Vibration sensor on MEMS technology
Interface**: PROFIsafe/PROFINET**
Model **NVT / S3**

SUPREME SENSORING
TWK

Document no.: NVT 14587 FE
Date: 23.04.2019

Handbook: NVT 14588

- **Contactless, wear-free sensor system in MEMS technology**
- **Number of measurement axes: 2**
- **Frequency range: 0.05 ... 60 Hz**
- **Measuring range: ± 2 g**
- **Special features:**
  - **Various signal settings: RMS, PEAK**
  - **In addition: signal output on PROFINET standard protokol (grey chan.)**

Certified according to EN ISO 13849: PLd

Design

The sensor system is intended as a component for use e.g. in wind power plants to measure and evaluate vibrations in the mast head. Registration of dynamic accelerations by means of MEMS sensors (Micro-Electro-Mechanical System) with subsequent digitisation by a controller.

The device consists of an acceleration sensor, a controller unit and the output interface PROFIsafe over PROFINET for output of the acceleration values.

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 out using three connectors.

5 LEDs help at installation and diagnosis of NVT90/S3.

Function

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

After determining the steady component and scaling, the measured values supplied by the acceleration sensor are made available to the filter units. The steady component arises as a result of installation which is not precisely horizontal, with the result that part of the earth's gravitational field would also be measured. The offset which occurs in the measured vibration value curve (zero point shift) due to the steady component is determined by means of calculation (distribution of the positive and negative measured values around the zero point) and is subtracted. The pure alternating component is output within a matter of 30 seconds. This calculation takes place continually. This function can be shut off in the factory.

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 the horizontal axes (usually called x and y) also to the resulting ones.

The signals which are then available can be used for:

- output on PROFIsafe over PROFINET
- output on PROFINET standard protokol
- calculation of momentary or RMS output or peak or integral output

The Profinet interface according to IEC 61158 / 61784 or PNO specifications order No. 2.712 and 2.722, version 2.3, is integrated into the series NVT.

Real time classes 1 and 3 are supported, i.e. Real Time (RT) and Isochronous Real Time (IRT) plus the requirements of conformance class C.The integrated 2-fold switch enables the TWK PROFINET inclinometer to be used in star, tree and line network topologies.

The PROFIsafe protocol is implemented according to the PROFIsafe Profile for Safety Technologie version 2.4 (PNO Order No. 3.192).

An exhaustive description of integration into a PROFINET network can be found in the NVT14588 manual.

PROFINET properties

- Real Time (RT) and Isochronous Real Time (IRT)
- Device exchange without interchangeable medium or programming device
- Prioritised start-up (Fast Start Up)
- Media redundancy possible
- Firmware update via Profinet

Description

General information

The vibration sensor measures on two axes in a frequency spectrum from 0.05 to 60 Hz. These two axes are located parallel to the mounting surface of the NVT90. This spectrum can be subdivided into a maximum of 6 frequency ranges. The frequency ranges are set in the factory. All acceleration values acting within the relevant frequency window are registered and are output as a digital value via PROFIsafe over PROFINET.

The measuring axis is x and y (partly called y and z) or the vector sum $\sqrt{(x^2+y^2)}$ built from x and y.

The acceleration value (instantaneous value) can be used directly or a mean value of the acceleration which occurs (RMS) may be used as the output value. The time over which averaging is carried out can be set (e.g. 30 s). A PEAK value or an integration value is also selectable. The peak value can be decremented to certain times and with a certain decrementation rate.

This sensor is meant for horizontal installation only. Tilt angles up to 15° are allowed. Increases the tilt angle 15° an error message is generated by the sensor and transmitted by PROFIsafe over PROFINET.

Filter characteristics

After the steady component suppression (SCS) a digital pre-filtering is initially carried out in the NVT to extensively suppress higher-frequency interference vibrations (> ~95 Hz), as they reveal comparatively high amplitudes due to the higher frequencies (1st-order FIR filter).

The individual frequency bands are then realised in the downstream controller via further digital filters. The following behavior of the filters are selectable ex works:

- 8th to 11th-order Chebichev filters (11th order in the lower frequency range, 8th order in the upper frequency range).
- 2nd-order Butterworth filter
- other filters on request

Due to the high-order Chebichev filters the frequencies are highly separated. The group delay t_V is therefore high (depending on upper frequency. It is roughly defined: t_V =~ 1/(fo*2) + 16 msec (with fo = upper frequenz edge +16 ms due to prefiltering).

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. This limit is determinated by the steady component suppression (SCS). The upper frequency is 60 Hz.

The steady component - generally caused by axis inclination on inclined installation - is calculated out by means of averaging which is performed prior to filtering. As a result of this, the lower limit frequency - irrespective of filter - is around 0.05 Hz. Steady component suppression (SCS) can be shut off in the factory.

Figures 1 and 2 show examples of a possible frequency curve due to Chebichev filter behavior (Diagrams for Butterworth filter behavior will follow). The filter's output values are signed.

