SUPREME SENSORING

Acceleration sensor NVW
with LoRaWAN® and USB interface
Corresponding data sheet NVW 16631

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User manual

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1 Safety instructions

1.1 Scope

This user manual is valid exclusively for the following vibration sensor with LoRaWAN and USB interface:

- NVW90 - x x x - x E x U Wxx

1.2 Documentation

The following documents must be observed:

- The owner's system-specific operating instructions
- This user manual NVW16705
- Data sheet number NVW16631
- The connection assignment enclosed with the device

1.3 Proper use

The TWK-ELEKTRONIK GmbH sensors and linear transducers are used to measure angular or linear positions or vibrations and output their measured values in the form of an electrical output signal. As part of a system, they have to be connected to the downstream electronics and must only be used for this purpose.

The device has the possibility to transmit the status information and a limited amount of data over a LoRaWAN interface. Further data is logged into a flash memory and can be accessed via a USB interface.

1.4 Commissioning

- The relevant device may only be set up and operated in combination with this and the documentation specified under point 1.2.
- Protect the device against mechanical damage during installation and operation.
- Device commissioning and operation may only be undertaken by a specialist electrician.
- Do not operate the device outside of the limit values specified in the data sheet.
- Check all electrical connections before commissioning the system.

2 General information

The sensor system is intended for use e.g. in wind turbines to measure and evaluate tower vibrations. The accelerations of the tower head are detected by MEMS sensors (Micro-Electro-Mechanical System) with subsequent digitisation by a controller.

The device consists of an acceleration sensor, a controller unit, a flash memory for data storage and a LoRaWAN interface for wireless transmission of status information over several kilometres.

Thanks to its high resistance to vibration and shock - more than the defined measuring range - the sensor is suitable for use in areas with rough environmental conditions.

Electrical connection is carried via a M12 connectors for data and power supply and a N-type connector for the antenna.

Four status LEDs assist during installation and diagnosis of the NVW.

MEMS sensors are integrated circuits which are manufactured in silicon bulk micromechanics technology. They have a long usage duration and are very robust.

First, DC component, which originates from gravitational component in the measurement axes e.g. due to misalignment of the sensor, is substracted from the raw signales of the MEMS sensor. The DC component is determined as the floating average over 40 s measurement time. Afterwards, output values are processed by software filters.

The filter units can be individually programmed in the filter characteristics for frequency selection in the factory (low pass, high pass or band pass). They can be assigned to a single axis or to a combination of axes (e.g. RMS of x and y).

The resulting signals can be:

- saved on internal flash memory
- output via LoRaWAN interface

3 Function

3.1 Filtering

The MEMS sensors are sampled with a frequency of 100 Hz. The output signal is limited to a frequency of 25 Hz to avoid aliasing effects.

The raw signal from the MEMS sensor is processed in digital pre-filtering (FIR) to suppress higher-frequency components (above around 20 Hz -50 Hz, depending on customer application), as they interfere with the measurement signal (1st-order FIR filter).

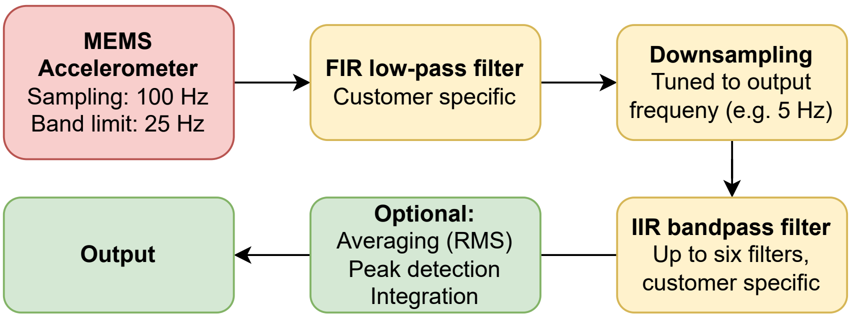
Up to six main filter bands are implemented as digital filters in the main controller to achieve the desired frequency band. Common filter types include

- Chebichev filter
- Butterworth filter
- other filters on request

High-order Chebichev filters are used for highly separated frequencies The group delay t_V is therefore high (depending on upper frequency). It is roughly defined as t_V =~ 1/(fo*2) + 16 ms (with fo = upper frequency edge +16 ms due to pre-filtering).

Butterworth filters of a small order have less time delay t_V. They can be used for adjustment control purposes e.g. in wind turbines. Exposing accelerations and the output signal do have little time delay (momentary value).

The minimum lower frequency limit of the vibrations to be measured is 0.05 Hz. The upper frequency is 50 Hz.



