SUPREME SENSORING

Inclination sensor
Model NBT/S3
Interface: PROFIsafe/PROFINET

Document no.:
NBT 13911 ME
04.12.2023

- **SIL2 and Performance Level d**
- **Number of measurement axes: 1 or 2**
- **Selectable measuring range: ± 5° to ± 90°**
- **With preset function**
- **Housing: aluminium or stainless steel**
- **Protection type: up to IP69K**
- **TÜV certified**

KEY INFORMATION OVERVIEW

DESIGN & 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 ~ g * sin α**. 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. Is the deviation of the two systems higher than a certain value, the sensor will enter the failsafe state.

FEATURES INTERFACE

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.

- 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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GENERAL INFORMATION

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, short-term shocks, impacts or vibrations can occur during normal operation. The resulting accelerations can exceed the measuring range of the internal MEMS sensor (2.2 g). On occurrence of such an even, 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. When these vibrations are temporarily limited, the sensor does not switch to the fail-safe state.

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°.

If the external disturbances exceed a certain time, the sensor enters the fail-safe state and needs to be reset with a power cycle.

When the external accelerations exceed the configured measurement range of the NBT/S3 but to do not exceed the measurement range of the internal MEMS sensor, the overflow value of +180° and the bit "Out_of_range" are send.

TECHNICAL DATA

ELECTRICAL DATA

Sensor system	MEMS acceleration sensor
Operating voltage	9 to 36 VDC
Number measuring axes	1 or 2
Measuring range	± 5° to ± 90° (selectable for example ± 5°, ± 10° .... ± 85°, ± 90°)
Resolution	0.01°
Power consumption	< 3 W
Current	approx. 90 mA (at 24V)
Absolute accuracy	< ± 0.5° (see below)
Repeatability	± 0.05°
Noise	± 0.05°
Zero error	± 0.5°
Tolerance of the internal deviation monitoring	± 2°
Signal path	ascending values with CCW
Reaction time	1 s (for 100 % of the current end value)

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]

MEASURING ACCURACY: 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°

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TECHNICAL DATA

INPUT DATA *

2 byte status word
3x2 byte position data

OUTPUT DATA *

2 byte control word
2 byte preset word

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

DIAGNOSIS LEDS

LED 1 (VS, green)	Operating voltage available
LED 2 (L1, green)	Link 1: Network connection established
LED 3 (L2, green)	Link 2: Network connection established
LED 4 (NS, green/red)	Device Status & error modes

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	IP66 / IP67, IP68 with cable output, IP69K with casting
Humidity	≤ 95% non-condensing
Max. altitude	4000 m
Salt mist test	Test Kb according to IEC 60068-2-52
Weight	Approx. 0.3 kg (aluminium) or approx. 0.65 kg (stainless steel)

EMC STANDARDS

EN 61000-6-4:2006 + A1:2011	EMC Part 6-4: Generic standards-Emission standard for industrial environments
EN 61000-6-2:2005	EMC Part 6-2: Generic standards-Immunity for industrial environments
EN 61000-4-2:2009	EMC Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test
EN 61000-4-3:2006 A1:2008 + A2:2010	EMC Part 4-3: Testing and measurement techniques - Radiated, radio frequency. electromagnetic field immunity test
EN 61000-4-4:2004	EMC Part 4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test
EN 61000-4-5:2006	EMC Part 4-5: Testing and measurement techniques - Surge immunity test
EN 61000-4-6:2009	EMC Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields
EN 61000-4-8:2010	EMC Part 4-8: Testing and measurement techniques - Power frequency magnetic field immunity test. Power frequency magnetic field immunity test: 30 A/m, test criterion A, 100 A/m, test criterion B
EN 61000-4-29:2000	EMC Part 4-8: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests
IEC 61326-3-2:2018	Electrical equipment for measurement, control and labortory use - EMC requirements Part 3-2: Immunity for safety-related systems and for equipment intended to perform safety related functions (functional safety) - industrial applications with specified electromagnetic environment

* From the point of view of the control system

TECHNICAL DATA

SAFETY DATA

According to IEC 61508 . . . . . PFH = 5.27 x10^{-8} 1/h
SFF = 97.3 %
HFT = 0
SIL2
According to ISO 13849-1 . . . . . MTTFd = 100 years (calculated 211.5 years)
DCavg = 96.7 %
Categorie 2
Performance Level D
. . . . . Maximum service life: 20 years

