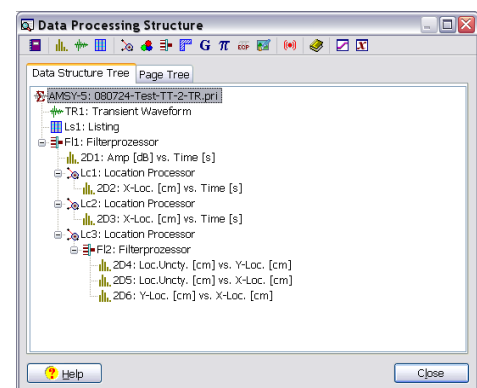
Figure 13: Example of a Data Processing Structure

VisualAE strictly separates data from data presentation. The information of the processing structure (i.e. the number of *Visuals*, *Processors* and their arrangement) is stored in a separate setup file. This enables to use the same setup on different raw data files.

4.4.1.2 Projects Settings

Project Settings manage the data that is displayed by defining a start- and stop criterion. The criterion can be a label or data set number. Project Settings manages also some global properties like what kind of data is displayed on pages.

4.4.1.3 Parametric Conversion

Parametric data is recorded in units of mV no matter if it is a temperature sensor, pressure sensor, force sensor, etc. A parametric conversion converts the mV scale to engineering units such as °C (temperature), bar (pressure), N (force), etc.

4.4.1.4 Variable Editor

During data analysis filter conditions are frequently used in diagrams and processors. Sometimes filter conditions in different diagrams or processors are the same. If the values of the filter conditions are defined

in many visuals individually, changing every single one to reflect new analysis criteria can be a tedious task. The variable editor can be used to ease the situation. It provides means to define the name and value of up to 32 variables. These variables can be used in setting up filter conditions where applicable. Changing the value of the filter condition can be done at a single location for all filter conditions using the according variable.

4.4.1.5 User Text Editor

User text editor provides string variables similarly to the variable editor. The user text editor allows the definition of up to 10 strings which can be used globally in legends, comments and headers of visuals.

4.4.1.6 Reporting

Once results are derived the next important step is to include them in reports. Reporting of results is aided by

- printing functions with preview, size, and format selection. In this context still images (see section 4.4.2.4) may be useful to include the corporate identity of a header and footer into the print out.

- Set-up reports for all analysis and acquisition parameters which can be output on screen, printer or file. This is important to keep track of all the settings made during analysis.

- In the SWBN version page export to *.bmp is enabled. In case of BDSWB version of VisualAE (VAE1+2 required see section 4.4.4) page and diagram export to *.bmp, .jpg and .png file as well as to clipboard with user-defined resolution and size is possible.

4.4.1.7 Language Selection

One out of seven different languages (English, Chinese, Japanese, Russian, German, French and Italian) can be selected for the graphical user interface. The language is switched immediately and does not require restarting VisualAE.

4.4.1.8 TR-Viewer

TR-Viewer (see also 4.4.2.1, TR-diagrams) is an application that displays waveform diagrams in time and frequency domain. It supports ASCII-output, bitmap output, Windows printing with preview capability and adjustable printer page setup. The TR-Viewer is implemented in VisualAE via the TR-diagram.

4.4.1.9 Library for visuals and processors

VisualAE stores the *Visuals* and *Processors* in the VisualAE setup file (file extension vae). A setup file can be applied to different primary data files enabling the same analysis of different raw data files. In case of reusing only single *Visuals* or *Processors* the library function is more useful. The library can be used to store and import single *Processors* or *Visuals*. Since data in library is stored externally it can be used from any VisualAE setup.
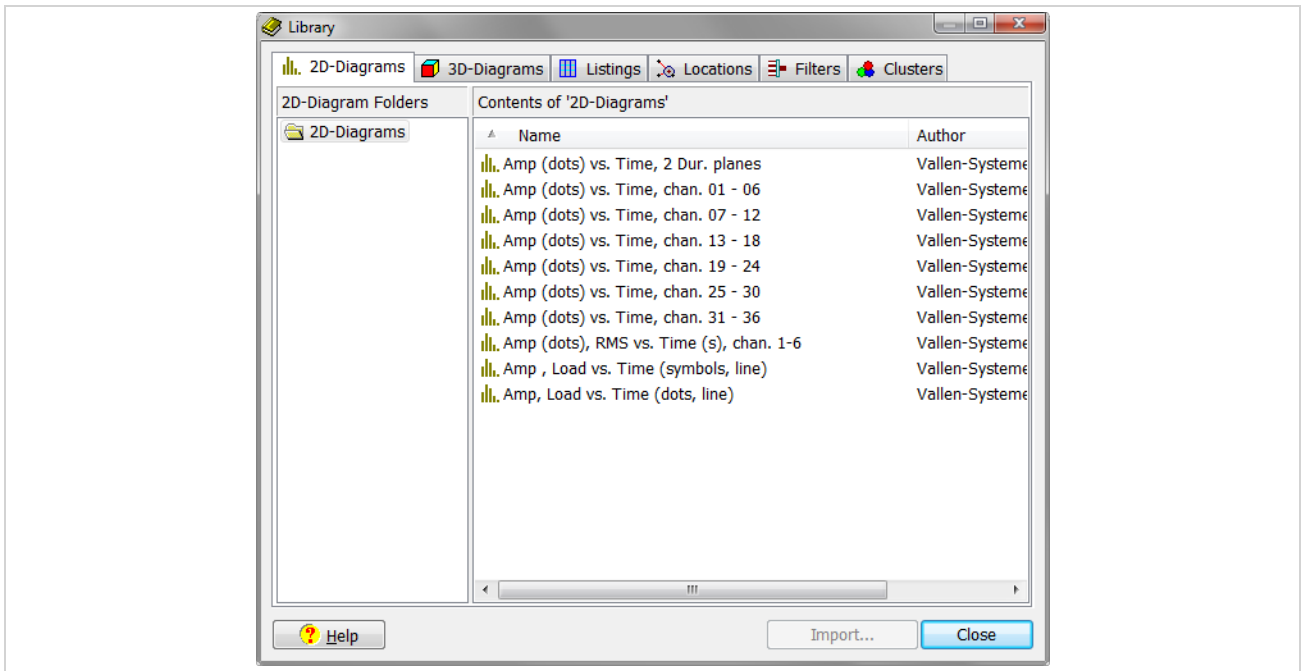
Figure 14: Screenshot of Library dialog

4.4.1.10   Coupling Table

During an inspection it is important to ensure that the sensor coupling does not change. A degradation in sensor coupling leads to less sensitivity in a channel and it will effectively measure lower amplitudes. This is potentially dangerous and the operator needs to check that sensor coupling is constant throughout an inspection. The pulsing function (see section 3.3.9) is a tool to verify sensor coupling. Measured amplitudes of each pulsing cycle can be displayed in a Coupling Table. Coupling Tables can be automatically compared pair wise (e.g. Coupling Table before inspection to Coupling Table after inspection) revealing any changes in sensor coupling.

Additionally, a Coupling Table provides a tool to calculate the speed of sound for each sensor pair that is considered (requires a location processor).

4.4.1.11   Attenuation Profile

Next to the speed of sound, the attenuation is the second most important material property in AE. The attenuation in the material determines the maximum possible sensor spacing in case location of AE sources is necessary. The Attenuation Profile is a tool which aids creating an attenuation profile according to EN 14584.

4.4.1.12   Data Export to New File

An export function allows storing selected data to a separate file. Data selection is done on basis of processors, e.g. exporting data that passes a certain location processor and the time marker criteria (see chapter 4.1).

4.4.1.13   Data Integrity Check

A data integrity check is included in VisualAE that can determine if data of files PRIDB or TRADB have been changed by some other application during or after acquisition of data. A data integrity check verifies that data has not been deliberately or undeliberately altered.

4.4.2 Visuals

Visuals display measurement data and results. Visuals can be freely positioned in the data processing tree and on individual pages within VisualAE. A page in VisualAE usually holds more than one visual. To overcome the limited resolution of TFT screens, visuals can be zoomed for a better resolution.

Visuals are linked to each other if they are on the same branch of the processing tree. The link ensures that a selected data point is highlighted in all linked visuals.

4.4.2.1 Diagrams

Diagrams are used to display results of an AE measurement and *Processors*. Diagrams can be of 2D or 3D type (requires BDSWB).

TR Diagrams

TR-diagrams show waveforms (transient data) in time and/or frequency domain. If VisualTR (see section 4.5) is installed, the corresponding extra functions (e.g. digital filtering and more) are available for the TR Diagrams in VisualAE.

A TR-diagram can have a master and a client window, whereby the client window shows only the data range selected in the master window.

