Acoustic Emission Sensors and Preamplifiers

Description

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2021-11	Contact address updated
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Contents

1. Introduction to Acoustic Emission (AE) Sensors

The sensor constitutes the first part in an AE measurement chain and as of this is of particular importance. A subsequent measurement system can only process signals which the AE sensor picked up. Anything an AE sensor does not pick up is lost for analysis.

An AE sensor converts the surface movement caused by an elastic wave into an electrical signal which can be processed by the measurement equipment. The piezoelectric element of the AE sensor should pick up faintest surface movements (i.e. have high sensitivity) and convert this movement most efficiently to an electrical voltage.

AE sensors can be designed highly sensitive at a certain frequency (also termed resonant) or with a broad frequency response (broad band). Special AE sensor models for high temperatures are also available as well as ATEX certified sensors for installation in hazardous area. Our ATEX certified sensors are not part of this specification but described in an own specification (see Note below).

The following sections of this document give an overview about the right AE sensor selection for an application and detailed specifications of the Vallen Systeme sensor product range.

2. Guide for AE Sensor Selection

Vallen Systeme GmbH provides various sensors for all kinds of AE applications. Selecting an appropriate sensor for a specific AE application is crucial for the success of the measurement. In most cases the main criterion for the AE sensor selection should be the frequency response which must suit the application. In some special applications environmental and legal requirements (e.g. high temperature, water/oil tightness, hazardous area installation) may pose more severe restrictions on AE sensor selection than the frequency response. This chapter gives useful hints on how to select a suitable AE sensor for every application. For more information about our AE sensors, AE sensor selection or specific applications please contact us directly at info@vallen.de.

2.1. Environmental Conditions

The majority of AE sensors are specified for normal environmental conditions as one would face during field testing or in the lab. However some applications on hot machinery surfaces require special AE sensors. Using the AE sensors outside of the specified temperature range could cause permanent damage to the sensor or corrupt the sensor signal. For high temperature environments only a few AE sensors may be suitable and the temperature range should be the first criterion to constrict the AE sensor variety.

Some applications have a demand for AE sensors suitable for installation in hazardous areas or for water-/oil resistant AE sensors. Special solutions are available for this demand and need to be first priority for the AE sensor selection.

Note: AE sensors for hazardous areas

Vallen Systeme offers an intrinsically safe product family (ISAFE3). This product family is ATEX certified and consists not only of a family of AE sensors but also of special signal isolator to fulfil all safety requirements for hazardous areas of zone 0, zone 1 or zone 2. For more details please see the 'Vallen ISAFE3 Operation Manual' or contact us at info@vallen.de.

2.2. Frequency Range

Vallen Systeme follows a coarse and arbitrary classification into 3 frequency regimes, which is justified by the fact that most applications can be classified into one of these frequency regimes: low (20 kHz - 100 kHz), standard (100 kHz - 400 kHz) and high (>400 kHz). Attenuation per unit distance increases with frequency. For most applications, frequencies above 400 kHz are meaningless and are cut-off in order to minimize electronic noise. Some standard preamplifiers and signal processors are able to process frequencies up to 2.2 MHz (e.g. AMSY-6). The classification in low, standard and high frequency regime is arbitrary and there are applications which use different frequency classes dependent on the presence of background noise (move to higher frequencies) or wide sensor spacing (move to lower frequencies). However, for the majority of applications this classification is useful for getting a fast overview.

AE sensors that respond uniformly to a very broad band of exciting frequencies are referred to as broadband or wideband sensors. Wideband AE sensors with a flat response curve are usually desired if the frequency of interest is still unknown (e.g. research or feasibility study) or if different frequencies in one signal should be analyzed (e.g. modal analysis).

Most AE sensors are of resonant type which means they are most sensitive at their resonance frequency. These AE sensors may have other frequency bands where their sensitivity is low. The resonance frequency is the decisive factor for which application these AE sensors can be used.

Resonant AE sensors are usually used if the frequency content itself is not of interest but only AE features such as amplitude, arrival time or energy. To clarify: These features are - to some extend - affected by the peak frequency and frequency range of the AE sensor. Therefore AE features can only be compared if recorded with the same AE sensor type.

Finding the right frequency range for a specific application has to consider factors such as material, specimen size and background noise. Attenuation is frequency dependent: the higher the frequency, the higher is the attenuation per unit distance. Usually the AE sensor spacing can be extended when moving to lower frequencies. On the other hand background noise, such as from production machinery, is usually more prominent in lower frequency range (<100 kHz). Therefore false triggering can be avoided when moving to higher frequencies.