PROGRAMMABLE PARAMETERS (REFER TO HANDBOOK NBT13912 FOR DETAILS)

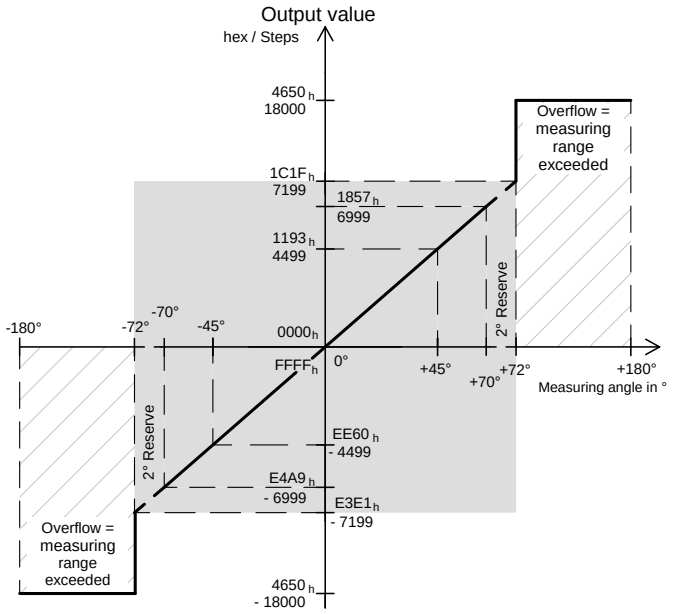
Scaling . . . . . Switches parameterisation on / off
Preset . . . . . Sets the output value of x, y, or z
Firmware download . . . . . Sets NBT in the state „firmware download mode“

PRODUCT CHARACTERISTICS

CHARACTERISTIC CURVE

Example . . . . . ± 70° ≙ 2 x 7000 steps with resolution 0.01°
Data format . . . . . Signed 16-bit

When exceeding the selected range (here ± 70°), 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.



PRODUCT CHARATERISTICS

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 NBN. The installation position is clearly marked on each device ('TOP'). This surface/edge must point upwards.

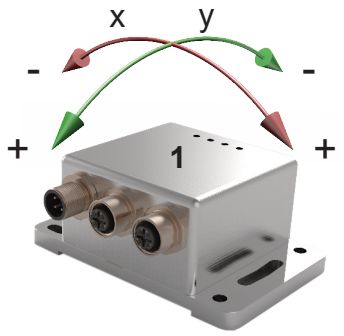
The definition of the side of the housing facing upwards (TOP1 to 6) refers to the side of the connector outlet. This applies to design form 65 (pictures below) and also to design form 90, e.g: Side TOP5 is to the left of the connector side, TOP4 = connector side, etc. Only 2 of 3 axes are selectable. The installation position determines these axes x, y and z.

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 8: Available types (standard).

