Document No.: NBN 12054 ME
Date: 13.03.2015

Inclination sensor on MEMS technology
Interface: **CANopen Safety - SIL2**
Model **NBN / S3**

- **Certified (TÜV) SIL2 according to IEC 61508**
- **Use in mobile as well as stationary machines and systems. Especially for undercarriage levelling and measuring inclination on booms**
- **Interface: CANopen safety according to CiA DS304 CANopen Framework for safety-relevant communication, version 1.0.1**
- **Number of measurement axes: 1 or 2**
- **Selectable measuring range: ± 5° to ± 90°**
- **High vibration and shock resistance**
- **Option: Filter measures for masking interference vibrations and interference shocks → version V**

Contens

Design and function

Registration of inclination in the gravitational field by means of MEMS sensors (Micro-Electro-Mechanical-System) with subsequent digitisation and linearisation via controllers.

The housing-based inclinometer (model NBN 65) has a stable aluminium housing (optionally stainless steel) and is highly-resistant to vibration and shock. Elongated holes are available for mechanical alignment (up to approx. ± 7.5°). One or two connectors/socket in the case of CANopen can optionally be selected for connection. Casting measures in the housing lead to the achievement of protection class IP 69K, e.g. for use under water.

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 $U \propto g * \sin \alpha$. 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 NBN has a **redundant MEMS sensor system**.

Data output is carried out via the CANopen interface by means of the object SRDO (Safety Relevant Data Object). Normal and bit-inverted.

General description

Two independent nodes are implemented in the sensor system; in terms of logic, these behave as one node, i.e. both systems are addressed via one node address. The primary node controls the logical CANopen functions such as SDO processing, NMT and LSS services, and provides information to the redundant node via internal communication. The redundant node checks the safety parameters and internally compares its safety status with that of the primary node.

A synchronisation check is carried out in 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, an error message is given by the NBN. The master receives this message and can react.

One set of safety parameters exist for the primary node (object 1301h). The SRDO COB ID can be enabled or disabled as desired.

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:

The measured axis is no longer detected in case of an inclination in a second axis (cross-axis inclination) is greater than 15°. Meaning the sensor will go in an over flow stage (+180°). 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, transmitting an alarm message (emergency message) is unfavourable, as the machine then assumes a safe status and is no longer operable.

The following two versions are available to meet the various requirements:

1. Standard version: An error message (emergency message, override or sensor error) is immediately output and the machine/system switches to its safe status.

2. Special version variant 'V' with vibration filter: As soon as the interference occurs, the position output value is set to -180°. This is not a defined measured value. The control system is thereby notified that inclination measurement is not possible due to shock and vibration stresses. An error message (emergency message) is not output in this case to prevent the system from switching to its safe status. This behaviour is not temporally limited.

As no emergency message is transmitted with this version, 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 NBN as a measuring range overshoot (the MEMS sensor is an acceleration sensor). In this case, the overflow value of +180° is 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 +85 °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 +85 °C] for ± 60° ± 0,6°; range [-40 °C to +85 °C] for ± 90°

Measuring accuracy

Accuracy optional (not SIL 2 certified yet):

Devices with 1 or 2 axes with a measuring angle of max. ±15° have an accuracy of ± 0.25°.

This accuracy specification includes the following operating conditions:
Lateral inclination up to and including ± 15°. An operating temperature range from -10°C to 60°C.