Note:

Most EN- or ASTM standards recommend a frequency range for an application and an operator or inspector should stick to this recommendation.

2.2.1. Overview of Frequency Regimes and Applications

Certain frequency ranges have been proven to be best suitable for specific applications.

Application	20-100 kHz	100-400 kHz	>400 kHz
Corrosion screening of flat bottom storage tanks	x		
Leakage detection in water/oil pipelines	x		
Hot reheat pipe crack detection		x	
Integrity testing of pressure vessels		x	
Partial discharge detection	x	x	
Integrity testing of metallic structures		x	

Integrity testing of composite materials		x	
Integrity testing of concrete structures	x		
Drying process monitoring of plants/wood		x	
AE testing of small specimen			x

2.2.2. Determining the Correct Frequency Range of AE Sensors for an Integrity Testing Application

The elastic wave is usually heavily affected by the propagation mechanisms before it reaches the AE sensor. The frequency content of the wave is particularly affected by the source mechanism as well as the material through which the wave propagates.

The material in which an elastic wave propagates has a very inhomogeneous effect on the frequency distribution; attenuating certain frequencies stronger than others. Also wave propagation could be affected by macroscopic features of the test object, e.g. dispersion (different wave velocities at different frequencies) in plate like structures.

The correct frequency range for a certain application can be determined experimentally where possible. A very flat-response broadband AE sensor and AE measurement equipment is needed. The broadband AE sensor shall be mounted to the object. Pencil lead breaks (Hsu-Nielsen source) are used to excite elastic waves which the AE sensor picks up. The waveforms of the measured signals can be characterized for their primary frequency content by performing Fast Fourier Transforms (FFT) on the signals. The FFTs should be done on the time periods of the signal that have the highest amplitudes. AE sensor selection is guided by the primary frequency content identified by the FFTs. An AE sensor (wideband or resonant) should have significant response over the range of frequencies excited with the highest amplitudes.

Note for AE source mechanisms not related to crack initiation or - propagation:

The above mentioned method is applicable in cases were a pencil lead break is a good equivalent for an AE source. This may not be the case for all AE source mechanisms (e.g. leakage). A similar approach would be possible if a different artificial AE source is applied which is similar to the expected source.

Note for plate like structures:

If the object under test is a plate like structure, pencil lead breaks should be performed in a sufficient distance from the AE sensor in order that only plate waves excite the AE sensor. Usually distances larger than 20x plate thickness are sufficient. Additionally pencil lead breaks should be made on the top (or bottom side) of the plate, to generate asymmetric wave modes, and, if possible, at the center of the plate’s edge to generate symmetrical wave modes.

2.3. AE Sensor Size and Frequency Response

The size of the piezoelectric element affects the resonance frequency of the AE sensor. In general the resonance frequency is higher for smaller piezo-elements. Therefore the desired resonance frequency has a major influence on the sensor size; i.e. the lower the frequency range of an AE sensor the larger its size.

2.4. Integrated Preamplifier vs. External Preamplifier

Vallen Systeme GmbH provides AE sensors with and without integrated preamplifier. AE sensors with integrated preamplifier are referred to as active sensors, whereas those without integrated preamplifiers are referred to as passive sensors. In general AE sensors with integrated preamplifier are larger and heavier than similar AE sensors without integrated preamplifier. However, AE sensors with integrated preamplifier are better suited for usage in the field, because measurement setup can be realized faster and the number of connectors which can be mixed-up is reduced. Especially thin cables such as the sensor-to-preamplifier cable may be troublesome in the field since they must be handled with extra care.

Passive AE sensors require an external preamplifier. The cable length between AE sensor and external preamplifier is usually 1.2 meters and should not be further extended unless the setup cannot be realized with this cable length. The shorter the cable from sensor to preamplifier, the higher is the sensitivity of the sensor. The lower the AE sensor's capacity, the worse is the influence of cable length on the sensitivity. The cable transmitting the signal from the preamplifier to the measuring system can be several hundred meters long.

In general, AE sensors with integrated preamplifier are more cost effective than a similar passive AE sensor together with an external preamplifier. The additional costs of the second solution can be justified by a more flexible setup when for instance the gain of the external preamplifier or the frequency response of AE sensor needs to be adapted for different applications.

2.5. Vallen Smart Line™

Sensors of the Vallen Smart Line™ like the VS150-RSC support a proprietary protocol to exchange information with the Vallen acoustic emission system AMSY-6, for example the sensor type, the serial number, and the gain of an integrated preamplifier. With Vallen Smart Line™ it is no more necessary to enter the connected input device manually in the AMSY-6 acquisition settings which saves time and avoids errors. The automatically retrieved serial number is important information for documenting the test configuration.

