User manual

GEMAC Motus® IB

Version: 1.0

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IB6MZ360-C
IB6MZ360-J
IB6MZ360-O

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17.02.2021	1.0	first release

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Note:
To use the sensor and for proper understanding of this manual, general knowledge of the field bus system CAN-Bus, CANopen respectively SAE J1939 is required.

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1 Safety information

1.1 Incoming inspection

Unpack the device immediately after you received it and check the entire delivery for completeness. If transport damage is to be assumed, inform the delivery agent within 72 hours and keep the packaging for inspection. The device must only be transported in its original or equivalent packaging.

1.2 Intended use

The GEMAC Motus® IB is a device consisting of an electronic sensor and an integrated evaluation unit. The device is designed to determine accelerations and angular rates in large-scale fixed installations like photovoltaics or installations for solar heat or industrial automation as well as non-road mobile machinery or means of transport for persons or goods like agricultural and forestry machinery, utility vehicles or crane and hoisting technology.

GEMAC Chemnitz GmbH assumes no liability for losses or damages arising from the use of the product, either directly or indirectly. This applies in particular to use of the product that does not conform to this intended purpose and is not described in this document.

1.3 Incorrect use

The GEMAC Motus® IB is not a safety component according to the EC Machinery Directive (2006/42/EC). It must not be used in explosion hazardous areas. Any use that is not described in section 1.2 “Intended use” is prohibited. Any use of accessories that is not specifically approved by GEMAC Chemnitz GmbH is at your own risk.

1.4 Requirements for the qualification of personnel

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

- Has received specialist training, which is backed up by additional knowledge and experience according to operation and service of the sensor and the respective application.
- Knows the relevant technical terms and regulations.
- Can appraise the work assigned to them, recognize potential hazards, and take suitable safety precautions.

2 Overview

2.1 Characteristics

- 6 axial inertial measurement unit with accelerometer and gyroscope
- Easy to handle parametrization with GEMAC programming tools
  - Configurable filter for vibration suppression
- High sampling rate and bandwidth
- Comfortable CAN CANopen or SAE J1939 interface
  - Baud rates from 10 kBit/s to 1 MBit/s
  - Automatic baud rate detection
- Robust zinc die-cast housing
- Wide input voltage range (7,5 - 36 V)
- Low power consumption
- Suitable for industrial use:
  - Temperature range: -40 °C to +80 °C
  - Degree of protection: IP65/67 and IPK69K
- EMC-tested according to ECE R10

The sensor is factory calibrated in all six measuring axes to ensure high accuracy.

The compact and robust design makes the sensors a suitable inertial measurement unit in rough surroundings for different applications in industry and vehicle technology.

A simple configuration and putting into operation is possible by the digital interface.

2.2 Applications

- Agricultural and forestry machinery
- Construction machinery
- Crane and hoisting technology

3 Technical Data

General Parameters[1]	Acceleration Sensor		Angular Rate Sensor
Measurement range	±8 g		±250 °/s
Resolution	0.244 mg		0.00875 °/s
In run bias stability	-		typ. 2.5 °/h (z axis 5 °/h)
Angular random walk (ARW)	-		0.1 °/$\sqrt{h}$
Temperature coefficient (zero point)	typ. 0.2 mg/K		typ. 0.005 °/s/K
General Parameters			
Sampling rate	200 Hz		
Operating temperature	-40 °C to +80 °C		
Characteristics			
Interface	IB6MZ360-**C**	IB6MZ360-**O**	IB6MZ360-**J**
	CAN 2.0 A and B (11- and 29-Bit-ID) according to ISO 11898-2	CANopen according to CiA DS-301	SAE J1939
Data rates	10k, 20k, 50k, 100k, 125k, 250k, 500k, 800k Bit/s, 1 MBit/s automatic detection		125k, 250k Bit/s automatic detection
Functions	cyclical and synchronized outputs, parametrization, digital filter (critically damped (default) or Butterworth low pass, 8th order), configuration via digital interface		
Electrical Parameters			
Supply voltage	7.5 to 36 V DC		
Current consumption	approx. 12 mA @ 24 V		
Necessary overcurrent protective device	400 mA[2]		
Maximum output current	350 mA		
Mechanical Parameters			
Electrical connector	2 x sensor connector 5-pole M12 (male + female, loop through connection)		
Degree of protection	IP65/67 - IP6K9K[3]		
Dimensions / Weight	114 mm x 66 mm x 30 mm / approx. 330 g		
Reliability according EN ISO 13849-1[4]			
MTTF	587 years		
MTTFd	1074 years		
CE Conformity			
EC Directives			
RL 2014/30/EU	Harmonisation of the laws of the Member States relating to electromagnetic compatibility		
RL 2011/65/EU	Restriction of the use of certain hazardous substances in electrical and electronic equipment		
Harmonized standards			
DIN EN 61326-1:2013-07	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 1: General requirements		
DIN EN IEC 63000:2019-05	Technical documentation for the assessment of electrical and electronic products with respect to the restriction of hazardous substances		

Table 1: Technical Data

1 All indicated accuracies are valid after a running time of 10 minutes at 25 °C.
2 The electrical power supply has to be designed in a way, that a current of more than 400 mA can flow for maximum 3 s.
3 Only in connection with article no. 1404066 from Phoenix Contact GmbH and a tightening torque of 0.4 Nm.
4 This product is a standard product and no safety part in accordance with the machinery directive. The calculation is based on an average environment temperature of 40 °C and a usage of 8760 h/a.

Electromagnetic Compatibility (EMC)	
Transient Emissions	
Radiated disturbance / Radio field strength	Limit curves broadband and narrowband according to UN ECE R10 (Automotive) and DIN EN ISO 13766-1 (construction machinery) **30 ... 1000 MHz (vertical and horizontal)**
Immunity to Radio Frequency Fields (RF fields)	
Strip line according to ISO 11452-5	Limits superior to UN ECE R10 (Automotive) and DIN EN ISO 13766-1 (construction machinery) 20 ... 400 MHz **100 V/m** Performance criteria A
Anechoic chamber according to ISO 11452-2	Limits superior to UN ECE R10 (Automotive) and DIN EN ISO 13766-1 (construction machinery) **200 ... 1000 MHz, 30 V/m (vertical and horizontal)** **800 ... 2000 MHz, 30 V/m (vertical and horizontal)** Performance criteria A
Immunity to Conducted Disturbances (on-board power supply 24 VDC)	
Test pulse according to ISO 7637-2	Limits according to UN ECE R10 (Automotive) Test pulse / Severity level / Performance criteria 1 -450 V / III / C 2a +37 V / III / B 2b +20 V / III / C 3a -150 V / III / A 3b +150 V / III / A 4 -12 V / III / A Additional Tests 5a +70 V / Ri = 0.5 Ω / A 5b +36 V / Ri = 0.5 Ω / A
Immunity to Electromagnetic Discharge (ESD)	
ESD according to ISO 10605	Limits according to DIN EN ISO 13766-1 (construction machinery) discharge combination 330 pF / 2 kΩ **Contact discharge 6 kV bipolar (metallic parts)** **Air discharge 8 kV bipolar** Performance criteria A

Table 2: Electromagnetic Compatibility (EMC)

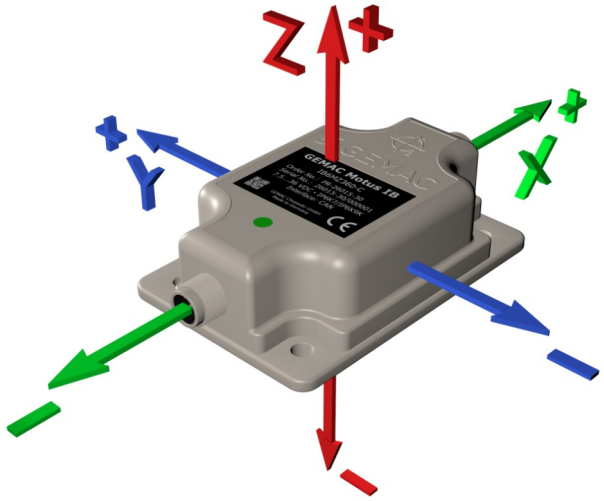


Figure 1: Orientation of the measuring axes for the acceleration

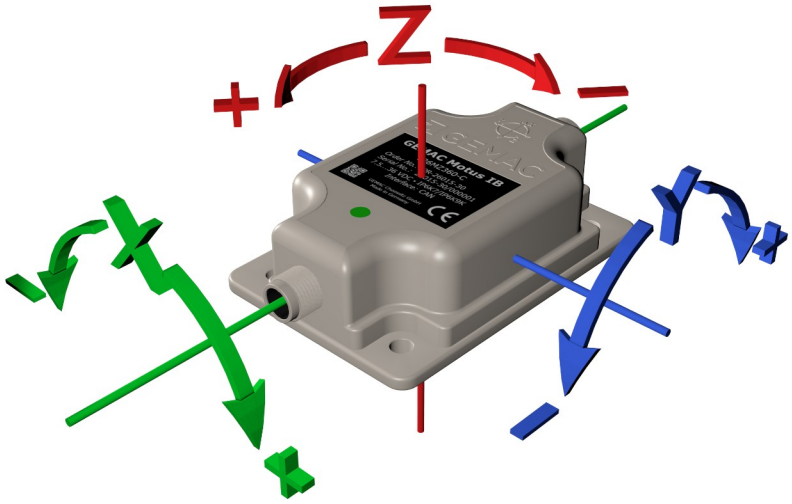


Figure 2: Orientation of the measuring axes for the angular rate

4 Mounting

4.1 Fixation

The Sensor has to be screwed in place by using 4 hexagon socket screws M5 according to DIN 912 A2 and 4 hexagon nuts M5 according to DIN 934 with a torque of 3 Nm in a manner, that one full thread of the screw is overlapping minimum.

4.2 Position of mounting holes

Holes to mount the sensor (Figure 3) are situated in the base plate of the sensor.

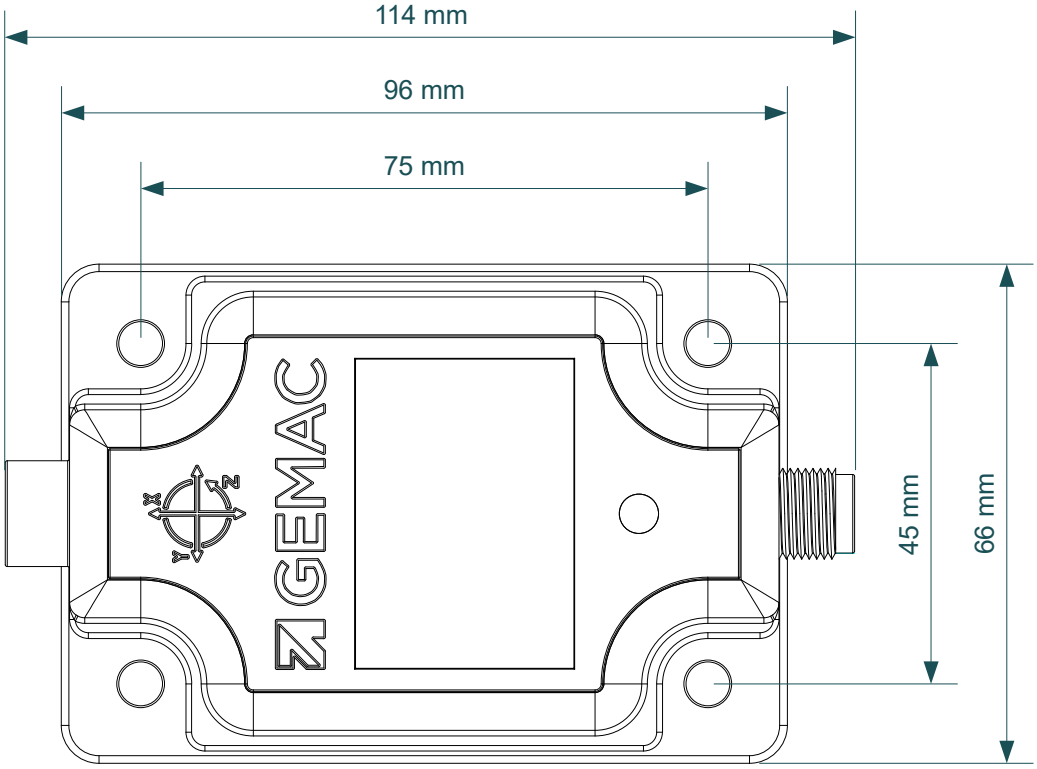


Figure 3: Mounting holes (dimensions in mm)

5 Connection

5.1 General connection information

The sensor is equipped with a 5-pole round male connector M12 (A-coded) according to IEC 61076-2-101. There is an additional 5-pole round female connector (A-coded) available. The voltage supply is forwarded from the male connector to the female connector. That allows to power further sensors with one cable harness. It is necessary to ensure that that current draw of all connected devices is less than 350 mA total.