(Measurement accuracy with lateral inclination of ~0° in a temperature range of +15°C to +30°C: **0.1°**)

General technical data

Electrical data

- Sensor system: MEMS acceleration sensor
- Operating voltage: 11 to 36 VDC
- No. measuring axes: 1 or 2
- Measuring range: ± 5° to ± 90° (selectable for example ± 5°, ± 10° .... ± 85°, ± 90°)
- Resolution: 0.01°
- Power consumption: < 1 W
- Current: approx. 40 mA
- Absolute accuracies: < ± 0.5° (see note on page 2)
- Repeatability: ± 0.05°
- Noise: ± 0.05°
- Zero error: ± 0.5°
- System synchronisation deviation: internally controlled
- Signal path: ascending values with CCW
- Reaction time: 1 s (for 100 % of the current end value, see note on page 2)
- EMC standards: EN 61000-4-2 (ESD)
  EN 61000-4-4 (Burst)
  EN 61000-6-3(4) (Emission)
- Transmission rate: 1 MBaud
- Output code: Binary
- CAN interface: According to ISO/DIS 11898
- Address/baud rate setting: Via SDO/LSS
- Terminating resistor: To be implemented separately
- Galvanic isolation between power supply and bus

Environmental data

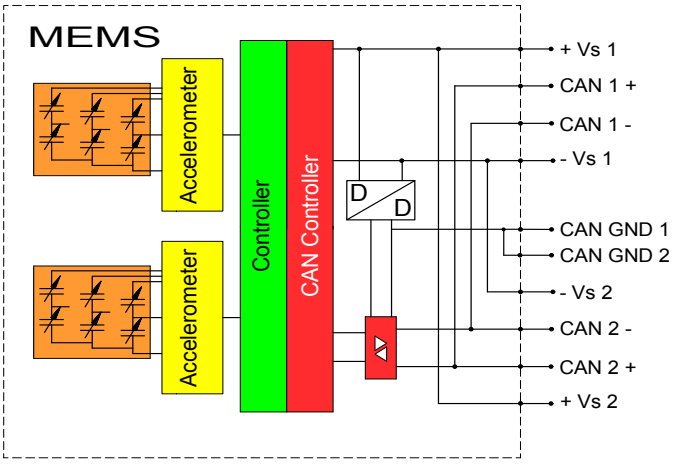
- Temperature range:: - 40 °C ... + 85 °C
- Storage temp. range: - 20 °C ... + 60 °C (due to packaging)
- Resilience
  - ☐ To shock: 200 m/s²; 11 ms, DIN EN 60068-2-27
  - ☐ To vibration: 100 m/s²; 10 ... 2000 Hz, DIN EN 60068-2-6
- Protection grade: IP 67
  IP 69K (option)
- Weight: Approx. 0.3 kg (aluminium)
  Approx. 0.65 kg (stainless steel)

Safety relevant Data

PFH:	1,53 * 10^{-7} 1/h
SFF:	95,33 %
MTR/MTTR:	8 h
T_1:	1 a
TÜV-Nord Zertifikatsnummer:	44 799 12 401439-000

CANopen data

NBN principle circuit diagram



Standard: 1 Connection for power supply and CANopen
Option: 2 connections for power supply and CANopen

Interface according to the following specifications

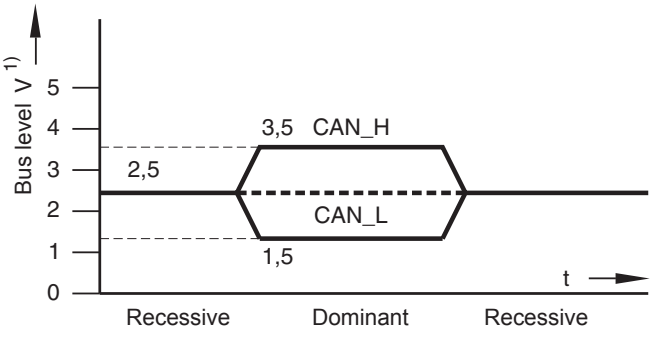
CiA DS301	CANopen Application Layer and Communication Profile, Version 4.1
CiA DS304	CANopen Framework for safety-relevant communication, Version 1.0.1
CiA DS305	CANopen - Layer Setting Sevices and Protocol (LSS)
CiA DS410	CANopen - Device Profile for Inclinometers, Version 1.2
IEC 61508	Functional safety of safety-related electrical/programmable electronic systems

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 oder LSS
- No of PDOs: 2 Tx / Node
- PDO-Modes: sync, async, cyclic, acyclic
- Variables PDO-Mapping: no
- Emergency Message: yes
- Heartbeat: yes
- No. of SDOs: 1 Rx / 1 Tx
- Device Profiles: CiA DSP 410 Version 1.2
  CiA DSP 304 Version 1.0.1
- Baudrate (factory setting): 20 kBaud
- Node ID (factory setting): 1

A detailed description of the profile you will find in the specification NBN 12599.