3.2 Statistical values

The momentary output of the IIR filter can be processed to calculate further statistical quantities

The **average** value $\bar{x}$ over the n measuring points x_i in a time interval t_{av} is calculated as

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

The **RMS value ρ** is defined as

$$\rho^2 = \frac{1}{n}\sum_{i=1}^{n} x_i^2$$

The estimate of the **standard deviation s** is calculated as

$$s^2 = \frac{1}{(n-1)}\sum_{i=1}^{n} (x_i - \bar{x})^2$$

The estimate of the **kurtosis value** ω is:

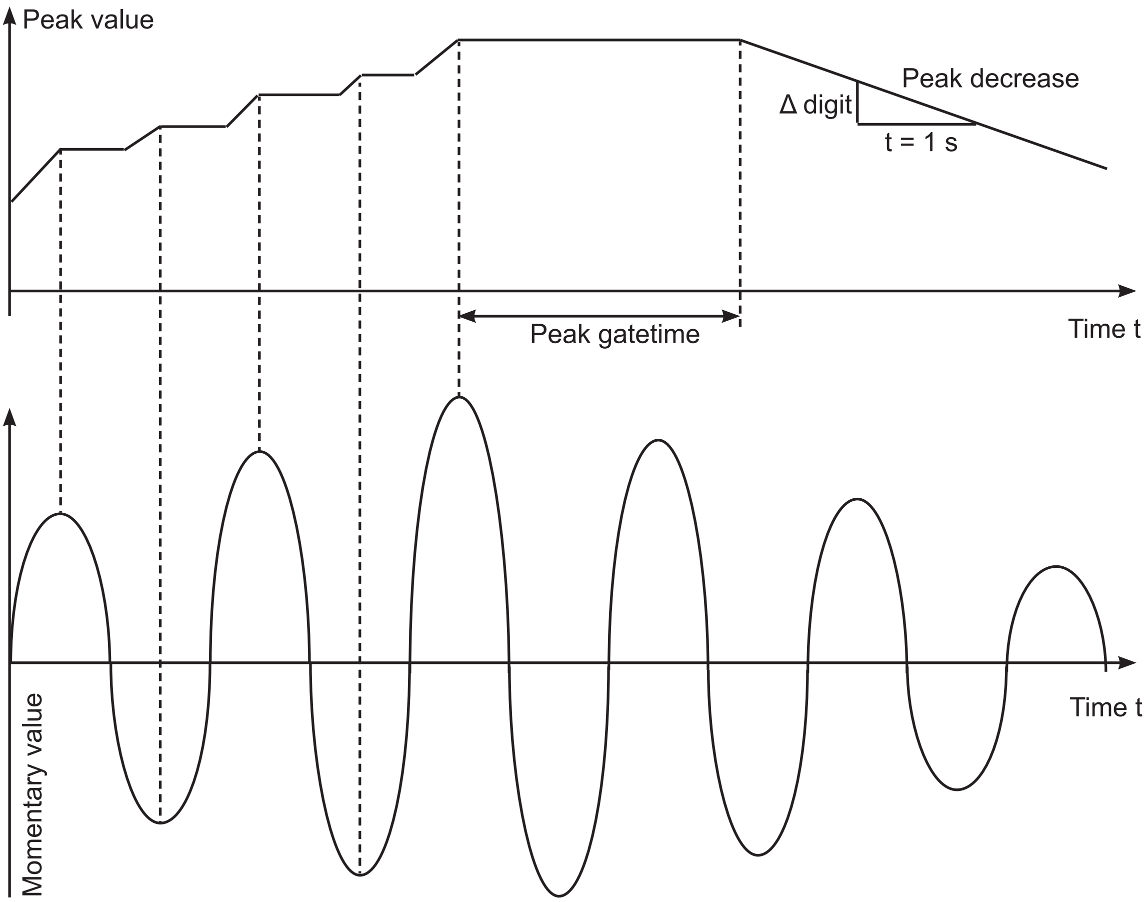
$$\omega = \frac{n\,(n+1)}{(n-1)\,(n-2)\,(n-3)}\sum_{i=1}^{n}\left(\frac{x_i - \bar{x}}{s}\right)^4$$

Average frequency f

The average frequency is determined by counting the zero crossings of the momentary signal. The sensor automatically determines the axis with the highest average signal and uses this axis to determine the average frequency. To avoid errors due to noise around the zero crossing, a dead time is used. The dead time is defined as half of the cycle time of the upper limit frequency of the filter band.

Peak value

The **peak value** is kept at the momentary peak value for a time defined by the peak gate time and the gradually decreases with a rate defined by the peak decrease:



Integral values
There are different forms of integration readily available for the output signal. See manual 13660 for details.

Parameters and timings
All parameters for the processing of the filter outputs need to be set ex works. Further statistical computations can be implemented on customer request.

3.3 Axis definition and dynamic adjustment of the coordinate system

The standard definition of the coordinate system is indicated on the device. The sensor monitors the alignment of the gravitational axis and generates a fault if a constant acceleration is detected in an axis other than the one that should be aligned with gravity. The limit for this behaviour can be defined by the customer.
On request, the customer can define other valid orientations and the device can adjust the coordinate system when those orientations are detected.

