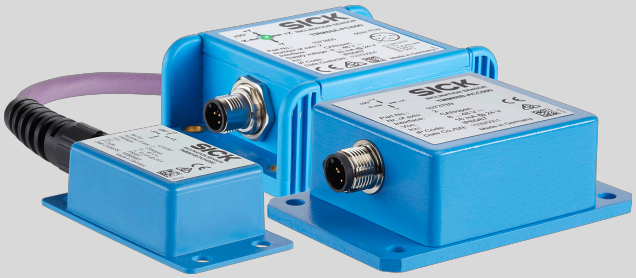
OPERATING INSTRUCTIONS

TMS/TMM88, TMS/TMM61

Inclination sensors with CANopen interface

SICK
Sensor Intelligence.



Described product

1- and 2-dimensional inclination sensors:

TMS88A

TMM88A

TMS88B

TMM88B

TMS88D

TMM88D

TMS61B

TMM61B

Manufacturer

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Legal information

Original document

This document is an original document of SICK AG.

Contents

1 About this document

1.1 Function of this document

These operating instructions are intended to give technical personnel working for the machine manufacturer or machine operator instructions on the mounting, electrical installation, commissioning, and operation of the TMS/TMM61 and TMS/TMM88 inclination sensors.

These operating instructions do not provide information on operating the machine in which an inclination sensor is integrated. For information about this, refer to the operating instructions of the particular machine.

1.2 Explanation of symbols

Warnings in these operating instructions are labeled with symbols. The warnings are introduced by signal words that indicate the extent of the danger. These warnings must be observed at all times and care must be taken to avoid accidents, personal injury, and material damage.

DANGER
... indicates a situation of imminent danger, which will lead to a fatality or serious injuries if not prevented.

WARNING
... indicates a potentially dangerous situation, which may lead to a fatality or serious injuries if not prevented.

CAUTION
... indicates a potentially dangerous situation, which may lead to minor/slight injuries if not prevented.

NOTICE
... indicates a potentially harmful situation, which may lead to material damage if not prevented.

NOTE
... highlights useful tips and recommendations as well as information for efficient and trouble-free operation.

2 Safety information

2.1 Intended use

The TMS/TMM88 and TMS/TMM61 inclination sensors are measuring devices consisting of an electronic sensor and integrated evaluation electronics. The tasks for which the measuring devices are designed include recording inclinations in solar thermal energy, photovoltaics or heavy-duty vehicle applications.

SICK AG assumes no liability for losses or damage arising from the use of the product, either directly or indirectly. This applies in particular to use of the product that does not conform to its intended purpose and is not described in this documentation.

2.2 Incorrect use

TMS/TMM88 and TMS/TMM61 inclination sensors do not constitute safety components in accordance with the EC Machinery Directive (2006/42/EC). The inclination sensors must not be used in explosion-hazardous areas. Any other use that is not described as intended use is prohibited. Any use of accessories not specifically approved by SICK AG is at your own risk.

WARNING
Danger due to improper use!

Any incorrect use can result in dangerous situations.

Therefore, take note of the following information:

- Inclination sensors should be used only according to intended use specifications.
- All information in these operating instructions must be strictly complied with.

2.3 Requirements for the qualification of personnel

The personnel who work on and with the device must be suitably authorized, trained, and sufficiently qualified. Skilled personnel refers to the following:

- A member of staff who has received specialist training, which is backed up by additional knowledge and experience.
- A member of staff who knows the relevant technical terms and regulations.
- A member of staff who can appraise the work assigned to them, recognize potential hazards, and take suitable safety precautions.

Table 1: Skilled personnel qualifications

Task	Qualification
Mounting	• Technical training • Knowledge of current workplace safety regulations
Electrical installation	• Electrotechnical training • Knowledge of the current electrotechnical workplace safety regulations • Knowledge of the operation and control of the sensor in the particular application
Commissioning, configuration, and operation	• Technical training • Knowledge of the operation and control of the sensor in the particular application

3 Overview

Properties

- 1-dimensional inclination sensor with measuring range: 360° (±180°)
- 2-dimensional inclination sensor with measuring range: 90° (X/Y)
- High sampling rate and bandwidth
- High resolution (0.01°)
- High accuracy (up to 0.02°)
- Compensated cross sensitivity
- Configurable vibration suppression
- Intelligent and flexibly adaptable sensor fusion algorithm for dynamic applications (TMS/TMM88D)
- Convenient CANopen interface
  - Meets the requirements of CiA DS-301, device profile CiA DSP-410
  - Baud rates from 10 kbit/s up to 1 Mbit/s
  - Automatic baud rate detection
  - Setting of node ID and baud rate via LSS service
- Functions:
  - One or two (TMS/TMM88D) Transmit PDOs: Can be mapped dynamically (RTR, cyclic, event-driven, synchronized)
  - SYNC consumer (sync. sending of the Transmit PDOs following receipt of a SYNC message)
  - EMCY producer fault monitoring using heartbeat or node guarding/lifeguarding
- UV-resistant, impact-resistant plastic housing or compact and rugged aluminum housing
- Suitable for industrial use:
  - Temperature range: -40 °C to +80 °C
  - Enclosure rating: IP65/67 (TMS/TMM88D: IP67/69)

TMS 1-dimensional inclination sensors are used to measure inclinations in the 360° range. TMM 2-dimensional inclination sensors are used to measure inclinations in 2 ±90° ranges (X/Y). To ensure high levels of accuracy, the sensors are calibrated at the factory.

A compact and rugged design makes the sensors an ideal solution for measuring angles in harsh environments. They are compatible for use in all manner of applications in industry and automotive engineering. All parameter settings can be made easily via the CANopen interface or with the PGT-12-Pro hand-held programing tool.

Areas of application

- Agricultural and forestry machinery
- Construction machinery and special-purpose vehicles
- Solar thermal energy and photovoltaics
- Automated guided systems
- Crane and lifting technology

4 Technical data

Notice

NOTE
This chapter contains an extract of the technical data. For full details, see the TMS/TMM88 (8019180), TMS/TMM88 Dynamic (8023359), TMS/TMM61 and TMM55 product information.

4.1 Technical data for TMS88A/TMM88A

Table 2: Technical data for TMS88A/TMM88A

General parameters[1)]	TMS88A			TMM88A		
Number of measuring axes	1			2		
Measuring ranges	360°			±90°		
Resolution	0.01°			0.01°		
Accuracy	Range 0...360°	Typical ±0.04°	Maximum ±0.10°	Range up to ±60° up to ±70° up to ±80° up to ±85°	Typical ±0.02° ±0.04° ±0.08° ±0.16°	Maximum ±0.05° ±0.10° ±0.20° ±0.40°
Cross sensitivity (compensated)	-			Typ. ±0.09° (±0.10%FS) Max. ±0.45° (±0.50%FS)		
Temperature coefficient (zero point)	Typ. ±0.008°/K					
Sampling rate	80 Hz					
Limit frequency	Typ. 20 Hz, 2nd order (no digital filter) / 0.1 ... 25 Hz, 8th order (with digital filter)					
Operating temperature	-40 °C to +80 °C					
Properties						
Data rates	10 k, 20 k, 50 k, 62.5 k, 100 k, 125 k, 250 k, 500 k , 800 kbit/s, 1 Mbit/s Automatic detection					
Functions	Polling of angle, cyclic and synchronized transmission, digital filter (critically damped (default) or Butterworth low pass, 8th order), configuration via object directory					
Electrical parameters						
Supply voltage	8 to 36 V DC					
Current consumption	<33 mA @ 24 V					
Mechanical parameters						
CAN connection	2 x 5-pin M12 plug connectors (male connector - female connector, looped through) to CiA 303-1					
Enclosure rating	IP65/67					
Dimensions / Weight	Large plastic housing: 66 mm x 90 mm x 36 mm / approx. 215 g					
CANopen conformity						
CiA DS-301, v4.2.0	Application layer and communication profile					

General parameters[1)]	TMS88A	TMM88A
CiA DS-410	Device profile for inclinometer	
CiA DSP-305	Layer setting service (LSS) and protocols	
CiA DR-303-3	Indicator specification (status LED)	
CiA AN-801	Automatic bit-rate detection	

1) All specified angular accuracies apply after a run-in time of 10 min at 25 °C, limit frequency 0.3 Hz, absolute calibration accuracy (at 25 °C): ±0.05°

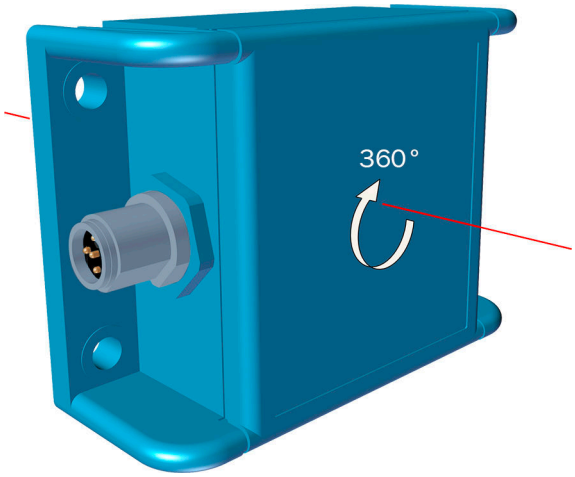

Figure 1: TMS88A measuring axis (large plastic housing)

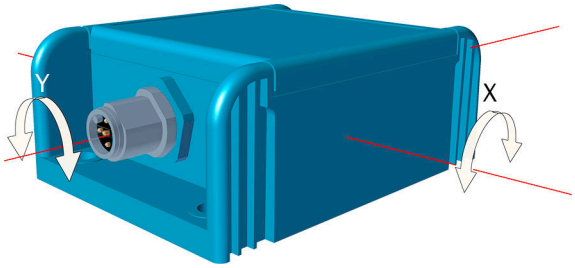

Figure 2: TMS88A measuring axes (large plastic housing)

4.2 Technical data for TMS88B/TMM88B

Table 3: Technical data for TMS88B/TMM88B

General parameters[1)]	TMS88B			TMM88B		
Number of measuring axes	1			2		
Measuring ranges	360°			±90°		
Resolution	0.01°			0.01°		
Accuracy	Range 0...360°	Typical ±0.15°	Maximum ±0.25°	Range up to ±60° up to ±80°	Typical ±0.10° ±0.20°	Maximum ±0.20° ±0.30°
Cross sensitivity (compensated)	-			Typ. ±0.10° (±0.11%FS) Max. ±0.20° (±0.22%FS)		
Temperature coefficient (zero point)	Typ. ±0.008°/K					

