

Inclination sensor on MEMS technology

Interface: **PROFIsafe/PROFINET**

Model **NBT / S3**



- **SIL2 and Performance Level d**
- **Number of measurement axes: 1 or 2**
- **Selectable measuring range: $\pm 5^\circ$ to $\pm 90^\circ$**
- **With preset function**
- **Housing: aluminium or stainless steel**
- **Protection type: up to IP69K**
- **As of hardware version 2 TÜV certified**

Design and function

The inclinometer measures the inclination in the gravitational field by means of MEMS sensors (Micro-Electro-Mechanical-System) with subsequent digitisation and linearisation via controllers. It has a stable aluminium housing (optionally stainless steel) and is highly-resistant to vibration and shock. Casting measures in the housing lead to the achievement of protection class IP 69K.

MEMS sensors are integrated circuits manufactured using silicon bulk micromechanical technology. Double capacities are formed with the aid of moveable micromechanical structures. If these structures are deflected in the case of acceleration, e.g. gravitational acceleration (**g**), this results in capacity changes, which are registered and further processed using measuring technology. The output voltage follows the function $U \sim g \cdot \sin \alpha$. In this case, the angle α is the sensor's inclination angle measured against the **g** vector. These sensors measure precisely, have a long service life and are very robust. The measuring axes operate independently of each other.

The NBT has a **redundant MEMS sensor system**, which is used to make a plausibility check inside the inclinometer. Only one position datum is output; the plausibility of this is checked using the second system's position datum. If the deviation of the two systems is higher than a certain value, the sensor will enter the failsafe state.

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 inclinometer series NBT/S3.

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 [NBT13912](#) 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

Inclinometer NBT/S3

General description

Behaviour in the event of a measured value change due to averaging:

Dynamic, arithmetic averaging of the measured values is implemented in the inclinometer. This involves linear averaging over 1000 values, whereby a new value is recorded every millisecond. This results in a low-pass effect. In the event of an abrupt change in the measuring angle, the end value is reached after approx. 1 second. In the event of a linear change in the measuring angle, the relevant output signal follows after a delay of approx. 0.6 seconds. Other, e.g. shorter, values may be set depending on application conditions. However, the output signal then tends to have a higher noise factor.

Behaviour in the case of lateral inclination:

For one axis sensors please consider the following: the measured axis is no longer detected in case of an inclination in a second axis (cross-axis inclination) greater than 15°. Meaning the sensor will go in an over flow stage (+180°). In the status word the bit "Out_of_range" is set. This feature is required since measuring accuracy decreases with increasing cross-axis inclination.

Behaviour in the case of interference accelerations (shocks and vibrations):

In certain applications, interference accelerations occur due

to shocks, impacts or resulting post-oscillation processes in normal operating condition. These interferences are temporally limited and can exceed the measuring range of the internal MEMS sensor (2.2 g). On occurrence of such interference the position output value is set to -180° and in the status word the bit "Position_not_valid" is set. The control system is thereby notified that inclination measurement is not possible due to shock and vibration stresses. The sensor does not switch to the failsafe state. This behaviour is not temporally limited.

As the sensor does not enter the failsafe state, the user is required to ensure that the machine/system is in normal operating state during the period of time in which inclination measurement is not possible due to interference accelerations. Via his control system programme, the user must ensure that no dangers arise due to the application during this time.

As soon as there is no further interference acceleration due to shock and vibrations, regular inclination data are output again, and not -180°.

Depending on the current measuring range, interferences which reveal an amplitude of less than 2.2 g are interpreted by the NBT/S3 as a measuring range overshoot (the MEMS sensor is an acceleration sensor). In this case, the overflow value of +180° and the bit "Out_of_range" are output.

Measuring accuracy

Device with 1 or 2 axes, ± 20° measuring angle:

Accuracy:	± 0.25° (cross tilt ± 5°), otherwise ± 0.5°
Drift:	± 0.3°; range [-10 °C to +60 °C] ± 0.5°; range [-40 °C to +70 °C]

Device with 1 axis, ± 90° measuring angle:

Accuracy:	± 0.5° (cross tilt ± 3°) ± 0.25° within 20° (cross tilt ± 3°)
Drift:	± 0.3°; range [-10 °C to +60 °C] for ± 60° ± 0.4°; range [-40 °C to +65 °C] for ± 90° ± 0.5°; range [-40 °C to +70 °C] for ± 60° ± 0.6°; range [-40 °C to +70 °C] for ± 90°