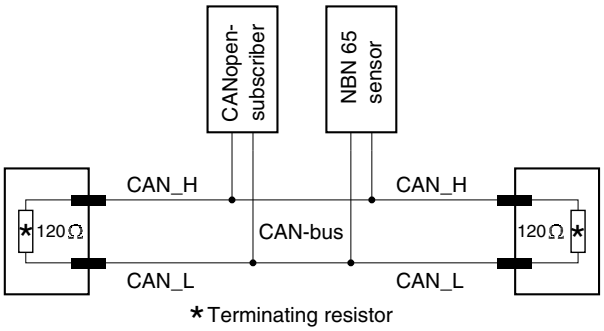
Output level according to ISO/DIS 11898



1) With common mode voltage = 0V

CANopen data

Bus activation according to ISO/ DIS 11898



The design guideline "CiA Draft Recommendation 303 CANopen additional specification Part 1: Cabling and connector pin assignment" must be observed on installation.

CANopen safety data format, SIL2 (Safety Relevant Data Object SRDO)

Output of three axis, x, y, and z, from Objects 6010_h, 6020_h und 6030_h (maximum 2 axis with relevant measuring values, else 0). Resolution 0.01° per digit.

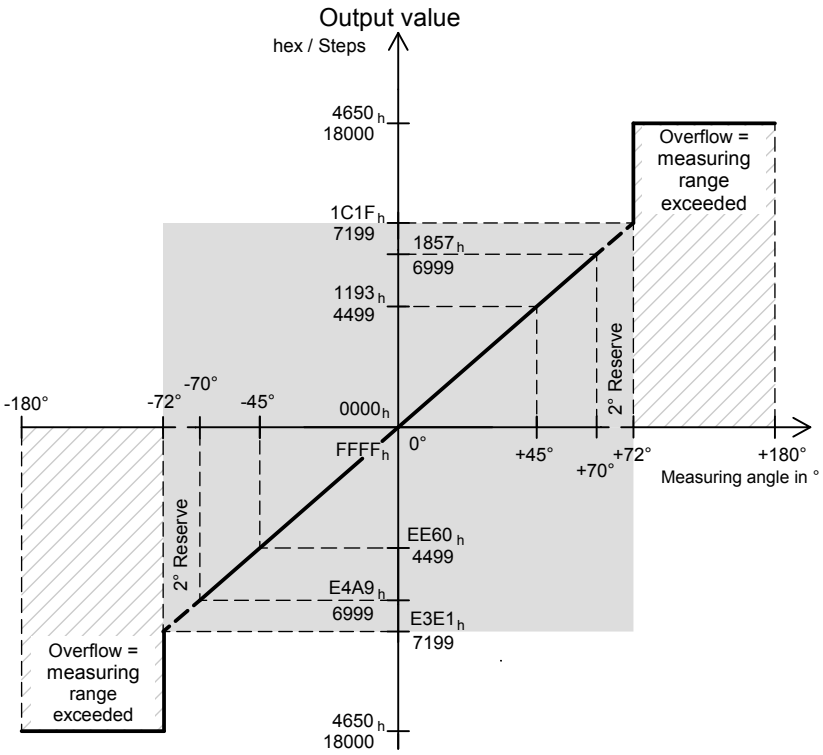
Data Byte 0								Data Byte 1								Data Byte 2								Data Byte 3								Data Byte 4								Data Byte 5							
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
LSB															MSB	LSB															MSB	LSB															MSB
Angle x-axis																**Angle y-axis**																**Angle z-axis**															