5.2 Requirements to the voltage supply

The voltage supply has to be dimensioned in a manner that the voltage values given in Table 1 are not exceeded.

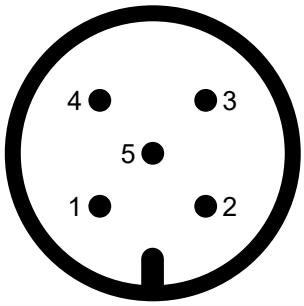
The power supply has to be protected with a suitable fuse, that guarantees that a current of more than **400 mA** can flow for **3 s maximum**.

5.3 Connector Pin Out

The pin allocation fulfills CiA DR-303-1 (Table 3 + Table 4).

Pin	Signal	Allocation
1	CAN_SHLD	Shield
2	V+	Supply voltage (+24 V)
3	V-	GND / 0 V / V-
4	CAN_H	CAN_H bus line
5	CAN_L	CAN_L bus line

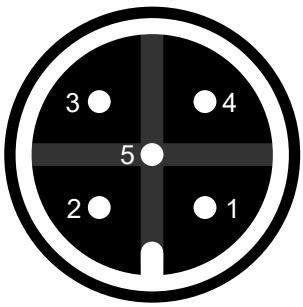
Table 3: M12 Plug Connector Pin Out CAN Bus



(View from the outside)

Pin	Signal	Allocation
1	CAN_SHLD	Shield
2	V+	Supply voltage (+24 V)
3	V-	GND / 0 V / V-
4	CAN_H	CAN_H bus line
5	CAN_L	CAN_L bus line

Table 4: M12 Female Connector Pin Out CAN Bus



(View from the outside)

5.4 Internal circuit

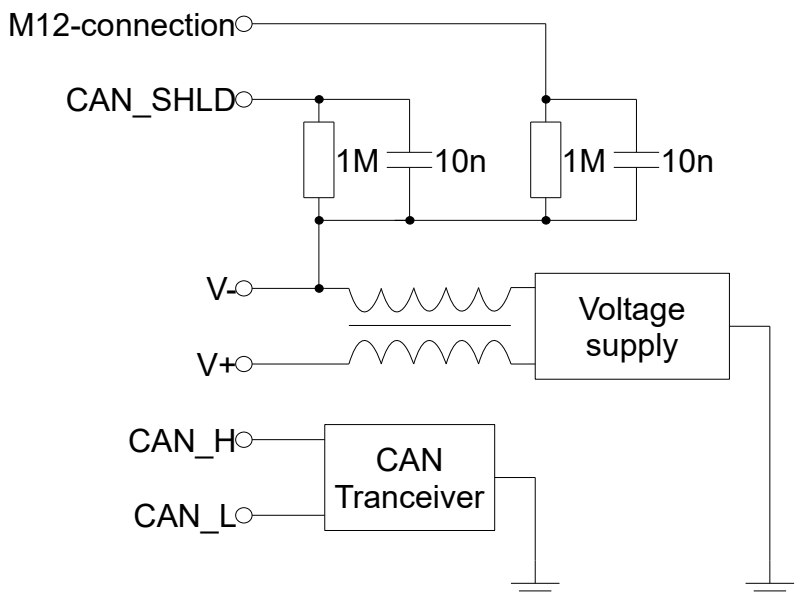


Figure 4: internal circuit

5.5 Bus-Termination Resistor

The sensor does **not** contain an internal termination resistor.

6 Functional description

6.1 Low pass filter

The sensor offers the possibility to filter the measured acceleration in order to separate oscillations and vibrations from the signal to be measured. Two low pass filters are available in the sensor, which can be selected according to the area of application of the sensor.

The programmable low pass filter (Butterworth or critically damped) of 8th order are good for suppressing vibrations up to 0.1 Hz.

Filter	Adjustable frequency range	Applications
Butterworth	0.1 Hz ... 25 Hz	Static acceleration measurement with high damping to vibration
Critically damped	0.1 Hz ... 8 Hz	Acceleration measurement in applications that requires a certain dynamism, without overshoot at acceleration changes with good damping

Table 5: Filter selection low pass filter

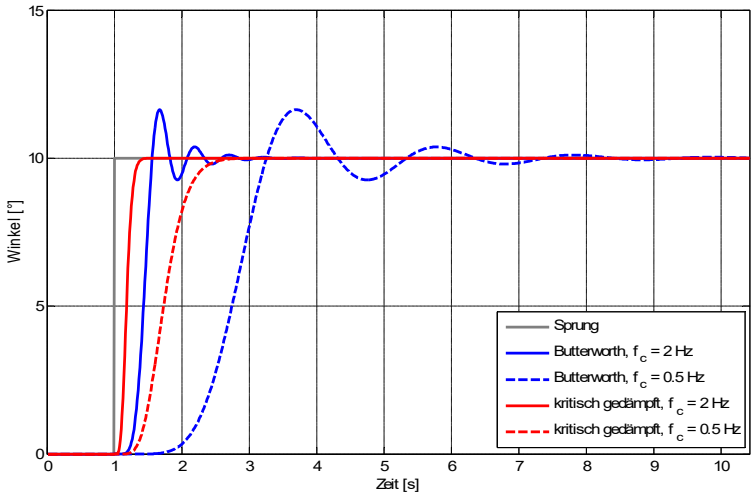


Figure 5: Impulse response of the two low pass filter

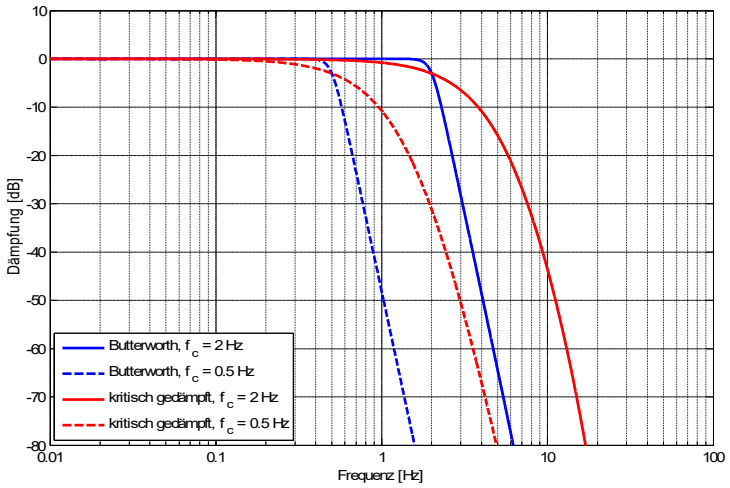


Figure 6: Amplitude response of the two low pass filter

7 Functional description of the CAN interface

7.1 Digital filter

The cut-off frequency is programmable by FSC = 27h (Set Parameter Frame). Values for CF (cut-off frequency) are allowed between 100 (= 0.1 Hz) and 25000/8000 (= 25 Hz/8 Hz). The filter type is selected with the parameter FT.

7.2 Status LED

The integrated two-color Status LED signals the current device state (Run LED, green) as well as CAN communication errors that might have occurred (Error LED, red). The color and the flashing frequency of the LED distinguish the different device states as shown in Table 6.

Status LED		
Run LED	**LED state**	**Description**
○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○...	Off	The device is in state Reset or no power supply is connected
✺ ✺ ✺ ✺ ✺ ✺ ✺ ✺ ✺ ✺ ✺ ✺...	Flickering	Automatic baud rate detection is currently running (active)
✺ ✺ ✺ ✺ ✺ ✺ ✺ ✺ ✺ ✺ ✺ ✺...	On	The device is in normal operating state
Error LED	**LED state**	**Description**
○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○...	Off	The device is in working condition
✹ ○ ○ ○ ○ ○ ✹ ○ ○ ○ ○ ○...	Single Flash	CAN Warning Limit reached
✹ ✹ ✹ ✹ ✹ ✹ ✹ ✹ ✹ ✹ ✹ ✹...	On	The device is in state Bus-Off

Legend: ○ LED off ✺ LED on ✺ LED flickering (50 ms on/off) Duration of one state (○/✺): 200 ms

Table 6: Status and Error Display through Status LED

7.3 Format of the CAN Frames

For reading and writing device parameters, and to output the data from the sensor, two CAN-IDs exists. One ID for receiving data/commands and another one to send the response/confirmation. These IDs are saved in an internal permanent memory (EEPROM) and can be configured freely. CAN 2.0 A (Standard Frame Format) as well as CAN 2.0 B (Extended Frame Format) are supported.

7.3.1 Data Part in the CAN Frame

The data part of all transmission and reception frames always contains a function select code (FSC) and additionally up to seven data bytes depending on the FSC. The length of the data part of the CAN frame is defined in the DLC field (Data Length Code). The general format of the data part is structured as follows:

Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7
FSC	D0/Status	D1	D2	D3	D4	D5	D6

Table 7: Format of the CAN Frames

FSC: **F**unction **S**elect **C**ode – Function code (detailed description in the sections about the operation modes). Each frame of the sensor always contains the FSC of the preceding request as confirmation.

D0-D7: Data bytes, depending on the function select code

Status: Status information which is included in each frame output by the sensor (see section 7.3.2 “Status Byte (STATUS)”).

Frames which are transmitted to the sensor may contain further data bytes beyond the needed ones – those will be discarded. Frames sent by the sensor only contain the data bytes defined by the function select code.

7.3.2 Status Byte (STATUS)

Each frame sent by the sensor contains the recent status of the device in Byte1 (see Table 7) of the CAN frame. The status byte is structured as follows:

Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
reserved	reserved	reserved	reserved	CmdParam Error	EEPROM Error	Autobaud Detection	Default Param

Table 8: Status Byte

DefaultParam: The standard device parameters are set. This bit is reset only when a device parameter was changed to a value different from the factory parameters. The sensors are supplied with the standard device parameters, so this bit is set by default (refer to section 7.6 “Default Device Parameters”).

AutobaudDetection: The baud rate is set to automatic detection (BR = 0) (refer to section 7.9.3 “Configuration of the Baud Rate”).

EEPROMError: While reading/writing on the EEPROM an error occurred, for example data loss. The correct function of the sensor is no longer guaranteed. This bit is reset by reading the status byte (Set Parameter Telegram with FSC = 02h).

CmdParamError: A received frame contained a command or parameter error (invalid FSC, too less data bytes, invalid values). This bit is also set if an error occurred in the execution of a function (for example writing/reading error on EEPROM). This bit is reset by reading the status byte (Set Parameter Frame with FSC = 02h).

AccuracyWarning: If the maximum values for acceleration or angular rate are exceeded, the accuracy of the sensor is limited. This bit resets automatically when the sensor operates under the specified conditions again.