Inclinometer NBT/S3

Technical data

Input data *

- 2 byte status word
- 3x2 byte position data

Output data *

- 2 byte control word
- 2 byte preset word

Electrical data

- Sensor system: MEMS acceleration sensor
- Operating voltage: 9 to 36 VDC
- No. measuring axes: 1 or 2
- Measuring range: $\pm 5^\circ$ to $\pm 90^\circ$ (selectable for example $\pm 5^\circ$, $\pm 10^\circ$ $\pm 85^\circ$, $\pm 90^\circ$ → see page 8)
- Resolution: 0.01°
- Power consumption: < 3 W
- Current: approx. 90 mA (at 24V)
- Absolute accuracies: $< \pm 0.5^\circ$ (see note on page 2)
- Repeatability: $\pm 0.05^\circ$
- Noise: $\pm 0.05^\circ$
- Zero error: $\pm 0.5^\circ$
- Tolerance of the internal deviation monitoring: $\pm 2^\circ$
- Signal path: ascending values with CCW
- Reaction time: 1 s (for 100 % of the current end value, see note on page 2)

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 μ s

Environmental data

- Temperature range: - 40 °C ... + 70 °C
- Storage temp. range: - 20 °C ... + 60 °C (due to packaging)
- Resilience
 - To shock: 200 m/s²; 11 ms, DIN EN 60068-2-27
 - To vibration: 100 m/s²; 10 ... 2000 Hz, DIN EN 60068-2-6
- Protection grade: IP 66 / IP 67, IP 68 with cable output, IP 69K with casting
- Humidity: $\leq 95\%$ non-condensing
- Max. altitude: 4.000 m
- EMC standards:
 - EN 61000-4-2 (ESD) (Only use shielded cable for power supply and PROFINET)
 - EN 61000-4-4 (Burst)
 - EN 61000-6-3(4) (Emission)
- Salt mist test: Test Kb according to IEC 60068-2-52
- Weight: Approx. 0.3 kg (aluminium) or approx. 0.65 kg (stainless steel)

Safety relevant data of hardware version 2

- According to DIN EN 61508: PFH = $5,27 \cdot 10^{-8}$
SFF = 97,3%
HFT = 0
SIL2
- According to DIN EN ISO 13849-1: MTTF_d = 100 years (calculated 211,5 years)
DC_{avg} = 96,7%
Categorie 2
Performance Level D
- Maximum service life: 20 years

* From the point of view of the control system

Inclinometer NBT/S3

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

Cable output PROFINET (optional)

- 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

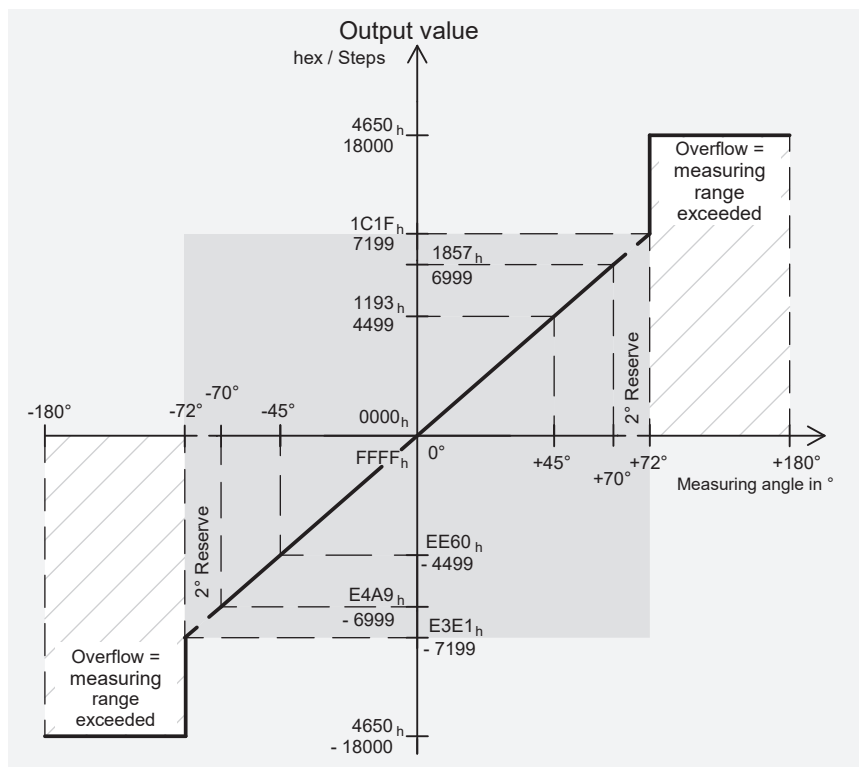
Cable output power supply (optional)

