MEMS vibration sensor NVA 65
with analogue and CANopen interface

- ■ **Contactless, wear-free sensor system in MEMS technology**
- ■ **Number of measurement axes: 2**
- ■ **Frequency range: 0.1 ... 60 Hz Option: 0.1 ... 100 Hz**
- ■ **Measuring range: ± 2 g**
- ■ **Interfaces: analogue, CANopen, relays**
- ■ **Resolution: 4096 digits / g**
- ■ **Output: Momentary value RMS value Peak value**
- ■ **Operating temperature range: - 40 °C to + 85 °C**
- ■ **Parameterisable via CANopen**

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 sensors, a controller unit and three types of output interface. Data output is carried out via two analogue interfaces with 4 ... 20 mA plus CANopen and via 4 relay contacts (currently 1 error relay contact). The NVA is parameterised via the CANopen interface. This is not galvanically separated.

The sensor is equipped with a filter circuit to protect against fast transients and surge voltages of up to 2 kV in the supply. The protection types are IP 69K (housing) and IP 67 (connector/socket). With its good vibration and shock values, the sensor is suitable for use in areas with rough environmental conditions.

The vibration sensor is equipped with a stable aluminium housing (optionally stainless steel). Elongated holes are available for mechanical alignment (up to approx. ± 7.5°). Electrical connection is carried out using two connectors or two cables.

Function

MEMS sensors are integrated circuits which are manufactured in silicon bulk micromechanics technology. Double capacities are formed with the aid of these micromechanical structures. If these structures are deflected in the case of accelerations, this leads to capacity changes which are registered using measuring technology and further processed. The sensors measure precisely, 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 six 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 seconds. This calculation takes place continually.

The filter units can be individually programmed by the customer as regards their sampling frequency, whilst their filter characteristics can be programmed in the factory. Each filter unit additionally has two outputs (flags) for alarm and warning. If the amount of a filter output's measured value exceeds the set limit value the output is activated. The limit values for triggering the outputs can also be programmed by the customer.

The warning and alarm outputs can be connected to the four relay outputs via a matrix which can be programmed by the customer. Several filter outputs may additionally be connected to the relay outputs by means of an OR link.

The analogue outputs are firmly connected to filters 1 and 2. The outputs output the filtered signed signal supplied by the acceleration sensor. The quiescent level of the 4 ... 20 mA interface is 12 mA with an acceleration of 0 m/s² or 0 g. Amplifier setting is individually possible for each channel via the CANopen interface.

The CANopen interface can be used to set the parameters and call up the 6 filters' outputs. With the exception of the filter characteristics, all parameters are programmable.

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General information

The vibration sensor measures on two axes in a frequency spectrum from 0.1 to 60 Hz (Option: 0.1 to 100 Hz). This spectrum can be subdivided into a maximum of 6 frequency ranges. The frequency ranges are set in the factory. They can also be subsequently shifted by the customer by means of CANopen objects. All acceleration values acting within the relevant frequency window are registered and are output firstly as an analogue value (4 ... 20 mA, max. two outputs possible) and secondly as a digital value via CANopen. The acceleration values which are present are additionally compared with limit values (maximum values). If these limit values are exceeded, relevant relays switch (normally closed contacts, a maximum of four is possible). There is a warning stage and a stop stage. The limit value for 'warning' is lower than the limit value for 'stop'. The limit values for these stages can be set in the factory or by the customer.

The measuring axis is x, y or the vector sum $\sqrt{(x^2+y^2)}$.

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 and the further processing value for the relay circuit. The time over which averaging is carried out can be set.

Filter characteristics

Digital pre-filtering is initially carried out in the MEMS sensor to extensively suppress higher-frequency interference vibrations (> ≈ 100 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 digital 8th to 11th-order Chebichev filters (11th order in the lower frequency range, 8th order in the upper frequency range).

The 6 filter units are of the same design; their characteristics can be set in the factory as desired by the customer. In the standard version, these filters (low-pass, band-pass and high-pass) are implemented as Chebichev filters. Chebichev filters are continuous frequency filters which are designed for the sharpest possible kinking of the frequency response at the limit frequency fg. To achieve this, amplification in the pass range or in the stop range is not monotonous but possesses a waviness which has to be defined. The higher the permissible waviness, the sharper the drop within an order. A distinction is made between type I and type II Chebichev filters. In the pass range, type I Chebichev filters possess an oscillating frequency response curve. Type II Chebichev filters have this frequency response waviness in the stop range and are also referred to as inverse Chebichev filters in the specialist literature. The case here involves type II.