First SW release supporting Vallen Smart Line™ is R2018.0726. Vallen Smart Line™ sensors work also with older SW releases, but then without the new Vallen Smart Line™ features.

2.6. Sensor Coupling Verification Pulse

The piezoelectric element of an AE sensor transforms mechanical vibrations into an electrical signal. In turn, an electrical pulse applied to the piezoelectric element results in a mechanical excitation which could be used to emit a mechanical wave into the test object. This wave can be used for instance to verify the sensor coupling quality.

A voltage pulse is transmitted from the AE system (i.e. AMSY series) through the preamplifier to the AE sensor and generates a wave in the structure under test. The wave from the pulsing AE sensor propagates through or along the test object and can be picked up by neighboring AE sensors. The amplitude of the received AE signal gives an indication whether an AE sensor is coupled appropriately to the structure.

The preamplifier must support the so-called "pulse through” functionality. That means, the preamplifier, when not supplied by 28 VDC, internally disconnects the preamplifier output from the cable that delivers the high voltage pulse, in order to prevent damage from the preamplifier, and connects the high voltage pulse to the piezo electric sensor element. Preamplifiers that do not support the pulse through functionality must not be used for pulsing, because they might get damaged permanently. The user of an AMSY-6 (or its predecessors) defines in a software menu which kind of preamplifier is connected to a signal processor. With the Vallen Smart Line™ feature the type of connected preamplifier is retrieved by the AMSY-6 automatically.

All Vallen Systeme external preamplifiers (i.e. AEP series, see “Acoustic Emission Preamplifier” document) support the pulse through capability. Most Vallen Systeme AE sensors with integrated preamplifiers also support the pulse through functionality. This is indicated by a “C” (calibration bypass) at the end of the AE sensor name, e.g. VS150-RIC. All passive AE sensors (without integrated preamplifier) can be used for pulsing anyway.

Vallen Systeme supports another pulsing mode for its intrinsically safe AE sensors. Hereby only a low energy control signal is transmitted from the signal processor to the sensor and sensor-internal electronics is used to supply a high energetic pulse to the piezoelectric element, because high energetic pulses are prohibited on intrinsically safe circuit cables.

By investigating the post-pulse oscillation of the piezoelectric element, which is influenced by coupling, the coupling quality of the pulsing AE sensor can be verified. This coupling verification method is referred to as ‘auto sensor test - self test mode' in ASTM E2374-04.

Investigating the pulse received by neighboring sensors is called 'auto sensor test - near neighbor mode’.

3. AE Sensor Handling

Vallen Systeme AE sensors are built for tough field testing conditions. Nevertheless AE sensors should be handled with care and should not be dropped or subject to excessive mechanical force.

Please make sure that the metal parts of the AE sensor are electrically isolated against the test object´s surface. If full metal AE sensor cases are used (-L, -A1, -A2 and -Z2 case) and the surface of the test object is a conductive material use, e.g. Flashbreaker® tape as isolating interface.

4. Mounting of AE Sensors

An AE sensor needs to be mounted firmly to the surface of the structure under test. The mounting shall assure that an AE sensor cannot move during the test and ensure that transmission losses through the interface between test object surface and sensitive face of the AE sensor is minimal. Methods for mounting can be categorized into two groups: compression mounts and adhesive mounts.

4.1. Compression Mount

A compression mount holds the AE sensor in contact with the surface of the test object through the use of pressure.

One of the most popular compression mount methods is using magnetic holders. Magnetic holders (also called magnetic locks) can be used if the test object is ferromagnetic. The compressive force is delivered via the springs attached to the magnet(s). Magnetic holders for Vallen AE sensors can be found in ‘Accessories for AE Systems’.

Other typical mounting aids are clamps, adhesive tape or elastic bands. It is strongly advised to use couplant together with compression mounts in order to reduce transmission losses and effectively increase AE sensor’s sensitivity.

4.2. Adhesive Mount (Bonding)

An AE sensor may also be bonded directly to the object's surface. Care should be taken choosing the right adhesive which should not attack the surface it is applied to. The adhesive will also act as a couplant.

Most sensors have a ceramic wear plate glued in front of the sensitive area to protect the piezoelectric element. Irreparable damage could be introduced to the ceramic wear plate if this bond breaks before the mounting adhesive during the attempt to remove the sensor from the test object. Similarly the test object (e.g. composite materials) could get damaged when removing a sensor.

