SUPREME SENSORING

TWK

Inclination sensor
Model NBN45-G/S3
Interface: CANopen Safety

Document no.:
NBN 17382 CE
18.11.2025

USER MANUAL

CANopen safety easy to use

SAE INTERNATIONAL J1939

SIL2 IEC 61508 FUNCTIONAL SAFETY SENSOR

PLd ISO 13849 FUNCTIONAL SAFETY SENSOR

E1 UN ECE R10 OFFICIAL LISTED SENSOR

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INTRODUCTION

1. INTRODUCTION

The inertial sensor family NBN45-G/S3 offer the functionality of an inertial measuring unit (IMU) based on a micro-electromechanical system (MEMS) sensor technology. The accelerations and rotation rates occurring in all three spatial axes are measured and output. The sensors also provide inclination values in all three spatial axes.

The sensor is also available as functional safe version according SIL 2 or PLd.

The sensor technology used in combination with a compact and robust zinc die-cast housing with an M12 plug/socket combination is ideal for applications in mobile machines and harsh environmental conditions.

To improve the stability of the measured values, various configurable filter algorithms are available to the user. In addition to the classic low-pass filters such as Butterworth and "critically damped", a Kalman filter can also be activated for dynamic applications. This makes them ideal for use in dynamic applications such as mobile machinery.

The measurement values are made available via the CANopen Safety interface. Optionally, a non-safety output of the measurement values via a CANopen or SAE J1939 interface is also possible if configured accordingly. This enables easy integration of the sensor into existing systems. Protocol and measuring range are freely selectable.

The NBN45-G/S3 family is designed for operation in working machinery and further suitable application areas. It is qualified especially for use under harsh conditions.

Inertial sensors can be used in many different application scenarios. They can be deployed e.g. for:

- Determination of the inclination for driving and working movements e.g.
    - to detect the position of an excavator bucket or a concrete pump
    - to limit the steering angle of a vehicle in case of a critical inclined position
    - for the alignment and adjustment of the sieves and threshing units in harvesting machines
- Reduction or avoidance of strong ship swaying due to wave action
- Theft warning systems
- Position estimation (position and orientation) → Odometry
- Display acceleration of the vehicle by "G" indication
- Shock detection when driving against an obstacle or over a pothole can be used, for example, to map ground conditions
- Predictive maintenance, in combination with machine learning
- Vehicle and/or attachment levelling
- Orientations of photovoltaic systems, solar panels, wind turbines

This user and safety manual describes:

- The safety requirements for using the NBN45-G/S3 in a safety application
- The qualification tests
- The technical data of the NBN45-G/S3
- Overall installation and how to mount the NBN45-G/S3 correctly
- How to configure the NBN45-G/S3

GENERAL INFORMATION

2 GENERAL INFORMATION

2.1 Contact

Address:

TWK Elektronik GmbH

Bismarckstr. 108

40210 Düsseldorf

Germany

Phone: +49 211 96117-0

Web: www.twk.de

E-Mail: info@twk.de

2.2 Copyright

The information provided in this document contains function descriptions that in case of actual use do not always apply as described due to the configuration of the product. An obligation to provide the respective functions shall only exist if expressly agreed in the terms of contract.

Subject to change without prior notice.

2.3 Declaration of Conformity

coming soon

2.4 Warranty

Warranty will be void if:

- The product was opened by unauthorized persons
- The product was modified
- Damage has been caused as a result of use, storage or installation that does not comply with the user manual

2.5 Documents

Overview of documents that are available for NBN45-G/S3:

Document title	Description
Data sheet NBN17266	Contains main technical data of the device
User and Safety manual NBN45-G/S3	This document. It provides the description of the functionality of the device

More documents and files can be found on www.twk.de.

GENERAL INFORMATION

Accessibility and archiving:

Make sure to store and archive this document for everyone accessible working with this product. This document contains safety instructions that must be observed and followed.

2.6 Target Group

This manual describes the handling and characteristics of the NBN45-G/S3. It is designed to be a comprehensive source of information about the NBN45-G/S3 for OEM design, engineering and maintenance personnel.

System development, installation and commissioning of the NBN45-G/S3 must only be carried out by trained and experienced personnel who are sufficiently familiar with the used components and with the complete system.

This personnel are people who, on the basis of their professional education, knowledge and experience, are able to assess the work assigned to them and identify typical problem areas during embedded software development and its potential risks.

2.7 Storage

Store the NBN45-G/S3 in

- an indoor space with a clean and dry environment. For the storage temperature see Mechanical Data.
- the original packaging.

2.8 Disposal

The disposal of the unit shall be conform to the recycling regulations of the country and regions in which they are disposed. Dispose the unit according to the valid local regulations.

2.9 Ordering Information

The NBN45-G/S3 is an inertial measurement unit (IMU) and can be ordered as IMU as functional safe version and non functional safe standard version.

For all sensors the communication interface as well as the angle measuring range can be configured. The various default configurations are listed in the table below.

	Default configuration	**Order number**
NBN45-G/S3 (IMU)	IMU, SIL2, PLd, CANopen Safety interface	See data sheet NBN17266

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2.10 Used Symbols and Formats

The following symbols and formats are used in our manuals to mark important information:

Requirements which shall be adhered to maintain safe system operations.

Recommendation on how to handle certain aspects of requirements in the chapter Safety Requirements.

A note provides additional and important information in the chapter Safety Requirements.

WARNING

Describes the type and source of danger. Describes results or effects if the safety advice will not be followed.

- Describes steps to avoid the danger

NOTE

A note provides additional and important information of the system behavior.

GENERAL INFORMATION

2.11 Abbreviations

ASCII . . . . . American standard code for information interchange
BCD . . . . . Binary coded decimal
CAN . . . . . Controller area network
CCF . . . . . Common Cause Failure
CiA . . . . . CAN in Automation e.V., international users' and manufacturers' group for the CAN network
COB . . . . . Communication object
COB-ID . . . . . COB identifier
CRC . . . . . Cyclic Redundancy Check
DB . . . . . Data byte, of a CAN message
DC_{avg} . . . . . Diagnostic Coverage Average
DLC . . . . . Data length code, number of bytes in a CAN message
DTI . . . . . Diagnostic Test Interval [described in IEC 61508-4]
ECE . . . . . Economic Commission for Europe
ECU . . . . . Electronic control unit
EEPROM . . . . . Electrically erasable programmable ROM
EMC . . . . . Electromagnetic compatibility
EMCY . . . . . Emergency object
FRT . . . . . Failure Reaction Time
FS . . . . . Full scale
HFT . . . . . Hardware Fault Tolerance
IC . . . . . Inclinometer Class (1 or 2)
ID . . . . . Identifier
IEC . . . . . International electro technical commission
IMU . . . . . Inertial measurement unit
ISO . . . . . International organization for standardization
KBA . . . . . Kraftfahrt- Bundesamt
LSS . . . . . Layer Setting Services
MTTF . . . . . Mean Time To Failure
MTTFD . . . . . Mean Time To Dangerous Failure
NMT . . . . . Network management
NVM . . . . . Non-volatile Memory, e.g. an EEPROM
OD . . . . . Object dictionary
PDO . . . . . Process data object
PDU . . . . . Protocol data unit
PFH . . . . . Average frequency of dangerous failure per hour
PGN . . . . . Parameter group number
PL . . . . . Performance Level: Safety classification according to ISO 13849
RAM . . . . . Random Access Memory
SCT . . . . . Safety Cycle Time
SDO . . . . . Service data object
SFF . . . . . Safe Failure Fraction
SIL . . . . . Safety Integrity Level: Safety classification according to IEC 61508
SN . . . . . Siemens Standard
SPN . . . . . Suspect parameter number
SRDO . . . . . Safety Relevant Data Object
SRVT . . . . . Safety Relevant Validation Time
SYNC . . . . . Synchronization object
TPDO . . . . . Transmit process data object

SAFETY REQUIREMENTS

3. SAFETY REQUIREMENTS

3.1 Contents

Type	Description	ID
§	The Safety Manual describes how to use the NBN45-G/S3 within safety critical applications.	213817
i	The Safety Manual requirements are intended to be used by application developers and system integrators that want to integrate the NBN45-G/S3 into systems to provide safety critical functionality. The following knowledge is required in order to integrate the NBN45-G/S3 within that context: • Development of safety critical systems in compliance with [IEC 61508] resp. [ISO 13849] • Development of safety critical communication in compliance with [EN 50325-5] and [CiA 410 DSP] • Functionality of the NBN45-G/S3	213815

3.2 How to read the Safety Manual

Type	Description	ID
i	The Safety Manual contains requirements, information and recommendations.	213822
i	Each piece of information consists of a text block that contains the actual information and a requirement ID. This ID can be used to trace requirements that shall be followed through the development process of the application.	213818
i	All safety functions described in section "Safety Functions" have references to other sections of this manual, e.g. chapter "Filtering" or chapter "Status Flags" or chapter "Parameters".	213823
§	All information marked as "requirement" in this way shall be followed when developing the application. Non-compliance with these instructions may lead to severe injuries or equipment damage. For a description of all formats see the chapter "Used Symbols and Formats".	213819

3.3 References

Type	Description	ID
i	IEC 61508]: IEC 61508 Parts 1 through 7, Edition 2.0, 2010, Functional safety of electrical/electronic/programmable electronic safety-related systems	213826
i	[ISO 13849-1]: EN ISO 13849-1:2023 Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design	213828
i	[SN 29500]: Siemens standard SN 29500 Parts 1 through 16, January 2004 - July 2011, Failure rates of components	213830

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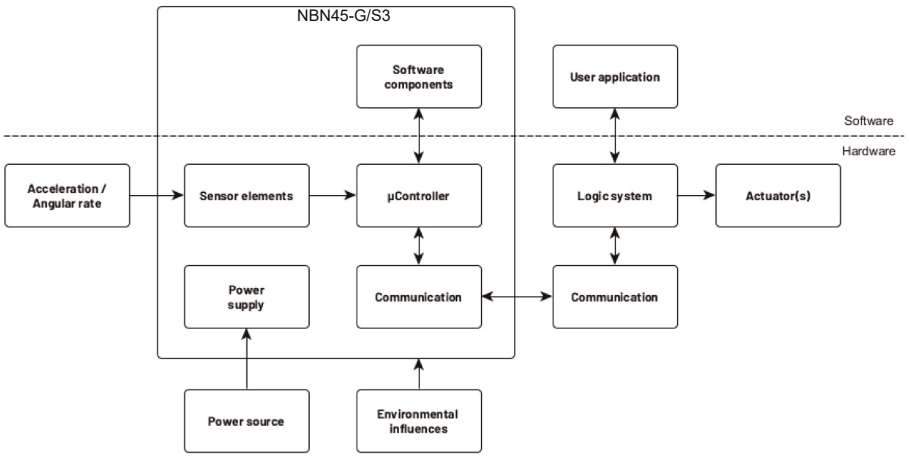
Type	Description	ID
	EN 50325-5]: DIN EN 50325-5, 2016-06, Industrielles Kommunikationssubsystem basierend auf ISO 11898 (CAN) – Teil 5: Funktional sichere Kommunikation basierend auf EN 50325-4; Englische Fassung EN 50325-5: 2010	213874
	[CiA 410 DSP]: CiA 410 Draft Standard Proposal, Version: 2.0.0 25 March 2014, CANopen Device profile for inclinometer	214495

3.4 System

Type	Description	ID
	The following diagram shows the inclination sensor NBN45-G/S3 in a typical application:	213923
		214708

3.4.1 Safety Standards

Type	Description	ID
	The current safety regulations, laws, and standards for the whole safety lifecycle shall be observed (national and international).	213883

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3.4.2 Known Issues

Type	Description	ID
	There are no known issues for the sensor NBN45-G/S3.	213884
	Safety critical issues will be communicated to the company contact provided to TWK. Please keep your details up to date and inform TWK of any relevant changes.	215998

3.4.3 General

Type	Description	ID
	All safety-related system components including the NBN45-G/S3 shall be operational before machine operation.	213896
	The environmental, electrical and EMC conditions shall not exceed the specified limits of the NBN45-G/S3.	213897
	The characteristics of accelerometer, gyroscope and angle in chapter "Sensor Data" shall be considered.	214707
	The definition of the measuring axes in chapter "Definition of measuring axes" shall be considered.	213919
	The description of the filters in chapter "Filtering" shall be considered.	213920
	The Kalman filter shall not be used for the safety functions.	213921
	The meaning of the STATUS flags in chapter "Status Flags" shall be considered.	213922
	Any errors occurring with regard to functional safety shall be reported to TWK Elektronik GmbH: info@twk.de.	213898
	Use of the NBN45-G/S3 shall be in accordance with this manual. In particular, attention shall be paid to correct mounting of the NBN45-G/S3 and valid communication settings as required for safety-related operation.	213899
	The currently valid version of this manual can be requested from TWK Elektronik GmbH: info@twk.de.	213900
	The integrator of the system application is responsible for the functional safety of the system. Using the NBN45-G/S3 in accordance with this manual is essential for achieving functional safety, but does not guarantee the safety of the entire system, e.g. including externally connected control unit.	213901

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3.4.4 Valid Safety Relevant Configuration

Type	Description	ID
	A "Valid Safety Relevant Configuration" (VSRC) shall be used as shown in the following table. The VSRC describes the configuration of components, i.e. hardware, software and document artifacts.	214488
	Components that are part of the VSRC shall not be modified in any way.	214564
	The TWK article number on the label shall match the NBN45-G/S3 for safety, according to chapter "Ordering Information".	215989
	If customer specific article number is used, the article number shall match the customer specific article number of the device for safety.	215990
	In order to check the article number of the sensor the object "Article Number" (2000h:02h) can be read.	215991
	The embedded hardware version shall be read by sending a SDO reading request for the object "Manufacturer Hardware-Version" (1009h:00h). It shall match the selected VSRC.	215992
	The embedded software version shall be read by sending a SDO reading request for the object "Manufacturer Software-Version" (100Ah:00h). It shall match the selected VSRC.	215993
	The document version shall be checked in the corresponding PDF file. It shall match the selected VSRC.	215994
	VSRC for embedded components and documentation. **Component** **VSRC 1.0** Hardware v1.00r0 Software v2.05r1 User and Safety Manual NBN 17382 **CE**[1)] [1)] Later versions (see chapter 12 REVISION HISTORY) are also valid.	215995
	To obtain the correct VSRC of the NBN45-G/S3, the VSRC should be specified when ordering the NBN45-G/S3. If no specific VSRC is ordered, TWK Elektronik GmbH will deliver the last released VSRC of the NBN45-G/S3, which could result in the safetycritical application no longer properly working.	215996

SAFETY REQUIREMENTS

3.4.4.1 Functional Safety Classification

Type	Description				ID
	The NBN45-G/S3 has the following functional safety classification and parameters.				213905
	**Standard**	**Description**	**Safety Function**	**Parameter**	213907
	[IEC 61508]	**Safety Integrity Level (SIL)**	all	**2**	
		Operation Mode	all	High demand mode / continuous mode	
		Architecture	all	1oo1 (single channel)	
		Hardware Fault Tolerance (HFT)	all	0	
		Safety-related subsystem	all	Type B	
		β-Factor	all	5 % (Sensor), 2 % (Logic Subsystem)	
		β_D-Factor	all	2 % (Sensor), 1 % (Logic Subsystem)	
		Safe Failure Fraction (SFF)	Safety Function 1 (acceleration)	93.5 % (incl. Soft-errors)	
			Safety Function 2 (angular rate)	93.5 % (incl. Soft-errors)	
			Safety Function 3 (inclination angles)	93.5 % (incl. Soft-errors)	
			Safety Function 4 (rotation angles)	93.5 % (incl. Soft-errors)	
			Safety Function 5 (Euler angles)	93.5 % (incl. Soft-errors)	
		Average frequency of dangerous failure per hour (PFH)	Safety Function 1 (acceleration)	$64.9 * 10^{-9}$ failure/hour (incl. Soft-errors)	
			Safety Function 2 (angular rate)	$64.9 * 10^{-9}$ failure/hour (incl. Soft-errors)	
			Safety Function 3 (inclination angles)	$64.9 * 10^{-9}$ failure/hour (incl. Soft-errors)	
			Safety Function 4 (rotation angles)	$64.9 * 10^{-9}$ failure/hour (incl. Soft-errors)	
			Safety Function 5 (Euler angles)	$64.9 * 10^{-9}$ failure/hour (incl. Soft-errors)	

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Type	Description				ID
	[ISO 13849-1]	**Performance Level (PL)**	all	**d**	213907
		Category (Cat.)	all	2	
		Common Cause Failures (CCF)	all	70 points	
		Diagnostic Coverage (DC_{avg})	Safety Function 1 (acceleration)	92.2 % (medium; incl. Soft-errors)	
			Safety Function 2 (angular rate)	92.2 % (medium; incl. Soft-errors)	
			Safety Function 3 (inclination angles)	92.2 % (medium; incl. Soft-errors)	
			Safety Function 4 (rotation angles)	92.2 % (medium; incl. Soft-errors)	
			Safety Function 5 (Euler angles)	92.2 % (medium; incl. Soft-errors)	
		Mean Time To dangerous Failure ($MTTF_D$)	Safety Function 1 (acceleration)	136.5 years (high; incl. Soft-errors)	
			Safety Function 2 (angular rate)	136.7 years (high; incl. Soft-errors)	
			Safety Function 3 (inclination angles)	136.5 years (high; incl. Soft-errors)	
			Safety Function 4 (rotation angles)	136.5 years (high; incl. Soft-errors)	
			Safety Function 5 (Euler angles)	136.5 years (high; incl. Soft-errors)	

3.4.5 Reliability and Maintenance

<table>
<tr><th>Type</th><th colspan="5">Description</th><th>ID</th></tr>
<tr><td rowspan="4">  </td><td colspan="5">MTTF and Lifetime of the NBN45-G/S3:</td><td rowspan="4">213902</td></tr>
<tr><td></td><td>Value</td><td>Temperature [1)]</td><td>Operation Mode</td><td>Standard</td></tr>
<tr><td>MTTF</td><td>203.62 years</td><td>+40 °C</td><td>Continuous operation (8760 operating hours per year)</td><td>[SN 29500], Parts Count Method</td></tr>
<tr><td>Lifetime</td><td>20 years</td><td>-40 °C ... +85 °C</td><td>Continuous operation (8760 operating hours per year)</td><td>-</td></tr>
<tr><td colspan="6">1) Board temperature of the NBN45-G/S3.
The lifetime of the NBN45-G/S3 can be further reduced under certain circumstances by wear and tear of the following hardware elements:
• Exceeding the maximum number of erase/programming cycles of the EEPROM.
• Exceeding the maximum number of 100 plug-in cycles of the M12 connector.
• Cyclical plugging of the M12 connector.
For the NBN45-G/S3 the "Proof Test Interval" is set to the lifetime. Thus, periodic maintenance is not required.</td></tr>
</table>

SAFETY REQUIREMENTS

Type	Description	ID
	The EEPROM should be protected against excessive write cycles. There is no protection mechanism. For the EEPROM the manufacturer specifies 1 million write cycles at 25 °C.	214506
	The NBN45-G/S3 shall be replaced at the end of the lifetime.	213904

3.4.6 Safety Functions

Type	Description	ID
	As the sensor does not have a reference measurement, the static accuracy of inclination, rotation and Euler angles can only be guaranteed under the following conditions: • The values of the sensor elements are plausible to each other • The sensor is not in motion • The sensor is used at its specified operating temperature	213918

3.4.6.1 Safety Function 1 - Safe and redundant detection and safe output of acceleration in 3 axes

Type	Description	ID
	The sensor detects the actual acceleration in 3 axes safe and redundant and transmits the acceleration values safe via the CAN communication interface using the protocol CANopen Safety. Safety relevance: • Data integrity across the entire signal path and difference in redundantly detected values • The accuracy of the acceleration values (see chapter "Sensor Data") Safety integrity: • IEC 61508: SIL2 • ISO 13849: PLd Diagnosis: • Diagnostic test interval (DTI): 250 ms • Failure reaction: Safe state • Failure reaction time (FRT): 5 ms Parameter: • Measuring axes: X, Y, Z in acceleration axes • Filter: Configurable low-pass filter • Status flags: SAT_XL, PC_XL, TOV, HNIR • Transmit-SRDO: SRDO3 with configurable COB-IDs, information direction and refresh-time • CANopen safety relevant objects: 4000h:01h, 4000h:02h, 4010h, 4011h, 4012h	213917
	In order to detect the acceleration values safely, the user shall configure the low-pass filter. The configuration contains following parameter: • Filter type: one of the three filter type shall be set • Filter frequency: a valid value according to the configured filter type shall be set	213925

SAFETY REQUIREMENTS

<table>
<tr><th>Type</th><th>Description</th><th>ID</th></tr>
<tr><td></td><td>In order to output the acceleration values safely, the user shall configure the SRDO communication objects for SRDO3.
The configuration contains following parameter:
• Information direction: shall be set to transmit (=1)
• Refresh-time: shall be set to value > 0 ms
• COB-ID 1: shall be set to an unique and odd value between 101h and 17Fh
• COB-ID 2: shall be set to the value of COB-ID 1 increased by 1
• SRDO3 signature: shall be set to the calculated CRC value according to the standard [EN 50325-5]</td><td>213924</td></tr>
<tr><td></td><td>The current acceleration values can be read also by sending a SDO reading request for the safety relevant objects:
• 4000h:01h - Acceleration Status
• 4000h:02h - Inverted Acceleration Status
• 4010h:01h - Safety Acceleration value X axis
• 4010h:02h - Safety Inverted Acceleration value X axis
• 4011h:01h - Safety Acceleration value Y axis
• 4011h:02h - Safety Inverted Acceleration value Y axis
• 4012h:01h - Safety Acceleration value Z axis
• 4012h:02h - Safety Inverted Acceleration value Z axis</td><td>213926</td></tr>
<tr><td></td><td>The mapping of the safety relevant objects is static and cannot be changed and can be read out by SDO reading requests with index 1383h.
<table>
<tr><th>Byte number</th><th>0</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th></tr>
<tr><td>CAN Frame 1</td><td colspan="2">4010h:01h</td><td colspan="2">4011h:01h</td><td colspan="2">4012h:01h</td><td>4000h:01h</td><td>-</td></tr>
<tr><td>CAN Frame 2</td><td colspan="2">4010h:02h</td><td colspan="2">4011h:02h</td><td colspan="2">4012h:02h</td><td>4000h:02h</td><td>-</td></tr>
</table></td><td>213927</td></tr>
<tr><td></td><td>The user shall monitor the STATUS flags within the SRDO3 (Byte number 6). If flag WARN (Bit 1) is set, the current acceleration values are not reliable (e.g. saturation, extreme acceleration or overtemperature). If flag HNIR (Bit 0) is set, the accuracy of the sensor values is only within the limits, that are defined for the sensor operating without heater.</td><td>213928</td></tr>
<tr><td></td><td>The user should define and monitor a maximum time during which the acceleration values may be unreliable.</td><td>213929</td></tr>
</table>

SAFETY REQUIREMENTS

3.4.6.2 Safety Function 2 - Safe and redundant detection and safe output of angular rate in 3 axes

<table>
<tr><th>Type</th><th>Description</th><th>ID</th></tr>
<tr><td></td><td>The sensor detects the actual angular rate in 3 axes safe and redundant and transmits the angular rate values safe via the CAN communication interface using the protocol CANopen Safety.
Safety relevance:
• Data integrity across the entire signal path and difference in redundantly detected values
• The accuracy of the angular rate values (see chapter "Sensor Data")
• Safety integrity:
• IEC 61508: SIL2
• ISO 13849: PLd
Diagnosis:
• Diagnostic test interval (DTI): 250 ms
• Failure reaction: Safe state
• Failure reaction time (FRT): 5 ms
Parameter:
• Measuring axes: X, Y, Z in gyro axes
• Gyroscope measuring range: ±125 °/s ... ±4000 °/s (see parameter GFSR in chapter "Parameters")
• Status flags: SAT_GY, PC_GY, TOV, HNIR
• Transmit-SRDO: SRDO4 with configurable COB-IDs, information direction and refresh-time
• CANopen safety relevant objects: 4000h:03h, 4000h:04h, 4020h, 4021h, 4022h</td><td>213934</td></tr>
<tr><td></td><td>In order to output the angular rate values safely, the user shall configure the SRDO communication objects for SRDO4.
The configuration contains following parameter:
• Information direction: shall be set to transmit (=1)
• Refresh-time: shall be set to value > 0 ms
• COB-ID 1: shall be set to an unique and odd value between 101h and 17Fh
• COB-ID 2: shall be set to the value of COB-ID 1 increased by 1
• SRDO4 signature: shall be set to the calculated CRC value according to the standard [EN 50325-5]</td><td>213935</td></tr>
<tr><td></td><td>The current angular rate values can be read also by sending a SDO reading request for the safety relevant objects:
• 4000h:03h - Gyro Status
• 4000h:04h - Inverted Gyro Status
• 4020h:01h - Safety Gyro value X axis
• 4020h:02h - Safety Inverted Gyro value X axis
• 4021h:01h - Safety Gyro value Y axis
• 4021h:02h - Safety Inverted Gyro value Y axis
• 4022h:01h - Safety Gyro value Z axis
• 4022h:02h - Safety Inverted Gyro value Z axis</td><td>213936</td></tr>
<tr><td></td><td>The mapping of the safety relevant objects is static and cannot be changed and can be read out by SDO reading requests with index 1384h.
<table>
<tr><td>Byte number</td><td colspan="2">0</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">3</td><td colspan="2">4</td><td colspan="2">5</td><td colspan="2">6</td><td>7</td></tr>
<tr><td>CAN Frame 1</td><td colspan="4">4020h:01h</td><td colspan="4">4021h:01h</td><td colspan="4">4022h:01h</td><td colspan="2">4000h:03h</td><td>-</td></tr>
<tr><td>CAN Frame 2</td><td colspan="4">4020h:02h</td><td colspan="4">4021h:02h</td><td colspan="4">4022h:02h</td><td colspan="2">4000h:04h</td><td>-</td></tr>
</table></td><td>213937</td></tr>
</table>

SAFETY REQUIREMENTS

Type	Description	ID
	The user shall monitor the STATUS flags within the SRDO4 (Byte number 6). If flag WARN (Bit 1) is set, the current angular rate values are not reliable (e.g. saturation, extreme accelerations or overtemperature). If flag HNIR (Bit 0) is set, the accuracy of the sensor values is only within the limits, that are defined for the sensor operating without heater.	213938
	The user should define and monitor a maximum time during which the acceleration values may be unreliable.	213939
	The gyroscope measuring range can be changed by writing the apropriate value to the object "Gyro Full-Scale Range" (3120h:04h) according to the description of the parameter GFSR in chapter "Parameters".	214712

3.4.6.3 Safety Function 3 - Safe determination and safe output of inclination angles in 2 axes

Type	Description	ID
	The sensor determines the inclination of the X and Y axes in the +/- 90° range safe and redundant from the acceleration values and transmits the angle values safe via the CAN communication interface using the protocol CANopen Safety. Safety relevance: • Data integrity across the entire signal path and difference in redundantly detected values • The static accuracy of the determined angle values (see chapter "Sensor Data") Safety integrity: • IEC 61508: SIL2 • ISO 13849: PLd Diagnosis: • Diagnostic test interval (DTI): 250 ms • Failure reaction: Safe state • Failure reaction time (FRT): 5 ms Parameter: • Measuring axes: X, Y in inclination angle axes with measuring range ±90° • Filter: Configurable low-pass filter • Zero Offset: ZERO_IX, ZERO_IY • Status flags: SAT_XL, PC_XL, I90_X_OOR, I90_Y_OOR, TOV, HNIR • Transmit-SRDO: SRDO1 with configurable COB-IDs, information direction and refresh-time • CANopen device profile inclinometer class: C2 • CANopen safety relevant objects: 4000h:05h, 4000h:06h, 6210h:01h, 6211h:01h, 6220h:01h, 6221h:01h	214523
	In order to determine the angle values safely, the user shall configure the low-pass filter and the zero offset. The configuration contains following parameter: • Filter type: one of the three filter type shall be set • Filter frequency: a valid value according to the configured filter type shall be set • Zero offset X axis: a valid value shall be set, if the X axis zero point of the ±90° inclination angle is shifted • Zero offset Y axis: a valid value shall be set, if the Y axis zero point of the ±90° inclination angle is shifted	213890

SAFETY REQUIREMENTS

<table>
<tr><th>Type</th><th>Description</th><th>ID</th></tr>
<tr><td></td><td>In order to output the angle values safely, the user shall configure the SRDO communication objects for SRDO1.
The configuration contains following parameter:
• Information direction: shall be set to transmit (=1)
• Refresh-time: shall be set to value > 0 ms
• COB-ID 1: shall be set to an unique and odd value between 101h and 17Fh
• COB-ID 2: shall be set to the value of COB-ID 1 increased by 1
• SRDO1 signature: shall be set to the calculated CRC value according to the standard [EN 50325-5]</td><td>214524</td></tr>
<tr><td></td><td>The current angle values can be read also by sending a SDO reading request for the safety relevant objects:
• 4000h:05h - Inclination Status
• 4000h:06h - Inverted Inclination Status
• 6210h:01h - Safety slope long16 value
• 6211h:01h - Safety inverted slope long16 value
• 6220h:01h - Safety slope lateral16 value
• 6221h:02h - Safety inverted slope lateral16 value</td><td>214525</td></tr>
<tr><td></td><td>The mapping of the safety relevant objects is static and cannot be changed and can be read out by SDO reading requests with index 1384h.
<table>
<tr><td>Byte number</td><td colspan="2">0</td><td colspan="2">1</td><td colspan="2">2</td><td colspan="2">3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td>CAN Frame 1</td><td colspan="4">6210h:01h</td><td colspan="4">6220h:01h</td><td>4000h: 05h</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>CAN Frame 2</td><td colspan="4">6211h:01h</td><td colspan="4">6221h:01h</td><td>4000h: 06h</td><td>-</td><td>-</td><td>-</td></tr>
</table></td><td>214526</td></tr>
<tr><td></td><td>The user shall monitor the STATUS flags within the SRDO1 (Byte number 4). If flag WARN_X (Bit 1) is set, the current angle values of X axis are not reliable (e.g. saturation, extreme acceleration or overtemperature). If flag WARN_Y (Bit 2) is set, the current angle values of Y axis are not reliable (e.g. saturation, extreme acceleration or overtemperature). If flag HNIR (Bit 0) is set, the accuracy of the sensor values is only within the limits, that are defined for the sensor operating without heater.</td><td>214527</td></tr>
<tr><td></td><td>The user should define and monitor a maximum time during which the inclination angle values may be unreliable.</td><td>214528</td></tr>
</table>

SAFETY REQUIREMENTS

3.4.6.4 Safety Function 4 - Safe determination and safe output of rotation angle of one axis

Type	Description	ID
	The sensor determines the rotation of one axis in the 360° range safe and redundant from the acceleration values and transmits the angle values safe via the CAN communication interface using the protocol CANopen Safety. Safety relevance: • Data integrity across the entire signal path and difference in redundantly detected values • The static accuracy of the determined angle values (see chapter "Sensor Data") Safety integrity: • IEC 61508: SIL2 • ISO 13849: PLd Diagnosis: • Diagnostic test interval (DTI): 250 ms • Failure reaction: Safe state • Failure reaction time (FRT): 5 ms Parameter: • Measuring axes: Z in rotation angle axis with measuring range 360° • Filter: Configurable low-pass filter • Zero Offset: ZERO_RZ • Status flags: SAT_XL, PC_XL, R360_Z_NA, TOV, HNIR • Transmit-SRDO: SRDO1 with configurable COB-IDs, information direction and refresh-time • CANopen device profile inclinometer class: C1 • CANopen safety relevant objects: 4000h:05h, 4000h:06h, 6210h:01h, 6211h:01h	214538
	In order to determine the rotation values safely, the user shall configure the low-pass filter and the zero offset. The configuration contains following parameter: • Filter type: one of the three filter type shall be set • Filter frequency: a valid value according to the configured filter type shall be set • Zero offset Z axis: a valid value shall be set, if the Z axis zero point of the 360° rotation angle is shifted	214503
	In order to output the angle values safely, the user shall configure the SRDO communication objects for SRDO1. The configuration contains following parameter: • Information direction: shall be set to transmit (=1) • Refresh-time: shall be set to value > 0 ms • COB-ID 1: shall be set to an unique and odd value between 101h and 17Fh • COB-ID 2: shall be set to the value of COB-ID 1 increased by 1 • SRDO1 signature: shall be set to the calculated CRC value according to the standard [EN 50325-5]	214539
	The current angle values can be read also by sending a SDO reading request for the safety relevant objects: • 4000h:05h - Inclination Status • 4000h:06h - Inverted Inclination Status • 6210h:01h - Safety slope long16 value • 6211h:01h - Safety inverted slope long16 value	214540