The axes of a TR-diagram can be scaled automatically or set to fixed user specific limits.
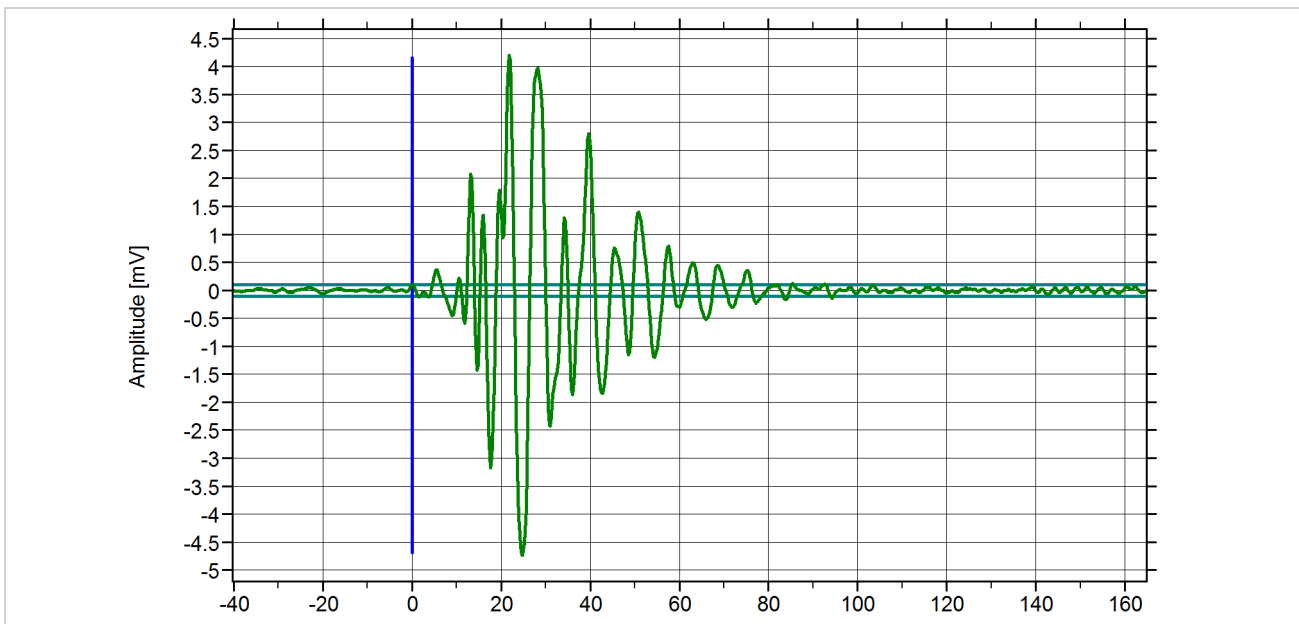
Figure 15: TR diagram of a hit, time axis scale is µs.

AE Diagrams

AE diagrams are used to plot any of the available AE attributes, time or parametric data against each other. AE diagrams can be 2D or 3D (requires BDSWB).
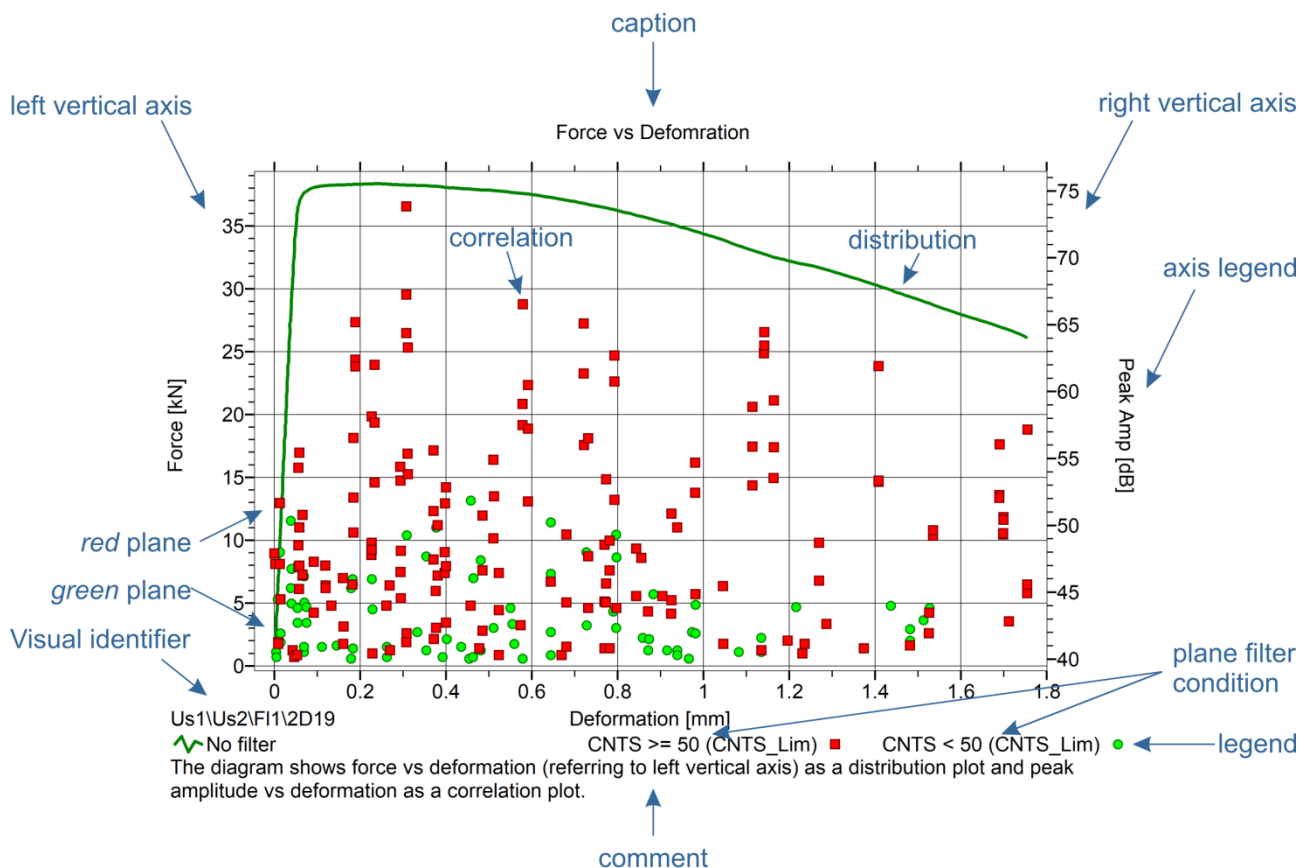
Figure 16: example of an AE diagram that shows a distribution plot (refers to left vertical axis) and a correlation plot on two planes (refers to right vertical axis). AE feature data (Peak Amp) and parametric data (Force and Deformation) are plotted against each other.

There are two basic diagram types: distributions and correlations (point plots). In the standard configuration a diagram can show only one plane; enabling more planes requires module BDSWB. Data represented on each plane can be filtered (e.g. show a certain amplitude range or a certain channel) and the color and shape of symbols can be selected.

3D-diagrams (requires BDSWB) can be rotated around each axis and each axis can be scaled.

4.4.2.2   Listings

A listing presents data in columns. The number of columns, the properties listed in each column and their order can be defined by the user. Additionally, simple listing filters can be selected, e.g. to show first-hits of a sensor group only, include/exclude time driven data such as parametric data or status sets.

A fast forward and – backward scrolling accelerate navigation within large data files.

AMSY-6 System Description - System Description

Id	DSET	CHAN	A [dB]	R [µs]	D [µs]	CNTS	E(TE) [eu]	RMS [µV]	THR [dB]	PA0 [mV]	FLAG MRSFXCTAEDN
Ht	1186283	1	51,7	0,8	1,4	1	755E00	127,2	51,3	0,000	
Ht	1186284	1	53,6	45,6	766,8	3	250E01	127,2	51,3	0,000	
Ht	1186285	3	68,2	1018,4	1020,4	5	857E02	630,1	66,0	0,000	
Ht	1186286	1	51,3	0,8	1,6	1	671E00	127,2	51,3	0,000	
Ht	1186287	3	67,9	573,6	709,8	6	829E02	630,1	66,0	0,000	
Ht	1186288	1	52,4	1,6	15,4	1	112E01	127,2	51,3	0,000	
Ht	1186290	1	52,8	2,2	174,0	1	104E01	127,2	51,3	0,313	
Ht	1186291	3	66,4	236,8	237,4	3	341E02	630,1	66,0	0,313	
Ht	1186292	1	55,1	339,4	1309,6	5	456E01	127,2	51,3	0,313	
Ht	1186293	3	69,7	100,6	1817,6	7	170E03	630,1	66,0	0,313	
Ht	1186294	1	52,1	71,6	73,6	1	876E00	127,2	51,3	0,313	
Ht	1186295	1	55,1	574,0	2334,4	15	788E01	127,2	51,3	0,313	
Ht	1186296	3	67,1	363,4	364,2	2	441E02	630,1	66,0	0,313	
Ht	1186297	3	70,5	588,4	710,4	7	783E02	630,1	66,0	0,313	
Ht	1186298	3	70,9	2,6	234,8	1	474E02	630,1	66,0	0,313	
Ht	1186299	1	52,4	144,0	146,4	1	131E01	127,2	51,3	0,313	
Ht	1186300	3	66,0	0,2	0,4	1	192E02	630,1	66,0	0,313	

Figure 17: Listing in VisualAE showing a portion of data.