The maximum upper frequency limit of the vibrations to be measured is 60 Hz (Option: 100 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 0.1 Hz. Figures 1 and 2 show examples of a possible frequency curve. The filter's output values are signed.

The output of each filter 1 - 6 is further processed for the analogue outputs (filters 1 + 2 only), for output via CANopen and for the limit value relays which respond to the exceeding of acceleration limit values.

The filters' relevant output signal can be set via the CANopen interface as follows:

- Output of the momentary value of the measured acceleration
- Output of a mean value over time for the measured acceleration (RMS averaging time adjustable via CAN)
- Output of the peak value (peak) of the measured acceleration

   (Note: this value is retained until the peak value is next exceeded, or it is reduced again over a parameterisable time if this value is no longer reached during the subsequent period of time: Adjustable via CAN).

Switching outputs

The switching outputs react to the amount of the filter's output value (folding up of the negative half-waves of the measured vibration curve).

The warning output is activated after exceeding the corresponding limit, i.e. the relay contact opens. The relevant relay drops off. It is reset when the limit is no longer reached for 10 s. Otherwise the time is extended.

The alarm output is activated after exceeding the corresponding limit, i.e. the relay contact opens. The relay drops off and remains constantly triggered. It can only be deleted by resetting the system.

The reference value is the amount of the currently measured vibration's momentary value. If a positive deviation event occurs 1 x, the corresponding relay is triggered. During normal operation, the relays are picked up. They drop off in the event of triggering or when the NVA is voltage-free.

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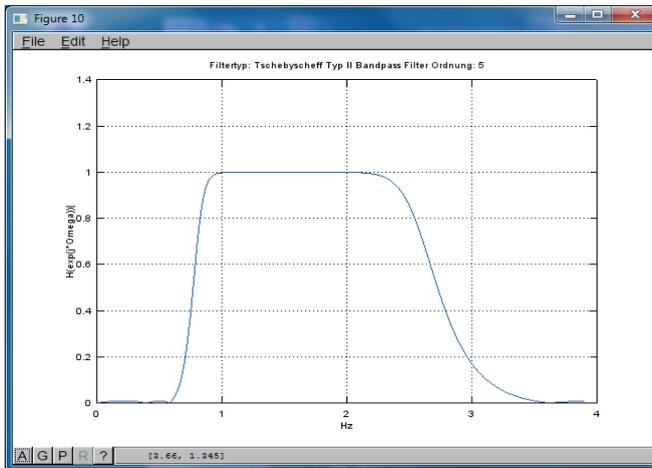
Examples for fiter output

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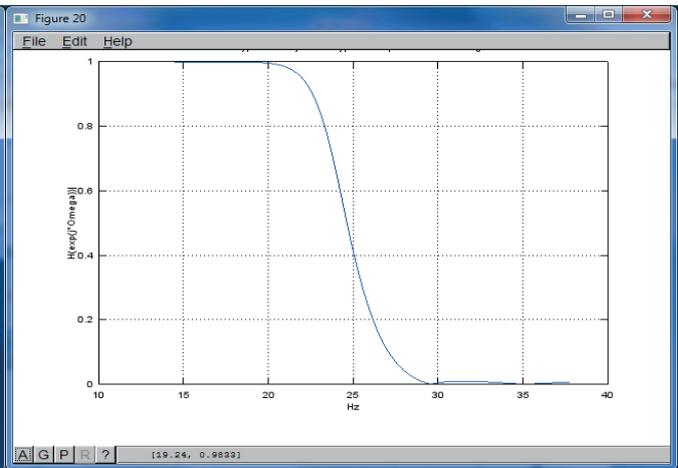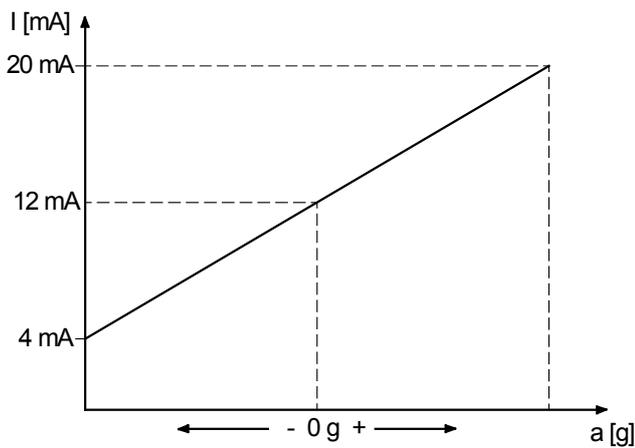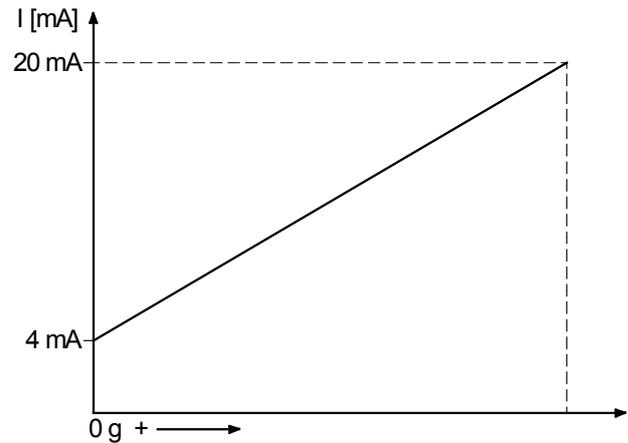f_{gu} = 0.8Hz, f_{go} = 2.5 Hz

