spotWave Instructions Manual

Instructions Manual

Revision 2022-07

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1. spotWave Instructions Manual

This instructions manual applies to the device type spotWave model 201 and input ranges of 94 dB_{AE}, 100 dB_{AE} and 134 dB_{AE}.

Read the instructions manual before the first use of the product and follow the instructions to ensure safe usage of the product.

1.1. Original Instructions

The original instructions are written in English language and are verified by Vallen Systeme GmbH.

1.2. Information Provided in the Manual

The information provided in the instruction's manual shall enable an operator a safe storage, transportation, installation and operation of the device.

1.3. Information Provided in Other Resources

The spotWave Operation Manual describes the usage of the spotWave acoustic emission measurement device with a focus on the acquisition and analysis software.

The technical specifications of a spotWave device are summarized in the spotWave Device Specification.

Accessories such as cables, sensors, magnetic holders, etc. are specified and described in the according data sheets and summarized in the Accessories for Acoustic Emission Systems document.

1.4. Intended Audience

This instructions manual is intended for qualified personnel. Qualified personnel have one or more of the listed characteristics:

- have an appropriate technical education
- can recognize the safety of a spotWave device
- have been trained to operate a spotWave device
- hold a valid certification according to ISO 9712, ASNT or any other comparable standard or standardization organization

Furthermore, such personnel know regulations concerning employment protection and on-the-job safety.

2. Contact Information

Vallen Systeme GmbH is the manufacturer of Acoustic Emission measurement systems and accessories for acoustic emission testing.


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```


Information about Vallen Systeme GmbH and the products can be found at www.vallen.de

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4. Safety Notices

The following safety notice(s) are used in this manual.

NOTICE

A NOTICE notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a NOTICE notice until the indicated conditions are fully understood and met.

5. Safety Symbols

No safety symbols are used on the device.

6. Important Information for Your Safety

Read these instructions carefully and follow them in order to safely operate the equipment and to maintain safety throughout its usage. Always make sure that the equipment is used in the intended way. Keep the instructions manual available for later usage.

Do not operate damaged equipment. Whenever it is possible that the safety protection features built into this product have been impaired, either through physical damage, excessive moisture, or any other reason, remove power and do not use the product until safe operation can be verified by service-trained personnel. If necessary, return the product to a Vallen Systeme GmbH sales and service office for service and repair to ensure that safety features are maintained.

Only use accessories that are approved by Vallen Systeme GmbH.

Always make sure that you comply with all regulations at the site of installation of the device.

A spotWave device has to be installed and used in non-hazardous areas. Do not operate a spotWave device in an explosion hazardous area.

7. Important Handling Information

NOTICE

Impaired Ingress Protection

Ingress protection requirements are only met in mated condition. Make sure an AE sensor and CCT-device is connected, and the USB plug secured. Otherwise the device is not waterproof and IP67 rating is not given.

How to Avoid Damaging the spotWave Device

Only expose the spotWave device to a moist and wet environment in mated condition, meaning with AE sensors, CCT-device connected and USB connector securely fixed.

Do not expose the device to dirt and humidity or submerse it in a liquid with open connectors.

What to do in Case of a Damaged Device

In the case a spotWave device got exposed to humidity, dirt or water, in unmated condition send the device to Vallen Systeme in order that correct function can be verified by Vallen Systeme. Similarly, if a liquid was able to enter its housing send it to Vallen Systeme for verifying its correct function.

8. Software and Firmware Updates

Vallen Systeme GmbH releases software updates including new firmware for its measurement devices to (i) add new features, (ii) include product enhancements and (iii) fix software issues. The latest software release can be obtained from www.vallen.de/downloads.

9. Differentiation of Hardware and Terms

spotWave

spotWave is a trademark of Vallen Systeme and the type designation of a single channel AE measurement system that can be operated by a mobile device or a PC. It has a USB interface for communications and power supply. Measurement data is stored to the host device to a *.pridb and .*tradb file.

linWave

linWave is a trademark of Vallen Systeme and the type designation of a dual-channel AE measurement system that can be integrated into an existing LAN infrastructure. The measurement data is collected over the LAN interface by an acquisition software that is running on a host device.

conditionWave

conditionWave is a trademark of Vallen Systeme and the type designation of a dual-channel AE measurement system that can be integrated into an existing LAN infrastructure and a machine monitoring environment. It receives commands via an API.

Measurement device vs. measurement system

A spotWave-, linWave- or conditionWave measurement system consists of the appropriate measurement device (or simply called device), an AE sensor, and an end device (such as a PC, laptop, mobile device, etc.) as well as all necessary accessories for conducting a measurement. The device is the box or chassis which holds the signal processor and logic. It is labeled accordingly as spotWave-, linWave- or conditionWave device.

10. General Information about the Usage

A spotWave device is part of the spotWave measurement system (short: spotWave system). The single channel spotWave system can be used for measuring acoustic emission. It can be operated in an acquisition mode or logging mode. Figure 1 shows a block diagram of the spotWave system in acquisition mode.

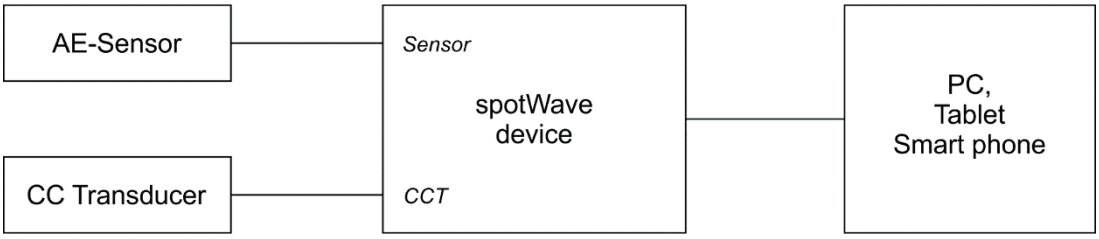


Figure 1: spotWave measurement system (acquisition mode) as block diagram consisting of one AE sensor, one coupling check transducer (CCT), the spotWave device, and a PC or mobile device running the data acquisition program storing the measurement data.

In acquisition mode the spotWave system consists of an AE sensor, of an optional coupling check transducer, the spotWave device and a suitable end device (e.g. PC, tablet or smartphone). The end device is required for storing measurement data and supplying power.

Figure 2 shows a block diagram of the spotWave system in logging mode. For the logging mode the spotWave device is configured by the use of an appropriate end device. After the configuration for logging mode the end device is disconnected. An external power supply needs to be connected to the USB interface of the spotWave device. When powered the spotWave device records and stores AE data autonomously. After finishing the logging mode, an end device is used to collect the accumulated AE feature data via the USB connection.

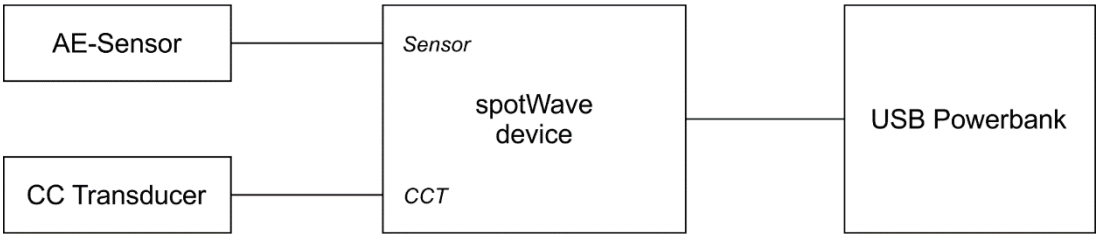


Figure 2: spotWave measurement system (logging mode) as block diagram consisting of one AE sensor, one coupling check transducer, the spotWave device and a PC or mobile device for configuring the spotWave device and collecting the data. The USB connection is not persistent.