4.4.2.3 Numeric display

1: PA0U (pressure in bar) [bar]

20,875

A numeric display shows the last value of the property selected for displaying. A numeric display is suited for displaying the result of parametric inputs since they are supposed to change only slowly with time.

4.4.2.4 Still images

Still images are regarded as a visual in VisualAE. Any number of still images (e.g. a logo, a picture of the test object, etc.) can be inserted on different pages of the data analysis. Still images can be used to place a company logo on a VisualAE page.

4.4.2.5 Exporting Data of Visuals

The data presented in Visuals can be exported either as a file or via the clipboard. Exporting data requires option BDSWB of VisualAE.

4.4.3 Processors included in VisualAE

4.4.3.1 Location Processor - Event Builder

In a basic version the Location Processor can be used to derive zonal location results. It consists of an Event Builder which groups hits of a channel array into event sets. A channel array is a set of AE channels which is defined in the Event Builder part of the Location Processor.

Event building is governed by time criteria, which define the minimum time differences between event-sets, consecutive hits within an event-set and first and last hit of an event-set.

Event building is a preceding step of location calculation using location algorithms (see section 4.4.5.2).
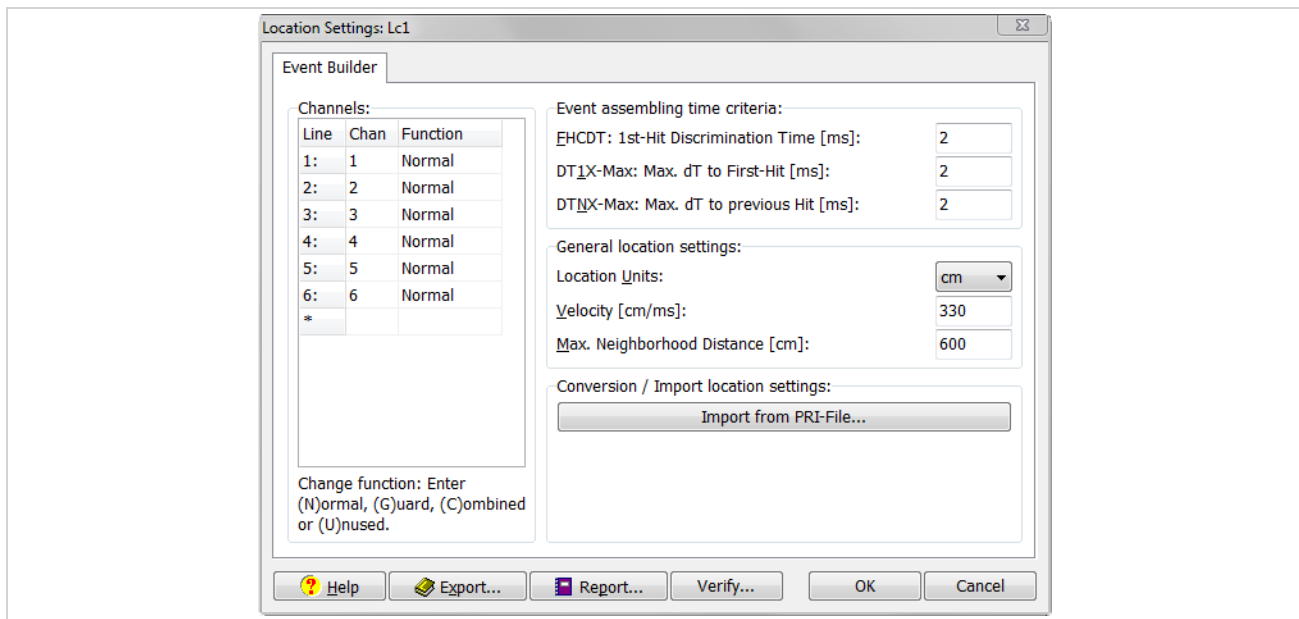
AMSY-6 System Description - System Description

Figure 18: Screenshot of event builder dialog

A Location Processor cannot be positioned on a subsequent branch of the processing tree that originates from a preceding Location Processor. However, there is no limit to the number of other processors and visuals behind a Location Processor. Visuals and processors behind a location processor can process results of the event builder (e.g. first-hit channel number for zonal location, arrival time differences), location results according to the used location module (e.g. location coordinates, location uncertainty), AE parameters (e.g. amplitude, duration, rise time, etc.), and external parameters. For AE parameters, the user can define that for each event-set only the first or all hit data sets shall be processed.

4.4.3.2   Grading Processor

For pressure vessel integrity testing (metal as well as FRP vessels) an interpretation scheme for results of AE tests has been proposed and published by T. Fowler et al. "The Monpac system", Journal of AE, Vol. 8, No. 3, 1989, pp 1 – 8.

A Grading Processor delivers a Historic Index and a Severity Value, which can be used in visuals or in other processors. Historic Index compares signal strength of most recent hits to signal strength of all hits (per channel). Severity is a measure of the average of a user specified number of largest signal strength hits striking a sensor (evaluated per channel).

Currently VisualAE contains a preliminary version of the Vallen Grading Processor (VGP) that is still in development. Presently it is included in VisualAE for testing and feedback purposes.

4.4.3.3   Filter Processor (Option: BDSWB)

Filter Processors are a powerful tool to modify the data flow and to separate meaningful from not so important data. Filter Processors do not change stored data. They just prevent some data from being processed further. A Filter Processor rejects AE data sets based on user specified logical criteria.
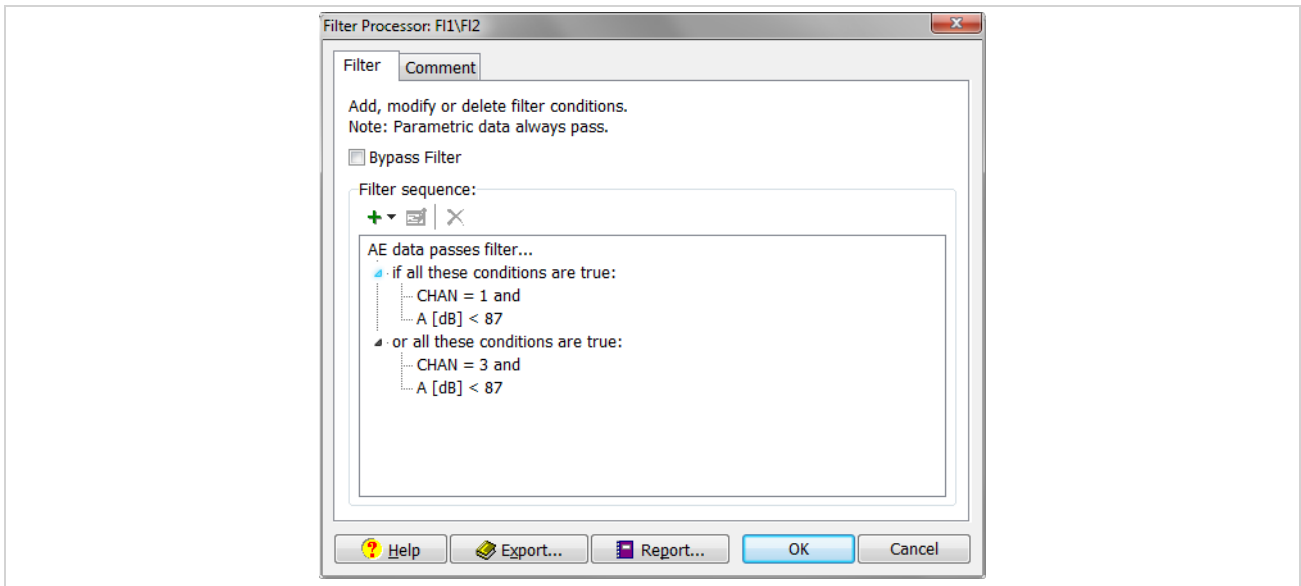
Figure 19: Filter Processor with an AND and OR condition.

Filter Processors work with any attributes that are available to them. E.g. placed behind a Location Processor (see section 4.4.5.2) it will be able to filter also located data. In such a case it only considers the hit data of the first hit of an event but filters all data of an event.

Filters can be placed anywhere in the processing tree affecting every element of the branch behind them. They can be rearranged by drag & drop. Any processor or visual can be placed behind a Filter Processor.

An unlimited number of Filter Processors can be used in the data processing structure.

4.4.3.4   Polygon Processor (Option: BDSWB)

The Polygon Processor basically is a graphic filter. It allows defining 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. This allows the definition of very complex filters that are not possible with the Filter Processor (see section 4.4.3.3). In contrast to the Filter Processor it does not reject any data but adds a polygon ID to the data set.