- Cable type: 2 x 0,75 mm², shielded
- Cable jacket: PUR, color: gray
- Temperatur range: - 40 °C to + 70 °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

Characteristic curve

Characteristic curve (example)

- Example: $\pm 70^\circ \triangleq 2 \times 7000$ steps with resolution 0.01°
- Example: $\pm 20^\circ \triangleq 2 \times 2000$ steps with resolution 0.01°
- Data format: Signed 16-bit.

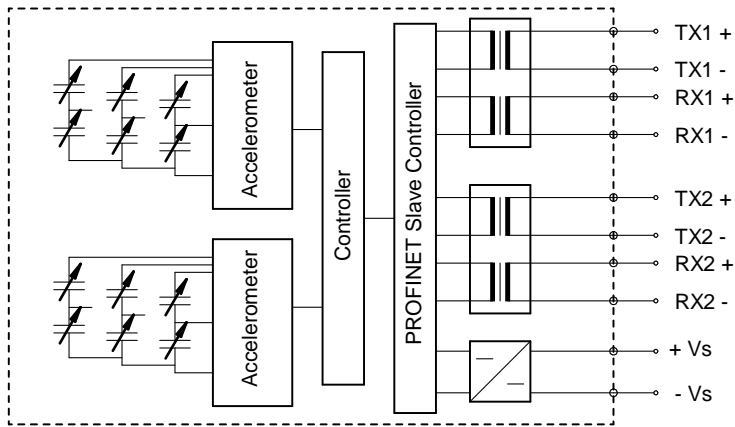


When exceeding the selected range (eg $\pm 70^\circ$), plus about 2° the output value is set to 4650_{hex} (= 18,000_{dez} = 180°) in order to signal the controller that the inclinometer is tilted out of the selected scale.

Inclinometer NBT/S3

Electrical connection

Block diagram



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	—

Remark

Only use shielded cable for power supply and PROFINET.

Inclinometer NBT/S3

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 controller
			red, slow flashing	Firmware download mode
			red flashing	Error message occurred, see NBT13912 chapter 7
			Fast red flashing	Device error
			red	Connection to the PROFINET controller disrupted

Inclinometer NBT/S3

Order number

NBT 90 - A x / y / z V S3 - 1 - S 3 T 01 → Standardversion

Electrical and mechanical variants *:

01 Standard

Output interface:

T PROFINET

Electrical connections:

- 1 Connector (hybrid connector)
- 2 Connector (1x PROFINET, 1x power supply)
- 3 Connector (2x PROFINET, 1x power supply)
- x Cable length in m (for cable output)

Electrical connections***:

- S Connector M12
- K Cable

Installation position (See pages 11-12):

- 1 TOP 1, 2, 3, 4, 5, 6

See below: Available types

Profile:

- S3 PROFIsafe, SIL2

Behaviour during disturbance acceleration:

- V Standard (See page 2)

Measuring ranges ** (See pages 11-12):

- ± z° z-axis
- ± y° y-axis
- ± x° x-axis

See below: Available types. Other types on request.

Housing material ***:

- A Aluminium AlMgSi1
- V Stainless steel 1.4404

Design form:

- 65 Design form 65
- 90 Design form 90

NBT Inclinometer with Profinet interface

Available types

(Standard versions. Other measuring ranges and installation positions on request)

- NBTxx-A20/20/0 V S3-1-xx T01
- NBTxx-A90/0/0 V S3-2-xx T01

* 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 measuring ranges for the various measurement axes can be selected in 5° steps, whereby it must be noted that only 2 axes can be used at any one time. For the undesired axis please choose '0'. Accuracy differences may possibly arise in terms of the compatibility of the measuring ranges or the measuring angles. Please talk to one of our employees.

*** Aluminium housing with connector M12, stainless steel housing preferably with cable (D-sub connector for test purposes mounted).