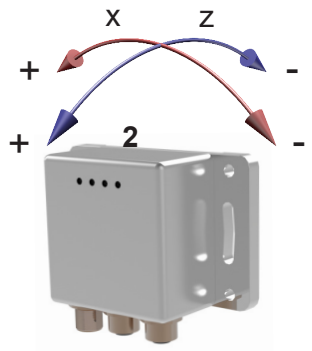
INSTALLATION POSITION TOP 1

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



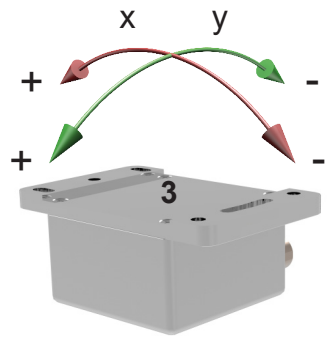
INSTALLATION POSITION TOP 2

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



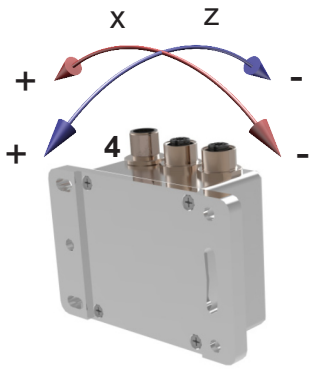
INSTALLATION POSITION TOP 3

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



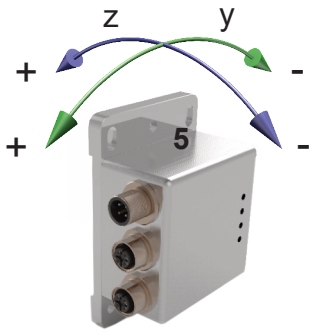
INSTALLATION POSITION TOP 4

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



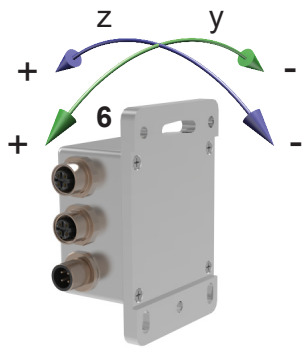
INSTALLATION POSITION TOP 5

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



INSTALLATION POSITION TOP 6

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



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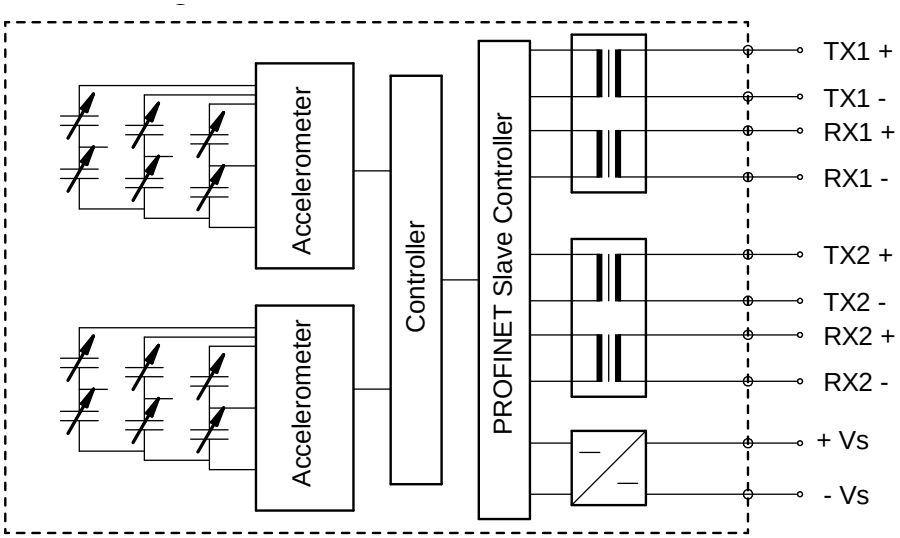
TECHNICAL DATA

PRINCIPAL CIRCUIT DIAGRAM



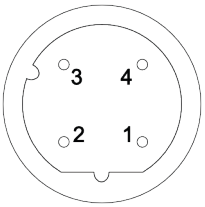
ELECTRICAL CONNECTION

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 CONNECTOR, 2 X M12, D-CODED, SOCKET/FEMALE

PIN.	Function
1	TX+
2	RX+
3	TX-
4	RX-

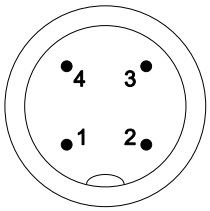


PROFINET CABLE OUTPUT (2X)

Colour*	Function
Yellow	TX+
White	RX+
Orange	TX-
Blue	RX-

SUPPLY CONNECTOR, M12, A-CODED, PINS/MALE

PIN.	Function
1	+UB (+24 VDC)
2	not used
3	-UB (0 VDC)
4	not used



SUPPLY CABLE OUTPUT

Colour.	Function
White	+UB (+24 VDC)
Brown	-UB (0 VDC)

REMARK

Only use shielded cable for power supply and PROFINET.

* Industrial Ethernet cable colours according to ISO / IEC 8802-3.