General parameters[1)]	TMS88B	TMM88B
Sampling rate	80 Hz	
Limit frequency	Typ. 20 Hz, 2nd order (no digital filter) / 0.1 to 25 Hz, 8th order (with digital filter)	
Operating temperature	-40 °C to +80 °C	
Properties		
Data rates	10 k, 20 k, 50 k, 62.5 k, 100 k, 125 k, 250 k, 500 k, 800 kbit/s, 1 Mbit/s Automatic detection	
Functions	Polling of angle, cyclic and synchronized transmission, digital filter (critically damped (default) or Butterworth low pass, 8th order), configuration via object directory	
Electrical parameters		
Supply voltage	8 to 36 V DC	
Current consumption	<16 mA @ 24 V	
Mechanical parameters		
CAN connection	1 x 5-pin M12 sensor plug connector (male connector)	
Enclosure rating	IP65/67	
Dimensions / Weight	Aluminum housing: 58 mm x 90 mm x 31 mm / approx. 200 g	
CANopen conformity		
CiA DS-301, v4.2.0	Application layer and communication profile	
CiA DS-410	Device profile for inclinometer	
CiA DSP-305	Layer setting service (LSS) and protocols	
CiA DR-303-3	Indicator specification (status LED)	
CiA AN-801	Automatic bit-rate detection	

1) All specified angular accuracies apply after a run-in time of 10 min at 25 °C, limit frequency 0.3 Hz, absolute calibration accuracy (at 25 °C): ±0.05°

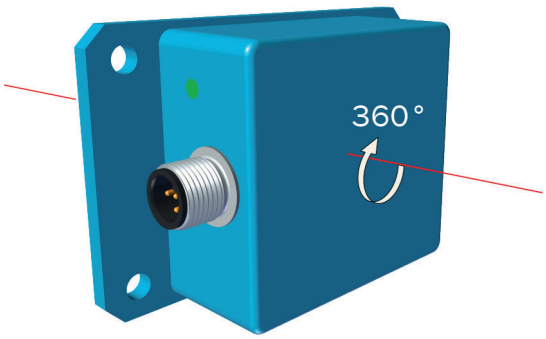

Figure 3: TMS88B measuring axis (aluminum housing)

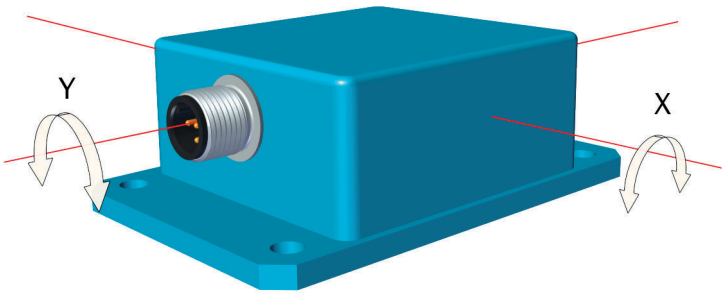

Figure 4: TMM88B measuring axis (aluminum housing)

4.3 Technical data for TMS88D/TMM88D

Table 4: General parameters for the dynamic inclination sensor

General parameters for the dynamic inclination sensor[1]	**TMS88D**		**TM88D**	
Number of measuring axes	1		2	
Measuring ranges	360°		±90°	
Resolution	0.01°			
Static accuracy	±0.3° (typical)	±0.5° (maximum)	±0.3° (typical)	±0.5° (maximum)
Dynamic accuracy	±0.5° (typical)			
Duration of spurious acceleration suppression (configurable)	100 to 10000 ms			
Temperature coefficient (zero point)	±0.01°/K (typical)			
General parameters for the IMU[2]	**Acceleration sensor**		**Gyro sensor**	
Measuring ranges	±8 g		±250 °/s	
Resolution	0.244 mg		0.00875 °/s	
In run bias stability	–		6 °/h (typical)	
Angular random walk (ARW)	–		0.2 °/√h	
Temperature coefficient (zero point)	0.2 mg/K (typical)		0.005 °/s/K (typical)	
General parameters				
Sampling rate	200 Hz			
Operating temperature	-40 °C to +80 °C			
Properties				
Data transmission rates	10k, 20k, 50k, 100k, 125k, 250k, 500k, 800k bit/s, 1 Mbit/s; Automatic detection			
Functions	Polling of angle, cyclic and synchronized transmission, parameterization, sensor fusion filter, digital low pass filter (critically damped or Butterworth, 8th order), configuration via a digital interface			
Electrical parameters				
Supply voltage	8 to 36 V DC			
Current consumption	15 mA @ 24 V			
Maximum output current	350 mA			
Mechanical parameters				
Electrical connection	2 x sensor plug connectors, 5-pin M12 (male connector - female connector, looped through)			

General parameters for the dynamic inclination sensor[1]	TMS88D	TM88D
Enclosure rating	IP67/69	
Dimensions of large plastic housing	66 mm x 90 mm x 36 mm	
Weight	approx. 200 g	
CANopen conformity		
CiA DS-301, v4.2.0	Application level and communications profile	
CiA DS-410	Device profile for inclinometer	
CiA DSP-305	Layer setting service (LSS) and protocols	
CiA DR-303-3	Indicator specification (status LED)	
CiA AN-801	Automatic bit rate detection	

1 All specified angular accuracies apply after a run-in time of 10 min. at 25 °C, absolute calibration accuracy (at 25 °C): ±0.05°
2 All specified accuracies apply after a run-in time of 10 min. at 25 °C

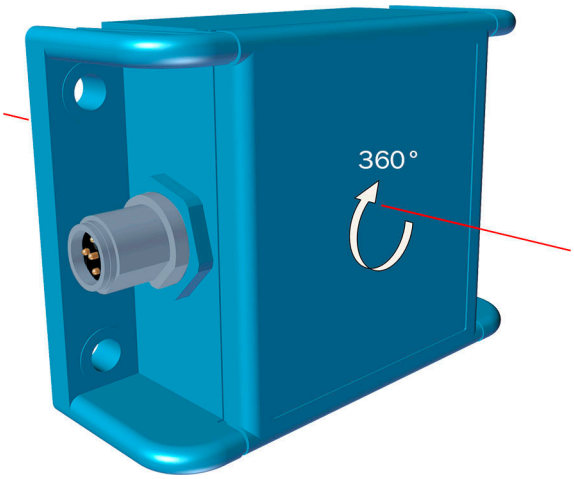

Figure 5: TMS88D measuring axis (large plastic housing)

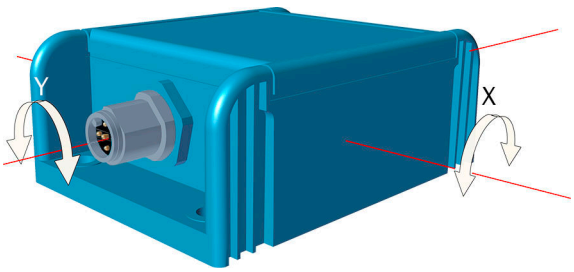

Figure 6: TMM88D measuring axes (large plastic housing)

4.4 Technical data for TMS61B/TMM61B

Table 5: Technical data for TMS61B/TMM61B

General parameters[1)]	TMS61B	TMM61B
Number of measuring axes	1	2
Measuring ranges	360°	±90°
Resolution	0.01°	0.01°

General parameters[1)]	TMS61B			TMM61B		
Accuracy	Range 0...360°	Typical ±0.15°	Maximum ±0.25°	Range up to ±60° up to ±80°	Typical ±0.10° ±0.20°	Maximum ±0.20° ±0.30°
Cross sensitivity (compensated)	-			Typ. ±0.09° (±0.10%FS) Max. ±0.45° (±0.50%FS)		
Temperature coefficient (zero point)	Typ. ±0.01°/K					
Sampling rate	80 Hz					
Limit frequency	Typ. 20 Hz, 2nd order (no digital filter) / 0.1 to 25 Hz, 8th order (with digital filter)					
Operating temperature	-40 °C to +80 °C					
Properties						
Data rates	10 k, 20 k, 50 k, 62.5 k, 100 k, 125 k, 250 k, 500 k, 800 kbit/s, 1 Mbit/s Automatic detection					
Functions	Polling of angle, cyclic and synchronized transmission, Digital filter (critically damped (default) or Butterworth low pass, 8th order), configuration via object directory					
Electrical parameters						
Supply voltage	8 to 36 V DC					
Current consumption	<16 mA @ 24 V					
Mechanical parameters						
CAN connection	Cable, 5-wire, 0.2 m, with 5-pin M12 male connector					
Enclosure rating	IP65/67					
Dimensions / Weight	Small plastic housing: 68 mm x 36.3 mm x 20.7 mm / approx. 80 g (with cable)					
CANopen conformity						
CiA DS-301, v4.2.0	Application layer and communication profile					
CiA DS-410	Device profile for inclinometer					
CiA DSP-305	Layer setting service (LSS) and protocols					
CiA DR-303-3	Indicator specification (status LED)					
CiA AN-801	Automatic bit-rate detection					

1) All specified angular accuracies apply after a run-in time of 10 min at 25 °C, limit frequency 0.3 Hz, absolute calibration accuracy (at 25 °C): ±0.05°

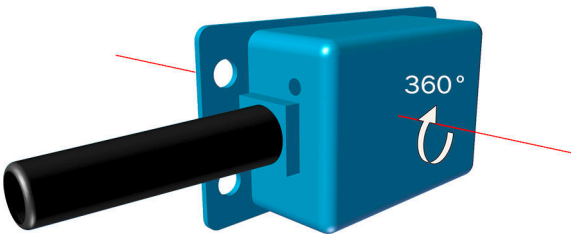

Figure 7: TMS61B measuring axis (small plastic housing)

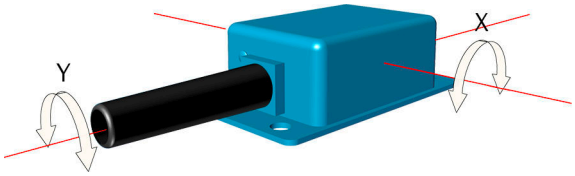

Figure 8: TMS61B measuring axis (small plastic housing)

5 Transport and storage

5.1 Transport

For your own safety, please read and observe the following notes:

NOTE

Damage to the device due to improper transport.

- The device must be packaged for transport with protection against shock and damp.
- Recommendation: Use the original packaging as it provides the best protection.
- Transport should be performed by trained specialist staff only.
- The utmost care and attention is required at all times during unloading and transportation on company premises.
- Note the symbols on the packaging.
- Do not remove packaging until immediately before you start mounting.

5.2 Transport inspection

Immediately upon receipt in Goods-in, check the delivery for completeness and for any damage that may have occurred in transit. In the case of transit damage that is visible externally, proceed as follows:

- Do not accept the delivery or only do so conditionally.
- Note the scope of damage on the transport documents or on the transport company's delivery note.
- File a complaint.

NOTE

Complaints regarding defects should be filed as soon as these are detected. Damage claims are only valid before the applicable complaint deadlines.

5.3 Storage

Store the device under the following conditions:

- Recommendation: Use the original packaging.
- Do not store outdoors.
- Store in a dry area that is protected from dust.
- So that any residual damp can evaporate, do not package in airtight containers.
- Do not expose to any aggressive substances.
- Protect from sunlight.
- Avoid mechanical shocks.
- For storage periods of longer than 3 months, check the general condition of all components and packaging on a regular basis.

6 Mounting

Layout of the fixing holes

The holes for screw-mounting the sensor are located in the baseplate of the inclination sensor (dimensions in mm).