In logging mode, the spotWave system consists of an AE sensor, of an optional coupling check transducer, the spotWave and an USB power bank. An end device is not required for operation, just for downloading the AE feature data.

The spotWave system measures event based Acoustic Emission in both logging- and acquisition mode. An event-based measurement is characterized by measuring individual bursts that are separated in time. The spotWave device extracts features from the time domain of the AE signal according to EN 13477-1. The spotWave device also provides the sampled burst signal (i.e. the waveform) at the device's interface to the acquisition software if operated in acquisition mode. In logging mode waveforms are not stored.

10.1. Intended Use

The spotWave device as part of the spotWave measurement system is used to digitize the AE signal, apply bandpass filters to it, extract features of the time stream of data, prepare the transient signal for storing it to an end device and to provide a USB interface to a remote device for collecting the measurement data. The

intention is to measure signals with amplitudes in the range of a few Microvolts to Volt and a frequency range of 20 kHz to 500 kHz. As of these characteristics it is suited for measuring Acoustic Emission.

The coupling check transducer is driven by the spotWave device and can be used as an artificial source of acoustic emission for (i) checking the mounting quality and function of the AE sensor, (ii) measuring the time-of-flight or (iii) measuring the speed of sound.

Acquisition software, compatible to Android 8 or later and Windows 10, is part of the spotWave device. A license for using the VisualAE™ analysis program is also part of the spotWave device.

A spotWave AE measurement system shall only be used by qualified personnel. A definition of qualified personnel can be found in the section Intended Audience.

10.2. Environmental Conditions

Environment	Specification
Site of installation	Indoor and outdoor
Temperature range	0 °C to +50 °C
Relative humidity	No limitations
Maximum altitude	2000 m
Pollution degree (*)	4 (in mated condition)
Ingress Protection	IP67 (in mated condition)

(*) per IEC 61010-1 and 60664-1.

11. Reasonably Foreseeable Misuse

The spotWave device shall only be used in the foreseen measurement frequency range. Do not use it with sensors that provide output signals in a frequency range too low (less than 1 kHz) or too high (more than 1 MHz). Especially do not use it with e.g. temperature sensors, strain gauges, displacement sensors or AE sensors with RMS and/or stretched APK output.

The spotWave device is rated IP67 in mated condition. The spotWave device is water tight for a period of 30 minutes submerged in a depth up to 1 m. Do not submerge the spotWave device for a longer period of time or at a greater depth.

A spotWave device can only be used in a non-hazardous area. Do not install and use a spotWave device in an explosion hazardous area.

12. Hardware Types

The spotWave device is characterized by its model number and input range. The full description of the spotWave device is indicated on the side of it.

The spotWave device code consists of `<type>_<sampling-rate><channel-number>_<input-range>dBAE`:

- `<type>`: device type designation: spotWave
- `<sampling-rate>` max. sampling rate in MHz
- `<channel-number>` double-digit channel number
- `<input-range>` the input range in dB_{AE} scale.

Type	Sampling rate in MHz	Channel No.	Model	Input Range	Code
spotWave	2	1	201	94 dB_{AE}	spotWave_201_94dBAE
				100 dB_{AE}	spotWave_201_100dBAE
				134 dB_{AE}	spotWave_201_134dBAE

12.1. Mechanical Properties

Property	Specification
Dimensions	78 mm x 14 mm x 58 mm (W x H x D)
Weight	107 g
Ingress Protection	IP67 (*)
Connector	2x SMA female, 1x USB mini-B female
LED	1x RGB LED for indicating operational conditions

(*) No ingress of dust; complete protection against contact (dust-tight). No ingress of water in harmful quantity when immersed in water at a depth of 1 m for 30 minutes

13. Operating Elements of a spotWave Device

Figure 3 shows the front panel elements of a spotWave device.

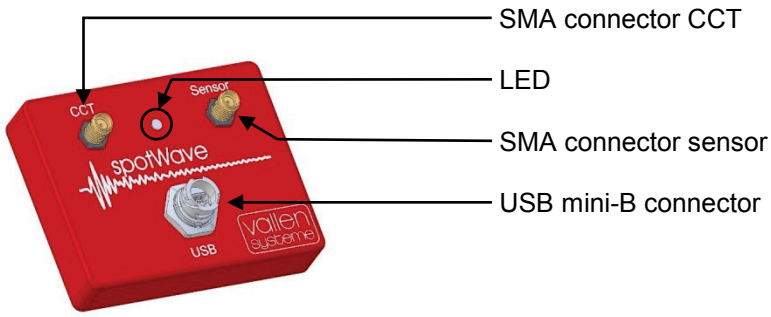


Figure 3: Operation elements of a spoWave device

13.1. USB Mini-B Connector

A spotWave device is connected to a mobile device or PC via USB and also powered over it.

Property	Description
USB	USB mini-B female connector

Use an end device such as a PC, laptop or mobile device for configuring the spotWave, starting and stopping storage of measurement data and as data storage device.

Connect a USB power bank instead of an end device to power the spotWave device and for running it in Logging Mode (see next section).

13.2. LED

The LED indicates the status of the device.

Property	Description
Blue – on	Power on, ready to measure burst signal
Blue – blinking (5s interval)	Logging mode active, ready to measure burst signals
Green – flashing	Detection threshold exceeded, measurement of a burst signal is started (holding time 30 ms)
Yellow – flashing	Detection threshold exceeded, measurement of a burst signal started, saturation of ADC occurred (95% of input range exceeded; holding time 30 ms)
Red – blinking	Buffer full in Acquisition mode or logging memory full in Logging mode.

13.3. Sensor Connector (in)

The SMA socket labelled Sensor is used to connect an AE sensor to it.

Property	Description
Connector type	SMA (IP67), female
Input impedance	16 kΩ || 12 pF (±50 mV, ±100 mV input range); 500 kΩ || 940 pF (±5000 mV input range)
Input range (*)	94 dB_{AE}, (±50 mV), 100 dB_{AE}, (±100 mV) 134 dB_{AE}, (±5000 mV)

(*) The input range is defined by hardware and marked on the device

13.4. CCT Connector (out)

The CCT connector (Coupling Check Transducer) is used to connect a coupling check transducer to the spotWave device.

Property	Description
Connector type	SMA (IP67), female
Output range	3.3 V, 20 mA

14. Storing, Transporting and Shipping

A spotWave device is delivered in a special card-board box. It shall be used for storage and transportation since it offers protection against shock.

Make sure that the environmental conditions are within specified limits during storage, transportation or shipping of the device.

When a spotWave device is stored or has to be shipped, make sure that the device is protected against ESD.

15. Installation

Make a visual check of the housing components and connectors when installing a device after it has been shipped or transported. Do not continue with installation (or operation) of a device that is visibly damaged. Contact your service technician or Vallen Systeme GmbH for guidance.

The environmental conditions at the installation site need to comply with the specified ones.

The spotWave device is passively cooled and does not require extra or a guaranteed airflow if it is operated within the specified environmental limits.

In the case of a long-term or permanent monitoring task the installation site should not be exposed to permanent direct sunlight for reasons of overheating the device.

15.1. Connecting to Power

The spotWave is powered over USB. To power it connect the device to a PC or mobile device or a battery pack with USB interface.

