Acoustic Emission Preamplifiers

Specification

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Revision Record

Date	Changes
07-2013	Parts of document edited

Purpose of this Document

This document

- describes the features of Vallen Systeme preamplifiers
- outlines specifications of preamplifiers
- can be used as reference and explanation of part codes used in quotations of Vallen Systeme GmbH

1 Introduction

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.

2 Features of Vallen Systeme preamplifiers

Vallen Systeme preamplifiers have several features making them well suited for any AE-measurement application. These features are described in the subsequent sections 2.1 to 2.9.

2.1 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 AEP4).

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 the SEC, 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.

2.2 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 AEP4 preamplifier supports single ended only, whereas the AEP3N preamplifier supports both; single ended and differential input.

2.3 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.

2.4 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 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 2.5 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.

2.5 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.

2.6 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.

2.7 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 (DCPL1, see 'Accessories for Acoustic Emission Systems'). The DCPL1 has additional electronic components to reduce electronic noise from the power supply in the decoupled AE signal.

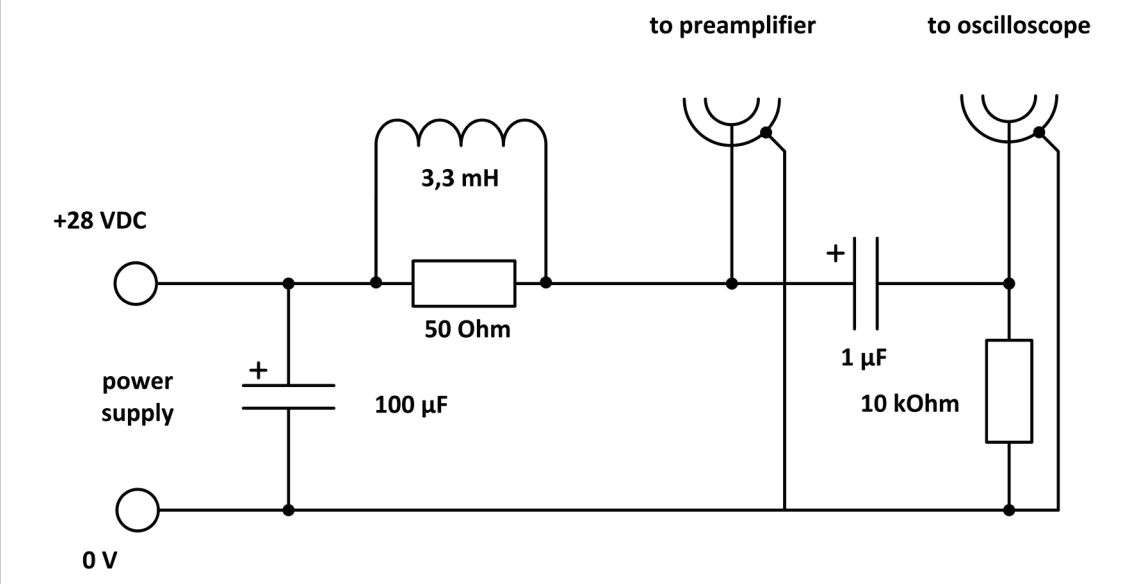

Figure 1: Principle electronic circuit to supply power to the preamplifier and decoupling AC component from the signal

2.8 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 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.

2.9 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, AEP4 and AEP4H, 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.

3 AEP3N

Special Feature:

differential and single ended input • exchangeable filter modules • programmable gain

The filter modules of the AEP3N can be exchanged to support different frequency ranges. The AEP3N supports both, single ended and differential sensor input. Its gain is programmable by software or can be adjusted manually by jumpers.

Figure 2: AEP3N preamplifier. Connectors from left to right are: (i) signal output and power supply input, (ii) differential BNO input and (iii) single ended BNC input.