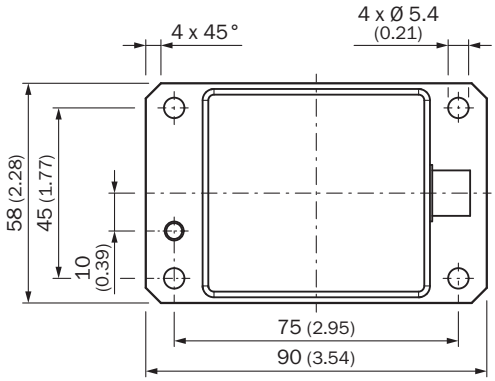

Figure 9: Fixing holes, aluminum housing

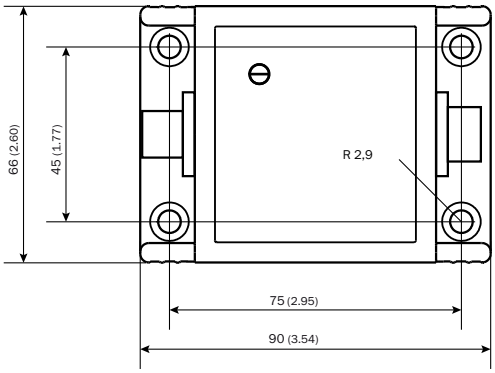

Figure 10: Fixing holes, large plastic housing

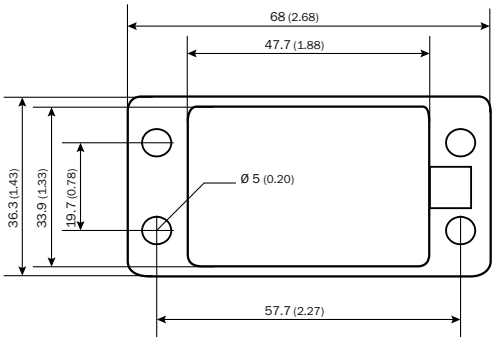

Figure 11: Fixing holes, small plastic housing

NOTICE

There is a risk of damage to the housing if inadequate lifting accessories are used!

- Use suitable washers for plastic housings.

7 Connection

Plug connector pin assignment

TMS/TMM88A, TMS/TMM88B and TMS/TMM88D inclination sensors are equipped with a standard 5-pin M12 round male connector (A-coded). TMS/TMM61 inclination sensors are supplied with a 20 cm long cable at the end of which there is a 5-pin M12 round male connector (A-coded). TMS/TMM88A and TMS/TMM88D inclination sensors also have a 5-pin M12 female connector (A-coded). The pin assignment corresponds to CiA DR-303-1.

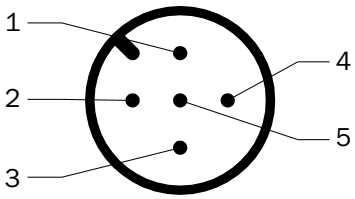

Table 6: CANopen M12 male connector pin assignment

Pin	Signal	Pin assignment
1	CAN_SHLD	Screen
2	CAN_V+	Supply voltage (+24 V)
3	CAN_GND	GND / 0 V / V-
4	CAN_H	CAN_H bus cable
5	CAN_L	CAN_L bus cable

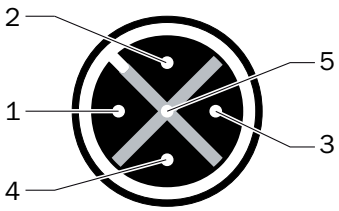

Table 7: CANopen M12 female connector pin assignment

Pin	Signal	Pin assignment
1	CAN_SHLD	Screen
2	CAN_V+	Supply voltage (+24 V)
3	CAN_GND	GND / 0 V / V-
4	CAN_H	CAN_H bus cable
5	CAN_L	CAN_L bus cable

Bus terminator

NOTE
The inclination sensors do not have an internal terminator.

8 Description of operation

8.1 Function overview

The inclination sensors have a standardized CANopen interface according to CiA DS-301 and a device profile according to CiA DS-410. All measured values and parameters can be accessed via the object directory (OD). The individual configuration can be saved in the internal permanent memory (EEPROM). The following CANopen functions are available:

- One or two (TMS/TMM88D) sending data objects (Transmit PDOs), dynamically mappable to four possible operating modes:
  - Specific request via remote transmit request (RTR) message
  - Cyclic transmission based on interval time
  - Event-controlled transmission on inclination change
  - Synchronous transmission following receipt of a SYNC message
- One service data object (standard SDO)
- Error messages based on emergency object (EMCY) with support:
  - Of the general error register
  - Of the manufacturer specific status register
  - Of the pre-defined error field
- Monitoring mechanisms: heartbeat as well as node guarding / lifeguarding
- Save and restore functions for all parameters (store and load parameter field)
- Status and error display via bi-color LED (according to CiA DR-303-3)

There are more manufacturer-specific / profile-specific properties in addition to the CiA DS-301 functionality:

- Limit frequency (digital filter), freely configurable
- Sensor fusion filter, freely configurable (TMS/TMM88D only)
- Configuration of the minimum change in angle for Transmit PDO transmission event
- Change in direction of the inclination angle
- Zero-point setting of the inclination angle
- Setting of node ID and baud rate via LSS service according to CiA DSP-305
- Automatic baud rate detection according to CiA AN-801

9 CANopen interface

9.1 Communication profile

The CANopen communication profile (documented in CiA DS-301) regulates how the devices in a CANopen network exchange data.

9.1.1 CANopen in the OSI model

The CANopen protocol is a standardized Layer 7 protocol for the CAN bus. This layer is based on the CAN Application Layer (CAL).

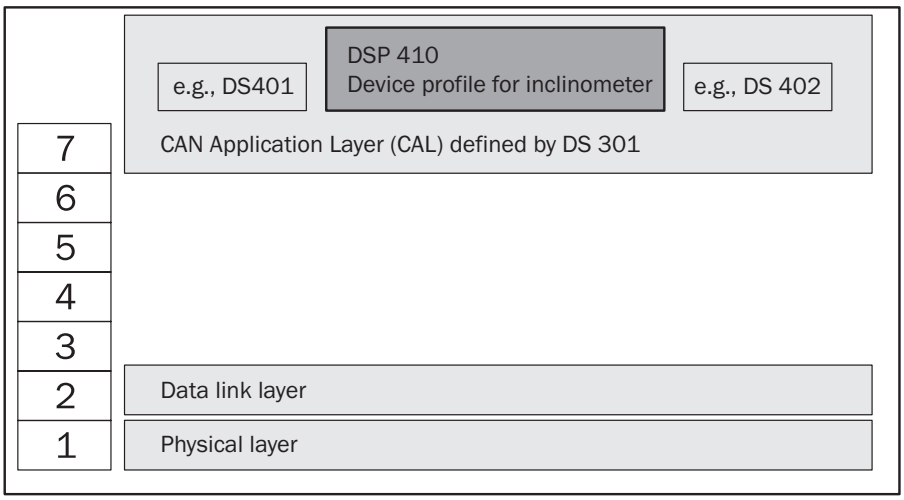

Figure 12: CANopen in the OSI layers model

NOTE
Layers 3 to 6 are not used in the CANopen definition.

9.1.2 Communication channels

CANopen features various communication channels (SDO, PDO, Emergency Messages). These channels are formed with the help of the communication object identifier (COB ID). The COB IDs are based on the node IDs of the individual devices on the CANopen bus (see "Node IDs and COB IDs", page 20).

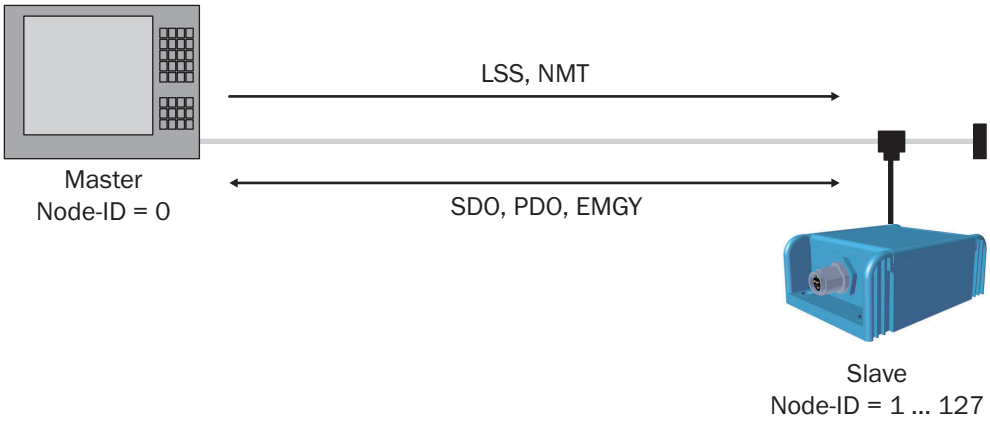

Figure 13: Master/slave model

- Layer setting services (LSS) are used to set the node ID of the inclination sensor (see "Layer setting services (LSS)", page 21).
- After this, the inclination sensor can be addressed via the network management services (NMT) (see "Network management: NMT", page 24) and its CANopen state machine can be switched to the necessary status (Pre-Operational, Operational, or Stopped) by the master.
- In Pre-Operational status, communication and configuration can be carried out via service data objects (SDO) (see "Service data objects (SDO)", page 28). In Operational status, communication is also possible via process data objects (PDO) and emergency messages (EMGY).

9.1.3 Topology

T-connectors or Y-cables are used to integrate the inclination sensors into the CANopen trunk cable (the T-connectors are available as accessories). The trunk cable must be terminated at the end. This is not necessary for the stub cables that are connected to the sensors.

NOTE
Since TMS/TMM88A and TMS/TMM88D inclination sensors have a female connector with looped-through CAN bus, they can also be integrated into the trunk cable without the need for T-connectors or Y-cables.

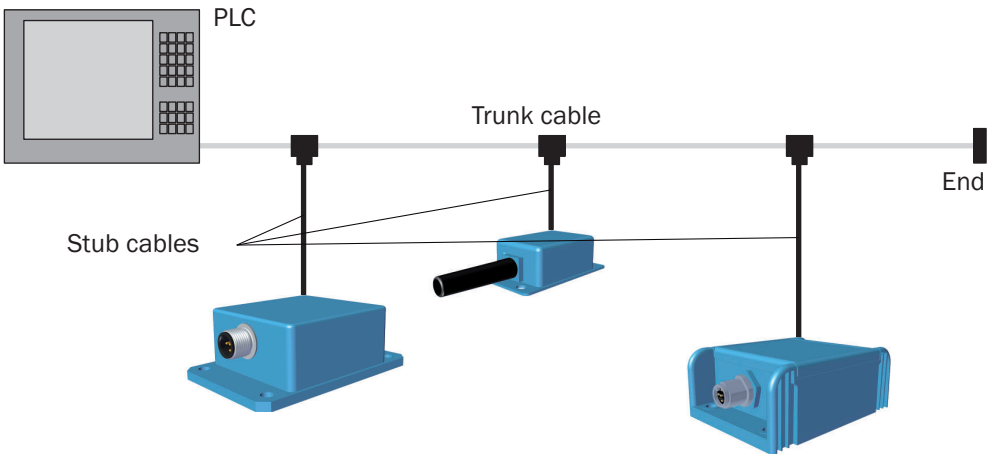

Figure 14: Example: Network topology

9.1.4 Integrating an inclination sensor into a CANopen network

An ESD file makes it easy to link the inclination sensors to a CANopen master.