The spotWave device's LED is switched to blue if it is powered.

15.1.1. Power Requirements

Description	Specification
Power supply	USB (5 V)
Power consumption	< 0.7 W

15.2. Establishing Connection to an End Device

The spotWave device is of the USB communications device class (USB CDC). It does not require a specific driver to be recognized and initialized by the end device.

The connection between the spotWave device and the end device is established via USB 2.0. The spotWave device is automatically detected if it is connected to an end device

In order to install and run the Acquisition software the end device needs fulfill the requirements listed in section 15.2.1.

15.2.1. Mobile Device Specifications

A mobile end device needs to run the Android 8 operating system or any later one. The mobile device needs to comply with the OTG standard. Such devices are usually marked with the label shown in figure 4.

Figure 4: USB On-The-Go logo

15.2.2. PC Specifications

The external PC controls the measurement hardware, runs the system front-end and stores the measurement data. Any kind of PC, e.g. desktop, lunchbox, 19” rack industry standard PC with an USB 3.1 Gen 1 interface can be used.

Table 1: Requirements of a PC or laptop that is used as end device for the spotWave device. The end device runs the data acquisition and the measurement data is stored to its disk drive.

PC Requirements	
OS	Windows 10
CPU	minimum: dual core processor CPU, 32-bit (x86) or 64-bit (x64), > 2GHz, recommended is a quad core CPU.
RAM	minimum of 2 Gigabyte (GB), recommended is 4 GB for 32 bit OS or more in case of 64 bit OS
HDD	NTFS format, 1 GB free disk space for program installation, depending on your test data much more disk space will be needed.
USB	Free USB port

16. Operating a spotWave Device

Only operate a spotWave device if it has been properly installed.

16.1. Connecting an AE Sensor

Only connect passive AE sensors (without integrated preamplifier) to the input socket of a spotWave device. It is recommended to use AE sensors from Vallen Systeme GmbH.

Use a cable that is not defective and in good shape. The length of the cable influences the electrical signal attenuation. The standard length of the sensor-to-device cable is 1.2 m. Only use longer cables if the impact on the signal attenuation is known.

NOTICE

Damaging Electronic Components

Feeding in energy outside the specified range will damage the electronics.

Risk

Feeding in high current will lead to blown fuses and possible damaged electronic components leaving the device inoperable.

How to Avoid the Risk of Damaging Electronic Components

Before connecting a cable to the SMA input sockets of the device, make sure that the external source is within specified limits.

16.2. Connecting a Coupling Check Transducer

Only connect a device from Vallen Systeme that is labelled and specified as Coupling Check Transducer (CCT).

For connecting the CC-transducer to the spotWave device use the appropriate cable (product code: CBL-1-1M2-V70).

16.3. Operation Modes

A spotWave device can be operated in two modes (i) acquisition mode and (ii) logging mode.

16.3.1. Acquisition Mode

In Acquisition Mode the spotWave device is permanently connected to an end device. The end device is running the Acquisition software which writes the measurement data to the storage medium of the end device. In this operating mode the spotWave device is powered by the end device.

16.3.2. Logging Mode

In Logging Mode, the spotWave device is not connected to an end device. It writes the measurement data to its internal storage medium. In this operating mode the spotWave device has to be powered by an external battery pack.

The Logging Mode is configured by the use of the Acquisition software. For configuration purposes the spotWave device needs to be connected to an end device. Upon disconnecting the spotWave from the end device it loses power. The real time clock information can be retained in the internal memory for 60 minutes

without external power. If the spotWave device is connected within this time period to a battery pack, it runs in the Logging Mode with real time clock.

The measurement data can be retrieved from the spotWave device by connecting it to an end device and downloading the data.

16.4. Measurement Mode

A spotWave device measures features of an AE signal. The measured data is stored to a feature file that meets the SQLite3 standard. The file extension of the feature file is *.pridb. Vallen AE Suite analysis software can read and process this file.

The sampled signal is stored to a transient recorder file that meets the SQLite3 standard. The file extension of the transient recorder file is *.tradb. Vallen AE Suite analysis- and feature extraction software can read and process this file.

A list of measured features is found in the subsequent chapter 16.4.3, List of Time Domain Features.

16.4.1. Hit Based Measurement Mode

A measurement of an AE-signal is triggered when the AE signal exceeds a certain, user defined detection threshold. An AE signal that exceeds the detection threshold is called a detected burst signal or hit. The spotWave device detects hits and discriminates them from each other.

A set of features describing a hit are extracted by the spotWave processor's feature extraction unit.

Intensity analysis of recorded data can be done based on the peak amplitude, energy and the number of threshold crossings of a hit.

Activity analysis can be done for a single channel based on the number of hits measured within a certain time period.

16.4.2. Long Duration Mode

The spotWave device switches into a long duration mode if its internal hit buffer is full. It stays in a long duration mode until a hit data set can be written to the internal buffer again. As a result, the data set that is written in long duration mode can include many hits.

The internal hit buffer can run full if more data is generated than transferred to the end device. Such a situation can occur in the cases of (i) a high hit rate, (ii) wrong, i.e. too low, threshold setting and (iii) data is not polled fast enough by a data acquisition program.

Intensity analysis of the recorded data can be done based on the peak amplitude, energy and the number of threshold crossings.

An activity analysis can be done based on the number of threshold crossings of a certain time period.

Data sets that are generated in long duration mode receive a D flag.

16.4.3. List of Time Domain Features

The time domain features are extracted by the Feature Extraction unit of the signal processor of the spotWave device. A list of time domain features follows in the table below.

Feature	Description
A	Burst signal peak amplitude in units of dB_{AE}. Maximum voltage excursion within the duration of a burst signal

Feature	Description
ALIN	Burst signal peak amplitude in units of µV.
D	Burst signal duration: Time difference of the last crossing of the detection threshold and the first crossing of the detection threshold
R	Burst signal risetime: Time difference between the time of occurrence of the peak amplitude and the time of the first threshold crossing
E	Burst signal energy: Integral of the squared acoustic emission signal voltage within the duration of the burst signal
CNTS	Burst signal counts: Number of positive threshold crossings in upward direction
RMS	Acoustic emission signal root mean square: Root mean square of the acoustic emission signal within the period of 1 second. A hit's RMS is taken from the actual status data set's RMS (identified as RMSS in VisualAE).
TS	Burst signal arrival time: Time of the first threshold crossing of a burst signal
TRAI	Transient recorder index: database key of transients in the transient data file used as common key in the primary data file.

16.5. Command Set

The spotWave is a USB CDC (Communications Device Class) device and can be controlled with serial commands.

Windows uses the usbser.sys driver by default, which exposes a virtual COM port. If the Vallen AE Suite Software is installed, a setup information file for the spotWave device (C:\Vallen\Drivers\spotWave\vspwv1.inf) is installed to use the low-level and stable winusb.sys driver. The driver can be uninstalled manually to use the default usbser.sys driver and the virtual COM port as an easy interface (see 16.5.5).