Examples for fiter output - Chebichev

amplidude vs f

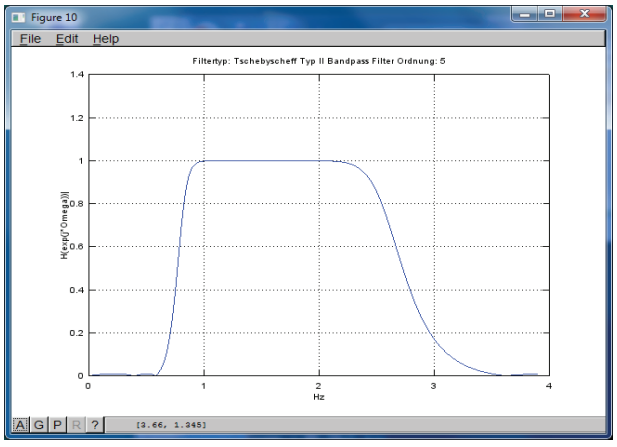


Fig. 1: Example band pass filter f_{gu} = 0.8Hz, f_{go} = 2.5 Hz

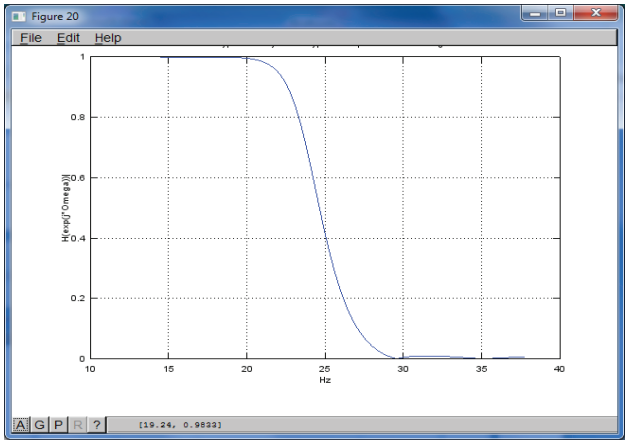


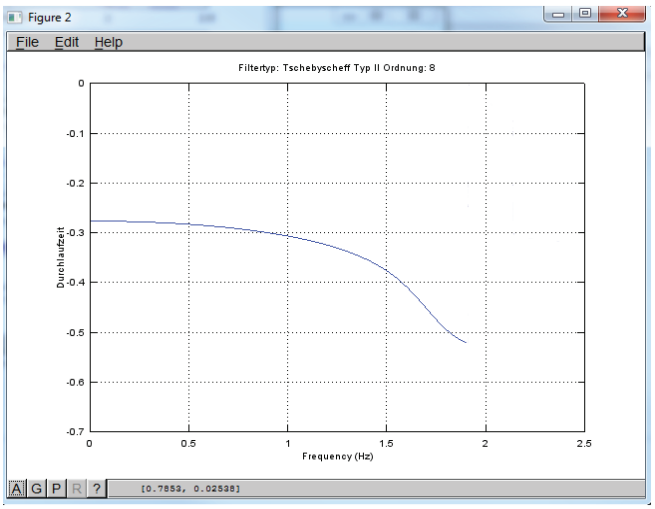
Fig. 2: Example of a low pass filter f_{go} = 23 Hz

Examples for fiter output - Chebichev t_V vs f

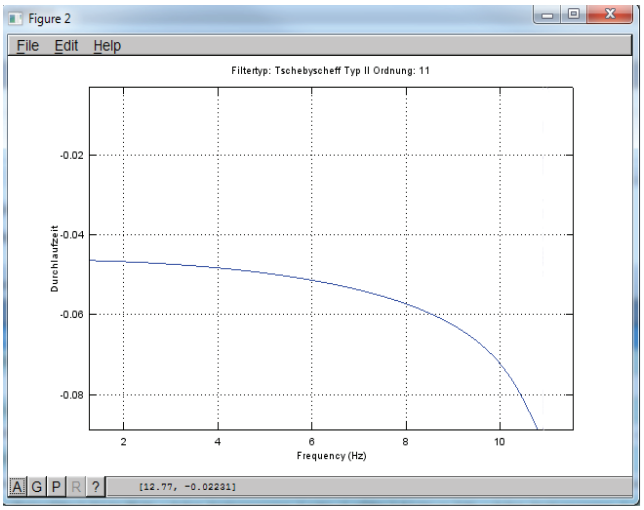
The time lag in seconds (y axis) is entered over the applied frequency f (x axis). The different diagrams apply to the different upper frequency limits fo of a filter (fo is set in the factory → filter pass behaviour → low-pass - high-pass - band-pass).

Rough calculation of t_V: t_V = ~1/(fo*2) + 16 msec. with fo = upper frequenz edge (+16 ms due to prefiltering).