This file contains information on the following features of the inclination sensors:

- Information about the device manufacturer
- Name, type and version number of the device
- Type and version number of the protocol to be used for this device
- Inclination sensor default parameters
- Process data default configuration

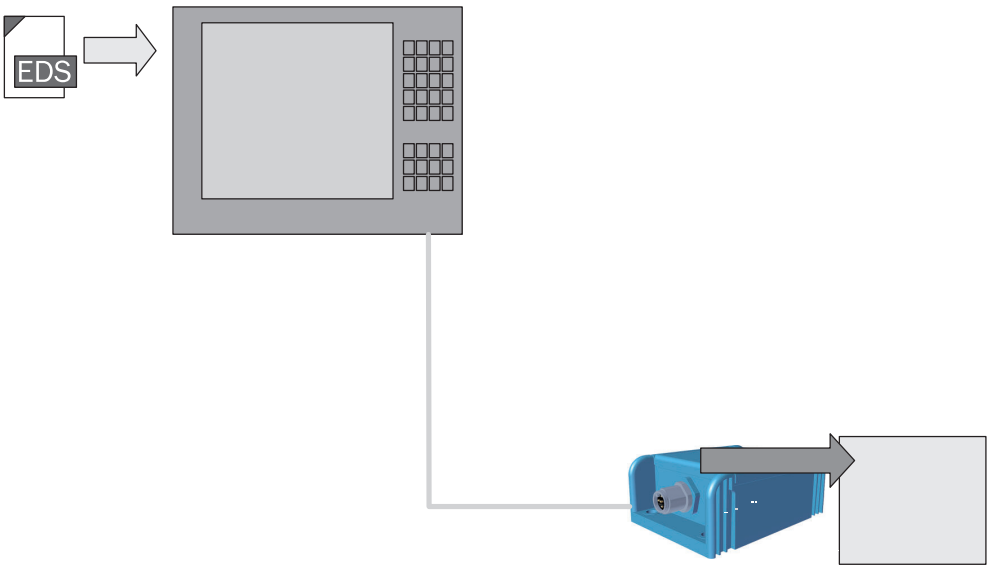

Figure 15: ESD file integration

9.2 Node IDs and COB IDs

There can be a maximum of 128 devices on a CANopen network: one master and up to 127 slaves. Every device has a unique node ID (node address).

The COB IDs (communication object identifiers) of the communication channels are derived from this ID.

Table 8: Overview of node IDs and COB IDs

Calculation of COB ID [dec] [hex]	ID ranges [dec] [hex]	Function	Direction from the point of view of the sensor
0	0	Network management	Receive
128 0080h	128 0080h	SYNC	Receive
128 + node ID 0080h + node ID	129 ... 255 0081h ... 00FFh	Emergency message	Transmit
384 + node ID 0180h + node ID	385 ... 511 0181h ... 01FFh	Transmit PDO 1	Transmit
640 + node ID 0280 + node ID	641 to 767 0280h to 02FFh	Transmit PDO 2 (TMS/TMM88D only)	Send
1408 + node ID 0580h + node ID	1409 ... 1535 0581h ... 05FFh	Transmit SDO	Transmit
1536 + node ID 0600h + node ID	1537 ... 1663 0601h ... 067Fh	Receive SDO	Receive

Calculation of COB ID [dec] [hex]	ID ranges [dec] [hex]	Function	Direction from the point of view of the sensor
1792 + node ID 0700h + node ID	1793 ... 1919 0701h ... 077Fh	Node guarding, heartbeat, boot up	Transmit
2020 07E4h	2020 07E4h	Transmit LSS	Transmit
2021 07E5h	2021 07E5h	Receive LSS	Receive

Example

The sensor receives node ID = 5, then sends emergency messages via ID 133, Transmit PDO 1 via ID 389, and SDOs via ID 1413.

The layer setting services can be used to configure the node ID of the sensor (see "Layer setting services (LSS)", page 21).

9.3 Layer setting services (LSS)

Layer setting services are supported to set the node ID and the baud rate of the inclination sensor.

The LSS slave is accessed via its LSS address (identity object), which is stored in object 1018h.

The LSS address comprises:

- Manufacturer ID
- Product code
- Revision number
- Serial number

The master uses the LSS services to request the individual services that are then executed by the inclination sensor. The LSS telegrams facilitate communication between LSS master and LSS slave.

The following COB IDs are used:

07E4h = LSS slave to LSS master

07E5h = LSS master to LSS slave

Format of an LSS telegram

NOTE
An LSS telegram is always 8 bytes long. Byte 0 contains the command specifier (CS), followed by 7 bytes for the data. All bytes that are not in use must be set to zero.

Table 9: Format of an LSS telegram

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
	CS	Data						

Switch Mode Global

The Switch Mode Global command switches the configuration mode on or off. The command remains unconfirmed and the inclination sensor does not respond.

Table 10: Format of the Switch Mode Global command

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
07E5h	04h	Mode	00h	00h	00h	00h	00h	00h

Byte 1 mode:

00h = Switches LSS configuration mode off

01h = Switches to LSS configuration mode

Configure Node ID

This command is used to set the node address.

Table 11: Format of the Configure Node ID command

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
07E5h	11h	Node ID	00h	00h	00h	00h	00h	00h

Byte 1 node ID:

01h = node address 1

...

7Fh = node address 127

Response:

Table 12: Response to the Configure Node ID command

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
07E4h	11h	Error code	Error extend	00h	00h	00h	00h	00h

Byte 1 error code:

00h = Configuration successful

01h = Parameter invalid

FFh = Contains a specific error code

Byte 2 error extend:

The error extension is manufacturer-specific; it is always 00h in the case of the inclination sensor.

Configure Bit Timing Parameters

This command is used to set the baud rate based on a baud rate table.

Table 13: Format of the Configure Bit Timing Parameters command

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
07E5h	13h	00h	Table index	00h	00h	00h	00h	00h

Byte 1 table index from the baud rate table:

Table 14: Baud rate table

Table index	Baud rate	Supported
0	1,000 kbit/s	Yes
1	800 kbit/s	Yes
2	500 kbit/s	Yes
3	250 kbit/s	Yes
4	125 kbit/s	Yes

Table index	Baud rate	Supported
5	100 kbit/s	Yes (TMS/TMM88D only)
6	50 kbit/s	Yes
7	20 kbit/s	Yes
8	10 kbit/s	Yes
9	Automatic detection	Yes

Response:

Table 15: Response to the Configure Bit Timing Parameters command

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
07E4h	13h	Error code	Error extend	00h	00h	00h	00h	00h

Byte 1 error code:

00h = Configuration successful

01h = Parameter invalid

FFh = Contains a specific error code

Byte 2 error extend:

The error extension is manufacturer-specific; it is always 00h in the case of the inclination sensor.

Store Configuration

The command saves the configuration.

NOTE
The configuration is not saved in the non-volatile memory (EEPROM). Object 1010h – Save Parameters must be used in order to do this.

Table 16: Format of the Store Configuration command

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
07E5h	17h	00h	00h	00h	00h	00h	00h	00h

Response:

Table 17: Response to the Store Configuration command

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
07E4h	17h	Error code	Error extend	00h	00h	00h	00h	00h

Byte 1 error code:

00h = Store successful

01h = Store Configuration command is not supported

02h = Error occurred during store operation

FFh = Contains a specific error code

Byte 2 error extend:

The error extension is manufacturer-specific; it is always 00h in the case of the inclination sensor.

Inquire LSS Address Service

This command can be used to read out the node ID of the inclination sensor and, from object 1018h, the manufacturer ID, the product code, the revision number, and the serial number.

Table 18: Format of the Inquire LSS Address Service command

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
07E5h	CMD	00h	00h	00h	00h	00h	00h	00h

Byte 0 CMD from the command table:

Table 19: Command table

CMD	Parameter	Subindex of object 1018h
5Eh	Node ID	
5Dh	Serial number	.4
5Ch	Revision number	.3
5Bh	Product code	.2
5Ah	Vendor ID	.1

Response:

Table 20: Response to the Inquire LSS Address Service command

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
07E4h	CMD	Data-X (LSB)	Data-X	Data-X	Data-X (MSB)	00h	00h	00h

NOTE
The data is 4 bytes long in little-endian byte sequence. If fewer than 4 bytes of data are read out, the remaining bytes are set to 0.

Identify Non-Configured Slave Device

The command is used to identify non-configured devices.

Table 21: Format of the Identify Non-Configured Slave Device command

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
07E5h	4Ch	00h	00h	00h	00h	00h	00h	00h

Response:

Table 22: Response to the Identify Non-Configured Slave Device command

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
07E4h	50h	00h	00h	00h	00h	00h	00h	00h

9.4 Network management: NMT

Network management (NMT) initializes the nodes in a CANopen network. It also adds the nodes to the network, as well as stopping and monitoring them.

There is only one NMT master (network management master) in a CANopen network. All other devices, including the inclination sensor, are NMT slaves. The NMT master monitors all devices and can change their status.

A PLC or a PC usually serves as the NMT master.

9.4.1 CANopen state machine

Like every CANopen slave, the inclination sensor features what is known as a CANopen state machine. The following statuses can be identified:

Table 23: Status of the CANopen state machine

Status	Description
Initializing	Initialization commences. Both the device application and device communication are initialized. After this, the node automatically switches to Pre-Operational status.
Pre-Operational	The inclination sensor is ready for configuration; acyclic communication can take place via SDO. However, the inclination sensor is not yet able to commence PDO communication and is not sending out any emergency messages.
Operational	In this status, the inclination sensor is fully ready for operation and can transmit messages autonomously (PDOs, emergency messages).
Stopped	In this status, the inclination sensor is not actively communicating (although communication is still being actively monitored via node guarding).

9.4.2 Network management services

NMT services are used to switch between the individual statuses of the CANopen state machine. The NMT telegrams for device monitoring use the COB ID 0 and thus have the highest priority.

Table 24: Format of the NMT telegram

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
00h	CCD	Node ID	00h	00h	00h	00h	00h	00h

Table 25: Meaning of byte 0

Byte 0, CCD	Parameter
01h	Start Remote Node Sets the inclination sensor to Operational status.
02h	Stop Remote Node Sets the inclination sensor to Stopped status and stops it communicating (although communication is still being actively monitored via node guarding).
80h	Enter Pre-Operational Sets the inclination sensor to Pre-Operational status. All communication channels except the PDOs can be used.
81h	Reset Node Resets the values of the profile parameters to the default values. After this, the inclination sensor switches to Reset Communication status.
82h	Reset Communication Sets the inclination sensor to Reset Communication status. After this, the inclination sensor switches to Initialization status.