SAFETY REQUIREMENTS

<table>
<tr><th>Type</th><th>Description</th><th>ID</th></tr>
<tr><td rowspan="4">  </td><td colspan="8">The mapping of the safety relevant objects is static and cannot be changed and can be read out by SDO reading requests with index 1384h.</td><td rowspan="4">214541</td></tr>
<tr><td>Byte number</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr>
<tr><td>CAN Frame 1</td><td colspan="2">6210h:01h</td><td colspan="2">7FFFh</td><td>4000h: 05h</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>CAN Frame 2</td><td colspan="2">6211h:01h</td><td colspan="2">8000h</td><td>4000h: 06h</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>  </td><td colspan="8">The user shall monitor the STATUS flags within the SRDO1 (Byte number 4). If flag WARN (Bit 1) is set, the current angle values are not reliable (e.g. saturation, extreme acceleration or overtemperature). If flag HNIR (Bit 0) is set, the accuracy of the sensor values is only within the limits, that are defined for the sensor operating without heater.</td><td>214542</td></tr>
<tr><td>  </td><td colspan="8">The user should define and monitor a maximum time during which the rotation angle values may be unreliable.</td><td>214543</td></tr>
</table>

3.4.6.5 Safety Function 5 - Safe determination and safe output of Euler angles pitch and roll

Type	Description	ID
	The sensor determines the Euler angles of the Roll and Pitch axes safe and redundant from the acceleration values and transmits the angle values safe via the CAN communication interface using the protocol CANopen Safety. Safety relevance: • Data integrity across the entire signal path and difference in redundantly detected values • The static accuracy of the determined angle values (see chapter "Sensor Data") Safety integrity: • IEC 61508: SIL2 • ISO 13849: PLd Diagnosis: • Diagnostic test interval (DTI): 250 ms • Failure reaction: Safe state • Failure reaction time (FRT): 5 ms Parameter: • Measuring axes: Roll, Pitch in Euler angle axes • Filter: Configurable low-pass filter • Status flags: SAT_XL, PC_XL, TOV, HNIR • Transmit-SRDO: SRDO2 with configurable COB-IDs, information direction and refresh-time • CANopen safety relevant objects: 4000h:07h, 4000h:08h, 4040h, 4041h	214537
	In order to determine the Euler angle values safely, the user shall configure the low-pass filter. The configuration contains following parameter: • Filter type: one of the three filter type shall be set • Filter frequency: a valid value according to the configured filter type shall be set	214563

SAFETY REQUIREMENTS

Type	Description	ID
§	In order to output the angle values safely, the user shall configure the SRDO communication objects for SRDO2. The configuration contains following parameter: • Information direction: shall be set to transmit (=1) • Refresh-time: shall be set to value > 0 ms • COB-ID 1: shall be set to an unique and odd value between 101h and 17Fh • COB-ID 2: shall be set to the value of COB-ID 1 increased by 1 • SRDO1 signature: shall be set to the calculated CRC value according to the standard [EN 50325-5]	214556
i	The current angular rate values can be read also by sending a SDO reading request for the safety relevant objects: • 4000h:07h - Euler Status • 4000h:08h - Inverted Euler Status • 4040h:01h - Safety Roll Euler angle value • 4040h:02h - Safety Inverted Roll Euler angle value • 4041h:01h - Safety Pitch Euler angle value • 4041h:02h - Safety Inverted Pitch Euler angle value	214544
i	The mapping of the safety relevant objects is static and cannot be changed and can be read out by SDO reading requests with index 1381h.	214557

Byte number	0	1	2	3	4	5	6	7
CAN Frame 1	4040h:01h		4041h:01h		4000h:07h	-	-	-
CAN Frame 2	4040h:02h		4041h:02h		4000h:08h	-	-	-

§	The user shall monitor the STATUS flags within the SRDO2 (Byte number 4). If flag WARN (Bit 1) is set, the current angle values are not reliable (e.g. saturation, extreme acceleration or overtemperature). If flag HNIR (Bit 0) is set, the accuracy of the sensor values is only within the limits, that are defined for the sensor operating without heater.	214558
	The user should define and monitor a maximum time during which the Euler angle values may be unreliable.	214559

3.4.7 Diagnosis

Type	Description	ID
i	The sensor uses several mechanisms to detect faults in the electronic circuit. Those are realized in a start-up and a cyclic diagnosis.	214630

SAFETY REQUIREMENTS

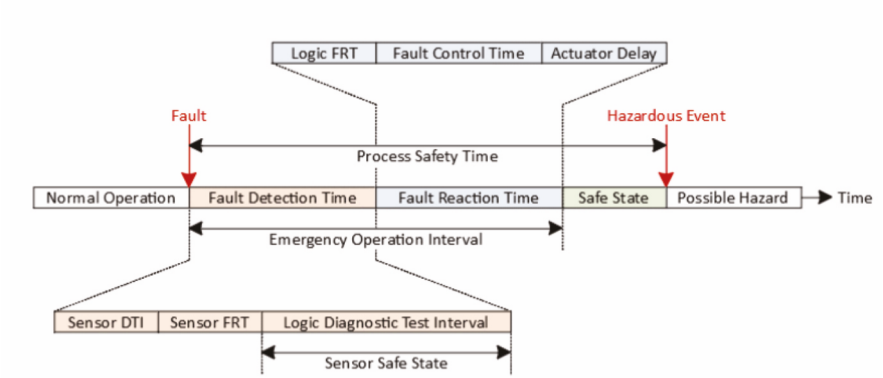
3.4.7.1 Start-Up Diagnosis

Type	Description	ID
	The start-up diagnosis is made once after powering the sensor and includes internal tests concerning e.g. the watchdog or any persistent memory. If the start-up diagnosis detects a fault, the safe state is entered.	214665
	The sensor is designed for operation with continuous demand, but will restart automatically after 240 hours of continuous operation.	214666
	The maximum sensor run time of 240 hours should be considered.	214664

3.4.7.2 Cyclic Diagnosis

Type	Description	ID
	The cyclic diagnosis is made at least every 250 ms and includes: • testing the CPU, controller register, internal flash and RAM of the micro controller • check of the internal sensor supply voltage for over-voltage and under-voltage • check of the internal sensor elements (connection check, check for valid and up-to-date data) • check of the usage of the stack • check if the period of the periodic tasks is within its limits • triggering the watchdogs within its windows if the relevant program sections have been executed correctly If the cyclic diagnosis detects a fault, the safe state is entered.	214667
	The fault reaction time depends on the detected fault: • If fault reaction is reset, the communication is stopped in 5 ms maximum and the sensor will restart by watchdog within 100 ms maximum. • If fault reaction is enter SAFE_FAIL mode, the CANopen NMT state "Pre-Operational" is entered in 5 ms maximum and the output of SRDOs is stopped. • if fault reaction is send EMCY message, the EMCY message is sent in 5 ms maximum, the CANopen NMT state "Pre-Operational" is entered and the output of SRDOs is stopped.	214668
	The following diagram shows the system fault reaction overview:	214695

SAFETY REQUIREMENTS

Type	Description	ID
		214710
	The diagnostic test interval of the superordinate logic system shall be short enough to detect the safe state reliably.	214700

3.4.8 Safe State

Type	Description	ID
	In the safe state, either no transmission of sensor data should be possible (1) or no SRDOs are output (2), (3), (4). (1) The sensor may be in reset or is unable to communicate. (2) The sensor is in not in SAFE mode, see chapter "CANopen Operating Modes". (3) The CANopen NMT state of the sensor is not "Operational". (4) The sensor sends an EMCY message with a defined error code and exits the CA-Nopen NMT state "Operational".	214565

3.4.9 Security

Type	Description	ID
	The overall system shall take care of security.	213885

SAFETY REQUIREMENTS

3.5 System Installation and Wiring

Type	Description	ID
	The external wiring of the NBN45-G/S3 (power supply, control unit) shall be designed so that all specified electrical parameters of the NBN45-G/S3 are fulfilled.	214565
	The environmental conditions of the NBN45-G/S3 (e.g. temperature, mechanical and electromagnetic stress) shall be selected so that all specified environmental parameters of the NBN45-G/S3 are met.	213887
	The instructions for mounting the NBN45-G/S3 in chapter "Mounting" shall be considered.	213889
	The instructions for electrical connection to the NBN45-G/S3 in chapter "Electrical Connection" shall be considered.	213891
	The NBN45-G/S3 shall not be connected directly to a DC voltage network (e.g. DC grid via the car battery).	213894
	The integrator shall ensure that the maximum overall cable length does not exceed 30 m.	213895
	For protection against humidity the unused M12 connector shall be sealed correctly.	213892
	In order to reduce interferences in the CAN communication an 120 Ω termination resistor should be pluged at the ends of the CAN bus.	213893

3.6 Safety Communication - CANopen Safety

Type	Description	ID
	According to the CANopen Safety standard [EN 50325-5] the sensor is a SRDO producer. According to the device profile specification [CiA 410 DSP] the sensor is a CANopen node with pre-defined device type for inclinometers. Safety communication is available only in SAFE operation mode and with protocol CANopen Safety.	214485
	In order to check the current device type of the sensor the object "Device Type" (1000h:00h) can be read. The device profile is set to 410, the Inclinometer class is set to C1 (one-axis 16-bit value measurements) or C2 (two axes 16-bit value measurements), the PDO mapping is set to manufacturer-specific and the SRDO mapping is set to CANopen Safety is supported (Manufacturer-specific SRDO mapping).	214551
	In order to use CANopen Safety the protocol type in the object "CAN protocol" (3100h:01h) shall be set to the value 3 (CANopen Safety).	214487
	The requirements of the CANopen Safety standard [EN 50325-5] for a SRDO consumer node shall be met in order to receive safety relevant application data from the sensor.	214489

SAFETY REQUIREMENTS

Type	Description	ID
	The integrator shall configure the SRDO communication objects according to his application in compliance with the CANopen Safety standard [EN50325-5].	214490
	The assignment of the SRDO messages to the safety functions can be found in chapter "Safety Functions".	214491
	On delivery, SRDO1 is pre-configured for the Safety Function 3 and following values are pre-set in the SRDO1 communication object 1301h: • Information direction: 1 (transmit) • refresh-time: 20 ms • COB-ID 1: 101h • COB-ID 2: 102h	214492
	The "Safety Cycle Time" (SCT) of the SRDO consumer should always be longer than the SRDO refresh time set in the sensor as SRDO producer. However, the time tolerance window should also correlate with the fault reaction time determined from the risk analysis. When designing the system, care should be taken to ensure that all components involved in the safety function contribute to the overall reaction time.	214705
	The "Safety Relevant Validation Time" (SRVT) od the SRDO consumer depends on the used bitrate and the data length of the SRDO. Higher priority messages such as NMT, SYNC or EMCY can theoretically be sent between the two messages of an SRDO and this time span should therefore be taken into account. However, the SRVT should be significantly smaller than the SCT.	214706
	The SRDO consumer should monitor the CANopen NMT state of the sensor, e.g. by activating the heartbeat via the object "Producer Heartbeat Time" (1017h).	214504
	The SRDO consumer should monitor the receive of EMCY messages (COB-ID can be found in the object "COB-ID EMCY" (1014h)) from the sensor.	214505
	The integrator shall configure the profile-specific safety objects according to his application in compliance with the CANopen device profile [CiA 410 DSP].	214497
	The profile-specific object "Safety configuration parameters" (6200h) has no influence on the sensor, every write attempt will be rejected.	214499
	According to the device profile specification [CiA 410 DSP] the data object "Safety application configuration signature" (63FFh) provides the configuration signature for Safety application parameters. The CRC sum shall comprise terms of the both 16-bit and 32-bit resolution safety parameters for slope longitudinal and lateral, therfore the content of object "Safety configuration parameters" (6200h). As the content of object "Safety configuration parameters" (6200h) does not change at runtime, the CRC is calculated when the device is started and stored in this object. The CRC value is calculated using the same CRC generator polynomial as used in the CRC value calculation in Safety configuration signature [EN 50325-5]. The CRC generator polynomial is a CRC-16-CCITT polynomial.	214500
	The value in the device profile specific object "Safety application configuration signature" (63FFh) should remain set to 95A1h for inclinimeter class C1 or 1C0Bh for inclinomter class C2	214501
	In order to receive the configured SRDOs, the SRDO communication configuration and the device profile specific object "Safety application configuration valid" (63FEh) should be set to valid according to the CANopen Safety standard [EN 50325-5].	214502

QUALIFICATION TESTS

4. QUALIFICATION TESTS

4.1 Compliance information

Standard		Description	Parameter
ISO/IEC 17050-1	CE	Conformity	See Declaration of Conformity
KBA (Kraftfahrt-Bundesamt)	E1	Certification	According UN ECE Regulation No. 10 No. 10R - 06 10285

4.2 Electromagnetic and electrical tests

EMC (CE Conformity)		
Standard	**Test description**	**Test parameter**
DIN EN 61326-1:2013 DIN EN 61000-4-3	Immunity - For electrical equipment for measurement, control and laboratory use - Radiated, radio-frequency, electromagnetic field immunity test	80 MHz to 1 GHz →10 V/m; 1.4 GHz to 6.0 GHz →3 V/m; horizontal and vertical
EN 61326-1:2013 (and 2021) EN IEC 61000-6-2:2019 DIN EN 61000-4-6	Immunity to conducted disturbances, induced by radio-frequency fields - supply and data lines	150 kHz to 80 MHz, 10 V 150 kHz to 80 MHz, 3 V
EN 61326-1:2013 (and 2021)	CISPR11	150 kHz to 30 MHz 30 MHz to 1 GHz (18 GHz)
EN 61326-1:2013 (and 2021) DIN EN 61000-4-8	Immunity - Electrical equipment for measurement, control and laboratory use - magnetic field	Frequency: 50 Hz, 60 Hz Duration: 3 s Field strength: 30 A/m
EMC (E1)		
UN ECE R10 Add. 9, Rev. 6 Annex 7 CISPR25:2004	Radiated broadband emissions from ESAs	30 MHz to 1000 MHz
UN ECE R10 Add. 9, Rev. 6 Annex 8 CISPR25:2004	Radiated narrowband emissions from ESAs	30 MHz to 1000 MHz
UN ECE R10 Add. 9, Rev. 6 Annex 9 DIN EN ISO 13766-2:2018	Immunity of ESAs to electromagnetic radiation General: ISO 11452-1:2015 ALSE: ISO 11452-2:2019 BCI: ISO 11452-4:2020 (Stripline and TEM alternative test methods)	General 20 MHz … 2000 MHz 20 MHz … 800 MHz: AM 800 MHz … 3200 MHz: PM BCI: 1 MHz … 400 MHz, 60 mA (substitution (150 mm, 450 mm, 750 mm) or closed loop (900 mm) method allowed) Antenne, ALS E (vert): 200 MHz … 800 MHz, 30 V/m, CW, AM 800 MHz … 3200 MHz, 30 V/m, CW, PM
UN ECE R10 Add. 9, Rev. 6 Annex 9 ISO 7637-2:2004	Emissions - Voltage transient emissions	12 V: +75/-100 V 24 V: +150/-450 V
ISO 7637-2: 2011	Conducted transient emission from ESAs on supply lines, Level 3	12 V slow+: +37 V slow-: -75 V fast+: +75 V fast-: -112 V 24 V slow+: +37 V slow-: -150 V fast+: +150 V fast-: -150 V
UN ECE R10 Add. 9, Rev. 6 Annex 10 ISO 7637-2:2004	Immunity -Electrical transient conduction along supply lines 12 V System, Level 3	Pulse 1 (12 V) -75 V, 5000 pulses Pulse 2a (12 V) +37 V, 5000 pulses Pulse 2b (12 V), +10 V, 10 pulses Pulse 3a (12 V), -112 V, 1 h Pulse 3b (12 V), +75 V, 1 h Pulse 4 (12 V), -6 V, 1 pulse

QUALIFICATION TESTS

Standard	Test description	Test parameter
UN ECE R10 Add. 9, Rev. 6 Annex 10 ISO 7637-2:2004	Immunity -Electrical transient conduction along supply lines 24 V System, Level 3	Pulse 1 (24 V) -450 V, 5000 pulses Pulse 2a (24 V) +37 V, 5000 pulses Pulse 2b (24 V), +20 V, 10 pulses Pulse 3a (24 V), -150 V, 1 h Pulse 3b (24 V), +150 V, 1 h Pulse 4 (24 V), -12 V, 1 pulse
ISO 7637-2:2011	Immunity -Electrical transient conduction along supply lines 24 V System, Level 4	Pulse 1 (24 V) -600 V, 500 pulses Pulse 2a (24 V) +112 V, 500 pulses Pulse 2b (24 V), +20 V, 10 pulses Pulse 3a (24 V), -300 V, 1 h Pulse 3b (24 V), +300 V, 1 h
ISO 10605:2008	Immunity - ESD component test method - Powered-up test	330 Ω /330 pF, 330 Ω /150 pF, Contact discharge: ±2, ±4, ±8 kV Air discharge: ±8, ±15 kV Indirect contact discharge: ±2, ±4, ±8 kV
ISO 10605:2008-07	Immunity - ESD component test method - Packaging and Handling test (unpowered test)	2 kΩ /150 pF Contact discharge : ±2, ±4 kV, ±8 kV Air discharge on
DIN EN ISO 13766-2:2018	Immunity - ESD component test method - Packaging and Handling test (unpowered test) - direct discharges	2 kΩ /300 pF Contact discharge: ±2, ±4 kV, ±8 kV Air discharge: ±4, ±8 kV, ±15 kV
DIN EN ISO 13766-2:2018	Immunity - ESD component test method - Packaging and Handling test (unpowered test) - indirect discharges	2 kΩ /300 pF Contact discharge: ±2, ±4 kV, ±8 kV
DIN EN ISO 13766-2:2018	Electrical transient conduction along supply lines - 12 V and 24 V System, Level 3	12 V /24 V: Pulse 1, 2a, 2b, 3a, 3b, starting profile, load dump
DIN EN ISO 13766-2:2018 ISO 7637-3:2016	Faults on data lines; 12 V an 24 V system, Level 4	12 V: Slow +: ICC, +6 V, 5 min, t1 = 0,2 s to 5 s Slow -: ICC, -6 V, 5 min, t1 = 0,2 s to 5 s Pulse 3a: CCC, -110 V, 10 min Pulse 3b: CCC, +75 V, 10 min 24 V: Slow +: ICC, +6 V, 5 min, t1 = 0,2 s to 5 s Slow -: ICC, -6 V, 5 min, t1 = 0,2 s to 5 s Pulse 3a: CCC, -110 V, 10 min Pulse 3b: CCC, +75 V, 10 min

4.3 EMC automotive

Standard	Test description	Test parameter
UN ECE R10 Add. 9, Rev. 6 Annex 7 CISPR25:2004	Radiated broadband emissions from ESAs	30 MHz to 1000 MHz
UN ECE R10 Add. 9, Rev. 6 Annex 8 CISPR25:2004	Radiated narrowband emissions from ESAs	30 MHz to 1000 MHz
UN ECE R10 Add. 9, Rev. 6 Annex 9 DIN EN ISO 13766-2:2018	Immunity of ESAs to electromagnetic radiation General: ISO 11452-1:2015 ALSE: ISO 11452-2:2019 BCI: ISO 11452-4:2020 (Stripline and TEM alternative test methods)	General 20 MHz … 2000 MHz 20 MHz … 800 MHz: AM 800 MHz … 3200 MHz: PM BCI: 1 MHz … 400 MHz, 60 mA (substitution (150 mm, 450 mm, 750 mm) or closed loop (900 mm) method allowed) Antenne, ALS E (vert): 200 MHz … 800 MHz, 30 V/m, CW, AM 800 MHz … 3200 MHz, 30 V/m, CW, PM
UN ECE R10 Add. 9, Rev. 6 Annex 9 ISO 7637-2:2004	Emissions - Voltage transient emissions	12 V: +75/-100 V 24 V: +150/-450 V

QUALIFICATION TESTS

Standard	Test description	Test parameter
ISO 7637-2: 2011	Conducted transient emission from ESAs on supply lines, Level 3	12 V slow+: +37 V slow-: -75 V fast+: +75 V fast-: -112 V 24 V slow+: +37 V slow-: -150 V fast+: +150 V fast-: -150 V
UN ECE R10 Add. 9, Rev. 6 Annex 10 ISO 7637-2:2004	Immunity -Electrical transient conduction along supply lines 12 V System, Level 3	Pulse 1 (12 V) -75 V, 5000 pulses Pulse 2a (12 V) +37 V, 5000 pulses Pulse 2b (12 V), +10 V, 10 pulses Pulse 3a (12 V), -112 V, 1 h Pulse 3b (12 V), +75 V, 1 h Pulse 4 (12 V), -6 V, 1 pulse
UN ECE R10 Add. 9, Rev. 6 Annex 10 ISO 7637-2:2004	Immunity -Electrical transient conduction along supply lines 24 V System, Level 3	Pulse 1 (24 V) -450 V, 5000 pulses Pulse 2a (24 V) +37 V, 5000 pulses Pulse 2b (24 V), +20 V, 10 pulses Pulse 3a (24 V), -150 V, 1 h Pulse 3b (24 V), +150 V, 1 h Pulse 4 (24 V), -12 V, 1 pulse
ISO 7637-2:2011	Immunity -Electrical transient conduction along supply lines 24 V System, Level 4	Pulse 1 (24 V) -600 V, 500 pulses Pulse 2a (24 V) +112 V, 500 pulses Pulse 2b (24 V), +20 V, 10 pulses Pulse 3a (24 V), -300 V, 1 h Pulse 3b (24 V), +300 V, 1 h
ISO 10605:2008	Immunity - ESD component test method - Powered-up test	330 Ω /330 pF, 330 Ω /150 pF, Contact discharge: ±2, ±4, ±8 kV Air discharge: ±8, ±15 kV Indirect contact discharge: ±2, ±4, ±8 kV
ISO 10605:2008-07	Immunity - ESD component test method - Packaging and Handling test (unpowered test)	2 kΩ /150 pF Contact discharge : ±2, ±4, ±8 kV Air discharge on surfaces: ±4, ±8 kV, ±15 kV
DIN EN ISO 13766-2:2018	Immunity - ESD component test method - Packaging and Handling test (unpowered test) - direct discharges	2 kΩ /300 pF Contact discharge: ±2, ±4, ±8 kV Air discharge: ±4, ±8, ±15 kV
DIN EN ISO 13766-2:2018	Immunity - ESD component test method - Packaging and Handling test (unpowered test) - indirect discharges	2 kΩ /300 pF Contact discharge: ±2, ±4, ±8 kV
DIN EN ISO 13766-2:2018	Electrical transient conduction along supply lines - 12 V and 24 V System, Level 3	12 V /24 V: Pulse 1, 2a, 2b, 3a, 3b, starting profile, load dump
DIN EN ISO 13766-2:2018 ISO 7637-3:2016	Faults on data lines; 12 V an 24 V system, Level 4	12 V: Slow +: ICC, +6 V, 5 min, t1 = 0,2 s to 5 s Slow -: ICC, -6 V, 5 min, t1 = 0,2 s to 5 s Pulse 3a: CCC, -110 V, 10 min Pulse 3b: CCC, +75 V, 10 min 24 V: Slow +: ICC, +6 V, 5 min, t1 = 0,2 s to 5 s Slow -: ICC, -6 V, 5 min, t1 = 0,2 s to 5 s Pulse 3a: CCC, -110 V, 10 min Pulse 3b: CCC, +75 V, 10 min

4.4 Environmental Qualification

Standard	Test description	Test parameter
ISO 16750-4:2010-04	Tests at constant temperature: Low temperature - storage	-40 °C for 24 h
ISO 16750-4:2010-04	Tests at constant temperature: High temperature - storage	+85 °C for 48 h

QUALIFICATION TESTS

Standard	Test description	Test parameter
ISO 16750-4:2010-04	Tests at constant temperature: Low temperature - operation	-40 °C for 24 h
ISO 16750-4:2010-04	Tests at constant temperature: High temperature - operation	+85 °C for 96 h
ISO 16750-4:2010-04	Temperature step test	+20 °C to Tmin to Tmax, 5 °C steps Duration: 16 h (-40 °C to +85 °C) Perform functional tests when DUT has reached the new temperature
ISO 16750-4:2010-10 DIN EN 60068-2-14:2010-04	Temperature cycling test - Rapid change of Temperature	Test Na 100 cycles, -40 °C to +85 °C Transfer time ≤ 30 s Dwell time: 60 min.
ISO 16750-4:2010-04 DIN EN 60068-2-14	Temperature cycling test - specified change rate of Temperature	Test Nb 30 cycles á 480 min , Tmin to Tmax Duration: 10 days
ISO 16750-4:2010-04	Ice water shock test - Splash water test	Test Fluid: de-ionized water Chamber Temperature: +85 °C Water Temperature: 0 to +4 °C Water Flow: (3 to 4 l)/3 sec (splash duration) Cycle Duration: 66 min Number of cycles: 100 Total Duration 110 h In operation during splash
ISO 16750-4:2010-04 IEC 60068-2-11	Salt spray test - Leakage and function	Test Ka 8 h salt spray and 16 h without spray minimum 6 cycles á 24 h In operation between fourth and fifth hour of each cycle
ISO 16750-4:2010-04 DIN EN 60068-2-52: 2018-08	Salt spray test - Corrosion test	Severity 4 Duration: 14 days
ISO 16750-4:2010 IEC 60068-2-38	Humid heat - Test 2: Composite temperature / humidity cyclic test	Test Z/AD 10 cycles, upper temperature +65 °C, 93 % relative humidity, 5 cycles with frost phase (-10 °C) Duration: 11 days In operation when the maximum cycle temperature is reached
ISO 16750-4: 2010-04 IEC 60068-2-30: 2005	Humid heat - Test 3: Dewing test	Test Db Lower temperature: +25 °C Upper temperature: +80 °C 5 cycles and 98 % relative Humidity In operation
ISO 16750-4: 2010-04 DIN EN 60068-2-78:2014-02	Damp heat, steady-state test	Severity: (40 ±2) °C and (85 ±3) % relative humidity Not in operation for 20 days 23 h In operation for the last hour Duration: 21 days
ISO 16750-4:2010-04 IEC 60068-2-60	Corrosion test with flow of mixed gas	acc to IEC60068-2-60, Test Ke, method 4; (SO2, H2S, NO2, CL2) 10 days (mounting passenger or luggage/load compartment) 21 days (other mounting locations)
ISO 16750-1:2018 Annex B	Life-time Temperature cycling test - Rapid change of Temperature (Weibull)	
ISO 16750-3:2012 Test VII	Vibration (random) with temperature superimposition	Vibration noise with temperature superimposition in case of natural frequencies of DUT upper 30 Hz: random vibration acc IEC60068-2-64 from 10 Hz to 2000 Hz for 32 hrs each axis, Temperature cycle 8 h from Tmin to Tmax

QUALIFICATION TESTS

Standard	Test description	Test parameter
ISO 16750-3: 2012-12 DIN EN 60068-2-27	Mechanical Shock - Test for devices on rigid points on the body and on the frame	Acceleration: 50 g , half sine Time: 6 ms room temperature 10 shocks /direction
ISO 16750-3: 2012-12 DIN EN 60068-2-27: 2010-02	Bump	Acceleration: 30 g, sine Time: 6 ms 500 Shocks/direction, 6 directions
ISO 16750-3:2012 EN 60068-2-32 : 1993	Free fall	3 devices, 2 falls every device on the opposite side of the housing drop height: 1 m to concrete ground or steel plate
ISO 16750-3:2012	Resonance search	10 Hz - 2000 Hz, 1 g, 0,5 oct/min
ISO 16750-4:2010	Solar radiation	Confirmation of housing- and plug manufacturer about UV and OZON durability or test e.g. ISO 75220 or DIN EN 60068-2-5
ISO 16750-4:2010 ISO 20653:2013	IP Protection grade	IP6K5/IPX7

4.5 Safety Requirements

Standard	Test description	Test parameter
EN 61326-1:2013 (and 2021) DIN EN 61000-4-2	Electrostatic discharge immunity test - direct discharges	330 Ω / 150 pF, Contact discharge ±4 kV Air discharge ±8 kV
DIN EN 61326-3-1:2018 DIN EN 61000-4-2	Functional safety-Electrostatic discharge immunity test - direct discharges	330 Ω / 150 pF, Contact discharge ±6 kV Air discharge ±8 kV
EN 61326-1:2013 (and 2021) DIN EN 61000-4-2	Electrostatic discharge immunity test - indirect discharges (HCP, VCP)	330 Ω / 150 pF, Contact discharge ±4 kV
DIN EN 61326-3-1:2018 DIN EN 61000-4-2	Functional safety-Electrostatic discharge immunity test - indirect discharges	330 Ω / 150 pF, Contact discharge ±6 kV
DIN EN 61326-3-1:2018 DIN EN 61000-4-3	Functional safety- Radiated, radio-frequency, electromagnetic field immunity test	80 MHz to 1.0 GHz →20 V/m 1.4 GHz to 2 GHz →10 V/m 2 GHz to 2.7 GHz →3 V/m 3 m, horizontal and vertical
EN 61326-1:2013 (and 2021) DIN EN 61000-4-4	Immunity - Electrical equipment for measurement, control and laboratory use - Electrical fast transient / burst immunity test	data lines ±1 kV waveform: 5/50 ns tr/th repetition frequency 5 kHz
DIN EN 61326-3-1:2018 DIN EN 61000-4-4	Functional safety- Electrical fast transient / burst immunity test	Supply lines ±3 kV data lines ±2 kV waveform: 5/50 ns tr/th repetition frequency 5 kHz
DIN EN 61326-3-1:2018 DIN EN 61000-4-6	Functional safety- Immunity to conducted disturbances, induced by radio-frequency fields	Supply lines, data lines 150 kHz to 80 MHz, 10 V

QUALIFICATION TESTS

4.6 Electrical Safety Requirements

Standard	Test description	Test parameter
ISO 16750-1:2018-11	Direct current supply voltage	Umin = 9 V Umax = 36 V Test duration for each voltage level: 60 min.
ISO 16750-2:2012-11	Overvoltage	36 V for 60 min. at 20 °C below Tmax
ISO 16750-2:2012-11	Superimposed alternating voltage (12 V and 24 V System)	12 V System Usmax = 16 V (for UN = 12 V) Sweep duration: 120 seconds Number of sweeps: 5 Severity 1, 2, 4 24 V System Usmax = 32 V (for UN = 24 V) Sweep duration: 120 seconds Number of sweeps: 5 Severity 1, 2, 3
ISO 16750-2:2012-11	Slow decrease and increase of supply voltage	Decrease supply voltage from Usmin to 0 V and increase it from 0 V to Usmin. Applying a change rate of (0.5 ±0.1)V per minute
ISO 16750-2:2012-11	Discontinuities in supply voltage - Reset behaviour at voltage drop	Decrease supply voltage from Usmin =9 V in 5 % steps
ISO 16750-2:2012-11	Discontinuities in supply voltage - Starting profile (12 V and 24 V System)	12 V System Voltage cranking; Level 4 24 V System Voltage cranking; Level 3
ISO 16750-2:2012-11	Discontinuities in supply voltage - Load Dump (12 V and 24 V System)	with centralized load dump suppression 5 Pulses
ISO 16750-2:2012-11	Reversed voltage - Case 2 - 24 V Systems	Unom. = 24 V -> Case 2 - Test Voltage = 28 V reversed polarity Duration: 60 s
ISO 16750-2:2012-11	Short circuit protection - signal circuits	Connect every In- and Output to max. supply voltage (Usmax) and Ground for 1 minute various modes necessary
ISO 16750-2:2012-11	Short circuit protection - load circuits (supply lines)	to load circuits
ISO 16750-2:2012-11	Open circuit tests - Single line interruption - 24 V Systems	Interruption of each single Output for (10 ±1) s.
ISO 16750-2:2012-11	Open circuit tests - Multiple line interruption - 24 V Systems	Disconnect the DUT for (10 ±1) s.