Four polygon groups are available (Poly-A, Poly-B, Poly-C, Poly-D), each having a unique index. Each polygon group can be linked to an AE diagram and can contain an arbitrary number of polygons.

The Polygon Processor provides a tool for drawing polygons, ellipses or any arbitrary shape by using the mouse and according drawing tools. Vertices of shapes can be specified by their x- and y-coordinate. All polygons will be displayed in appropriate diagrams that are located behind the Polygon Processor.

AMSY-6 System Description - System Description
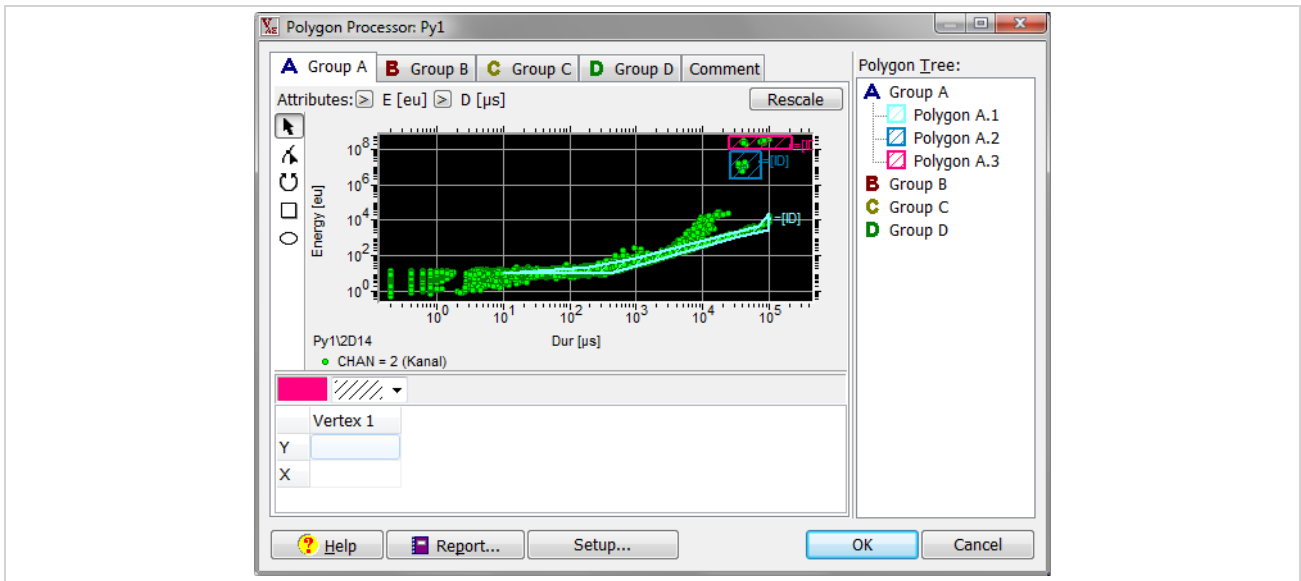
Figure 20: Setup of a Polygon Processor.

4.4.3.5 User Processor (Option: BDSWB)

In some cases of analysis, it is desirable to produce results which are not provided by VisualAE, e.g. summing up the energy of hits. 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 processor and visual behind the User Processor.

Available mathematical operations are: sum, min, max, variance, means, standard deviation, average change.

4.4.3.6 User Processor Extension (Option: BDSWB)

This module extends the User Processor (see section 4.4.3.5) by the mathematical operations of: division, multiplication, power, linear scale, logarithm, and different rate calculations.

4.4.3.7 Alarm Processor

The Alarm Processor monitors user-defined alarm and warning criteria within VisualAE and triggers the Alarm Manager (see section 4.9.1) when the user-defined limits are exceeded.

Within the Alarm Processor the user can define a warning- and an alarm condition based on any available results. As soon as these conditions are fulfilled a signal is fired to the Alarm Manager which in turn triggers the actions bound to the signal. This supports monitoring of safety related tests where various criteria may lead to a halt or even abort of the test.

Figure 21: Screenshot of Alarm Processor dialog

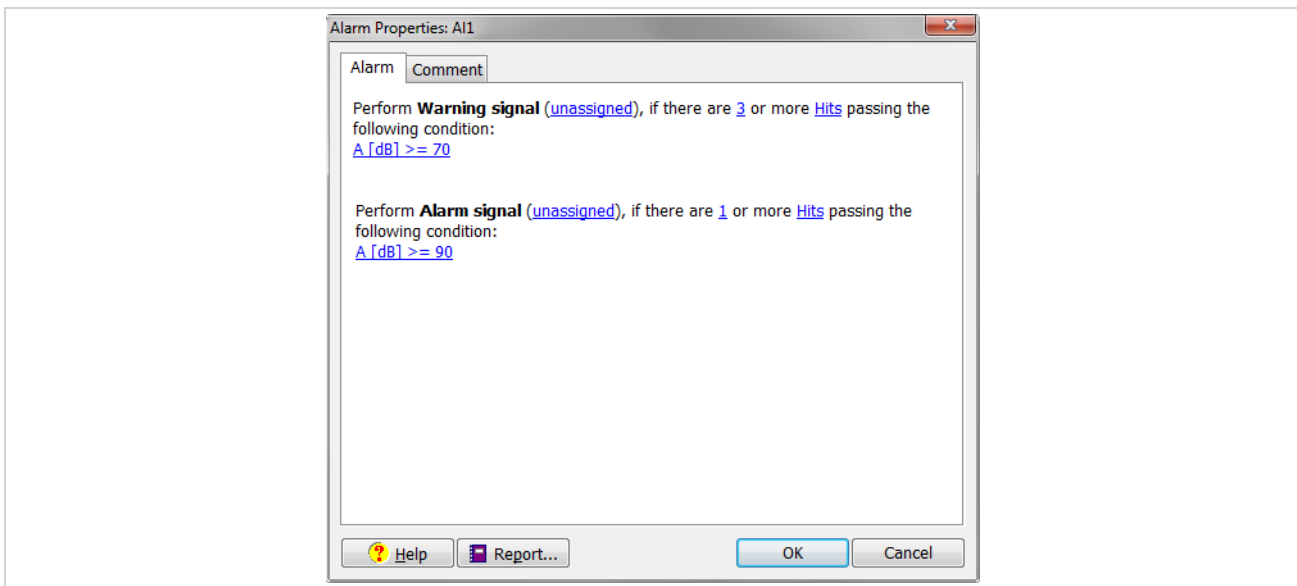### 4.4.4 VisualAE Extension: VAE1+2

VAE1 and VAE2 were two separate modules which have been combined to one module called VAE1+2. In following paragraphs VAE1+2 functionality is listed as it has been implemented in VAE1 and VAE2.

VisualAE option SWBN does not include VAE1+2 functionality. Only VisualAE option BDSW includes all the listed functionality.

VAE1:

- Enables second (right) vertical axis result for distribution, history or point plot, e.g. to show external parameters within an AE diagram

- Multi-plane support: unlimited number of planes at each axis, individual plane settings (style, colour, symbol, filter, legend), for each plane multiple filter conditions can be used.

- A diagram's ASCII-table can be exported to file or clipboard

- A diagram's bitmap (graphic) can be exported to clipboard, resolution is selectable

- Caption and multi-line comment text for each diagram and listing can be activated

- Visual-IDs, to indicate the position of each Visual in the analysis tree and to identify the Visuals (for transparent analysis structure)

- Waveform features (extracted by VisualClass, TR-utilities or user-written program) can be used and visualized in combination with other results or used as filter criteria

- Display of the Free disk space history is available, indicating currently free HDD space

VAE2:

- Provides 3D diagrams: any result combination possible, can be rotated around any axis and stretched into any direction

- Diagram: picture overlay (a bitmap or vector graphic can be placed behind a diagram), background black or white selection

- Diagram/Listing position on page can be changed: Exchange, Shift, or Move to other page

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- Export of listings: ASCII output to file and clipboard enabled

- Page: layout selection from a number of predefined arrangements; the name of a page (tabs), caption, and multi-line comment text for each page can be entered

- Page export in BMP and JPG format (data compression)

- Exporting diagrams, listings, processors etc. to the library

- Waveform diagrams as provided with TR-Viewer, waveform selectable by a mouse click on an AE data point

4.4.5 Optional VisualAE Processors

Optional VisualAE processors extend the functionality and analysis capabilities of VisualAE.

4.4.5.1 Cluster Processor

Cluster Processor clusters data sets according to certain attributes and color codes their quantity. The most prominent way to use Cluster Processor is to cluster local densities of (located) AE sources. This provides a measure of how active an AE source is.

Cluster Processor adds density levels as defined by thresholds and provides additional statistics about clusters. The density levels, color codes, thresholds and cluster statistics can be defined by the user.