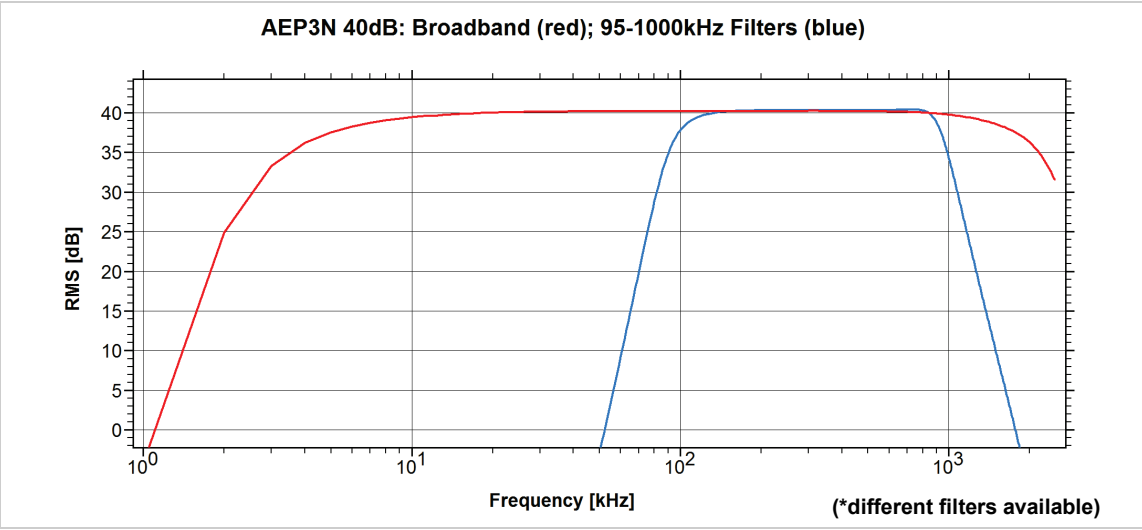

Figure 3: Frequency response of AEP3N with two different band-pass filter settings.

AEP3N – Specifications (Typical):

Preamplifier gain:	Software selectable to 34, 37, 40, 43, 46, or 49 dB (can also be defined by jumper), into 50 Ω. Additional -34dB attenuator (jumper selectable), resulting in a total gain of 0, 3, 6, 9, 12 or 15 dB
Bandwidth (-3 dB):	Defined by plug-in filter modules (easily exchangeable), 5 kHz to 2 MHz when using dummy filter modules
Preamp input impedance:	10 kΩ parallel 15 pF
Power supply:	28 V_{DC}, 18 mA (no signal) / 55 mA (max. signal), fed-in via signal cable
Pulse through:	For up to 450 V_{PP}, suited for AMSY series
Output connector:	BNC
Input connectors:	BNC (single ended), BNO (differential), selected by manual switch
Input range:	17.7 mV_{PK} at 49 dB gain 100 mV_{PK} at 34 dB gain (200 mV_{PK} in filter stop-band) 0.89 V_{PK} at 15 dB (-34 dB (att.-stage)+ 49 dB) gain 5.0 V_{PK} at 0 dB (-34 dB (att.-stage) + 34 dB) gain input protected
Output range:	10 V_{PP} into 50Ω
Dimensions & weight:	H x W x L: 57 x 80 x 125 mm (W + 18 mm BNC), 525 g
Temperature range:	5°C to 65°C
Noise (max. once per 1 s) (input: 50 Ohm)	14.0 dB_{AE} / 1.1 μV_{RMS} at 95-300 kHz, 49dB Gain 20.0 dB_{AE} / 1.8 μV_{RMS} at 95-850 kHz, 49dB Gain
Noise (max. once per 1 s) at 330 pF input:	16.7 dB_{AE} / 1.5 μV_{RMS} at 95-300 kHz, 49dB Gain 19.6 dB_{AE} / 1.7 μV_{RMS} at 95-850 kHz, 49dB Gain
Noise (max. once per 1 s) (input: VS150-M)	20.4 dB_{AE} / 2.6 μV_{RMS} at 95-300 kHz, 49dB Gain 22.1 dB_{AE} / 2.7 μV_{RMS} at 95-850 kHz, 49dB Gain
Filters: High pass modules:	54 dB/octave (9^{th} order), one frequency of: 17, 20, 25, 30, 35, 40, 50, 65, 75, 85, 95, 110, 125, 140, 160, 180, 230, 300, 340, 400, 520 or 600 kHz
Filters: Low pass modules:	30 dB/octave (5^{th} order), one frequency of: 310, 330, 380, 440, 550, 630, 800, 1000, 1350 or 2000 kHz

4 AEP4 / AEP4H

The AEP4(H) is a general purpose preamplifier supporting single ended sensors. This preamplifier is a wide-band preamplifier available in two different bandwidth settings (AEP4 and AEP4H). Gain can be set to 34dB or 40dB. The gain selection jumpers are located inside the preamplifier to prevent any accidental changes of gain settings. The operator only needs to open the lid of the housing and change the jumper setting to change the gain. As every preamplifier of Vallen Systeme GmbH the AEP4(H) can put a voltage pulse (up to 450 V_{PP}) through to the AE-sensor (sensor coupling test).