Filter setting 0,1 Hz to 1,5 Hz

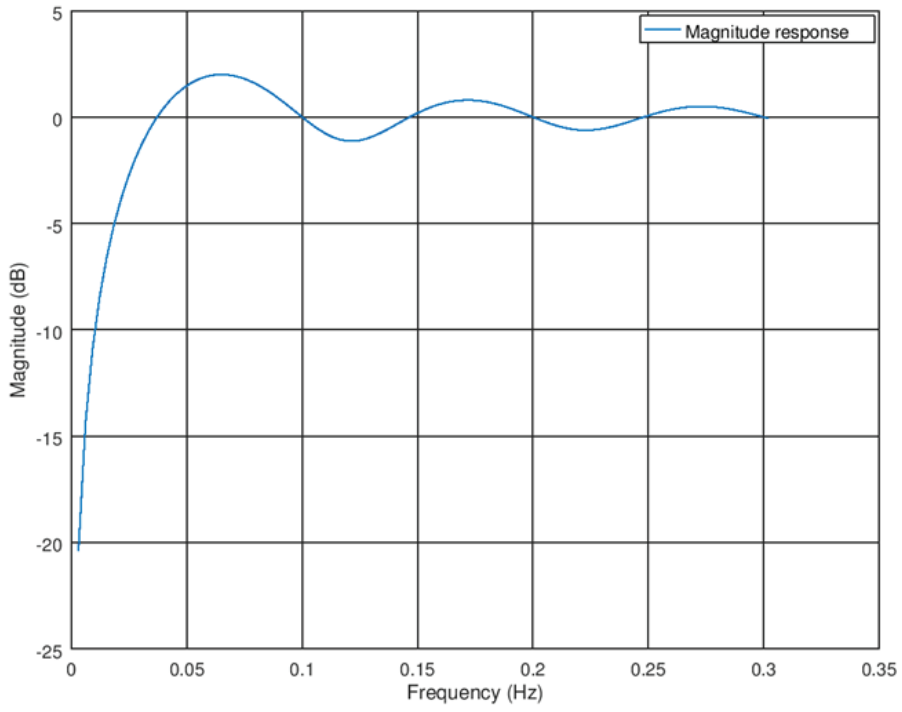


Filter setting 0,1 Hz to 10 Hz



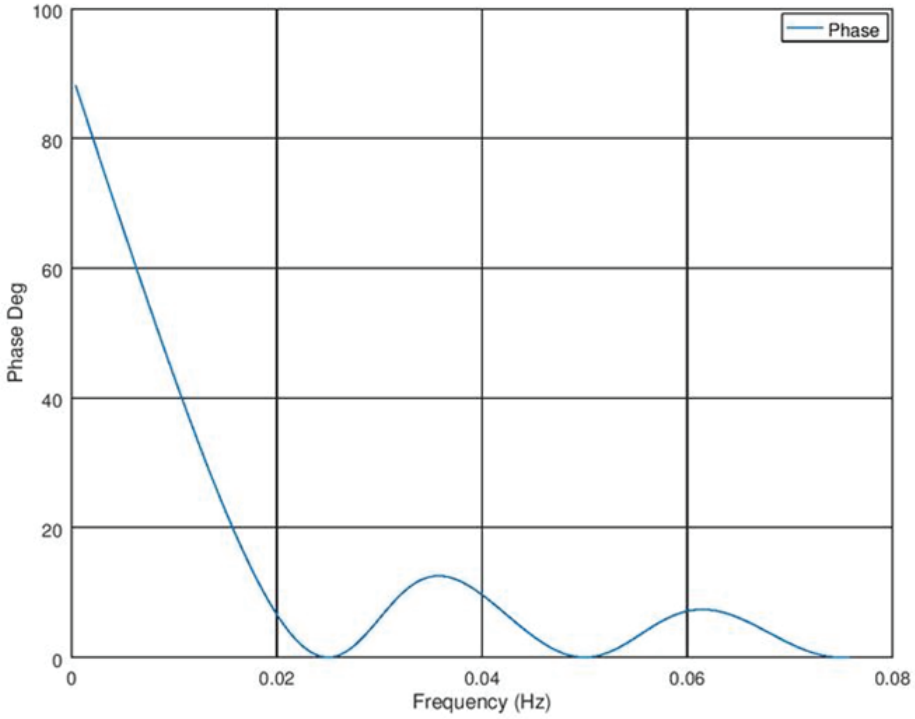
Examples for fiter output - 0.05 - 5 Hz with SCS, prefiltering, Butterworth 5 Hz