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

Diagram for analogue output $I_0(a)$

Output: signed

- x, momentary value
- y, momentary value

Output: absolute value

- x, RMS value
- y, RMS value
- x, Peak value
- y, Peak value
- $\sqrt{(x^2+y^2)}$, RMS value
- $\sqrt{(x^2+y^2)}$, Peak value
- $\sqrt{(x^2+y^2)}$, momentary value

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Parameters programmable via CANopen interface

- Measuring axis: x or y or $\sqrt{(x^2+y^2)}$ separately for each filter 1 - 6
- Sampling frequency (120 ... 800 Hz). Can be set separately for each frequency band.
- Filter frequency range (by changing the sampling frequency)*
- Signal type at filter output 1 - 6: momentary value, RMS mean value, peak value or degressive peak value
- Averaging time for signal type 'RMS'
- Decrease time for signal type 'Peak'
- Amplification for analogue outputs 4 ... 20 mA
- Acceleration limit values (limit) for relay warning function
- Acceleration limit values (limit) for relay stop function
- Frequency band ↔ relay assignment

*Note: The frequency ranges (frequency windows) are pre-set in the factory in accordance with the customer's wishes. Factory-set sampling frequency: 240 Hz. If the sampling frequency is increased e.g. by 10%, all of the individual frequency windows' lower and upper frequency limits are shifted upwards 10% (example: before: sampling frequency 240 Hz, lower frequency limit 1 Hz, upper frequency limit 15 Hz. After: sampling frequency 264 Hz → lower frequency limit = 1.1 Hz and upper frequency limit = 16.5 Hz.

Electrical data

- Sensor system: MEMS acceleration sensor
- Resolution: 4096 digits / g (9.81 m/s² = 1 g)
- Operating voltage range: + 18 to + 30 VDC
- Power consumption: ≤ 2 W

Environmental data

- Operating temperature range: - 40 °C to + 85 °C
- Storage temperature range: - 45 °C to + 85 °C
- Resistance to shock: 500 m/s² / 5 ms, according to DIN EN
- Resistance to vibration: 10 Hz ... 2000 Hz / 100 m/s², according to DIN EN 60068-2-6
- Protection type (DIN 40 050):   IP 67   plug connection
              IP 69K   housing
- 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)
- Weight: 0.3 kg

Signal acquisition

- Number of axes: maximum of 2
- Value output on analogue output: x and y as separate components or vector sum (resulting R)
- Number of frequency bands: maximum of 6
- Measuring range: ± 2 g for each axis
- Sampling frequency: 240 Hz (cycled down to 120 Hz in the lower frequency range)
- Accuracy of the measured acceleration value: 1. : MEMS sensor: ± 20 mg over the entire frequency range
              2. : Signal processing error: 0 to 20 Hz: ± 1%, with reference to 1 g
              20 to 60 Hz: - 5%, with reference to 1 g
- Maximum inclination vs. horizon: 10°
- Lower limit frequency: 0.1 Hz
- Upper limit frequency: 60 Hz (Option: 100 Hz)