Inclinometer NBT/S3

Accessories, documentation, GSD file

Accessories (to be ordered separately)

■ Straight mating connector

STK4GP81 for PROFINET in/out (die-cast zinc, nickel-plated), see data sheet [STK14570](#)

STK4GP110 for PROFINET in/out (stainless steel 1.4404), see data sheet [STK14569](#)

STK4GS60 for the supply voltage (die-cast zinc, nickel-plated), see data sheet [STK14572](#)

STK4GS104 for the supply voltage (stainless steel 1.4404), see data sheet [STK14571](#)

■ Angled mating connector (only suitable for design form 90)

STK4WP82 for PROFINET in/out, see data sheet [STK14676](#)

STK4WS61 for the supply voltage, see data sheet [STK14675](#)

■ Connecting cable - Profinet

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), see data sheet [KBL14673](#)

KABEL-xxx-118 Industrial Ethernet data cable with M12 connector to RJ 45, IP 20 (xxx = length in metres),
see data sheet [KBL14655](#)

■ Connecting cable - power supply

KABEL-5-191 With moulded M12 connector, A-coded, straight, 2. side open, length 5m,
see data sheet [KBL13411](#)

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 NBT/S3

- Data sheet No. NBT13911
- Manual No. [NBT13912](#)

Inclinometer NBT/S3

Installation positions and measurement axis assignment

Installation position TOP 1... 6 of the 1- or 2-axis inclinometer must be taken into consideration on assignment or selection of the **measurement axes**. The installation positions specified below define the measurement axes and measuring range centre for x, y and z.

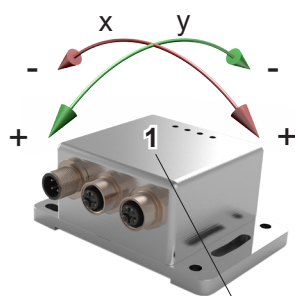
Which of housing surfaces 1 to 6 is to point upwards must be specified in the order number for the NBN65 (see figure on the right). The installation position is clearly marked on each device ('TOP'). This surface/edge must point upwards.

Only 2 of 3 axes are selectable. The installation position determines these axes.

Signal path: with the CW setting, the prefixes in the figures below specify the direction of rotation in which the output values increase positively during inclination measurement. This is accordingly reversed with the setting CCW.

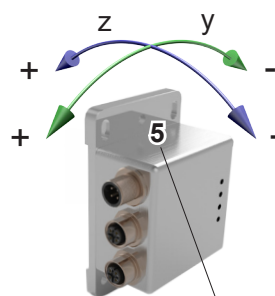
See page 7: Available types.