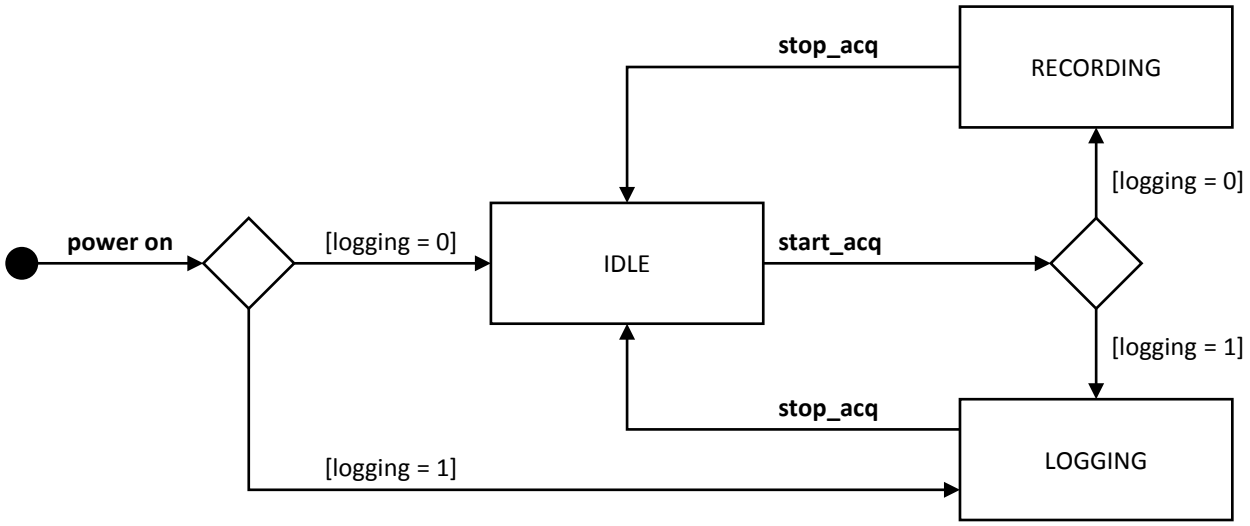
Every command has to be terminated with a newline character "\n" (ASCII value 10 or 0x0A).

Syntax conventions:

Convention	Information
<>	Angle brackets indicate values entered by the programmer
|	"Or" indicates a choice of one element from a list
[ ]	Square brackets indicate that the enclosed items are optional
{ }	When several items are enclosed by braces, one, and only one of these elements must be selected
~	A tilde indicates a valid range of values

16.5.1. States and transitions

The executable commands are dependent on the device state. Following diagram shows the possible states and transitions.



16.5.2. Commands

Overview

set_acq thr

Set threshold for hit-based acquisition.

Command: `set_acq thr <thr>`

`<thr>`	Threshold in µV (0 ~ range) range = 50/100/5000 mV (94/100/134 dBAE)

Valid state: IDLE

set_acq ddt

Set the duration discrimination time (DDT). DDT will determine the block size in continuous mode.

Command: `set_acq ddt <ddt>`

`<ddt>`	DDT in µs (0 ~ 100.000)

Valid state: IDLE

set_acq cont

Enable/disable continuous mode.

Command: `set_acq cont 0|1`

Valid state: IDLE

set_acq status_interval

Set interval of status data acquisition.

Command: `set_acq status_interval <interval>`

`<interval>` Interval in ms (0 ~ 2.000.000), 0: disabled

Valid state: IDLE

set_acq tr_enabled

Enable/disable transient data acquisition.

Command: `set_acq tr_enabled 0|1`

Valid state: IDLE

set_acq tr_decimation

Set decimation factor for transient data.

Command: `set_acq tr_decimation <factor>`

`<factor>` Decimation factor (1 ~ 100)
1: 2 MHz
2: 1 MHz
4: 0,5 MHz
…

Valid state: IDLE

set_acq tr_pre_trig

Set pre-trigger samples for transient data.

Command: `set_acq tr_pre_trig <samples>`

`<samples>` Number of samples (0 ~ 2048 / tr_decimation)

Valid state: IDLE

set_acq tr_post_dur

Set post-duration samples for transient data.

Command: `set_acq tr_post_dur <samples>`

`<samples>` Number of samples (0 ~ 2 * $ddt_{\mu s}$ / tr_decimation)

Valid state: IDLE

set_cct interval

Set coupling check transmitter / pulser interval in seconds.

Command: `set_cct interval <interval>`

`<interval> = 0` Disabled

`<interval> > 0` Enabled with chosen interval (0.008192 ~ 35184372088832)

`<interval> = -1` Triggered with command `get_tr_snapshot` [1]

Valid state: IDLE

[1] `set_cct interval -1` is used for time of flight measurements. When command `get_tr_snapshot` is issued the CCT is activated and the transient recorder starts simultaneously. The time difference from start sample to the sample of first threshold crossing is the time of flight.

set_data_log enabled

Enable/disable data logging mode. Enabling logging mode is only possible, if the data log memory is empty (execute command `clear_data_log` before).

Command: `set_data_log enabled 0|1`

Valid state: IDLE

set_datetime

Set current date and time.

Command: `set_datetime <datetime>`

`<datetime>` Date and time in following format: `%Y-%m-%d %H-%M-%S.%f`, e.g.: 2020-09-29 08:29:50.301

Valid state: IDLE

set_filter

Set filter cutoff frequencies and order.

Command: `set_filter <hp>|none <lp>|none [<order>]`

	<hp>	Highpass cutoff frequency in kHz (0.5 ~ <lp>)
	<lp>	Lowpass cutoff frequency in kHz (<hp> ~ 1000)
	<order>	Filter order {2, 4, 6, 8}, default: 4

Valid state: IDLE

start_acq

Start acquisition. Acquired data is saved on the device and can be read with `get_ae_data` and `get_tr_data` in recording mode or with `get_data_log` in logging mode.

Command: `start_acq`

Valid state: IDLE

stop_acq

Stop acquisition. If logging mode was enabled, it will be deactivated.

Command: `stop_acq`

Valid state: RECORDING | LOGGING

get_ae_data

Read AE / hit data sets. The records are deleted from the device memory afterwards.

Command: `get_ae_data`

Valid state: RECORDING | IDLE

Response:

```
S temp=27 T=20000000 A=22 R=1166717 D=10000000 C=0 E=38788614 TRAI=0 flags=0\n
H temp=27 T=43686000 A=31004 R=496 D=703 C=4 E=74860056830 TRAI=1 flags=0\n
H temp=27 T=43686983 A=15545 R=279 D=624 C=5 E=42194101126 TRAI=2 flags=0\n
\n
```

The returned lines contain the information of one hit per line using the output format:

`<type> <key1>=<value1> <key2>=<value2> ...`

The unit of temperature is degree celsius. The unit of time quantities, such as rise time and duration is tics. The unit of the intensity features, amplitude and energy, is ADC values and ADC values squared, respectively. The unit of CNTS is dimensionless. The formulas below can be used for converting the raw numbers to engineering units. Following conventions are used:

- The sampling rate is abbreviated, f_s (in Hz), and is 2 MHz in case of the spotWave device.
- The conversion factor into energy units is $\beta_{eu} = 10^{-4} \frac{[eu]}{[\mu V]^2[\mu s]}$.
- The conversion factor from ADC values to µV, ⟨`adc2uv`⟩, can be obtained via the command `get_info`.