Transitions between the individual operating statuses

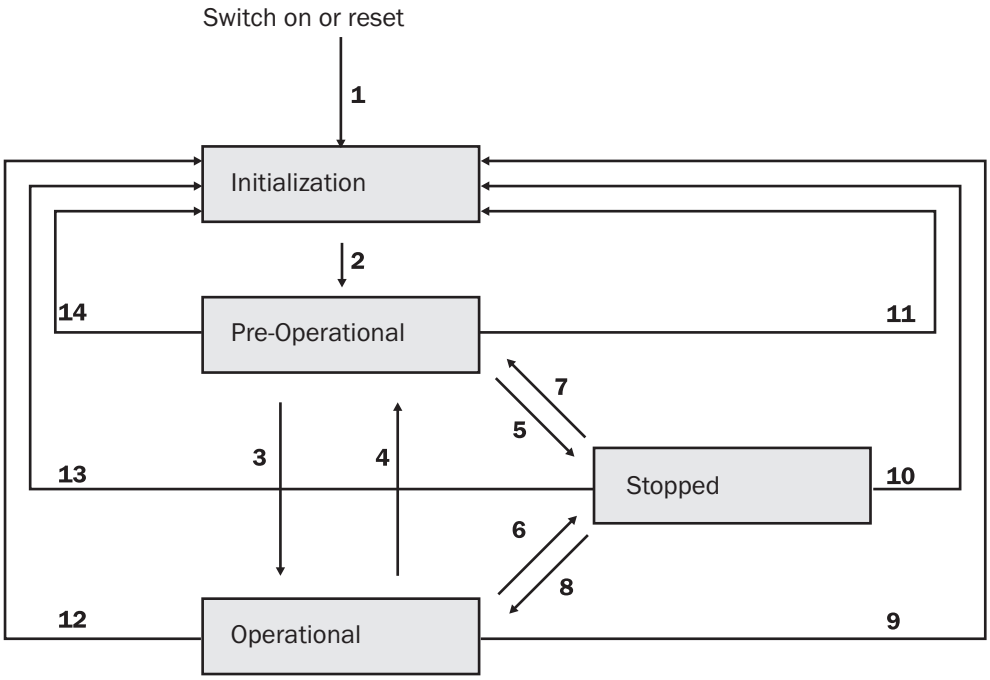

Figure 16: Process diagram of status changes

Table 26: Transitions between operating statuses

Transition	Description
1	After switching on, the inclination sensor switches to Initialization status.
2	After Initialization, the inclination sensor automatically switches to Pre-Operational status.
3 and 8	The Start Remote Node command switches the inclination sensor to Operational status.
4 and 7	The Enter Pre-Operational State command resets the inclination sensor to Pre-Operational status.
5 and 6	The Stop Remote Node command switches the inclination sensor to Stopped status.
9, 10, and 11	The Reset Node command switches the inclination sensor to Initialization status.
12, 13, and 14	The Reset Communication command switches the inclination sensor to Initialization status.

9.4.3 Boot-up message

To signal that the device is ready for operation following switching on, a “boot-up message” is sent out. This message uses the ID of the NMT error control protocol and is permanently linked to the set device address (700h + node ID).

9.4.4 Node guarding and heartbeat

The inclination sensor can be monitored permanently with the node guarding protocol or the heartbeat protocol.

NOTE
It is not possible to use the node guarding protocol and the heartbeat protocol in parallel with a single node. If the heartbeat time parameter of object 1017h is not equal to 0, the heartbeat protocol is used.

Node guarding

The node guarding telegram is sent to poll the status of the inclination sensor at regular intervals. The sensor responds within the response time configured in objects 100Ch (guard time) and 100Dh (life-time factor).

This time is referred to as the node life time. It is calculated as follows:

“Node life time” = “guard time” x “life-time factor”

If the inclination sensor does not send a response within this time, the connection is considered to have been lost.

Table 27: Format of the node guarding telegram

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
700h + node ID	Status	00h	00h	00h	00h	00h	00h	00h

Table 28: Meaning of byte 0

Byte 0, status	Parameter
Bit 7	Toggle bit The bit changes its value every time it is polled.
Bits 6 ... 0	Operating status of the inclination sensor: 127 = Pre-Operational 5 = Operational 4 = Stopped 0 = Boot Up

Example for an inclination sensor in Operational operating status:

85h, 05h, 85h = no error

85h, 05h, 05h = error

NOTE
If node guarding is active, the inclination sensor expects to receive a corresponding status query from an NMT master within a certain time frame. If it does not, the slave switches to Pre-Operational status.

Heartbeat

If the heartbeat telegram is used, the inclination sensor sends its status autonomously at cyclic intervals. This can be monitored by every other node in the network.

The heartbeat time is configured with object 1017h.

Table 29: Format of the heartbeat telegram

COB-ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
700h + node ID	Status	00h	00h	00h	00h	00h	00h	00h

Table 30: Meaning of byte 0

Byte 0, status	Parameter
Bit 7	Toggle bit The bit changes its value every time it is polled.

Byte 0, status	Parameter
Bits 6 ... 0	Operating status of the inclination sensor: 127 = Pre-Operational 5 = Operational 4 = Stopped 0 = Boot Up

NOTE
Heartbeat has a significant influence on the bus load of the CANopen network but only generates half the bus load of node guarding.

9.5 Service data objects (SDO)

Service data objects (SDO) form the communication channel through which device parameters are transmitted. They are used for status queries.

SDOs can be used to transmit data of any length. The data might have to be split into several CAN messages. An SDO is always transmitted with confirmation, i.e. the receipt of every message is acknowledged by the receiver.

Transmit SDO and Receive SDO

The inclination sensor has a Transmit SDO channel and a Receive SDO channel, to which two CAN identifiers are assigned.

SDO communication corresponds to the client-server model. The inclination sensor functions as an SDO server.

In its request, the SDO client (e.g., the PLC) specifies the parameter, the access method (read/write), and the value, if applicable. The inclination sensor executes read or write access and responds to the request.

The maximum data length of a CAN telegram of 8 bytes is assigned by an SDO as follows:

Table 31: Format of the SDO telegram

COB-ID	CCD	Index		Subindex	Data			
600h + node ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7

The command code (CCD) identifies whether read or write access is required. In the event of an error, the data range will contain a 4-byte error code which provides information about the cause of the error.

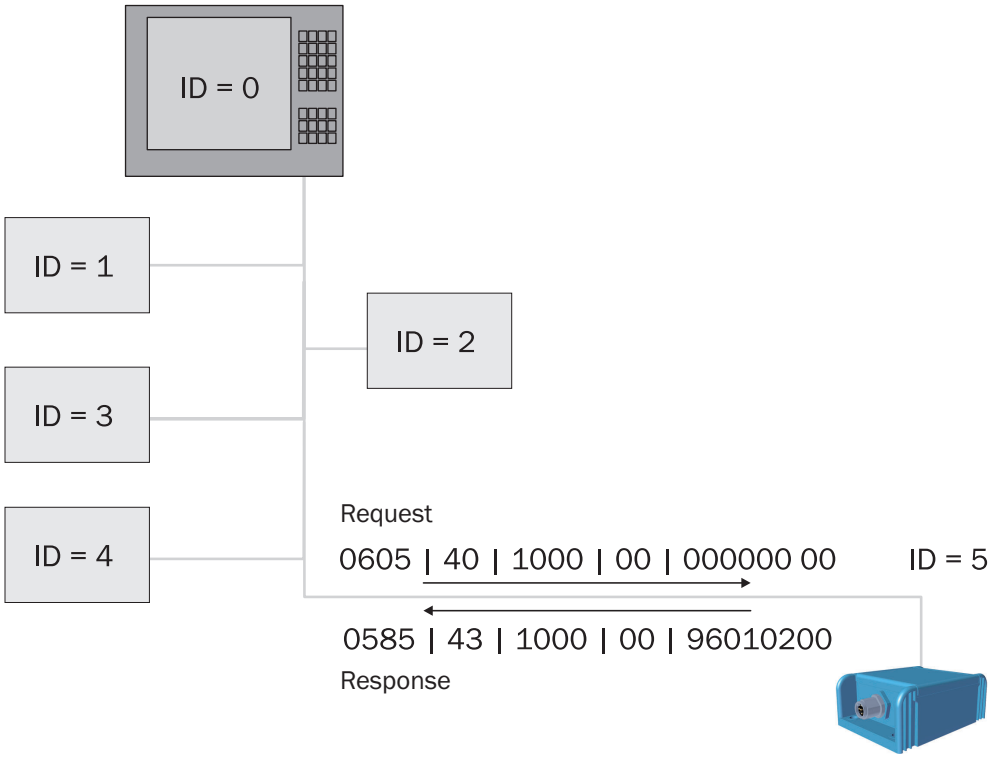

Figure 17: Example request/response telegram

In the example, the inclination sensor (ID = 5) receives the read request (CCD = 40h) for object 1000h from the PLC via ID 0605h (Receive SDO 0600h + inclination sensor ID).

The inclination sensor responds by sending ID 0585h (Transmit SDO 0580h + inclination sensor ID) with feedback (CCD = 43h).

9.6 Process data objects (PDO)

Process data objects (PDO) are used for rapid and efficient data exchange of real-time data (e.g., I/O data, setpoint values or actual values).

PDOs are transmitted without confirmation.

The inclination sensor supports one or two (TMS/TMM88D) transmit PDOs.

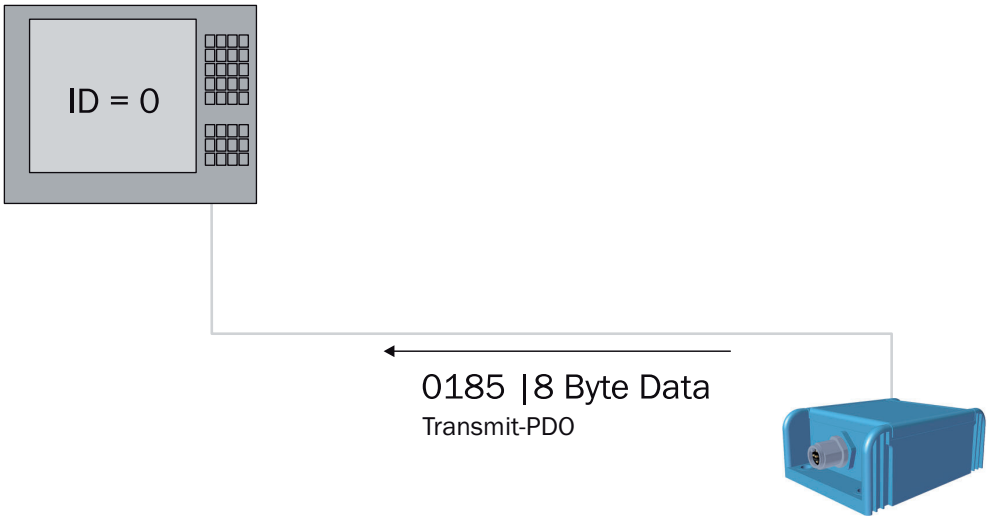

Figure 18: Structure of the Transmit PDO

Table 32: Format of the PDO telegram

COB-ID	Data							
0180h + node ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7

9.6.1 PDO mapping

The format of the PDO telegram between master and inclination sensor must be agreed through what is known as PDO mapping. The process data can be arranged at will in the PDO message. The address (i.e. index and subindex) and the size (number of bits) from the entry in the object directory are entered in the mapping object for this purpose.