7.4 Boot Up Message

After device reset (hardware or software reset) the sensor outputs a “boot up” message twice. With this the correct boot process is displayed and the Set-Parameter-ID is notified (CAN-ID on which the sensor can be parametrized). This frame contains the following information:

“Boot up“ message after device reset: Reply-Parameter-ID (default ID: 301h)

FSC	D0	D1	D2	D3	D4	D5	D6
FFh	Status	SID0	SID1	SID2	SID3	SWV0	SWV1

Table 9: “Boot Up” Message

SID0-3: Set-Parameter-ID (see section 7.5 “Read/Write device parameters”)

SWV0-1: Software version

Example: SWV0 = 0x44, SWV1 = 0x03 → Software version v3.44

7.5 Read/Write device parameters

All parameters like acceleration values, angular rate, CAN-IDs, Baud Rate, Cyclic Time etc. can be set and requested via the **Set Parameter Frames** (Request frame). The sensor confirms each frame with a **Reply Parameter Frame** which also contains the requested data according to FSC (Reply frame).

7.5.1 Set Parameter Frame

Table 10 shows all the supported function select codes and the parameters of a Set Parameter Frame.

FSC	D0	D1	D2	D3	D4	D5	D6	Description	
02h	-	-	-	-	-	-	-	Read status	
03h	-	-	-	-	-	-	-	Read product number and revision	
04h	-	-	-	-	-	-	-	Read serial number and software version	
0Ch	-	-	-	-	-	-	-	Read acceleration data	
0Dh	-	-	-	-	-	-	-	Read unfiltered acceleration data	
0Eh	-	-	-	-	-	-	-	Read the angular rate	
10h	-	-	-	-	-	-	-	Set-Parameter-ID	Read device parameters
11h	-	-	-	-	-	-	-	Reply-Parameter-ID	
12h	-	-	-	-	-	-	-	Sync-ID	
13h	-	-	-	-	-	-	-	Baud Rate	
14h	-	-	-	-	-	-	-	Automatic Bus-Off Recovery	
15h	-	-	-	-	-	-	-	Cyclic Time	
16h	-	-	-	-	-	-	-	Cyclic Mode	
17h	-	-	-	-	-	-	-	Cut-off Frequency Digital Filter, Filter selection	
20h	ID0	ID1	ID2	ID3	-	-	-	Set-Parameter-ID*	Write device parameters
21h	ID0	ID1	ID2	ID3	-	-	-	Reply-Parameter-ID*	
22h	ID0	ID1	ID2	ID3	-	-	-	Sync-ID*	
23h	BR	-	-	-	-	-	-	Baud Rate*	
24h	ABOR	-	-	-	-	-	-	Automatic Bus-Off Recovery	
25h	ZYZ0	ZYZ1	-	-	-	-	-	Cyclic Time	
26h	ZYM	-	-	-	-	-	-	Cyclic Mode	
27h	FG0	FG1	FT	-	-	-	-	Cut-off Frequency Digital Filter, Filter selection	
40h	'L'	'O'	'A'	'D'	-	-	-	Load default device parameters (factory defaults)	
50h	'S'	'A'	'V'	'E'	-	-	-	Write device parameters in EEPROM	
FFh	'R'	'E'	'S'	'E'	'T'	-	-	Software reset	
FFh	-	-	-	-	-	-	-	Read alive frame (“Boot Up” Message)	

Table 10: Supported FSC and Parameters of the Set Parameter Frames (Request)

* Changes to communication parameters such as ID and Baud Rate will take effect after reboot.

7.5.2 Reply Parameter Frames

As confirmation to the correctly received Set Parameter Frame each Reply Parameter Frame contains the identical FSC. The error bits of the status byte indicate insufficient or invalid parameters or errors that occurred while writing into the nonvolatile memory. (refer to section 7.3.2 “Status Byte (STATUS)”). The structure of the Reply Parameter Frames in dependence to the FSC is shown in Table 11.

FSC	D0	D1	D2	D3	D4	D5	D6	Description	
02h	Status	-	-	-	-	-	-	Read status	
03h	Status	PR0	PR1	PR2	PR3	RV0	RV1	Read product number and revision	
04h	Status	SN0	SN1	SN2	SN3	SWV0	SWV1	Read serial number and software version	
0Ch	Status	ACC_X		ACC_Y		ACC_Z		Read acceleration data	
0Dh	Status	ACC_UNF_X		ACC_UNF_Y		ACC_UNF_Z		Read unfiltered acceleration data	
0Eh	Status	AR_X		AR_Y		AR_Z		Read the angular rate	
10h	Status	ID0	ID1	ID2	ID3	-	-	Set-Parameter-ID	Read device parameters
11h	Status	ID0	ID1	ID2	ID3	-	-	Reply-Parameter-ID	
12h	Status	ID0	ID1	ID2	ID3	-	-	Sync-ID	
13h	Status	BR	-	-	-	-	-	Baud Rate	
14h	Status	ABOR	-	-	-	-	-	Automatic Bus-Off Recovery	
15h	Status	ZYZ0	ZYZ1	-	-	-	-	Cyclic Time	
16h	Status	ZYM	-	-	-	-	-	Cyclic Mode	
17h	Status	FG0	FG1	FT	-	-	-	Cut-off Frequency Digital Filter, Filter selection	
20h	Status	-	-	-	-	-	-	Set-Parameter-ID*	Write device parameters
21h	Status	-	-	-	-	-	-	Reply-Parameter-ID*	
22h	Status	-	-	-	-	-	-	Sync-ID*	
23h	Status	-	-	-	-	-	-	Baud Rate*	
24h	Status	-	-	-	-	-	-	Automatic Bus-Off Recovery	
25h	Status	-	-	-	-	-	-	Cyclic Time	
26h	Status	-	-	-	-	-	-	Cyclic Mode	
27h	Status	-	-	-	-	-	-	Cut-off Frequency Digital Filter, Filter selection	
40h	Status	-	-	-	-	-	-	Load default device parameters (factory defaults)	
50h	Status	-	-	-	-	-	-	Save device parameters in EEPROM	
FFh	Status	Set-Param ID	Set-Param ID	Set-Param ID	Set-Param ID	SWV0	SWV1	Alive frame (“Boot Up” Message) Software reset (2 messages with FSC = FFh)	

Table 11: Function Codes and Parameters of the Reply Parameter Frames

* Changes to communication parameters such as ID and Baud Rate will take effect after reboot.

7.6 Default Device Parameters

The sensor is delivered with the default device parameters shown in Table 12. These can be re-stored by a Set Parameter Frame with FSC = 40h (see section 7.5 “Read/Write device parameters”).

Parameter	Default Value	Description
Set-Parameter-ID	300h	CAN 2.0 A Standard Frame
Reply-Parameter-ID	301h	CAN 2.0 A Standard Frame
Sync-ID	100h	CAN 2.0 A Standard Frame
Baud Rate (BR)	0	Automatic Baud Rate Detection
Automatic Bus-Off Recovery	0	deactivated
Cyclic Time (CYT)	250	250 ms
Cyclic Mode (CYM)	0	deactivated
Cut-off Frequency (CF); filter type	5000; 2	5000 mHz = 5 Hz; critically damped filter

Table 12: Device parameters default settings

These default settings will also be set if invalid device parameters are read from the nonvolatile memory after device reset. If the default settings have been restored this is displayed by the status bit STATUS:DefaultParam =1.

7.7 Transfer of the measurement values

For the transfer of acceleration and angular rate the sensor supports following modes:

- Polling Mode
- Cyclic Mode

Both modes are active at any time and usable at the same time. Mode-switching is not necessary.

7.7.1 Polling Mode

The polling mode is always available. The measurement value(s) of the sensor can be requested via a **Set Parameter Frame**. The sensor replies to that frame via a **Reply Parameter Frame**. Both frames are structured as follows:

FSC	D0	D1	D2	D3	D4	D5	D6
00h	-	-	-	-	-	-	-

Table 13: Request frame: acceleration (FSC = 0Ch)

FSC	Status	D1	D2	D3	D4	D5	D6
00h	Status	AccX0	AccX1	AccY0	AccY1	AccZ0	AccZ1

Table 14: Reply frame: acceleration (FSC = 0Ch)

AccX/Y/Z0/1: acceleration values of the X/Y/Z-axis

Format: 16 bit signed value, complement on two (-32768 ... +32767)

Conversion: Value / 4096 = acceleration value in g

FSC	D0	D1	D2	D3	D4	D5	D6
0Eh	-	-	-	-	-	-	-

Table 15: Request frame: angular rate (FSC = 0Eh)

FSC	Status	D1	D2	D3	D4	D5	D6
0Eh	Status	ArX0	ArX1	ArY0	ArY1	ArZ0	ArZ1

Table 16: Reply frame: angular rate (FSC = 0Eh)

ArX/Y/Z0/1: angular rate of the X/Y/Z-axis

Format: 16 bit signed value, complement on two (-32768 ... +32767)

Conversion: Value * 7 / 800 = angular rate in °/s

7.7.2 Cyclic Mode

The sensor supports the cyclical transmission of the measurement values after the expiration of a defined time interval. This operation mode can be (de)activated separately and the needed time interval (Cyclic Time) can be parametrized freely. Corresponding to the operational principle shown in Figure 7 the sensor outputs the recent position value in periodical intervals (Cyclic Time) with a Reply Parameter Frame as in the polling mode with additional counter in the following data bytes (Table 14 and Table 16).

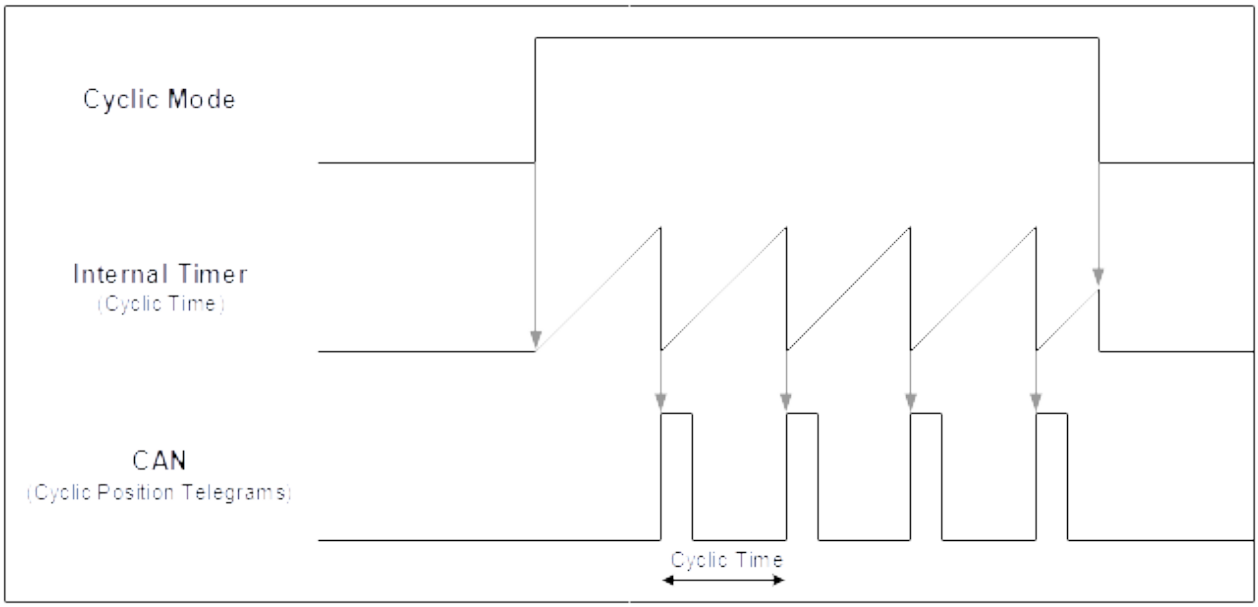


Figure 7: Operational Principle of the Cyclic Mode

7.8 Output values

7.8.1 Angular Rate output (Gyro sensor raw data)

With the set parameter telegram FSC 0Eh, the angular rates of all three axes of the gyro sensor queried.