<type> H for hit, S for status data

temp device temperature in °C

T time period since start data acquisition in tics. The conversion into µs is done the following way:

$$T_{\mu s} = \frac{T}{f_s} \cdot 10^6 = \frac{T}{2}$$

A peak amplitude as ADC value. The conversion to µV is done the following way:

$$A_{\mu V} = A \cdot \langle adc2uv \rangle$$

R rise time in tics. The conversion in µs is done the following way:

$$R_{\mu s} = \frac{R}{f_s} \cdot 10^6 = \frac{R}{2}$$

D duration in tics. The conversion in µs is done the following way:

$$D_{\mu s} = \frac{D}{f_s} \cdot 10^6 = \frac{D}{2}$$

C counts (number of positive threshold crossings)

E energy in ADC values, that is E is the sum of squared ADC values. The conversion factor to engineerign units of [µV² s] is

$$\hat{E}\ [\mu V^2 s] = E \cdot \langle adc2uv \rangle^2 \frac{1}{f_s}$$

The conversion factor ⟨adc2uv⟩ is available via the get_info or get_setup command. The conversion factor depends on the input range and gain.

Vallen Systeme software uses arbitrary energy units [eu]. A conversion to energy units is done the following way:

$$E_{eu} = \hat{E} \cdot \alpha \cdot \beta_{eu}$$

with the scaling factor $\alpha = 10^6$ for converting seconds into microseconds.

TRAI transient recorder index (link between AE and TR data)

flags hit flags

RMS Calculation

The RMS value can be computed from the energy and the duration. For status data and AE data recorded in countinuous mode this is:

$$RMS_{\mu V} = \sqrt{\frac{1}{D_{\mu s}} \cdot \frac{E_{eu}}{\beta_{eu}}}$$

In the case of event based recording, the time window in which the energy is measured is of length duration of the burst plus the duration discrimination time:

$$RMS_{\mu V} = \sqrt{\frac{E_{eu}}{D_{\mu s} + DDT_{\mu s}} \cdot \frac{1}{\beta_{eu}}}$$

get_tr_data

Read transient data sets. The records are deleted from the device memory afterwards.

Command: `get_tr_data [a]`

`[a]`	Return data in ASCII format as floats in µV, otherwise ADC values as binary (int16)

Valid state: RECORDING | IDLE

Response (binary):

```
TRAI=1 T=43686000 NS=768\n
<ADC values as binary data (2 * 768 bytes)>
TRAI=2 T=43686983 NS=692\n
<ADC values as binary data (2 * 692 bytes)>
\n
```

Response with a flag (ASCII):

```
TRAI=1 T=43686000 NS=768\n
7127\n
8640\n
[...]
-3453\n
-3444\n
TRAI=2 T=43686983 NS=692\n
8177\n
8212\n
[...]
4846\n
4557\n
\n
```

The return structure has got a header that contains the information of the transient recorder index (`TRAI`), arrival time (`T`) and number of samples (`NS`). The header line is followed by the ADC samples as binary data (`int16`, `2 x NS` bytes). The conversion to µV is done using the factor `<adc2uv>` which is available via the `get_info` or `get_setup` command. The conversion to µV is done using the factor `<adc2uv>` which is available via the `get_info` or `get_setup` command.

`TRAI` transient recorder index

`T` time period since the start of acquisition in tics

$$T_{\mu s} = \frac{T}{f_s} \cdot 10^6 = \frac{T}{2}$$

`NS` the number of samples in the waveform

The last line is an empty line.

get_tr_snapshot

Read snapshot of transient data. The sampling rate is configured with the `set_acq tr_decimation` command.

If the CCT interval (configured with the `set_cct interval` command) is `-1`, the first acquired sample is synchronized with the start of the pulse.

Command: `get_tr_snapshot [a] <samples>`

`[a]`	Return data in ASCII format as floats in µV, otherwise ADC values as binary (int16)
`<samples>`	Number of samples (0 ~ 100.000)

Valid state: IDLE

Response: The response syntax is the same as for `get_tr_data` but without TRAI and T in the header line.

```
NS=1024\n
<ADC values as binary data (2 * 1024 bytes)>
```

get_data_log

Read logged data from device memory. The records have to be deleted explicitly from the device memory with the command `clear_data_log`.

Command: `get_data_log`

Valid state: LOGGING | IDLE

Response: The response syntax is the same as for `get_ae_data`. An additional record with the type flag `R` and the acquisition start timestamp is returned first. All following time attributes (`T`) are relative to this timestamp.

```
R stamp=2021-06-17 15:13:29.800\n
S temp=31 T=2000000 A=35 R=1527415 D=2000000 C=0 E=93888725 TRAI=0 flags=0\n
S temp=31 T=4000000 A=35 R=1677302 D=2000000 C=0 E=94053651 TRAI=0 flags=0\n
S temp=31 T=6000000 A=36 R=1642879 D=2000000 C=0 E=93914471 TRAI=0 flags=0\n
[...]
\n
```

clear_data_log

Delete logged records from device memory.

Command: `clear_data_log`

Valid state: IDLE

get_info

Read device information.

Command: `get_info`

Valid state: ALL

Response:

```
fw_version=00.25\n
type=spotWave\n
model=201\n
```

```
adc2uv=1.74\n
input_range=94 dBAE\n
input_resistance=16 kOhm\n
input_capacity=12 pF\n
max_samplerate=2 MHz\n
analog_bandwidth=20-500 kHz\n
cct_voltage=3.3 V\n
flash_memory=64 MB\n
serial_number=50345\n
pcb_vid=200505-06-0123\n
verification=2021-01-01 06:41:09.54\n
```

get_status

Read status information.

Command: `get_status`

Valid state: ALL

Response:

```
temp=26 °C\n
recording=0\n
logging=0\n
log_data_usage=1636 sets (0.12 %)\n
date=2020-12-17 19:23:40.140\n
```

get_setup

Read setup information.

Command: `get_setup`

Valid state: ALL

Response:

```
recording=0\n
logging=0\n
adc2uv=1.74\n
cct=0 s\n
filter=none - none kHz, order 0\n
cont=1\n
thr=10000000.0 uV\n
ddt=100000  us\n
status_interval=0 ms\n
tr_enabled=1\n
tr_decimation=4\n
tr_pre_trig=10000\n
```

16.5.3. API changes firmware 0.25

Firmware 00.25 introduced breaking changes which are summarized in the following tables.

Commands

Old command	New command
`set_acq enabled 1`	`start_acq`
`set_acq enabled 0`	`stop_acq`
`set_cct <ms>`	`set_cct interval <ms>`
`set_data_log 0|1`	`set_data_log enabled 0|1`
`set_filter <hp> <lp> [<order>]`	`set_filter <hp>|none <lp>|none [<order>]`
`get_tr_data [b]` `(default: ASCII)`	`get_tr_data [a]` `(default: binary)`
`get_data [b] <samples>` `(default: ASCII)`	`get_tr_snapshot [a] <samples>` `(default: binary)`
`read_data_log`	`get_data_log`

Response message syntax

The response message syntaxes were different for AE records (number of records in first line) and TR records (new line character for new line). Now both responses end with an empty line, if there are no further records to read and parse.

The `get_data` command just returned the ASCII or binary ADC values without any header or final line. A headerline was introduced to use the same command for multi-channel devices. Each record (for each channel) is started with a headerline followed by the ADC values. An empty line marks the end of the response.

Command	Old response	New response

`get_ae_data`	`3\n`
	`S temp=27 T=20000000 A=22…\n`
	`H temp=27 T=43686000 A=31004…\n`
	`H temp=27 T=43686983 A=15545…\n`
		`S temp=27 T=20000000 A=22…\n`
		`H temp=27 T=43686000 A=31004…\n`
		`H temp=27 T=43686983 A=15545…\n`
		`\n`

`get_data /`
`get_tr_snapshot`
	`<ADC values as ASCII/binary data>`	`NS=768\n`
		`<ADC values as binary/ASCII data>`
		`\n`

Lines marked with yellow background highlight the changes in the response.