Signal output

- 1 CANopen interface with 4096 digits / g
- 2 analogue outputs 4 ... 20 mA (12-bit resolution)
- 4 relays for warning and/or stop function on exceeding limit values
- 1 relay for error display

- System calibration for higher accuracy
- Programmable steady component in the output signal (measured vibration value curve zero point shift)
- Up to 8 relays
- Transistors instead of relays
- Further filters
- Evaluation procedures (Datalogging, log functions with programmable triggering, statistics, protocol functions)
- Safety design for safety applications
- Other customer variants

CANopen technical data

CANopen communication profile

- Full CAN part A (11-bit) CANopen 301 V 4.1 (no galvanic bus separation)
- CANopen output code: signed 16-bit

Output level according to ISO/DIS 11898
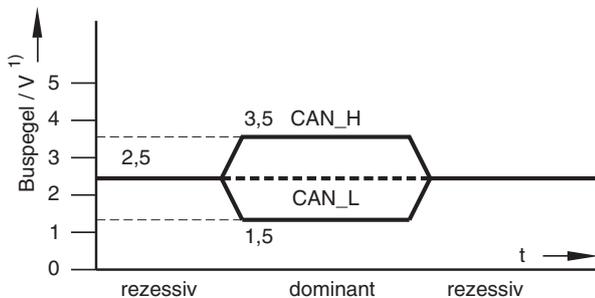
1) bei Common-Mode-Spannung = 0V

Bus activation according to ISO / DIS 11898
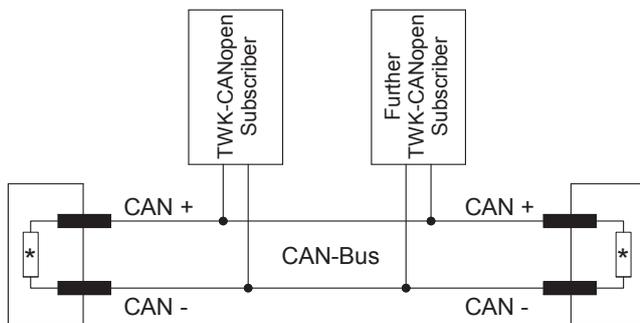
*Terminating resistor (120 Ω)

CANopen features

- NMT master: no
- NMT-slave: yes
- Maximum boot-up: no
- Minimum boot-up: yes
- COB ID distribution: default, SDO
- Node ID distribution: via Index 2000 or LSS
- No. of PDOs: 2 Tx
- PDO modes: sync, async, cyclic, acyclic
- Variable PDO mapping: no
- Emergency message: yes
- Heartbeat: yes
- No. of SDOs: 1 Rx / 1 Tx
- Device profile: CiA DSP 410 version 1.2

The details of the profile are exhaustively describedin the NVA 12657 specifications.