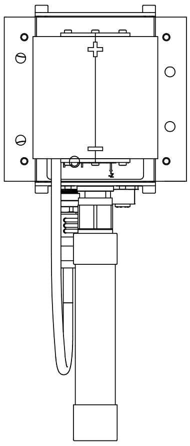
4 Installation

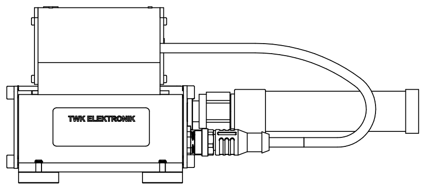
4.1 Orientation

By default, two orientations relative to the axis of gravity are allowed for the device:

- Magnetic feed pointing downward
- Electrical connectors pointing downward

If the device is orientated out of those positions by more than 5°, the device will display an error (LED and status bit). Data will still be stored and transmitted.





4.2 Electrical connection

The acceleration sensor "NVW...UW01" has three connector outputs for the power connection, the LoRaWAN antenna and the USB connection.

Connection	Designation	Connector type
Power	3.6 VDC	M12x4 A-coded pins
RF	Antenna	N-type connector
Data	USB	M12x4 A-coded socket

Refer to data sheet No. NVW16631 for connector assignment and ordering information.

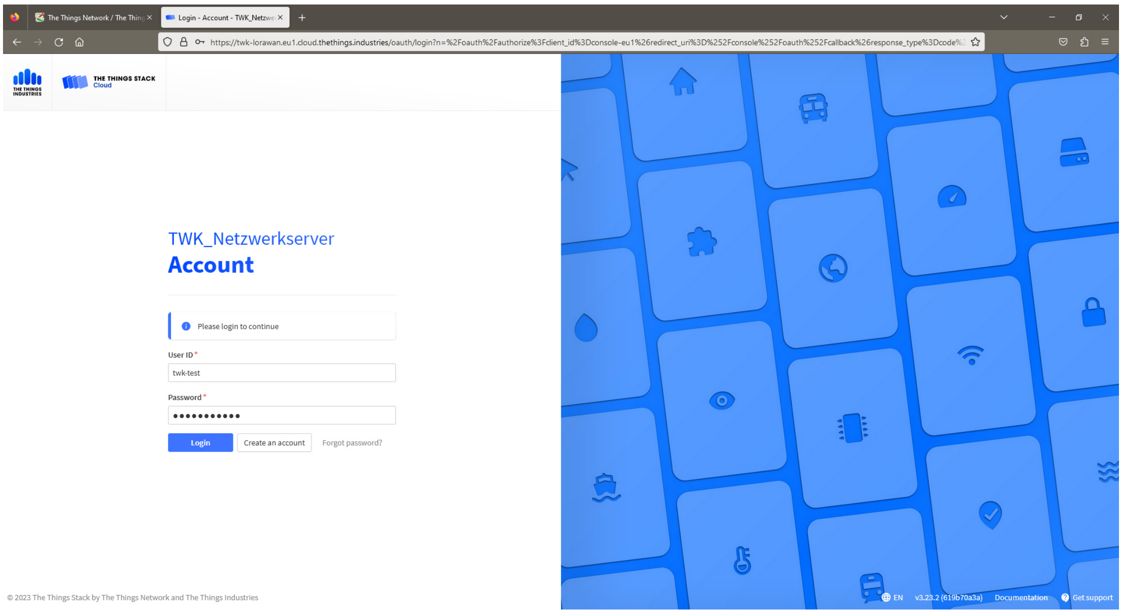
4.3 Status LEDs

Device Error (ER)	Error source (ES)	LoRaWAN Connection (LC)	Transmit-ting (TR)	Description
red	**green**	**green**	**red**	
on				Device error
on	on			Device not orientated correctly
on	flashing			Power low (<3.4 V)
		flashing		Searching for LoRaWAN connection
			single flash	Data transmitted via LoRaWAN