Steady component suppression (SCS) - Magnitude

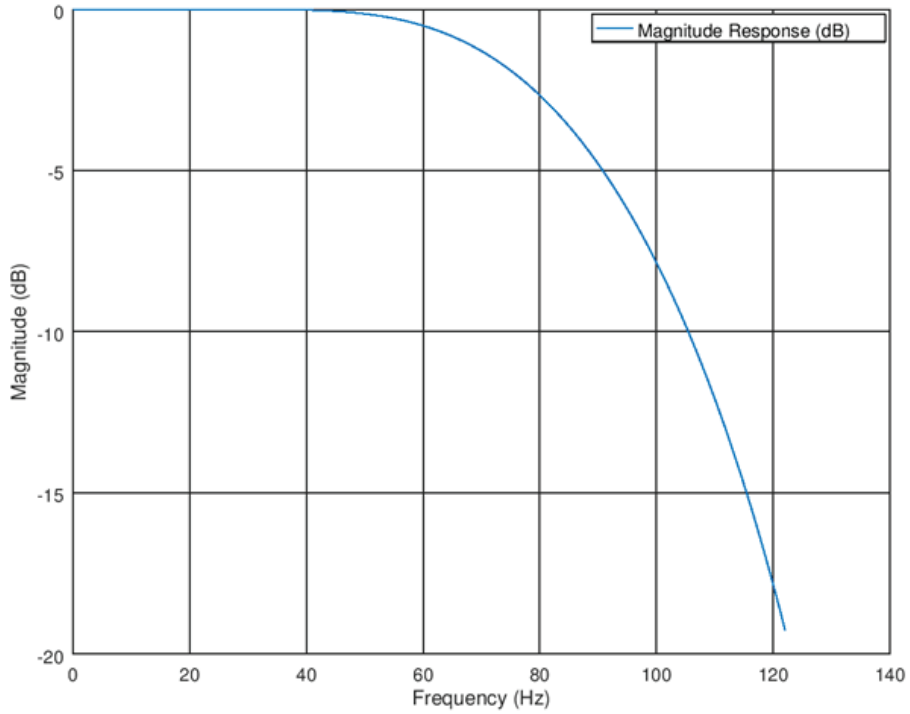


Examples for fiter output - 0.05 - 5 Hz with SCS, prefiltering, Butterworth 5 Hz

Steady component suppression (SCS) - Phase

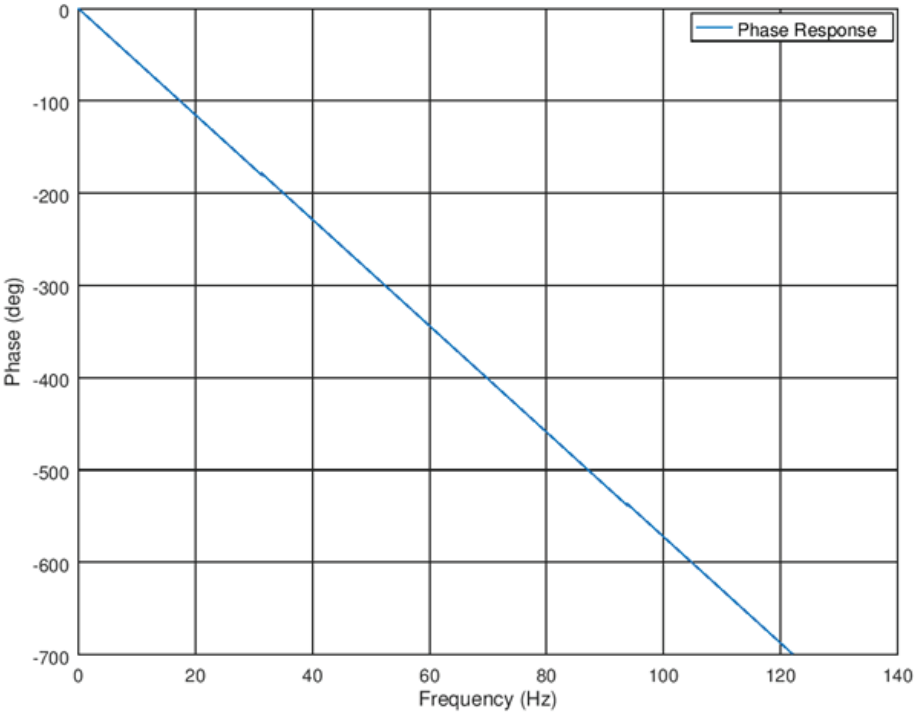


Prefilter - Magnitude

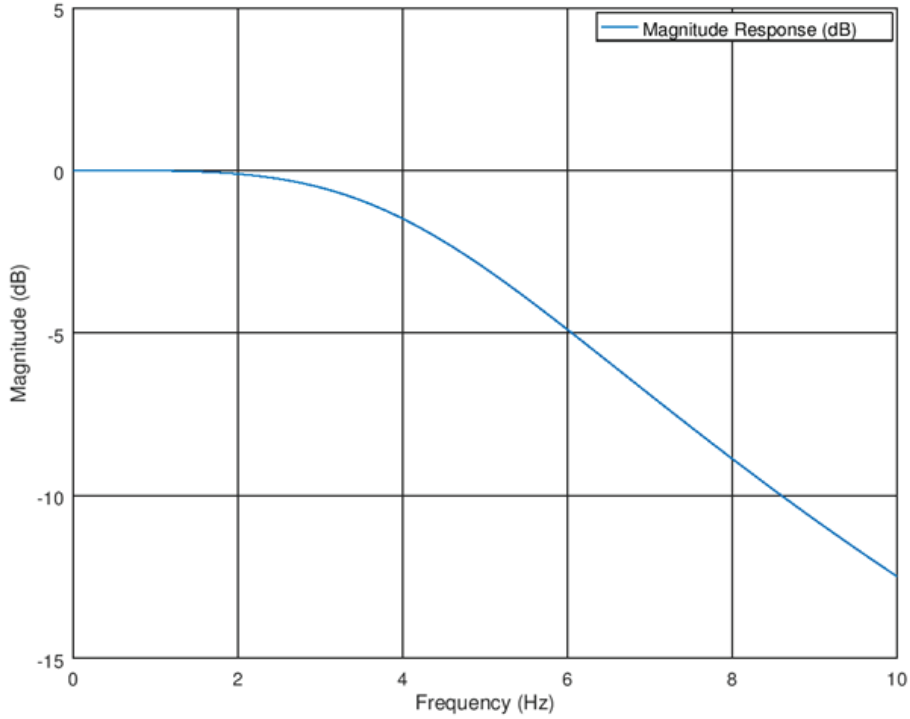


Examples for fiter output - 0.05 - 5 Hz with SCS, prefiltering, Butterworth 5 Hz