16.5.4. Example

Recording mode

Following example shows how to setup the device and start acquire data.

```
set_filter 80 350 8\n         // set 8th order bandpass 80-350 kHz
set_acq thr 1000\n            // set threshold to 1000 µV / 60 dB(AE)
set_acq ddt 400\n             // set ddt to 400 µs
set_acq cont 0\n              // disable continuous mode
set_acq tr_enabled 1\n        // enable transient data
set_acq tr_decimation 2\n     // set TR decimation factor to 2 -> 1 MHz
set_acq tr_pre_trig 200\n     // set TR pre-trigger samples to 200 = 100 µs
set_acq tr_post_dur 200\n     // set TR post-duration samples to 200 = 100 µs
set_acq status_interval 1000\n  // set status interval to 1000 ms = 1 s
set_cct interval 0\n          // disable CCT / pulser

start_acq\n                   // start data acquisition
                              // wait a little bit
get_ae_data\n                 // retrieve hits and status data
3\n
S temp=27 T=16024576 A=22 R=1166717 D=2000000 C=0 E=38788614 TRAI=0 flags=0\n
S temp=26 T=18024576 A=23 R=119636 D=2000000 C=0 E=38927169 TRAI=0 flags=0\n
S temp=27 T=20024576 A=22 R=588985 D=2000000 C=0 E=38857408 TRAI=0 flags=0\n
get_tr_data\n                 // retrieve transient data of hits
0\n                           // no hit so far
                              // produce a hit
get_ae_data\n
2\n
S temp=27 T=2010240 A=21 R=502689 D=2000000 C=0 E=38849818 TRAI=0 flags=0\n
H temp=27 T=3044759 A=3557 R=24 D=819 C=31 E=518280026 TRAI=1 flags=0\n
get_tr_data a\n
TRAI=1 T=942670 NS=1902\n
667\n
1016\n
1243\n
…
-130\n
0\n
stop_acq\n                    // stop data acquisition
```

Logging mode

Following example shows how to setup the device for logging mode and read out the data from the internal memory afterwards.

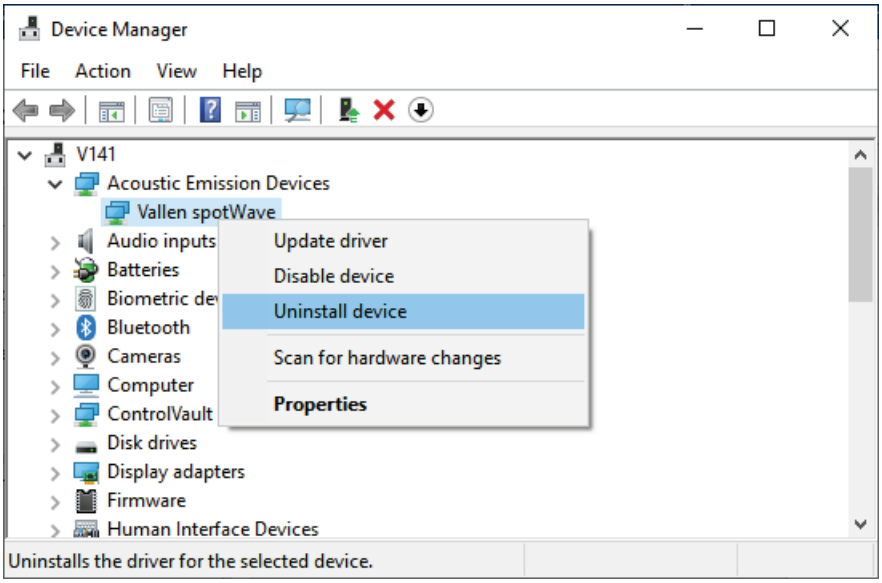
```
set_datetime 2020-09-29 08:29:50.301\n // set current date and time
…                             // set acquisition settings
clear_data_log\n              // clear logged data from internal memory
set_data_log enabled 1\n      // enable logging mode
start_acq\n                   // start acquisition in logging mode
                              // or: unplug spotWave and power on again
…
stop_acq\n                    // optional: stop acquisition
get_data_log\n                // read all logged data from internal memory
R stamp=2020-12-17 18:31:53.199\n
H temp=27 T=0 A=21 R=188222 D=200000 C=0 E=4415998 TRAI=0 flags=0\n
H temp=27 T=200000 A=23 R=196638 D=200000 C=0 E=4399477 TRAI=0 flags=0\n
…
clear_data_log\n
```

16.5.5. Getting started

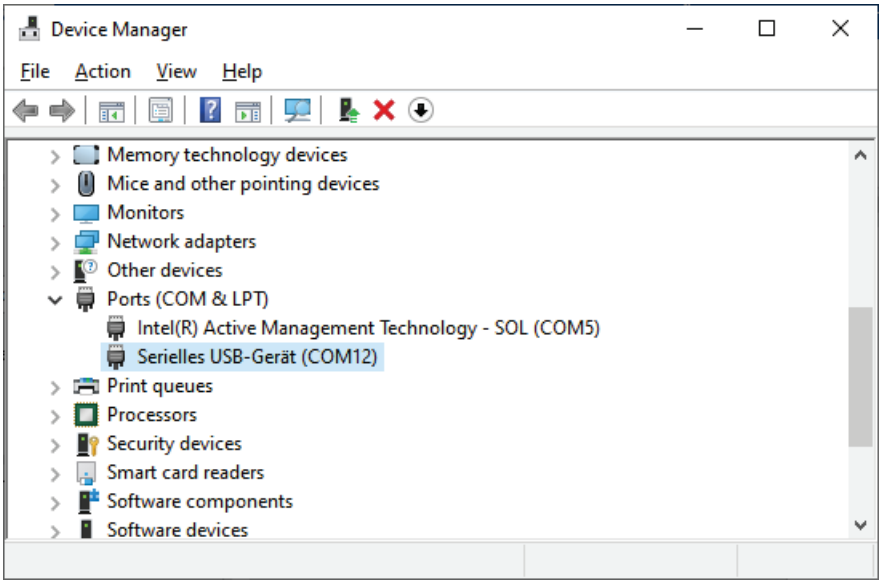
Test communication with HTerm (Windows)

The communication with a spotWave device can be easily tested with e.g. HTerm. You can download it here: http://www.der-hammer.info/pages/terminal.html.