The most appropriate way of removing a bonded AE sensor is to move the AE sensor sideways to generate shear stress in the bond interface or tab the AE sensor gently on the side until it comes off.

Note:

Bonding is a rather rigid way of mounting an AE sensor to a surface. Surface deformation due to mechanical loading or thermal expansion may cause the bond to crack. These cracks are a source of unwanted AE signals.

Special Feature: AE sensors suitable for bonding

Vallen Systeme supplies also full metal housing AE sensors (e.g. VS600-Z2, VS150-L) which are particularly suitable for bonding.

4.3. Sensor's Mounting Verification

Once the sensors are mounted onto the test object, the quality of acoustic coupling to the test object has to be checked. This check is one of the keys to a high quality data acquisition. AE sensor mounting is usually verified by Hsu Nielsen sources. A Hsu-Nielsen source is a pencil lead break of a 0.5 mm 2H lead at a 30° angle to the surface (see separate document Acoustic Emission Accessories for more information about Hsu Nielsen source). AE sensor mounting is considered good, if the responses of all AE sensors to Hsu Nielsen sources differ less than 3dB.

4.4. Usage of a Couplant

A couplant applied between surface of test object and sensitive face of an AE sensor reduces the transmission losses of elastic wave energy entering the AE sensor, effectively increasing the sensitivity of the sensor. A couplant should be selected under consideration of the environment (e.g. temperature, pressure, composition of atmosphere or liquid environment). Most important a couplant should be chemically compatible to the test object's surface (e.g. not corroding).

A couplant should be applied with the thinnest practical layer. No voids or entrapped air inclusions should be present. Thick layers of couplant or unevenness of it can reduce the sensitivity of an AE sensor.

Applying couplant:

A practical way of applying couplant is to place a small amount of couplant on the center of the sensitive face of the AE sensor. Carefully press the AE sensor onto the surface of the object under test. The couplant should spread evenly from the center to the outside and ooze a bit out under the AE sensor.

Most AE sensors are sensitive to normal surface motion, only. Hence the viscosity of the couplant is not of significant importance under normal conditions. Most liquids or greases will work when they wet the surfaces of both the AE sensor and the object under test. See document "Accessories for Acoustic Emission Systems" for our couplant product range.

5. AE Sensor Verification

We recommend verifying every AE sensor in certain intervals depending on its usage and application. This verification is especially recommended if an AE sensor has been dropped, exposed to high temperatures or in any case when the AE sensor response give reasons to doubt the integrity of it. Vallen Systeme is able to verify most AE sensors available on the market. The verification tool called Vallen Sensor Tester (VST) is also available for purchase. The VST generates frequency response graphs which can be used to identify response changes over time. See document “Accessories for Acoustic Emission Systems” for more information.

5.1. Frequency Response Measurement

All Vallen AE sensors come with a test certificate. The test certificate shows the frequency response of the specific AE sensor to a reproducible excitation. When comparing the original certificate with the result of a comparative test at a later date possible AE sensor response changes can be identified. Some aspects of AE sensor response are not addressed:

- The type of wave (pulse or continuous) may affect the AE sensor output, especially with resonant AE sensors. AE sensor under test is coupled face-to-face to an emitter. Emitter is driven by a continuous sine wave. Response of AE sensor is recorded at different frequencies and plotted in diagram.
- The surface displacement caused by a wave is three dimensional, the electrical AE signal is one dimensional. How an AE sensor performs with respect to each displacement direction is not identified in a frequency response curve.
- The AE sensor’s response will be affected by the structure on which it is mounted. Even when the same setup is used, care must be taken to align the AE sensor and emitter properly to maintain relative reproducibility.

5.2. Pressure Excitation

With this testing method the exciting displacement is uniform over the whole crystal face. This is realized by coupling the AE sensor under test face-to-face with a wideband ultrasonic emitter. The emitter can be stimulated in two ways: (i) by a continuous sine wave, which frequency is swept over the range of interest or (ii) by a number of Dirac like pulses. In the case of (i) the RMS signal level of the AE sensor under test is plotted in dB versus frequency, whereby 0 dB refers to a AE sensor output of 1 V at an excitation of 1 µbar. In the case of (ii) the FFTs of the pulses are averaged to get the frequency response of the sensor under test.

This testing method is fast, easy to reproduce (e.g. by the Vallen Sensor Tester, VST) and most standard test certificates are made by this method.

This document shows pressure excitation results.