Format: 16 bit signed value
Conversion: value * 7 / 800 = angular rate in °/s (measurement range ±250°/s)

7.8.2 Transfer of acceleration values

FSC 0Ch outputs the acceleration values of all three axes of the sensor. FSC 0Ch contains the filtered acceleration values, which calculated with the parameterizable low pass filter (FSC 27h). With FSC 0Dh, the acceleration data can be output unfiltered.

Format: 16bit signed value
Conversion: value / 4096 = acceleration in g (measurement range ±8g)

7.9 Configuration of the sensor

7.9.1 Configuration of Cyclic Mode

ZYZ0/1: Cyclic Time in ms
Format: 16 bit unsigned integer value (1 … 65535)

ZYM: (De)activate Cyclic Mode
= 0 → Cyclic Mode deactivated
= 1 → Cyclic Mode activated

The section 7.7.2 “Cyclic Mode” contains a detailed description of the usage of the Cyclic Mode.

7.9.2 Configuration of the CAN Identifier

ID0-3: CAN Identifier (ID), 11-Bit-ID (CAN 2.0 A) or 29-Bit-ID (CAN 2.0 B)
Format: 32 bit value with the following structure:

ID3								ID2								ID1								ID0							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
0	-																				11-Bit-ID (CAN 2.0 A)										
1	-							29-Bit-ID (CAN 2.0 B)																									

Table 17: CAN Identifier

Example: CAN-ID = 361h (29-Bit-ID, CAN 2.0 B)
ID0 = 61h, ID1 = 03h, ID2 = 00h, ID3 = 80h

If a CAN-ID is set newly, it must not be used by another frame type. If this occurs the error bit STATUS:CmdParamError is set in the Reply Parameter Frame and the CAN-ID is refused.

7.9.3 Configuration of the Baud Rate

BR: Code of a Baud Rate

Format: 8 bit unsigned integer value (0 … 10)

Code: 0: Automatic Baud Rate Detection

1: 10 kBit/s	2: 20 kBit/s	3: 50 kBit/s
4: 100 kBit/s	5: 125 kBit/s	6: 250 kBit/s
7: 500 kBit/s	8: 800 kBit/s	9: 1 Mbit/s

7.9.4 Configure Automatic Bus-Off Recovery

ABOR: Enable/Disable Automatic Bus-Off Recovery

= 0 Enable Automatic Bus-Off Recovery (Device remains in the state Bus-Off)

= 1 Disable Automatic Bus-Off Recovery (Device starts up again)

7.9.5 Configuration Cut-off frequency of the low pass filter

FG0/1: Cut-off Frequency in mHz when selecting the Butterworth or critically damped filter

Format: 16 bit unsigned integer value (100 … 25000/8000)

FT:

0	Digital Filter deactivated
1	Butterworth Filter activated
2	Critically Damped Filter activated

The section 6.1 “Low pass filter” contains a detailed description.

7.9.6 Restoration of Default Device Parameters

The sensor can be reset to default device parameters by writing the signature "LOAD" to the sensor (FSC = 40h). Thus the default parameters with the exception of the ID and the Baud Rate are immediately active again. After a software reset of the sensor or a hardware reset, the factory parameter of the IDs and the baud rate take effect again.

D0	D1	D2	D3
'L'	'O'	'A'	'D'
4Ch	4Fh	41h	44h

Table 18: Restore Default Device Parameters

The section 7.6 “Default Device Parameters” contains a detailed description.

7.9.7 Save Device Parameters

If parameters are changed in the sensor, they take effect immediately, except for the IDs and the Baud Rate. Thus the new parameters are still active after a reset, these must be stored in the internal nonvolatile memory. This is done by writing the signature "SAVE" on the FSC = 50h.

D0	D1	D2	D3
'S'	'A'	'V'	'E'
53h	41h	56h	45h

Table 19: Save Device Parameters

8 Functional Description CANopen interface

8.1 Overview of Function

The sensor contain a standardized CANopen interface according to CiA DS-301 and a device profile according to CiA DSP-410. All measured values and parameters are accessible through the object dictionary (OD). The individual configuration can be saved in the internal permanent memory (EEPROM). The following CANopen functions are available:

- four transmission data objects (TPDO1 to TPDO4),
  dynamically mappable in three possible operating modes:
  - Individual request via remote transmit request message frame (RTR)
  - Cyclic transmission at defined intervals
  - Synchronous transmission after receiving a SYNC message frame
- One Service Data Object (Default SDO)
- Error messages by Emergency Object (EMCY) with support of the
  - General Error Register
  - Manufacturer specific status register (Manufacturer Status)
  - List of errors (Pre-defined Error Field)
- Heartbeat and Nodeguarding / Lifeguarding monitoring mechanisms
- Store and load function of all parameters (Store and Load Parameter Field)
- Condition and error information by two-colored LED (according to CiA DR-303-3)

Further manufacturer and profile specific characteristics exist in addition to the CiA DS-301 functionality:

- Configurable cut-off frequency (low pass filter)
- Setting of the Node-ID as well as the baud rate via LSS service according to CiA DSP-305
- Automatic baud rate detection according to CiA AN-801

8.2 CANopen Structure

CANopen is a CAN-based open protocol standard in automation and was standardized in association with “CAN in Automation” (CiA). Like virtually all field buses CANopen is based also on the ISO/OSI 7-layer model. The protocol makes use of the CAN bus as a transmission medium and defines the elements for network management, the use of the CAN identifier (message address), the temporal behavior on the bus, the type of data transfer and application profiles. This is to ensure that CANopen devices from different manufacturers can be combined.

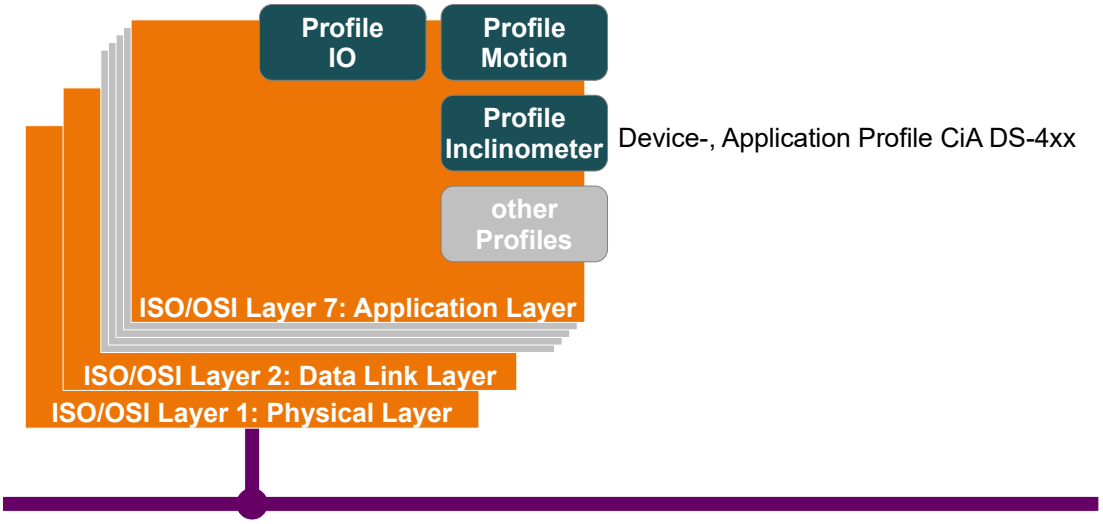


Figure 8: CANopen structure

CANopen describes the ISO / OSI layer 7 (application layer) as a communication profile that was specified in the CiA standard CiA DS-301. The standard defines the method of communication for all devices consistently. In addition, more device and application profiles for specific classes of devices and applications in the CiA standard DS-4xx are defined.

8.3 CANopen Device Model

The exchange of data between CANopen devices is realized via data objects. The CANopen communication profile thus provides for the following types of objects. The process data objects (PDO) are high-priority messages used for the exchange of process data. Access to the object dictionary of a device is done via the service data objects (SDOs). Network management objects are used to control the state machine of the CANopen device and to monitor the nodes. Furthermore, there are special objects for error messages (Emergency), Synchronization (SYNC) and time stamp. Every CANopen device has a CANopen object dictionary, in which the parameters for all CANopen objects are registered.

8.4 COB-IDs

The CAN identifier of the communication objects is determined according to the Pre-defined connection set at each reset (communication, application and hardware reset), depending on the selected Node-ID. Table 20 shows the calculation base with the default values (Node-ID = 10).

Communication object (COB)	Calculation of the COB-ID	Default value (Node-ID = 10)
NMT	0h	0h
SYNC	80h	80h
EMCY	80h + Node-ID	8Ah
TPDO1	180h + Node-ID	18Ah
TPDO2	280h + Node-ID	28Ah
TPDO3	380h + Node-ID	38Ah
TPDO4	480h + Node-ID	48Ah
Standard-SDO (Client > Server)	600h + Node-ID	60Ah
Standard-SDO (Server > Client)	580h + Node-ID	58Ah
Heartbeat	700h + Node-ID	70Ah

Table 20: Calculation of the COB-IDs for Pre-defined Connection Set

8.5 Network Management: NMT

Figure 9 shows the NMT state machine of a CANopen device. After **Initialization** the device automatically goes into the state **Pre-Operational**. The device sends a **Boot-Up Message**. In this state it can be configured via the object dictionary. The service data objects (SDO) are already active. The process data objects, however, are still locked.

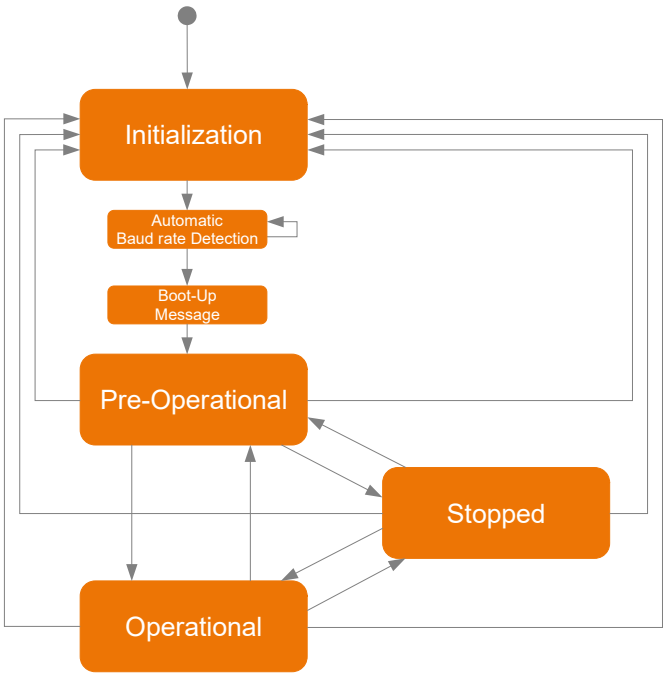


Figure 9: NMT State diagram

By sending the CAN message "Start Remote Node" the unit will go into the state **Operational**. Now the process data objects are active. In **Stopped** state, no communication with the exception of Nodeguarding and Heartbeat is possible.

8.6 Process Data: PDO (TPDO1 - TPDO4)

The sensor has four transmit process data objects (TPDO1 to TPDO4). TPDO1 contains the current values of acceleration by default. TPDO2 contains the angular rate data. The PDO mapping of the measured values is dynamically adjusted. The default mapping is shown in Table 21 and Table 22.