ELECTRICAL CONNECTION

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

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ORDER CODE FORMAT

NBT	90 -	A	20 /	20 /	0	V	S3	- 1 -	S	3	T	01	STANDARD VERSION

NBT	Inclination sensor with PROFINET interface		
90	Design form	65 90	Design form 65 mm Design form 90 mm
A	Housing material***	A V	Aluminium (see page 10) Stainless steel 1.4404
20	Measuring range**	± x°	x-axis (see below: Available types. Other types on request.)
20	Measuring range**	± y°	y-axis (see below: Available types. Other types on request.)
0	Measuring range**	± z°	z-axis (see below: Available types. Other types on request.)
V	Behaviour during disturbance acceleration	V G	Standard (see page 2 “interference accelerations“) Dynamic compensation with gyroscope data (on request)
S3	Profile	S3	SIL2 / PLd certified according to this data sheet
1	Installation position	1, 2, 3, 4, 5, 6	TOP position: see below: Available types and page 5
S	Electrical connection***	S K	Connector M12 Cable
3	Electrical connection	1 2 3 X	1 x connector (Hybrid connector) 2 x connector (1 x PROFINET, 1 x power supply) 3 x connector (2 x PROFINET, 1 x power supply) Cable length in m (for cable output)
T	Output	T	PROFINET
01	Electrical and mechanical variants*	01	Standard

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 at TWK.
** 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. When ordering a stainless steel housing, the connectors or cable glands will be of the same stainless steel quality or higher.

ACCESSORIES (TO BE ORDERED SEPARATELY)

MATING CONNECTORS

Order number, Datasheet	Type	Design & wire fixing	Housing-material	Cable ø & wire size	Shielding & IP grade
STK4GP81 STK14570	M12-D, 4-pole, male	Straight, screws	Die-cast zinc nickel-plated	5 – 8 mm ≤ 0.75 mm²	On housing IP67
STK4GP110 STK14569	M12-D, 4-pole, male	Straight, screws	Stainless steel 1.4404	5.5 – 8.6 mm ≤ 0.75 mm²	On housing IP67
STK4GS60 STK14572	M12-A, 4-pole, female	Straight, screws	Die-cast zinc nickel-plated	4 – 6 mm ≤ 0.75 mm²	On housing IP67
STK4GS104 STK14571	M12-A, 4-pole, female	Straight, screws	Stainless steel 1.4404	5.5 – 8.6 mm ≤ 0.75 mm²	On housing IP67
STK4WP82 STK14676	M12-D, 4-pole, male	Angled, screws	Die-cast zinc nickel-plated	5 – 8 mm ≤ 0.75 mm²	On housing IP67
STK4WS61 STK14675	M12-A, 4-pole, female	Angled, screws	Polyamid (PA)	4 – 6 mm ≤ 0.75 mm²	- (due to PA) IP67

CONNECTING CABLE - PROFINET

KABEL-xxx-114 . . . . Industrial Ethernet data cable with M12 connectors, D-coded, moulded on at both ends,
xxx = length in meters, standard lengths: 1, 2, 3, 5, 10, 15 and 20 m, see data sheet KBL14673

KABEL-xxx-118 . . . . Industrial Ethernet data cable with M12 connector to RJ 45, IP 20,
xxx = length in meters, standard lengths: 2, 3, 5, 10, 15 and 25 m, see data sheet KBL14655

CONNECTING CABLE - POWER SUPPLY

KABEL-xxx-191 . . . . With moulded M12 connector, A-coded, straight, 2. side open,
xxx = length in meters, standard lengths: 2, 5, 10, 15, 20 and 25 m, see data sheet KBL13411

