**Vibration sensor** on MEMS technology

**Interface:** PROFIsafe/PROFINET

**Model** NVT / S3

- **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.)

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**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 Technology 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

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**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: $t_v = 1/(f_0^2) + 16$ msec (with $f_0$ = 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.

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**Examples for filter output - Chebichev**

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

Fig. 2: Example of a low pass filter $f_{go} = 23$ Hz
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 $t_V$: $t_V = \frac{1}{f_0 \times 2} + 16$ msec. with $f_0 =$ upper frequenz edge (+16 ms due to prefiltering).

Examples for filter output - Chebichev

Filter setting 0,1 Hz to 1,5 Hz

![Chebichev filter response](image1.png)

Filter setting 0,1 Hz to 10 Hz

![Chebichev filter response](image2.png)

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

Steady component suppression (SCS) - Magnitude

![Magnitude response](image3.png)
Examples for filter output - 0.05 - 5 Hz with SCS, prefiltering, Butterworth 5 Hz

Steady component suppression (SCS) - Phase

![Phase Graph]

Prefilter - Magnitude

![Magnitude Graph]
Examples for filter output - 0.05 - 5 Hz with SCS, prefiltering, Butterworth 5 Hz

Prefilter - Phase

Mainfilter, Butterworth 2nd order - Magnitude
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

#### 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)
- Accuracy: 5 % typ.
- Operating voltage range: + 9 to + 36 VDC
- Power consumption: < 3 W
- Current consumption: 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
- EMC: 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
  - 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)
  - MTTFd = 100 years (220 years calculated)
  - DC = 97.25 %
  - Categorie 2
  - Performance Level D
- Maximum service life: 20 years
- Number of certificate: 44 799 13172913 (TÜV NORD CERT GmbH)
**Electrical connection**

### Block diagram NVT

![Block diagram NVT](image)

### PROFINET M12 connection assignment connector / cable output

**Port1 and Port 2**

<table>
<thead>
<tr>
<th>PIN</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal</td>
<td>TX+</td>
<td>RX+</td>
<td>TX-</td>
<td>RX-</td>
</tr>
<tr>
<td>Colour</td>
<td>yellow</td>
<td>white</td>
<td>orange</td>
<td>blue</td>
</tr>
</tbody>
</table>

### Supply M12 connection assignment connector / cable output

<table>
<thead>
<tr>
<th>PIN</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal</td>
<td>+ UB (+ 24 VDC)</td>
<td>—</td>
<td>- UB (0 VDC)</td>
<td>—</td>
</tr>
<tr>
<td>Colour</td>
<td>white</td>
<td>—</td>
<td>brown</td>
<td>—</td>
</tr>
</tbody>
</table>

### Diagnosis-LEDs

<table>
<thead>
<tr>
<th>UB (VS)</th>
<th>Link 1 (L1)</th>
<th>Link 2 (L2)</th>
<th>Status (NS)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>green</td>
<td>green</td>
<td>green</td>
<td>green/red</td>
<td>Operating voltage available</td>
</tr>
<tr>
<td>on</td>
<td>on</td>
<td>on</td>
<td>Network connection established</td>
<td></td>
</tr>
<tr>
<td>on</td>
<td>green</td>
<td>green</td>
<td>Network connection established</td>
<td></td>
</tr>
<tr>
<td></td>
<td>green flashing</td>
<td>green flashing</td>
<td>Data exchange, device in operation and OK</td>
<td></td>
</tr>
<tr>
<td></td>
<td>red, slow flashing</td>
<td></td>
<td>Network connection o.k. but no connection to a PROFINET controller</td>
<td></td>
</tr>
<tr>
<td></td>
<td>red flashing</td>
<td></td>
<td>Firmware download mode</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fast red flashing</td>
<td></td>
<td>Interference accelerations to high or preset error</td>
<td></td>
</tr>
<tr>
<td></td>
<td>red</td>
<td></td>
<td>Device error</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Connection to the PROFINET controller disrupted</td>
<td></td>
</tr>
</tbody>
</table>
**Vibration sensor / monitor NVT / S3**

### Order number

<table>
<thead>
<tr>
<th>NVT 90 - A 5 0 0 - 2 S3 M T 01</th>
</tr>
</thead>
</table>

**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 | 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 |

**Design form:**

| 90 | Design form 90 mm |

**NVT** Vibration sensor NVT with PROFIsafe over PROFINET Interface

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* 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 connector 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)

Further 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 area 'Support and Service' > 'Documentation' > NVT

- Data sheet No. NVT14587
- Manual No. NVT14588
## 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 mm²
- **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 mm²
- **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 mm² (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
- **Temperature 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 mm², shielded
- **Cable jacket:** PUR, color: gray
- **Temperature 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.
Vibration sensor / monitor NVT / S3

Installation drawing

Version with 3 connectors

Dimensions in mm

Materials used

- Aluminium housing: AlMgSi0.5 (EN AW 6060)
- Aluminium front plates: AlMg2Mn0.8 (EN AW-5050)
- Stainless steel housing: On request
- Connector: Brass, nickel plated or Diecast zinc, nickel plated
- Sealing rings: Silicone / NBR

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, ....).

Mounting orientation: horizontal.

Date: 23.01.2020
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