Data Byte 0								Data Byte 1								Data Byte 2								Data Byte 3								Data Byte 4								Data Byte 5							
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
LSB															MSB	LSB															MSB	LSB															MSB
Angle x-axis inverted																**Angle y-axis inverted**																**Angle z-axis inverted**															

Characteristic curve

Characteristic curve

- Example: ± 70° ≙ 2 x 7000 increments with resolution 0.01°
- Example: ± 20° ≙ 2 x 2000 increments with resolution 0.01°
- Data format: Signed 16-bit.



When exceeding the selected range (eg ± 70°), plus about 2° the CANopen output values is set to 4650hex (= 18,000 steps = 180°) in order to signal the controller that the inclinometer is tilted out of the selected scale.

Documentation, EDS file, etc.

- The following documents plus the EDS file, a bitmap and example programmes can be found in the Internet under www.twk.de in the documentation section, model NBN (letter "N")
  - Data sheet No. NBN 12054
  - Specification No. NBN 12599

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)

Available versions

(See order numbers on page 7)

Profiles

- **CANopen profile S3:** SIL2-certified with CANopen safety profile according to CiA, DS 304 version 1.0.1
- **CANopen profile S2:** not SIL2-certified with CANopen safety profile according to CiA, DS 304 version 1.0.1
- **CANopen profile C2:** CANopen standard profile. See separate datasheet NBX11918

Electrical connection

- One connector or one cable
- Connector/socket combination or two cables to loop the CANopen bus and the voltage supply through.

Inclinometer NBN / S3

Order code format

NBN	65	- A	x / y / z	V	S3	- 1	- S	1	N	01

Electrical and mechanical variants *:
- 01 Standard
- 50 Connection via connector M12, 5-pin

Output interface:
- N CANopen

Electrical connections:
- 1 Single connection
- 2 Double connection

Electrical connections *:**
- S Device connector M12
- K Cable 1 m (further cable length on demand)

Installation position:
- 1 TOP 1, 2, 3, 4, 5, 6 (See pages 10-11)

Profiles:
- S3 SIL2 certified. CANopen safety profile according to CiA, DS 304 version 1.0.1
- S2 CANopen safety profile but not SIL2 certified

Vibration protection measures (only complete if desired):
- V V = with vibration protection measure (see page 2).

Measuring ranges **:

± z° z-axis
± y° y-axis
± x° x-axis

Please assign the measuring angles which you require to the "x, y, z" axes. Two axes at maximum selectable (Selectable from ± 5° to ± 90° in 5° steps). For the undesired axis please choose '0' (Explanation on page 10 -11).

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

Design form:
- 65 65 mm

NBN with **CANopen safety interface**

Recommended types

- NBN65-A**20/20**/0S3-1-S2 N50 or NBN65-A**20/20**/0 **V** S3-1-S2 N50
- NBN65-A**90**/0/0S3-2-S2 N50 or NBN65-A**90**/0/0 **V** S3-2-S2 N50

Sensor with improved accuracy and CANopen Safety profile. No SIL2 certification.

- NBN65-A**15/15**/0S2-1-S2N51 (5-pin M12 male/female combination)

* 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. NBN: variant 50 is firmly assigned: electrical connection via M12, 5-pin (instead of 8-pin).