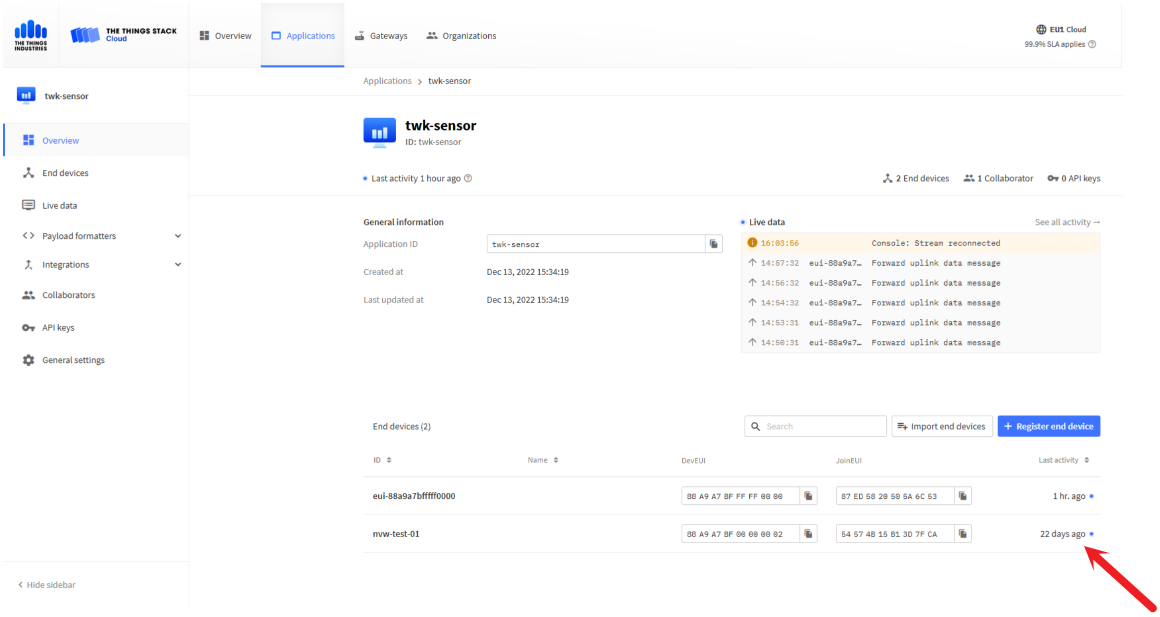
4.4 Registering a LoRaWAN device

To access the LoRaWAN data, it needs to be transferred from the device into an online accessible storage. This can either be done by a local server or by using commercially available services. *The Things Industries* is the largest provider with over 20,000 accessible gateways worldwide and therefore provides an easy and efficient possibility to get LoRaWAN data from the device into the cloud. Here, we will describe how to register a device in the *The Things Industries* interface.

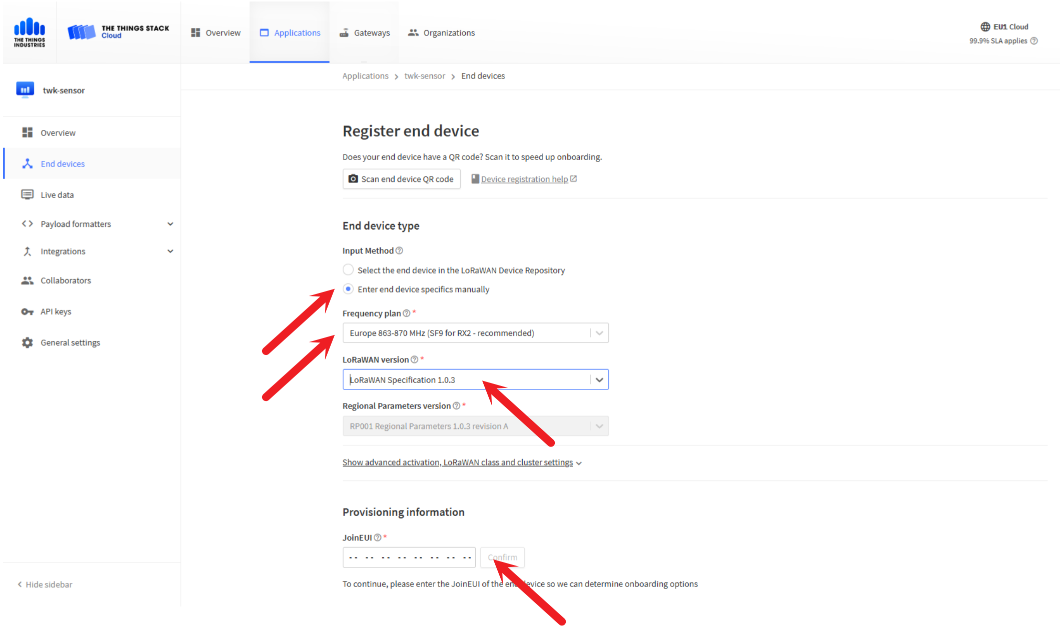
First, log into the interface by providing your login details:



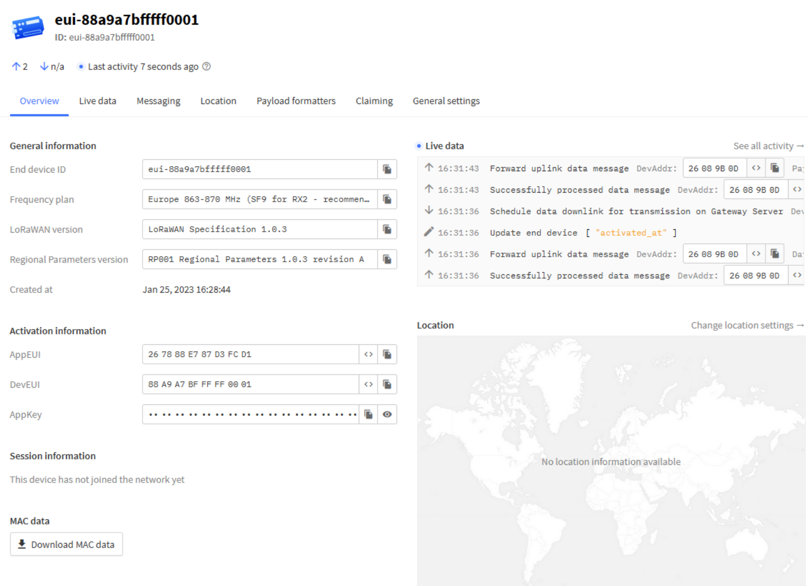
From the start page select *Got to applications* to get to the applications. Within an application, several devices can be registered.