Example:

Object 1A00h is factory-set to contain the following objects, depending on sensor type:

6010.00h - inclination value, axial (TMS) or longitudinal (TMM)

6020.00h - inclination value, lateral (TMM only)

The content of the objects is transmitted in the Transmit PDO telegram.

Table 33: Example Transmit PDO telegram (TMS)

COB-ID	Data							
0180h + node ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
	Inclination value, axial		Not used					

Table 34: Example Transmit PDO telegram (TMM)

COB-ID	Data							
0180h + node ID	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
	Inclination value longitudinal		Inclination value lateral		Not used			

The following objects can be mapped in the TPDOs:

Table 35: Mappable objects

Index	Subindex	Size	Description	Format
0x3100	1	16	Euler angle: pitch	signed, 0.01°/bit
0x3100	2	16	Euler angle: roll	signed, 0.01°/bit
0x3101	1	16	Quaternion: w	signed, 1/30000 / bit
0x3101	2	16	Quaternion: x	signed, 1/30000 / bit
0x3101	3	16	Quaternion: y	signed, 1/30000 / bit
0x3101	4	16	Quaternion: z	signed, 1/30000 / bit
0x3102	1	16	Acceleration, x-axis	signed, 1/4096g / bit
0x3102	2	16	Acceleration, y-axis	signed, 1/4096g / bit
0x3102	3	16	Acceleration, z-axis	signed, 1/4096g / bit
0x3103	1	16	Yaw rate, x-axis	signed, 7/800°/s / bit
0x3103	2	16	Yaw rate, y-axis	signed, 7/800°/s / bit
0x3103	3	16	Yaw rate, z-axis	signed, 7/800°/s / bit
0x6010	0	16	Slope long16	signed, 0.01°/bit
0x6020	0	16	Slope lateral16	signed, 0.01°/bit
0x6511	0	8	Temperature	signed, 1K/bit

9.6.2 PDO data transmission

The PDOs can be transmitted cyclically or acyclically. This is determined by the Transmit PDO and the transmission type defined in its subindex 02.

Synchronized data transmission

In synchronized data transmission, the process data is transmitted with the SYNC messages. The cycle is formed from a multiple of the SYNC messages. The factor can be between 1 and 240.

Cyclic data transmission

In cyclic data transmission, the inclination sensor sends the PDO at defined intervals. The associated period duration is configured in object 1800.05h.

Acyclic data transmission

For acyclic data transmission, the inclination sensor is triggered by one of the following criteria:

- Application-specific / device-specific triggering
  The sending of the PDO is triggered by an event. This event is defined in object 3001h (TPDO 1 only).
- On request (RTR telegram)
  In this case, another bus node (usually the master) requests the process data.

NOTE

For the inclination sensor to output the PDO cyclically or acyclically, the transmission type must be changed in the Transmit PDO in object 1800.02h (see "Transmit PDO – Transmission type (1800h/1801h)", page 35).

9.7 Object directory

The object directory contains all data objects which can be accessed from outside and which have an impact on communication, application and state machines. It is divided into three parts:

- Communication-specific part (index: 0x1000 – 0x1FFF)
- Manufacturer-specific part (index: 0x2000 – 0x5FFF)
- Profile-specific part (index: 0x6000 – 0x9FFF)

The parameters it contains can be read and written with the standard SDO based on index and subindex.

The following sections describe all parameters in the object directory of an inclination sensor including index, subindex, data type, access right and default value (factory setting). The Storage column indicates whether a parameter can be saved in the internal permanent memory (write save signature to OD index 1010h/01h).

9.7.1 Communication parameters (to CiA DS-301)

Table 36: Communication parameters in the object directory

Index	Subindex	Parameter	Data type	Access	Default value	Storage
1000h	0	Device type (device profile 410)	UNS32	ro	1019Ah/ 2019Ah	
1001h	0	Error register	UNS8	ro	0	
1002h	0	Manufacturer status register	UNS32	ro	0	
1003h	Predefined error field					
	0	Number of error entries	UNS32	rw	0	
	1..5	Error code (oldest error assigned to highest index)	UNS32	ro	0	
1005h	0	COB ID sync message	UNS32	rw	80h	
1008h	0	Device name	VSTR	const	dep. on type	
100Ah	0	Software version (“Vxx.yy”)	VSTR	const	dep. on type	
100Ch	0	Guard time (multiple of 1 ms)	UNS16	rw	0	x
100Dh	0	Life-time factor	UNS8	rw	0	x
1010h	Save parameters (signature: 's','a','v','e' - 65766173h in subindex 1...4)					
	0	Highest subindex supported	UNS32	ro	4	
	1	Save all parameters (OD: 0x1000-0x9FFF)	UNS32	rw	1	
	2	Save communication parameters (OD: 0x1000-0x1FFF)	UNS32	rw	1	
	3	Save application parameters (OD: 0x6000-0x9FFF)	UNS32	rw	1	
	4	Save manufacturer parameters (OD: 0x2000-0x5FFF)	UNS32	rw	1	
1011h	Restore default parameters (signature: 'l','o','a','d' - 64616F6Ch in subindex 1...4)					
	0	Highest subindex supported	UNS32	ro	4	
	1	Restore all parameters (OD: 0x1000-0x9FFF)	UNS32	rw	1	
	2	Restore communication parameters (OD: 0x1000-0x1FFF)	UNS32	rw	1	
	3	Restore application parameters (OD: 0x6000-0x9FFF)	UNS32	rw	1	
	4	Restore manufacturer parameters (OD: 0x2000-0x5FFF)	UNS32	rw	1	

Index	Subindex	Parameter	Data type	Access	Default value	Storage
1014h	0	COB ID emergency message	UNS32	ro	80h + node ID	
1015h	0	Inhibit time between two EMCY messages (multiple of 100 µs)	UNS16	rw	0	x
1017h	0	Heartbeat rate time (multiple of 1 ms, 0 deactivated)	UNS16	rw	0	x
1018h	Identity object					
	0	Highest subindex supported	UNS8	ro	4	
	1	Vendor ID (SICK AG ident number)	UNS32	ro	01000056h	
	2	Product code	UNS32	ro	{dep. on type}	
	3	Revision number	UNS32	ro	{dep. on type}	
	4	Serial number	UNS32	ro	{dep. on type}	
1200h	Server SDO1 parameters					
	0	Highest subindex supported	UNS8	ro	2	
	1	COB ID client > server	UNS32	ro	600h + node ID	
	2	COB ID server > client	UNS32	ro	580h + node ID	
1800h	Transmit PDO 1 communication parameters					
	0	Highest subindex supported	UNS8	ro	5	
	1	COB-ID	UNS32	ro	180h + node ID	
	2	Transmission type (synchronous / asynchronous manufacturer-specific)	UNS8	rw	1	x
	3	Inhibit time between two Transmit PDO messages (multiple of 100 µs)	UNS16	rw	0	x
	4	Compatibility entry	UNS8	rw	0	x
	5	Event Timer (multiple of 1 ms, 0 deactivated)	UNS16	rw	0	x
1801h	Transmit PDO2 communication parameters (TMS/TMM88D only)					
	0	Highest subindex supported	UNS8	ro	5	
	1	COB-ID	UNS32	ro	280h + node ID	x
	2	Transmission type (synchronous / asynchronous manufacturer-specific)	UNS8	rw	1	x
	3	Inhibit time between two TPDO messages (multiple of 100 µs)	UNS16	rw	0	x
	4	Compatibility entry	UNS8	rw	0	x
	5	Event timer (multiple of 1 ms, 0 deactivated)	UNS16	rw	0	x
1A00h	Transmit PDO 1 mapping parameters					
	0	Highest subindex supported	UNS8	ro	dep. on type	
	1	Mapping entry 1, both types: TMS / TMM	UNS32	rw	0x60100010	x
	2	Mapping entry 2, type: TMS / TMM	UNS32	rw	0 / 0x60200010	x
	3	Mapping entry 3	UNS32	rw	0	x
	4	Mapping entry 4	UNS32	rw	0	x

Index	Subindex	Parameter	Data type	Access	Default value	Storage
	5	Mapping entry 5	UNS32	rw	0	x
	6	Mapping entry 6	UNS32	rw	0	x
	7	Mapping entry 7	UNS32	rw	0	x
	8	Mapping entry 8	UNS32	rw	0	x
1A01h	Transmit PDO2 mapping parameters (TMS/TMM88D only)					
	0	Highest subindex supported	UNS8	ro	2	
	1	Mapping entry 1	UNS32	rw	0x31000110	x
	2	Mapping entry 2	UNS32	rw	0x31000210	x
	3	Mapping entry 3	UNS32	rw	0	x
	4	Mapping entry 4	UNS32	rw	0	x
	5	Mapping entry 5	UNS32	rw	0	x
	6	Mapping entry 6	UNS32	rw	0	x
	7	Mapping entry 7	UNS32	rw	0	x
	8	Mapping entry 8	UNS32	rw	0	x
1F51h	Program download - control					
	0	Highest subindex supported	UNS8	ro	3	
	1	Firmware range	UNS8	rw	1	
	2	Range for configuration 1 (access for manufacturer only)	UNS8	rw	1	
	3	Range for configuration 2 (access for manufacturer only)	UNS8	rw	1	

9.7.1.1 Error register (1001h)

The error register indicates the general error status of the device. Each bit stands for an error group. If a bit is set (= 1), at least one error in this group is currently active. The content of this register is transmitted in every EMCY message. The following error groups may be encountered:

Table 37: Error register (1001h)

Error register (1001h)							
Bit7	**Bit6**	**Bit5**	**Bit4**	**Bit3**	**Bit2**	**Bit1**	**Bit0**
Manufacturer-specific error	Accuracy Warning	Profile-specific error	Communication error	Not used			At least one error active

If the device is in error status (at least one error active), this is indicated by bit 0 being set. In the event of a communication error (overrun of send/receive buffer, guarding error or CAN controller in passive/busoff mode), bit 4 is set. A profile-specific error (sensor error) is indicated by bit 5. Bit 7 signals a manufacturer-specific error (EEPROM error).

9.7.1.2 Manufacturer status register (1002h)

This register indicates the current status of all detectable errors. Each bit represents a specific error. If a bit is set (= 1), this error is currently active. The lower-value 16 bits of this register (bits 15 to 0) are transmitted in the first two bits of the manufacturer-specific part of each EMCY message as well as in the additional information field (bits 31 to 16) of the predefined error field 1003h.