Data format CANopen - PDO

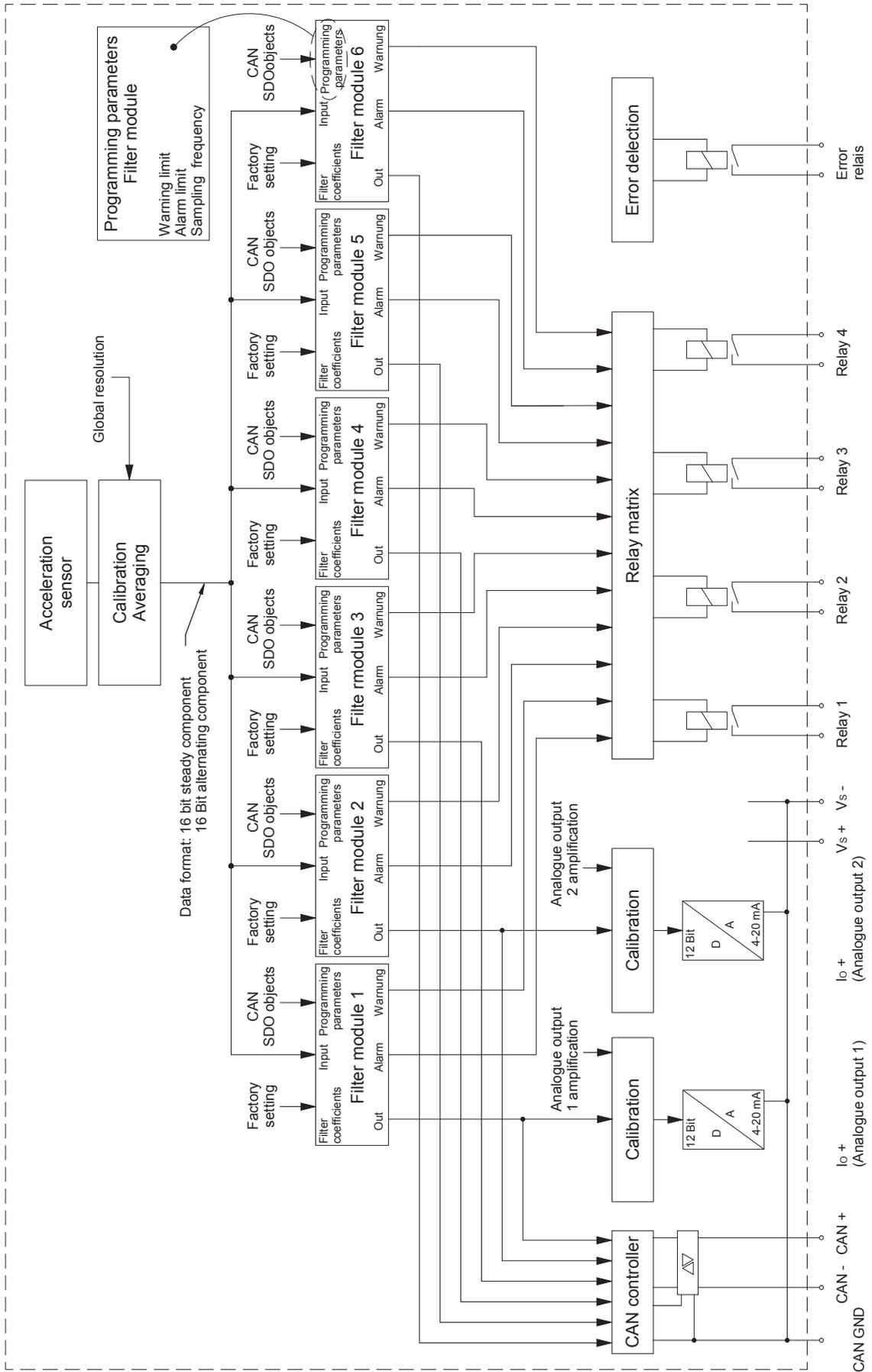| Data Byte 0	Data Byte 1
0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15
LSB	MSB
Filter 3	

Data Byte 2	Data Byte 3
0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15
LSB	MSB
Filter 4	

Data Byte 4	Data Byte 5
0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15
LSB	MSB
Filter 5	

Data Byte 6	Data Byte 7
0 1 2 3 4 5 6 7	8 9 10 11 12 13 14 15
LSB	MSB
Filter 6	

The momentary values of filters 1 and 2 are output via the analogue outputs. With CANopen, they can be read out via relevant objects, not via the PDO (e.g. for cyclical output), as it has a maximum size of 8 bytes. See NVA 12657 specifications.

Analogue technical data

Output circuits

Output A
$I_o = 0 - 20$ mA
$R_L = 0 - 0.5$ k

Output B
$I_o = 4 - 20$ mA
$R_L = 0 - 0.5$ k

Output data

- **Current output**
  - **A:** 0 to 20 mA
  - **B:** 4 to 20 mA
- Accuracy: ± 10 µA at room temperature, ± 50 µA over the entire temperature range
- Load resistance: 0 ... 500 Ω

Limit value relay technical data

- Maximum switching current: 1.0 A at 30 VDC / VAC
- Maximum switching voltage: 60 VDC / VAC   Note: The effective maximum voltage is dependent on the connector into which the switching contacts are integrated: M12, 12-pin: max. 30 VDC, M12, 8-pin: max. 60 VDC.
- Maximum contact resistance: 100 mΩ
- Response time: 3 ms (ON and OFF)
- Relay service life: 20 FIT ** with 10^5 switching cycles / year
- Switching: 10 digits (~1°)