Prefilter - Phase

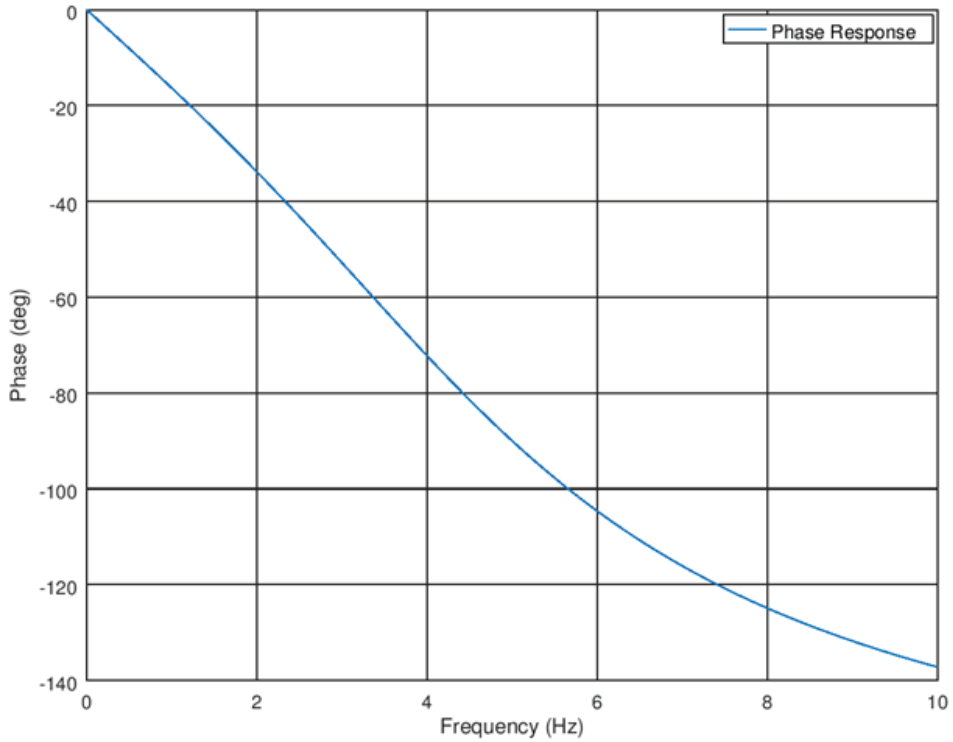


Mainfilter, Butterworth 2nd order - Magnitude



Examples for fiter output - 0.05 - 5 Hz with SCS, prefiltering, Butterworth 5 Hz

Mainfilter, Butterworth 2nd order - Phase



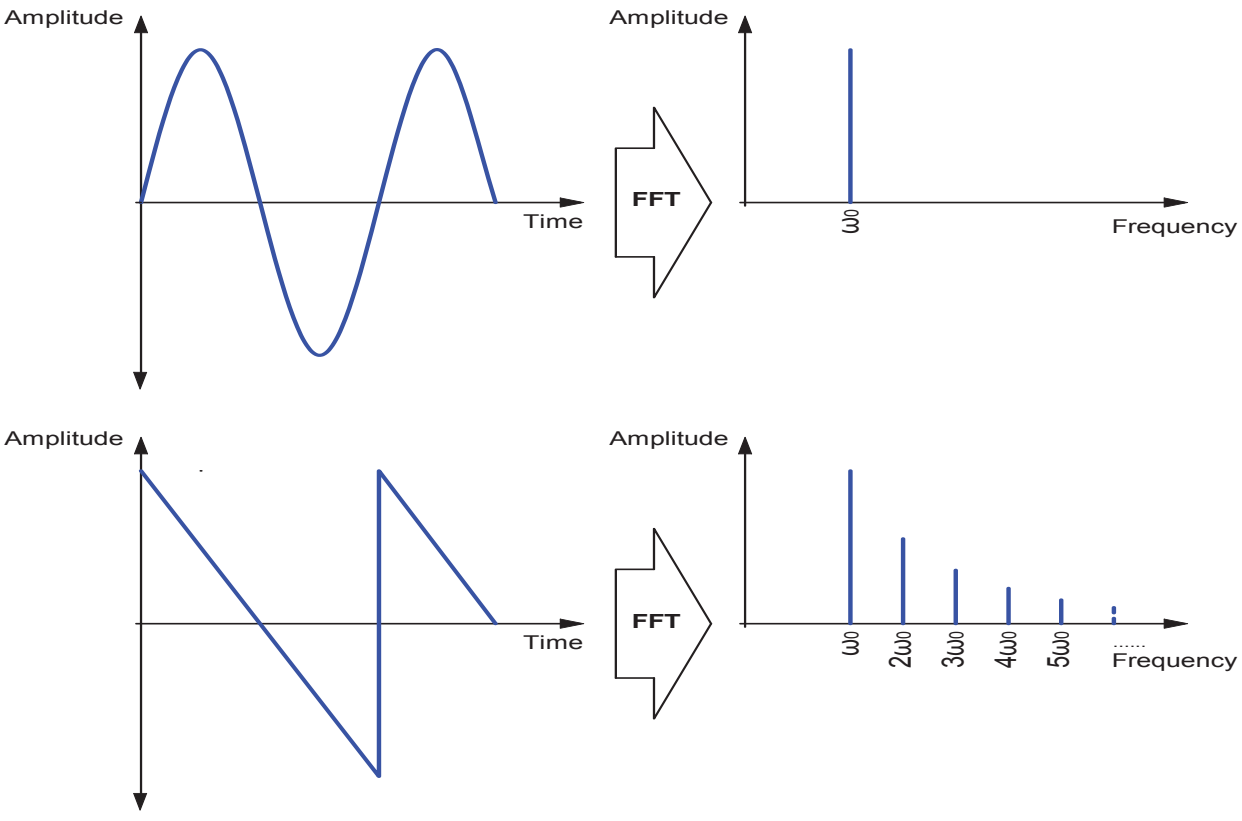
Frequency detection by Fourier transformation FFT