DOCUMENTATION

DOCUMENTATION

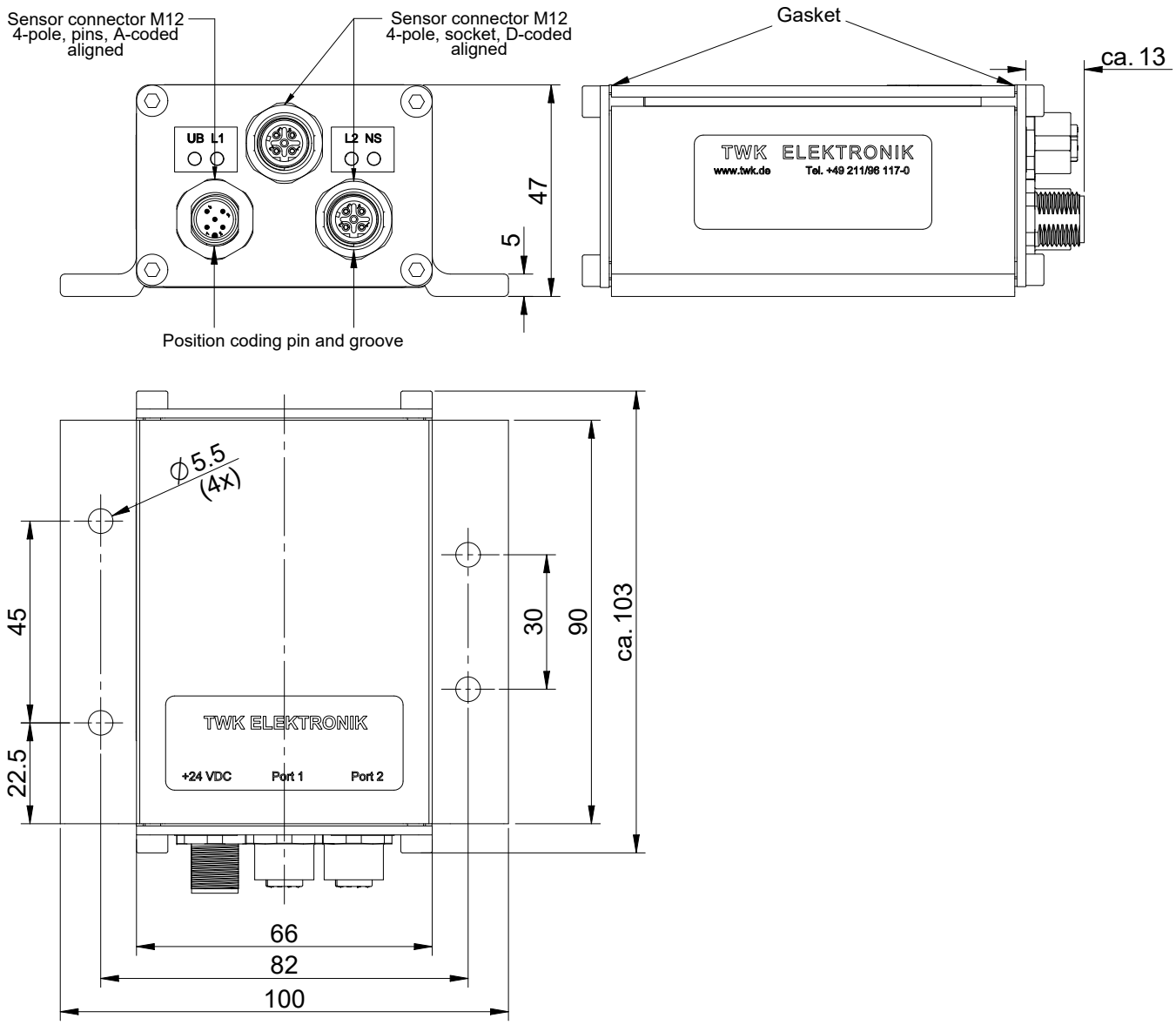
The following documents plus the GSD file and bitmap can be found in the Internet under www.twk.de/en in the documentation area, model NBT/S3

Data sheet NBT13911
Manual. NBT13912
Certificate PROFINET NBT14715
Certificate PROFIsafe NBT14717
Certificate TÜV NBT15395
GSD file . . . . . GSD file NBT/S3
Declaration of Conformity ZE16569
Safety Library (VDMA/Sistema) . . . . . Safety Library
Reach-compliant QS15286
RoHS-compliant QS13284
Installation instructions AN16169