To register a new device, click on *Register end device*. Select *Enter end device specifics manually*.



Under *Frequency plan* select *Europe 863-870 MHz (SF9 for RX2 - recommended)*. Under *LoRaWAN version*, select *LoRaWAN Specification 1.0.3*. Enter the JoinEUI, which can be found on the device. Click *confirm*.

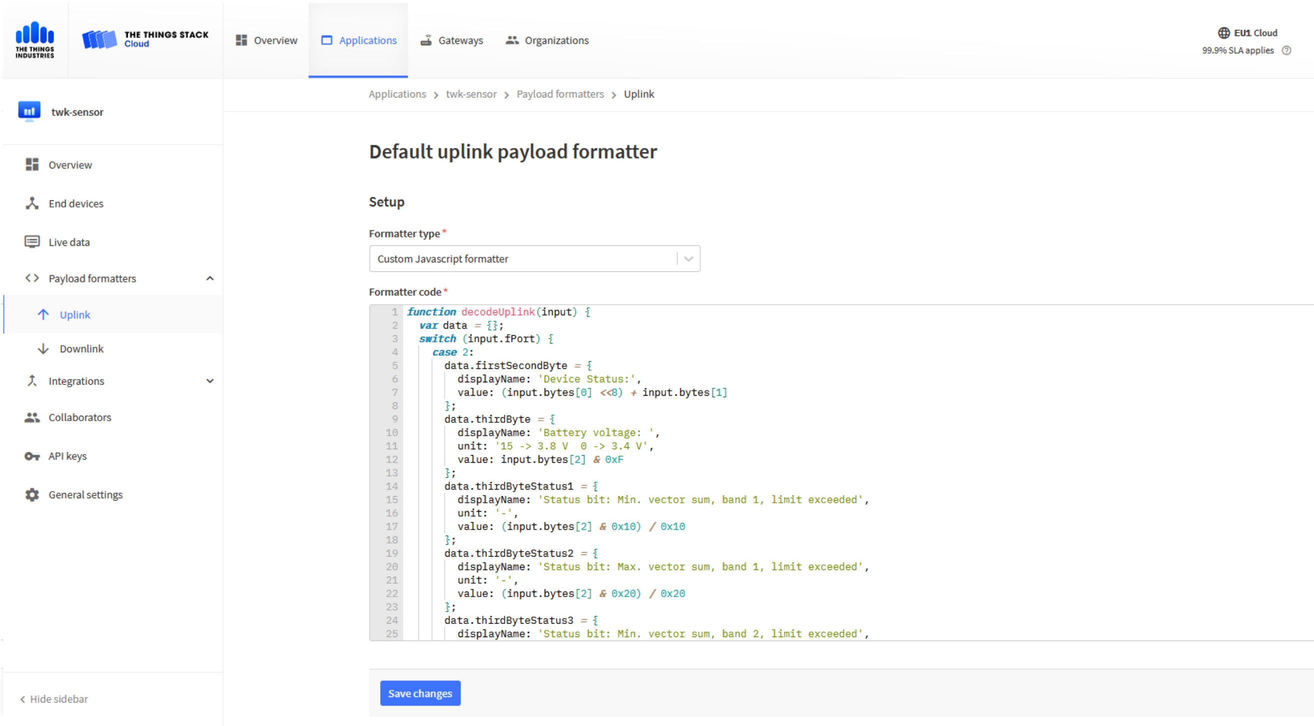


Enter the DevEUI from the nameplate of your device. You also need to enter the AppKey or Network key, which is customer specific and can be found on the connection assignment sheet delivered with each sensor. Finally, press *Register end device*. The device will then start to search for the nearest LoRaWAN access point and connect to the network.