In preparation

In preparation is an NVA version which provides the output of the spectrum of measured frequencies via PROFINET. This spectrum is get by Fourier transformation (FFT) of the momentary value of the acceleration measurement versus time.

This functionality can be used for blade or tower frequency detection.

See two simple examples for such a transformation in the following diagrams.



Technical data

Input data *

- 2 byte status word
- 3x2 byte position data

Output data *

- 2 byte control word

* From the point of view of the control system

Output data *

- 2 byte control word

Electrical data

Sensor system:	MEMS acceleration sensor
Number of frequency bands:	maximum of 6 (Setting ex works)
Measuring range:	± 2 g for each axis
Sampling frequency:	120 to 800 Hz, depending on the frequency range of according filter
Resolution:	4096 digits / g (9.81 m/s² = 1 g)
Operating voltage range:	+ 9 to + 36 VDC
Power consumption:	< 3 W
Current consuption:	ca. 90 mA at 24 VDC
Maximum inclination vs. horizon:	15° (at angles >15° an error message will be transferred by PROFINET)
Sign of output data:	See drawing concerning axes and sign of acceleration direction
Electrical connection:	3 x connector M12 or 3 x Cable (1 x Power supply / 2 x PROFINET)

Environmental data

Operating temperature range:	- 40 °C to + 70 °C
Resistance to shock:	200 m/s² / 5 ms, according to DIN EN 60068-2-27
Resistance to vibration:	100 m/s² at 10 Hz ... 2000 Hz according to DIN EN 60068-2-6
Protection type (DIN 40 050):	IP 67 plug connection IP 69K housing (option)
EMC: (Only use shielded cable for power supply and PROFINET)	EN 61000-6-4 interference emission EN 61000-6-2 interference immunity EN 61000-4-2 (ESD) EN 61000-4-4 (burst) EN 61000-6-3 (emission)
Housing material:	Aluminium (see drawing)
Weight:	0.4 kg

PROFINET data

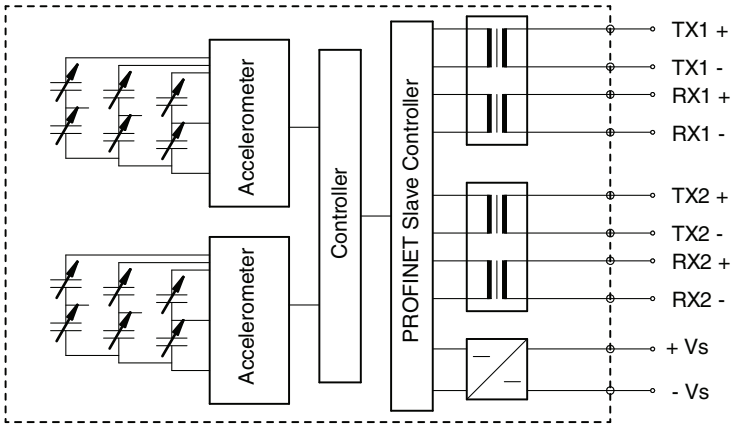
MAC address:	88:A9:A7:BX:XX:XX The relevant, current MAC address is located on the model plate.
Transfer technology:	100 Base-TX
Transfer rate:	10 / 100 MBit/s
Line length:	Max. 100 m (between two subscribers)
Minimum transmission cycle:	250 µs

Safety relevant Data

According to DIN EN ISO 13849-1: (certified to this standard)	$MTTF_d$ = 100 years (220 years calculated) DC = 97,25 % Categorie 2 Performance Level D
Maximum service life:	20 years
Number of certificat:	44 799 13172913 (TÜV NORD CERT GmbH)

Electrical connection

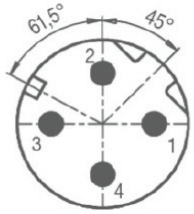
Block diagram NVT



PROFINET M12 connection assignment connector / cable output

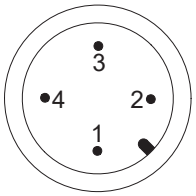
(Port1 und Port 2)