Data part of the CAN Frame of the TPDO1							
Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7
Acceleration X (OV: 3102h:01h)		Acceleration Y (OV: 3102h:02h)		Acceleration Z (OV: 3102h:03h)		unused	

Table 21: TPDO1 Default mapping

Data part of the CAN Frame of the TPDO2							
Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7
Angular rate X (OV: 3103h:01h)		Angular rate Y (OV: 3103h:02h)		Angular rate Z (OV: 3103h:03h)		unused	

Table 22: TPDO2 Default mapping

The following objects can be mapped to the TPDOs:

Index	Subindex	Description	Format		
3102h	1	Acceleration, x axis	16bit signed	1/4096 g/bit	-8 … 8
3102h	2	Acceleration, y axis	16bit signed	1/4096 g/bit	-8 … 8
3102h	3	Acceleration, z axis	16bit signed	1/4096 g/bit	-8 … 8
3102h	4	Unfiltered acceleration: x axis	16bit signed	1/4096 g/bit	-8 … 8
3102h	5	Unfiltered acceleration: y axis	16bit signed	1/4096 g/bit	-8 … 8
3102h	6	Unfiltered acceleration: z axis	16bit signed	1/4096 g/bit	-8 … 8
3103h	1	Angular rate, x axis	16bit signed	7/800 °/s/bit	-250 … 250
03103h	2	Angular rate, y axis	16bit signed	7/800 °/s/bit	-250 … 250
3103h	3	Angular rate, z axis	16bit signed	7/800 °/s/bit	-250 … 250
6511	0	Temperature	8bit signed	1 °C / bit	-128 … 127

Table 23: Mappable objects

8.6.1 PDO Communication Types

8.6.1.1 Individual Request (Polling)

The TPDOs (when activated) can be requested at any time by transmitting a remote-transmit request message (RTR) frame.

8.6.1.2 Cyclic Transmission

The configuration of the TPDOs 1 to 4 is done via the objects 1800h to 1803h.

Cyclic transmission of the TPDO is activated when the sub-index 05h (interval time in milliseconds) contains a value greater than 0, and the COB-ID at sub-index 01h is valid (bit 31 deleted). Furthermore, the sub-index 02h (transmission type) must contain the value 254 (asynchronous, manufacturer-specific). In the OPERATIONAL state, the sensor then cyclically transmits the TPDO with the set period duration.

8.6.1.3 Synchronous Transmission

The synchronous transmission is used to get measurement values from more then one sensor at the same time. Therefore CANopen provides a SYNC object - a CAN message without user data - transmitted with high priority on the bus. This SYNC object is transmitted from a bus node (usually the master) cyclically at fixed intervals. The sensor reads its current measurement value after every " n-th" reception of the SYNC object and sends the TPDO directly afterward as soon as the bus allows this.

Synchronized transmission activates by writing the configuration object for the corresponding TPDO. (Object 1800h to 1803h for TPDO 1 to 4). For this, the sub-index 02h (transmission type) must contain the value n = 1...240.

8.7 Service Data: SDO

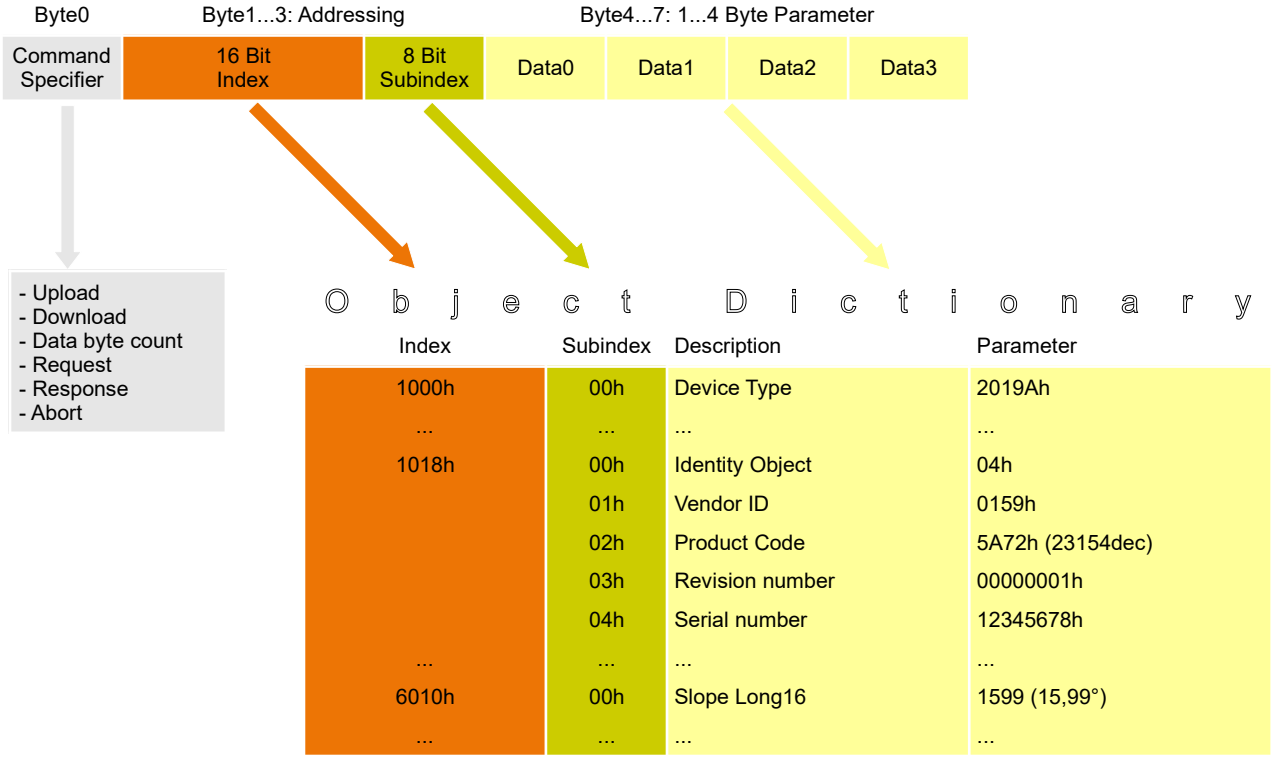


Figure 10: SDO Protocol – Access to Object Dictionary

The parameters, listed in the object dictionary, are read and written through Service Data Objects (SDOs). As shown in Table 24, every object can directly be addressed over a 16-bit index. In addition, each index has an 8-bit subindex that allows an additional choice within an index. The 8 bytes of the SDOs are placed in the data area of the CAN message.

8.8 Object Dictionary

The object directory contains all data objects that are accessible from the outside and affect the behavior of communication, application and status machines. It is divided into three parts:

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

All parameters in the object dictionary can be read and written using the standard SDO via index and subindex.

The following sections describe all the parameters in the object dictionary of the sensor with index, subindex, data type, access rights and default (factory setting). The column "Save" indicates whether a parameter in the internal volatile memory ("save" signature in OD-Write Index 1010h/01h) can be saved.

8.8.1 Communication Parameters (according to CiA DS-301)

Index	Sub-Index	Parameter		Data Type	Access	Default Value	Save
1000h	0	Device Type		UNS32	const	{dep. on type}	
1001h	0	Error Register		UNS8	ro	0	
1002h	0	Manufacturer Status Register		UNS32	ro	0	
1003h	Pre-defined Error Field						
	0	Number of Errors entries		UNS32	rw	0	
	1..5	Error Code (oldest error on highest index)		UNS32	ro	0	
1005h	0	COB-ID Sync Message		UNS32	rw	80h	
1008h	0	Manufacturer Device Name		VSTR	const	{dep. on type}	
100Ah	0	Manufacturer Software Version („Vxx.yy“)		VSTR	const	{dep. on type}	
100Ch	0	Guard Time (Multiple of 1 ms)		UNS16	rw	0	x
100Dh	0	Life Time Factor		UNS8	rw	0	x
1010h	Store Parameters (Signature: 's','a','v','e' - 65766173h at SubIndex 1...4)						
	0	Largest supported SubIndex		UNS32	ro	4	
	1	Save all Parameters	(OV: 0x1000-0x9FFF)	UNS32	rw	1	
	2	Save Communication Parameters	(OV: 0x1000-0x1FFF)	UNS32	rw	1	
	3	Save Application Parameters	(OV: 0x6000-0x9FFF)	UNS32	rw	1	
	4	Save Manufacturer Parameters	(OV: 0x2000-0x5FFF)	UNS32	rw	1	
1011h	Restore Default Parameters (Signature: 'l','o','a','d' - 64616F6Ch at SubIndex 1...4)						
	0	Largest supported SubIndex		UNS32	ro	4	
	1	Restore all Default Parameters	(OV: 0x1000-0x9FFF)	UNS32	rw	1	
	2	Restore Communication Default Parameters	(OV: 0x1000-0x1FFF)	UNS32	rw	1	
	3	Restore Application Default Parameters	(OV: 0x6000-0x9FFF)	UNS32	rw	1	
	4	Restore Manufacturer Default Parameters	(OV: 0x2000-0x5FFF)	UNS32	rw	1	
1014h	0	COB-ID Emergency Message		UNS32	ro	80h + Node-ID	
1015h	0	Inhibit Time Emergency (multiple of 100 µs)		UNS16	rw	0	x
1017h	0	Producer Heartbeat Time (multiple of 1 ms, 0 inactive)		UNS16	rw	0	x
1018h	Identity Object						
	0	Largest supported SubIndex		UNS8	ro	4	
	1	Vendor-ID (Manufacturer ID: GEMAC Chemnitz GmbH)		UNS32	ro	159h	
	2	Product Code		UNS32	ro	{dep. on type}	
	3	Revision number		UNS32	ro	{dep. on type}	
	4	Serial number		UNS32	ro	{dep. on type}	
1200h	Server SDO1 Parameter						
	0	Largest supported SubIndex		UNS8	ro	2	
	1	COB-ID Client > Server		UNS32	ro	600h + Node-ID	
	2	COB-ID Server > Client		UNS32	ro	580h + Node-ID	
1800h	Transmit PDO1 Communication Parameter						
	0	Largest supported SubIndex		UNS8	ro	5	
	1	COB-ID		UNS32	ro*	180h + Node-ID	x*
	2	Transmission Type (synchronous / asynchronous manufacturer specific)		UNS8	rw	1	x
	3	Inhibit Time between two TPDO Messages (multiple of 100 µs)		UNS16	rw	0	x
	4	Compatibility Entry		UNS8	rw	0	x

Index	Sub-Index	Parameter	Data Type	Access	Default Value	Save
	5	Event Timer (Multiple of 1 ms, 0 inactive)	UNS16	rw	0	x
1801h	Transmit PDO2 Communication Parameter					
	0	Largest supported SubIndex	UNS8	ro	5	
	1	COB-ID	UNS32	ro*	280h + Node-ID	x*
	2	Transmission Type (synchronous / asynchronous manufacturer specific)	UNS8	rw	1	x
	3	Inhibit Time between two TPDO Messages (multiple of 100 µs)	UNS16	rw	0	x
	4	Compatibility Entry	UNS8	rw	0	x
	5	Event Timer (Multiple of 1 ms, 0 inactive)	UNS16	rw	0	x
1802h	Transmit PDO3 Communication Parameter					
	0	Largest supported SubIndex	UNS8	ro	5	
	1	COB-ID	UNS32	ro*	80000380h + Node-ID	x*
	2	Transmission Type (synchronous / asynchronous manufacturer specific)	UNS8	rw	1	x
	3	Inhibit Time between two TPDO Messages (multiple of 100 µs)	UNS16	rw	0	x
	4	Compatibility Entry	UNS8	rw	0	x
	5	Interval time for cyclic transmission (multiple of 1 ms, 0 deactivated)	UNS16	rw	0	x
1803h	Transmit PDO4 Communication Parameter					
	0	Largest supported SubIndex	UNS8	ro	5	
	1	COB-ID	UNS32	ro*	80000480h + Node-ID	x*
	2	Transmission Type (synchronous / asynchronous manufacturer specific)	UNS8	rw	1	x
	3	Inhibit Time between two TPDO Messages (multiple of 100 µs)	UNS16	rw	0	x
	4	Compatibility Entry	UNS8	rw	0	x
	5	Interval time for cyclic transmission (multiple of 1 ms, 0 deactivated)	UNS16	rw	0	x
1A00h	Transmit PDO1 Mapping Parameter					
	0	Largest supported SubIndex	UNS8	ro	3	
	1	Mapping Entry 1, both types: IS1BP360-O-DL, IS2BP090-O-DL	UNS32	rw	0x31020110	x
	2	Mapping Entry 2, Type: IS1BP360-O-DL / IS2BP090-O-DL	UNS32	rw	0x31020210	x
	3	Mapping Entry 3	UNS32	rw	0x31020310	x
	4	Mapping Entry 4	UNS32	rw	0	x
	5	Mapping Entry 5	UNS32	rw	0	x
	6	Mapping Entry 6	UNS32	rw	0	x
	7	Mapping Entry 7	UNS32	rw	0	x
	8	Mapping Entry 8	UNS32	rw	0	x
1A01h	Transmit PDO2 Mapping Parameter					
	0	Largest supported SubIndex	UNS8	ro	3	
	1	Mapping Entry 1	UNS32	rw	0x31030110	x
	2	Mapping Entry 2	UNS32	rw	0x31030210	x
	3	Mapping Entry 3	UNS32	rw	0x31030310	x
	4	Mapping Entry 4	UNS32	rw	0	x
	5	Mapping Entry 5	UNS32	rw	0	x
	6	Mapping Entry 6	UNS32	rw	0	x
	7	Mapping Entry 7	UNS32	rw	0	x
	8	Mapping Entry 8	UNS32	rw	0	x