SYSTEM INFORMATION

5. SYSTEM INFORMATION

The NBN45-G/S3 is characterized by the following features:

- Inertial measurement unit (IMU) to measure the inclination angle of an object in relation to the earth's gravity field and the angular velocity that have an effect on the system.
- Output of acceleration, gyroscope and inclination values
- Metal housing and robust design for use in harsh environments
- With ECE type approval

The key technical data are:

- Measurement ranges:
  - Inclination angles up to ±90° and resolution of 0.01°
  - Rotation angles with range 0° ... 360° and resolution of 0.01°
  - Gyroscope angular speeds up to ±4000°/s, resolution down to ~0.004°/s (measurement range is user-selectable)
  - Acceleration ±3 g with a resolution of 0.25 mg
- Internal adjustable Butterworth and critical damped low-pass filter algorithms for reducing the influences of parasitic accelerations
- Sensor variant with additional Kalman filter (sensor data fusion)
- Sensor can be operated with enabled or disabled temperature compensation
- Integrated status LED
- Operating temperature range -40 ... 85 °C (-40 ... 185 °F)
- Interface configurable for CANopen, CANopen Safety or SAE J1939
- Protection class IP6K5/IPX7.
- 2 x M12 connectors (5-pole, plug and socket, A-coded)

5.1 Technical Data

5.1.1 Sensor Data

Characteristics	Parameter	NBN45-G/S3
Accelerometer	Measuring range	±3 g
	Resolution	0.25 mg
	Offset error @ TA=25 °C	±5 mg
	Offset error @ TH[4)]	±10 mg
	Offset error @ -40 °C ... +85 °C	±20 mg
	Gain error @ TA=25 °C	±0.4 %
	Gain error @ TH[4)]	±0.5 %
	Gain error @ -40 °C ... +85 °C	±0.7 %

SYSTEM INFORMATION

Characteristics	Parameter	NBN45-G/S3	
Gyroscope	Measuring range	±125°/s ... 4000°/s	
	Resolution	0.004375°/s ... 0.140°/s [1)]	
	Offset error @ TA=25 °C	±2°/s	
	Offset error @ TH[4)]	±3°/s	
	Offset error @ -40 °C ... +85 °C	±5°/s	
	Gain error @ TA=25 °C	±2 %	
	Gain error @ TH[4)]	±3 %	
	Gain error @ -40 °C ... +85 °C	±5 %	
	Bias Instability @ TA=25 °C	typ. 3 °/h	
	Angle Random Walk @ TA=25 °C	typ. 0.2 °/√h	
Angle	Measuring range	max. 360°	
	Resolution	0.01°	
	Accuracy @ TA=25 °C	static ±0.3°	dynamic ±0.62° [2)]
	Accuracy @ TH[4)]	static ±0.5°	dynamic ±1.0° [2)]
	Accuracy @ -40 °C ... +85 °C	static ±0.8°	dynamic ±1.6° [2)]
	Filter options *(configurable)*[3)]	IIR Butterworth filter 8th order IIR Critical damped filter 8th order	

[1)] The resolution depends on the measuring range.

[2)] Valid for Kalman parameters R=10.0, Q=0.01.

[3)] The IIR filter algorithms act on the acceleration values, from which the angles are calculated.

[4)] Valid if target temperature of heater is reached (HNIR=0).

5.1.2 CAN Interface

Feature	**Properties**
Output signal	CAN, bit rate 100 to 1000 kBit/s
Protocol	CANopen safety
Electrical protection	Short circuit protected (signal on GND/VCC)
Two-Colour-Status LED	Green / Red

5.1.3 Power Supply

Feature	**Properties**
Voltage supply (power supply pin VCC)	9 to 36 V DC Supply lines inverse-polarity protected
Current Consumption (without active heating)	25 mA @ 12 V DC
Current Consumption (with active heating)	350 mA @ 12 V DC

5.1.4 Housing

Feature	**Properties**
Housing material	Zinc die cast
Dimensions (L x W x H)	83 x 73 x 26 mm
Weight	250 g
Degree of protection	IP6K5/IPX7
Electrical connection	5 pole M12 plug, A coded 5 pole M12 socket, A coded
Operating temperature	-40 °C to +85 °C / -40 °F to +185 °F
Storage temperature	-40 °C to +85 °C / -40 °F to +185 °F

SYSTEM INFORMATION

5.1.5 Functional Safety

Standard	Description	Parameter
SN 29500	Mean Time To Failure (MTTF)	MTTF = 203 years
IEC 61508:2010	Safety Integrity Level (SIL)	SIL 2
	Operation Mode	High demand mode / continuous mode
	Architecture	1oo1 (single channel)
	Hardware Fault Tolerance (HFT)	HFT = 0
	Safety-related subsystem	Type B
	Safe Failure Fraction (SFF)	SFF >= 90 % (incl. Soft-errors)
	Average frequency of dangerous failure per hour (PFH)	PFH <= 65 * 10-9 failure/hour (incl. Soft-errors)
EN ISO 13849-1:2023	Performance Level (PL)	PL d
	Category (Cat.)	Category 2
	Diagnostic Coverage (DCavg)	DCavg= medium
	Mean Time To dangerous Failure ($MTTF_D$)	$MTTF_D$ >= 75 years (high; incl. Soft-errors)

SYSTEM INFORMATION

5.2 Technical Drawings

5.2.1 Mechanical Dimensions

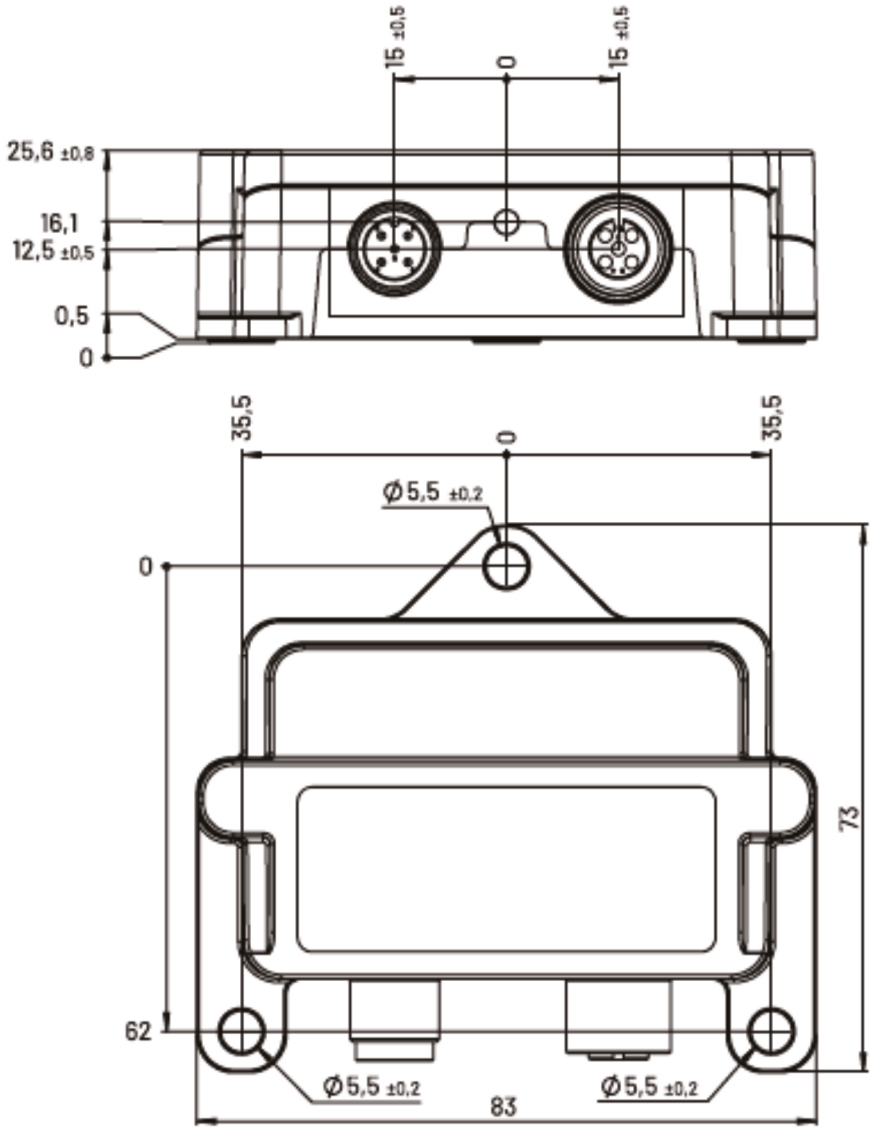
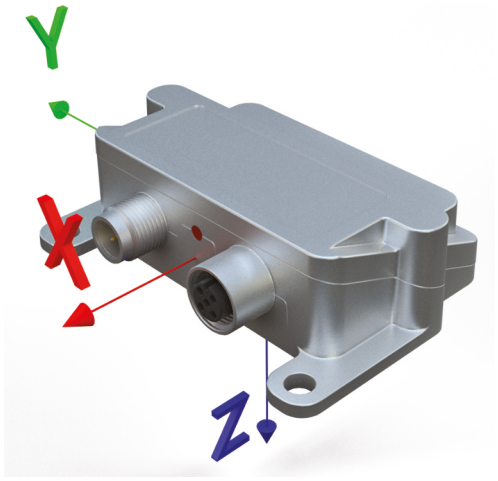


Figure 1: NBN45/G-S3 dimensions

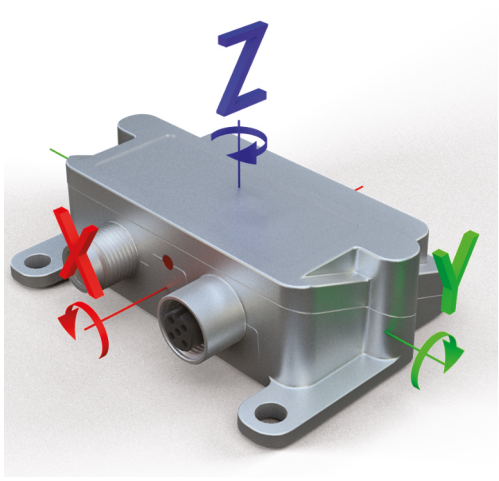
SYSTEM INFORMATION

5.2.2 Definition of measuring axes

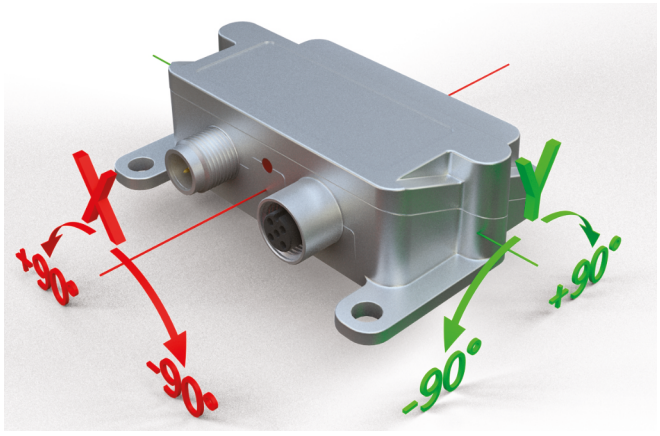
This section describes the axes of the various measurement values, the sensor provides (acceleration, angular speed, angles). The following figures show, how to axes relate to the housing of the sensor.



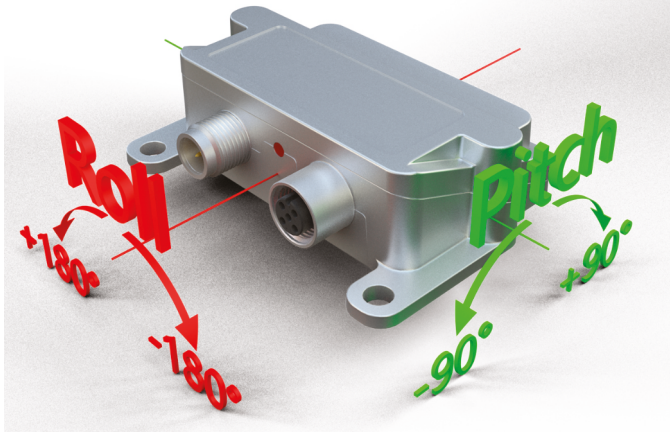
NBN45-G/S3 acceleration axes, downward-pointing axis has +1 g



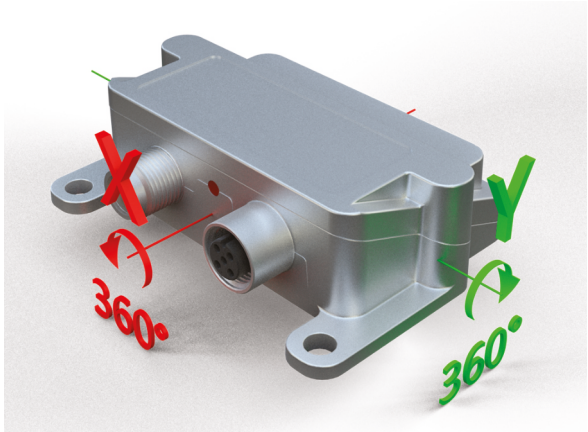
NBN45-G/S3 gyro axes



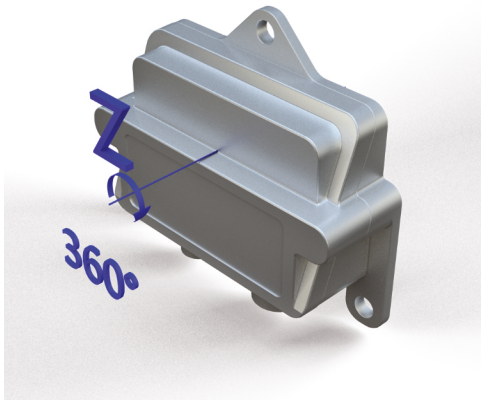
NBN45-G/S3 inclination angle axes with measuring range ±90°



NBN45-G/S3 Euler angle axes



NBN45-G/S3 rotation angle for X and Y axes with measuring range 360°

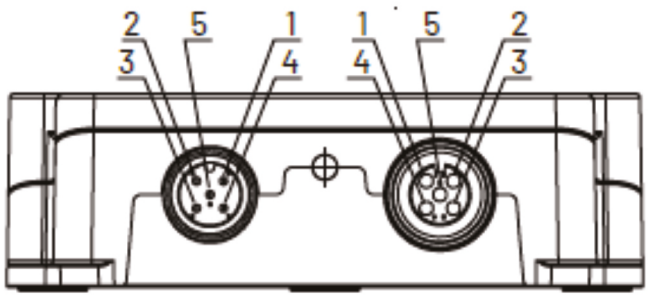


NBN45-G/S3 rotation angle for Z axis with measuring range 360°

SYSTEM INFORMATION

5.3 Connector Pin Assignment

For electrical connection the sensor is equipped with A-coded M12 male and female connector:



Pin connection (CiA DR303-1) for the 5 pole M12 connectors:

Pin	Name	Description
1	CAN_SHLD	PE, housing
2	VCC	Power supply
3	GND	Common groun
4	CAN_H	CAN bus (high)
5	CAN_L	CAN bus (low)

5.4 Electrical Connection

The sensor is equipped with a 5-pin M12 plug and socket. The use of the M12 socket allows “daisy chain” cabling. This means that additional devices can be connected to the sensor. Please note that a maximum current of 2 A can be drawn by the connected devices. The use of a 2 A fuse is recommended.

The socket is fitted with a cover cap at the factory. To ensure the degree of protection the cap was mounted with a torque of 0.4 Nm.

Connect the socket of the system network to the plug of the sensor. To guarantee the degree of protection it is important that the sealing within that connection is present. Make sure to use an appropriate counterpart (socket with seal).

The usage of a torque wrench is strictly recommended in order to guarantee the degree of protection of the connection. The defined torque depends on the manufacturer. Refer to the related connector datasheet regarding the required torques.

Attach the used cables for the NBN45-G/S3 with a cable relief. No force must act on the connectors and cables.

5.5 Termination Resistor

The sensor does not contain an internal 120 Ω termination resistor at the CAN interface.

5.6 Maximum Cable Length

NOTE

For CE conformity the maximum overall cable length must not exceed 30 m.

SYSTEM INFORMATION

5.7 Displaying the operational state

The sensor is equipped with an integrated status LED (green, red). It signals the current operational state. Different states will be signalized by variation of colour and flash frequency.

The sensor with active CANopen protocol will provide status information by LED according to CiA DR-303-3.

The following table shows possible displayed operational states, if the communication protocol is configured as SAE J1939:

LED signal color	State	Code	Meaning
green	Normal run state	Permanent OFF	Device is hold in RESET- State or no power supply available
		Permanent ON	Device runs under normal conditions
red	Error state	Permanent OFF	No failure detected
		Permanent ON	Device is held in Bus Off state
		Flashing slow	CAN-Controller error counter has reached the threshold **Note:** The sensor will also flash slowly, if it is the only node on a CAN bus. This is not to be treated as a fault, but has its reason in the fact, there is no other node, that acknowledges the message(s) send out by the sensor.

Table 1: Status LED

MOUNTING

6. MOUNTING

The NBN45-G/S3 sensor will be mounted to the application directly. In preparation, the holes and/or threads need to be placed according to the technical drawing (see chapter 5.2.1).

The NBN45-G/S3 only may to be installed to the designated location by screws. The maximum tightening torque of the screws is 5 Nm. A deformation of the sensor housing needs to be avoided under all circumstances.

WARNING

The sensor shall be checked for deformation before installation. If deformations are visible, the sensor must no longer be used, as the sensor data may no longer correspond to the specification.

NOTE

The sensor can be mounted in one of 6 orientations depending on the application needs. See chapter 8.3 for details.

GETTING STARTED

7. GETTING STARTED

7.1 Required items

- NBN45-G/S3
- Power supply connection (see chapter 5.1.3 for details)
- Signals for CAN connection:
  – Two 120 Ω resistors for terminating the CAN bus
  – PC CAN interface (example CAN is used on PC)

NOTE

To assemble your cable see chapter 5.3 Connector Pin Assignment.

7.2 Connection of CAN bus (example CAN is used on PC)

- Install the CAN interface to your computer
- Connect the NBN45-G/S3 with the CAN interface
- Connect the power supply to the NBN45-G/S3
- Start your preferred CANopen monitoring tool

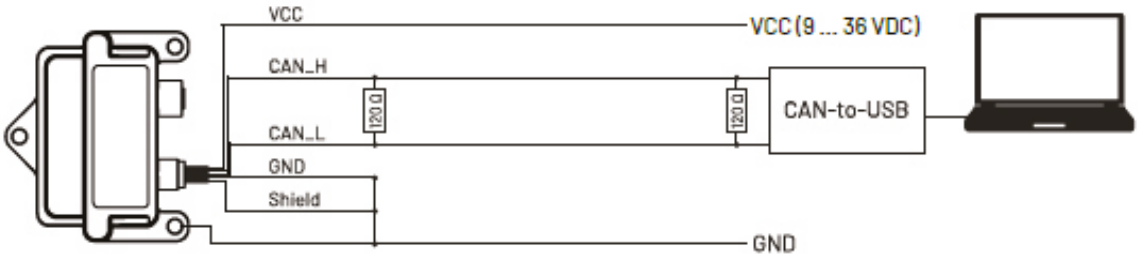


Figure 2: PC connection example

8. SIGNAL PROCESSING

This chapter contains information related to the signal processing functions of the sensor, e.g. filtering.

8.1 Filtering

The sensors of the NBN45-G/S3 family are equipped with 2 different types of filters:

- Low-Pass Filter for the values of the accelerometer
- Kalman Filter

Figure Fig. 3: Data flow of sensor data illustrates the data flow of data through these filters.

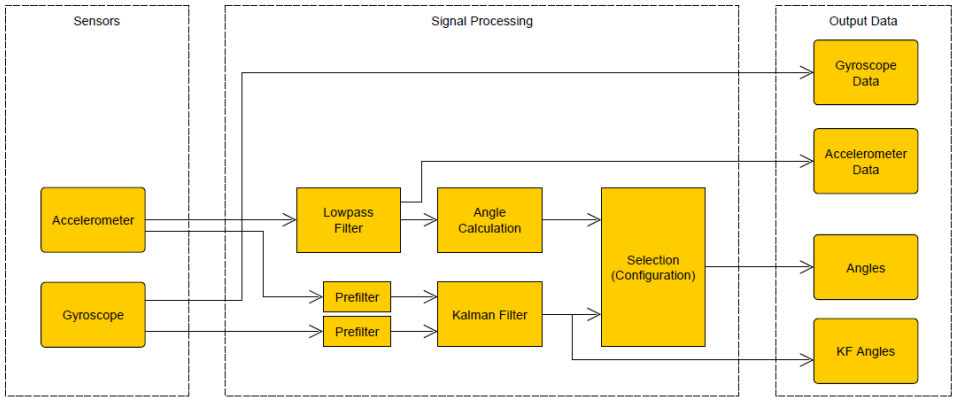


Figure 3: Data flow of sensor data

Depending on sensor configuration the angles are calculated by the Kalman filter using accelerometer and gyroscope data or byan algorithm, that uses only the low-pass filtered accelerometer data.

NOTE

Kalman filter is only supported by certain variants of the NBN45-G/S3 family sensors.

8.1.1 Low-Pass Filter

The accelerometer data can be filtered with digital low-pass filters. The sensors of the NBN45-G/S3-family are equipped with two adjustable low-pass filters for signal correction:

- Critical damped filter 8th order
- Butterworth filter 8th order

Critical Damped Filter

The Critical Damped Filter is suitable for most requirements, due to the short response time of the filter, which is needed in most applications. The attenuation in the stop-band is quite good, while there are no overshooting effects in time-domain. In the case of output signals overlaid with noise or disturbances, the optimum setting is determined by stepwise reducing the cut-off frequency fG to the limit of the response time tR. For this filter type the response time is approximately

$$t_R = \frac{1}{f_G}$$

SIGNAL PROCESSING

The lowest cut-off frequency fG that can be set is 0.1 Hz and should be tested if the response time tR is not relevant for the application.

The cut-off frequency of 2 Hz is set as default at the factory. The following figure shows the response of the filter in frequency domain and in time domain (step response) for a filter with fG set to 2 Hz.

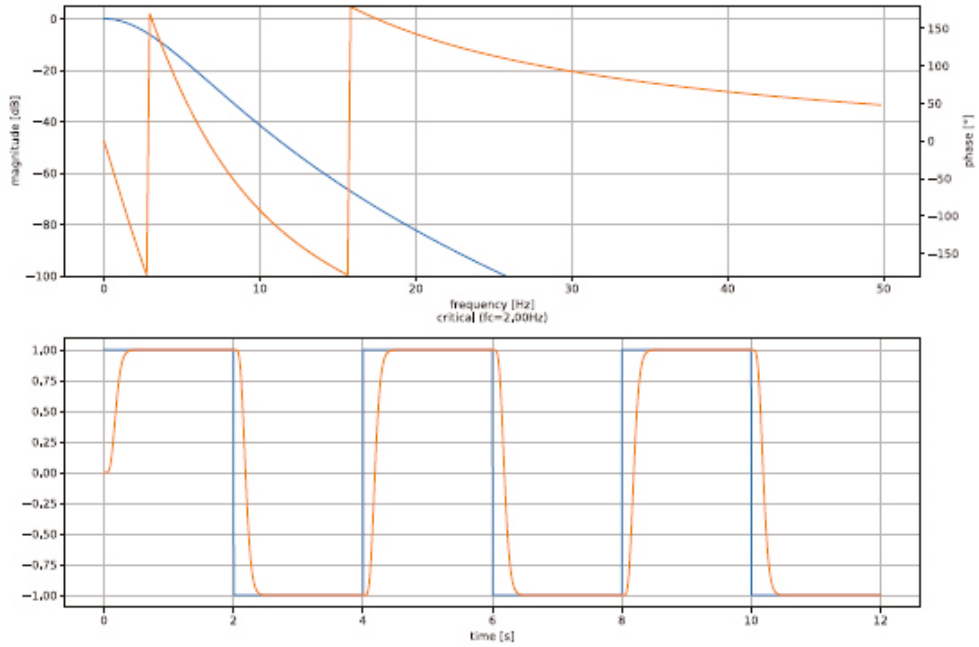


Figure 4: Filter characteristics critical damped filter

Butterworth Filter

The Butterworth filter is characterized by strong attenuation of high-frequency disturbances in the stop-band, which is much stronger than that of the critical damped filter. In the time-domain the filter tends to overshoot, especially after steps in the filter input (see following figure). It depends on the specific application, if that overshooting is acceptable or not (overshooting might be a problem, if the sensor is operated in a control loop).

The following figure shows the response of the filter in frequency domain and in time domain (step response) for a filter with fG set to 2 Hz.

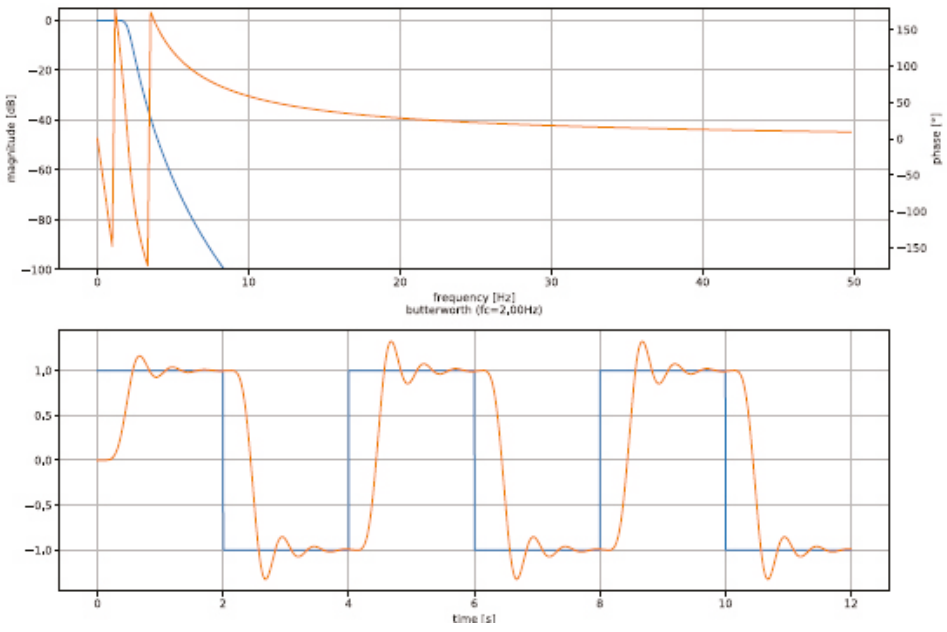


Figure 5: Filter characteristics Butterworth filter

SIGNAL PROCESSING

	Critical damped filter	Butterworth filter
Application	Universal filter	Specific applications
Response Time	Short response time (in comparison with Butterworth Filter)	Higher damping (in comparison with Critical Damped Filter)
Frequency-Domain Behaviour	Moderate Attenuation. Only weak damping of frequencies above, but near to the limit frequency.	Strong attenuation in stop-band. Good separation between pass-band and stop-band. Damping starts shortly above the set limit frequency.
Time-Domain Behaviour	No overshooting	Overshooting

Table 2: Filter characteristics in comparison

The following figure shows the comparison between attenuation of critical and butterworth filter:

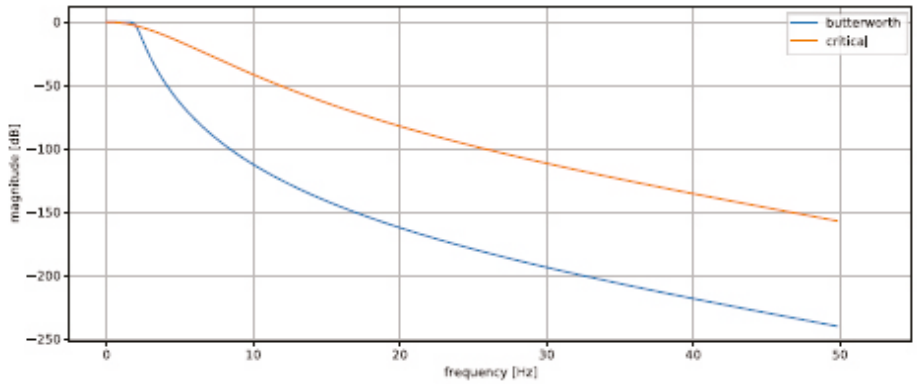


Figure 6: Comparison of attenuation between critical damped and butterworth filter

SIGNAL PROCESSING

8.1.2 Kalman Filter

8.1.2.1 General Information

The Kalman filter combines sensor data read from the accelerometer and the gyroscope to achieve the following goals:

- Fast filter response: The output of the Kalman filter responds to changed sensor orientation immediately with negligible delay.
- Good attenuation of the influence of acceleration components besides earth's gravity on the calculated angles.

The following diagram shows the response of Kalman filter and low-pass filter of a sensor, that is rotated from -45° to +45°. It can be seen, that the Kalman filter responds immediately, while the low-pass filter has some delay of around 0.2 seconds.

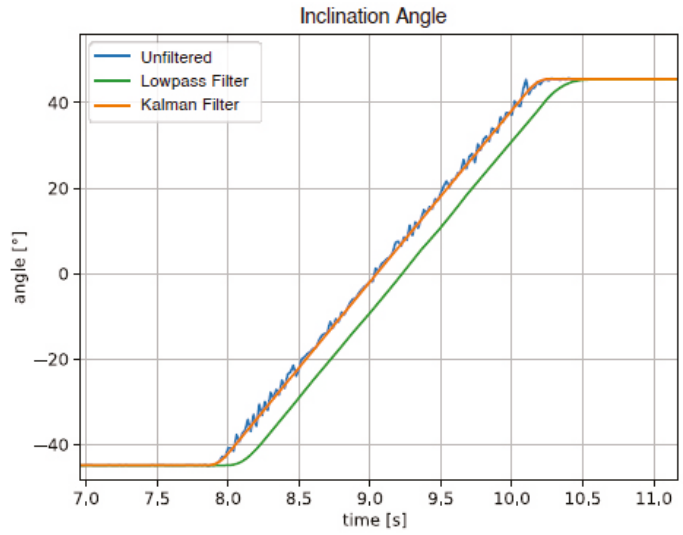


Figure 7: Filter types latency

NOTE

The Kalman prefilters are deactivated here. Activation of the prefilters introduces delay, that increases with decreased filter frequency. See chapter Prefilters for details related to the Kalman prefilters.

The following diagram shows the response of Kalman filter and low-pass filter to vibrations applied to the sensor.