Customers having the Vallen Sensor Tester (VST) can qualitatively reproduce the frequency response curves with the following settings:

	Pressure Excitation:
Output Voltage	0.1 V_{RMS} (0.05 V_{RMS} if preamplifier gain > 40 dB)
Offset	-114 dB – external gain (+ 6 dB if preamplifier gain > 40 dB)
Cable length used	RG178m 1.2 m, if no other length is stated for the frequency curve.

Olympus V103 (ultrasonic wideband sensor) is used as emitter. AE sensor under test is coupled face-to-face to emitter using a suited couplant (e.g. light machine oil).

For the VS30-V and VS75-V an Olympus V101 is used instead of the V103. The other settings can be seen from the legends in the frequency curves.

6. Sensor Categories

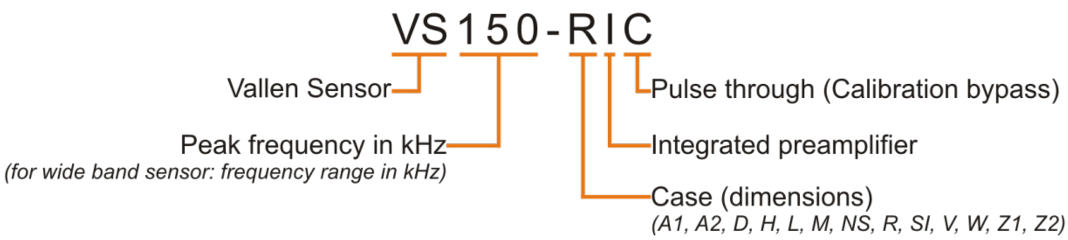
AE sensors can be classified into sensors with integrated preamplifier and sensors without integrated preamplifier.

According to the classification into 3 frequency regimes (see section 2.3) low frequency-, standard frequency- and high frequency sensors are available. Furthermore sensors for a broad frequency range are available as well.

AE sensors can also be categorized into the environment in which they can be installed: standard environment sensors, water tight sensor, high temperature sensors and sensors for explosion hazardous areas (ATEX certified sensors).

AE sensors may also be categorized in big- and small sensors. Usually high frequency sensors are small whereas low frequency sensors are big. High frequency sensors are always produced without integrated preamplifier. Low frequency sensors and standard frequency sensors are usually available without integrated preamplifier (medium size) and with integrated preamplifier (large).

Vallen Systeme GmbH follows a naming convention which allows identifying the frequency range and the functionality of a sensors as well as the application environment in which a sensor can be installed.



The peak frequency in the sensor code identifies in which frequency regime a sensor is optimally used. E.g. VS30-V is an AE sensor for the low frequency regime whereas a VS600-Z1 is an AE sensor for the high frequency regime.

The case code is arbitrary and informs to some extent about the environment in which a sensor can be used: water tight sensors have case code *W*, and *K*; high temperature sensor have case code *NS*; outdoor- or rough environment sensors have case code *O*.

The integrated preamplifier code informs about the functionality of a sensor: an *I* indicates a sensor with integrated preamplifier; an *S* indicates a sensor with a Vallen Smart Line ™ preamplifier.

The third letter *C* indicates if the integrated preamplifier is capable of putting a pulse through to the PZT element. If that letter code is missing this functionality is missing. This is the case for all sensors without integrated preamplifier. AE sensors with integrated preamplifier are usually produced with a pulse bypass and thus have the *C* code in their product code. Only for two special sensors, the VS75-SI and the VS150-RI, the pulse bypass in the integrated preamplifier is missing.

As the variation of sensors and their functionality grows an Appendix to the three-letter code has evolved. It either informs about the gain as in case of the VS30-SIC-46dB or the specific version of a sensor, e.g. the VS75-SIC-V2.

Vallen Systeme offers also third party sensors for special applications.

6.1. AE sensors for hazardous areas

Vallen Systeme offers an intrinsically safe product family (ISAFE3). This product family is ATEX certified and consists not only of a family of AE sensors but also of special signal isolator to fulfil all safety requirements for hazardous areas of zone 0, zone 1 or zone 2. For more details please see the ‘Vallen ISAFE3 Operation Manual’ or contact us at info@vallen.de.

7. Features of Vallen Systeme Preamplifiers

Preamplifiers are part of the measurement chain of a multichannel Acoustic Emission measurement system such as an AMSY-6 or its predecessors. A preamplifier has usually one input for receiving an AE-signal from the AE-sensor and one output which is connected to an Acoustic Emission signal processor (e.g. one of the two ASIP-2 channels).