Index	Sub-Index	Parameter	Data Type	Access	Default Value	Save
1A02h	Transmit PDO3 Mapping Parameter					
	0	Largest supported SubIndex	UNS8	ro	0	
	1	Mapping Entry 1	UNS32	rw	0	x
	2	Mapping Entry 2	UNS32	rw	0	x
	3	Mapping Entry 3	UNS32	rw	0	x
	4	Mapping Entry 4	UNS32	rw	0	x
	5	Mapping Entry 5	UNS32	rw	0	x
	6	Mapping Entry 6	UNS32	rw	0	x
	7	Mapping Entry 7	UNS32	rw	0	x
	8	Mapping Entry 8	UNS32	rw	0	x
1A03h	Transmit PDO4 Mapping Parameter					
	0	Largest supported SubIndex	UNS8	ro	0	
	1	Mapping Entry 1	UNS32	rw	0	x
	2	Mapping Entry 2	UNS32	rw	0	x
	3	Mapping Entry 3	UNS32	rw	0	x
	4	Mapping Entry 4	UNS32	rw	0	x
	5	Mapping Entry 5	UNS32	rw	0	x
	6	Mapping Entry 6	UNS32	rw	0	x
	7	Mapping Entry 7	UNS32	rw	0	x
	8	Mapping Entry 8	UNS32	rw	0	x
1F51h	Download Program Control					
	0	Largest supported SubIndex	UNS8	ro	1	
	1	Area Firmware	UNS8	rw	1	

* The valid Bit (Bit 31) of COB-ID is saved

Table 24: Communication Parameters in the Object Dictionary

8.8.1.1 Error Register (1001h)

The error register displays the general error state of the device. Each bit stands for an error group. If one bit is set (= 1), at least one error of that specific group occurred. The content of this register is transmitted in each EMCY object. The following error groups may occur:

Error Register (1001h)							
Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Manufacturer Specific Error	Accuracy Warning	Profile Specific Error	Communication Error	Unused			At least one active fault

Table 25: Error Register (1001h)

If the device is in error state (at least one active error) this is shown by the set Bit0 (= 1). In case of a communication error (overflow of the transmit / receive buffers, guarding errors or CAN controller in passive mode / Bus-Off) the Bit4 is set. A device profile specific error (sensor error) is shown by Bit5. The Bit7 indicates a vendor-specific error (EEPROM error).

8.8.1.2 *Manufacturer Status Register (1002h)*

This Register shows the recent state of all detectable errors. Here each bit represents a specific error. If a bit is set (= 1), this error is active at that moment. The lower 16 bits of this register (Bit15...Bit0) are transmitted in the first two bytes of the manufacturer specific part of each EMCY object and are also registered in the additional information field (Bit31-Bit16) of the Pre-defined Error Field 1003h. The definitions of the individual bits in the bit fields "Device Error" and "Communication Error" are shown in Table 33.

Manufacturer Status Register (1002h)		
Bit31...Bit16	**Bit15...Bit8**	**Bit7...Bit0**
Unused	Bit field Communication Error	Bit field Device Error

Table 26: Manufacturer Status Register (1002h)

8.8.1.3 *Pre-defined Error Field (1003h)*

Each sensor has an error list holding the last five errors. The entry 1003h/00h contains the number of error entries in the error field. The other subindices contain all occurred error states in chronological order. The last error occurred is always located at SubIndex 01h. The oldest error can be found in the largest available SubIndex (value of 1003h/00h) and will be the first to be deleted from the list with occurrence of more than five errors. If a new error occurs a new error entry is added in 1003h and the master is notified by an EMCY object. An error entry is structured as follows:

Error Entry in Pre-defined Error Field (1003h)		
Additional Information Field (Bit31...Bit16)		Error Code (Bit15...Bit0)
Bit15...Bit0 of the manufacturer status register 1002h (at the moment of error occurrence)		0000 Error reset or no error present 5010 Sensor Error / Sensor Error X 8110 Overflow of the transmit / receive buffers 8120 CAN Warning Limit reached 8130 Node Guard Event 8140 Recovered from Bus-Off
Bit field Communication error	Bit field Device Error	

Table 27: Error Entry in Pre-defined Error Field (1003h)

The error list can be reset completely by writing “0” to entry 1003h/00h.

8.8.1.4 *Saving (1010h) and Loading (1011h) of Parameters*

If parameters are changed in the object dictionary those changes will take effect immediately. To ensure the changed parameters are still active after Reset they have to be saved in the internal EEPROM. By writing the signature „save“ (65766173h) to the entry 1010h/01h all the current parameters of the object dictionary will be saved in the internal permanent memory.

The object dictionary can be reset to its default settings by writing the signature „load“ (64616F6Ch) into the entry 1011h/01h. By doing this the factory parameters are written in the permanent memory. After a „Reset Application“ (NMT command) or a hardware reset the changes will take effect (a „Reset Communication“ (NMT command) effects the communication parameters only).

By writing the signature on SubIndex: 02h, 03h or 04h, it is possible to store or load only parts of the object directory.

8.8.1.5 Transmit PDO – Transmission Type (1800h / 1801h / 1802h / 1803h)

The sub-index 02h can be used to define how the sending of the PDO is triggered.

Transmit PDO - Transmission Type	
Transmission Type	**Description**
1...240	Synchronous (cyclic) Transmission after each 1...240 reception of a SYNC message only „Synchronized Transmission“ via SYNC possible
253	Transmission with RTR only
254	Asynchronous, manufacturer-specific „Cyclic Transmission“ activated by appropriate configuration

Table 28: Transmit PDO - Transmission Type

8.8.2 Manufacturer Specific Part

Index	SubIndex	Parameter	Data type	Access	Default value	Save
2002h	0	Automatic Bus-Off Recovery	BOOL	rw	0	x
3000h	Low pass Filter Settings					
	0	Largest supported SubIndex	UNS8	ro	2	
	1	Filter type (0=off, 1=Butterworth, 2=critical damped)	UNS16	rw	2	x
	2	Cut-off frequency low pass filter (100...25000/8000, in mHz)	UNS16	rw	5000	x
3102h	Acceleration output					
	0	Largest supported SubIndex	UNS8	ro	3	
	1	Acceleration x axis (in 1/4096 g)	INT16	ro	-	
	2	Acceleration y axis (in 1/4096 g)	INT16	ro	-	
	3	Acceleration z axis (in 1/4096 g)	INT16	ro	-	
	4	Unfiltered acceleration x axis (in 1/4096 g)	INT16	ro	-	
	5	Unfiltered acceleration y axis (in 1/4096 g)	INT16	ro	-	
	6	Unfiltered acceleration z axis (in 1/4096 g)	INT16	ro	-	
3103h	Raw data output angular rate sensor					
	0	Largest supported SubIndex	UNS8	ro	3	
	1	Angular rate x axis (in 7/800 °/s)	INT16	ro	-	
	2	Angular rate x axis (in 7/800 °/s)	INT16	ro	-	
	3	Angular rate x axis (in 7/800 °/s)	INT16	ro	-	
5555h	Reserved index (access for manufacturer only)					

Table 29: Manufacturer Specific Part of the Object Dictionary

8.8.2.1 Automatic Bus-Off Recovery (2002h)

This property determines the behavior of the sensor when it is in the state Bus-Off. If enabled, the sensor, which is in Bus-Off state may become error-active (no longer Bus-Off) with its error counters both set to zero after having monitored 128 occurrences of 11 consecutive recessive bits on the bus.

If disabled, the sensor remains in Bus-Off state.

8.8.2.2 *Low Pass Filter Settings (3000h)*

Through the entry 3000h/01h the filter type will be selected. The cut-off frequency is programmable through the object 3000h/02. Values for the cut-off frequency are allowed between 100 (= 0.1 Hz) and 25000/8000 (= 25 Hz/8 Hz). A description of the digital filter can be found in section 6.1 “Low pass filter”.

Filter	Filter type (3000h/01h)	Adjustable frequency range (3000h/02h)	Applications
deactivated	0	-	static acceleration measurement for applications without disturbing vibrations
Butterworth	1	0.1 Hz ... 25 Hz	Static acceleration measurement with high damping to vibration
Critically damped	2	0.1 Hz ... 8 Hz	Acceleration measurement in applications that requires a certain dynamism, without overshoot at acceleration changes with good damping

Table 30: Filter selection

8.9 *Emergency Objects*

Each sensor supports EMCY objects which are transmitted in case of sensor and hardware errors. If such an error occurs the OD entries 1001h (Error Register), 1002h (Manufacturer Status Register) and 1003h (Pre-defined Error Field) are updated. After abolishment of an error, the device transmits an emergency message with the Error Reset Code 0x0000. Remaining errors are signaled in Byte2 (Error Register) and Bytes 3 and 4 in the Manufacturer specific error field. Once the device is error-free, it sends an emergency message which contains only zeros. The current state of the device (Pre-Operational, Operational or Stopped) is not influenced by the error states, except in case of a guarding error.

Emergency messages are sent with high priority on the bus and are always 8 bytes long. The structure of the telegram is shown in Table 31:

Emergency Object							
Byte0	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7
Emergency Error Code		Error Register (1001h)	Manufacturer Specific Error Field				
			Bit field Communication Error	Bit field Device Error	0x00	0x00	0x00

Table 31: Emergency Object

Emergency Error Codes	
0x0000	Error Reset or no Error (Error Register = 0)
0x5010	Sensor Error / Sensor Error X
0x8110	Overflow of the transmit / receive buffers, CAN messages were lost
0x8120	CAN Warning Limit reached
0x8130	Node Guard Event (The loss of the Guarding-Master has been detected)
0x8140	Recovered from Bus-Off

Table 32: Emergency Error Codes

Bit field Device Errors		
0x01	Sensor Error x axis	
0x80	EEPROM Error: An error occurred while saving the configuration.	
Bit field Communication Errors		
0x01	CAN Warning Limit reached (too many Error Frames)	
0x02	CAN Bus-Off State reached. An Emergency message will be transmitted after the device has recovered from Bus-Off.	
0x04	Receive Queue Overrun,	CAN messages were lost
0x08	Transmit Queue Overrun,	CAN messages were lost
0x80	Guarding Error,	The loss of the Guarding-Master has been detected (Node Guard Event)

Table 33: Emergency: Manufacturer Specific Error Field

8.10 Failure monitoring

Since the nodes do not respond at regular intervals with the event-controlled transmission in a CANopen network, Heartbeat and Nodeguarding / Lifeguarding failure monitoring mechanisms are provided. Only one of the two monitoring methods can be active.