Table 38: Manufacturer status register (1002h)

Manufacturer status register (1002h)		
Bit31...Bit16	**Bit15...Bit8**	**Bit7...Bit0**
Not used	Bit field Communication error	Bit field Device error

9.7.1.3 Predefined error field (1003h)

Each inclination sensor keeps a list of the five most recent errors that have occurred. Entry 1003.00h contains the number of error entries in the error field. All other subindices contain all of the error states that have occurred in chronological order. The most recent error is always listed under subindex 01h. The oldest error is located in the highest available subindex (value of 1003.00h). It is removed from the list first when more than five errors occur. When an error occurs, a new error entry is added to 1003h and an EMCY message is also sent by way of notification. An error entry is structured as follows:

Table 39: Error entry in predefined error field (1003h)

<table>
<tr><th colspan="3">Error entry in predefined error field (1003h)</th></tr>
<tr><th colspan="2">Additional information field (bits 31 to 16)</th><th>Error code (bits 15 to 0)</th></tr>
<tr><td colspan="2">Bits 15 to 0 of the manufacturer-specific register 1002h
(at the time the error occurred)</td><td rowspan="2">0x0000 Error reset or no more errors pending
0x5010 Sensor error / sensor error X
0x5020 Sensor error Y
0x8110 Receive / send buffer overflow
0x8120 CAN warning limit exceeded
0x8130 Node guard event
0x8140 Exit busoff status</td></tr>
<tr><td>Bit field
Communication error</td><td>Bit field
Device error</td></tr>
</table>

To delete the entire content of the error list, write a value of 0 to entry 1003.00h.

9.7.1.4 Saving (1010h) and restoring (1011h) parameters

Changes that are made to parameters in the object directory are applied immediately. So that the modified parameters remain active even after a reset, they must be saved in the internal permanent memory. Writing the Save signature (65766173h) to entry 1010.01h transmits all current parameters from the object directory to the permanent memory.

To reset the object directory to the factory settings, write the Load signature (64616F6Ch) to entry 1011.01h. This writes the factory parameters to the permanent memory. The changes are applied after a Reset Application (NMT command) or a Hardware Reset (if only a Reset Communication (NMT command) is sent, only the factory settings of the communication parameters are effective initially).

It is possible to save or load only parts of the object directory by writing the signature to subindex: 02h, 03h, or 04h.

9.7.1.5 Transmit PDO – Transmission type (1800h/1801h)

The entries 1800.02h/1801.02h are used to define how the sending of the PDO is triggered.

Table 40: Transmit PDO - Transmission type (1800.02h/1801.02h)

Transmit PDO - Transmission type (1800.02h/1801.02h)	
Transmis-sion type	**Description**
1...240	Synchronous (cyclic) Transmission after every 1...240th receipt of the SYNC object Only synchronized transmission with SYNC possible
253	Transmission exclusively with RTR
254	Asynchronous, manufacturer-specific Cyclic sending and/or sending when angle changes can be activated by means of corresponding configuration.

9.7.2 Manufacturer-specific part

Table 41: Manufacturer-specific part of the object directory

Index	Subindex	Parameter	Data type	Access	Default value	Storage
2002h	0	Automatic busoff recovery	BOOL	rw	0	x
3000h	Digital filter settings					
	0	Highest subindex supported	UNS16	ro	2	
	1	Filter type (0=off, 1=Butterworth, 2=critically damped)	UNS16	rw	2	x
	2	Digital filter limit frequency (100...25000/8000, in mHz)	UNS16	rw	2000	x
3001h	Transmit PDO 1, send when angle changes, types TMS88/TMS61					
	0	Highest subindex supported	UNS16	ro	2	
	1	Activate/deactivate send when angle changes (1/0)	UNS16	rw	0	x
	2	Minimum change in angle for axial axis (in °/100)	UNS16	rw	100	x
3001h	Transmit PDO 1, send when angle changes, types TMM88/TMM61					
	0	Highest subindex supported	UNS16	ro	3	
	1	Activate/deactivate send when angle changes (1/0)	UNS16	rw	0	x
	2	Minimum change in angle for longitudinal (X) axis (in °/100)	UNS16	rw	100	x
	3	Minimum change in angle for lateral (Y) axis (in °/100)	UNS16	rw	100	x
3002h	Sensor fusion configuration (TMS/TMM88D only)					
	0	Highest subindex supported	UNS8	ro	2	
	1	Activate/deactivate sensor fusion (1/0)	UNS8	rw	1	x
	2	Maximum interference suppression time (in ms)	UNS16	rw	5000	x
	3	Activate/deactivate dynamic gyro offset correction (1/0)	UNS8	rw	1	x
	4	Perform gyro offset correction. Writing 1 performs the offset correction and permanently saves the calculated values. The process takes approx. 2 s.	UNS8	wo	-	

Index	Subindex	Parameter	Data type	Access	Default value	Storage
	5	Level of dynamic offset correction, value range from 1 (slightly dynamic) to 10 (very highly dynamic)	UNS8	rw	3	x
3100h	Output Euler angles (TMS/TMM88D only)					
	0	Highest subindex supported	UNS8	ro	2	
	1	Pitch Euler angle (in °/100)	INT16	ro	-	
	2	Roll Euler angle (in °/100)	INT16	ro	-	
3101h	Output quaternion (TMS/TMM88D only)					
	0	Highest subindex supported	UNS8	ro	4	
	1	Quaternion scalar part w (in 1/30000)	INT16	ro	-	
	2	Quaternion vector part x (in 1/30000)	INT16	ro	-	
	3	Quaternion vector part y (in 1/30000)	INT16	ro	-	
	4	Quaternion vector part z (in 1/30000)	INT16	ro	-	
3102h	Output acceleration sensor raw data (TMS/TMM88D only)					
	0	Highest subindex supported	UNS8	ro	3	
	1	Acceleration, x-axis (in 1/4096 g)	INT16	ro	-	
	2	Acceleration, y-axis (in 1/4096 g)	INT16	ro	-	
	3	Acceleration, z-axis (in 1/4096 g)	INT16	ro	-	
3103h	Output yaw rate sensor raw data (TMS/TMM88D only)					
	0	Highest subindex supported	UNS8	ro	3	
	1	Yaw rate, x-axis (in 7/800 °/s)	INT16	ro	-	
	2	Yaw rate, y-axis (in 7/800 °/s)	INT16	ro	-	
	3	Yaw rate, z-axis (in 7/800 °/s)	INT16	ro	-	
5555h	Reserved index (for manufacturer access only)					

9.7.2.1 Automatic busoff recovery (2002h)

This feature regulates the behavior of the inclination sensor whenever it is in busoff status. When activated, the inclination sensor can switch out of this status back to the error-active status with reset error counters. To do this, it must detected 11 consecutive recessive bits on the bus 128 times.

When deactivated, the inclination sensor remains in busoff status.

9.7.2.2 Digital filter settings (3000h/3002h)

The inclination sensor supports an option to make the continuously generated angle value more insensitive to external vibration interference. Oscillation/vibration interference up to 0.1 Hz can be suppressed with the configurable 8th order low-pass filter. The sensor has two digital filters which can be selected according to the area of application in which the sensor is being used.

Table 42: Filter selection

Filters	Configurable Frequency range	Areas of application
Butterworth	0.1 Hz to 25 Hz	Static inclination measurement with high damping against vibrations
Critically damped	0.1 Hz to 8 Hz	Inclination measurement for applications subject to specific dynamics / without overshoot in the event of changes in angle combined with good damping

The digital filter is selected via entry 3000.01h. The limit frequency is set via object 3000.02h. Values from 100 (= 0.1 Hz) to 25,000/8,000 (= 25 Hz/8 Hz) are permitted.

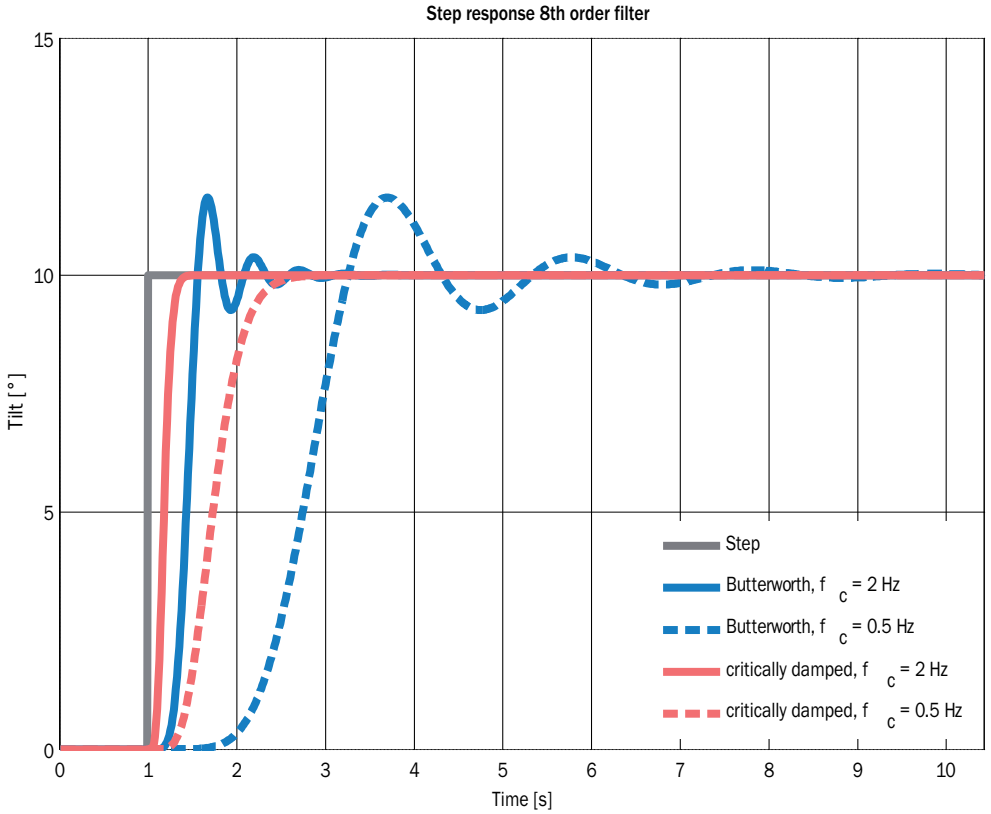

Figure 19: Pulse response of both filters

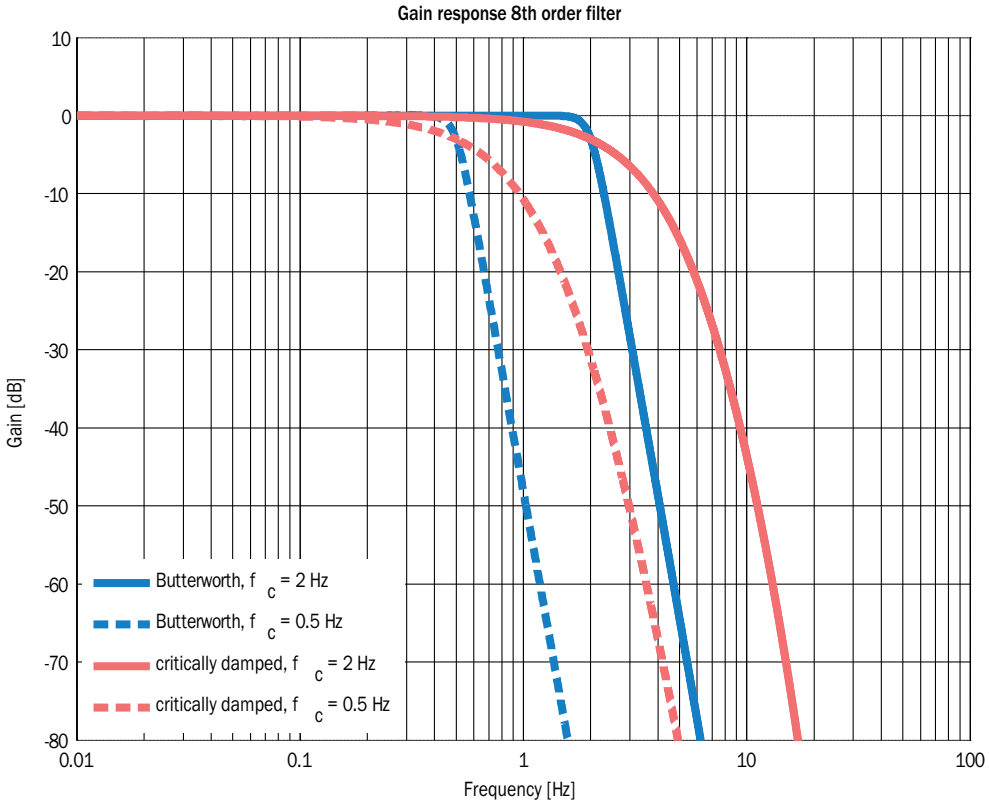

Figure 20: Amplitude characteristic of both filters

The sensor fusion filter uses as a measurand not only the Earth's gravitational field but also the yaw rate information from a gyroscope. This enables external accelerations and vibrations to be suppressed without causing a noticeable delay in the calculation of the angle information.