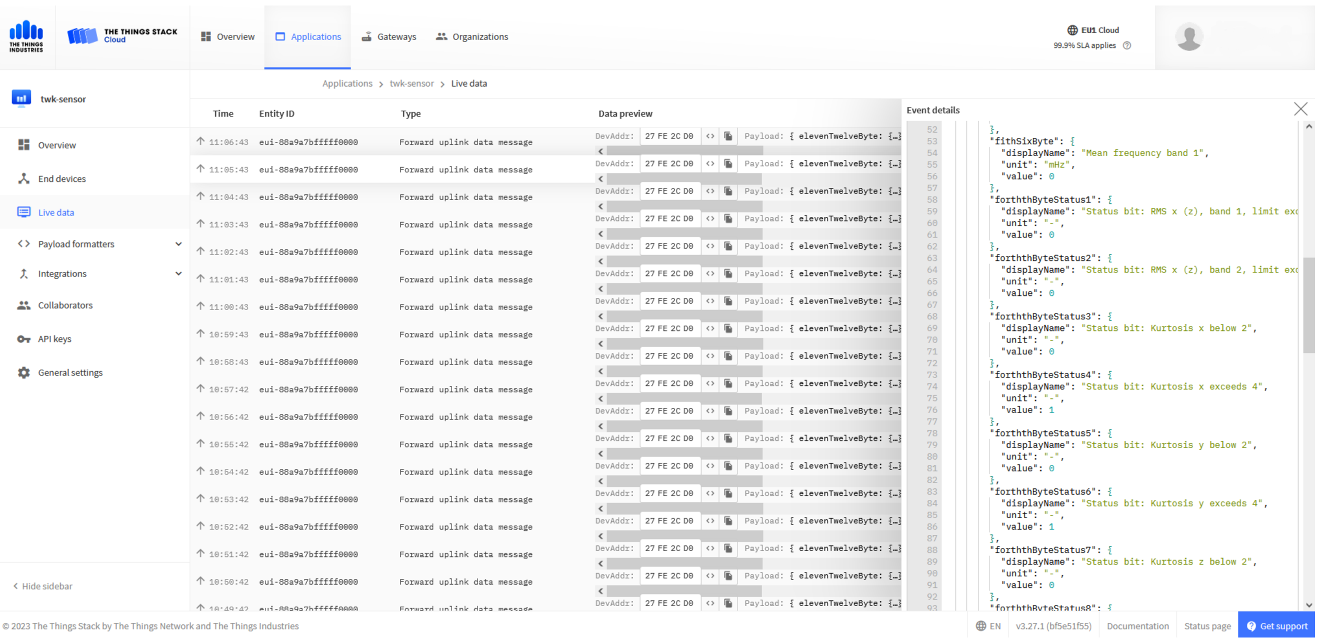
Once the sensor is connected, it will start to show data in the live data feed on the right.

To format the data in a human readable format, you can add a payload formatter. A text file with the java code for your sensor configuration can be obtained from TWK.

Selecting *Payload formatters → Uplink* from the menu on the left side. Select *Custom Javascript formatter* and copy and paste the java code from the payload formatter file from TWK into the *Formatter code* window. Press *Save changes.*



Now, when selecting *Live data* from the menu on the left side and selecting a line with data, the payload will be decoded according to the formatter and displayed on the right side:



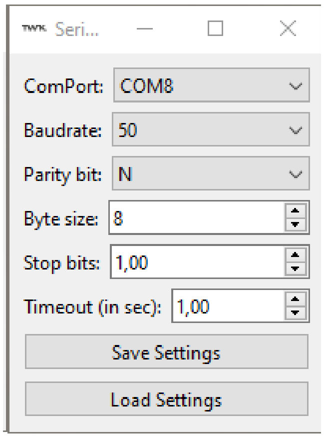
4.5 Serial communication

For serial communication via the USB interface the program logplot can be used. It can be downloaded from

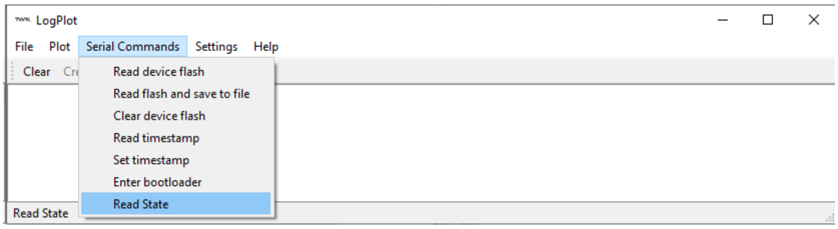
www.twk.de/files/logplot.zip

After program start-up, the serial setting need to be configured. Select *Settings* → *Serial Settings* to enter the serial setting window:

Choose the correct *ComPort* and select a suitable *Timeout* (e.g. 1s):

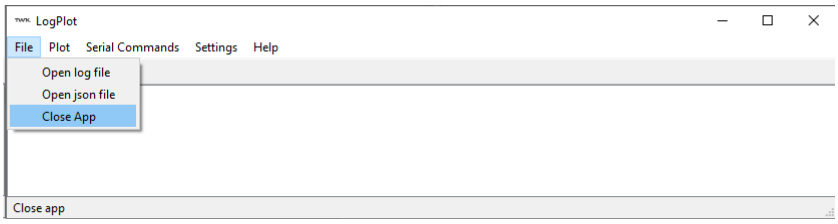


After connection, the following serial commands are available:



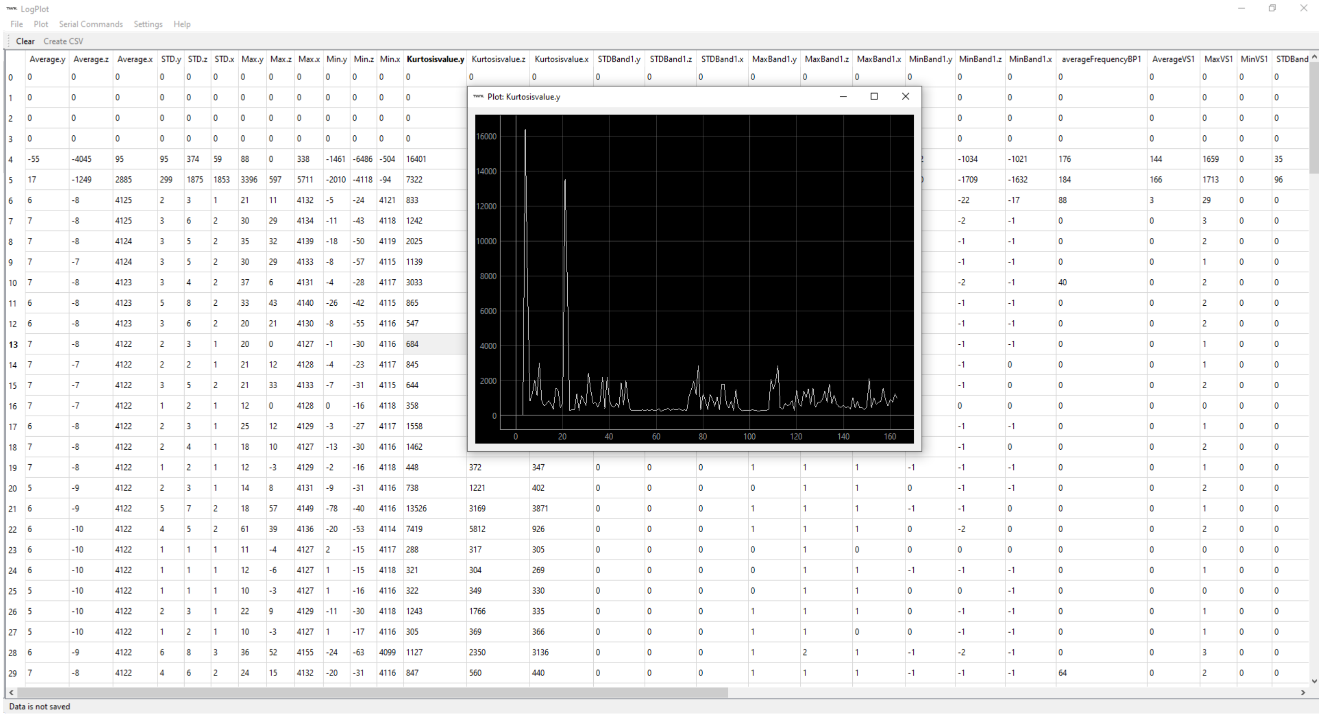
- *Read device flash*
  Reads all the data from the device flash and displays it in a table
- *Read flash and save to file*
  Reads all the data from the device flash, displays it in a table and saves it to a csv file
- *Clear device flash*
  Deletes all data from the device flash
- *Read timestamp*
  Read the current system time of the device and returns it as a unix timestamp
- *Set timestamp*
  Sets the system time of the device to a given value. Time needs to be given as unix timestamp.
- *Enter bootloader*
  Sets the device into bootloader mode. Required for firmware update.
- *Read state*
  Returns the error state of the device. See below for error code.

The file menu provides the possibility to read previously stored data:



- *Open log file*
  Opens previously saved logfile (csv format)
- *Open json file*
  Opens a json file, for example LoRaWAN data that was downloaded form the TTI/TTN interface using the matching payload formatter
- *Close App*
  Closes the program

Once data is present in the table, the data of a column can be plotted by clicking on a cell from the respective column. Note, that a separate window opens with every click. The windows can be closed by selecting *Plot → Close* all plot windows. To clear the table, click on *Clear* in the upper right corner, beneath the *File* menu.



4.6 Serial commands

If you do not want to use the logplot program, the following commands can be transferred via a serial program to execute the serial commands:

02 11 30 30 0D 30 30 37 46 0D 31 31 0D	Read flash data
02 11 30 30 0D 30 30 37 46 0D 31 32 0D	Clear flash data
02 11 30 30 0D 30 30 37 46 0D 31 33 0D	Enter bootloader
02 11 30 30 0D 30 30 37 46 0D 31 34 0D	Read time stamp
02 11 30 30 0D 30 30 37 46 0D 31 35 0D	Read device state

5 I/O data

5.1 LoRaWAN data

LoRaWAN data is transmitted in a pre-defined interval, e.g. every minute. Due to the airtime restriction in some world regions (e.g. 14.4 min per day in Europe), LoRaWAN payload data is limited to 12 bytes per minute. When the air time is exceeded, no data will be sent until the end of the (UTC) day. The resolution of the measurement values is 13 bit. For the standard version, payload data is transmitted in the following format:

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5
Device status		Vibration status		Measurement value 1	
Byte 6	Byte 7	Byte 8	Byte 9	Byte 10	Byte 11
Measurement value 2		Measurement value 3		Measurement value 4	

The device status is defined as follows:

Byte	Bit	Meaning
0	0	No error
	1	Device error
	2	Mounting position error
	3	Daily air-time exceeded
	4	Flash warning (more than 90% full)
	5	Flash error
	6	RTC error
	7	Battery voltage low
1	0	Voltage too high
	1-7	reserved

The vibration status can be used to indicate, if certain statistical values exceed a predefined value. Statistical values, limits and four measurement values can be chosen according to customer specification.