8.10.1 Nodeguarding / Lifeguarding

Nodeguarding is the monitoring of one or several nodes by the NMT master. The NMT master periodically sends a RTR message frame to the slave to be monitored, which responds with its status and a toggle bit. If the status or the toggle bit do not comply with the status or toggle bit expected by the guarding master or if no response is provided, the master assumes a slave error.

The node to be monitored may also use this mechanism to detect a failure of the guarding master. Therefore two parameters are used. The interval time after which the guarding master polls the sensor to be monitored is the Guard Time (100Ch). Another parameter, the Life Time Factor (100Dh), defines a multiplier after which the connection is deemed to be interrupted. This time is designated as the node life time.

„Node Life Time“ = „Guard Time“ x „Life Time Factor“

If the sensor does not receive a guarding request from the master within the parametrized time, it also assumes a master failure, sends an emergency message frame and returns to the "Pre-Operational" state. If either of the two parameters is "0" (default setting), the master is not monitored (no Lifeguarding).

8.10.2 Heartbeat

Heartbeat is a failure monitoring mechanism which can operate without using RTR message frames. In this case, the sensor cyclically transmits a heartbeat message which contains the state of the device. The master can monitor these message frames. Heartbeat is activated once a value greater than "0" is entered in the heartbeat interval time register (1017h).

Remarks:
Heartbeat has a significant influence on the bus load of the CANopen network, but produces only half the bus load of Nodeguarding / Lifeguarding.

8.11 LSS: Layer Setting Service (according to CiA DSP-305)

8.11.1 Setting of Node-ID and Baud Rate

The setting of the node address (Node-ID) and the Baud Rate is realized by LSS (Layer Setting Service). For communication between LSS Master and LSS Slave (sensor) two CAN identifiers (7E5h and 7E4h) are used. Each sensor has a unique 128-bit LSS address, at which it can be addressed in the CAN network. This address is composed of the three 32-bit parameters of the Identity object 1018h and the serial number:

Vendor-ID	0000 0159h	(Manufacturer ID: GEMAC Chemnitz GmbH)
Product Code	0000 69ECh	(6603h = 26115dec = PR-**26115**-30)
Revision Number	0000 001Eh	(1Eh = 30dec = PR-26115-**30**)
Serial Number	xxxx xxxxh	(serial number of the sensor → nameplate)

The default values for Node-ID and Baud Rate at delivery (factory settings) are:

Node-ID	10
Baud Rate	Automatic Baud Rate Detection

Index	Baud Rate
0	1 MBit/s
1	800 kBit/s
2	500 kBit/s
3	250 kBit/s
4	125 kBit/s
5	unused
6	50 kBit/s
7	20 kBit/s
8	10 kBit/s
9	Automatic Baud Rate Detection

Table 34: LSS Baud Rate Index according to CiA DSP-305

8.12 Automatic Baud Rate Detection (according to CiA AN-801)

The automatic baud rate detection is used to automatically adjust the baud rate of the sensor on the existing baud rate in the network. For this purpose, after switching on the power supply, the sensor is in the so-called "Listen-Only" mode, in which it observes the telegrams on the CAN bus, but does not give any acknowledge itself. This operating condition is characterized by the flickering RUN-LED (see also section 8.13 “Status LED (according to CiA DR-303-3)”). The sensor checks all the available baud rates. Upon reception of a valid CAN telegram, the correct baud rate is adjusted. Then the sensor starts up, sends its boot-up message and enters the Pre-Operational state. (see also Figure 9).

Remarks:

For proper operation of the automatic baud rate detection it is necessary to receive messages from other can nodes on the bus.

8.13 Status LED (according to CiA DR-303-3)

The integrated two-color Status LED signals the recent device state (Run LED, green) as well as CAN communication errors that might have occurred (Error LED, red). The color and the flashing frequency of the LED distinguish the different device states as shown in Table 35.

Status LED		
RUN LED	**LED State**	**Description**
○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○...	Off	The device is in state Reset or no power supply is connected
☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼...	Flickering	Automatic baud rate detection is currently running (active)
○ ☼ ○ ☼ ○ ☼ ○ ☼ ○ ☼ ○ ☼...	Blinking	The device is in state Pre-Operational
○ ☼ ○ ○ ○ ○ ○ ☼ ○ ○ ○ ○...	Single Flash	The device is in state Stopped
☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼...	On	The device is in state Operational
ERROR LED	**LED State**	**Description**
○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○...	Off	The device is in working condition
☼ ○ ○ ○ ○ ○ ☼ ○ ○ ○ ○ ○...	Single Flash	CAN Warning Limit reached or exceeded
☼ ○ ☼ ○ ○ ○ ○ ○ ☼ ○ ☼ ○...	Double Flash	The loss of the Guarding-Master has been detected (Node Guard Event)
☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼ ☼...	On	The device is in state “Bus-Off”

Legend: ○ LED off ☼ LED on ☼ LED flickering (50 ms on/off) Duration of ○/☼: 200 ms

Table 35: Status and Error Display of the Status LED

9 Functional Description SAE J1939 Interface

9.1 Message format

SAE J1939 uses extended identifiers (29 bit) for CAN-bus communication. A general distinction can be made between telegrams that are exchanged between two participants with direct addressing (PDU format 1) and Broadcast messages that are sent to all participants on the bus (PDU format 2).

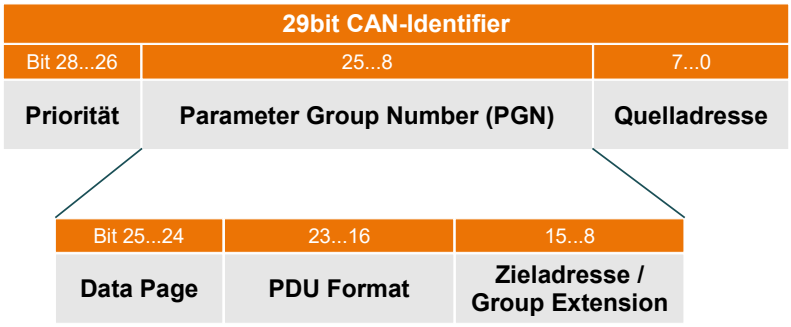


Figure 11: SAE J1939 CAN-Identifier

Point-to-point messages are sent with a PDU format value of 00h to EFh and a specific destination address. Broadcast messages contain the PDU format values F0h to FFh. The field group extension increases the number of available broadcast messages.

The sensor supports broadcast messaging with PDU format 2 for sending process data (like acceleration values or angular rate data, see section 9.3 „Process data (Transmit PGNs)“). For configuration of the sensor, direct addressing with PDU format 1 and proprietary A PGN is used (see section 9.4 „Sensor configuration“).

9.2 Device name and address

With factory default setting, the sensor starts with a device address of 128 (80h). Dynamic addressing is supported. After power-on, the sensor transmits an address-claim message containing the used address and the 64 bit device name, which identifies the sensor uniquely on the bus. The device name also defines the priority of the sensor in the network.

The 64 bit device name contains the following fields:

- 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)

The Manufacturer Code is the identifier of GEMAC Chemnitz GmbH (value 854 decimal). The Identity Number is the SAE J1939 serial number of the sensor.

The following fields are set to fixed factory settings:

- Manufacturer Code: 854 (GEMAC Chemnitz GmbH)
- Identity Number: SAE J1939 unique serial number of the sensor
- Industry Group: 0
- Vehicle System: 0
- Function: 145 (Inertial Sensor)

All other fields of the device name can be changed by the user by configuration messages (see section 9.4 „Sensor configuration“).

9.3 Process data (Transmit PGNs)

For sending of measurement values, the sensor supports PGN 61482 (Angular Rate Information) and PGN 61485 (Acceleration Sensor). Additionally, Proprietary B messages (broadcast) are supported.

The device supports 5 different parameter groups (TxPGNs):

- TxPGN3 61482 Angular Rate Information
- TxPGN4 61485 Acceleration Sensor
- Proprietary B TxPGN8 65283 acceleration x, y, z
- Proprietary B TxPGN9 65284 angular rate x, y, z
- Proprietary B TxPGN10 65285 Acceleration unfiltered x, y, z

The activation/deactivation of transmission, the cycle time, and the priority of the messages, as well as the LSB of the PG number for the Proprietary B PGNs, can be set via configuration messages. By default, TxPGNs 3 (Angular Rate Information) and 4 (Acceleration Sensor) activated with a cycle time of 10 ms.

PGN	Name	SPN name	SPN position (bit)	SPN size (bit)	Resolution	Offset	Data range
61482	Angular Rate Information	Pitch Rate (ext. Range)	0	16	1/128°/s/bit	-250°/s	-250...250°/s
		Roll Rate (ext. Range)	16	16	1/128°/s/bit	-250°/s	-250...250°/s
		Yaw Rate (ext. Range)	32	16	1/128°/s/bit	-250°/s	-250...250°/s
		Pitch Rate Status	48	2	4 States	0	0...3
		Roll Rate Status	50	2	4 States	0	0...3
		Yaw Rate Status	52	2	4 States	0	0...3
		Latenz	56	8	0,5 ms/bit	0	0...125 ms
		Latency	56	8	0.5 ms/bit	0	0...125 ms

Table 36: Transmit PGN 3 - 61482 Angular Rate Information

Latency describes only the internal latency of the sensor and is defined as the time between data acquisition in the sensor and output to the CAN interface. No account is taken of additional latencies caused by the CAN bus and the general system implementation.

PGN	Name	SPN name	SPN position (bit)	SPN size (bit)	Resolution	Offset	Data range
61485	Acceleration Sensor	Lateral Acceleration (y axis)	0	16	0,01 m/s²/bit	-320m/s²	-80...80m/s²
		Longitudinal Acceleration (x axis)	16	16	0,01 m/s²/bit	-320m/s²	-80...80m/s²
		Vertical Acceleration (z axis)	32	16	0,01 m/s²/bit	-320m/s²	-80...80m/s²
		Lateral Acceleration Figure of Merit	48	2	4 States	0	0...3
		Longitudinal Acceleration Figure of Merit	50	2	4 States	0	0...3
		Vertical Acceleration Figure of Merit	52	2	4 States	0	0...3
		Support variable transmission repetition rate	54	2	4 States	0	0...3

Table 37: Transmit PGN 4 - 61485 Acceleration Sensor

PGN*	Name	SPN name	SPN position (bit)	SPN size (bit)	Resolution	Offset	Data range
65283	Proprietary B TxPGN8 Acceleration sensor raw data	Acceleration x axis	0	16	1/4096g / bit	0	-8g...8g
		Acceleration y axis	16	16	1/4096g / bit	0	-8g...8g
		Acceleration z axis	32	16	1/4096g / bit	0	-8g...8g

Table 38: Transmit PGN 8 - Acceleration

PGN*	Name	SPN name	SPN position (bit)	SPN size (bit)	Resolution	Offset	Data range
65284	Proprietary B TxPGN9 Gyroscope sensor raw data	Angular rate x axis	0	16	7/800°/s / bit	0	-250...250°/s
		Angular rate y axis	16	16	7/800°/s / bit	0	-250...250°/s
		Angular rate z axis	32	16	7/800°/s / bit	0	-250...250°/s

Table 39: Transmit PGN 9 - Angular rate

PGN*	Name	SPN name	SPN position (bit)	SPN size (bit)	Resolution	Offset	Data range
65285	Proprietary B TxPGN10 unfiltered acceleration	Acceleration x axis	0	16	1/4096g / bit	0	-8g...8g
		Acceleration y axis	16	16	1/4096g / bit	0	-8g...8g
		Acceleration z axis	32	16	1/4096g / bit	0	-8g...8g

Table 40: Transmit PGN 10 - unfiltered acceleration

The meaning of the status bits of the output values described in the PGNs is explained in Table 41.