Diagrams linked to a Cluster Processor (i.e. located on the branch of the cluster processor) and showing the cluster attributes will display color-coded clusters along with a cluster-legend. Clusters are drawn as color coded rectangles or circles around clusters of AE data.
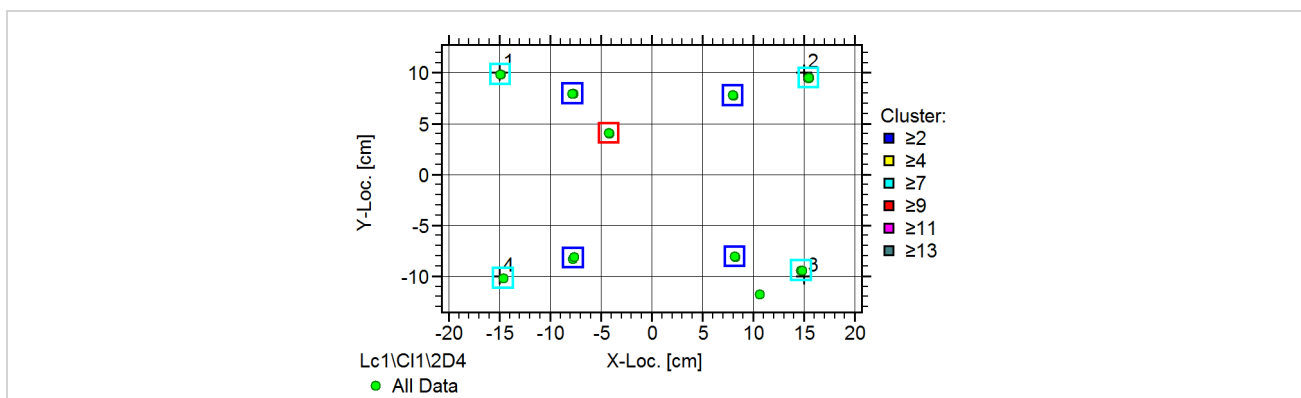
Figure 22: Results of the Cluster Processor shown in a location diagram

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

4.4.5.2 Programming Interface – Embedded Code Processor (ECP)

The Embedded Code Processor (ECP) provides a programming interface within VisualAE allowing the implementation of user designed code in a C-like programming language. Any VisualAE results can be imported into the ECP and processed according to the implemented code. The number of returned results is only limited by VisualAE. The new results are available in VisualAE for further processing and display.

There are 3 different license types available for the ECP (details in table below):

- VAECPU: ECP-User: allows one to run an ECP, but not modify or view the source code.

- VAECPP: ECP-Programmer: allows one to create ECP and write code for it (includes VAECPU).

- VAECPV: ECP-Validator: allows one to protect an ECP against unauthorized usage (includes VAECPP).

Special Feature:

The ECP is useful when service providers (or any other user) want to implement their own analysis routines. These routines can be protected so that other operators cannot access the source code. This secures the intellectual property right of the inventor. This enables a licensing model where analysis routines can be licensed by the IP-owner to different entities identified by the Vallen license number.

Available functions:	Roles			
	No ECP license	**VAECPU**	**VAECPP**	**VAECPV**
Open VAE w/ ECP	X	X	X	X
Delete ECP	X	X	X	X
Copy/duplicate ECP	X	X	X	X
Move ECP	X	X	X	X
Create ECP			X	X
Run validated ECP		X*	X*	X*
View validated ECP / Export Code				X**
Edit validated ECP / Import Code				X**
Run non-validated ECP		X	X	X
View non-validated ECP / Export Code		X	X	X
Edit non-validated ECP / Import Code			X	X
Validate ECP				X

*) KeyID must be in Licensee List and Expiration Date valid

**) KeyID of original Validator only

4.4.6   Add-on Algorithms for the Location Processor

A location algorithm of a Location Processor will generate a location result based on arrival times of hits belonging to an event set (see chapter 4.4.2.3). All location algorithms work with event set data. They will evaluate arrival time differences of hits of an event-set and derive a location result.

There are several location algorithms available which are suitable for different test object geometries.
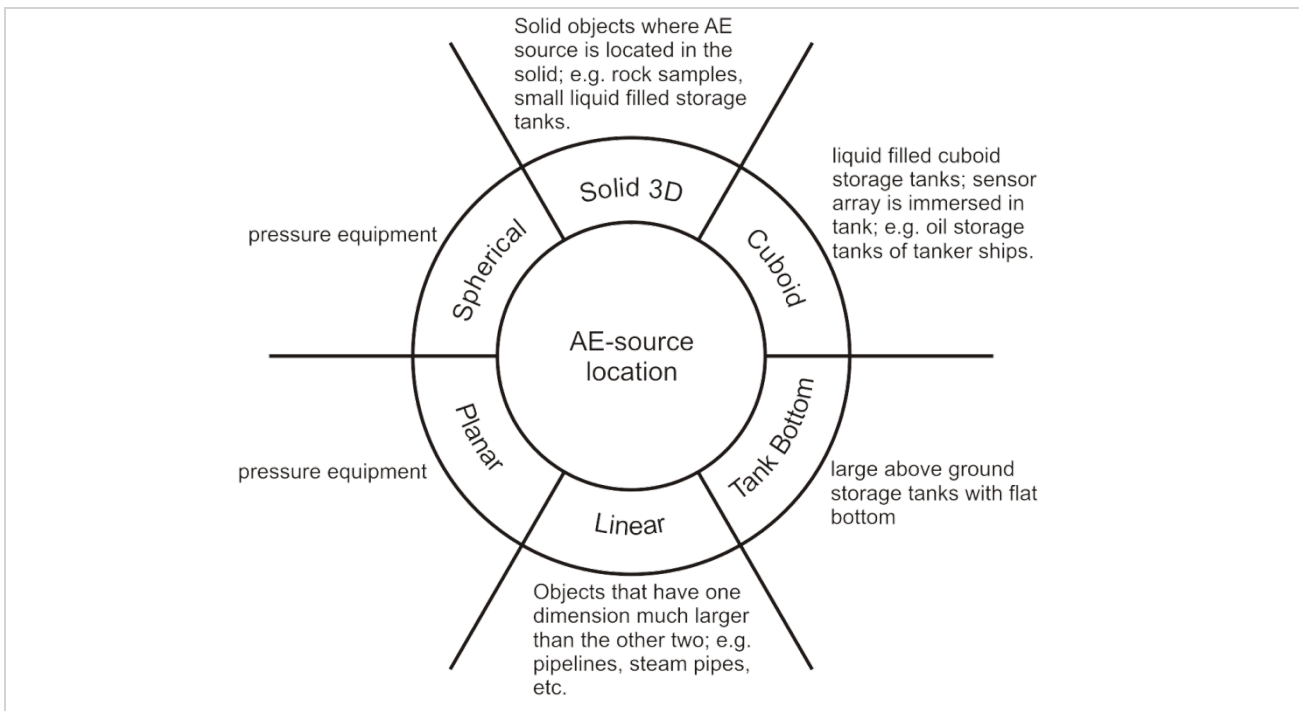
Figure 23: Different location algorithms and their intended use.

Location Processors add results, such as location coordinates, LUCY (location uncertainty), time-differences, number of hits of the event, and more, to the event's data set for further processing by subsequent processors or visuals. Subsequent processors and visuals use and display only AE attributes of the first hit of an event.

Within a Location Processor more than one channel group can be defined. Each channel group can have its own location algorithm (i.e. linear, planar, 3D, etc). Location result of each channel group is rated automatically. Based on a rating filter, the result of the best rated location can be selected.

The possibility of defining more than one channel group within a Location Processor is useful in case of complex structures that need to be covered by use of e.g. triangulation. In such case only one Location Processor needs to be defined for the structure. Also, if a cylindrical vessel has to be monitored, the cylindrical part and the end caps can be combined in one location set by using multiple sensor arrays.

For each channel group the maximum number of hits that contribute to the location result can be defined. Only the nearest neighbors of the first hit channel should contribute.