Installation position Top 1



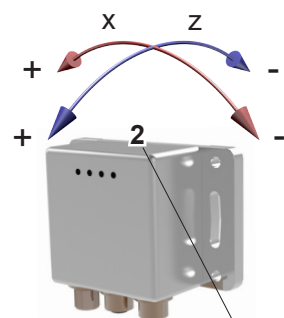
NBT65 - A xx/xx/0 C1 - 1 - S3 T01

Installation position Top 5



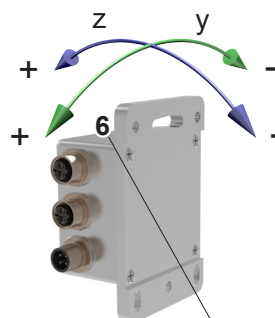
NBT65 - A 0/xx/xx C1 - 5 - S3 T01

Installation position Top 2



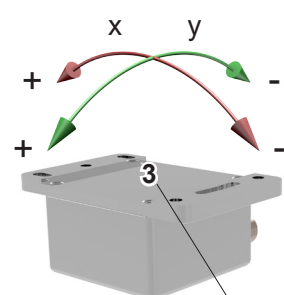
NBT65 - A xx/0/xx C1 - 2 - S3 T01

Installation position Top 6



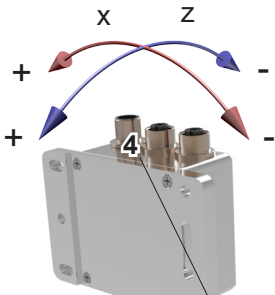
NBT65 - A 0/xx/xx C1 - 6 - S3 T01

Installation position Top 3



NBT65 - A xx/xx/0 C1 - 3 - S3 T01

Installation position Top 4



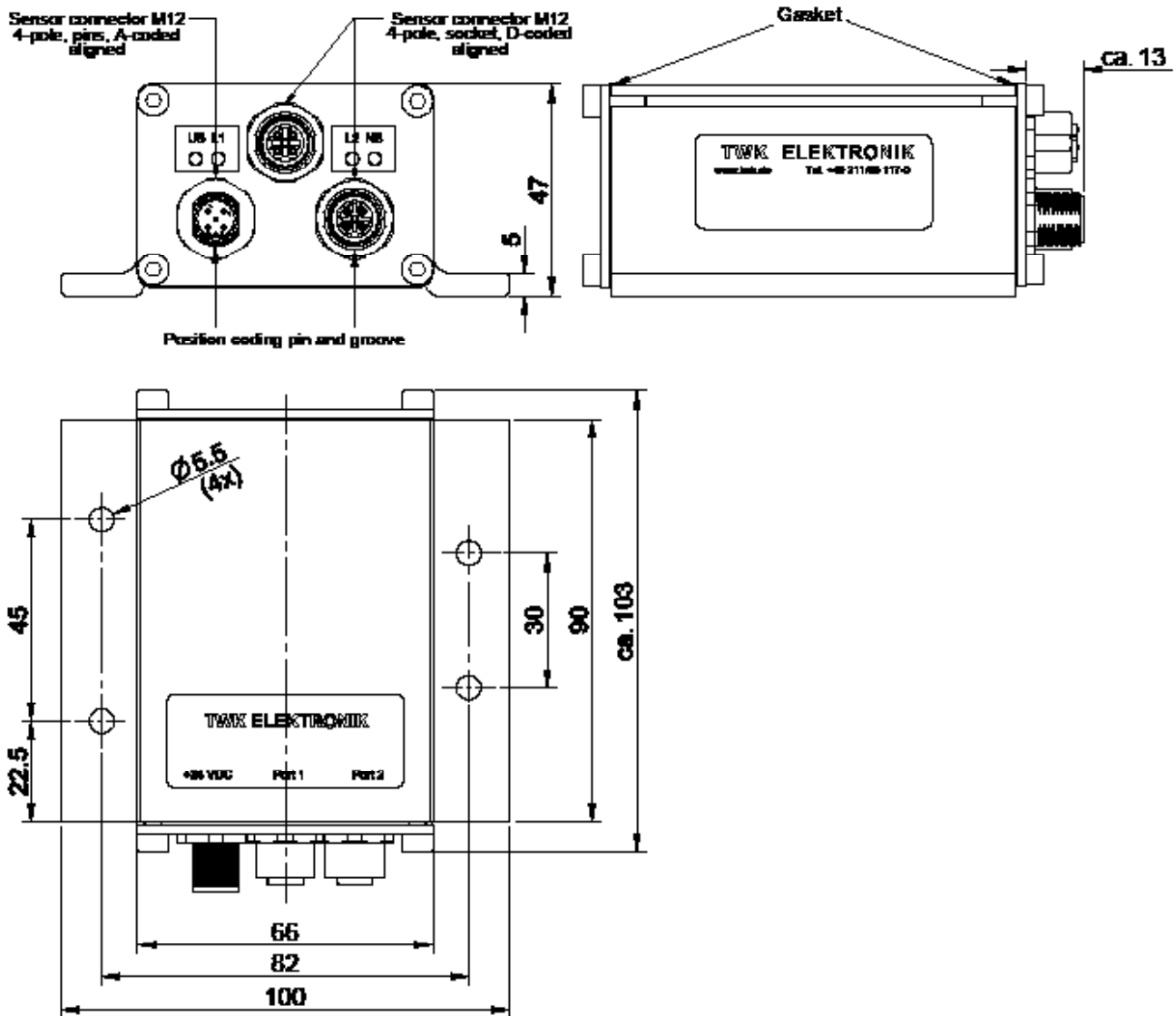
NBT65 - A xx/0/xx C1 - 4 - S3 T01

Inclinometer NBT/S3

Installation drawing

Design form 90, order number: NBT90-Axx/xx/xxVS3-x-S3T01

Dimensions in mm



Materials used

Aluminium housing:	AlMgSi1
Aluminium front plates:	AlMg2Mn0,8
Connector/cable gland:	Die-cast zinc, nickel-plated
Sealing rings:	NBR