** FIT = Failure In Time, 1 FIT = 1 failure in 10^9 years

Signal processing

NVA principle circuit diagram with signal flow

Order number

| NVA | 65 | - | A | 5 | 5 | 2 | S | 1 | - | 1 | - | B | 01 |

Electrical and / or mechanical variants*
01   Standard

Analogue output signal:
A   0 - 20 mA
B   4 - 20 mA

Installation position:
1   Top: 1, 2, 3, 4, 5 or 6 (see below), **preferably 1**

Cable length in metres:
1   (complete in the case of a cable only)

Electrical connections:
S   Device connector M12 - connector / socket
K   Cable

Number of analogue outputs:
2   1 or 2

Number of relays:
5   0 to a maximum of 4 warning- / alarmrelays plus 1 error relay (obligatory): 1 to max 5

Number of frequency ranges:
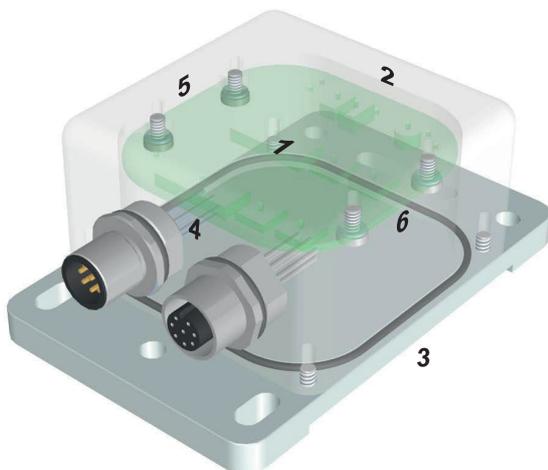5   1 to a maximum of 6

Housing material:
A   Aluminium AlMgSi1
S   Stainless steel 1.4305 or 1.4404

Design form:
65   Design form 65 mm

NVA   NVA vibration sensor with analogue interface and CANopen interface

The sensor installation position desired by the customer must be specified using an ID digit in the order number: the digit belonging to the surface which is to point upwards is specified. Example : if the side with the connectors is to point upwards: 4. Recumbent: 1, etc.

* 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. The special version in accordance with the table on page 9 is reflected in the variant number.

Accessories

Straight mating connector

- **STK8GS54 (socket, female)**
- **STK8GP99 (connector, male)**

Documentation, EDS file, etc.

- The following documents can be found in the Internet under
  www.twk.de in the documentation area
  NBN model (letter "N")

  ☐ EDS file
  ☐ Bit map image file
  ☐ Data sheet No. NVA 12634
  ☐ Specification No. NVA 12657
  ☐ Description of the filter and programming settings
     (individually for each pre-set device, therefore on request only)

Optionally, a CD-ROM can be supplied.
(Article No. TWK-CD-01; please specify when ordering.)

- Supply source for the listed CANopen specifications:
  CAN in Automation (CiA),
  Kontumazgarten 3, D-90429 Nuremberg
  (Email: headquarters@can-cia.org, www.can-cia.org)

Table for factory programming according to customer specifications

Here, please specify your wishes for the required properties of the vibration sensor concerning the output signal and switching relays. Delivery from the factory is then carried out with this programming.

Signal evaluation: Whether the acceleration values are further processed without changes (momentary values) (enter M), whether RMS mean value determination over time (R) is to take place or whether the peak value is to be output (P) is entered here. The related time-constant (Peak decrease / RMS averaging) can be entered in row - Time decr. / averag. [s].

(In part, the programming can be changed using CANopen objects. See remark on page 11)

Frequency band 1 - customer designation:

Lower limit frequency [Hz]	Upper limit frequency [Hz]	Measurement axis: x or y or resulting R	Signal evaluation: M, P oder R	Time decr. / averag. [s]	Analogue signal measuring range [± .. g]	Switching lim. warning relay [g]	Switching limit stop relay [g]

Frequency band 2 - customer designation:

Lower limit frequency [Hz]	Upper limit frequency [Hz]	Measurement axis: x or y or resulting R	Signal evaluation: M, P oder R	Time decr. / averag. [s]	Analogue signal measuring range [± .. g]	Switching lim. warning relay [g]	Switching limit stop relay [g]

Frequency band 3 - customer designation:

Lower limit frequency [Hz]	Upper limit frequency [Hz]	Measurement axis: x or y or resulting R	Signal evaluation: M, P oder R	Time decr. / averag. [s]		Switching lim. warning relay [g]	Switching limit stop relay [g]

Frequency band 4 - customer designation:

Lower limit frequency [Hz]	Upper limit frequency [Hz]	Measurement axis: x or y or resulting R	Signal evaluation: M, P oder R	Time decr. / averag. [s]		Switching lim. warning relay [g]	Switching limit stop relay [g]

Frequency band 5 - customer designation:

Lower limit frequency [Hz]	Upper limit frequency [Hz]	Measurement axis: x or y or resulting R	Signal evaluation: M, P oder R	Time decr. / averag. [s]		Switching lim. warning relay [g]	Switching limit stop relay [g]

Frequency band 6 - customer designation:

Lower limit frequency [Hz]	Upper limit frequency [Hz]	Measurement axis: x or y or resulting R	Signal evaluation: M, P oder R	Time decr. / averag. [s]		Switching lim. warning relay [g]	Switching limit stop relay [g]

Example: Frequency band 1 - customer designation: low-frequency mast vibration

Lower limit frequency [Hz]	Upper limit frequency [Hz]	Measurement axis: x or y or resulting R	Signal evaluation: M, P oder R	Time decr. / averag. [s]	Analogue signal measuring range [± .. g]	Switching lim. warning relay [g]	Switching limit stop relay [g]
0.1	15	R	M	10	1 - 1 g to + 1 g = 4 to 20 mA	0.7 At 0,7 g: Warning	1 At 1 g: Stop

Note: 'Output signal measuring range' can only be assigned in the case of filters 1 + 2

The 'warning relays' and 'stop relays' can be assigned a maximum of 4 times, as there are a maximum of four relays

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Remarks on the table on page 10

"Analogue signal measuring range" means the analogue output signal 4 ... 20 mA (max. 2). The analogue output signal is possible only for filter 1 and 2. The amplification factor can be added in this field (for example: ±0.5 g = 4 ... 20mA). **All** instantaneous values of the individual frequency bands are communicated through CANopen.

Please consider that the sampling frequency f_a influences the upper and lower threshold frequency f_{gu} and f_{go} of a frequency band.

For the lower threshold frequency the following relationship is established: $f_{gu} \geq f_a \cdot 0.005$.

Example: sampling frequency f_a = 240 Hz (factory setting): The following applies in this case: $f_{gu} \geq 240$ Hz $\cdot 0.005 = 1.2$ Hz, i.e. f_{gu} must be selected higher than 1.2 Hz. f_a can be set separately from 120 Hz to 800 Hz for each frequency band.

This results in the fact that the lower limit frequency fgu cannot/must not fall below certain values, i.e. it must not lie or cannot be selected in the 0.1 Hz < f_{gu} < 0.6 Hz range. f_{go} is not critical.
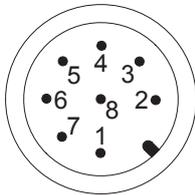
In case a low pass filter is selected instead of a band pass filter, the lower frequency limit of 0.1 Hz is valid.

Electrical connection

Via connector - socket combination M12, 8-pin or using 2 x cables.
The connector / socket cannot be exchanged.

Connector S1
(connection M12, 8-pin, connector, A-coded. Viewed looking at the contacts)

PIN	Function
1	+ U_B supply voltage
2	Analogue output 1: 4 ... 20 mA
3	Analogue output 2: 4 ... 20 mA
4	- UB supply voltage and reference potential for analogue outputs plus CAN GND
5	CAN +
6	CAN –
7	'System error' relay - normally open contact 1
8	'System error' relay - normally open contact 2

Connector S2
(connection M12, 8-pin, socket, A-coded. Viewed looking at the contacts)
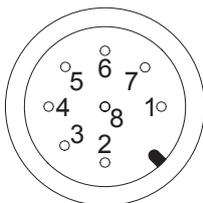
PIN	Function
1	Limit value relay 1 - normally open contact 1
2	Limit value relay 1 - normally open contact 2
3	Limit value relay 2 - normally open contact 1
4	Limit value relay 2 - normally open contact 2
5	Limit value relay 3 - normally open contact 1
6	Limit value relay 3 - normally open contact 2
7	Limit value relay 4 - normally open contact 1
8	Limit value relay 4 - normally open contact 2