INSTALLATION DRAWINGS

DESIGN FORM 90, ORDER NUMBER: NBT90-AXX/XX/XXVS3-X-S3T01 - STANDARD DESIGN FORM

Dimensions in mm



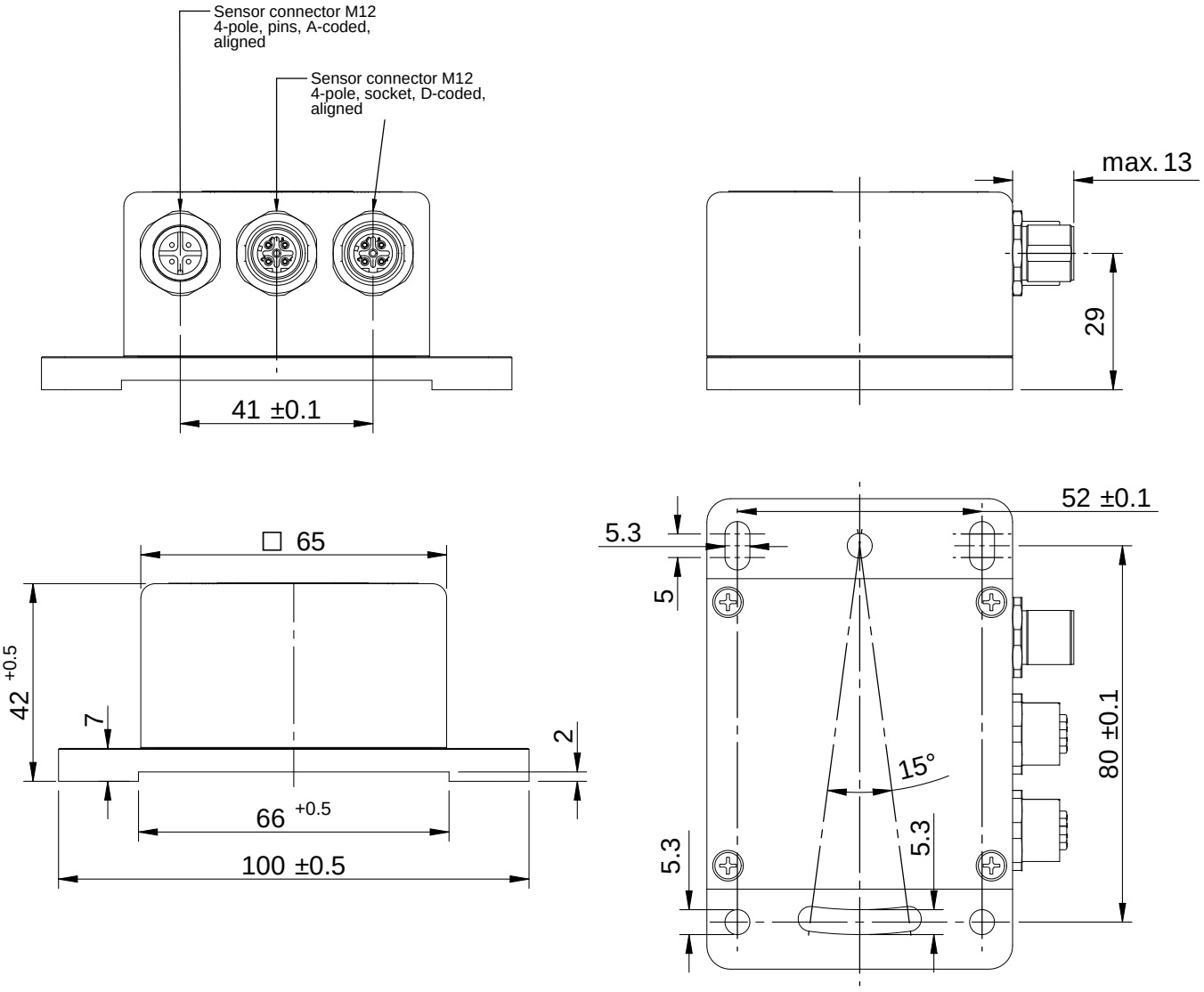
MATERIALS USED

Aluminium housing . . . . . Aluminium 3.3206
Aluminium front plates . . . . . Aluminium 3.3316
Connectors . . . . . Brass, nickel plated or diecast zinc, nickel plated
Sealing rings . . . . . PTFE / NBR

INSTALLATION DRAWINGS

DESIGN FORM 65, ORDER NUMBER: NBT65-A XX/XX/XXVS3-X-S3T01 - NON-STANDARD DESIGN FORM

Dimensions in mm



The installation is done via round and slotted mounting holes for M5 bolts. The inclination sensor can be mechanically adjusted up to approx. ± 7.5° 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.

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