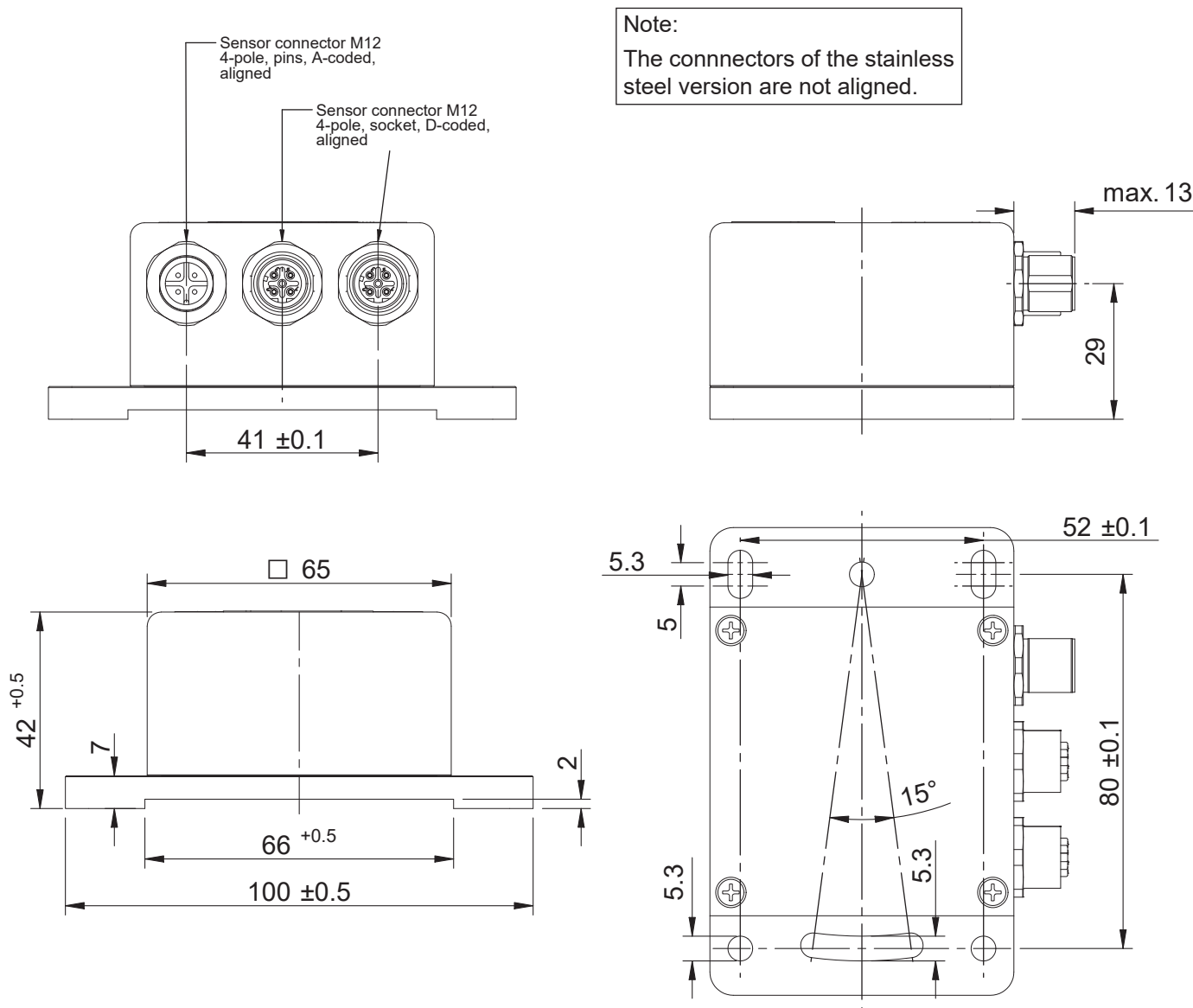
Inclinometer NBT/S3

Installation drawing

Design form 65, order number: NBT65-Axx/xx/xxVS3-x-S3T01

The installation is done via round and slotted mounting holes for M5 bolts. The inclination sensor can be mechanically adjusted up to approx. $\pm 7.5^\circ$ via the slots. Fasteners are not enclosed in the scope of delivery. When using the long holes additional security measures must be taken to prevent the device from any accidental displacement.

Dimensions in mm



Note:

The connectors of the stainless steel version are not aligned.

Materials used

Aluminium housing:	AlMgSi1
Stainless steel housing:	1.4404
Connector/cable gland:	Die-cast zinc, nickel-plated (when ordering a stainless steel housing, the connectors or cable glands will be of the same stainless steel quality or higher.)
Sealing rings:	NBR