AE-sensors produce a high impedance AC signal unsuitable for transmission over long cables. Therefore preamplifiers transform the high impedance AE-signal to a low impedance signal. Such signals experience only minimal loss when transmitted over long cables. Additionally, the AE-signal of the sensor is amplified to a voltage range suitable for the Acoustic Emission signal processor board ASIP-2 or its predecessor ASIPP. Vallen Systeme preamplifiers are carefully designed to maintain highest possible signal-to-noise ratio in order to minimize disturbance of the wanted signal.

Preamplifiers are either integrated into an AE-sensor (e.g. VS30-SIC-46db, VS150-RIC, etc.) being a non-removable part of the sensor or can be provided as external unit.

Vallen Systeme preamplifiers (integral or external) are originally designed for usage with measurement equipment of the AMSY series. However, they can also be used with AE-measurement equipment or data acquisition cards of other brands.

Vallen Systeme preamplifiers have several features making them well suited for any AE-measurement application. These features are described in the subsequent sections 7.1 to 7.10.

7.1. Integral- and external preamplifiers

Vallen Systeme preamplifiers are available as an integral or external design. An integral preamplifier is part of the sensor residing inside its housing whereas external preamplifiers have a separate housing and are connected to the sensor by a usually 1 m long cable.

Sensors without integral preamplifiers are usually a bit smaller and lighter than those sensors with integral preamplifier. For some applications with small specimen size AE testing becomes only possible when using external preamplifiers together with small and lightweight sensors. Using external preamplifiers is more cost efficient when different sensor types (e.g. VS150-M, VS900-M or VS30-V) are used alternatively with the same measurement equipment. Also selectable gain and filter settings can be realized with some external preamplifiers. For high temperature applications an external preamplifier can be located away from the hot surfaces. Vallen Systeme provides external preamplifiers in the AEP series (e.g. AEP3N and AEP5).

Sensors with integral preamplifiers are especially suited for field work. These AE-sensors do not need an external preamplifier and the additional sensor cable between sensor and preamplifier. This speeds-up measurement setup and reduces the risk of mixed-up connections. Especially thin cables, such as thin sensor cables, may be troublesome in the field since they need to be handled with care.

The AEP4 preamplifier series features one preamplifier with integrated sensor: the AEP4H-ISTB. This version combines magnetic holder, AE-sensor, sensor cable, preamplifier to one single unit. In combination with the VS30-V, the AEP4H-ISTB was designed especially for field testing purposes such as corrosion screening of tank floors.

7.2. Single ended- and differential input

A preamplifier with single ended input amplifies the voltage difference between the inner wire and shield of the coaxial input connector (BNC). AE sensor and preamplifier are connected over a coaxial cable, which is cheap, widely available and easy to handle.

A differential preamplifier amplifies the voltage difference on two input lines (BNO connector) and rejects a possible common voltage on both inputs against the shield. In most cases, differential sensors use an integrated differential cable with BNO connector at the preamplifier side.

Two main advantages speak for the more expensive differential variant against the single ended variant: Immunity against EMI (electromagnetic interference) and ground loop currents.

EMI usually adds a disturbing voltage to the inner wire(s) and shield. The voltage added to the shield is usually shortened to ground over the shield of the preamplifier to AE system cable.

When using a single ended input, the voltage caused by EMI on the inner wire enters the high impedance preamplifier, is amplified and adds noise to the AE signal.

When using a differential preamplifier, the voltage caused by EMI is identical on both input lines, not amplified, so the signal to noise ratio is better.

Ground loop currents are driven by potential differences between the ground of the test object and ground of AE system, if the case of an AE sensor is not electrically isolated from the test object.

When using a single ended input, the ground loop current will cause a voltage across the cable shield between sensor and preamplifier. This voltage is amplified and adds noise to the AE signal. Therefore single ended sensor should be electrically isolated form the test object.

When using a differential input, the voltage across the cable shield has no influence on the AE signal, the voltages on the two input lines are common mode and not amplified and do not add noise to the AE signal.

Despite the advantages of the differential sensors, single ended sensors are much more widely used due to its cost efficiency and since the low amplitude noise can be tolerated for most applications.

Whether using preamplifiers that support single ended or differential input is dictated by the AE-sensors in use. Most AE-sensors of the Vallen Systeme product range are single ended. The AEP5 preamplifier supports single ended only, whereas the AEP3N preamplifier supports both; single ended and differential input.

7.3. Long cable transmission

One important feature of preamplifiers is to convert the high impedance signal of the sensor into a low impedance signal. Contrary to a high impedance signal a low impedance output can drive long cables. By using a preamplifier the cable between preamplifier and AMSY-6 chassis can be several hundred meters long while transmission losses are still acceptable.

The thinner the cable the higher the electrical resistance and the DC-voltage loss on the cable.