AMSY-6 System Description - System Description

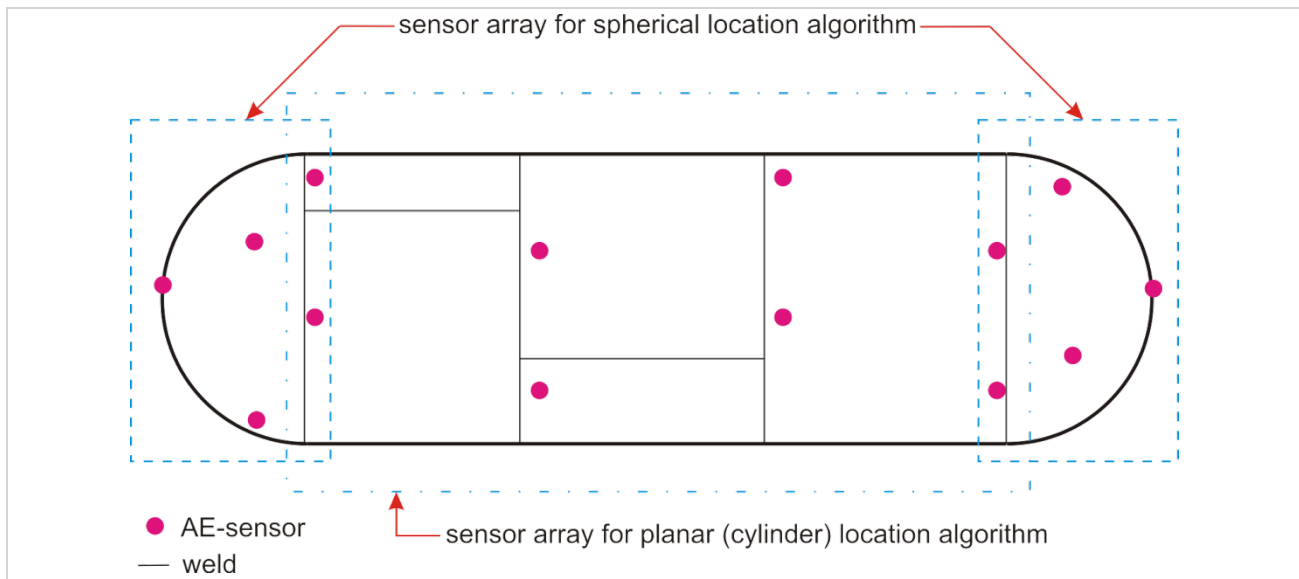*Figure 24: Outline of cylindrical pressure vessel with spherical end caps. AE sources on end caps can be located by use of a spherical location processor, while AE sources on cylindrical hull can be located with planar location algorithm. Sensors can be part of more than one sensor array.*

4.4.6.1 Linear Location Module

Linear location is the simplest way of locating AE sources. It is useful if one dimension of the test object is much longer than the other two (i.e. a beam, pipeline, etc.).

The linear location module contains two linear location algorithms:

- Linear location on an imaginary straight line or a circumference between two or more sensors. In case of a straight line a location result is derived in between the first and last sensor of the sensor array. In case the sensors are located along a circumference the location results will be derived on the circumference.

- Lin3D: linear location on imaginary straight-line segments between two neighboring sensors. Data display and location processor setup account for 3D locations of sensors.

Both location algorithms account for arbitrary sensor placement. Sensor array can be arranged as an open line with two ends (e.g. a line) or as a closed loop (e.g. circular).

4.4.6.2 Planar/Cylindrical Location Module

The planar location module provides location algorithms that locate AE sources on planes or cylinder shells. The algorithm allows for an arbitrary sensor placement. Thus, it is not necessary to arrange the sensors in a predefined array and so the sensors may be placed according to the structure's requirements.

Numerical, analytical and mixed algorithms are available. Each algorithm evaluates a location uncertainty in case of an over determined system. The location uncertainty gives an indication of how reliable a result is (from a mathematical point of view).

For a cylindrical hull the required minimum number of sensors is 4 (an over determined system would consist of at least 5 sensors). In case of a plane the required minimum number of sensors is 3 (an over determined system would consist of at least 4 sensors).

It is recommended to exceed the minimum number of sensors contributing to a location result. This way a location uncertainty can be calculated and regarded as a measure of reliability for the location result.

4.4.6.3　Multi-Group Extension for Location Modules

It features:

- Several channel groups can be used within one location processor and a global coordinate system, allowing for processing complex geometries like cones or end caps of pressure vessels.

- Each channel group with its own co-ordinates and location algorithm

4.4.6.4　Spherical Location Module

The spherical location module provides an algorithm to located AE sources on the shell of a sphere. It features:

- Arbitrary sensor locations, i.e. position the sensors according to the test objects requirements.

- Location results can be displayed as points on a 3-dimensional image of a sphere. Location results can also be listed in degree longitude and latitude. The image of the sphere can be rotated and zoomed to any desired point-of-view (needs VAE1+2, see section 4.4.3). Places of high location density can be indicated by round clusters (requires clustering option VAECP, section 4.4.5.1).

- The location algorithm needs hits from at least 3 sensors. It is recommended to have 5 sensors contribute to location result.

Note:

The spherical location algorithm together with the planar location algorithm can be used to locate AE sources on a pressure vessel. The spherical location algorithm is used to locate AE sources on the end caps of the vessel while the planar location algorithm is used to locate AE sources on the hull. All three location algorithms (2x end caps, 1x hull) can be setup within a single location processor (see figure 24).

4.4.6.5　3D-Location Module to Detect AE Sources in a Three-Dimensional Solid Part, or Liquid

The 3D location module provides algorithms which locate AE sources in the volume of a body. It features:

- Arbitrary sensor locations.

- Needs at least hits from 4 sensors, 5 sensors recommended

Results can be shown in 3-dimensional dot-plots, rotated and zoomed (needs VAE1+2, see section 4.4.3), or in several 2-dimensional dot-plots from different views.

In small diameter (up to 16m diameter) above-ground storage tanks the 3D location algorithm can be used to locate corrosion, leakage, water droplets, etc. AE sources, such as water droplets from the roof, are easily discriminated by their height position.

Nakamura, Hideyuki / Arakawa, Takahiro / Sekine, Kazuyoshi / Kasai, Naoya, "Study of Identification and Removal Method for Drop Noise at AE Measurement of a Tank", 19th International AE-Symposium December 9-12, 2008, IAES-19 Kyoto, Japan

4.4.6.6　Above-Ground Flat-bottomed Tank Floor Location

The tank floor location module provides algorithms to locate AE sources on the floor of a cylindrical containment (tank bottom). The tank floor location module incorporates different numerical and analytical algorithms.

Special Feature:

Depending on the selected location algorithm equal sensor spacing on the circumference is not mandatory.

4.4.6.7   Amplitude Correction Module

☞ **Note:**

The Amplitude Correction module requires VAEUP (see section 4.4.3.5) and a location processor.

The amplitude correction module takes the attenuation and the distance of sensor to source into account to deliver the amplitude at the source location. The amplitude correction considers near-field and far-field attenuation.

4.5   VisualTR - Waveform Analysis Software (VTR)

An ASIP-2 signal processor equipped with TR-2 memory modules is capable of recording waveforms. While the AE data set is a set of features describing the waveform, TR data is the actual sampled signal. TR data allows a more precise interpretation of what was measured and enables a data analysis in frequency domain.

VisualTR assists analysis of waveforms. It displays one or multiple graphs of transient recorder data (sampled waveform data) per page. Multiple pages containing TR-diagrams are possible. Additionally it performs FFT and plots the results in frequency domain.

VisualTR supports selectable FFT window functions (Rectangle, Hamming, Hanning, Trapezium, Bartlet, Welsch), digital frequency filtering (high-pass, low-pass, band-pass, band-rejection). Corner frequencies and steepness (in dB/octave) is set by user. Single frequency selection can be done by use of Gaussian cross-correlation. Editing of page legend text and many more features are possible. The waveform displayed can be exported to an ASCII file, one sample per line via the "copy ASCII table to Clipboard" function, or as bitmap in any size and resolution.

4.5.1   FFT Averager

FFT Averager can be used to calculate and display the average spectrum of all waveforms in a transient data file. It can be used to discover lowest level spectral compositions out of the white noise. Averaging the spectra reduces the white noise level shown and pronounces other spectral components, if any. It can also be used to discover changes in the averaged spectrum, e.g. when comparing files from different kinds of sources, or after filtering a file by spectral criteria, e.g. using spectral ratios.

From all FFTs, for each frequency bin, 3 averaging methods are calculated and shown in 3 graphs:

- RMS: Root mean square, result converted to dB above 1 μV_{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.

As an additional result the RMS subtracted by AVG[dB] is provided. The result gives an indication which frequencies are equally distributed in the analyzed data, (difference is very small) and at which frequencies the waveforms differ.