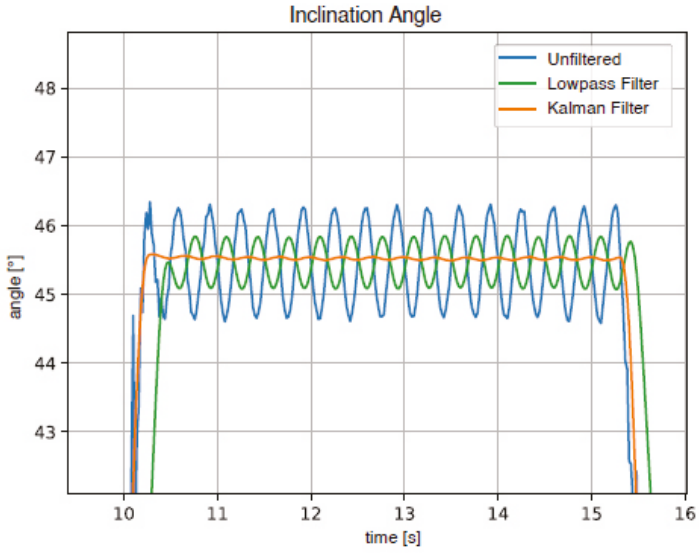


Figure 8: Filter type vibration suppression

SIGNAL PROCESSING

These measurements were made with following filter settings:

- Low-pass filter: Critical damped, fc = 3.0 Hz
- Kalman filter parameters: R = 10.0, Q = 0.001
- Kalman prefilters are disabled

It should be mentioned, that depending on the frequency of the disturbance the low-pass filter might produce better results. Especially if the signal to noise distance is small, low-pass filter might be the better choice, if the signal delay is acceptable. As a compromise additional filters exist, that filter the acceleration and gyro values before feeding them into the Kalman filter (see chapter Prefilters).

8.1.2.2 Prefilters

As a compromise between fast response and good attenuation of disturbances prefilters exist, that are applied to the acceleration and gyro values, before they are fed into the Kalman filter. These filters are 2nd order Bessel type lowpass filters. They might be used in environments with large amplitude vibrations close to or above 1 g and medium to low frequencies. The Kalman filter angles might tend to drift away in such situations, which can be prevented by activating the prefilters at the cost of increased delay.

The frequency of the filters can be configured separately for the acceleration and the gyro values in the range 1.0 Hz to 51.0 Hz in steps of 0.2 Hz. The filters can also be turned off completely. See chapters KFPF_EN (0x1A), KFPF_FCA (0x1B) and KFPF_FCG (0x1C) for more details.

8.1.2.3 Configuration

The configuration of the Kalman filter consists of 2 parameters R and Q.

8.1.2.3.1 Useful Values

It is usually sufficient to adjust parameter Q and leave parameter R at its default value of 10.0. Changes in behavior due to changes in parameter Q can be achieved to the same extent by changing parameter R.

Assuming, that parameter R is set to its default value of 10.0, useful values for the parameter Q are usually in the range 0.1 to 0.0001 (exceptions in special applications cannot be excluded). It is usually sufficient to adjust the exponent E of the parameter Q to adapt the behavior of the Kalman filter to the application. Smaller values of Q cause a stronger influence of the gyroscope on the angular value, which also increases the static error due to the gyro offset error. At the same time, disturbing acceleration components due to vibrations and shocks are suppressed more strongly.

The influence of the parameters Q and R on the dynamics of the filter (signal delay) is negligible in almost all cases.

SIGNAL PROCESSING

8.1.2.3.2 Valid Value Ranges

The value ranges of the mantissa and exponent of the parameters Q and R are limited as follows:

- Mantissa: 1 to 127
- Exponent: -8 to +8

NOTE

See chapter 9.2.15 for information about the Kalman filter parameters Q and R.

Attempts to write values outside these limits will be acknowledged with an error.

8.1.3 Selecting the right Filter

The decision, which filter to use for a specific application, depends on the requirements of that application. The following table gives some hints:

Requirement	**Preferred filter**
High Static Accuracy	Low-Pass Filter
High Noise Suppression	Low-Pass Butterworth
Use in Control Loops	Low-Pass Critical or Kalman Filter
Suppression of Vibrations	Low-Pass Filters or Kalman Filter depending on kind of disturbance
Fast Filter Response	Kalman Filter

NOTE

If the Kalman filter is exposed permanently to high amplitude vibrations, e. g. close to or above 1.0 g, angles might tend to drift over time. You should carefully check, if the Kalman filter is the right choice in such situations. Consider activating the Kalman prefilters or using the low-pass filter instead. You could also try to decouple the mounting point of the NBN45-G/S3 from these vibrations mechanically.

The following table lists some features, where the different filter types perform good or not so good.

	The "Good"	**The "Bad"**
Critical Damped Lowpass	• suitable for many applications • small delay (compared to butterworth) • no overshooting	• weak attenuation near the cutoff frequency
Butterworth Lowpass	• strong attenuation in stop-band	• overshooting • large delay
Kalman with prefilters	• low signal delay (depending on prefilter frequency)	• static accuracy worse than low-pass filter
Kalman without prefilters	• nearly zero signal delay	• static accuracy worse than low-pass filter • angles might tend to drift in case of permanent high amplitude vibrations

SIGNAL PROCESSING

8.2 Status Flags

8.2.1 General Information

The sensor maintains and provides a list of so called STATUS flags, that represent several information related to the measured values. The following table lists all STATUS flags.

Bit	Name	Meaning	Category
0	SAT_XL	At least 1 acceleration sensor axis is in saturation.	WARN
1	SAT_GY	At least 1 gyroscope sensor axis is in saturation.	WARN
2	PC_XL	The values of the redundant acceleration sensors are not plausible. Indication of hardware error or extreme accelerations to which the sensor is currently exposed (e.g. strong vibrations).	WARN
3	PC_GY	The values of the redundant gyroscope sensors are not plausible. Indication of hardware error or extreme accelerations to which the sensor is currently exposed (e.g. strong vibrations).	WARN
4	I90_X_OOR	±90° inclination angle X-axis is out-of-range.	WARN
5	I90_Y_OOR	±90° inclination angle Y-axis is out-of-range.	WARN
6	R360_X_NA	360° rotation angle of X axis is not available.	WARN
7	R360_Y_NA	360° rotation angle of Y axis is not available.	WARN
8	R360_Z_NA	360° rotation angle of Z axis is not available.	WARN
9	HNIR	Heater temperature Not In Range: Heating is activated, but the target temperature has not yet been reached.	HNIR
10	UCFG_INV	User Config Invalid: User settings are invalid. An error can occur if the power supply is interrupted while the user settings are being saved. The sensor can be reset to factory settings.	ERR
11	PC_TSENS	The values of the redundant temperature sensors are not plausible (indication of hardware error).	ERR
12	IFC	Invalid Filter Configuration; the configuration of the low-pass filters for the acceleration values is invalid.	ERR
13	TOV	Overtemperature: Temperature is above the permitted maximum (max. values of the MEMS chips). Tolerances of the measured values are not guaranteed.	WARN

Table 3: Description of the STATUS-Flags

These flags can be read using the STATUS parameter (see chapter 9.2.6 for details).

Note regarding I90_X_OOR and I90_Y_OOR:

The ±90° inclination angles can theoretically represent inclinations in the range of -90°...+90°. If the sensor is moved beyond the ±90° point, the value of the angle becomes smaller again for algorithmic reasons. In addition, offset and gain errors in the acceleration sensors prevent values up to exactly ±90° from being determined. For this reason, these flags are set if the associated inclination angle exceeds the limit of ±85° of if the sensor is in an upside-down position.

Note regarding R360_X/Y/Z_NA:
To determine the 360° rotation angle, it is necessary for the rotation axis to be horizontal. In extreme cases - when the axis of rotation is vertical - the calculation of a rotation angle is algorithmically impossible, as the acceleration sensor values used for the calculation then no longer change during a rotation. To a certain extent, the deviation from the horizontal position is tolerated. However, if the axis is moved too far from the ideal horizontal position, the corresponding flag R360_X/Y/Z_NA is set. If the magnitude of both components of the acceleration vector, that are used for the calculation of the associated 360° rotation angle, is smaller than 0.1 g, the flag will be set. The angles are calculated from the following acceleration vector components:

- R360_X is calculated from acceleration Y and Z axis
- R360_Y is calculated from acceleration X and Z axis
- R360_Z is calculated from acceleration X and Y axis

SIGNAL PROCESSING

Note regarding PC_XL and PC_GY:

If the comparison of the signals of the redundant MEMS chips detects a difference, these flags will be set. Under normal ciscumstances this is indicates a hardware problem. However, if the sensor is exposed to high-amplitude vibrations, shock or similar disturbances, the plausibility check might also fail, although there is no defect. The flags will be reset to 0, as soon as the disturbance goes away.

Note regarding HNIR:

If the heater is enabled, it takes a while after power-on, before the target temperature is reached. During this phase the HNIR flag is set. During that phase accuracy of the sensor values is only within the limits, that are defined for the sensor operating without heater. As soon as the target temperature is reached, the flag will be reset to 0.

8.2.2 Combined Warning and Error Flags (Status Bytes)

Telegrams that transmit measured values contain abbreviated status flags that represent the individual bits of this STATUS parameter. For example, the measured value in the SRDO1 is marked as untrustworthy if the acceleration sensor is in saturation. The messages of the CANopen and CANopen Safety protocols, that transmit sensor data, contain for that reason a STATUS byte. This STATUS byte contains bits, that represent warnings and errors. The error bit is set, if at least one of the following STATUS flags is set:

- UCFG_INV (User Config Invalid)
- IFC (Invalid Filter Configuration)
- PC_TSENS (Temperature Sensor Problem)

Which STATUS flags are combined to the warning bit, depends on the type of data and the sensor configuration. The following table shows, which of the STATUS flags must be set at least for the warning bit to be set (the warning bit is a logical OR combination of these STATUS flags):

Name	Type of Data	SAT_XL	PC_XL	SAT_GY	PC_GY	I90_X_OOR	I90_Y_OOR	R360_X_NA	R360_Y_NA	R360_Z_NA	TOV
WARN_XL	Acceleration	X	X								X
WARN_GY	Angular Speed			X	X						X
WARN_IX	Inclination Angle X	X	X	X[1)]	X[1)]	X					X
WARN_IY	Inclination Angle Y	X	X	X[1)]	X[1)]		X				X
WARN_EU	Euler Angles	X	X	X[1)]	X[1)]						X
WARN_RX	360° Rotation Angle X	X	X	X[1)]	X[1)]			X			X
WARN_RY	360° Rotation Angle Y	X	X	X[1)]	X[1)]				X		X
WARN_RZ	360° Rotation Angle Z	X	X	X[1)]	X[1)]					X	X

Table 4: Logical OR combination of warning flags

[1)] only if sensor fusion is enabled

Each kind of measurement value the sensor provides (e. g. acceleration), has an associated STATUS byte, that contains status information related to that measurement value. The following sections describe the structure of these STATUS bytes.

SIGNAL PROCESSING

Acceleration STATUS

Bit	Type of Data	Function
0	HNIR	Heater not in range (see chapter 8.2 for details)
1	WARN_XL	Measured values are unreliable (see chapter 8.2 for details).
2	ERR	There is a hardware problem that prevents correct measured values from being determined.
3…7	-	unused

Table 5: Structure of the Acceleration STATUS byte

Gyro STATUS

Bit	Type of Data	Function
0	HNIR	Heater not in range (see chapter 8.2 for details)
1	WARN_GY	Measured values are unreliable (see chapter 8.2 for details).
2	ERR	There is a hardware problem that prevents correct measured values from being determined.
3…7	-	unused

Table 6: Structure of the Gyroscope STATUS byte

Inclination STATUS

Bit	Type of Data	Function
0	HNIR	Heater not in range (see chapter 8.2 for details)
1	WARN_IX	X Axis: Measured values are unreliable (see chapter 8.2 for details).
2	WARN_IY	Y Axis: Measured values are unreliable (see chapter 8.2 for details).
3	ERR	There is a hardware problem that prevents correct measured values from being determined.
4…7	-	unused

Table 7: Structure of the Inclination STATUS byte

Euler STATUS

Bit	Type of Data	Function
0	HNIR	Heater not in range (see chapter 8.2 for details)
1	WARN_EU	Measured values are unreliable (see chapter 8.2 for details).
2	ERR	There is a hardware problem that prevents correct measured values from being determined.
3…7	-	unused

Table 8: Structure of the Euler STATUS byte

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Rotation X/Y/Z STATUS

Bit	Type of Data	Function
0	HNIR	Heater not in range (see chapter 8.2 for details)
1	WARN_RX/Y/Z	Measured values are unreliable (see chapter 8.2 for details).
2	ERR	There is a hardware problem that prevents correct measured values from being determined.
3…7	-	unused

Table 9: Structure of the Rotation Angle STATUS byte

Temperature STATUS

Bit	Type of Data	Function
0	-	unused
1	-	unused
2	ERR	There is a hardware problem that prevents correct measured values from being determined.
3…7	-	unused

Table 10: Structure of the Temperature STATUS byte

Kalman Filter Inclination STATUS

Bit	Type of Data	Function
0	HNIR	Heater not in range (see chapter 8.2 for details)
1…7	-	unused

Table 11: Structure of the Kalman Filter Inclination STATUS byte

Kalman Filter Euler STATUS

Bit	Type of Data	Function
0	HNIR	Heater not in range (see chapter 8.2 for details)
1…7	-	unused

Table 12: Structure of the Kalman Filter Euler STATUS byte

Kalman Filter Rotation X/Y/Z STATUS

Bit	Type of Data	Function
0	HNIR	Heater not in range (see chapter 8.2 for details)
1…7	-	unused

Table 13: Structure of the Kalman Filter Rotation X/Y/Z STATUS byte

SIGNAL PROCESSING

8.3 Coordinate System Rotation

The sensor has a default measurement axis definition as described in chapter 5.2.2. However it is possible to rotate the coordinate system, if the actual mounting situation demands it, e.g. because the sensor can only be mounted vertically. The sensor can be configured for one of 6 possible mounting situations. The codes in the following table are used by parameter CS_ROT (see chapter 9.2.16 for details).

Code	Name	Order Code	Description
0	ZDN	TOP 1	Z axis points downwards (standard)
1	ZUP	TOP 2	Z axis points upwards
2	YDN	TOP 3	Y axis points downwards
3	YUP	TOP 4	Y axis points upwards
4	XDN	TOP 5	X axis points downwards
5	XUP	TOP 6	X axis points upwards

Table 14: Coordinate System Rotation Options

The sensor internally rotates the coordinate system such, as if it was mounted in standard mounting situation. These situations can be characterized by the axis, that points downwards. Since that does not fully describe the situation, the rotation, that gets the sensor into the non-standard mounting situation, is given in the figures below. The arrows indicate the coordinate system orientation of the supervisory system (e.g. the vehicle).

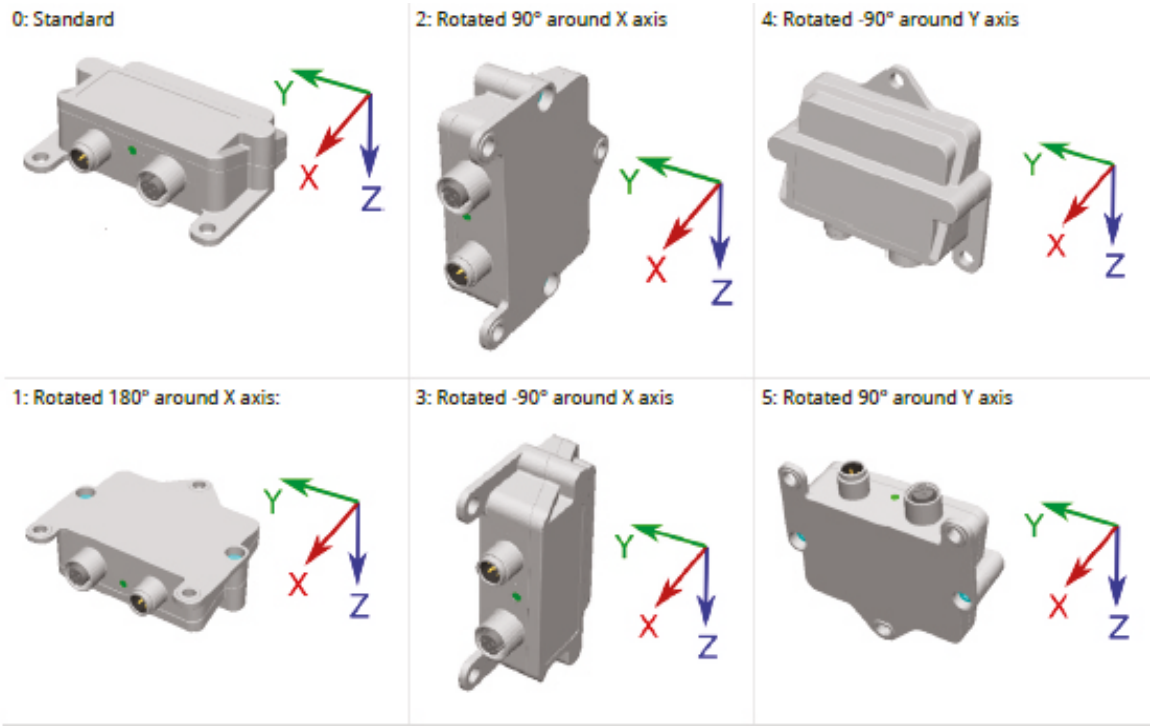

Table 15: Coordinate system rotations

The sensor mounting situation can be configured using parameter CS_ROT (see chapter 9.2.20) or command CS_ROT (see chapter 9.3.6).

SIGNAL PROCESSING

8.4 Angle Offsets

The angles calculated by the sensor can be shifted by a user-defined offset. This can be used for instance to compensate for skewed mounting situations. There are offsets for the ±90° inclination angles and for the 360° rotation angles. Separate offsets exist for the low-pass filtered angles and for the Kalman filter angles. The communication protocols offer two types of communication objects. The first type accesses the offsets of the low-pass filter or the Kalman filter, depending on the current filter selection for the angle output (output of Kalman filtered angles enabled or disabled). The second type always accesses the Kalman filter offsets, regardless of sensor configuration. Table *16: Example for accessing the offsets via CANopen* demonstrates this behaviour exemplary for reading and writing the X axis inclination offset using CANopen. It shows, which values are read and written, depending on the currently selected filter (low-pass or Kalman).

Kalman Filter Selected (3110_h,02_h)	**Inclination offset X axis (3130_h,00_h)**	**KF Inclination offset X axis (3135_h,00_h)**
0: Low-pass filter selected	Reads and writes the low-pass filter offset	Reads and writes the Kalman filter offset
1: Kalman filter selected	Reads and writes the Kalman filter offset	Reads and writes the Kalman filter offset

Table 16: Example for accessing the offsets via CANopen

NOTE

The ZERO command described in chapter ZERO (0x06) always zeros both the low-pass filter offset and the Kalman filter offset.

8.5 Temperature Compensation

The sensors of the NBN45-G/S3 family are equipped with temperature compensation in the form of an integrated heater, that heats up the electronics to a constant temperature, regardless of current ambient temperature. This reduces the sensitivity of the measurement results to temperature changes and improves the accuracy over the whole operating temperature range. The data sheet contains separate specifications for the temperature compensation operating mode (see there for details).

Heating up to the target temperature can take up to a 1 minute or longer, depending on current ambient temperature. The sensor provides status information, that indicates, whether or not the target temperature has been reached (see description of flag HNIR in chapter 8.2). As long as target temperature is not yet reached, the tolerances specified for operating the sensor without heater are valid.

CONFIGURATION

9. CONFIGURATION

The configuration contains all relevant data for the operation of the sensor. Some data can be read only and some can be written persistent to the internal memory. The access to this information is done either by a parameter or by a special command using the current communication protocol.

Overview of the sensor information:

- Information about the product (e.g. serial number, article number, version)
- Measurement values (e.g. angle values)
- Sensor status
- CAN protocol settings (e.g. protocol type, bit rate)
- Filter settings
- Zero offset
- Commands for load and save settings, reset or automatic zero offset

9.1 Persistent Memory

The sensor saves its configuration permanently in a non-volatile memory (persistent memory). The content of this memory is loaded into the main memory (register) when the firmware is initialized. The firmware then works with this copy.

The commands for modifying the configuration (e.g. by a SET telegram) only modify the copy in the memory. The same way commands also read only the copy in the main memory (e.g. by a GET telegram). This has the advantage that changes to certain settings can be tested before they will apply permanently. For permanently saving the configuration, the settings must be saved in the persistent memory with the SAVE command (e.g. by a CMD telegram).

A stored configuration can be loaded from the persistent memory into the working memory with the LOAD command. There are exceptions to this mechanism. These are explicitly marked accordingly in the text. The persistent memory contains two areas for saving the configuration:

- area for the user settings
- area for the factory settings

The factory settings are saved during production and can not be written by user.

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9.2 Parameters

Parameters are values, that can be read from or written to the sensor. This includes several kind of data, e.g. meaurement values, configuration data, etc. All communication protocols support reading and writing parameters. How this is exactly done, is described in the respective chapters, e.g. chapter 11 (CANopen Interface).

Unless explicitly stated otherwise, writing a parameter only modifies the RAM. A permanent transfer of changes to the sensor's NVM must be initiated explicitly, e.g. by the SAVE command (see chapter 9.3.3). Exceptions to this rule are explicitly pointed out.

NOTE

CANopen: GET is a SDO read access and SET is a SDO write access.

Parameters will be addressed using an index IDX.

NOTE

CANopen: this will be defined by the object dictionary.

9.2.1 Overview

The following table contains a list of all parameters. For each parameter a brief description, the index, the type of access and the protocols, that support access to this parameter are given. A detailled description of each parameter is given in the subsequent chapters.

IDX	Name	Description	Supporting protocols	rw[1)]
0x00	XI_INCL	Status byte and angle values of the X- and Y-axis[3)]	CANopen, J1939	ro
0x01	EULER	Status byte and Euler angle values pitch and roll[3)]	CANopen, J1939	ro
0x02	ARTNR	TWK Article number	CANopen, J1939	ro
0x03	VERSION	Hardware and software version	CANopen, J1939	ro
0x04	STATUS	Status information (i.e. error bits)	CANopen, J1939	ro
0x08	CAN_BR	CAN bit rate[2)]	CANopen, J1939	rw
0x09	CAN_ABOR	CAN automatic bus off recovery[2)]	CANopen, J1939	rw
0x0A	CAN_PROT	Used CAN protocol[2)]	CANopen, J1939	rw
0x0E	FLT_ACC	Acceleration filter configuration (frequency and type)	CANopen, J1939	rw
0x0F	FLT_KF	Kalman filter configuration	CANopen, J1939	rw
0x10	KF_EN	Enable sensor fusion	CANopen, J1939	ro
0x11	ZERO_IX	Zero offset of X-axis[3)]	CANopen, J1939	ro
0x12	ZERO_IY	Zero offset of Y-axis[3)]	CANopen, J1939	ro
0x13	ZERO_RX	Zero offset of Rotation angle X-axis[3)]	CANopen, J1939	ro
0x14	ZERO_RY	Zero offset of Rotation angle Y-axis[3)]	CANopen, J1939	ro
0x15	ZERO_RZ	Zero offset of Rotation angle Z-axis[3)]	CANopen, J1939	rw
0x16	X_ROT	360° rotation angle X-axis[3)]	CANopen, J1939	rw
0x17	Y_ROT	360° rotation angle Y-axis[3)]	CANopen, J1939	rw

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IDX	Name	Description	Supporting protocols	rw[1)]
0x18	Z_ROT	360° rotation angle Z-axis[3)]	CANopen, J1939	rw
0x19	CS_ROT	Rotation of the coordinate system	CANopen, J1939	rw
0x1A	KFPF_EN	Kalman Filter Prefilter Enable	CANopen, J1939	rw
0x1B	KFPF_FCA	Kalman Filter Prefilter Frequency Accerlerometer	CANopen, J1939	rw
0x1C	KFPF_FCG	Kalman Filter Prefilter Frequency Gyro	CANopen, J1939	rw
0x1D	HT_EN	Deactivation/activation of the heating	CANopen, J1939	rw
0x1E	HT_STAT	Status heating	CANopen, J1939	ro
0x1F	TEMP	Temperature sensor value	CANopen, J1939	ro
0x21	GFSR	Gyro full scale range	CANopen, J1939	rw
0x22	KZ_ZERO_IX	Zero offset of Kalman Filter X-axis	CANopen, J1939	rw
0x23	KF_ZERO_IY	Zero offset of Kalman Filter Y-axis	CANopen, J1939	rw
0x24	KF_ZERO_RX	Zero offset of Kalman Filter Rotation angle X-axis	CANopen, J1939	rw
0x25	KF_ZERO_RY	Zero offset of Kalman Filter Rotation angle Y-axis	CANopen, J1939	rw
0x26	KF_ZERO_RZ	Zero offset of Kalman Filter Rotation angle Z-axis	CANopen, J1939	rw
0x27	KF_XY_INCL	Inclination angles of Kalman Filter X- and Y-axis	CANopen, J1939	ro
0x28	KF_EULER	Kalman Filter Euler angle values pitch and roll	CANopen, J1939	ro
0x29	KF_X_ROT	Kalman Filter 360° rotation angle X-axis	CANopen, J1939	ro
0x2A	KF_Y_ROT	Kalman Filter 360° rotation angle Y-axis	CANopen, J1939	ro
0x2B	KF_Z_ROT	Kalman Filter 360° rotation angle Z-axis	CANopen, J1939	ro
0x80	J1939_DEV_ADDR	SAE J1939 device address of the sensor [2)]	J1939	rw
0x81	IDENT_ACC	Arbitrary Address Capable for the SAE J1939 64-bit device name [2)]	J1939	rw
0x82	IDENT_VSI	Vehicle System Instance for the SAE J1939 64-bit device name [2)]	J1939	rw
0x83	IDENT_FI	Function Instance for the SAE J1939 64-bit device name [2)]	J1939	rw
0x84	IDENT_ECU (0x84)	ECU Instance for the SAE J1939 64-bit device name [2)]	J1939	rw
0x91	TPGN2_ID	PGN and SLOT for TPGN2	J1939	rw
0x92	TPGN3_ID	PGN and SLOT for TPGN3	J1939	rw
0x93	TPGN4_ID	PGN and SLOT for TPGN4	J1939	rw
0x94	TPGN5_ID	PGN and SLOT for TPGN5	J1939	rw
0x95	TPGN6_ID	PGN and SLOT for TPGN6	J1939	rw
0x96	TPGN7_ID	PGN and SLOT for TPGN7	J1939	rw
0x97	TPGN8_ID	PGN and SLOT for TPGN8	J1939	rw
0x97	TPGN8_ID	PGN and SLOT for TPGN8	J1939	rw
0x98	TPGN9_ID	PGN and SLOT for TPGN9	J1939	rw
0x99	TPGN10_ID	PGN and SLOT for TPGN10	J1939	rw

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IDX	Name	Description	Supporting protocols	rw[1)]
0xA0	TPGN1_PRIO	Priority for TPGN1	J1939	rw
0xA1	TPGN2_PRIO	Priority for TPGN2	J1939	rw
0xA2	TPGN3_PRIO	Priority for TPGN3	J1939	rw
0xA3	TPGN4_PRIO	Priority for TPGN4	J1939	rw
0xA4	TPGN5_PRIO	Priority for TPGN5	J1939	rw
0xA5	TPGN6_PRIO	Priority for TPGN6	J1939	rw
0xA6	TPGN7_PRIO	Priority for TPGN7	J1939	rw
0xA7	TPGN8_PRIO	Priority for TPGN8	J1939	rw
0xA8	TPGN9_PRIO	Priority for TPGN9	J1939	rw
0xA9	TPGN10_PRIO	Priority for TPGN10	J1939	rw
0xB1	TPGN2_CT	Transmission Repetition Rate for TPGN2	J1939	rw
0xB2	TPGN3_CT	Transmission Repetition Rate for TPGN3	J1939	rw
0xB3	TPGN4_CT	Transmission Repetition Rate for TPGN4	J1939	rw
0xB4	TPGN5_CT	Transmission Repetition Rate for TPGN5	J1939	rw
0xB5	TPGN6_CT	Transmission Repetition Rate for TPGN6	J1939	rw
0xB6	TPGN7_CT	Transmission Repetition Rate for TPGN7	J1939	rw
0xB7	TPGN8_CT	Transmission Repetition Rate for TPGN8	J1939	rw
0xB8	TPGN9_CT	Transmission Repetition Rate for TPGN9	J1939	rw
0xB9	TPGN10_CT	Transmission Repetition Rate for TPGN10	J1939	rw

Table 17: List of Parameters

1) ro (read-only), shows if the parameter can be read only
rw (read-write), shows if the parameter can be read and written

2) Parameter changes will be effective after configuration storage and sensor restart only

3) The angle value output is influenced by the parameter KF_EN (0x10)

9.2.2 XY_INCL (0x00)

XY_INCL contains the inclination angles of the X and Y axes.

Byte number	0	1	2	3	4
Field	STATUS	X0	X1	Y0	Y1

Field . . . . . Description
STATUS. . . . . Status byte (see Table 7: Structure of the Inclination STATUS byte for details)
X0/X1. . . . . Angle value X-axis in ° (degree) in 2's complement format with a resolution of 0.01°
Y0/Y1. . . . . Angle value Y-axis in ° (degree) in 2's complement format with a resolution of 0.01°

Parameter-specific RESULT codes when reading with GET:

Code . . . . . Result . . . . . Description
0x10. . . . . NYA . . . . . Data not yet available (see below)

NOTE

The code NYA is returned if no sensor values are available at the time of access.
This is only the case immediately after the reset (power-on) and has technical reasons (initialization of sensor element and firmware). The status does not last longer than a few 100 ms.

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9.2.3 EULER (0x01)

EULER contains the Euler angles pitch and roll.

Parameter:

Byte number	0	1	2	3	4
Field	STATUS	R0	R1	P0	P1

Field . . . . . Description
STATUS. . . . . Status byte (see Table 8: Structure of the Euler STATUS byte for details)
R0/R1 . . . . . Roll angle value in ° (degree) in 2‘s complement format with a resolution of 0.01°
P0/P1. . . . . Pitch angle value in ° (degree) in 2‘s complement format with a resolution of 0.01°

Parameter-specific RESULT codes when reading with GET:

Code . . . . . Result . . . . . Description
0x10. . . . . NYA . . . . . Data not yet available (see below)

NOTE

The code NYA is returned if no sensor values are available at the time of access. This is only the case immediately after the reset (power-on) and has technical reasons (initialization of sensor element and firmware). The status does not last longer than a few 100 ms.

9.2.4 ARTNR (0x02)

ARTNR contains the article number in unsigned 32 bit format:

Byte number	0	1	2	3
Field	NR0	NR1	NR2	NR3

9.2.5 VERSION (0x03)

VERSION contains hardware and software version number information and has the following structure:

Byte number	0	1	2	3	4
Field	MA	MI	REL	HW	RSVD

Field . . . . . Description
MA. . . . . Major version number of the firmware
MI. . . . . Minor version number of the firmware
REL . . . . . Firmware release number
HW. . . . . Hardware revision number
RSVD. . . . . reserved value; can be ignored

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Example: Firmware version 1.2r7, hardware revision is 2:
Field . . . . . Value
MA 1
MI. 2
REL 7
HW. 2
RSVD. 0

9.2.6 STATUS (0x04)

STATUS contains various status information and has the following structure:

Byte number	**0**	**1**
Field	ST0	ST1

The following tables contain a description of all bits of the parameter. The "Category" column contains the category of the bit (see chapter 8.2 for details).