When the preamplifier gets less than 28 V DC over the cable, the saturation point decreases accordingly.

7.4. Preamplifier gain

Integral preamplifier have a fixed gain setting, which can either be 34dB (e.g. VS150-RIC, VS75-SIC-34dB), 40dB (e.g. VS75-SIC-40dB) or 46dB (e.g. VS30-SIC-46dB). For sensor types which are available with different gains, the gain setting is part of their product code (e.g. VS30-SIC-46dB, VS75-SIC-40dB).

The external preamplifier AEP4 and AEP5 can either have 34dB or 40dB gain. The gain is selected by a jumper located inside the preamplifiers housing. The operator can change the gain setting by removing the preamplifier cover and set the jumper even in the field. (The jumper setting of AEP4-IS/ISTB is inside the compound and can't be changed.)

The external preamplifier AEP3N supports gain settings of 34, 37, 40, 43, 46 or 49dB. These gains can be programmed with the Vallen Acquisition software or be changed manually by a jumper inside the preamplifier (See chapter 7.5 for more information). Additionally a 34dB attenuator (non-programmable) can be activated by an additional jumper, resulting in gain settings of 0, 3, 6, 9, 12 or 15dB. Reducing the gain might be necessary when AE from very strong sources is measured (e.g. relaxation of residual stresses during proof testing of newly manufactured composite pressure vessels).

Decibel is a logarithmic scale which is calculated by: $A[dB] = 20 * \log(U_o/U_i)$. Therefore if the gain is 34dB the AE signal from the sensor [mV] gets amplified by a factor of 50. A gain of 40dB amplifies the input by a factor of 100.

The gain should be chosen according to the application. The highest possible gain setting is not necessarily the best choice for a specific application. Every measurement channel will have a saturation limit (e.g. ±5 V or ±10 V) above of which signal information is lost. For example the information about peak amplitude of a saturated signal is lost, similarly the signal energy information is corrupted. While a higher gain increases the resolution of small signals, dynamic range is lost since saturation of measurement channel will be caused at smaller input signal levels. Hence in case of applications with strong AE-sources (crack in a metallic vessel) and/or short distances between sensors (e.g. laboratory samples) a gain of 34dB is sufficient in most cases. In case of weak sources (e.g. corrosion of a tank floor) a gain of 46dB might be more appropriate. Gain settings are optimized to match the amplified AE-signal to the input range of the ASIP-2 signal processor.

7.5. Programmable gain (AEP3N only)

Programmable gain is a feature of the AEP3N only and requires the AMSY-6 (or its predecessors) and the Vallen Acquisition software. By default programmable gain is enabled and the gain setting can be changed using Vallen Acquisition software. If the AEP3N is not connected to an AMSY, gain settings can be changes manually by a jumper inside the preamplifier housing. Therefore the preamplifier cover needs to be removed. The jumper position is printed inside the preamplifier lid for reference. The operator can do this modification at any time even in the field.

7.6. Vallen Smart Line™

Preamplifiers of the Vallen Smart Line™ like the sensor VS150-RSC with integrated preamplifier support a datasheet protocol to exchange information with the Vallen acoustic emission system AMSY-6, for example the sensor type, the serial number, and the gain of an integrated preamplifier. With Vallen Smart Line™ it is no more necessary to enter the connected input device manually in the AMSY-6 acquisition settings which saves time and avoids errors. The automatically retrieved serial number is important information to document the test configuration

First SW release supporting Vallen Smart Line is R2018.0726. Vallen Smart Line™ preamplifiers work also with older SW releases but then without the Vallen Smart Line™ features.

7.7. Pulse through functionality

All Vallen Systeme preamplifiers (only very special integral preamplifiers are excluded) support the Vallen pulse through functionality (or calibration bypass). For sensor coupling verification a voltage pulse generated by a pulser module within the AMSY-6 (or its predecessors) chassis is transmitted to the piezoelectric element of the sensor to generate a mechanical wave. Internally, the Vallen Systeme preamplifier by-passes the high voltage pulse from the output through to the AE-sensor.

If a preamplifier in use does not support pulse through, care has to be taken in the acquisition program that the proper input device is selected, otherwise the preamplifier might get damaged by the pulse.

For more information please refer to the ‘Acoustic Emission Sensor’ document.

7.8. Power supply

Every Vallen Systeme preamplifier, no matter if integral or external, requires a power supply of 28 V_{DC}. Power supply and signal transmission use the same line from preamplifier to measuring system. This method of providing power to the preamplifier is often referred to as phantom power.