4.6   Feature Extractor

Feature Extractor is a tool that makes frequency domain features of waveforms available to VisualAE (online and offline). Similarly, to AE feature data, the frequency domain provides characteristic features too, e.g. peak frequency (frequency of maximum amplitude, FMAX), mean frequency (frequency center of gravity, FCOG), spectral ratios and more.
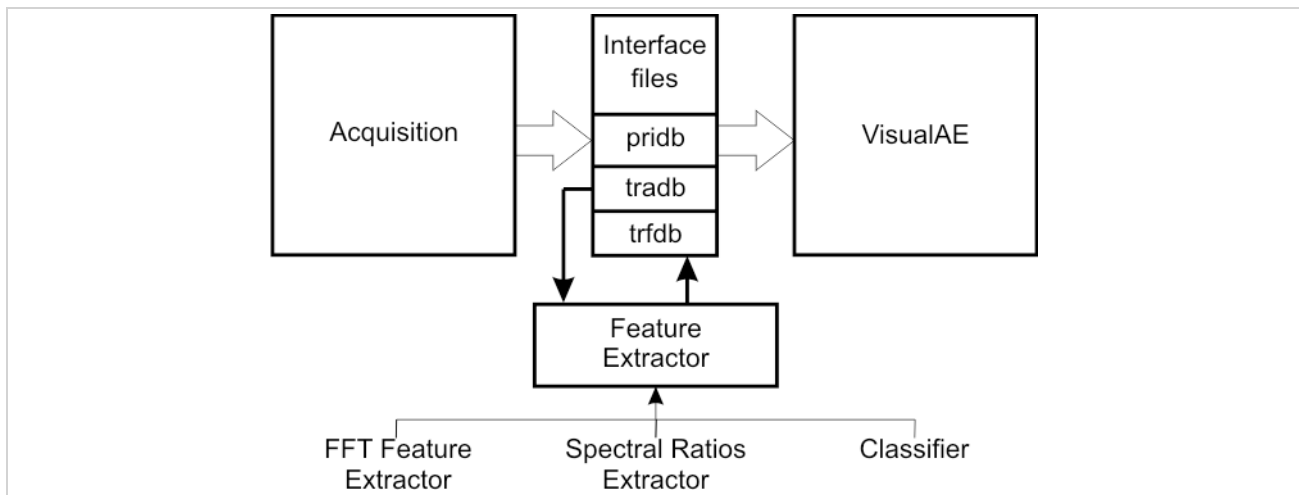
Figure 25: Feature Extractor and how it interacts with analysis software.

Feature Extractor provides an interface to the FFT Feature Extractor, Spectral Ratios Extractor and VisualClass Classifier (requires VisualClass, see section 4.5.1).

FFT Feature Extractor extracts frequency of peak amplitude and center of gravity frequency from frequency spectra.

Spectral Ratios Extractor extracts features from 4 user definable time and 5 frequency segments and generates (spectral) ratios from this data.

Feature Extractor can run in real time parallel to the acquisition software.

4.7   VisualClass - Pattern Recognition Software (VCL)

VisualClass is a powerful pattern recognition and classification software package. It is designed for fast, comfortable and transparent development of an analytical classifier to recognize different AE signal patterns. It provides supervised and non-supervised learning strategies.

VisualClass is a toll for constructing a classifier that classifies based on frequency domain data. Once a classifier has been found it can be used in on-line and off-line analysis to assign a class number and class fitting values to each transient data set.

Results of the classifier are written to a feature file. These results can be used by VisualAE for combined analysis with other AE features.

4.8   Tools for VisualClass

VisualClass requires training data sets for constructing a classifier. A training data set consists of transients that are characteristic for a single class. Transients for training data sets can originate from many different transient data files. The following tools help constructing training data sets out of different transient data files.

4.8.1   TR-Combi

TR-Combi is a utility developed for use in conjunction with VisualClass. It eases the selection of learning data sets for the VisualClass classifier. Learning data sets should contain representative waveforms of each class. By use of TR-Combi waveforms of multiple input files can be exported to one or more output files. Usually the output files constitute classes into which a VisualClass classifier (see section 4.5.1) should classify the waveform data.

4.8.2 TR-Copy

TR-Copy is a tool that copies selected waveforms from one input file to one or more output files. Similarly to TR-Combi (see section 4.8.1) it can be used to build a training data set for VisualClass. In contrast to TR-Combi the export of waveforms can be governed by a single script file (i.e. export is done automatically). The script file can be generated by use of VisualAE.

4.8.3 TR-Filter

TR-Filter applies a digital (software) filter to already recorded TR data. This is useful to limit the frequency range of broad band acquired transients in order to match small band frequency range of existing TR-data. Frequency range matched transients of different transient data files can be combined and used in VisualClass or as input to a classifier.

4.8.4 TR-Unifier

TR-Unifier is a tool that changes sample rate and page length (number of samples per waveform) of a TR-file. This utility is used to unify different transient data files to a common format so that they can be combined to a single file or used with classifier or VisualClass.

4.9 System Management and Control Tools

Tools in this category help gathering information about the soft- and hardware and help changing settings.

4.9.1 Vallen Control Panel

Vallen Control Panel is the central control point of Vallen Systeme software. It provides access to all enabled programs of the Vallen AE-Suite software.

4.9.2 Alarm Manager

Alarm Manager is a utility running in the background. Usually the operator's first contact with the Alarm Manager is when Acquisition program indicates that it does not receive any data (blinking in the task bar). This is triggered by the Alarm Manager. Apart from that the Alarm Manager provides an interface for other predefined Watchdogs and Alarm Processors. Alarm Processors can be inserted into VisualAE analysis process to derive alarm criteria from any kind of AE data analysis (see section 4.4.3.3).

Alarm Manager is independent from acquisition or analysis programs. It receives signals from Watchdogs and Alarm Processors and triggers the action(s) that are bound to the signal. Such actions can be:

- turning on a sound (user selectable wave file), and/or

- sending an email using SMTP protocol, and/or

- sending a message to a machine or user within the network (using the Microsoft™ 'net send' command), and/or

- turning on dedicated Control Panel LEDs and pull down the corresponding line at the Alarm Connector (on rear), and/or

- triggering a custom action which can be any user-written routine using the Active-X Alarm Manager Programming Interface

4.9.2.1 Watchdogs

Watchdogs are pre-defined and monitor the run status of VisualAE and Acquisition as well as a number of PC resources, such as free disk space for data and temporary files. Watchdogs trigger alarm actions via the Alarm Manager, before a lack of such resources may endanger reliable data acquisition and online analysis. Alarm and warning limits of Watchdogs are set within the Alarm Manager.

4.9.3 Automation Manager

Vallen Automation Manager can be used in tasks of continuous monitoring and automation. The program runs on the acquisition PC. It is the central instance which controls and supervises other programs, including Acquisition program and VisualAE analysis program.

The Vallen Automation Manager program uses the concepts of events, tasks, and actions to perform its duties. A number of actions can be grouped to a task. A task is executed when the Automation Manager program identifies an event that has been defined in its context.

There are four categories of Events: Manual Triggers, Timers, Alarm Signals and Watchdogs. When an event occurs, the Automation Manager executes a user-defined task that consists of one or several actions. Examples of actions are to start/stop recording, switch to a new acquisition file, or send an email.

4.9.4 Key Reporter

Key Reporter is a tool that displays or prints out the complete list of available software modules and marks the ones that are currently installed. A printout of the KeyReporter, the KeyCertificate, is provided with every KeyFile that Vallen Systeme distributes.

4.9.5 Key Setup

If new modules are to be added to the AE-Suite software or software update contract is prolonged a new KeyFile is provided by Vallen Systeme. The new KeyFile has to be activated via the Key Setup utility to make changes available.

4.9.6 Hardware Reporter

HW-Reporter is a tool providing a detailed hardware configuration report of the connected AMSY-6 hardware.

4.9.7 Modify PAx Input

This utility modifies parametric data on a primary file. The user can assign to each parametric input (PA0...PA7) a list of data sets and the corresponding input voltages. A time linear voltage ramp is calculated for the parametric data between two specified data sets. It 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.

4.9.8 Pri-Glue

Pri-glue is a tool to concatenate several primary data and transient data files into one larger primary data and transient data file.

4.9.9 Data Converter Software

Data Converter software provides a tool that time-sorts and converts dta-files into the Vallen file format. This tool comes "as is" without the warranty to convert all existing sub versions of dta-files.

4.9.10   PRI2DB

PRI2DB is a conversion tool that converts files with PRI and TRA extension from binary format to a free file format based on SQLite. The new file extensions are PRIDB and TRADB.

4.9.11   TraDBComp

TraDBComp is a tool that compresses and uncompresses the wavform data stored in the TRADB file.

4.10   System Verification Tools

System verification tools let the operator of the equipment verify the correct operation (i.e. the operation according to manufacturer's specification) of the measurement equipment. EN 13477-2 suggests that an operator should be able to verify the acoustic emission measurement equipment.

By providing software and hardware for AMSY-6 one complies with the standard EN 13477-2, Non-destructive testing – Acoustic Emission – Equipment characterisation – Part 2: Verification of operation characteristics.

4.10.1   ADC-Tester and TR-Tester

The ADC-Tester is designed to test basic functionality of AE channels, even without TR memory modules. It features a live display of waveforms.

The TR-Tester is a utility to test TR-memory modules. The test signal has to be fed in externally.

4.10.2   Vallen Sensor Tester (VST)

Vallen Sensor Tester is a very versatile tool. Its foremost application is to verify that AE sensor sensitivity is still adequate. AE sensors may be subject to an aging process due to harsh environmental conditions or handling and should be checked on a regular basis. Regular verification ensures that sensitivity of a sensor is still adequate for inspection tasks.

Vallen Sensor Tester software measures and displays (and prints) a sensor's sensitivity curve versus frequency.

Additionally, the Vallen Sensor Tester can be used to evaluate the effects of different coupling agents, different cables and their length.