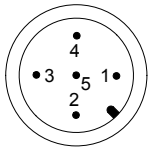
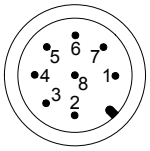
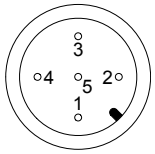
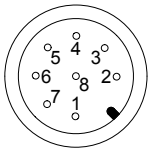
** The measuring ranges for the various measurement axes can be selected in 5° steps, whereby it must be noted that only 2 axes can be used at any one time. Accuracy differences may possibly arise in terms of the compatibility of the measuring ranges or the measuring angles. Please talk to one of our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

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

Electrical connections

Via: - 1 connector M12 (male), 5- or 8-pin
- 2 connectors M12 (male + female), 8-pin in each case
- 2 connectors M12 (male + female), 5-pin in each case (Variant 50 in CANopen sensor NBN65 order code format)
- 1 or 2 cables

Electrical connection at the mating connector

View on clamp- or soldering side	
 **Male connector:** 5 pin (pin)	 **Male connector:** 8 pin (pin)
 **Female connector:** 5 pin (socket)	 **Female connector:** 8 pin (socket)

Connection via cable

Colour of wire	Function
red	Power supply **+ V_B**
blue	Power supply **- V_B**
white	CAN_High
brown	CAN_Low
grey	CAN_GND
green	CAN_High #2 (Bus-Out, if realized)
yellow	CAN_Low #2 (Bus-Out, if realized)
pink	CAN_GND #2 (Bus-Out, if realized)

The pin assignment can be found in the connection assi-gnment which is enclosed with each device.

Connector male / female, 5 - pins

PIN	Function
1	CAN_GND
2	Power supply **+ V_B**
3	Power supply **- V_B**
4	CAN_High
5	CAN_Low

Connector male / female, 8 - pins

PIN	Function
1	Power supply **+ V_B**
2	Power supply **- V_B**
3	CAN_High
4	CAN_Low
5	CAN_GND
6	not connected
7	not connected
8	not connected

Accessories

- Mating connector (EMC) **STK5GP90** (M12, 5 pin male connector (pin), A-coded)
- Mating connector (EMC) **STK5GS56** (M12, 5 pin female connector (socket), A-coded)
- Mating connector (EMC) **STK8GP99** (M12, 8 pin male connector (pin), A-coded)
- Mating connector (EMC) **STK8GS54** (M12, 8 pin female connector (socket), A-coded)

(Mating connectors have to be ordered separately)