ST0:

Bit	**Name**	**Meaning**	**Category**
0	SAT_XL	At least 1 acceleration sensor axis is in saturation.	WARN
1	SAT_GY	At least 1 gyroscope sensor axis is in saturation.	WARN
2	PC_XL	The values of the redundant acceleration sensors are not plausible. Indication of hardware error or extreme accelerations to which the sensor is currently exposed (e.g. strong vibrations).	WARN
3	PC_GY	The values of the redundant gyroscope sensors are not plausible. Indication of hardware error or extreme accelerations to which the sensor is currently exposed (e.g. strong vibrations).	WARN
4	I90_X_OOR	±90° inclination angle X-axis is out-of-range.	WARN
5	I90_Y_OOR	±90° inclination angle Y-axis is out-of-range.	WARN
6	R360_X_NA	360° rotation angle of X axis is not available.	WARN
7	R360_Y_NA	360° rotation angle of Y axis is not available.	WARN

ST1:

Bit	**Name**	**Meaning**	**Category**
0	R360_Z_NA	360° rotation angle of Z axis is not available.	WARN
1	HNR	Heater temperature Not In Range: Heating is activated, but the target temperature has not yet been reached.	HNIR
2	UCFG_INV	User Config Invalid: User settings are invalid. An error can occur if the power supply is interrupted while the user settings are being saved. The sensor can be reset to factory settings.	ERR
3	PC_TSENS	The values of the redundant temperature sensors are not plausible (indication of hardware error).	ERR
4	IFC	Invalid Filter Configuration; the configuration of the low-pass filters for the acceleration values is invalid.	ERR
5	TOV	Overtemperature: Temperature is above the permitted maximum (max. values of the MEMS chips). Tolerances of the measured values are not guaranteed.	WARN
6 … 7	-	unused	

CONFIGURATION

9.2.7 CAN_BR (0x08)

CAN_BR defines the CAN bit rate. The coding of the bitrate in the byte BR is as follows:

Byte Number	**0**
Field	BR

Meaning of the field BR:

0	**1**	**2**	**3**	**4**	**5**
100 kBit/s	125 kBit/s	250 kBit/s	500 kBit/s	800 kBit/s	1000 kBit/s

A VALUE error is returned when invalid values are written. When this parameter is written, it is written directly to the persistent memory. Parameter-specific RESULT codes when writing with SET:

RESULT . . . . . Result . . . . . Meaning
0x10. . . . . NVE . . . . . NV-Error: Error when writing the persistent memory

9.2.8 CAN_ABOR (0x09)

CAN_ABOR can be used to specify whether the sensor automatically comes out of a bus-off state or not (auto bus-off recovery) and has the following structure:

Byte Number	**0**
Field	ABOR

Meaning of the field ABOR:

ABOR	**Condition**	**Remarks**
0	DISABLED	Automatic bus-off recovery is deactivated (sensor remains in bus-off mode; power-off-on cycle or reset required)
1	ENABLED	Automatic bus-off recovery is activated (sensor leaves bus-off state automatically)

A VALUE error is returned when invalid values are written.

CONFIGURATION

9.2.9 CAN_PROT (0x0A)

CAN_PROT is used to select the protocol used on the CAN interface.

Byte Number	**0**
Field	CP

Meaning of the field CP:

CP	**Condition**	**Remarks**
0	reserved	Factory communication only
1	J1939	SAE J1939 protocoll
2	CANopen	CANopen protocol without CANopen Safety
3	CANopen Safety	CANopen protocol with CANopen Safety

A VALUE error is returned when invalid values are written.

CONFIGURATION

9.2.10 FLT_ACC (0x0E)

FLT_ACC contains the settings of the digital low-pass filters of the acceleration values.

Byte Number	0	1	2
Field	FC0	FC1	FT

Field . . . . . Description
FC0/FC1 . . . . . -3dB cut off frequency of the digital low-pass filter in mHz
FT . . . . . Filter types see below

Valid frequency ranges depending on the filter type in mHz:

TYPE	FMIN	FMAX
Butterworth	100	25,000
Critical damped	100	8,000

Meaning of the field FT:

FT	Name	Behaviour
0	DISABLED	Filter deactivated
1	Butterworth	Filter characteristic Butterworth
2	Critical	Filter characteristic "critical damped"

A VALUE error is returned when invalid values are written.

For more information on filtering see chapter 8.1.

NOTE

This filtering only applies to the values read from the accelerometer and the angles, that are calculated solely using the accelerometer values. The values read from the gyro sensor are not filtered!

9.2.11 FLT_KF (0x0F)

FLT_KF contains the settings of the Kalman filter.

Byte Number	0	1	2	3
Field	QE	QM	RE	RM

Field . . . . . Description
QE . . . . . Exponent of the parameter Q
QM. . . . . Mantissa of the parameter Q
RE . . . . . Exponent of the parameter R
RM. . . . . Mantissa of the parameter R

Exponent E and mantissa M are given in 8-bit 2's complement format. The values Q and R are calculated as follows:

$x = M * 10^E$

CONFIGURATION

Examples:

VALUE	M	E	M(Hex)	E(Hex)
0.001	1	-3	0x01	0xFD
3.1	31	-1	0x1F	0xFF
10.0	1	1	0x01	0x01

Valid value range for mantissa and exponent:
Mantissa . . . . . 1 to 127
Exponent . . . . . -8 to +8

A VALUE error is returned when invalid values are written.

9.2.12 KF_EN (0x10)

KF_EN defines which values are output in the communication objects for the angles.

Byte Number	0
Field	EN

Meaning of the field EN:

EN	Condition	Remarks
0	DISABLED	Low-pass filtered angles are output.
1	ENABLED	Kalman filtered angles are output.

A VALUE error is returned when invalid values are written.

9.2.13 ZERO_IX, ZERO_IY (0x11, 0x12)

ZERO_IX and ZERO_IY can be used to shift the zero point of the ±90° inclination angle. The angle in the parameter is subtracted from the actually measured angle

Byte Number	0	1
Field	Z0	Z1

Field	Description
Z0/Z1	Displacement as 16-bit 2's complement with 0.01° resolution

CONFIGURATION

9.2.14 ZERO_RX, ZERO_RY, ZERO_RZ (0x13, 0x14, 0x15)

ZERO_RX, ZERO_RY and ZERO_RZ can be used to shift the zero point of the 360° rotation angle. The angle in the parameter is subtracted from the actually measured angle.

Byte Number	0	1
Field	Z0	Z1

Field	Description
Z0/Z1	Displacement as 16-bit unsigned with 0.01° resolution

9.2.15 X_ROT, Y_ROT, Z_ROT (0x16, 0x17, 0x18)

These parameters contain the current 360° rotation angles of axes X, Y and Z.

Byte Number	0	1	2
Field	Status	R0	R1

Field	Description
STATUS	See Table 9: Structure of the Rotation Angle STATUS byte for details
R0/R1	Rotation angle (16 bit, unsigned, resolution 0.01°)

Parameter-specific RESULT codes when reading with GET:

Code	Result	Description
0x10	NYA	Data not yet available (see below)

NOTE

The code NYA is returned if no sensor values are available at the time of access. This is only the case immediately after the reset (power-on) and has technical reasons (initialization of sensor lement and firmware). The status does not last longer than a few 100 ms.

CONFIGURATION

9.2.16 CS_ROT (0x19)

CS_ROT contains the rotation of the sensor's coordinate system (see chapter 8.3 for details). If the sensor mounting orientation differs from the standard installation position, this parameter can be used to rotate the coordinate system accordingly. The sensor then automatically performs transformations so that the sensor behaves as if it were mounted in the standard installation position.

Byte Number	**0**
Field	ROT

The following table contains the meaning of the ROT field. The accelerations are the nominal accelerations, the sensor would provide, if it were operated with standard axis rotation (ROT=0) in this mounting situation.

ROT	**Orientation**	**AX**	**AY**	**AZ**
0	Z-axis points downwards (default)	0	0	1
1	Z-axis points upwards	0	0	-1
2	Y-axis points downwards	0	1	0
3	Y-axis points upwards	0	-1	0
4	X-axis points downwards	1	0	0
5	X-axis points upwards	-1	0	0
other	undefined; attempts to write undefined values are replied with an error	-	-	-

A VALUE error is returned when invalid values are written.
See also command CS_ROT, which can be used to set the rotation automatically (see chapter 9.3.6). See chapter 8.3 for general information related to coordinate system rotation.

9.2.17 KFPF_EN (0x1A)

KFPF_EN contains the global enable flag for the Kalman filter prefilters.

Byte Number	**0**
Field	EN

Meaning of the fields EN:

EN	**Condition**	**Remarks**
0	DISABLED	Prefilters are diasbled (bypassed)
1	ENABLED	Prefilters are enabled

The frequency of the filters must be configured separately using parameters KFPF_FCA and KFPF_FCG.

A VALUE error is returned when invalid values are written.

CONFIGURATION

9.2.18 KFPF_FCA (0x1B)

KFPF_FCA contains the -3dB cut off frequency of the Kalman filter prefilters for the acceleration values.

Byte Number	**0**
Field	FC

Valid frequency range is from 1.0 Hz to 51.0 Hz (corresponding to FC field codes from 5 to 255).
Meaning of the fields FC:

FC	**Condition**	**Behaviour**
0	DISABLED	Filters are deactivated
1…4	INVALID	A VALUE error is returned upon attempts to write these illegal values
5…255	FREQ	-3dB cut off frequency with a resolution of 0.2 Hz

A VALUE error is returned when invalid values are written. For more information on filtering see chapter 8.1.

NOTE

The filters are enabled only, if the global enable flag for the Kalman prefilters is 1.
See chapter KFPF_EN (0x1A) for details.

NOTE

This filtering only applies to the values fed into the Kalman filter. It does not affect the acceleration values, that can be read using the appropriate communication objects or the angles, that are calculated from the acceleration values without Kalman filter.

9.2.19 KFPF_FCG (0x1C)

KFPF_FCG contains the -3dB cut off frequency of the Kalman filter prefilters for the gyro values.

Byte Number	**0**
Field	FC

Valid frequency range is from 1.0 Hz to 51.0 Hz (corresponding to FC field codes from 5 to 255).
Meaning of the fields FC:

FC	**Condition**	**Behaviour**
0	DISABLED	Filters are deactivated
1…4	INVALID	A VALUE error is returned upon attempts to write these illegal values
5…255	FREQ	-3dB cut off frequency with a resolution of 0.2 Hz

A VALUE error is returned when invalid values are written. For more information on filtering see chapter 8.1.

NOTE

The filters are enabled only, if the global enable flag for the Kalman prefilters is 1.
See chapter KFPF_EN (0x1A) for details.

NOTE

This filtering only applies to the values fed into the Kalman filter. It does not affect the gyro values, that can be read using the appropriate communication objects.

CONFIGURATION

9.2.20 HT_EN (0x1D)

HT_EN enables or disables the internal heating. See chapter 8.4 (*Temperature Compensation*) for details.

Byte Number	**0**	**1**
Field	EN	EN2

Meaning of the fields EN and EN2:

EN	**EN2**	**Condition**	**Remarks**
0x48 ('H')	0x45 ('E')	ENABLED	Heating is activated, sensor elements are heated to the target temperature
other values		DISABLED	Heating disabled

9.2.21 HT_STAT (0x1E)

HT_STAT contains status information of the internal heating.

Byte Number	**0**	**1**	**2**	**3**	**4**
Field	STATUS	TT0	TT1	AT0	AT1

Field	**Description**
STATUS	See below
TT0 / TT1	Target temperature
AT0 / AT1	Current temperature

The temperatures are available in 16-bit 2's complement format. The resolution is 0.1 °C.

STATUS:

Bit	**Name**	**Remarks**
0	ON	Is 1 when the heating is active
1	TOK	Is 1 if the temperature is within the defined target temperature window
2	ERR	There is a hardware problem that prevents correct measured values from being determined.
3….7		unused

CONFIGURATION

9.2.22 TEMP (0x1F)

TEMP contains the current temperature of the sensor elements.

Byte Number	0	1	2
Field	STATUS	TT0	TT1

Field	Description
STATUS	See Table 10: Structure of the Temperature STATUS byte for details
T0/T1	Temperature as 16-bit 2's complement with 0.1 °C resolution

9.2.23 GFSR (0x21)

GFSR contains the gyro measuring range (full-scale range).

Byte Number	0
Field	FSR

The resolution of the gyroscope values in telegrams of the communication protocols depends on the currently selected full-scale range. The table below contains the relationship between the code of byte FSR, the full-scale range and the resolution of the values in the telegrams.

Field	Measurement Range	Resolution
0	±125 dps	4.375 mdps
1	±250 dps	8.75 mdps
2	±500 dps	17.5 mdps
3	±1000 dps	35 mdps
4	±2000 dps	70 mdps
5	±4000 dps	140 mdps

Table 18: Gyroscope measurement ranges

A VALUE error is returned when invalid values are written.

Note:

If the Kalman filter is used, the user should select the measurement range such, that it is larger or at least as large as the maximum angular rate, that is expected to occur in its particular use case.

CONFIGURATION

9.2.24 KF_ZERO_IX, KF_ZERO_IY(0x22, 0x23)

KF_ZERO_IX and KF_ZERO_IY can be used to shift the zero point of the ±90° inclination angle of the Kalman filter. The angle in the parameter is subtracted from the actually measured angle.

Byte Number	0	1
Field	Z0	Z1

Field	Description
Z0/Z1	Displacement at 16-bit 2's complement with 0.01° resolution

9.2.25 KF_ZERO_RX, KF_ZERO_RY, KF_ZERO_RZ (0x24, 0x25, 0x26)

KF_ZERO_RX, KF_ZERO_RY and KF_ZERO_RZ can be used to shift the zero point of the Kalman filter 360° rotation angle. The angle in the parameter is subtracted from the actually measured angle.

Byte Number	0	1
Field	Z0	Z1

Field	Description
Z0/Z1	Displacement at 16-bit unsigned with 0.01° resolution

9.2.26 KF_XY_INCL (0x27)

KF_XY_INCL contains the inclination angles of the X and Y axes calculated by the Kalman filter.

Byte Number	0	1	2	3	4
Field	STATUS	X0	X1	Y0	Y1

Field	Description
STATUS	Status byte (see Table 11: Structure of the Kalman Filter Inclination STATUS byte for details)
X0/X1	Angle value X-axis in ° (degree) in 2's complement format with a resolution of 0.01°
Y1/Y2	Angle value Y-axis in ° (degree) in 2's complement format with a resolution of 0.01°

Parameter-specific RESULT codes when reading with GET:

Code	Result	Description
0x10	NYA	Data not yet available (see below)

NOTE

The code NYA is returned if no sensor values are available at the time of access. This is only the case immediately after the reset (power-on) and has technical reasons (initialization of sensor element and firmware). The status does not last longer than a few 100 ms.

CONFIGURATION

9.2.27 KF_EULER (0x28)

KF_EULER contains the Euler angles pitch and roll calculated by the Kalman filter.

Parameter:

Byte Number	0	1	2	3	4
Field	STATUS	R0	R1	P0	P1

Field	Description
STATUS	Status byte (see Table 12: Structure of the Kalman Filter Euler STATUS byte for details)
R0/R1	Roll angle value in ° (degree) in 2's complement format with a resolution of 0.01°
P1/P2	Pitch angle value in ° (degree) in 2's complement format with a resolution of 0.01°

Parameter-specific RESULT codes when reading with GET:

Code	Result	Description
0x10	NYA	Data not yet available (see below)

NOTE

The code NYA is returned if no sensor values are available at the time of access. This is only the case immediately after the reset (power-on) and has technical reasons (initialization of sensor element and firmware). The status does not last longer than a few 100 ms.

9.2.28 KF_X_ROT, KF_Y_ROT, KF_Z_ROT (0x29, 0x2A, 0x2B)

These parameters contain the current 360° rotation angles of axes X, Y and Z calculated by the Kalman filter.

Byte Number	0	1	2
Field	STATUS	R0	R1

Field	Description
STATUS	Status byte (see Table 13: Structure of the Kalman Filter Rotation Angle STATUS byte for details)
R0/R1	Rotation angle (16 bit, unsigned, reolution 0.01°)

Parameter-specific RESULT codes when reading with GET:

Code	Result	Description
0x10	NYA	Data not yet available (see below)

NOTE

The code NYA is returned if no sensor values are available at the time of access. This is only the case immediately after the reset (power-on) and has technical reasons (initialization of sensor element andfirmware). The status does not last longer than a few 100 ms.

CONFIGURATION

9.2.29 J1939_DEV_ADDR (0x80)

Specifies the SAE J1939 device address of the sensor. The value 255 is invalid.

Byte Number	**0**
Field	ADDR

A VALUE error is returned when invalid values are written and the device address is not accepted.

9.2.30 IDENT_ACC (0x81)

Specifies whether the sensor supports the SAE J1939 address claiming method and thus the device address is determined automatically. The corresponding bit is set in the SAE J1939 64-bit device name.

Byte Number	**0**
Field	AAC

Meaning of the field AAC:

AAC	**Condition**	**Remarks**
0	DISABLED	Arbitrary Address Capable is deactivated (Address Claiming is not possible)
1	ENABLED	Arbitrary Address Capable is active (Address Claiming is possible)

A VALUE error is returned when invalid values are written.

9.2.31 IDENT_VSI (0x82)

Specifies the Vehicle System Instance for the SAE J1939 64-bit device name of the sensor. Values above 15 are invalid.

Byte Number	**0**
Field	VSI

A VALUE error is returned when invalid values are written and the value is not accepted.

9.2.32 IDENT_FI (0x83)

Specifies the Function Instance for the SAE J1939 64-bit device name of the sensor. Values above 31 are invalid.

Byte Number	**0**
Field	FI

A VALUE error is returned when invalid values are written and the value is not accepted.

CONFIGURATION

9.2.33 IDENT_ECU (0x84)

Specifies the ECU Instance for the SAE J1939 64-bit device name of the sensor. Values above 7 are invalid.

Byte Number	**0**
Field	ECU

A VALUE error is returned when invalid values are written and the value is not accepted.

9.2.34 TPGN2_ID ... TPGN10_ID (0x91 ... 0x99)

Specifies the PGN and the SLOT function for the corresponding TPGN message.

Byte Number	**0**	**1**	**2**
Field	NR0	NR1	SN

Field	**Description**
NR0/NR1	Number of the parameter group
SN	Number of the active SLOT function

The following restrictions apply to the parameters:

- NR: each number must be different and in the range from 65280 (0xFF00) to 65535 (0xFFFF).
- SN: only the given SLOT numbers from the respective tables (see chapter 12.4) may be used for the TPGN.
- A VALUE error is returned when invalid values are written and the value is not accepted.

9.2.35 TPGN1_PRIO ... TPGN10_PRIO (0xA0 ... 0xA9)

Specifies the priority for the corresponding TPGN message. Values above 7 are invalid. The priority of the PGN messages has an inverse meaning. The highest priority has the value 0 and the lowest priority has the value 7.

Byte Number	**0**
Field	PRIO

A VALUE error is returned when invalid values are written and the value is not accepted.

9.2.36 TPGN2_CT ... TPGN10_CT (0xB1 ... 0xB9)

Specifies the Transmission Repetition Rate for the corresponding TPGN message.

Byte Number	**0**	**1**
Field	CT0	CT1

CONFIGURATION

Field	Description
CT0/CT1	The period in milliseconds with which the sensor writes the TPGN message to the bus. The value 0 deactivates cyclical transmission. The values 1 to 9 and above 10.000 are invalid.

A VALUE error is returned when invalid values are written and the value is not accepted.

9.3 Commands

The communication protocols provide commands, that can be used to control the sensor[1]. There are commands for load and save settings, reset or automatic setting of the zero offset. These commands are described in this chapter. How these commands are implemented by the communication protocols, is described in the respective chapters.

Commands will be addressed using a command code[2]. Some commands require arguments, that have a maximum length of 5 bytes. Commands are answered by the sensor with a reply, that contains the command index and a result code, that indicates success or failure of the command execution. The following table contains a list of result codes used by all commands.

Code	Result	Description
0x00	SUCCESS	Command finished successfully
0x01	ERROR	There were errors during command execution
0x10 ... 0xFF		Specific result codes of the respective command

Each command might define special result codes, that are specific for the respective command. These are described in the respective chapters.

1) CANopen: CMD is a SDO write access

2) CANopen: this will be defined by the object dictionary

CONFIGURATION

9.3.1 Overview

The following table contains an overview of all commands. The subsequent chapters contain detailled descriptions for each command.

CMD	Name	Function
0x01	LOAD	Load the configuration from EEPROM (user settings)
0x02	SAVE	Save the configuration into EEPROM (user settings)
0x03	LOAD_FS	Load the configuration from EEPROM (factory settings)
0x05	RESET	Controller Reset
0x06	ZERO	Automatic zero point setting at the current position
0x07	CS_ROT	Automatic rotation of the coordinate system

Table 19: Commands

9.3.2 LOAD, LOAD_FS (0x01, 0x03)

LOAD loads the user settings from the EEPROM into the register file. LOAD_FS loads the factory settings from the EEPROM into the register file.

Byte number	0	1	2	3
Field	'L' (0x4C)	'O' (0x4F)	'A' (0x41)	'D' (0x44)

Table 20: Arguments of the LOAD comman

Byte Number	0	1	2	3
Field	'L' (0x4C)	'D' (0x44)	'F' (0x46)	'S' (0x53)

Table 21: Arguments of the LOAD_FS command

Code	Result	Description
0x00	SUCCESS	Load operation finished successfully
0x10	ARG_ERR	Invalid value in the arguments
0x11	EE_ERR	Error reading the EEPROM

Table 22: Result codes of the LOAD and LOAD_FS command

CONFIGURATION

9.3.3 SAVE (0x02)

SAVE writes the register file to the area of the EEPROM intended for storing the user settings.

Byte Number	0	1	2	3
Field	'S' (0x53)	'A' (0x41)	'V' (0x56)	'E' (0x45)

Table 23: Arguments of the SAVE command

Code	Result	Remarks
0x00	SUCCESS	Save operation finished successfully
0x10	ARG_ERR	Invalid value in the arguments
0x11	EE_ERR	Error writing the EEPROM

Table 24: Result codes of the SAVE command

9.3.4 RESET (0x05)

RESET instructs the firmware to perform a reset.

Byte Number	0	1	2	3	4
Field	'R' (0x52)	'E' (0x45)	'S' (0x53)	'E' (0x45)	'T' (0x54)

Table 25: Arguments of the RESET command

NOTE

The reset is executed after a short delay of approximately 500 ms to allow the sensor to output the reply on the communication interface.

Code	Result	Remarks
0x00	SUCCESS	Load operation finished successfully
0x10	ARG_ERR	Invalid value in the arguments

Table 26: Result codes of the RESET command

9.3.5 ZERO (0x06)

ZERO is used to set the offset of one or more axes so that they correspond to an angle of 0° in the current sensor orientation.

Byte Number	0
Field	AXES see below

CONFIGURATION

The assignment of the bit numbers in the AXES field to the axes is listed in the following table:

Bit Number	0	1	2	3	4
Axis	INCL_X	INCL_Y	ROT_X	ROT_Y	ROT_Z

Code	Result	Remarks
0x00	SUCCESS	operation finished successfully

Table 27: Result codes of the SAVE command

NOTE

The ZERO command always zeros both the low-pass filter offset and the Kalman filter offset (see chapter ‘Angle Offsets’ for details).

9.3.6 CS_ROT (0x07)

CS_ROT is used to automatically set the rotation of the sensor's coordinate system according to the current installation situation. The sensor tries to detect the mounting orientation and selects one of 6 options automatically. On success the rotation will be stored in parameter CS_ROT. CS_ROT does not require arguments

If the sensor axes are not sufficiently aligned with the Earth's gravitational vector, the current alignment cannot be determined automatically. The command then returns an error.

Code	Result	Description
0x00	SUCCESS	Rotation detection finsihed successfully
0x10	ERR	Failed to detect the rotation automatically

Table 28: Result Codes of the CS_ROT command

See chapter 9.2.20 for a description of parameter CS_ROT, that can be used to set the rotation manually. See chapter 8.3 for general information related to coordinate system rotation.

10. DESCRIPTION SAE J1939-INTERFACE

10.1 General information

10.1.1 Supported Standards

The sensor with active SAE J1939 protocol is compliant with the SAE J1939 standard. The following parts of the standard are supported by the sensor:

SAE Standard	Description	Revision
J1939-21	Data link layer	2016-03
J1939-71	Vehicle application layer	2016-10
J1939-81	Network management	2017-03
J1939-DA	Digital annex	2019-04

Table 29: Supported SAE J1939 Standards

10.1.2 Byte Order

Unless explicitly stated otherwise, the byte sequence of all described data fields is little-endian. This means that low-order bytes are located at smaller addresses or are transmitted earlier. If a 16-bit number is specified that is made up of the bytes A0 and A1, A0 contains the least significant bits and A1 the most significant bits (analogous for numbers with more than 2 bytes).

10.1.3 Communication

Communication via the SAE J1939 protocol takes place either via broadcast messages or via point-to-point messages. The transport protocols BAM and CMDT specified by the SAE J1939 standard are not supported by the sensor.

The broadcast messages contain measurement results (e.g. angular values) which the sensor sends without prompting when configured accordingly.

The point-to-point messages work according to a request-reply-scheme. Requests are sent to the sensor and answered by it with a reply. The same PGN is used for this purpose.

10.1.4 DBC File

The SAE J1939 protocol with all used CAN messages and signals is described in a DBC file.

DESCRIPTION SAE J1939-INTERFACE

10.1.5 Structure of CAN-IDs

The SAE J1939 protocol uses Extended Identifiers (29 bit) for CAN bus communication.

The following figure shows the structure of the CAN-ID:

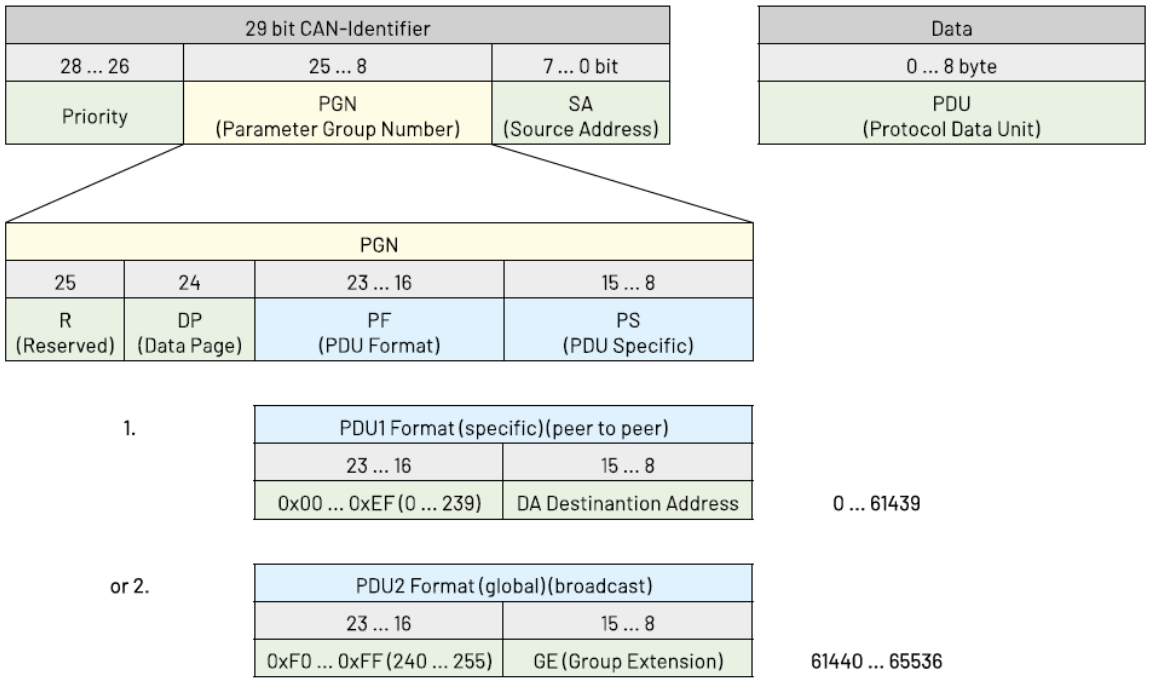

Figure 9: CAN-ID Structure

The sensor uses both point-to-point messages (PDU Format 1) and broadcast messages (PDU Format 2).

Point-to-point messages are sent with PDU format values 0x00 to 0xEF and a specific destination address. The PDU Format 1 and PGN Proprietary A are used to configure and query parameters (see chapter 10.4.1).

Broadcast messages are sent with PDU format values 0xF0 to 0xFF and a specific group extension. The PDU Format 2 and the PGNs of the Proprietary B group extension are used for the transfer of process data (see chapter 10.4).

10.2 Network Management

10.2.1 Device Name and Device Address

By default, the SAE J1939 sensor has the device address 128 (0x80). The sensor transmits an address claim message after device initialization or on request (via PGN 0xEA00). This message contains the device address and a 64-bit device name according to SAE J1939-81 standard.

This 64-bit device name is the unique identification of the sensor on the CAN bus and contains the following information:

- Arbitrary Address Capable, support of dynamic addressing (1 bit)
- Industry Group (3 bit)
- Vehicle System Instance (4 bit)
- Vehicle System (7 bit)
- Function (8 bit)
- Function Instance (5 bit)
- ECU Instance (3 bit)
- Manufacturer Code (11 bit)
- Identity Number (21 bit)

DESCRIPTION SAE J1939-INTERFACE

The Manufacturer Code is the unique number of the manufacturer. This number is assigned by SAE and has the value 1584 (0x630) for TWK Elektronik GmbH.

The 21 bits of the Identity Number are set once and uniquely during production by a company-wide process. These 21 bits are sufficient to uniquely identify the sensor.

The following values in the device name are fixed and cannot be changed:

- Industry Group: 0
- Vehicle System: 0
- Function: 145 (inclination sensor)
- Manufacturer Code: 1584 (TWK Elektronik GmbH)
- Identity Number: Unique number from the TWK Identity Number generation

All other values can be adjusted via TPGN1 (see chapter 10.4.1.1). By default, the Arbitrary Address Capable value is set to 1 and the remaining values to 0.

10.2.2 Address Claiming

The sensor supports dynamic address allocation as described in the SEA J1939-81 standard.

After device initialization, the sensor issues the address claim message (PGN 0xEE00) with the 64-bit device name specified above.

The sensor will wait 250 ms after sending its address claim message for another address claim message to be received. If the sensor does not receive another address claim message with its device address, the sensor starts communicating on the bus.

If an address claim message with the same device address is received, the sensor will react according to the set parameter value Arbitrary Address Capable described above.

If the Arbitrary Address Capable value is set to 0, the sensor sends a Cannot-Claim-Address message with device address 0xFE and stops communication until the next device start.

If the Arbitrary Address Capable value is set to 1, the sensor determines a new device address and sends its address claim message again with the new address. If no new device address could be determined via this process, the sensor sends a Cannot-Claim-Address message with device address 0xFE and stops communication until the next device start.

10.3 Request-PGN

The sensor responds to the PGN 59904 (0xEA00) as described in the SAE J1939-21 standard. A request via the broadcast address (0xFF) or via the device address of the sensor is answered as specified.

Description of the data within the CAN message of the request PGN:

0	1	2	3	4	5	6	7
PGN0	PGN1	PGN2	-	-	-	-	-

The data bytes PGN0 (low) to PGN2 (high) describe the requested PGN. The byte PGN2 must be 0, as no PGNs greater than 65535 are supported.

DESCRIPTION SAE J1939-INTERFACE

Requests are permitted for the following PGNs:

PGN (default)	Name	Reaction
60928 (0XEE00)	Address claimed	Sending the address claim message
61184 (0XEF00)	Proprietary A	Sending the PGN Proprietary A with telegram type ACK
65280 (0XFF00)	Transmit-PGN 2 - Acceleration info	Sending the Transmit-PGN 2 message
65281 (0XFF01)	Transmit-PGN 3 - Gyroscope info	Sending the Transmit-PGN 3 message
65282 (0XFF02)	Transmit-PGN 4 - Inclination info	Sending the Transmit-PGN 4 message
65283 (0XFF03)	Transmit-PGN 5 - Euler info	Sending the Transmit-PGN 5 message
65284 (0XFF04)	Transmit-PGN 6 - Rotation info	Sending the Transmit-PGN 6 message
65285 (0XFF05)	Transmit-PGN 7 - Temperature info	Sending the Transmit-PGN 7 message
65286 (0XFF06)	Transmit-PGN 8 - KF Inclination Info	Sending the Transmit-PGN 8 message
65287 (0XFF07)	Transmit-PGN 9 - KF Eulter Angle Info	Sending the Transmit-PGN 9 message
65288 (0XFF08)	Transmit-PGN 10 - KF Rotation Info	Sending the Transmit-PGN 10 message

A request for an unknown PGN is answered with a negative confirmation via PGN 59392 (0xE800).

10.4 Transmit-PGNs

The broadcast messages and point-to-point messages of the sensor are transmitted with a proprietary format and a configured PGN within its CAN-ID.

For the point-to-point messages the sensor uses the fixed PGN Proprietary A (0xEF00) according to SAE J1939-DA standard.