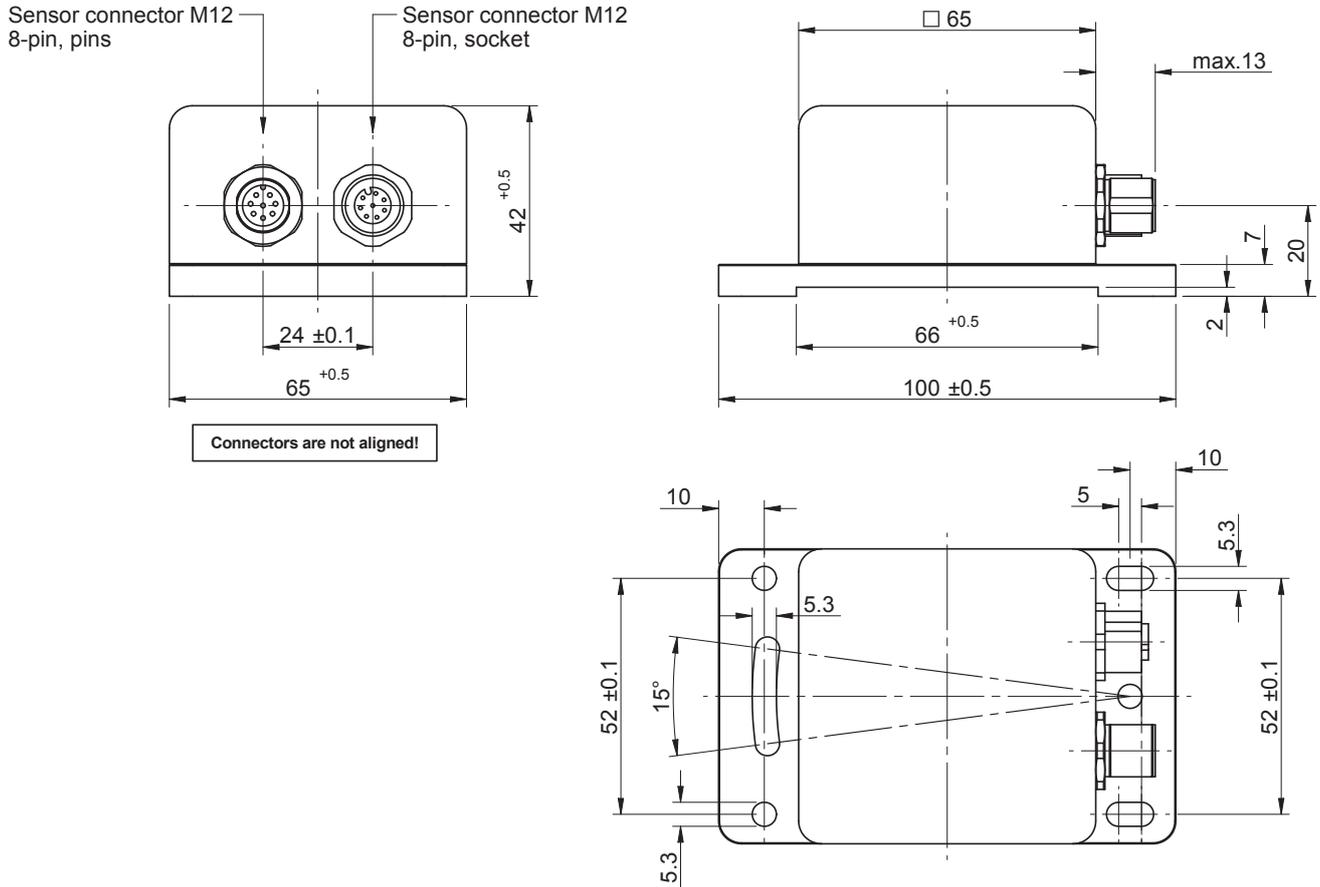Each switching contact is galvanically separated.

Important note: Refer to the connection assignment enclosed with each device for the contact assignment. Especially in case of special variants of the NVA.

MEMS vibration sensor NVA 65

Installation drawing

Dimensions in mm

Via round and elongated fastening holes for M5 bolts. The vibration sensor can be mechanically adjusted up to approx. ± 7.5° via the elongated holes. Fasteners are not included in the scope of delivery.

Sensor connector M12 8-pin, pins

Sensor connector M12 8-pin, socket

Connectors are not aligned!

Materials used

Aluminium housing: AlMgSi1
Stainless steel housing: 1.4305 or 1.4404
Connector: Nickel-plated brass
Threaded cable connection: Nickel-plated brass or stainless steel 1.4404
Sealing rings: NBR