Figure 4: AEP4 preamplifier

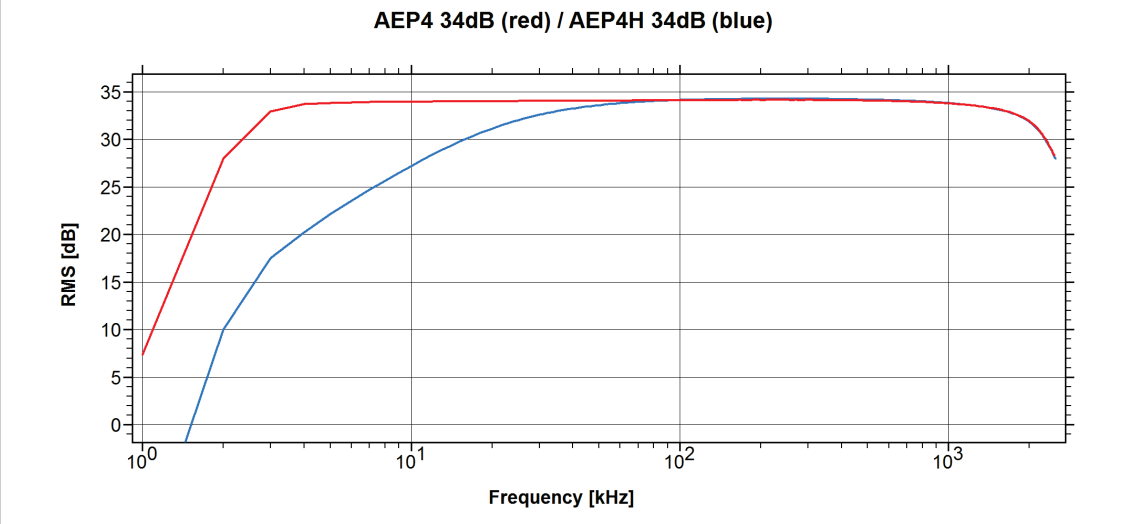

Figure 5: Frequency response of AEP4 and AEP4H preamplifier

AEP4 / AEP4H – Specifications (Typical):

Preamplifier gain:	34 dB or 40 dB (jumper-selectable) into 50 Ω
Bandwidth (-3 dB):	AEP4: 2.5 kHz to 1 MHz (10 V_{PP}) AEP4H: 20 kHz to 1 MHz (10 V_{PP})
Preamp input impedance:	50 MΩ parallel 22 pF
Power supply:	28 V_{DC}, 24 mA (no signal) / 64 mA (max. signal), fed-in via signal cable
Pulse through:	For up to 450 V_{PP}, suited for AMSY series
Output connector:	BNC
Output range:	10 V_{PP} into 50 Ω
Input connector:	BNC (input signal from single ended sensors)
Input range:	100 mV_{PK} at 34 dB gain 50 mV_{PK} at 40 dB gain
Dimensions & weight:	H x W x L: 35 x 60 x 65 mm (L + 2x 18 mm BNC), 200 g
Temperature range:	-5°C to 85°C
Noise (max. once per 1 s) (input: 50 Ohm):	12.5 dB_{AE} / 0.8 μV_{RMS} at 95-300 kHz 18.5 dB_{AE} / 1.6 μV_{RMS} at 95-850 kHz
Noise (max. once per 1 s) at 330 pF input:	10.9 dB_{AE} / 0.7 μV_{RMS} at 95-300 kHz 16.9 dB_{AE} / 1.3 μV_{RMS} at 95-850 kHz
Noise (max. once per 1 s) (input: VS150-M)	24.7 dB_{AE} / 4.3 μV_{RMS} at 95-300 kHz 25.8 dB_{AE} / 4.9 μV_{RMS} at 95-850 kHz
Filters:	To be located in subsequent measurement circuits (AMSY series)

5 AEP4H-ISTB

Special Feature:

compact unit, in combination with VS30-V optimized for tank bottom corrosion screening

The AEP4H-ISTB is a preamplifier specifically designed for the high sensitivity requirements of tank bottom tests and similar applications: It is a low-noise preamplifier, special gain (46 dB) and strong magnetic holders. The AEP4H-ISTB can accommodate a VS30-V or VS75-V sensor (spring loaded). The integrated sensor-to-preamplifier cable is well protected against EMI (electromagnetic interference).