First you need to figure out the COM port of the connected spotWave. Open the “Device Manager” (“Control Panel” → “Hardware and Sound” → “Device Manager”) and browse to “Ports (COM & LPT)”:

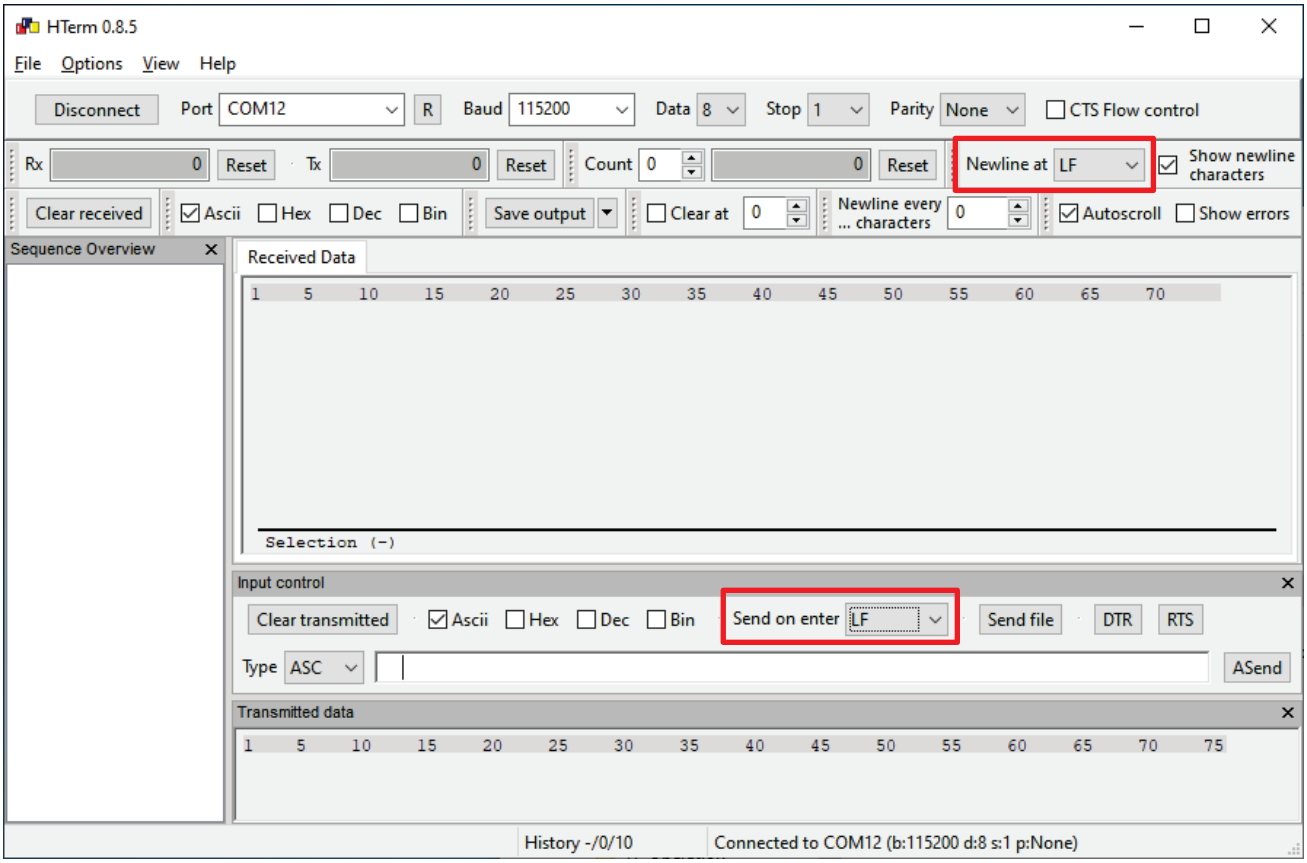


In this case, the spotWave in on COM4. If unsure, just unplug and plug the spotWave’s USB cable while watching the Device Manager. You will see the right COM port disappear and appear again. If the Vallen AE Suite Software is installed, the spotWave is recognized as a “Acoustic Emission Device” using the winusb.sys driver. Please uninstall the device with “Uninstall device” and “Delete this driver software for this device” to get the virtual COM port exposed by the default usbser.sys driver.

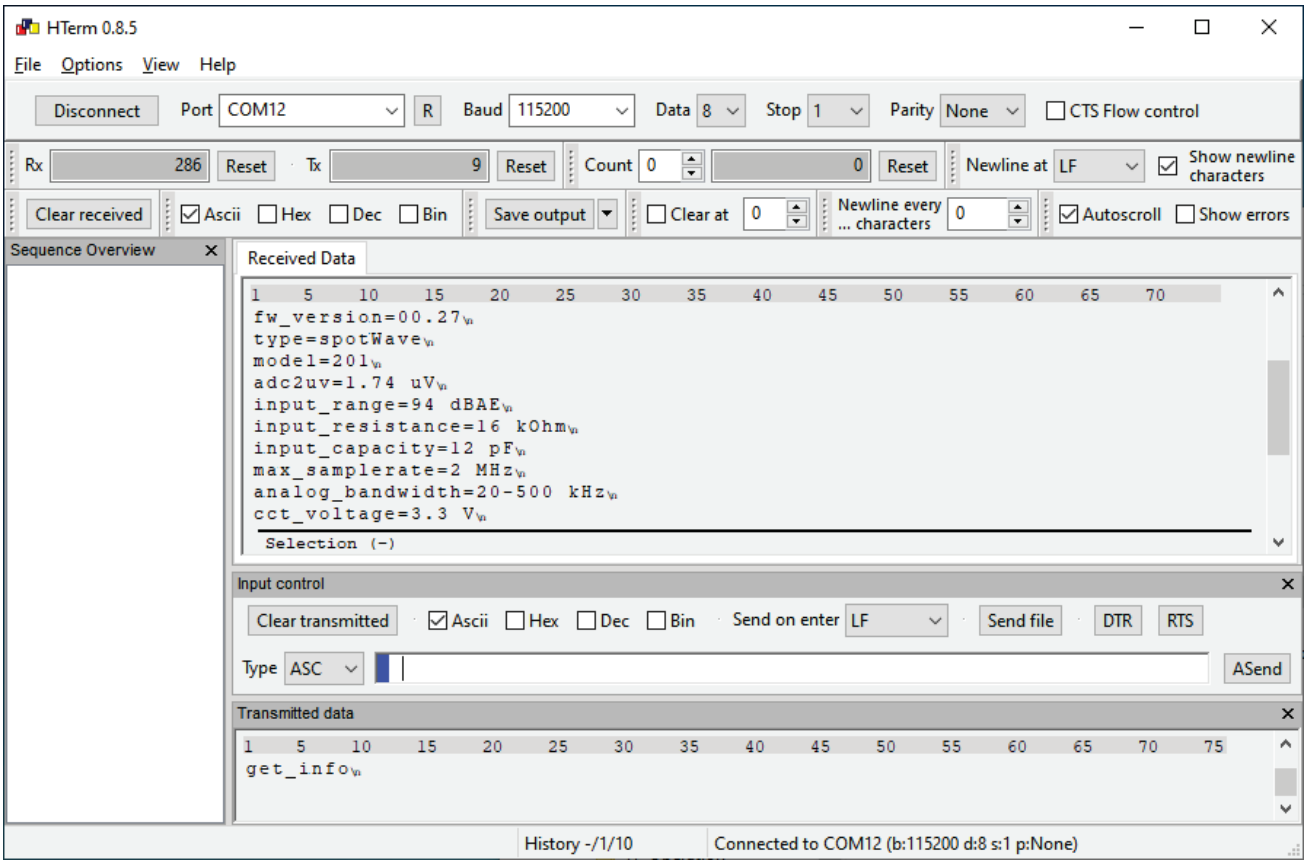


Open HTerm, choose the right COM port and press “Connect”.

The necessary newline character after commands can be appended by HTerm automatically. Choose “LF” for “Send on enter”. Format the output by setting “LF” for “Newline at”.



Now you are ready to communicate with the device. Test with a simple “get_info” command:



17. Accessories

Specific accessories for the spotWave device are dedicated cables that fulfill the water tightness requirement.

17.1. Cables

It is recommended to use cables from Vallen Systeme GmbH. For information about cables please see separate specification “Accessories for Acoustic Emission Systems” (available on www.vallen.de, on the Vallen AE Suite USB drive, or from sales@vallen.de).

AE sensors with microdot connector are connected with a type CBL-1-1M2-V63 cable to the spotWave device.