Vallen Sensor Tester requires additional hardware such as a:

- programmable function generator (KeySight 33500 series),
- signal emitter (e.g. Olympus V103 or V101),
- a special cable set
- AMSY-6 system with at least one verified ASIP-2

4.10.3   System Verification (SysVeri)

SysVeri software package allows for software supported (semi-automatic) verification of an AMSY-6 system and the ASIP-2 boards. After running the verification, a detailed report can be generated and printed. System verification requires a programmable KeySight function generator (model 33500 series)

4.11　SWupd

SWupd is the term for a software update contract lasting for 12 months. A valid software update contract enables the installation of software updates published during the validity period of the update contract. It covers all Vallen Systeme GmbH AE software modules.

A valid update contract is required for software extensions (e.g. purchasing new software modules).

4.12　Help Text

Context sensitive help is available for Acquisition32, VisualAE, VisualTR, VisualClass and many utility programs. Online help should be the first point of reference in case of questions. It provides information and explanations about settings.

4.13　Programs to Software Module Map

Vallen AE-Suite software programs can be executed from the Vallen Control Panel. Programs are organized in software modules. Software modules can be purchased from Vallen Systeme GmbH to extend the owned software configuration. In most cases a software module consists of more than one program. In some cases a module is an extension to an existing application and cannot run standalone. The following table lists applications in the first column and the module they belong to in the second column. The third column describes the dependencies.

Application (alphabetical order)	Module	Dependency
3D location	VAEL3D	SWBN (VAE1 and VAE2 recommended)
Acquisition	SWACQ	
ADC-Test	SWACQ	
Alarm Manager	SWBN	
API for transient files	XTR	
Automation Manager	AUTOMAN	
Classifier decoder	VCL	
Cluster processor	VAECP	SWBN
Control Panel	SWBN	
DTA Converter	SWBN	
ECP programmer	VAECPP	SWBN, VAECPU
ECP user	VAECPU	SWBN
ECP validator	VAECPV	SWBN
Feature Extractor	VTR	
FFT Averager	VTR	
Filter processor	VAEFP	SWBN
Firmware updater	SWACQ	
Hardware Reporter	SWACQ	
Key Reporter	SWBN	
Key Setup	SWBN	
Linear location	VAELL	SWBN
Multi group extension	VAELMG	SWBN + one location processor
Planar location	VAELP	SWBN

Application (alphabetical order)	Module	Dependency
Polygon processor	VAEPP	SWBN
PRI2DB	SWBN	
Pri-Glue	SWBN	
Scheduler	SWBN	
Spherical location	VAELS	SWBN (VAE1 and VAE2 recommended)
System Verification	SysVeri	SWACQ, SWBN, Microsoft Word
Tank bottom location	VAELTB	SWBN
TR-Combi	VTR	
TR-Copy	VTR	
TR-Filter	VTR	
TR-Test	SWACQ	
TR-Unifier	VTR	
User processor	VAEUP	SWBN
User processor extension	VAEUPE	SWBN, VAEUP
VAC Editor	SWBN	
Vallen Sensor Tester	VSTSW	SWACQ (additional hardware see section 4.10.2)
VisualAE	SWBN	
VisualAE extension 1	VAE1	SWBN
VisualAE extension 2	VAE2	SWBN, VAE1
VisualClass	VCL	VTR recommended
VisualTR	VTR	

5 Accessories

Accessories to extend or enhance the AMSY-6 such as cables, magnetic holders, verification equipment, etc. can be found in the according document: Accessories for Acoustic Emission.

6 Free File Format – Most Important Changes

Acquisition and Feature Extractor program of Vallen AE-Suite software write their measurement data to files based on the free file format of SQLite. The most important changes are listed below:

New file extensions „pridb" and „tradb"

The new file format extensions are pridb and tradb for primary- and transient data, respectively. The first three letters of the file extensions tell you what kind of data is recorded: primary data or transient data. The last two letters indicate that the new file format is a data-base.

A VAC (acquisition setup) file is no longer necessary. All that information is stored to PRIDB file. Importing acquisition setups to a new file is done the same way as before.

VisualAE and VisualTR support both file formats. Mixing of file formats in data analysis (e.g. PRIDB and TRA or PRI and TRADB) is not possible, however.

No more preallocation of primary and transient data files necessary

Preallocation of data files was necessary in times when hard disk storage area was limited. This practice ensured that no other application could occupy storage space that was reserved for measurement data.

Nowadays preallocation is inconvenient, gives rise to errors in case of preallocating large space and may be troublesome in an automated data acquisition environment.

With nowadays storage capacity of hard disk drives, the risk of another application taking up storage capacity that was envisaged for measurement data is minimal. The risk is much large that a preallocation fails because file size has been chosen too large for the program to handle. Especially in automated environments a failure in preallocation may result in an unrecoverable error.

New way of handling time

Time measurement by definition is unlimited. The old file format had fixed size of records, even for time. As a result, the maximum recording time in a single file was 320days. No such limitations apply in case of the new file format, simply because the size of records can be adapted on-the-fly. For the operator it is no longer necessary to distinguish between "Absolute date/time of recording" and "Recording time" for the start time reference. All relevant information, absolute date-time or relative time, can be extracted from the recorded time data.

Use all frequency domain features

There is no more limitation for the number of records stored per dataset. All possible frequency domain features can be used simultaneously next to the classical AE features in an analysis. No more limitation to a maximum of 14 frequency domain features – no more picking hexadecimal codes for frequency domain features. All frequency domain features can be selected by their name.

Record both Signal Strength and True Energy?

Both features are stored to hard disk when using the new, free file format.

Using data in old data format

VisualAE and VisualTR can read in and process old data format just the same way as before. Use the utility PRI2DB to convert primary data files and transient recording data files to the new free file format.

7 Summary of Unique Features of an AMSY-6

External PC instead of internal PC

Vallen Systeme follows the guideline that an AE measurement system should have a longer lifetime than a PC. Therefore, Vallen uses an external PC which can be upgraded anytime as PC technology advances. This ensures that the most state-of-the-art PC technology can be used.

USB 3.1 Gen 1 as PC interface

A USB 3.1 Gen 1 interface is available in every PC or laptop nowadays. Hence the MBx chassis can be operated with any PC that is available.

MBx chassis

MB chassis are available in different sizes. The MB2 chassis can be used for applications that require only up to 4 AE channels. The MB19 offers higher integration (3 more ASIP-2 slots i.e. 6 more AE channels) compared to older chassis versions of the same size.

Vallen bus architecture

The Vallen bus architecture offers high speed online time sorting of all acquired data for accurate and reliable online location without degradation of speed performance.

Duration adapted transient recording

In duration adapted transient recording mode a transient page size is dynamically adapted to the duration of the burst signal. A transient page always contains a fixed number of pretrigger samples, the samples of the burst signal from the first threshold crossing to the last threshold crossing and a fixed number of post duration samples.

Multiple trigger groups

For transient recording a channel can be assigned to a trigger group. In a trigger group the trigger modes per channel are evaluated when a channel measures a burst signal. Different trigger groups are independent from each other.

AE Speed performance

It is important to have a fast system to avoid loss of data during acquisition. Each MBx chassis of the AMSY-6 can process 100.000 hits/second sustained until data file is full.

TR-Speed performance

Hit triggered or continuous transient recording at up to 40 MS/s for up to 254 AE channels in parallel while onboard memory is not full or until TR-file full. TR-data is continuously downloaded; however, AE data transfer to PC is always prioritized over TR-data. A TR-data generation rate that is constantly higher than the transfer rate to hard disk drive will eventually lead to a loss of TR-data when onboard memory is full.

Streaming performance

AMSY-6 streams AE feature data of all channels (up to 254) in parallel until file is full if time slice period is 819.2 µs or longer.

The total data throughput (AE feature data and TR-data) of a chassis is between 60 MB/s and 80 MB/s. Maximum possible data transfer rate is influenced by chassis type (MB2 having larger transfer rate than MB6 than MB19) and transient recording mode (short pages in duration adapted mode lead to higher streaming performance than long pages in continuous mode). For example, an MB19 chassis in Continuous Mode

recording with 10 ms TR page length and a data throughput rate of 60 MB/s can stream data gapless sustained until file full for 3 channel @ 10 MHz -, 6 channels @ 5 MHz – and 12 channels at 2.5 MHz sample rate.

TR memory modules will eventually run full, if TR-data generation rate is larger than download rate.

254 AE channels in multi chassis setup

With a multi chassis setup 254 AE channels can be operated in parallel. Up to 9 chassis can be connected in parallel to USB interface of the acquisition PC and utilize the full bandwidth of USB 3.1 Gen 1.

ASIP-2 digital signal processing

ASIP-2 signal processing architecture converts a band pass filtered analog signal to a digital stream before application specific (digital) filters are applied. The advantage of this architecture is:

- ADC noise is filtered by a dedicated filter stage at 40 MSPS and additionally filtered by the application specific filters. The result is extremely low noise.
- Application specific filters are implemented digitally. This results in zero tolerance between filters.
- For any application the optimum bandwidth can be selected without interfering with the hardware.
- Filters can be added any time by simply importing a new firmware file.