For the broadcast messages the sensors uses the PGNs within the region Proprietary B (0xFF00 .. 0xFFFF). These PGNs can be configured within this region.

The sensor has 1 Transmit-PGN for the point-to-point messages and 6 Transmit-PGNs for the broadcast messages. The following Transmit-PGNs are assigned:

PGN (default)	PG Label	PG Acronym	PG Description
61184 (0xEF00)	Transmit-PGN 1 - Proprietary A	TPGN1	Response to configuration message, see chapter 10.4.1.1
65280 (0xFF00)	Transmit-PGN 2 - Acceleration Info	TPGN2	Output of the acceleration values of the 3 axes in proprietary format
65281 (0xFF01)	Transmit-PGN 3 - Gyroscope Info	TPGN3	Output of the angular rate values of the 3 axes in proprietary format
65282 (0xFF02)	Transmit-PGN 4 - Inclination Info	TPGN4	Output of the inclination values of the 2 axes in proprietary format[1]
65283 (0xFF03)	Transmit-PGN 5 - Euler Angle Info	TPGN5	Output of the Euler Angle values for roll and pitch angle in proprietary format[1]
65284 (0xFF04)	Transmit-PGN 6 - Rotation Info	TPGN6	Output of the rotation values of the 3 axes in proprietary format[1]
65285 (0xFF05)	Transmit-PGN 7 - Temperature Info	TPGN7	Output of the temperature values in proprietary format
65286 (0xFF06)	Transmit-PGN 8 - KF Inclination Info	TPGN8	Output of the inclination values of the 2 axes calculated by the Kalman filter in proprietary format
65287 (0xFF07)	Transmit-PGN 9 - KF Euler Angle Info	TPGN9	Output of the Euler Angle values for roll and pitch angle calculated by the Kalman filter in proprietary format
65288 (0xFF08)	Transmit-PGN 10 - KF Rotation Info	TPGN10	Output of the rotation values of the 3 axes calculated by the Kalman filter in proprietary format

[1] The angle value output is influenced by the parameter KF_EN (0x10).

DESCRIPTION SAE J1939-INTERFACE

The sensor also offers a selection of SLOT functions specified in the SAE J1939-DA standard for acceleration, angular velocity and inclination.

The activation/deactivation of the transmission, the cycle time, the PGN and the priority of the broadcast messages can be configured via the point-to-point message Transmit-PGN 1 - Proprietary A, see chapter 10.4.1.1.

10.4.1 Transmit-PGN 1 - Proprietary A

10.4.1.1 Overview

The TPGN1 (Proprietary A, 61184, Point-to-Point Messages) is used for access to manufacturer specific features of the sensor.

Technical definition details for the TPGN1 message:

Parameter	Value
Description	Request and response to configuration message in proprietary format
Transmission Repetition Rate	On request
Data length	8 Bytes
Data page	0
Extended data page	0
PDU format	239 (0xEF)
PDU Specific	Request: 128 (0x80) (default value, adjustable) Response: Source address of the sender
Default priority	3 (default value, adjustable)
PGN	61184 (0XEF00)
Source address	Request: Source address of the sender Response: 128 (0x80) (default value, adjustable)

The data part of the CAN messages of TPGN1 is structured as follows:

0	1	2	3	4	5	6	7
TYP	-	-	-	-	-	-	-

The first byte of the message data contains the type (TYP) of the message. It determines, how the rest of the data has to be interpreted. The type in a reply is always a copy of the type of the underlying request.

The following types are supported:

TYP	Name	Function
0x01	GET	Read parameter
0x02	SET	Write parameter
0x03	CMD	Send command to the sensor, i.e. RESET
0x11	GET_XL	Read acceleration values
0x12	GET_GY	Read gyroscope values
0x13	GET_SN	Read sensor serial number
0x80	ACK	Positive reply to the Request-PGN

Table 30: TPGN1 Telegram Types

DESCRIPTION SAE J1939-INTERFACE

10.4.1.2 GET (0x01)

GET is used to read the parameters of the sensor (see chapter 9.2). The parameter value will be transmitted with the reply.

The RESULT byte within the reply provides the information if the read operation was successful or not. The reply telegram only contain the requested data if it is executed successfully. In the event of an error, the reply only contains the fields GET, IDX and RESULT.

Request:

Byte Number	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Field	GET (0x01)	IDX	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF

GET: TYP code of the GET telegram

IDX: Parameter selection

Reply:

Byte Number	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Field	GET (0x01)	IDX	RESULT	DAT0	DAT1	DAT2	DAT3	DAT4

GET and IDX are a copy of the corresponding fields in the based request.

RESULT: Operation result according to the following table.

RESULT	**Result**	**Remarks**
0x00	SUCCESS	Parameter reading successfully
0x01	NODATA	Not enough data in the telegram
0x02	UNKNOWN	Unknown parameter (invalid IDX)
0x03	DENIED	Access denied (attempt to read a write-only paramter)
0x04	ERROR	Error occurd while reading parameter
0x10…	SPECIFIC	Parmeter specific codes: these codes are listed in the parameter description (see sub-chapter 9.2)

Table 31: RESULT codes of the GET telegramm

The fields DAT0 to DAT4 contain the parameter value. The value length varies depending on the parameter. Unused data bytes are set to 0xFF.

10.4.1.3 SET (0x02)

SET is used to write the parameters of the sensor (see chapter 9.2).

Request:

Byte Number	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Field	SET (0x01)	IDX	RESULT	DAT0	DAT1	DAT2	DAT3	DAT4

IDX: Parameter selection

The data byte 2 is reserved and will be ignored by the sensor. This byte shall be set to 0x00 or 0xFF.

The fields DAT0 to DAT4 contain the parameter value. The value length varies depending on the parameter. Unused data bytes shall be set to 0xFF.

Reply:

Byte Number	0	1	2	3	4	5	6	7
Field	SET (0x02)	IDX	RESULT	DAT0	DAT1	DAT2	DAT3	DAT4

SET and IDX are a copy of the correspondent fields in the based request.

RESULT: Operation result according to the following table.

RESULT	Result	Remarks
0x00	SUCCESS	Parameter reading successfully
0x01	NODATA	Not enough data in the telegram
0x02	UNKNOWN	Unknown parameter (invalid IDX)
0x03	DENIED	Access denied (attempt to read a write-only paramter)
0x04	ERROR	Error occurd while reading parameter
0x10…	SPECIFIC	Parmeter specific codes: these codes are listed in the parameter description (see sub-chapter 9.2)

Table 32: RESULT codes of the SET telegram

10.4.1.4 CMD (0x03)

CMD can be used to transmit commands as described in chapter 9.3 to the sensor.

Request:

Byte Number	0	1	2	3	4	5	6	7
Field	CMD (0x03)	CC	0xFF	ARG0	ARG1	ARG2	ARG3	ARG4

CC: Command Code

The data byte 2 is reserved and will be ignored by the sensor. This byte shall be set to 0x00 or 0xFF.

The fields ARG0 to ARG4 contain optional arguments of the command. The value length varies depending on the command code.

Unused data bytes shall be set to 0xFF.

Reply:

Byte Number	0	1	2	3	4	5	6	7
Field	CMD (0x03)	CC	RESULT	DAT0	DAT1	DAT2	DAT3	DAT4

CC: Copy of the field of the same name of the underlying request

RESULT: Result of the command (see chapter 9.3 for details)

The fields DAT0 to DAT4 contain optional command results. The value length varies depending on the command.

Refere to chapter 9.3 for details.

DESCRIPTION SAE J1939-INTERFACE

10.4.1.5 GET_XL (0x11)

The acceleration values can be explicitly requested with GET_XL.

Request:

Byte Number	0	1	2	3	4	5	6	7
Field	GET_XL (0x11)	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF

Reply format:

Byte Number	0	1	2	3	4	5	6	7
Field	GET_XL (0x11)	STATUS	X0	X1	Y0	Y1	Z0	Z1

Status	See below
X0 / X1	Acceleration value x-axis, resolution 0.25 mg, 2's complement format
Y0 / Y1	Acceleration value y-axis, resolution 0.25 mg, 2's complement format
Z0 / Z1	Acceleration value z-axis, resolution 0.25 mg, 2's complement format

The meaning of the bits in the STATUS bytes is shown in the following table:

Bit	Name	Function
0	HNIR	Heater not in range (see chapter 8.2 for details)
1	WARN	Measured values are unreliable (see chapter 8.2 for details)
2	ERR	There is a hardware problem that prevents correct measured values from being determined
3…7	-	unused

If no sensor values are available at the time of access, the data bytes 1 to 7 are set to 0xFF. This is only the case immediately after the reset (power-on) and has technical reasons (initialization of sensor element and firmware). This state does not last longer than a few 100 ms.

10.4.1.6 GET_GY (0x12)

The gyroscope values can be explicitly requested with GET_GY.

Request:

Byte Number	0	1	2	3	4	5	6	7
Field	GET_GY (0x12)	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF

Reply format:

Byte Number	0	1	2	3	4	5	6	7
Field	GET_GY (0x12)	STATUS / FSR	X0	X1	Y0	Y1	Z0	Z1

DESCRIPTION SAE J1939-INTERFACE

Status	See below
X0 / X1	Gyroscope value x-axis, 2's complement format
Y0 / Y1	Gyroscope value y-axis, 2's complement format
Z0 / Z1	Gyroscope value z-axis, 2's complement format

The resolution is coded in the upper 4 bits of the 2nd byte according to the table below.

The meaning of the bits in the STATUS bytes is shown in the following table:

Bit	Name	Function
0	HNIR	Heater not in range (see chapter 8.2 for details)
1	WARN	Measured values are unreliable (see chapter 8.2 for details)
2	ERR	There is a hardware problem that prevents correct measured values from being determined
3	-	unused
4…6	FSR	Full scale range see below
7	-	unused

If no sensor values are available at the time of access, the data bytes 1 to 7 are set to 0xFF. This is only the case immediately after the reset (power-on) and has technical reasons (initialization of sensor element and firmware). This state does not last longer than a few 100 ms.

The current measuring range of the gyro sensor is coded in the FSR bit field of the STATUS byte according to the following table:

FSR	Measuring range	Resolution of the measured value (value 1 LSB)
0x0	± 125 dps	4.375 mdps
0x1	± 250 dps	8.75 mdps
0x2	± 500 dps	17.5 mdps
0x3	± 1000 dps	35 mdps
0x4	± 2000 dps	70 mdps
0x5	± 4000 dps	140 mdps

10.4.1.7 GET_SN (0x13)

The serial number of the sensor can be read with GET_SN.

Request:

Byte Number	0	1	2	3	4	5	6	7
Field	GET_SN (0x13)	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF	0xFF

Reply format:

Byte Number	0	1	2	3	4	5	6	7
Field	GET_SN (0x13)	RESULT	SN0	SN1	SN2	SN3	SN4	SN5

DESCRIPTION SAE J1939-INTERFACE

The meaning of the field is shown in the following table:

RESULT	See below
SN0…SN5	Serial number, coding is no part of that specification

The meaning of the RESULT codes is shown in the following table:

Result	Name	Function
0x00	SUCCESS	Command writing successfully
0x01	ERROR	Error

10.4.1.8 ACK (0x80)

The ACK message is sent as a positive acknowledgement if the PGN (Proprietary A, 61184) is requested via the Request-PGN (see chapter 10.3). The ACK message has the following structure:

Byte Number	0	1	2	3	4	5	6	7
Field	ACK (0x80)	0x00	0x00	0xFF	0xFF	0xFF	0xFF	0xFF

10.4.2 Transmit-PGN 2 - Acceleration Info

The Acceleration Info (TPGN2) message contains information regarding the acceleration values of the 3 axes.

Technical definition details for the Acceleration Info message:

Parameter	Value
Description	Output of the acceleration values of the 3 axes in proprietary format
Transmission repetition format	0 deactivated (default value) or 10…1000 ms (adjustable)
Data length	8 bytes
Data page	0
Extended data page	0
PDU format	255
PDU specific	0 (default value, adjustable)
Default priority	3 (default value, adjustable)
PGN	65280 (0xFF00) (default value, adjustable)
Source address	128 (0x80) (default value, adjustable)

The transmitted data in the bytes have the following format:

Byte Number	0	1	2	3	4	5	6	7
Field	X0	X1	Y0	Y1	Z0	Z1	STATUS	0xFF

Status	Acceleration status (see Table 5: Structure of the Acceleration STATUS byte for details)
X0 / X1	Acceleration value of the x-axis using the configured SLOT function (see below)
Y0 / Y1	Acceleration value of the y-axis using the configured SLOT function (see below)
Z0 / Z1	Acceleration value of the z-axis using the configured SLOT function (see below)

DESCRIPTION SAE J1939-INTERFACE

The following configurable SLOTs[3)] can be used for the acceleration values:

Number	Name	Type	Scaling	Range	Offset	Length
0 (default)	TWKac01	Acceleration	0.00025 g per bit	-3 g … 3 g	-3 g	2 bytes
1	SAEac03	Acceleration	0.01 m/s² per bit	-320 m/s² … 320.55 m/s²	-320 m/s²	2 bytes
2	TWKac02	Acceleration	0.00025 g per bit	-8.192 g ... 8.191 g	-8.192 g	2 bytes
3	TWKac03	Acceleration	0.0005 g per bit	-16.384 g ... 16.383 g	-16.384 g	2 bytes

3) SLOT function can be configured by using the given SLOT number and sending TPGN1 with parameter TPGN2_ID

10.4.3 Transmit-PGN 3 - Gyroscope Info

The Gyroscope Info (TPGN3) message contains information regarding the angular rate values of the 3 axes.

Technical definition details for the Gyroscope Info message:

Parameter	Value
Description	Output of the acceleration values of the 3 axes in proprietary format
Transmission repetition format	0 deactivated (default value) or 10…1000 ms (adjustable)
Data length	8 bytes
Data page	0
Extended data page	0
PDU format	255
PDU specific	1 (default value, adjustable)
Default priority	3 (default value, adjustable)
PGN	65281 (0xFF01) (default value, adjustable)
Source address	128 (0x80) (default value, adjustable)

The transmitted data in the bytes have the following format:

Byte Number	0	1	2	3	4	5	6	7
Field	X0	X1	Y0	Y1	Z0	Z1	STATUS	0xFF

Status	Gyroscope status (see below)
X0 / X1	Gyroscope value of the x-axis using the configured SLOT function TWKva0x[1)] or SAEva03 (see below)
Y0 / Y1	Gyroscope value of the y-axis using the configured SLOT function TWKva0x[1)] or SAEva03 (see below)
Z0 / Z1	Gyroscope value of the z-axis using the configured SLOT function TWKva0x[1)] or SAEva03 (see below)

1) SLOT is set automatically depending on the set full scale range

DESCRIPTION SAE J1939-INTERFACE

The meaning of the bits in the STATUS bytes is shown in the following table:

Bit	Name	Function
0	HNIR	Heater not in range (see chapter 8.2 for details)
1	WARN	Measured values are unreliable (see chapter 8.2 for details)
2	ERR	There is a hardware problem that prevents correct measured values from being determined
3	-	unused
4…6	FSR	Full scale range see below
7	-	unused

The current measuring range of the gyroscope sensor is coded in the FSR bit field of the STATUS byte according to the following table:

FSR	Measuring range	Used default SLOT function
0x0	±125°/s	TWKva01
0x1	±250°/s	TWKva02
0x2	±500°/s	TWKva03
0x3	±1000°/s	TWKva04
0x4	±2000°/s	TWKva05
0x5	±4000°/s	TWKva06

The following configurable SLOTs[4)] can be used for the gyroscope values:

Number	Name	Type	Scaling	Range	Offset	Length
0 (default)	TWKva01	Velocity, angular	0.004375°/s per bit	-125…125°/s	-125°/s	2 bytes
	TWKva02	Velocity, angular	0.00875°/s per bit	-250…250°/s	-250°/s	2 bytes
	TWKva03	Velocity, angular	0.0175°/s per bit	-500…500°/s	-500°/s	2 bytes
	TWKva04	Velocity, angular	0.035°/s per bit	-1000…1000°/s	-1000°/s	2 bytes
	TWKva05	Velocity, angular	0.070°/s per bit	-2000…2000°/s	-2000°/s	2 bytes
	TWKva06	Velocity, angular	0.14°/s per bit	-4000…4000°/s	-4000°/s	2 bytes
1	SAEva03	Velocity, angular	1/128°/s per bit	-250…250,922°/s	-250°/s	2 bytes

[4)] SLOT function can be configured by using the given SLOT number and sending TPGN1 with parameter TPGN3_ID. SLOT SAEva03 fits best with a FSR of +/- 250 °/s

DESCRIPTION SAE J1939-INTERFACE

10.4.4 Transmit-PGN 4 - Inclination Info

The Inclination Info (TPGN4) message contains information regarding the inclination values of the 2 axes.

Technical definition details for the Inclination Info message:

Parameter	Value
Description	Output of the inclination values of the 2 axes in proprietary format
Transmission repetition format	0 deactivated (default value) or 10…1000 ms (adjustable)
Data length	8 bytes
Data page	0
Extended data page	0
PDU format	255
PDU specific	2 (default value, adjustable)
Default priority	3 (default value, adjustable)
PGN	65282 (0xFF02) (default value, adjustable)
Source address	128 (0x80) (default value, adjustable)

The transmitted data in the bytes have the following format:

Byte Number	0	1	2	3	4	5	6	7
Field	X0	X1	Y0	Y1	STATUS	0xFF	0xFF	0xFF

Status	Inclination status (see Table 7: Structure of the Inclination STATUS byte for details)
X0 / X1	Inclination value of the x-axis using the configured SLOT function (see below)
Y0 / Y1	Inclination value of the y-axis using the configured SLOT function (see below)

The following configurable SLOTs[5)] can be used for the inclination values:

Number	Name	Type	Scaling	Range	Offset	Length
0 (default)	TWKad01	Angle/Direction	0.01° per bit	-90°…90°	-90°	2 bytes
1	SAEad08	Angle/Direction	0.002° per bit	-64°…64,51°	-64°	2 bytes

[5)] SLOT function can be configured by using the given SLOT number and sending TPGN1 with parameter TPGN4_ID

DESCRIPTION SAE J1939-INTERFACE

10.4.5 Transmit-PGN 5 - Euler Angle Info

The Euler Angle Info (TPGN5) message contains information regarding the angle values for roll and pitch.

Technical definition details for the Euler Angle Info message:

Parameter	Value
Description	Output of the Euler angle values for roll and pitch angle in proprietary format
Transmission repetition format	0 deactivated (default value) or 10…1000 ms (adjustable)
Data length	8 bytes
Data page	0
Extended data page	0
PDU format	255
PDU specific	3 (default value, adjustable)
Default priority	3 (default value, adjustable)
PGN	65283 (0xFF03) (default value, adjustable)
Source address	128 (0x80) (default value, adjustable)

The transmitted data in the bytes have the following format:

Byte Number	0	1	2	3	4	5	6	7
Field	R0	R1	P0	P1	STATUS	0xFF	0xFF	0xFF

Status	Euler Angle status (see Table 8: Structure of the Euler STATUS byte for details)
R0 / R1	Roll angle value using the configured SLOT function TWKad02 or SAEad08 (see below)
P0 / P1	Roll angle value using the configured SLOT function TWKad01 or SAEad08 (see below)

The following configurable SLOTs[6)] can be used for the inclination values:

Number	Name	Type	Scaling	Range	Offset	Length
0 (default)	TWKad01	Angle/Direction	0.01° per bit	-90°…90°	-90°	2 bytes
	TWKad02	Angle/Direction	0.01° per bit	-180°…180°	-180°	2 bytes
1	SAEad08	Angle/Direction	0.002° per bit	-64°…64,51°	-64°	2 bytes

[6)] SLOT function can be configured by using the given SLOT number and sending TPGN1 with parameter TPGN5_ID

DESCRIPTION SAE J1939-INTERFACE

10.4.6 Transmit-PGN 6 - Rotation Info

The Rotation Info (TPGN6) message contains information regarding the rotation values of the 3 axes.

Technical definition details for the Rotation Info message:

Parameter	Value
Description	Output of the rotation values of the 3 axes in proprietary format
Transmission repetition format	0 deactivated (default value) or 10…1000 ms (adjustable)
Data length	8 bytes
Data page	0
Extended data page	0
PDU format	255
PDU specific	4 (default value, adjustable)
Default priority	3 (default value, adjustable)
PGN	65284 (0xFF04) (default value, adjustable)
Source address	128 (0x80) (default value, adjustable)

The transmitted data in the bytes have the following format:

Byte Number	0	1	2	3	4	5	6	7
Field	X0	X1	Y0	Y1	Z0	Z1	STATUS	0xFF

Status	Rotation status (see below)
X0 / X1	Rotation value of x-axis using the fixed SLOT function (see below)
Y0 / Y1	Rotation value of y-axis using the fixed SLOT function (see below)
Z0 / Z1	Rotation value of z-axis using the fixed SLOT function (see below)

The meaning of the bits in the STATUS bytes is shown in the following table:

Bit	Name	Function
0	HNIR	Heater not in range (see chapter 8.2 for details)
1	-	unused
2	ERR	There is a hardware problem that prevents correct measured values from being determined
3	WARN_X	X-axis: Measured values are unreliable (see chapter 8.2 for details)
4	WARN_Y	Y-axis: Measured values are unreliable (see chapter 8.2 for details)
5	WARN_Z	Z-axis: Measured values are unreliable (see chapter 8.2 for details)
6…7	-	unused

The following fixed SLOT will be used for the rotation values:

Number	Name	Type	Scaling	Range	Offset	Length
0 (default)	TWKad03	Angle/Direction	0.01° per bit	0°…360°	0°	2 bytes

DESCRIPTION SAE J1939-INTERFACE

10.4.7 Transmit-PGN 7 - Temperature Info

The Temperature Info (TPGN7) message contains information regarding the temperature values.

Technical definition details for the Temperature Info message:

Parameter	Value
Description	Output of the temperature values in proprietary format
Transmission repetition format	0 deactivated (default value) or 10…1000 ms (adjustable)
Data length	8 bytes
Data page	0
Extended data page	0
PDU format	255
PDU specific	5 (default value, adjustable)
Default priority	3 (default value, adjustable)
PGN	65285 (0xFF05) (default value, adjustable)
Source address	128 (0x80) (default value, adjustable)

The transmitted data in the bytes have the following format:

Byte Number	0	1	2	3	4	5	6	7
Field	T0	T1	STATUS	0xFF	0xFF	0xFF	0xFF	0xFF

Status	Temperature status (see Table 10: Structure of the Temperature STATUS byte for details)
T0 / T1	Temperature value using the fixed SLOT function (see below)

The following fixed SLOT will be used for the temperature values:

Number	Name	Type	Scaling	Range	Offset	Length
0 (default)	TWKtp01	Temperature	0.1 °C	-40°…210 °C	-40 °C	2 bytes

DESCRIPTION SAE J1939-INTERFACE

10.4.8 Transmit-PGN 8 - KF Inclination Info

The KF Inclination Info (TPGN8) message contains information regarding the inclination values of the 2 axes calculated by the Kalman filter.

Technical definition details for the KF Inclination Info message:

Parameter	Value
Description	Output of the inclination values of the 2 axes in proprietary format
Transmission repetition format	0 deactivated (default value) or 10…1000 ms (adjustable)
Data length	8 bytes
Data page	0
Extended data page	0
PDU format	255
PDU specific	6 (default value, adjustable)
Default priority	3 (default value, adjustable)
PGN	65286 (0xFF06) (default value, adjustable)
Source address	128 (0x80) (default value, adjustable)

The transmitted data in the bytes have the following format:

Byte Number	0	1	2	3	4	5	6	7
Field	X0	X1	Y0	Y1	STATUS	0xFF	0xFF	0xFF

Status	Inclination status (see Table 11: Structure of the Kalman Filter Inclination STATUS byte for details)
X0 / X1	Inclination value of the x-axis using the configured SLOT function (see below)
Y0 / Y1	Inclination value of the y-axis using the configured SLOT function (see below)

The following fixed SLOT[7)] will be used for the inclination values:

Number	Name	Type	Scaling	Range	Offset	Length
0 (default)	TWKad01	Angle/Direction	0.01° per bit	-90°…90°	-90°	2 bytes
1	SAEad08	Angle/Direction	0.002° per bit	-64°…64,51°	-64°	2 bytes

[7)] SLOT function can be configured by using the given SLOT number and sending TPGN1 with parameter TPGN8_ID

DESCRIPTION SAE J1939-INTERFACE

10.4.9 Transmit-PGN 9 - KF Euler Angle Info

The KF Euler Angle Info (TPGN9) message contains information regarding the angle values for roll and pitch calculated by the Kalman filter.

Technical definition details for the Euler Angle Info message:

Parameter	**Value**
Description	Output of the Euler Angle values for roll and pitch angle in proprietary format
Transmission repetition format	0 deactivated (default value) or 10…1000 ms (adjustable)
Data length	8 bytes
Data page	0
Extended data page	0
PDU format	255
PDU specific	7 (default value, adjustable)
Default priority	3 (default value, adjustable)
PGN	65287 (0xFF07) (default value, adjustable)
Source address	128 (0x80) (default value, adjustable)

The transmitted data in the bytes have the following format:

Byte Number	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Field	R0	R1	P0	P1	STATUS	0xFF	0xFF	0xFF

Status	**Euler Angle status (see Table 12: Structure of the Kalman Filter Euler STATUS byte for details)**
R0 / R1	Roll angle value using the configured SLOT function TWKad02 or SAEad08 (see below)
P0 / P1	Pitch angle value using the configured SLOT function TWKad01 or SAEad08 (see below)

The following configurable SLOT[8)] can be used for the inclination values:

Number	**Name**	**Type**	**Scaling**	**Range**	**Offset**	**Length**
0 (default)	TWKad01	Angle/Direction	0.01° per bit	-90°…90°	-90°	2 bytes
	TWKad02	Angle/Direction	0.01° per bit	-180°…180°	-180°	2 bytes
1	SAEad08	Angle/Direction	0.002° per bit	-64°…64,51°	-64°	2 bytes

[8)] SLOT function can be configured by using the given SLOT number and sending TPGN1 with parameter TPGN9_ID

DESCRIPTION SAE J1939-INTERFACE

10.4.10 Transmit-PGN 10 - KF Rotation Info

The KF Rotation Info (TPGN10) message contains information regarding the rotation values of the 3 axes.

Technical definition details for the Rotation Info message:

Parameter	Value
Description	Output of the rotation values of the 3 axes in proprietary format
Transmission repetition format	0 deactivated (default value) or 10…1000 ms (adjustable)
Data length	8 bytes
Data page	0
Extended data page	0
PDU format	255
PDU specific	8 (default value, adjustable)
Default priority	3 (default value, adjustable)
PGN	65288 (0xFF08) (default value, adjustable)
Source address	128 (0x80) (default value, adjustable)

The transmitted data in the bytes have the following format:

Byte Number	0	1	2	3	4	5	6	7
Field	X0	X1	Y0	Y1	Z0	Z1	STATUS	0xFF

Status	Rotation status (see Table 13: Structure of the Kalman Filter Rotation X/Y/Z STATUS byte for details)
X0 / X1	Rotation value of x-axis using the fixed SLOT function (see below)
Y0 / Y1	Rotation value of y-axis using the fixed SLOT function (see below)
Z0 / Z1	Rotation value of z-axis using the fixed SLOT function (see below)

The following fixed SLOT will be used for the rotation values:

Number	Name	Type	Scaling	Range	Offset	Length
0	TWKad03	Angle/Direction	0.01° per bit	0°…360°	0°	2 bytes

10.5 Working with the SAE J1939 Interface

This chapter describes by examples, how to use the implemented SAE J1939 commands for the configuration of the NBN45-G.

Typical steps are described, which might be done during the first commissioning of the NBN45-G in order to integrate it into a specific application. All numbers are in hexadecimal format if not noted otherwise. The address of the sender of Transmit-PGN1 is 1.

DESCRIPTION SAE J1939-INTERFACE

10.5.1 CAN Bit Rate Adjustment

No.	Sensor receives with CAN-ID: 0CEF8001	Sensor transmits with CAN-ID: 0CEF0180
1	Parameter CAN_BR write: 02 08 FF 09 FF FF FF FF BR=9 # invalid value	
2		02 08 04 FF FF FF FF FF RESULT = 0x04 (VALUE-Error) The value was not accepted.
1	Parameter CAN_BR write: 02 08 FF 03 FF FF FF FF BR=3 # 500 kBit/s	
2		02 08 00 FF FF FF FF FF RESULT=0x00 (SUCCESS) The value was accepted and would now be returned when reading the parameter, but is not yet effective.
3	RESET Command: 03 05 FF 52 45 53 45 54	
4		03 05 00 FF FF FF FF FF RESULT = 0x00 (SUCCESS) After reset no address claim message will be received. In order for the address claim message to be received, the CAN bus must be configured to the new bit rate after the RESET command has been sent.

10.5.2 Device Address Adjustment

No.	Sensor receives with CAN-ID: 0CEF8001	Sensor transmits with CAN-ID: 0CEF0180
1	Parameter J1939_DEV_ADDR write: 02 80 FF 05 FF FF FF FF J1939_DEV_ADDR = 5	
2		02 80 00 FF FF FF FF FF RESULT = 0x00 (SUCCESS) The value was accepted, but is not yet effective.
3	SAVE command for save the settings: 03 02 FF 53 41 56 45 FF	
4		03 02 00 FF FF FF FF FF RESULT = 0x00 (SUCCESS) The value is stored in the persistent memory of the sensor, but is still not effective.
5	RESET Command: 03 05 FF 52 45 53 45 54	
6		03 05 00 FF FF FF FF FF RESULT = 0x00 (SUCCESS) After reset the address claim message will be sent with the source address 0x05 within the CAN ID.

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10.5.3 Read Angle and Rotation Values

No.	Sensor receives with CAN-ID: 0CEF8001	Sensor transmits with CAN-ID: 0CEF0180
1	Parameter XY_INCL read: 01 00 FF FF FF FF FF FF	
2		01 00 00 00 40 05 8B FF RESULT = 0x00 (SUCCESS) STATUS = 0x00 X = 0x0540 (dec. 1344 => +13,44°) Y = 0xFF8B (dec. -117 => -1,17°) The actual values will vary depending on the current situation.
3	Parameter Z_ROT read: 01 18 FF FF FF FF FF FF	
4		01 18 00 00 2A 86 FF FF RESULT = 0x00 (SUCCESS) STATUS=0x00 X=0x862A (dec. 34346 => 343,46°) The actual values will vary depending on the current situation.

10.5.4 Load Factory Settings

No.	Sensor receives with CAN-ID: 0CEF8001	Sensor transmits with CAN-ID: 0CEF0180
1	LOAD_FS Command: 03 03 FF 4C 44 46 53 FF	
2		03 03 00 FF FF FF FF FF RESULT = 0x00 (SUCCESS)

10.5.5 Zero Point Adjustment

No.	Sensor receives with CAN-ID: 0CEF8001	Sensor transmits with CAN-ID: 0CEF0180
1	ZERO Command: 03 06 FF 01 00 00 00 00 AXES = 0x01 (zero the X-axis only)	
2		03 06 00 FF FF FF FF FF RESULT=0x00 (SUCCESS) The value has been accepted and is effective, but has not yet been written to the persistent memory, so it would be overwritten with the value from the persistent memory after the next restart.
3	Read back for verification. Not necessary for function. Only for information what is happening in the sensor. Read ZERO_IX parameter: 01 11 FF FF FF FF FF FF Actual values vary depending on the current situation.	

DESCRIPTION SAE J1939-INTERFACE

No.	Sensor receives with CAN-ID: 0CEF8001	Sensor transmits with CAN-ID: 0CEF0180
4		01 11 00 F5 FF FF FF FF RESULT = 0x00 (SUCCESS) ZERO = 0xFFF5 (dec. -11 => -0,11°)
5	SAVE command for save the settings: 03 02 FF 53 41 56 45 00	
6		03 02 00 FF FF FF FF FF RESULT = 0x00 (SUCCESS) Value is written to the persistent memory.