In case the preamplifiers are connected to a measuring system without phantom power supply the user must make sure that the required power is supplied and the wanted signal is decoupled from the power before feeding it into a data acquisition unit or oscilloscope. A schematic of such a power supply - decoupling circuit is shown below. Vallen Systeme also provides a so called decoupling box (DCPL2, see ‘Accessories for Acoustic Emission Systems’). The DCPL2 has additional electronic components to reduce electronic noise from the power supply in the decoupled AE signal.

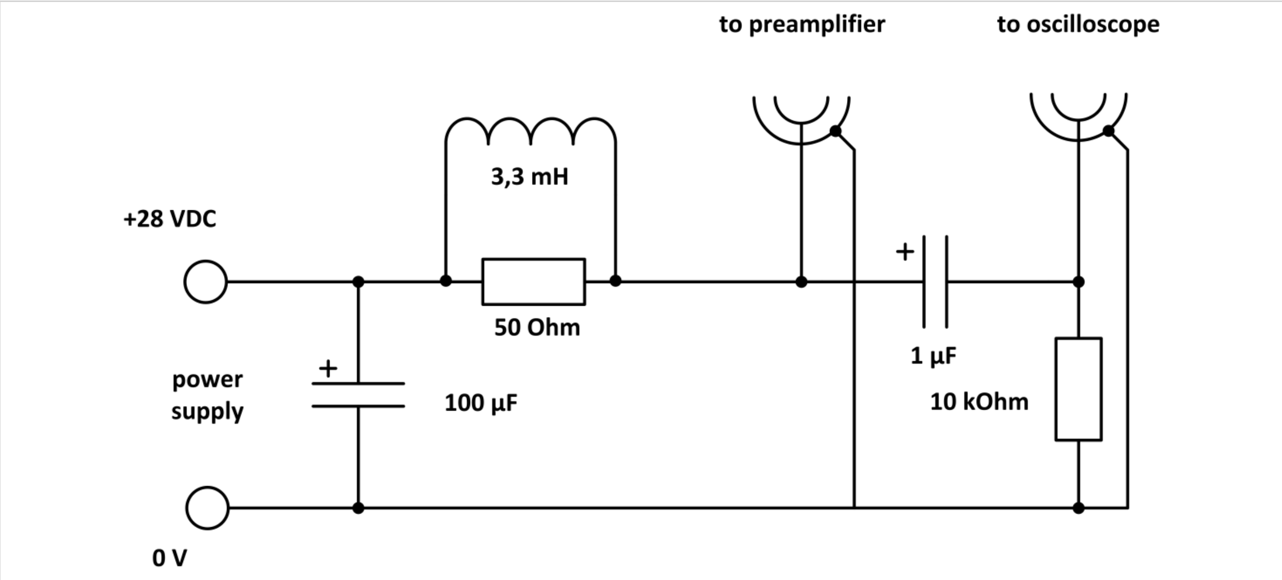


Figure 1: Principle electronic circuit to supply power to the preamplifier and decoupling AC component from the signal

7.9. Frequency filtering

Frequency filtering is, to some extent, necessary to avoid disturbance and saturation of ASIP-2 measurement channel with unwanted frequency components of the AE signal. Saturation is most likely caused by very low frequencies. Application specific frequency filtering should be done by ASIP-2 only. The digital filters of the ASIP-2 are more flexible and entirely reproducible. Therefore the bandwidth design of the AEP4 and AEP5 preamplifier series is rather broad band.

AEP3N preamplifiers support add-on band-pass filter modules for frequency filtering. However, it is recommended to use broad band-pass filter configuration if AEP3N is used with ASIP-2 signal processor boards. If AEP3N is used with other measuring systems without subsequent filter ability, e.g. an oscilloscope, it might be a good idea to limit the bandwidth by using appropriate filter modules for the AEP3N.

7.10. Connectors and switches

Each preamplifier has at least one output connector of BNC type. The output connector is used to transfer the AE-signal to the signal processor and to provide power to the preamplifier (28 V_{DC}). Additionally the output line is also used to switch the preamplifier into pulse through mode for sensor coupling tests. In case of AEP3N the programmable gain control signal is also transferred via output line.

A preamplifier provides an input for the AE-signal. However in case of integral preamplifiers and AEP4H-ISTB the input is hidden within the housing and internally connected to the piezoelectric element. On external preamplifiers, such as the AEP3N, AEP5, and AEP5H, signal input connector is always of type BNC.

The AEP3N has an additional differential input connector of type BNO. Hence either a single ended or a differential sensor can be connected. A switch on the front side between the input connectors lets an operator select the desired input.