PIN	1	2	3	4
Signal	TX+	RX+	TX-	RX-
Colour*	yellow	white	orange	blue



Supply M12 connection assignment connector / cable output

PIN	1	2	3	4
Signal	+ UB (+ 24 VDC)	—	- UB (0 VDC)	—
Colour	white	—	brown	—



View on pins

Diagnosis-LEDs

UB (VS)	Link 1 (L1)	Link 2 (L2)	Status (NS)	Description
green	green	green	green/red	
on				Operating voltage available
	on			Network connection established
		on		Network connection established
			green	Data exchange, device in operation and OK
			green flashing	Network connection o.k. but no connection to a PROFINET controler
			red, slow flashing	Firmware download mode
			red flashing	Interference accelerations to high or preset error
			Fast red flashing	Device error
			red	Connection to the PROFINET controller disrupted

Order number

NVT	90	-	A	5	0	0	-	2	S3		M	T	01

Electrical and / or mechanical variants *
01 Standard

Output interface:
T PROFIsafe over PROFINET

Electrical connection:
M Standard: 3 connectors M12 (A- and D-coded)
Mx Reduced number of connectors **: x = 1 or x = 2
Ky Standard: 3 cables with length y (e.g. K13,5)
(other numbers of cables on request)

Profile:
S3 PROFIsafe over PROFINET - Performance Level d

Measuring range:
2 2 g = ca. 20 m/s² - Higher values on request

Number of analogue outputs 0 (4) ... 20 mA:
0 → Not available at the time

Number of switching outputs:
0 → Not available at the time

Number of frequency filters:
5 1 to a maximum of 6 - set in the factory (frequency bands)

Housing material:
A Aluminium AlMgSi1

Design form:
90 Design form 90 mm

NVT Vibration sensor NVT with PROFIsafe over PROFINET Interface

* The basic versions according to the data sheet bear the number 01. Deviations are identified with a variant number and are documented in the factory.
For example will certain filter settings cause a variant number (e.g. 0,05 Hz to 5 Hz).

** Number of connections:

1 = Hybride
2 = 1x power supply, 1x PROFINET
3 = 1x power supply, 2x PROFINET

Only use shielded cable for connection of power supply and PROFINET

Accessories, documentation, GSD file

Accessories (to be ordered separately)

- Documentation on CD

TWK-CD-01	CD-ROM with documentation, device description file and bitmap

- Straight mating connector

STK4GP81	for PROFINET in/out
STK4GS60	for the supply voltage
STK4GP110	for PROFINET in/out (stainless steel 1.4404)
STK4GS104	for the supply voltage (stainless steel 1.4404)

- Angled mating connector

STK4WP82	for PROFINET in/out
STK4WS61	for the supply voltage

- Connecting cable

KABEL-xxx-114	Industrial Ethernet data cable with M12 connectors, D-coded, moulded on at both ends. Standard lengths: 1, 2, 3 and 5 m (xxx = length in metres)
KABEL-xxx-118	Industrial Ethernet data cable with M12 connector to RJ 45, IP 20 (xxx = length in metres)
KABEL-xxx-191	Cable for power supply (xxx = length in metres on request)
KABEL-xxx-216	Cable for power supply with conntector STK4GS60 and open ends (xxx = length in metres on request)
KABEL-xxx-217	Industrial Ethernet data cable, high flexible with connector STK4GP81 and open ends (xxx = length in metres on request)
KABEL-xxx-218	Industrial Ethernet data cable, high flexible with connector STK4GP81 and RJ45 (xxx = length in metres on request)

Furthur cables on request.

Documentation, GSD file, etc.

The following documents plus the GSD file and bitmap can be found in the Internet under www.twk.de in the documentation area, model NVT

- Data sheet No. NVT14587
- Manual No. NVT14588

Optionally, a CD-ROM can be supplied. Please specify article No. TWK-CD-01 on ordering.

Technical data

Electrical connection

- PROFINET: M12 connector D-coded 4-pin for bus in / bus out, socket or cable output via cable glands
- Supply: M12 connector A-coded 4-pin, pins or cable output via cable glands

PROFINET mating connector

- Connection type: M12 connector D-coded 4-pin
- Housing: Die-cast zinc, nickel-plated
- Contacts: Pins, gold
- Wire connection: Cage clamp
- Connection cross-section: Max. 0.75 mm^2
- Cable diameter: 6 - 8 mm
- Protection type: IP 67
- Order number: STK4GP81

Supply mating connector

- Connection type: M12 connector A-coded 4-pin
- Housing: Die-cast zinc, nickel-plated
- Contacts: Socket, gold
- Wire connection: Screw connection
- Connection cross-section: Max. 0.75 mm^2
- Cable diameter: 4-6 mm
- Protection type: IP 67
- Order number: STK4GS60

Pre-assembled Industrial Ethernet data cable

- Connection type: M12 connector D-coded 4-pin on both sides
- Contacts: Pins, gold
- Cable type: PUR, halogen-free, Profinet type C
- Cable cross-section: 4 x 0.38 mm^2 (AWG 22)
- Cable diameter: 6.2 mm
- Protection type: IP67
- Order number: KABEL-xxx-114