Figure 6: AEP4-ISTB with VS75-V sensor

AEP4H-ISTB – Specifications (Typical):

Preamplifier gain:	46 dB into 50 Ω
Bandwidth (-3 dB):	20 kHz to 1 MHz (10 V_{PP})
Preamp input impedance:	50 MΩ parallel, 22 pF
Power supply:	28 V_{DC}, 24 mA (no signal) / 64 mA (max. signal), fed-in via signal cable
Pulse through:	For up to 450 V_{PP}, suited for AMSY series
Output connector:	BNC
Output range:	10 V_{PP} into 50 Ω
Input connector:	Internal Microdot, no external access
Input range (internal):	25 mV_{PK} at 46 dB gain
Dimensions & weight:	H x W x L: 60 x 57 x 65 mm (L+18 mm BNC), 370 g (incl. VS30-V)
Temperature range:	-5°C to 85°C
Noise (max. once per 1 s) (input: VS30-V)	12.3 dB_{AE} / 1.2 μV_{RMS} at 25-45 kHz 27.2 dB_{AE} / 8.4 μV_{RMS} at 20-300 kHz

6 AE-Sensors with integral preamplifier

Special Feature:

AE-Sensors with integral preamplifier

Figure 7: Selection of different sensor with integral preamplifier

The RI / RIC and SI /SIC series are AE sensors with integrated preamplifier. The “R” and “S” indicates the dimensions of the sensor housing. Whereas the “I” indicates an integrated preamplifier and the ”C” the pulse through function.

All sensors are highly sensitive and are able to drive long cables (similar to AEP3N / AEP4 preamplifiers).

The advantage of these sensors with integrated preamplifiers is an easier handling due to the compact design and minimal loss between piezoelectric element and preamplifier for a better signal-to-noise ratio.

Model-Case	Freq. range (kHz)	Gain	Noise (Peak (once /sec) /RMS):	Pulse through
VS150-RIC	100-450	34 dB	25.2 dB_{AE} / 5.0 μV_{RMS} at 95-300 kHz	yes
VS150-RI	100-450	40 dB	22.2 dB_{AE} / 3.0 μV_{RMS} at 95-300 kHz	no
VS375-RIC	250-700	34 dB	28.0 dB_{AE} / 4.5 μV_{RMS} at 95-850 kHz	yes
VS900-RIC	100-900	34 dB	26.9 dB_{AE} / 4.5 μV_{RMS} at 95-850 kHz	yes
VS30-SIC-46dB	25-80	46 dB	18.5 dB_{AE} / 2.6 μV_{RMS} at 25-45 kHz	yes
VS75-SI-40dB	30-120	40 dB	29.5 dB_{AE} / 7.3 μV_{RMS} at 25-300 kHz	no
VS75-SIC-34dB	30-120	34 dB	29.2 dB_{AE} / 6.8 μV_{RMS} at 25-300 kHz	yes
VS75-SIC-40dB	30-120	40 dB	29.5 dB_{AE} / 7.3 μV_{RMS} at 25-300 kHz	yes

Literature:

For more information please see our documentation ‘Acoustic Emission Sensor’.

7 Warranty Conditions

The warranty period is two years for preamplifiers and three months for AE-sensors, starting from the date of the delivery. This warranty does not cover the repair of any damage to the products generated by accident or improper handling.

We warrant that the goods as delivered will conform to the given specifications. If notified during the warranty period that the delivered goods contains defects such it does not conform to the specifications, we will make it operate as specified by providing replacement parts as determined by us, free of costs and within a reasonable time. If transportation should become necessary, the customer has to provide the permits for export and re-import of replacement parts and bear the costs of transportation.

Except as expressed before, we disclaim all other warranties. We shall not be liable for any direct, indirect, consequential or incidental damage arising out of the use or inability to use of the delivered goods.