Filters	Configurable range	Areas of application
Sensor fusion	100 ms to 10.000 ms	Dynamic applications, measurements while accelerating, braking, or driving through curves, measurement with no signal delay time

9.7.2.3 Transmit PDO 1, send when angle changes (3001h)

The event-driven sending of Transmit PDO 1 when the angle changes can be activated (= 1) and deactivated (= 0) via entry 3001.01h.

For activation, the transmission type for Transmit PDO 1 must be set to asynchronous, manufacturer-specific (1800.02h = 254). Subindices 02h and 03h can be used to set the minimum necessary change in angle separately for the longitudinal (X) and the lateral (Y) axis. These two angle values are specified in °/100 (100x angle value) and can be set to user-defined values starting from 1 (= 0.01°).

If sending when the angle changes is activated, in Operational status, the inclination sensor will always send Transmit PDO 1 again whenever the inclination value of the longitudinal and/or the lateral axis has changed by the angle value set under 3001.02h and 03h. The difference in angle between the current inclination value and the last angle value sent with Transmit PDO 1 is constantly calculated and checked.

Every time the status switches to Operational, the inclination sensor signals the current position by sending Transmit PDO 1 once (only if 3001.01h = 1).

NOTE
If minor differences in angle are entered under 3001.02h and 03h, we recommend activating the digital filter (index 3000h) in order to minimize the effect of vibrations and thus the frequent sending of Transmit PDO 1.

9.7.3 Profile-specific part (to CiA DS-410)

Table 43: Profile-specific part of the object directory

Index	Subindex	Parameter	Data type	Access	Default value	Storage
6000h	0	Resolution (multiple of 0.001°)	UNS16	ro	10	
6010h	0	Inclination value, longitudinal (X axis, 100x angle value in °)	INT16	ro	-	
6011h	0	Operating parameter, longitudinal (inversion, zero-point setting)	UNS8	rw	0	x
6012h	0	Default value for longitudinal (X) axis	INT16	rw	0	x
6013h	0	Offset value for longitudinal (X) axis	INT16	rw	0	x
6014h	0	Difference offset value for longitudinal (X) axis	INT16	rw	0	x
6020h	0	Inclination value, lateral (Y axis, 100x angle value in °)	INT16	ro	-	
6021h	0	Operating parameter, lateral (inversion, zero-point setting)	UNS8	rw	0	x
6022h	0	Default value for lateral (Y) axis	INT16	rw	0	x
6023h	0	Offset value for lateral (Y) axis	INT16	rw	0	x
6024h	0	Difference offset value for lateral (Y) axis	INT16	rw	0	x

9.7.3.1 Resolution (6000h)

The resolution of all inclination sensors is set to a fixed value of 0.01° (default: 10 * 0.001°). All angle values in the object directory (6010h, 6012h, 6013h, 6014h plus 6020h, 6022h, 6023h, 6024h) must be interpreted as a multiple of 0.01°.

Example:
Angle value = -2370 x 0.01° → -23.70°

9.7.3.2 Longitudinal and lateral angle values (6010h and 6020h)

Up-to-date angle values for the inclination axes can be accessed both via SDO access to the object directory (in any device status) and with a Transmit PDO. When zero-point setting is activated (operating parameters: 6011h and 6021h), the inclination angle is calculated as follows:

Inclination value = inclination value physically measured + difference offset value + offset value

When zero-point setting is deactivated:

Inclination value = physically measured inclination value

Operating parameters (6011h and 6021h) describes how the 100x signed 16-bit inclination value (two's complement) is converted.

Example:
Value range, TMS type: -18,000 ... +17,999 → -180.00° ... +179.99° = 0 ...359.99°
Value range, type TMM: -9,000 ... +9,000 → - 90.00° ... + 90.00°

9.7.3.3 Operating parameters (6011h and 6021h)

The operating parameter settings of an inclination sensor (6011h and 6021h) can be used to convert the mathematical sign of the inclination value and also for zero-point setting. These options are deactivated on delivery, i.e., the direction of the angle value (polarity of the axes) corresponds to the assignment indicated on the device type label.

Table 44: Operating parameters (6011h and 6021h)

Operating parameters (6011h and 6021h)							
Bit7	**Bit6**	**Bit5**	**Bit4**	**Bit3**	**Bit2**	**Bit1**	**Bit0**
Not used						Zero-point setting 0 = /inactive 1 = active	Inversion 0 = /inactive 1 = active

9.7.3.4 Zero-point setting: Default value, offset value, difference offset value (60x1/2/3h)

A zero-point setting for the inclination angle can be made using the values for default value, offset value, and difference offset value. This setting is only active if bit 1 is set in the operating parameters (6011h/6021h).

Table 45: Zero-point setting

Value	Object	Description
Default value	6012h 6022h	Default value for zero-point setting Value range depending on setting in object 6000h
Offset value	6013h 6023h	Calculated offset value when writing to object 6012h or 6022h Calculated offset value = default value with tacc – inclination value physically measured with tacc – difference offset value tacc: time of write access to default value (6012h,6022h)
Difference offset value	6014h 6024h	Additional offset, independent of object 6012h and 6013h / 6022h and 6023h The value entered here is added directly to the current inclination value.

9.8 Error messages: Emergency

Emergency messages are used to transmit important internal device errors and CAN communication errors to other nodes on the bus. In the event of one of these errors, the OD entries 1001h (error register), 1002h (manufacturer status register), and 1003h (predefined error field) are updated.

Once an error has been resolved, an emergency message is sent with the error code 0x0000. Any errors that are still pending are signaled in byte 2 (error register) and bytes 3 and 4 of the manufacturer-specific error field. As soon as a device is error-free, it sends an emergency message containing zeros only. The current device status (Pre-Operational, Operational, or Stopped) is not affected by the error statuses, except in the case of guarding errors.

Emergency messages are sent with high priority on the bus. They are always 8 bytes long:

Table 46: Emergency object

Emergency object							
Byte0	**Byte1**	**Byte2**	**Byte3**	**Byte4**	**Byte5**	**Byte6**	**Byte7**
Emergency error code		Error register (1001h)	Manufacturer-specific error field				
			Bit field Communication error	Bit field Device error	0x00	0x00	0x00

Table 47: Emergency error code

Emergency error codes	
0x0000	An error has been reset or there are no more errors pending (error register = 0)
0x5010	Sensor error / sensor error X, angle value outside measuring range
0x5020	Sensor error Y, angle value outside measuring range
0x8110	Receive / send buffer overflow, CAN messages lost
0x8120	CAN warning limit exceeded
0x8130	Failure of the guarding master detected (node guard event)
0x8140	Exit busoff status

Table 48: Emergency: Manufacturer-specific error field

Bit field	
Device error	
0x01	Sensor error, only types: TMS88/TMS61
0x01	Sensor error, X axis, only types: TMM88/TMM61
0x02	Sensor error, Y axis, only types: TMM88/TMM61
0x80	EEPROM error: An error occurred when saving the configuration
Communication error	
0x01	CAN warning limit exceeded (too many error frames)
0x02	CAN busoff status reached. An emergency message is sent after automatically exiting busoff status.
0x04	Receive queue overrun, receive buffer overrun, CAN messages lost
0x08	Send queue overrun, send buffer overrun, CAN messages lost
0x80	Guarding error; the failure of the guarding master has been detected (node guard event)

9.9 Automatic baud rate detection (to CiA AN-801)

Automatic baud rate detection automatically sets the baud rate of the inclination sensor to the current baud rate on the network. For this purpose, following switching on of the power supply, the inclination sensor is in what is known as listen-only mode. In this mode, it monitors the messages that are being sent and received on the CAN bus but does not acknowledge them. This operational status is indicated by the RUN LED flickering (see also chapter Status LED (to CiA DR-303-3)).

In this status, it is testing all available baud rates. When a valid CAN telegram is received, the correct baud rate is identified and set. After this, the inclination sensor starts up, logs in with a boot-up message, and switches to Pre-Operational mode.

NOTE
In order for baud rate detection to function correctly, telegrams from other bus nodes must be available.

9.10 Status LED (to CiA DR-303-3)

The built-in status LED shows the current device status (RUN LED, green) as well as any CAN communication errors that might have occurred (ERROR LED, red). The statuses listed in the following table can be identified based on the color and flashing frequency of the associated LEDs.

Table 49: Status and error information indicated by the status LED

Status LED		
RUN LED	**LED status**	**Description**
○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ...	Off	The device is in Reset status or the power supply is absent.
✹ ✹ ✹ ✹ ✹ ✹ ✹ ✹ ✹ ✹ ✹ ✹ ✹ ...	Flickering	Automatic baud rate detection in progress (active).
○ ● ○ ● ○ ● ○ ● ○ ● ○ ● ...	Flashing	The device is in Pre-Operational status.
○ ● ○ ○ ○ ○ ○ ● ○ ○ ○ ○ ...	Simple flash	The device is in Stopped status.
● ● ● ● ● ● ● ● ● ● ● ● ● ...	On	The device is in Operational status.
ERROR LED	**LED status**	**Description**
○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ...	Off	The device is operating without errors.
● ○ ● ○ ○ ○ ○ ○ ● ○ ● ○ ...	Simple flash	CAN controller error counter has reached or exceeded its warning limit.
● ○ ○ ○ ○ ○ ● ○ ○ ○ ○ ○ ...	Double flash	The device has detected the failure of the guarding master (node guard event).
● ● ● ● ● ● ● ● ● ● ● ● ● ...	On	The device is in “busoff” status.

Key: ○ LED off, ● LED on, ◐ LED flickering (50 ms on/off), ○/● duration: 200 ms

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