Condition of the status bits	Meaning
00	The described datum is valid and within the specification of the sensor.
01	The forces acting on the sensor are outside of the specification. The datum described is invalid.
10	Error
11	Not available

Table 41: Status Bits in the PGN

9.4 Sensor configuration

For reading and writing the sensor configuration, proprietary A PGN 61184 (point-to-point messaging) is used. The data part of the telegram has the following structure:

D0	D1	D2	D3	D4	D5	D6	D7
INDEX		CMD	STATUS	DATA0	DATA1	DATA2	DATA3

INDEX Parameter index (see Table 42)
CMD Command (0x01: read, 0x02: write)
STATUS Status (only valid in reply from sensor, see Table 45)
DATA0...DATA3 0 to 4 bytes of data (valid number of bytes depends on the parameter index)

Index	Parameter	Data Type	Value	Access
0x1000	Vendor-ID	UNS32	-	ro
0x1001	Product-ID	UNS32	-	ro
0x1002	Product revision	UNS32	-	ro
0x1003	Serial number	UNS32	-	ro
0x1004	Firmware version	UNS16	-	ro
0x1005	Device-ID	UNS32	-	ro
0x1100	Device status	UNS8	-	ro
0x2000	CAN baudrate	UNS16	0: Autobaud 250 (default) 10, 20, 50, 100, 125, 500, 800, 1000	rw
0x2001	Device address	UNS8	128 (default)	rw
0x2002	Automatic Bus-Off Recovery	UNS8	0: (default) inactive 1: active	rw
0x2010	Arbitrary Address Capable	UNS8	0: address claiming inactive 1: address claiming active (default)	rw
0x2011	Industry Group	UNS8	0	ro
0x2012	Vehicle system instance	UNS8	0...15 (default: 0)	rw
0x2013	Vehicle system	UNS8	0	ro
0x2014	Function	UNS8	145	ro
0x2015	Function Instance	UNS8	0...31 (default: 0)	rw
0x2016	ECU Instance	UNS8	0...7 (default: 0)	rw
0x2100	Filter type low pass filter	UNS16	0: inactive 1: Butterworth filter 2: critical damped (default)	rw
0x2101	Cut-Off-frequency low pass filter	UNS16	100...25000 mHz default: 5000 mHz	rw
0x2300	Store parameters	VSTR	Write 'SAVE' (45564153h) to store parameters permanently	wo
0x2301	Load parameters	VSTR	Write 'LOAD' (44414F4Ch) to load parameters from permanent memory	wo
0x2302	Reset to factory default parameters	VSTR	Write 'CLR' (524C43h) to apply factory default settings	wo
0x2303	Reset sensor	VSTR	Write 'RST' (545352h) to reset the device	wo
Configuration TxPGNs				
0x3020	TxPGN3 cycle time PGN 61482 Angular Rate Information	UNS16	0: deactivated (default) 10...10000 ms cycle time default: 10 ms	rw

Index	Parameter	Data Type	Value	Access
0x3021	TxPGN3 priority PGN 61482 Angular Rate Information	UNS8	0...7 (default: 3)	rw
0x3030	TxPGN4 cycle time PGN 61485 Acceleration Sensor	UNS16	0: deactivated (default) 10...10000 ms cycle time default: 10 ms	rw
0x3031	TxPGN4 priority PGN 61485 Acceleration Sensor	UNS8	0...7 (default: 3)	rw
0x3070	TxPGN8 cycle time PGN 65283 Acceleration x, y, z axis	UNS8	0: deactivated (default) 10...10000 ms cycle time	rw
0x3071	TxPGN8 priority PGN 65283 Acceleration x, y, z axis	UNS8	0...7 (default: 3)	rw
0x3072	TxPGN8 LSB PGN 65283 Acceleration x, y, z axis	UNS8	0x00...0xFF default: 0x03	rw
0x3080	TxPGN9 cycle time PGN 65284 Angular Rate x, y, z axis	UNS8	0: deactivated (default) 10...10000 ms cycle time	rw
0x3081	TxPGN9 priority PGN 65284 Angular Rate x, y, z axis	UNS8	0...7 (default: 3)	rw
0x3082	TxPGN9 LSB PGN 65284 Angular Rate x, y, z axis	UNS8	0x00...0xFF default: 0x04	rw
0x3090	TXPGN10 cycle time PGN 65285 Acceleration unfiltered x, y, z	UNS16	0: deactivated (default) 10...10000 ms cycle time	rw
0x3091	TXPGN10 priority PGN 65285 Acceleration unfiltered x, y, z	UNS8	0...7 (default: 3)	rw
0x3092	TXPGN10 LSB PGN 65285 Acceleration unfiltered x, y, z	UNS8	0x00...0xFF default: 0x05	rw
Process data				
0x5001	Read temperature values	INT8	Temperature in °C	ro

Table 42: Configuration parameters

For permanent saving of the parameters, the "SAVE" command (Index 0x2300) must be sent. The CAN baud rate and device address are stored in the permanent memory during writing but are not immediately applied. A restart of the sensor is necessary to assume the new parameters.

9.4.1 Examples SAE J1939 communication

	CAN-Identifier	D0	D1	D2	D3	D4	D5	D6	D7
		INDEX		CMD	STATUS	DATA0	DATA1	DATA2	DATA3
Request	0x0CEF8001	0x04	0x10	0x01	0x00	0x00	0x00	0x00	0x00
Reply	0x0CEF0180	0x04	0x10	0x01	0x00	0x01	0x00	0x00	0x00

Table 43: Read the firmware version of the sensor (device address 128)

	CAN-Identifier	D0	D1	D2	D3	D4	D5	D6	D7
		INDEX		CMD	STATUS	DATA0	DATA1	DATA2	DATA3
Request	0x0CEF8001	0x00	0x21	0x02	0x00	0x02	0x00	0x00	0x00
Reply	0x0CEF0180	0x00	0x21	0x02	0x00	0x02	0x00	0x00	0x00

Table 44: Activate sensor fusion (device address 128)

9.4.2 Status byte description

Value	Description
0x00	Ok, processing successfully
0xF0	invalid index
0xF1	invalid parameter, parameter out of range
0xF2	EEPROM read-/write-error

Table 45: Statusbyte

10 Service

10.1 Calibration

Every GEMAC Motus® is calibrated by the manufacturer GEMAC Chemnitz GmbH as standard before delivery.

Even the highest quality sensors have to be recalibrated at certain intervals in order to continue to deliver reliable, safe and error-free measurement results. We therefore recommend regular recalibration. This shall be done exclusively by the manufacturer GEMAC GmbH.

10.2 Service

10.2.1 Reshipment

Reshipment of the sensor GEMAC Motus® IB for calibration or repairing purposes must be executed in the original packaging or an equivalent packaging. Please indicate a short error description and your phone number for further inquiries.

10.2.2 Support

Please indicate the serial number and the firmware revision of your sensor for technical support.

Manufacturer: GEMAC Chemnitz GmbH
Zwickauer Str. 227
09116 Chemnitz
Germany
Phone: +49 371 3377-0
Fax: +49 371 3377-272
Web: www.gemac-chemnitz.com
Mail: info@gemac-chemnitz.de

10.2.3 Warranty and limitation of liability

We will assume a warranty of 24 months for the sensor GEMAC Motus® IB, commencing from the date of delivery. Any repairs which are required during this time and fall under the manufacturer's obligation to give a warranty will be performed free of charge. Any damage resulting from improper use of the device or from exceeding of the specified technical parameters is not covered by the manufacturer's obligation to give a warranty.

GEMAC Chemnitz GmbH will only be liable for consequential damage resulting from use of the product in case of deliberate action or gross negligence on its own part.

The General Terms and Conditions of GEMAC Chemnitz GmbH shall apply.

11 Sensor configuration

11.1 Programming adapter

Use the separately available programming adapter (starter kit ISPA2 - PR-23999-10) to configure the sensor conveniently. The programming adapter is connected via USB to a PC. The connection of the sensors with the programming adapter is realized through the included CAN adapter cable. The sensor is supplied with power through the adapter. No additional voltage supply is necessary.

Figure 12: Starter kit

11.2 PC software ISDControl

The parametrization of all possible values is done with the PC software ISDControl, which is included in all starter kits. Each configuration can be stored in a file.

Properties:

- comfortable configuration of all parameters of the sensor
- Firmware Download option
- Automatic sensor search for unknown communication parameters

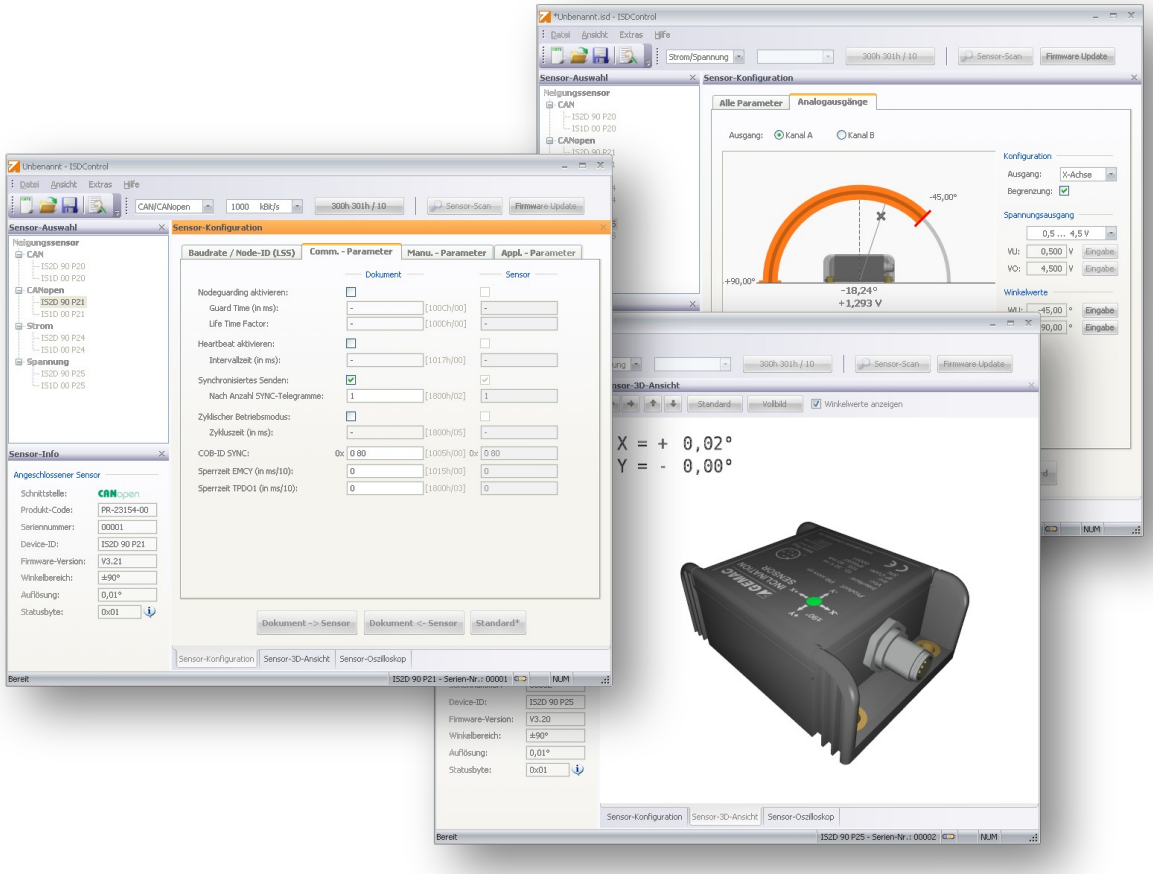


Figure 13: PC software

12 Ordering Information

Article Number	Product Type	Interface
PR-26015-30	IB6MZ360-C	CAN 2.0 A and B
PR-26715-30	IB6MZ360-J	SAE J1939
PR-26115-30	IB6MZ360-O	CANopen
PR-23999-10	ISPA2	programming adapter (Starter kit including programming adapter, cables and PC software)

Table 46: Ordering information