10.5.6 Filter Adjustment

No.	Sensor receives with CAN-ID: 0CEF8001	Sensor transmits with CAN-ID: 0CEF0180
1	Write parameter FLT_ACC: 02 0E FF E8 03 02 FF FF FC=0x03E8 (dec. 1000 => 1000 mHz) FT=0x02 (critical damped)	
2		02 0E 00 FF FF FF FF FF RESULT=0x00 (SUCCESS) The value has been accepted and is effective, but has not yet been written to the persistent memory, so it would be overwritten with the value from the persistent memory after the next restart.

10.5.7 Set Cycle Time for TPGN4

No.	Sensor receives with CAN-ID: 0CEF8001	Sensor transmits with CAN-ID: 0CEF0180
1	Write parameter TPGN4_CT: 02 B3 FF 64 00 FF FF FF CT = 0x0064 (dec. 100 => 100 ms)	
2		02 B3 00 FF FF FF FF FF RESULT=0x00 (SUCCESS) The value has been accepted and is effective, but has not yet been written to the persistent memory, so it would be overwritten with the value from the persistent memory after the next restart.
3		The TPGN4 message will be sent in cycles of 100 ms 40 05 8B FF 00 FF FF FF X = 0x0540 (dec. 1344 => +13,44°) Y = 0xFF8B (dec. -117 => -1,17°) STATUS = 0x00 The actual values will vary depending on the current situation.

DESCRIPTION CANOPEN - INTERFACE

11. DESCRIPTION CANOPEN-INTERFACE

11.1 General Information

11.1.1 Overview

CANopen is a CAN-based communication system, which was standardized by the “CAN in Automation” (CiA). It is based on the ISO/OSI 7-layer model and comprises higher-layer protocols and profile specifications. The CiA 301 specifies the application layer (ISO/ OSI layer 7) which is used for the CANopen communication. The standard defines the method of communication for all devices consistently. For the communication in special applications, several standards were defined. Such as the CiA DSP 410 for inclination sensors.

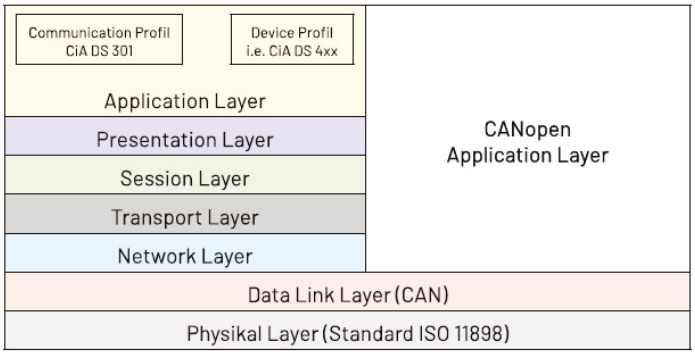

Figure 10: ISO-Layer

The TWK inclination and gyro sensors offer a CANopen interface which supports the device profile CiA DSP 410.

The CANopen sensor provides following CANopen functions:

- Service Data Object (SDO)
- Process Data Objects (PDO)
- Safety Relevant Data Objects (SRDO) according to EN 50325-5
- Emergency Object (EMCY)
- Heartbeat mechanism
- Store and load functions
- Status information by LED (according to CiA DR-303-03)
- Setting of Node-ID and bit rate via LSS service according to CiA 305

The objects are predefined in the Object Dictionary for the CANopen device.

11.1.2 Network Management

All CANopen devices must support the CANopen network management (NMT) slave state machine. The NMT state machine defines the communication behavior of a CANopen device. The CANopen NMT state machine consists of an initialization state, a pre-operational state, an operational state, and a stopped state. After power-on or reset, the device enters the initialization state. After the device initialization is finished, the device automatically transits to pre-operational state and indicates this transition by sending the boot-up message, i.e. the device indicates that it is ready to work. A device that stays in pre-operational state can start to transmit SYNC-, time stamp- or heartbeat messages, if these services are supported and configured correctly. In contrast to PDO or SRDO communication which is disabled in this state, the device can communicate via SDO. PDO and SRDO communication is only possible in the operational state.

During operational state, the device can use all supported communication objects. A device that was switched to the stopped state only reacts on received NMT requests. In addition, the device indicates the current NMT state by supporting the error control protocol during stopped state.

DESCRIPTION CANOPEN - INTERFACE

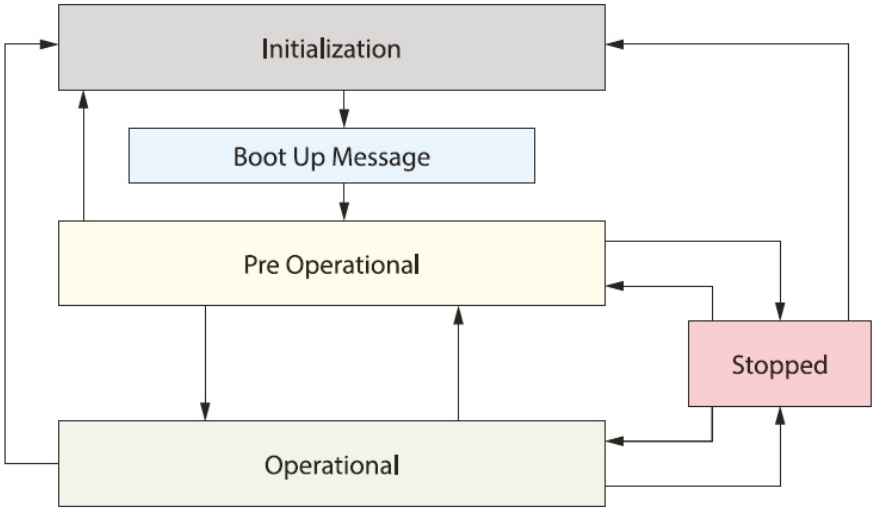

Figure 11: CANopen - Network management

The CANopen sensor provides following NMT services:

- Node control services:
  All Node control services can be be requested by a NMT master. The request "Service reset node" leads to the execution of a controller reset, thus the device enters the initialization state.
- Error control services:
  A heartbeat mechanism is implemented, see chapter Heartbeat Mechanism. The heartbeat consumer should initiate the Service heartbeat event, if the heartbeat mechanism is used.
- Boot-up service:
  The Service boot-up Event is implemented.

11.1.3 Service Data Object (SDO)

Each CANopen device has an object dictionary, which includes a list of all parameters provided by the device. Service data objects (SDOs) enable access to all entries in that dictionary.

Each object can be addressed by a 16-bit index. Each 16-bit index consists of an 8-bit sub-index which allows to add further data. Therefore, a SDO needs a special protocol structure, which defines what parameter will be addressed.

Command specifier	**Index, 16-bit**		**Sub-Index, 8-bit**	**Parameter**			
				Data 1	**Data 2**	**Data 3**	**Data 4**
Byte 0	**Byte 1**	**Byte 2**	**Byte 3**	**Byte 4**	**Byte 5**	**Byte 6**	**Byte 7**
Upload	$10\ 00_h$		00_h	Device Type: 0x0704019A			
Download	…		…				
Data	$10\ 18_h$		00_h	Identity Object: 4			

Table 33: SDO protocol structure

DESCRIPTION CANOPEN - INTERFACE

Command specifier	Index, 16-bit		Sub-Index, 8-bit	Parameter			
				Data 1	Data 2	Data 3	Data 4
Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Length			01h	Vendor ID: 0x0000010D			
Abort			02h	Product Code: 0x8710			
…			03h	Revision Number: 0x00010001			
			04h	Serial Number: …..			
	…		…				
	60 00h		00h	Resolution: 10			
	…		…				

Table 33: SDO protocol structure (cont.)

11.1.4 Process Data Object (PDO)

Process data objects (PDOs) are used in CANopen for broadcasting high-priority control and status information. A PDO consists of a single CAN frame and communicates up to 8 byte of pure application data. Device designers have to evaluate the amount of process data that the device needs to receive and transmit. Based on the result of this evaluation process, they have to provide the related amount of receive and transmit PDOs within the device.

11.1.5 Emergency Objects (EMCY)

The NBN45-G/S3 supports several Emergency Objects (EMCY) based on the CiA 301 Standard. Such an EMCY will occur in case of an internal error of the sensor.

If an error is detected the error registers 1001h will be written and a EMCY message will be sent. Furthermore the error will be registered in the pre-defined error field (1003h). The following tables show the structure and the error codes.

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Emergency Error Code		Error Register (1001h)	Manufacturer Specific Emergency (currently not set)				
			0x00	0x00	0x00	0x00	0x00

Table 34: Emergency Object

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Value	Error code
0x0000	Error reset or no error
0x8110	CAN overrun (objects lost)
0x8120	CAN in error passive mode
0x8140	Recovered from bus off
0xFF11	Device specific - Invalid filter configuration
0xFF12	Device specific - Temperature values not plausible

Table 35: EMCY Error Codes

11.1.6 Heartbeat Mechanism

The sensor provides a heartbeat mechanism which is cyclically transmitting the heartbeat message. It can be activated with the object 1017h - producer heartbeat time and monitored by the application master.

11.1.7 Layer Setting Services (LSS)

The NBN45-G/S3 with CANopen interface provides the slave functionality of LSS as described in CiA 305 standard.

Following services will be supported:

- Switch state global and selective
- Identify slave
- Inquire LSS address
- Inquire and configure Node-ID
- Configure and activate bit timing parameters (automatic bit rate detection won’t be supported)
- Store configuration

11.1.8 EDS File

All objects of the NBN45-G/S3 CANopen sensor are described in an EDS file. The EDS-File is provided on request.

11.2 CANopen Operating Modes

In addition to the current NMT state the NBN45-G/S3 maintains a so called operating mode. The current mode can be read from object 3002h of the object dictionary (see chapter 13.3.2 for details).

The following figure illustrates the operating modes statemachine.

DESCRIPTION CANOPEN - INTERFACE

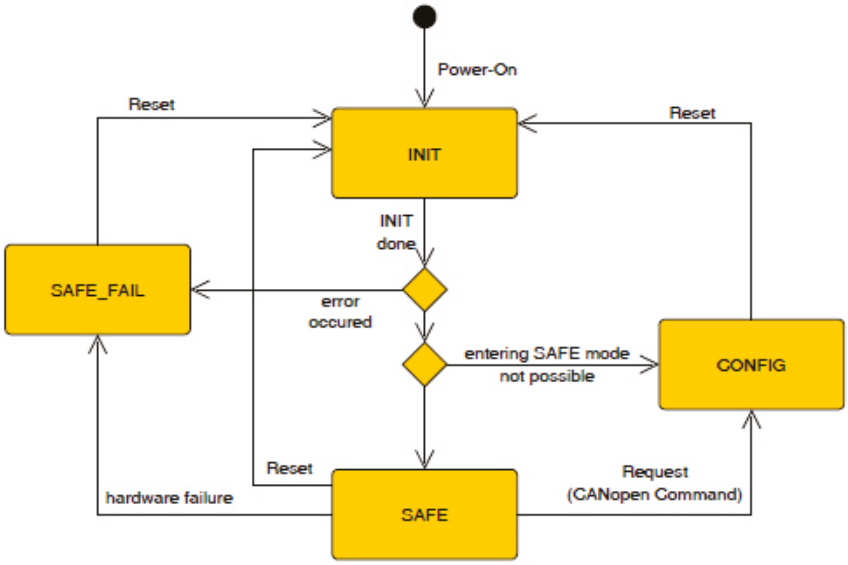

Figure 12: The Operating Modes statemachine

Mode	Details
INIT	Initialization after Power-On or Reset
SAFE	Safe Operating Mode, output of SRDOs is only possible in this mode
CONFIG	Config Mode, used for modifying the sensor configuration (EEPROM)
SAFE_FAIL	An error has been detected, that prevents safe values from being provided (e. g. hardware failure).

Table 36: CANopen Operating Modes

The availability of certain functions of the NBN45-G/S3 depends on the current mode. The following sections contains details related to these modes and the transitions between them.

11.2.1 INIT

In INIT mode the sensor initializes all its internal data structures and the hardware. The system is not operating within its specification. The safety functions are deactivated and the safe state is active. This mode is active only for a short amount of time. It is left automatically, if all initialization jobs are finished. After leaving INIT, one of three modes is entered, depending on several conditions:

SAFE_FAIL mode is entered if one of the following errors occured:

- configuration could not be read from EEPROM
- hardware error occured (failure of one of the electronic components detected)

SAFE mode is entered, if there was no error during initialization and if the configuration allows the SAFE operating mode of the NBN45-G/S3. For SAFE operating mode to be allowed all of the following conditions must be true:

- CANopen Safety protocol is selected for communication
- sensor fusion is deactivated

If one of these conditions is not true, the CONFIG mode is entered instead.

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11.2.2 SAFE_FAIL

Mode SAFE_FAIL is entered only upon serious hardware problems, that prevent the safe function of the NBN45-G/S3 to be realized. These include:

- configuration could not be read from EEPROM
- hardware error occured (failure of one of the electronic components detected)

Communication with the sensor is still possible. The system is not operating within its specification. The safety functions are deactivated and the safe state is active.

Mode SAFE_FAIL can only be left by reset. If the problem still persists, the SAFE_FAIL will be re-entered immediately after reset.

11.2.3 SAFE

If the sensor is configured properly, it enters SAFE mode automatically after reset. The safety functions are active and diagnostics are performed. In the event of an error, the safe state is entered. Only in SAFE mode safe sensor data can be output via SRDOs. In SAFE mode there is no write access to configuration data in non-volatile memory. Although changes can be made to the parameters, these only become active after saving and a restart.

The SAFE mode can be left intentionally to INIT mode via a restart or to CONFIG mode via request.

11.2.4 CONFIG

The main purpose of CONFIG mode is to be able to write non-volatile memories (EEPROM), which is not possible in SAFE mode. CONFIG mode is entered automatically after reset, if the current sensor configuration does not allow entering of the SAFE mode. It can also be activated upon user request by writing object 3200h of the object dictionary (see chapter 13.3.2 for details).

Although it is not possible to output SRDOs in that mode, the NMT state can still be set to OPERATIONAL and output of PDOs is possible. Besides the safe functions all other functionality is available in CONFIG mode, e. g. angles are calculated and can be output via SDO or PDO.

CONFIG mode can only be left by resetting the NBN45-G/S3.

11.3 Object Dictionary

The object dictionary is a list of accessible functions and parameters of a device. It is the interface between application program and device. Each line in the list of the dictionary represents a communication object, which is accessible by a specific 16-bit index and an 8-bit sub-index.

The object dictionary is divided into 3 segments:

- Communication Segment – objects for communication and data transmission defined by CiA 301 and EN 50325-5 standard
- Manufacturer Segment – device specific objects defined by the manufacturer
- Device Profile Segment – device specific objects defined by the supported device profile CiA 410

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11.3.1 Communication Segment 1000_h – $1FFF_h$

The following table describes all communication objects within region 1000h to 1FFFh.

Index	Sub Index[1)]	Parameter	Description	Access[2)]	Default Value	Store[5)]
1000_h	00_h	Device Type	Information about the profile number, inclinometer class, PDO and SRDO mapping usage.	ro	depends on actual sensor type	n
1001_h	00_h	Error Register	This object provide error information. The device profile specific bit in the error register indicates the occurrence of misconfigured sensor or temperature error.	ro	0	n
1003_h	Pre-defined error field		This object provides an error history for the last 10 errors that occurred on the CANopen device.	-		n
	00_h	Number of errors	This object provides the number of errors that occurred recently on the CANopen device. Writing 00h deletes the entire error history (empties the array).	rw	0	n
	01_h ... $0A_h$	Standard error field 1 ... Standard error field 10	This object provides the errors that occurred on the CANopen device and were signaled via the emergency object.	ro	-	n
1005_h	00_h	COB-ID SYNC	COB-ID of the synchronization object (SYNC). The value 80h cannot be changed.	co	00000080h	n
1008_h	00_h	Manufacturer Device Name	Name of the device.	ro	Inclinometer NBN45 Safety	n
1009_h	00_h	Manufacturer Hardware-Version	Manufacturer hardware version.	ro	variable[3)]	n
$100A_h$	00_h	Manufacturer Software-Version	Manufacturer software version.	ro	variable[3)]	n
1010_h	-	Store Parameters	This object controls the saving of parameters in non-volatile memory. See chapter 11.5 for more information.	rw	-	n
1011_h	-	Restore default Parameters	With this object the default values of parameters according to the communication profile, device profile, and application profile are restored. See chapter 11.5 for more information.	rw	-	n
1014_h	00_h	COB-ID EMCY	COB-ID for the EMCY write service	ro	Node-ID + 80_h	n

DESCRIPTION CANOPEN - INTERFACE

Index	Sub Index[1)]	Parameter	Description	Access[2)]	Default Value	Store[5)]
1017_h	00_h	Producer Heartbeat Time	Cycle time of the heartbeat in milliseconds. The value 0 disables the producer heartbeat, all other values, up to FFFFh, are valid.	rw	0000_h	y
1018_h	-	Identity Object	This object provides general identification information of the CANopen device. This is used for LSS.	ro	variable[3)]	
1301_h	SRDO1	CommPar	Communication parameters for SRDO 1			
	00_h	Nr Of Entries	Highest sub-index supported. The value is always 6.	ro	6	n
	01_h	Information Direction	Indicates if the SRDO is produced or consumed or if it is not valid. This can only be 0 (SRDO invalid or disabled) or 1 (SRDO is produced).	rw	01_h	y
	02_h	Refresh Time	SRDO refresh-time in milliseconds. This is the period, by which the SRDO is transmitted.	rw	14_h	y
	03_h	reserved	Since SRDO is valid for transmit only, this value is reserved (not used) and always 5.	ro	05_h	n
	04_h	Transmission Type	This is always 254.	ro	FE_h	n
	05_h	COB-ID 1	CAN-ID, that shall be used by the SRDO for the plain SR data (first CAN data frame). This CAN-ID shall be an odd number.	rw	00000101_h	y
	06_h	COB-ID 2	CAN-ID, that shall be used by the SRDO for the bitweise inverted SR data (second CAN data frame). This CAN-ID shall be an even number.	rw	00000102_h	y

DESCRIPTION CANOPEN - INTERFACE

Index	Sub Index[1)]	Parameter	Description	Access[2)]	Default Value	Store[5)]
1302_h	SRDO2 CommPar		Communication parameters for SRDO 2	-		
	00_h ,02_h … 04_h		These objects behave identical to those of index 1301h. See there for details.			
	01_h	Information Direction	Indicates if the SRDO is produced or consumed or if it is not valid. This can only be 0 (SRDO invalid or disabled) or 1 (SRDO is produced).	rw	00_h	n
	05_h	COB-ID 1	CAN-ID, that shall be used by the SRDO for the plain SR data (first CAN data	rw	80000000_h	y
	06_h	COB-ID 2	CAN-ID, that shall be used by the SRDO for the bitweise inverted SR data (second CAN data frame). This CAN-ID shall be an even number.	rw	80000000_h	y
1303_h	SRDO3 CommPar		Communication parameters for SRDO 3. See object 1302h for details.			
1304_h	SRDO4 CommPar		Communication parameters for SRDO 4. See object 1302h for details.			
1381_h	SRDO1 Mapping		Mapping for SRDO1			
	00_h	Nr Of Mapped Objects	The number of valid object entries within the mapping record. The number of valid object entries shall be the number of the safety relevant objects that shall be transmitted with the corresponding SRDO. The value is always 6.	co	6	n
	00_h … 06_h	Mapping Entry 1 ... Mapping Entry 6	Sub-index from 01h to 06h contains the information of the mapped safety relevant objects. The values are set according to the CiA and EN 50325-5 standard.	co	62100110_h 62110110_h 62200110_h 62210110_h 40000508_h 40000608_h	n

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Index	Sub Index[1)]	Parameter	Description	Access[2)]	Default Value	Store[5)]
1382_h	SRDO2 Mapping		Mapping for SRDO2			
	00_h	Nr Of Mapped Objects	The number of valid object entries within the mapping record. The number of valid object entries shall be the number of the safety relevant objects that shall be transmitted with the corresponding SRDO. The value is always 6.	co	6	
	00_h … 06_h	Mapping Entry 1 ... Mapping Entry 6	Sub-index from 01_h to 06_h contains the information of the mapped safety relevant objects. The values are set according to the CiA and EN 50325-5 standard.	co	40400110_h 40400210_h 40410110_h 40410210_h 40000708_h 40000808_h	n
1383_h	SRDO3 Mapping		Mapping for SRDO3			
	00_h	Nr Of Mapped Objects	The number of valid object entries within the mapping record. The number of valid object entries shall be the number of the safety relevant objects that shall be transmitted with the corresponding SRDO. The value is always 8.	co	8	n
	00_h … 08_h	Mapping Entry 1 ... Mapping Entry 8	Sub-index from 01_h to 08_h contains the information of the mapped safety relevant objects. The values are set according to the CiA and EN 50325-5 standard.	co	40100110_h 40100210_h 40110110_h 40110210_h 40120110_h 40120210_h 40000108_h 40000208_h	n
1384_h	SRDO4 Mapping		This object contains the mapping for SRDO4.	-		
	00_h	Nr Of Mapped Objects	The number of valid object entries within the mapping record. The number of valid object entries shall be the number of the safety relevant objects that shall be transmitted with the corresponding SRDO. The value is always 8.	co	8	
	00_h … 08_h	Mapping Entry 1 ... Mapping Entry 8	Sub-index from 01_h to 08_h contains the information of the mapped safety relevant objects. The values are set according to the CiA and EN 50325-5 standard.	co	40200110h 40200210h 40210110h 40210210h 40220110h 40220210h 40000308h 40000408h	

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Index	Sub Index[1)]	Parameter	Description	Access[2)]	Default Value	Store[5)]
$13FE_h$	00_h	Safety Configuration valid	This object indicates if the current configuration of the SRD is valid.	rw	00_h	n
$13FF_h$	Safety configuration signatures		This object is used to secure and verify the configuration of the SRDOs. To each SRDO a safety configuration signature is applied.	-		
	00_h	Number of signatures	For each configurable SRDO a signature shall be set. The value is always 4.	ro	4	n
	01_h	SRDO1 signature	SRDO1 signature according to EN 50325-5	rw	2952_h	y
	02_h	SRDO2 signature	SRDO2 signature according to EN 50325-5	rw	0253_h	y
	03_h	SRDO3 signature	SRDO3 signature according to EN 50325-5	rw	$F1B0_h$	y
	04_h	SRDO4 signature	SRDO4 signature according to EN 50325-5	rw	$38C3_h$	y
1800_h	TPDO1 CommPar		Communication parameters for the TPDO 1. See chapter 11.4.1 for more information.	-		
	00_h	Nr Of Entries	Highest sub-index supported. The value is always 5.	co	5	y
	01_h	COB-ID	COB-ID used by TPDO. The value results from NODE-ID+40000180h.	rw	40000181_h	y[4)]
	02_h	Transmission Type	Transmission Type according to CiA standard.	rw	FE_h	y
	03_h	Inhibit Time	The time is the minimum interval for PDO transmission if the transmission type is set to Fe_h and FF_h. The value can be set according to the CiA standard.	rw	0	y
	05_h	Event Timer	The time is the maximum interval for PDO transmission if the transmission type is set to FE_h and FF_h. The value is defined as multiple of 1ms. The value of 0 shall disable the event-timer.	rw	0	y

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Index	Sub Index[1)]	Parameter	Description	Access[2)]	Default Value	Store[5)]
1801_h	TPDO2 CommPar		Communication parameters for the TPDO2. It has the same objects as 1800_h, only Subindex 01_h has another value, see below.			
	01_h	COB-ID	COB-ID used by TPDO. The value results from NODE-ID+40000280h.	rw	80000281_h	y[4)]
1802_h	TPDO3 CommPar		Communication parameters for the TPDO 4. It has the same objects as 1800_h, only Subindex 01_h has another value, see below.			
	01_h	COB-ID	COB-ID used by TPDO. The value results from NODE-ID+40000380h.	rw	80000381_h	y[4)]
1803_h	TPDO4 CommPar		Communication parameters for the TPDO 4. It has the same objects as 1800h, only Subindex 01h has another value, see below.			
	01_h	COB-ID	COB-ID used by TPDO. The value results from NODE-ID+40000480h.	rw	80000481_h	y[4)]
$1A00_h$	TPDO1 Mapping		Mapping for TPDO1. See chapter 13.4.2 for more information.			
	00_h	Nr Of Mapped Objects	The number of valid object entries within the mapping record. The number of valid object entries shall be the number of the application objects that shall be transmitted with the corresponding TPDO.	rw	3	y
	00_h … 08_h	Mapping Entry 1 ... Mapping Entry 8	Sub-index from 01_h to 08_h contains the information of the mapped application objects. The value has to be set according to the CiA standard.	rw	60100010_h 60200010_h 30000508_h	y
$1A01_h$		TPDO2 Mapping	Mapping for TPDO2. It has the same objects as $1A00_h$, but contains per default no entries (sub-index 00h is 0).			
$1A02_h$		TPDO3 Mapping	Mapping for TPDO3. It has the same objects as $1A00_h$, but contains per default no entries (sub-index 00h is 0).			
$1A03_h$		TPDO4 Mapping	Mapping for TPDO4. It has the same objects as $1A00_h$, but contains per default no entries (sub-index 00h is 0).			

Table 37: List of communication objects within region 1000h to 1FFFh

1) If no subindex is given then all objects with the Index are described.

2) ro (read-only) indicates, that the parameter can only be read
rw (read-write) indicates, that the parameter can be read and written
co (const) indciates, that the parameter is constant and can only be read

3) Value is variable. Actual value reflects the current state of the specific device.

4) Only the VALID flag (bit 31) will be stored.

5) Indicates, whether this value is stored to and restored from non-volatile memory

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11.3.2 Manufacturer Segment 2000h – 5FFFh

The following table describe all manufacturer objects within the region 2000h to 5FFFh.

Index	Sub Index	Parameter	Description	Access[1)]	Default Value	Store[3)]
2000_h	Logistic Data		Communication parameters for the TPDO 2. It has the same objects as 1800_h, only Subindex 01_h has another value, see below.	ro		
	01_h	Serial Number	Serial number in the form of DDDDDDDDDDDD (12 digits) where 'D' represents a number [0, 9]	ro	variable[2)]	n
	02_h	Article Number	Article number of the unit.	ro	variable[2)]	n
	03_h	DeviceID	Device ID of the device.	ro	variable[2)]	n
2001_h	00_h	Bit Rate	The bit rate of the communication can be set here (in bits per second). The node bit rate is stored on writing it. There is no need to save the values by the use of Index 1010_h.	rw	2500000	y
2002_h	00_h	Node-ID	The CANopen Node-ID of the device can be set here. The value can be set according to the CiA standard. The value must be saved by the use of Index 1010_h in order to become active after a restart.	rw	1	y
2010_h	01_h	Controller Settings - Set Controller	Request controller specific reset command. The object corresponds to the command RESET as described in chapter 9.3.4. The NBN45-G/S3 initiates a Reset, if any value is written to this object.	wo	-	n
$20FF_h$	00_h	Version of Layout	The layout version of the current used manufacturer standard SDOs.	ro	1	n

DESCRIPTION CANOPEN - INTERFACE

Index	Sub Index	Parameter	Description	Access[1)]	Default Value	Store[3)]
3000_h	Status		Current status information of the sensor.	-		
	01_h	Status Byte ST0	The object corresponds to the lower 8 bits of the STATUS flags as described in Table 3: Description of the STATUS-Flags. The data object can be mapped to a TPDO.	ro	-	n
	02_h	Status Byte ST1	The object corresponds to the upper 8 bits of the STATUS flags as described in Table 3: Description of the STATUS-Flags. The data object can be mapped to a TPDO.	ro	-	n
	03_h	Acceleration Status	Acceleration STATUS byte as described in Table 5: Structure of the Acceleration STATUS byte. The data object can be mapped to a TPDO.	ro	-	n
	04_h	Gyro Status	Gyroscope STATUS byte as described in Table 6: Structure of the Gyroscope STATUS byte. The data object can be mapped to a TPDO.	ro	-	n
	05_h	Inclination Status	Inclination STATUS byte as described in Table 7: Structure of the Inclination STATUS byte. The data object can be mapped to a TPDO.	ro	-	n
	06_h	Euler Status	Euler STATUS byte as described in Table 8: Structure of the Euler STATUS byte. The data object can be mapped to a TPDO.	ro	-	n
	07_h	Rotation Status Z Axis	Z Axis Rotation Angle STATUS byte as described in Table 9: Structure of the Rotation Angle STATUS byte. The data object can be mapped to a TPDO.	ro	-	n
	08_h	Temperature Status	Temperature STATUS byte as described in Table 10: Structure of the Temperature STATUS byte. The data object can be mapped to a TPDO.	ro	-	n
	09_h	Rotation Status X Axis	X Axis Rotation Angle STATUS byte as described in Table 9: Structure of the Rotation Angle STATUS byte. The data object can be mapped to a TPDO.	ro	-	n

DESCRIPTION CANOPEN - INTERFACE

Index	Sub Index	Parameter	Description	Access[1)]	Default Value	Store[3)]
	$0A_h$	Rotation Status Y Axis	Y Axis Rotation Angle STATUS byte as described in Table 9: Structure of the Rotation Angle STATUS byte. The data object can be mapped to a TPDO.	ro	-	n
3001_h	Heating Status		Current heating status information of the sensor.	ro		n
	01_h	Target Temperature	The object corresponds to the fields TT0 and TT1 of parameter HT_STAT (see chapter 9.2.22). The data object can be mapped to a TPDO.		700	n
	02_h	Current Temperature	The object corresponds to the fields AT0 and AT1 of parameter HT_STAT (see chapter 9.2.22). The data object can be mapped to a TPDO.		variable[2)]	n
	02_h	Status	The object corresponds to field STATUS of parameter HT_ STAT (see chapter 9.2.22). The data object can be mapped to a TPDO.		0[2)]	n
3002_h	01_h	Operation Mode	Current operation mode. Following values are possible: 00h: INIT mode 01_h: SAFE mode 02_h: CONFIG mode 03_h: SAFE_FAIL mode The data object cannot be mapped to a TPDO	ro	variable[2)]	n
3010_h	02_h	Acceleration value X axis	Acceleration value of X axis. The resolution of the value is 0.25 mg. The data object can be mapped to a TPDO..	ro	-	n
3011_h	00_h	Acceleration value Y axis	Acceleration value of Y axis. The resolution of the value is 0.25 mg. The data object can be mapped to a TPDO.	ro	-	n
3012_h	00_h	Acceleration value Z axis	Acceleration value of Z axis. The resolution of the value is 0.25 mg. The data object can be mapped to a TPDO.	ro	-	n
3020_h	00_h	Gyro value X axis	Gyroscope value of X axis. The resolution depends on the set FSR (adjustable via 3120_h, 04_h) according to Table 14: Gyroscope measurement ranges. The data object can be mapped to a TPDO.	ro	-	n