Inclinometer NBN / S3

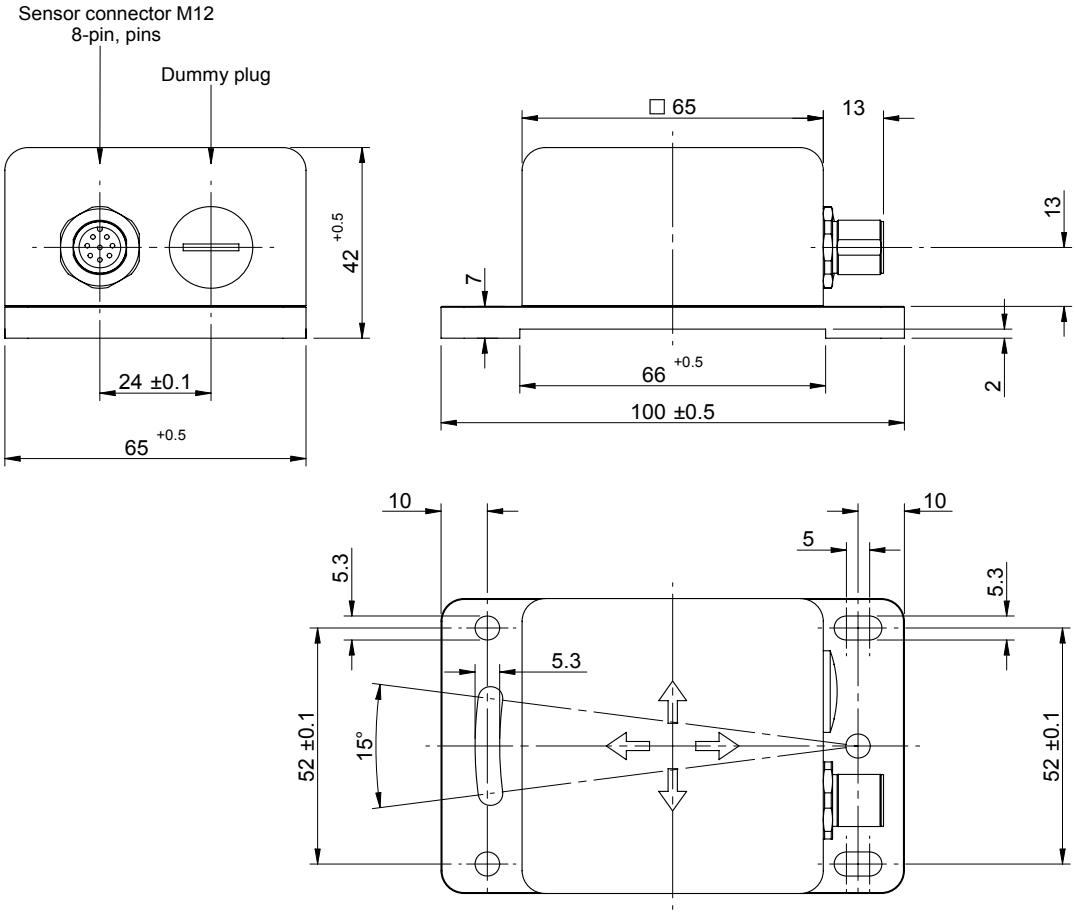
Installation drawing

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.

No dummy plug in case of two connectors.

Dimensions in mm



Materials used

Aluminium housing:	AlMgSi1
Stainless steel housing:	1.4305 (option 1.4404)
Connector/cable gland:	Ms, nickel plated (option stainless steel)
Sealing rings:	NBR

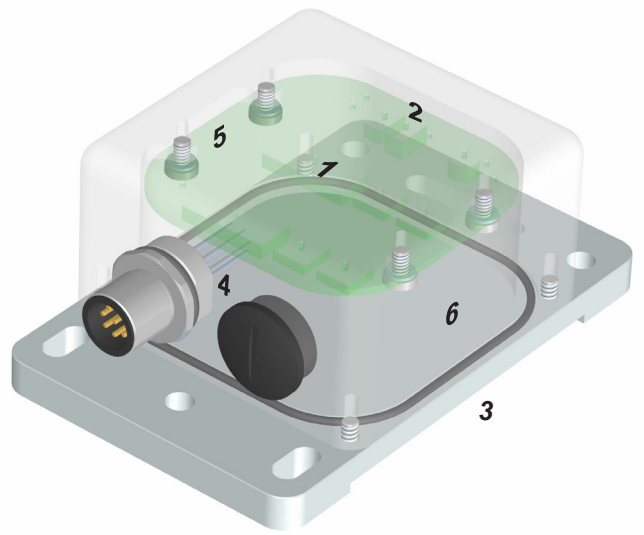
Installation positions and measurement axis assignment

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.

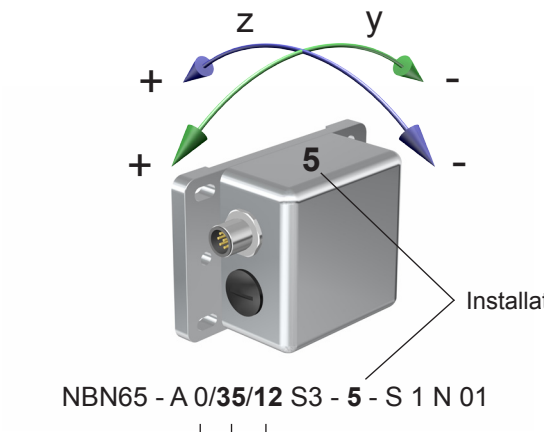


1: Upper side	2: Rear side	3: Lower side
4: Connector side	5: Left side	6: Right side

E.g. NBN 65 - A xx / yy / zz S3 - **1** - S 1 N 50: TOP1

In this example, circumstances necessitate the installation of the inclinometer in installation position "5".