AE sensors with an SMA connector are connected with a type CBL-1-1M2-V70 cable to the spotWave device.

AE sensors with an SMC connector are connected with a type CBL-1-1M2-V71 cable to the spotWave device.

17.2. AE Sensors

It is recommended to use AE sensors from Vallen Systeme. For information about sensors please see separate specification “Acoustic Emission Sensors” (available on www.vallen.de, on the Vallen AE Suite USB drive, or from sales@vallen.de).

Compatible AE sensors have not got an integrated preamplifier.

18. spotWave Device Extension: Coupling Check Transducer

A coupling check transducer (CCT) is an optional extension of the spotWave device. The CCT is not needed for measuring acoustic emission. The CCT is controlled by the spotWave device and can be used to stimulate artificial acoustic emission. Mounted to the surface of an object, the CCT can be used to excite elastic waves in the object in a controlled manner. The AE sensor mounted on the same object picks up the artificially generated elastic waves. Repeatedly measuring the artificial signal in regular intervals reveals any losses in the mounting quality and checks the proper function of the measurement system.

19. Maintenance

The input and output sockets can be subject to mechanical and environmental induced deterioration. Do not use the device where a socket is worn out or damaged.

A deteriorated or defective device has to be repaired by Vallen Systeme GmbH before it can be used again. Refer to section “What to do in case of malfunction or damage”.

19.1. System Verification

The device’s function can be checked against specifications. A so-called verification of function according to specification is recommended to be done once a year and (i) if a system is suspected to be defective or (ii) if a system has been operated in severe environmental conditions. Verification can be done by Vallen Systeme GmbH.

19.2. What to Do in Case of Malfunction or Damage

Disconnect the device. Do not attempt to repair a device. Contact Vallen Systeme and report the defect. Wait for instructions before sending a device back.

20. Compliances Statement

The spotWave device complies with following directive:

- Directive 2014/30/EU (EMC)

A spotWave AE measurement system complies with following standard

- EN 13477-1
- EN 13477-2

21. Regulations Concerning Redemption and Disposal

We, Vallen Systeme GmbH, are registered manufacturer of the measurement instruments (WEEE-Reg.-Nr. DE 68150283).

According to German law (§10 subparagraph 2 of Elektro- und Elektronikgerätegesetz – ElektroG) and in the interests of our customers, we accept the obligation for redemption and appropriate disposal of those systems which have been placed by us on the market within the scope of the before mentioned law, after August 13, 2005.

For this we provide the following procedure:

- Owners of old instruments request our agreement with the return of old instruments. The goods to be returned must be described unambiguously and identified by serial number and/or the identification numbers.
- Upon our approval owners may ship the goods free of costs for us.
- We will dispose the goods according to the relevant laws and regulations on our costs.
- Goods returned without our approval will not be accepted and returned to the owner on his account.

With this measure we wish to serve our customers in the best way to properly dispose old instruments and to contribute to re-use, recycling and proper disposal of electronic waste.

Equipment labeled with the symbol shown left must be disposed separately from unsorted municipal waste within the European Union.

22. Restriction of Hazardous Substances (RoHS)

Vallen Systeme GmbH is collaborating with its suppliers to comply with the European Union Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (“RoHS”) Directive (2011/65/EU). The RoHS directive prohibits the sale of electronic equipment containing certain hazardous substances such as lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls (“PBB”) and polybrominated diphenylethers (“PBDE”) in the European Union.

23. spotWave Device Data Sheet

Electrical Properties

Electrical property	Specification		
Input range	94 dB_{AE}, 100 dB_{AE} or 134 dB_{AE} ; input range is a hardware option		
Typical system noise (*) , (20-500 kHz)	Input range	Peak Noise, A_n	Noise RMS
	94 dB_{AE}	34.7 dB_{AE}	10.36 V_{rms}
	100 dB_{AE}	38.9 dB_{AE}	15.36 V_{rms}
	134 dB_{AE}	72.9 dB_{AE}	773.6 V_{rms}
Overvoltage protection	Input ranges	Overvoltage Protection	
	94 dB_{AE}, 100 dB_{AE}	±1 V	
	134 dB_{AE}	±50 V	

(*) Input terminated with 50 Ohm. A_n is the peak noise as defined in EN 13477-2

Signal Processing Properties

Signal processing	Specification
Analogue pass band filter	high pass: 20 kHz 2nd order; low pass 500 kHz 6th order
ADC	2 MHz at 16 bit
Application specific filters	IIR pass band filter, Butterworth characteristic
Filter order	user configurable (0, 2, 4, 6, 8), default is 4th order
High-pass- / low pass frequency	user configurable (1 - 1000 kHz)

Hit Detection and Processing

Hit detection	Specification
Detection threshold	software selectable, fixed during measurement
Hit discrimination	Burst signals are separated if Duration Discrimination Time expires without detection of a threshold crossing
Hit cascade separation	No hit cascading
Hit timeout	automatic termination of a hit if signal's duration exceeds 100 ms. An artificial hit is started automatically after a hit timeout

Hit Feature Extraction Properties

Feature Extraction	Specification			
Arrival time resolution	500 ns			
Arrival time range	63 bit at a sample rate of 2 MHz (approx.. 146 000 years)			
amplitude resolution	Input Range	94 dB_{AE}	100 dB_{AE}	134 dB_{AE}
	A_{pk} resolution (approx.)	1.75 µV	3.5 µV	175 µV
detection threshold resolution	Input Range	94 dB_{AE}	100 dB_{AE}	134 dB_{AE}
	A_{Thr} resolution (approx.)	1.75 µV	3.5 µV	175 µV
RMS resolution	Input Range	94 dB_{AE}	100 dB_{AE}	134 dB_{AE}
	U_{ms} resolution (approx.)	1.75 µV	3.5 µV	175 µV
Rise time resolution	500 ns			
Duration resolution	500 ns			
Hit flags	Flag	Description		
	T	hit time out (Duration > 100 ms)		
	A	artificially started hit (after a hit time out),		
	D	long duration mode		
Energy resolution	Input range	94 dB_{AE}	100 dB_{AE}	134 dB_{AE}
	Eng. Units	1.53 10^{-18} V²s	6.13 10^{-18} V²s	1.53 10^{-14} V²s
	Native Units	1.53 10^{-4} eu	6.13 10^{-5} eu	1.53 eu
Energy unit	1 eu = 10^{-14} V²s			

Processing Performance

Performance	Specification
Minimum guaranteed hit rate	100 hits/s with Vallen Systeme's spotWave Acquisition software
Hit buffer	200 hit data sets in Acquisition Mode
Logging buffer	64 MB, approximately 1.3 million hit data sets

Transient Recorder Performance

Transient Recorder	Specification
Sampling rate	maximum 2 MHz, software selectable decimation factor
Duration adapted recording mode	number of samples that are recorded per trigger depends on duration of the burst signal, pretrigger samples and post duration samples
Maximum samples per record	100 k samples with Vallen Systeme's Acquisition software; 200 k samples total.
Pretrigger	Selectable, maximum of 2 k samples

24. Worldwide Representatives

ASEAN countries: Singapore, Malaysia, Thailand, Indonesia

```
NDT Instruments Pte Ltd
No 50, Ubi Avenue 3, #05-20, Frontier
Singapore 408866
Singapore

telephone: 0065 6571 0668
```

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ATTAR
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```

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If you are not within a territory served by a Vallen Systeme GmbH representative, pick up contact with Vallen Systeme GmbH headquarter in Germany, directly.