Cable output PROFINET

- Cable type: PROFINET Type-C, 4 x 0,36 mm2 (AWG22)
- Cable jacket: PUR, color: green
- Temperatur range: - 40 °C to + 70 °C
- Outer diameter: 6.5 mm ± 0.2 mm
- Min. bend radius: 5 x d fixed installation, 10 x d freely movable

Cable output power supply

- Cable type: 2 x 0,75 mm^2, shielded
- Cable jacket: PUR, color: gray
- Temperatur range: - 40 °C to + 80 °C fixed installation, - 5 °C to + 70 °C freely movable
- Outer diameter: 6 mm
- Min. bend radius: 6 x d fixed installation, 15 x d freely movable

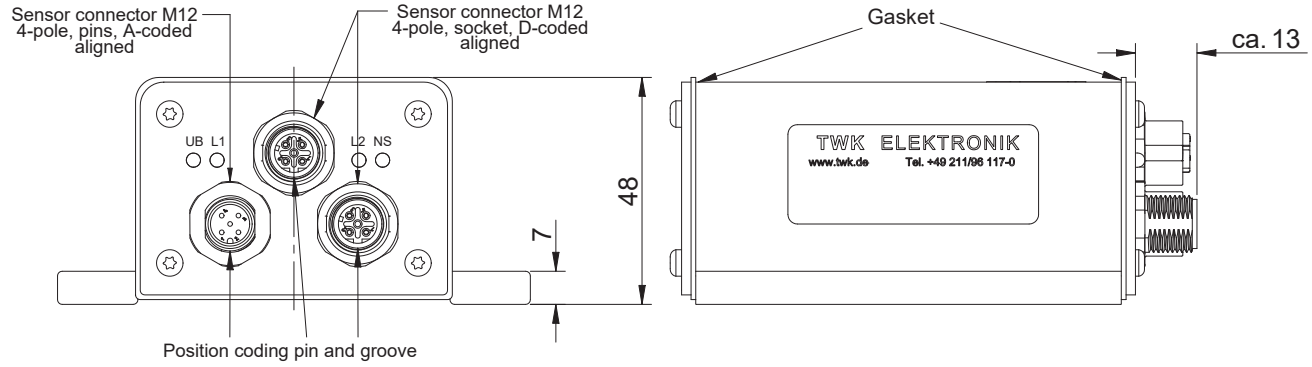
Other connectors and cables: See above and on request.

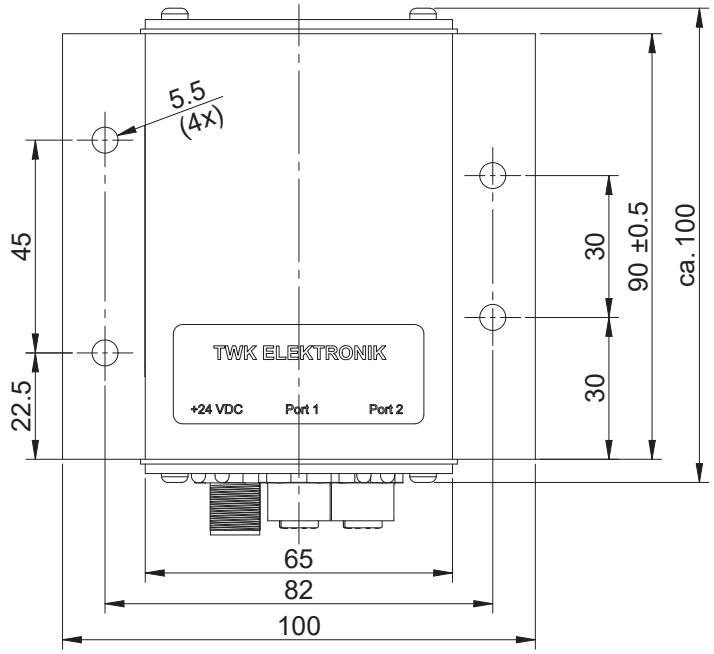
Installation drawing

Version with 3 connectors

Dimensions in mm

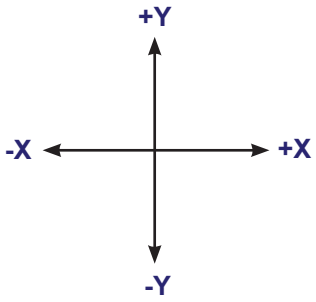
The splitted NS-LED can be realized by one LED (2-colour, red / green) as well.



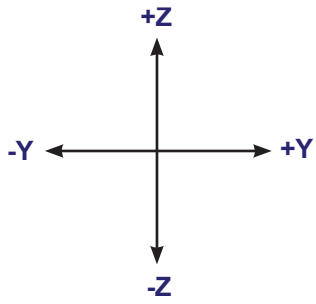


Definitionen of axes

Standard:



Special version (e.g. 02):



When NVA is accelerated in direction of the arrow the mentioned sign at the reated axis is put out (signed 16 Bit: ...., FFFD, FFFE, FFFF, 0, 1, 2, ...)

Materials used

Aluminium housing:	AlMgSi0.5 (EN AW 6060)
Aluminium front plates:	AlMg3
Stainless steel housing:	On request
Connector:	Nickel-plated brass
Sealing rings:	Silicone