The y axis with a range of ± 35° to be measured and the z axis with a range of ± 12° to be measured are required for measurement.



Installation position 5 (with reference to the upper side)

NBN65 - A 0/**35**/**12** S3 - **5** - S 1 N 01

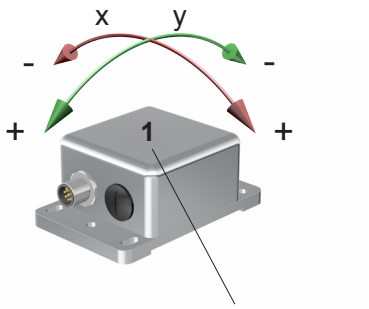
z-axis = 12° (± 12°)
y-axis = 35° (± 35°)
x-axis = 0° (As the x axis is not available in this installation position, it is specified as 0)

Further examples for installation positions

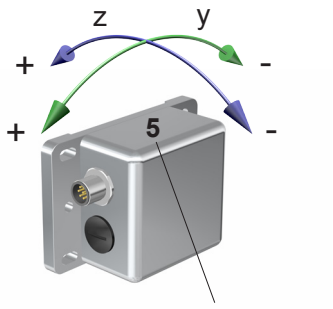
Further examples which refer to the assumed example measuring angles.

x = ± 90° y = ± 25° z = ± 15°

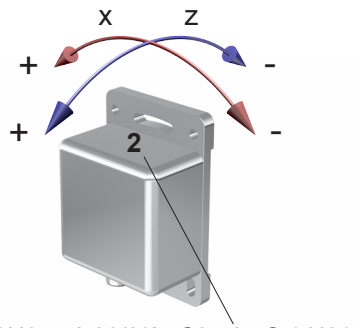
It is to be noted that the installation position always represents the device surface which is viewed from above. In the various illustrations, this is indicated with the bold number and must be specified on ordering under all circumstances.



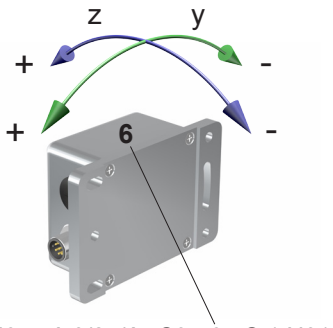
NBN65 - A **90**/**25**/0 S3 - 1 - S 1 N01



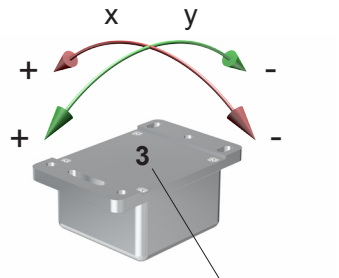
NBN65 - A 0/**25**/**15** S3 - 5 - S 1 N01



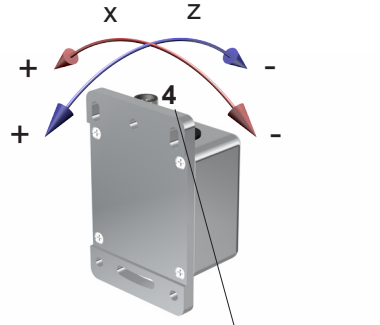
NBN65 - A **90**/0/**15** S3 - 2 - S 1 N01



NBN65 - A 0/**25**/**15** S3 - 6 - S 1 N01



NBN65 - A **90**/**25**/0 S3 - 3 - S 1 N01



NBN65 - A **90**/0/**15** S3 - 4 - S 1 N01

Ordering aid

Model NBN65 with CANopen safety interface

NBN	65	-		°	°	°		-		-			N	01
Model	Design form		Housing material	x axis	y axis	z axis	Profile (CANopen)		Installation position		Connector / cable	Connection (single/double)	CANopen	Variant *

Only two axes can be selected. The undesired axis is specified as 0°.

* Variant 01 contains the standard version according to the data sheet. If this version does not meet your wishes, please talk to one of our customer service advisors.