DESCRIPTION CANOPEN - INTERFACE

Index	Sub Index	Parameter	Description	Access[1)]	Default Value	Store[3)]
3021_h	00_h	Gyro value Y axis	Gyroscope value of Y axis. The resolution depends on the set FSR (adjustable via 3120_h, 04_h) according to Table 14: Gyroscope measurement ranges. The data object can be mapped to a TPDO.	ro	-	n
3022_h	00_h	Gyro value Z axis	Gyroscope value of Z axis. The resolution depends on the set FSR (adjustable via 3120_h, 04_h) according to Table 14: Gyroscope measurement ranges. The data object can be mapped to a TPDO.	ro	-	n
3030_h	00_h	Inclination value X axis[5)]	Inclination value of X axis. The resolution of the value is 0.01°. The data object can be mapped to a TPDO.	ro	-	n
3031_h	00_h	Inclination value Y axis[5)]	Inclination value of Y axis. The resolution of the value is 0.01°. The data object can be mapped to a TPDO.	ro	-	n
3032_h	00_h	KF Inclination value X axis	Inclination value of X axis calculated by Kalman filter. The resolution of the value is 0.01°. The data object can be mapped to a TPDO.	ro	-	n
3033_h	00_h	KF Inclination value Y axis	Inclination value of Y axis calculated by Kalman filter. The resolution of the value is 0.01°. The data object can be mapped to a TPDO.	ro	-	n
3040_h	00_h	Roll Euler angle value[5)]	Roll Euler angle value. The resolution of the value is 0.01°. The data object can be mapped to a TPDO.	ro	-	n
3041_h	00_h	Pitch Euler angle value[5)]	Pitch Euler angle value. The resolution of the value is 0.01°. The data object can be mapped to a TPDO.	ro	-	n
3042_h	00_h	KF Roll Euler angle value	Roll Euler angle value calculated by Kalman filter. The resolution of the value is 0.01°. The data object can be mapped to a TPDO.	ro	-	n
3043_h	00_h	KF Pitch Euler angle value	Pitch Euler angle value calculated by Kalman filter. The resolution of the value is 0.01°. The data object can be mapped to a TPDO.	ro	-	n
3050_h	00_h	Rotation value X axis[5)]	Rotation value of X axis. The resolution of the value is 0.01°. The data object can be mapped to a TPDO.	ro	-	n

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Index	Sub Index	Parameter	Description	Access[1)]	Default Value	Store[3)]
3051_h	00_h	Rotation value Y axis[5)]	Rotation value of Y axis. The resolution of the value is 0.01°. The data object can be mapped to a TPDO.	ro		
3052_h	00_h	Rotation value Z axis[5)]	Rotation value of Z axis. The resolution of the value is 0.01°. The data object can be mapped to a TPDO.	ro	-	n
3053_h	00_h	KF Rotation value X axis	Rotation value of X axis calculated by Kalman filter. The resolution of the value is 0.01°. The data object can be mapped to a TPDO.	ro	-	n
3054_h	00_h	KF Rotation value Y axis	Rotation value of Y axis calculated by Kalman filter. The resolution of the value is 0.01°. The data object can be mapped to a TPDO.	ro	-	n
3055_h	00_h	KF Rotation value Z axis	Rotation value of Z axis calculated by Kalman filter. The resolution of the value is 0.01°. The data object can be mapped to a TPDO.	ro	-	n
3060_h	00_h	Temperature value	Temperature value. The resolution of the value is 0.1 °C. The data object can be mapped to a TPDO.	ro	-	n
3100_h	CAN Settings		Set up parameter for the CAN communication.	-	-	
	01_h	CAN Protocol	he object corresponds to the field CP of parameter CAN_ PROT (see chapter 9.2.10). The value must be saved by the use of Index 1010_h in order to become active after a restart.	rw	3[2)]	y[4)]
	02_h	Automatic Bus Off Recovery	The object corresponds to the field ABOR of parameter CAN_ ABOR (see chapter 9.2.9). The value must be saved by the use of Index $1010h$ in order to become active after a restart.	rw	1	y[4)]
3110_h	Filter Configuration			-		
	01_h	Low Pass Filter Type	The object corresponds to the field FT of parameter FLT_ACC (see chapter 9.2.14).	rw	2	y
	02_h	Sensorfusion Filter	The object corresponds to field EN parameter KF_EN (see chapter 9.2.16).	rw	0	y
3111_h	00_h	Low Pass Filter Frequency	The object corresponds to fields FC0 / FC1 of parameter FLT_ACC (see chapter 9.2.14).	rw	2000	y

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Index	Sub Index	Parameter	Description	Access[1)]	Default Value	Store[3)]
3112_h	Kalman Filter Parameters		Settings for the Kalman filter.	-		
	01_h	Param Q Mantissa	The object corresponds to the field QM of parameter FLT_KF (see chapter 9.2.15).	rw	1	y
	02_h	Param Q Exponent	The object corresponds to the field QE of parameter FLT_KF (see chapter 9.2.15).	rw	-3	y
	03_h	Param R Mantissa	The object corresponds to field RM of parameter FLT_KF (see chapter 9.2.15).	rw	1	y
	04_h	Param R Exponent	The object corresponds to field RE of parameter FLT_KF (see chapter 9.2.15).	rw	1	y
	05_h	Prefilter Enable	The object corresponds to parameter KFPF_EN (see chapter 9.2.21)	rw	1	y
	06_h	Prefilter FC Accel	The object corresponds to parameter KFPF_FCA (see chapter 9.2.22)	rw	12	y
	07_h	Prefilter FC Gyro	The object corresponds to parameter KFPF_FCG (see chapter 9.2.23)	rw	12	y
3120_h	Sensor Configuration		Gen. sensor config. parameters	-		
	01_h	Sensor Configuration - Inclinometer Class	The inclinometer class defines the value region resp. device class of the sensor according to the CiA Profile 410. Depending on the set inclinometer class followig measuring axes (see chapter Definition of measuring axes) will be used: IC1: axis Z in rotation angle axis with measuring range 360° IC2: axes X, Y in inclination angle axes with measuring range ±90° Value 0 represents IC1 and value 1 represents IC2. All other values are invalid and rejected upon attempting to write. The value must be saved by the use of Index 1010h in order to become active after a restart.	rw	1	y[4)]
	02_h	Sensor Configuration - Enable Heating	Enables or disables the heater (see chapter 8.4). A value of 0 disables, while a value of 1 enables it.	rw	0	y
	03_h	Sensor Configuration - Rotation Coordinate System	The object corresponds to field ROT of parameter CS_ROT (see chapter 9.2.20).	rw	0	y
	04_h	Sensor Configuration - Gyro Full-Scale Range	The object corresponds to parameter GFSR (see chapter 9.2.24).	rw	3	y

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Index	Sub Index	Parameter	Description	Access[1)]	Default Value	Store[3)]
3130_h	00_h	Inclination offset value X axis[5)]	The object corresponds to parameter ZERO_IX (see chapter 9.2.17).	rw	0	y
3131_h	00_h	Inclination offset value Y axis[5)]	The object corresponds to parameter ZERO_IY (see chapter 9.2.17).	rw	0	y
3132_h	00_h	Rotation offset value X axis[5)]	The object corresponds to parameter ZERO_RX (see chapter 9.2.18).	rw	0	y
3133_h	00_h	Rotation offset value Y axis[5)]	The object corresponds to parameter ZERO_RY (see chapter 9.2.18).	rw	0	y
3134_h	00_h	Rotation offset value Z axis[5)]	The object corresponds to parameter ZERO_RZ (see chapter 9.2.18).	rw	0	y
3135_h	00_h	KF Inclination offset value X axis	The object corresponds to parameter KF_ZERO_IX (see chapter 9.2.28).	rw	0	y
3136_h	00_h	KF Inclination offset value Y axis	The object corresponds to parameter KF_ZERO_IY (see chapter 9.2.28).	rw	0	y
3137_h	00_h	KF Rotation offset value X axis	The object corresponds to parameter KF_ZERO_RX (see chapter 9.2.29).	rw	0	y
3138_h	00_h	KF Rotation offset value Y axis	The object corresponds to parameter KF_ZERO_RY (see chapter 9.2.29).	rw	0	y
3139_h	00_h	KF Rotation offset value Z axis	The object corresponds to parameter KF_ZERO_RZ (see chapter 9.2.29).	rw	0	y
3200_h	Sensor Commands		Execute a specific command.	-		
	01_h	Sensor Commands - Request Config Mode	Request a change of the operation mode to config mode. Each value is valid.	wo	-	n
	02_h	Sensor Commands - Autozero	The object corresponds to command ZERO (see chapter 9.3.5). Values according to the command specification are valid.	wo	-	n
	03_h	Sensor Commands - Autorotation	The object corresponds to command CS_ROT (see chapter 9.3.6). Each written value is valid. The write operation will be rejected, if the sensor orientation cannot be determined reliably.	wo	-	n
4000_h		Safety Status	This object contains the plain and bitwise inverted variants of the measurement value status bytes. These objects are mapped into the SRDOs.	-		

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Index	Sub Index	Parameter	Description	Access[1)]	Default Value	Store[3)]
	01_h	Acceleration Status	Acceleration STATUS byte as described in Table 5: Structure of the Acceleration STATUS byte	ro	-	n
	02_h	Inverted Acceleration Status	Bitwise inverted version of the value in subindex 01_h	ro	-	n
	03_h	Gyro Status	Gyroscope STATUS byte as described in Table 6: Structure of the Gyroscope STATUS byte	ro	-	n
	04_h	Inverted Gyro Status	Bitwise inverted version of the value in subindex 03_h	ro	-	
	05_h	Inclination Status	Inclination STATUS byte as described in Table 7: Structure of the Inclination STATUS byte	ro	-	n
	06_h	Inverted Inclination Status	Bitwise inverted version of the value in subindex 05_h	ro		n
	07_h	Euler Status	Euler STATUS byte as described in Table 8: Structure of the Euler STATUS byte	ro		n
	08_h	Inverted Euler Status	Bitwise inverted version of the value in subindex 07_h	ro		n
4010_h		Safety Acceleration Value X axis	This object contains the plain and bitwise inverted variants of the X axis acceleration value. These objects are mapped into the SRDOs.	-		
	01_h	Safety Acceleration Value	Safety Acceleration value of X axis. The Resolution of the value is 0.25 mg.	ro	-	n
	02_h	Safety Inverted Acceleration Value	Bitwise inverted version of the value in subindex 01_h	ro	-	n
4011_h		Safety Acceleration Value Y axis	This object contains the plain and bitwise inverted variants of the Y axis acceleration value. These objects are mapped into the SRDOs.	-	-	
	01_h	Safety Acceleration Value	Safety Acceleration value of Y axis. The Resolution of the value is 0.25 mg.	ro	-	n
	02_h	Safety Inverted Acceleration Value	Bitwise inverted version of the value in subindex 01_h	ro	-	n

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Index	Sub Index	Parameter	Description	Access[1)]	Default Value	Store[3)]
4012_h		Safety Acceleration Value Z axis	This object contains the plain and bitwise inverted variants of the Z axis acceleration value. These objects are mapped into the SRDOs.	ro	-	n
	01_h	Safety Acceleration Value	Safety Acceleration value of Z axis. The Resolution of the value is 0.25 mg.	ro	-	n
	02_h	Safety Inverted Acceleration Value	Bitwise inverted version of the value in subindex 01_h	ro		n
4020_h		Safety Gyroscope Value X axis	This object contains the plain and bitwise inverted variants of the X axis gyroscope value. These objects are mapped into the SRDOs.	-		
	01_h	Safety Gyro Value	Safety Gyroscope value of X axis. The Resolution depends on the set FSR (adjustable via 3120_h, 04_h).	ro	-	n
	02_h	Safety Inverted Gyro Value	Bitwise inverted version of the value in subindex 01_h	ro	-	n
4021_h		Safety Gyroscope Value Y axis	This object contains the plain and bitwise inverted variants of the Y axis gyroscope value. These objects are mapped into the SRDOs.	-	-	
	01_h	Safety Gyro Value	Safety Gyroscope value of Y axis. The Resolution depends on the set FSR (adjustable via 3120_h, 04_h)	ro	-	n
	02_h	Safety Inverted Gyro Value	Bitwise inverted version of the value in subindex 01_h	ro	-	n
4022_h		Safety Gyroscope Value Z axis	This object contains the plain and bitwise inverted variants of the Z axis gyroscope value. These objects are mapped into the SRDOs.	-		
	01_h	Safety Gyro Value	Safety Gyroscope value of Z axis. The Resolution depends on the set FSR (adjustable via 3120_h, 04_h).	ro	-	n
	02_h	Safety Inverted Gyro Value	Bitwise inverted version of the value in subindex 01_h	ro	-	n

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Index	Sub Index	Parameter	Description	Access[1)]	Default Value	Store[3)]
4040_h		Safety Euler Roll Angle	This object contains the plain and bitwise inverted variants of the Euler Roll angle. These objects are mapped into the SRDOs.	-		n
	01_h	Safety Roll Angle	Safety Euler Roll angle. The Resolution of the value is 0.01°.	ro	-	n
	02_h	Safety Inverted Roll Angle	Bitwise inverted version of the value in subindex 01_h	ro	-	n
4041_h		Safety Euler Pitch Angle	This object contains the plain and bitwise inverted variants of the Euler Pitch angle. These objects are mapped into the SRDOs.	-		
	01_h	Safety Pitch Angle	Safety Euler Pitch angle. The Resolution of the value is 0.01°.	ro	-	n
	02_h	Safety Inverted Pitch Angle	Bitwise inverted version of the value in subindex 01_h	ro	-	n

Table 38: List of manufacturer objects within region 2000h to 5FFFh

1) ro (read-only) indicates, that the parameter can only be read
rw (read-write) indicates, that the parameter can be read and written
wo (write-only) indicates, that the parameter can only be written

2) Value is variable. Actual value reflects the current state of the specific device.

3) Indicates, whether this value is stored to and restored from non-volatile memory

4) Changes to this parameter only take effect when the settings are stored and the sensor is restarted.

5) The angle value output is influenced by the parameter KF_EN (0x10).

DESCRIPTION CANOPEN - INTERFACE

11.3.3 Device Profile Segment 6000h – 9FFFh

The following table describe all device profile objects within the region 6000h to 9FFFh.

Index	Sub Index[1)]	Parameter	Description	Access[2)]
6000_h	00_h	Resolution	This data object indicates the resolution of the objects such as Slope long16 (data object 6010h) and the Slope lateral16 (data object 6020h). The resolution is fixed at 0.01°, the value is always 10.	co
6010_h	00_h	Slope long16[3)]	This data object provides the signed 16-bit slope value of the longitudinal axis. The value is given in angular degree with the resolution given in object 6000_h. Depending on the set inclinometer class following values will correspond to the data object: IC1: Rotation value of Z axis transformed so that it will be fit into ±180°. IC2: Inclination value of X axis. This data object can be mapped to a TPDO.	ro
6011_h	00_h	Slope long16 operating parameter	This data object indicate the interpretation of the Slope long16 value. Scaling is always disabled (value is 0), the Slope long16 value is equal to the physical measured angle.	ro
6020_h	00_h	Slope lateral16[3)]	This data object provides the signed 16-bit slope value of the lateral axis. The value is given in angular degree with the resolution given in object 6000_h. Depending on the set inclinometer class following values will correspond to the data object: IC1: Value is always invalid and set to 0x7FFF and cannot be read. IC2: Inclination value of Y axis.This data object can be mapped to a TPDO.	ro
6021_h	00_h	Slope lateral16 operating parameter	This data object indicate the interpretation of the Slope lateral16 value. Scaling is always disabled (value is 0), the Slope lateral16 value is equal to the physical measured angle.	ro
6200_h		Safety Configuration Parameters	This data object provides the configuration for CANopen Safety-related transmission of the inclinometer parameters.	-
	01_h	Safety slope long16 preset value	The preset value for slope long16 is not used, the inclination offset value X axis object (3130h, inclinometer class 2) or rotation offset value Z axis (3134h, inclinometer class) is used instead. Writing to the object will be rejected. Value is set to 0 and cannot be changed.	rw

DESCRIPTION CANOPEN - INTERFACE

Index	Sub Index[1)]	Parameter	Description	Access[2)]
	02_h	Safety slope lateral16 preset value	The preset value for slope lateral16 is not used, the inclination offset value Y axis object (0x3130) is used instead. Writing to the object will be rejected. Depending on the set inclinometer class following values will correspond to the data object: IC1: Value is always invalid and set to 0x8000. IC2: Value is set to 0 and cannot be changed.	rw
	03_h	Safety slope long32 preset value	Inclinometer class 3 and 4 are not supported, so the value is always invalid and set to 0x8000000.	ro
	04_h	Safety slope lateral32 preset value	Inclinometer class 3 and 4 are not supported, so the value is always invalid and set to 0x8000000.	ro
6210_h	01_h	Safety slope lateral16 preset value	This data object provides the signed 16-bit safety slope longitudinal value which shall be transmitted using Safety-related CANopen communication service. The value is given in angular degree with the resolution given in object 6000h. Depending on the set inclinometer class following values will correspond to the data object: IC1: Rotation value of Z axis transformed so that it will be fit into ±180°. IC2: Inclination value of X axis. The data object is mapped to SRDO1.	ro
6211_h	01_h	Safety inverted slope long16 value	bitwise inverted variant of object 6210h, 01h	ro
6220_h	01_h	Safety slope lateral16 value	This data object provides the signed 16-bit safety slope lateral value which shall be transmitted using Safety-related CANopen communication service. The value is given in angular degree with the resolution given in object 6000h. Depending on the set inclinometer class following values will correspond to the data object: IC1: Value is always invalid and set to 0x7FFF IC2: Inclination value of Y axis. The data object is mapped to SRDO1.	ro
6221_h	01_h	Safety inverted slope lateral16 value	bitwise inverted variant of object 6220h, 01h	ro

Table 39: List of device profile objects within region 6000h to 9FFFh - continued on next page

1) If no subindex is given then all objects with the Index are described.

2) ro (read-only) indicates, that the parameter can be read only
rw (read-write) indicates, that the parameter can be read and written
co (const) indicates, that the parameter is constant and read only

3) The angle value output is influenced by the parameter KF_EN (0x10)

DESCRIPTION CANOPEN - INTERFACE

Index	Sub Index[1)]	Parameter	Description	Access[2)]
$63FE_h$	00_h	Safety Application Configuration Valid	This object is an acknowledgement flag for a valid safety application configuration. It is set automatically to invalid (value 00h), after performing the write access to any of the Safety-relevant application parameters. It has to be set to valid (value A5h), after the Safety configuration is completed and the Safety application configuration signature is validated. Otherwise the node cannot be set OPERATIONAL.	rw
$63FF_h$	01_h	Safety Configuration Signature	This object provides the configuration checksum for Safety application parameters as defined by CiA 410. The CRC is calculated over parts of the OD, that cannot be modified by the user (object 6200h). Thus this value does not have to be modified. It is always in a valid state.	rw
6511_h	00_h	Device temperature	This data object provides the temperature of the inclinometer. The resolution of the value is 1 °C. This data object can be mapped to a TPDO.	ro

11.4 Transmit-PDOs

The NBN45-G/S3 configured with CANopen interface has 4 Transmit-PDOs. Each of these is dynamically mappable and will be transmitted in one of the following operating modes:

- Cyclic transmission with predefined period, if TPDO transmission type is set to FEh or FFh.
- Synchronous transmission after receiving a SYNC message, if TPDO transmission type is set to a value between 01h to F0h.

11.4.1 PDO Transmission

The operating modes for the PDO transmission will be set with the standardized TPDO communication parameters at 1800h to 1803h. Within these TPDO communication parameters, the transmission type, inhibit time and event time can be adjusted. The TPDO can be enabled or disabled by setting the valid flag (bit 31) in the PDOs COB-ID. Only if the TPDO is disabled, the mapping of the PDOs data can be configured. The TPDO communication parameters of all 4 TPDOs can be stored to the persistent memory.

11.4.2 TPDO Mapping

The data for the PDO transmission will be set with the standardized TPDO mapping parameters at 1A00h to 1A03h. Within these TPDO mapping parameters, the mapped object and the size in number of bits of the object's data can be defined. Only the following mappable objects can be set in the parameters:

Index	Sub Index	Parameter	Max. number of bits	Entry Value
3000_h	01_h	Status: Status Byte ST0	8	0x30000108
	02_h	Status: Status Byte ST1	8	0x30000208
	03_h	Status: Acceleration Status	8	0x30000308
	04_h	Status: Gyro Status	8	0x30000408
	05_h	Status: Inclination Status	8	0x30000508
	06_h	Status: Euler Status	8	0x30000608

DESCRIPTION CANOPEN - INTERFACE

Index	Sub Index	Parameter	Max. number of bits	Entry Value
	07_h	Status: Rotation Status Z axis	8	0x30000708
	08_h	Status: Temperature Status	8	0x30000808
	09_h	Status: Rotation Status X axis	8	0x30000908
	$0A_h$	Status: Rotation Status Y axis	8	0x30000A08
3001_h	01_h	Heating Status: Target Temperature	16	0x30010110
	02_h	Heating Status: Current Temperature	16	0x30010210
	03_h	Heating Status: Status	8	0x30010308
3010_h	00_h	Acceleration value X axis	16	0x30100010
3011_h	00_h	Acceleration value Y axis	16	0x30100010
3012_h	00_h	Acceleration value Z axis	16	0x30120010
3020_h	01_h	Gyroscope value X axis	16	0x30200010
3021_h	00_h	Gyroscope value Y axis	16	0x30210010
3022_h	00_h	Gyroscope value Z axis	16	0x30220010
3030_h	00_h	Inclination value X axis	16	0x30300010
3031_h	00_h	Inclination value Y axis	16	0x30310010
3032_h	00_h	KF inclination value X axis	16	0x30320010
3033_h	00_h	KF inclination value Y axis	16	0x30330010
3040_h	00_h	Roll Euler angle value	16	0x30400010
3041_h	00_h	Pitch Euler angle value	16	0x30410010
3042_h	00_h	KF Roll Euler angle value	16	0x30420010
3043_h	00_h	KF Pitch Euler angle value	16	0x30430010
3050_h	00_h	Rotation value X axis	16	0x30500010
3051_h	00_h	Rotation value Y axis	16	0x30510010
3052_h	00_h	Rotation value Z axis	16	0x30520010
3053_h	00_h	KF Rotation value X axis	16	0x30530010
3054_h	00_h	KF Rotation value Y axis	16	0x30540010
3055_h	00_h	KF Rotation value Z axis	18	0x30550010
3060_h	00_h	Temperature value	16	0x30600010
6010_h	00_h	Slope long16	16	0x60100010
6020_h	00_h	Slope lateral16	16	0x60200010
6511_h	00_h	Device temperature	8	0x65110008

Before the mapping parameters can be set, the TPDO has to be disabled and the first entry (1A0nh, 00h - Nr of Mapped Objects) of the object has to be set to 0. After the mapping parameters were changed, the first entry (1A0nh, 00h - Nr of Mapped Objects) of the object has to be set to the number of mapped objects (maximal 8) and the TPDO has to be enabled. The TPDO mapping parameters of all 4 TPDOs can be stored to the persistent memory.

11.5 Store and Restore Parameters

11.5.1 Save User settings

By writing the value 65766173h (ASCII: “evas” ←→ “save”) to the object Save User settings (1010h,01h), the SAVE command (see chapter 9.3.3) will be executed. Using the SAVE command, the storable parameters are written to the area of the EEPROM provided for storing the user settings.

DESCRIPTION CANOPEN - INTERFACE

11.5.2 Load All User Parameters

By writing the value 64616F6Ch (ASCII: “daol” ←→ “load”) to the object Load All User Parameters (1011h,01h), the LOAD command (see chapter 9.3.2) will be executed. Using the LOAD command, all storeable objects will load from the EEPROM into the main memory (register) and from this into the object dictionary and overwrite all changes. All changes, with a few exceptions, are effective immediately.

11.5.3 Restore Communication Default Parameters

By writing the value 64616F6Ch (ASCII: “daol” ←→ “load”) to the object Restore Communication Default Parameters (1011h,02h), the storeable objects within the Communication Segment (Index from 1000h to 1FFFh) will load from the main memory (register) into the object dictionary and overwrite all changes within the segment. All changes are effective immediately.

11.5.4 Restore Application Default Parameters

By writing the value 64616F6Ch (ASCII: “daol” ←→ “load”) to the object Restore Application Default Parameters (1011h,03h), the storeable objects within the Manufacturer and Device Profile Segment (Index from 6000h to 9FFFh) will load from the main memory (register) into the object dictionary and overwrite all changes within the segments. All changes, with a few exceptions, are effective immediately.

11.5.5 Restore Manufacturer Default Parameters

By writing the value 64616F6Ch (ASCII: “daol” ←→ “load”) to the object Restore Manufacturer Default Parameters (1011h,04h), the LOAD command (see chapter 9.3.2) will be executed. The storeable objects within the Manufacturer Segment (Index from 2000h to 5FFFh) will load from the EEPROM into the main memory (register) and from this into the object dictionary and overwrite all changes within the segment. All changes, with a few exceptions, are effective immediately.

11.5.6 Restore Factory Settings

By writing the value 0x64616F6C (ASCII: “daol” ←→ “load”) to the object Restore Factory Settings (1011h,05h), the LOAD_FS command (see chapter 9.3.2) will be executed. Using the LOAD_FS command, the factory settings will load from the EEPROM into the main memory (register) and from this into the object dictionary and overwrite all changes. All changes, with a few exceptions, are effective immediately.

11.6 Working with the CANopen Interface

This chapter describes by examples, how to use the implemented CANopen objects for the configuration of the NBN45-G/S3. Typical steps are described, which might be done during the first commissioning of the NBN45-G/S3 in order to integrate it into a specific application.

For reading and writing the objects of the NBN45-G/S3, please use a suitable CANopen PC tool. Such a tool is able to work with the EDS file and provide a comfortable way to access the object dictionary. Furthermore, the tool should be able to send NMT requests to the sensor.

11.6.1 CAN Bit Rate Adjustment

No.	Sensor receives	Sensor transmits
1	Object 2001_h, 00_h write: 500000_d Bitrate: 500 kBit/s	SDO write successful
2	Object 2001_h, 00_h read	SDO read successful: 500000_d The value was accepted and would now be returned when reading the object, but is not yet effective.
3	Object 2010_h, 01_h write: 0_d read RESET Command	SDO write successful After reset no boot-up message will be received. In order for the boot-up message to be received, the CAN bus must be configured to the new bit rate after the RESET command has been sent.

DESCRIPTION CANOPEN - INTERFACE

11.6.2 Node ID Adjustment

No.	Sensor receives	Sensor transmits
1	Object 2002_h, 00_h write: 5_d Node ID=5	SDO write successful
2	Object 2002_h, 00_h read	SDO read successful: 5_d The value was accepted and would now be returned when reading the object, but is not yet effective.
3	Object 1010_h, 01_h write: 65766173_h Save the user settings	SDO write successful The value is stored in the persistent memory of the sensor, but is still not effective.
4	Object 2010_h, 01_h write: 1_d RESET Command	SDO write successful After reset the boot-up message will be sent with Node ID 5 within the CAN ID.

11.6.3 Read Angle Values

Inclinometer class 2 (2-axes sensor ±90°)

No.	Sensor receives	Sensor transmits
1	Object 6010_h, 00_h read	SDO read successful: 1344_d X = 1344 (=> +13,44°) The actual values will vary depending the current situation.
2	Object 6020_h, 00_h read	SDO read successful: -117_d Y = -117 (=> -1,17°) The actual values will vary depending the current situation.

Inclinometer class 1 (1-axis sensor 360°)

No.	Sensor receives	Sensor transmits
1	Object 6010_h, 00_h read	SDO read successful: 34346_d X = 34346 (=> 343,46°) The actual values will vary depending the current situation.

DESCRIPTION CANOPEN - INTERFACE

11.6.4 Store User Settings

No.	Sensor receives	Sensor transmits
1	Object 1010_h, 01_h write: 65766173_h Save the user settings	SDO write successful

11.6.5 Load Factory Settings

No.	Sensor receives	Sensor transmits
1	Object 1011_h, 05_h write: $64616F6C_h$ Load the factory settings	SDO write successful

11.6.6 Zero Point Adjustment

Inclinometer class 2 (2-axes sensor ±90°)

No.	Sensor receives	Sensor transmits
1	Object 3200_h, 02_h write: 01_h ZERO Command for the inclination X axis only	SDO write successful The set zero point value has been accepted and is effective, but has not yet been written to the persistent memory, so it would be overwritten with the value from the persistent memory after the next restart.
2	Read back for verification. Not necessary for function. Only for information what is happening in the sensor. Object 3130_h, 00_h read	SDO read successful: Zero point X = -11_d (=> -0,11°) Actual values vary depending on the current situation.
3	Object 1010_h, 01_h write: 65766173_h Save the user settings	SDO write successful Value is written to the persistent memory.

DESCRIPTION CANOPEN - INTERFACE

Inclinometer class 1 (1-axis sensor 360°)

No.	Sensor receives	Sensor transmits
1	Object 1010_h, 01_h write: 65766173_h Save the user settings	SDO write successful The set zero point value has been accepted and is effective, but has not yet been written to the persistent memory, so it would be overwritten with the value from the persistent memory after the next restart.
2	Read back for verification. Not necessary for function. Only for information what is happening in the sensor. Object 3134_h, 00_h read	SDO read successful: Zero point Z = 5733_d (=> 57,33°) Actual values vary depending on the current situation.
3	Object 1010_h, 01_h write: 65766173_h Save the user settings	SDO write successful Value is written to the persistent memory.

11.6.7 Filter Adjustment

No.	Sensor receives	Sensor transmits
1	Object 3110_h, 01_h write: 2_d Filter Type = 2 (critical damped)	SDO write successful The value has been accepted and is effective, but has not yet been written to the persistent memory, so it would be overwritten with the value from the persistent memory after the next restart.
2	Object 3110_h, 02_h write: 1000_d Filter Frequency = 1000 (=> 1000 mHz)	SDO write successful The value has been accepted and is effective, but has not yet been written to the persistent memory, so it would be overwritten with the value from the persistent memory after the next restart.

11.6.8 Set Heartbeat Time

No.	Sensor receives	Sensor transmits
1	Object 1017_h, 00_h write: 10000_d Time = 10000 (=> 10 s)	SDO write successful The value has been accepted and is effective, but has not yet been written to the persistent memory, so it would be overwritten with the value from the persistent memory after the next restart.
2		The sensor will transmit the heartbeat message cyclical with period 10 s.

DESCRIPTION CANOPEN - INTERFACE

11.6.9 Set Event Time for TPDO1

No.	Sensor receives	Sensor transmits
1	Object 1800_h, 05_h write: 100_d Time = 100 (=> 100ms)	SDO write successful The value has been accepted and is effective, but has not yet been written to the persistent memory, so it would be overwritten with the value from the persistent memory after the next restart.
2	NMT-Request: Start-Node	The TPDO1 will be sent in cycles of 100 ms – if default configuration is load, the inclination value object(s) (6010_h, 6020_h) will be transmitted Inclinometer class 2: 40_h 05_h $8B_h$ FF_h 00_h X = 0540h (dec. 1344 => +13,44°) Y = FF8Bh (dec. -117 => -1,17°) STATUS = 00_h Inclinometer class 1: $2A_h$ 86_h FF_h $7F_h$ 00_h X = $862A_h$ (dec. 34346 => 343,46°) Y = $7FFF_h$ (invalid value) STATUS = 00_h The actual values will vary depending the current situation.

DESCRIPTION CANOPEN - INTERFACE

11.6.10 Set Mapping for TPDO2

No.	Sensor receives	Sensor transmits
1	Object $1A01_h$, 01_h write: 30100010_d Map Entry 1 = 30100010h (Acceleration value X axis)	SDO write successful The value has been accepted but is not effective.
2	Object $1A01_h$, 02_h write: 30110010_h Map Entry 2 = 30110010_h (Acceleration value Y axis)	SDO write successful The value has been accepted but is not effective.
3	Object $1A01_h$, 03_h write: 30120010_h Map Entry 3 = 30120010 (Acceleration value Z axis)	SDO write successful The value has been accepted but is not effective.
4	Object $1A01_h$, 04_h write: 30000308_h Map Entry 4 = 0x30000308 (Acceleration Status)	SDO write successful The value has been accepted but is not effective.
5	Object $1A01_h$, 00_h write: 04 Nr. of Entries = 4 (objects to map)	SDO write successful The mapping for TPDO2 has been accepted and is effective, but has not yet been written to the persistent memory, so it would be overwritten with the value from the persistent memory after the next restart.
6	Object 1801_h, 01_h write: 40000281_h COB-ID = 40000281_h (TPDO2 is valid)	SDO write successful The value has been accepted and is effective, but has not yet been written to the persistent memory, so it would be overwritten with the value from the persistent memory after the next restart.

REVISION HISTORY

12. REVISION HISTORY

Version	Date	Change
NBN 17382 AE	07.07.2025	Creation of the manual
NBN 17382 BE	19.09.2025	SAE J1939-Interface added
NBN 17382 CE	09.10.2025	Corrections and updates

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