5.2 Internal data

The following data is saved periodically (e.g. every 60 seconds) in the internal memory. This interval is also used for the calculation of the average/RMS values. All amplitude data is saved with 16 bit resolution, average frequencies with 32 bit resolution. When the memory is filled by more than 90%, the device will display a warning. Once the memory is full, the device will go into an error state. With the standard 512 Mbit flash storage, an interval of 60 seconds and 100 bits of data saved per interval, data of about 450 days of continuous operation can be saved.

		x-axis	y-axis	z-axis	vector sum (horizontal axes)	scaling
Momentary	Average	X*	X*	X*		4096 / g
	Standard deviation	X	X	X		4096 / g
	Max	X	X	X		4096 / g
	Min	X	X	X		4096 / g
	Kurtosis	X	X	X		x 100
Band 1	Standard deviation	X	X	X		4096 / g
	Average				X**	4096 / g
	Max	X	X	X	X	4096 / g
	Min	X	X	X	X	4096 / g
	Average frequency	Axis with highest RMS value				mHz
Band 2	Standard deviation	X	X	X		4096 / g
	Average				X**	4096 / g
	Max	X	X	X	X	4096 / g
	Min	X	X	X	X	4096 / g
	Average frequency	Axis with highest RMS value				mHz

Note: For single axis values the RMS*, for the vector sums the average values** are saved.

Additionally, the **time** (in UTC seconds, 32 bit), a **counter** (32 bit)**,** the **supply voltage** (32 bit) and the **device status** (16 bit) are saved.

6 Scope of delivery

The scope of delivery of an NVW includes:

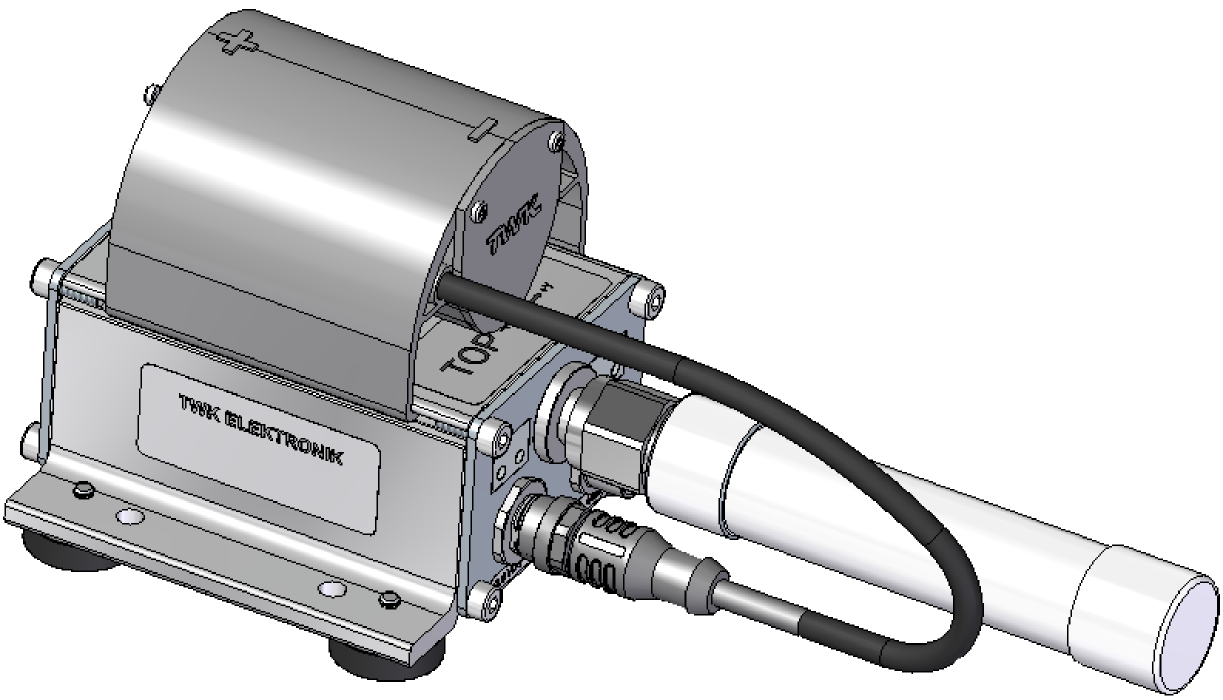
Vibration sensor with LoRaWAN® interface
Connection assignment TY XXXXX (depending on the device variant)

The scope of delivery of the NVW set includes:

Vibration sensor with LoRaWAN® interface
LoRaWAN® antenna
Battery holder with cable and connector
SAFT Battery 3.6 V, 17 Ah
Robust storage case for storage and transportation
Connection assignment TY XXXXX (depending on the device variant)

Available for download on www.twk.de are:

Data sheet NVW16631
Manual No. NVW16705
Installation instructions AN16169
Serial communication program Logplot



NVW fully assembled with battery and antenna