USER MANUAL

QG65D J1939 Dynamic Inclinometer (Type JA)

V1.1, Mar-22

DIS Sensors bv
Oostergracht 40
3763 LZ Soest | The Netherlands

T +31 (0)35 - 603 81 81
M info@dis-sensors.com
W www.dis-sensors.com

Contents

1. Safety information

1.1. Intended use

The QG65D J1939 Dynamic Inclinometer is a MEMS-based inclination sensor with J1939 interface. This device provides precise and reliable inclination measurement in both static and dynamic conditions. The use of this device in a machine or system is permitted only under the following conditions:

- The user is trained and competent in the integration and use of inclination sensors in machinery.
- The user is familiar with the contents of both the datasheet and user manual.
- The user has a full understanding of CAN and J1939.
- The device is used within the specified environmental conditions.
- The device is properly configured for its intended use.
- The device is mounted correctly as described in the datasheet and user manual.
- The device data is expressly not interpreted as safety data, except when used redundantly in a control system that is designed and tested for cross-check functionality between the primary and redundant devices.

1.2. Incorrect use

- Use of non-standard CAN cables.
- Device mounted incorrectly.
- Zero adjustment outside the specified range.
- Incorrect or absent CAN bus termination.
- Device used outside the specifications.

1.3. Sensor defective

The sensor is considered “defective” when

- No CAN output can be detected.

In the event of uncertainty, contact the distributor or manufacturer. Any unauthorised modification or unapproved use will void both the warranty and any liability on the part of the manufacturer.

2. About this manual

2.1. Intended use

This manual applies solely to the QG65D J1939 dynamic inclinometer (Type JA) with the following model designations:

- QG65D-KIXv-360H-CANJ-C(F)M-UL —— 1 axis, ± 180°, vertical mounting, high accuracy
- QG65D-KDXYh-090H-CANJ-C(F)M-UL —— 2 axes, ± 90°, horizontal mounting, high accuracy
- QG65D-KDXYh-030H-CANJ-C(F)M-UL —— 2 axes, ± 30°, horizontal mounting, high accuracy
- QG65D-KIXv-360-CANJ-C(F)M-UL —— 1 axis, ± 180°, vertical mounting, std. accuracy
- QG65D-KDXYh-090-CANJ-C(F)M-UL —— 2 axes, ± 90°, horizontal mounting, std. accuracy
- QG65D-KDXYh-030-CANJ-C(F)M-UL —— 2 axes, ± 30°, horizontal mounting, std. accuracy

DIS product code can be identified here.

2.2. Symbols used in the text

h	Subscript for hexadecimal values.
d	Subscript for decimal values.
⚠	Caution that indicates either potential damage to the sensor or explains how to avoid a problem.
ⓘ	Important information.
→	Cross-reference

2.3. Copyright

2.4. Document revision control

Version	Date(y-m-d)	Revision
V1.0	2021-12-03	1st release
V1.1	2022-03-08	Certain index are not supported in the J1939 interface. Removed from parameter list. Correct description of signal processing. Function mode etc not supported.

Table 1 - Document revision

3. Quick reference

General

- 1-axis ± 180° and 2-axes ± 30°/± 90° dynamic inclinometer
- Output type: SAE J1939
- Internal sample rate MEMS: 1000Hz
- Dynamic inclination application limitations: max. acceleration 1.5 g, max. angle rate 500°/s
- Approved for automotive use, approval number: E4-10R-05-4662

CAN, J1939

- CAN interface: CAN2.0 A and B (complies with ISO11898-1&2)
- Application layer: SAE J1939 (29-bit CAN identifier)
- CAN bus bit rate: 250 kbit/s default, optional 500kbit/s
- Device address: 128_d (80_h) default
- PGN cycle time: 100ms default
- Output data: PGN 65280 (Inclination), PGN 65283 (Acceleration)
- Sensor configuration: PGN 61184 ($EF00_h$)
- Zero adjustment via index $300F_h$
- Negative values: two's complement
- Byte-sequence on CAN bus: little-endian (least significant byte first)

4. Installation guide

4.1. Mechanical drawing

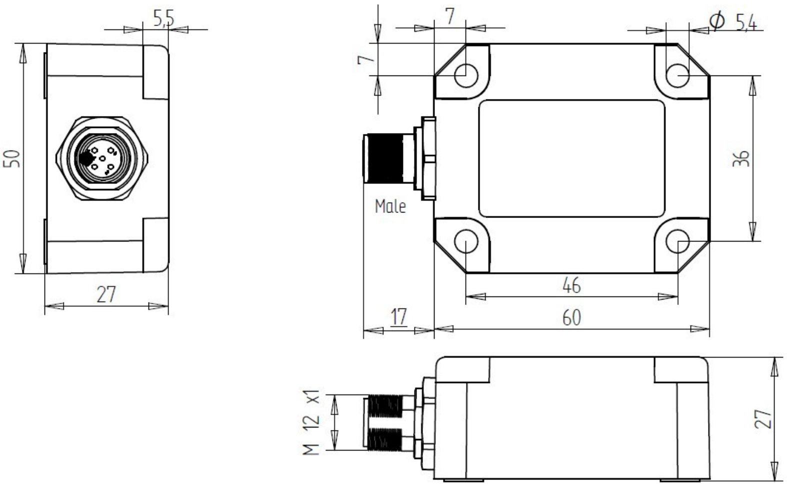


Figure 1 - Mechanical drawing of QG65D with a male M12.

4.2. Mounting

- Use the 4 screws provided (M5x25 mm zinc plated steel Pozidrive pan head screws with self-tapping PZ DIN7500CZ) to mount the device.
- If a software zero adjustment is impossible or undesirable, DIS provides an optional reference solution of replacing 2 of the provided screws with 2 optional 4mm Ø positioning pins, which can serve as mechanical reference.
- Tightening torque max. 2.5 Nm. A higher torque can cause damage to the housing or the internal electronics.
- Fix the sensor to a perfectly flat surface.
- A 1-axis inclinometer must be mounted vertically. The factory default zero position is with the male connector pointing down as shown in Figure 3. Sensor can be zero adjusted at any position within the full range.
- A 2-axis inclinometer must be mounted horizontally. The factory default zero position is shown in Figure 2. After installation, sensor can be zero adjusted to eliminate the mechanical offsets within a ±5° offset range.

Figure 3 - Vertical mounting 1-axis inclination

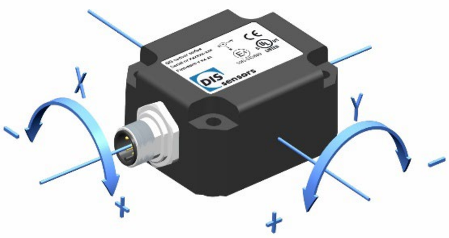


Figure 2 - Horizontal mounting 2-axes inclination

4.3. Connection

The sensor is equipped with either a single 5-pole M12 (A-coded) male connector according to IEC 61076-2-101, or with an additional 5-pole M12 (A-coded) female connector. This is specified in the suffix of the device model designation: suffix CM indicates single male connector; suffix CFM indicates both a female and a male connector.

The advantage of two connectors is that devices can be daisy-chained in the CAN network. The voltage supply is forwarded from the male to the female connector, providing both power and bus-connection to the next sensor with a single cable harness. The connection between male and female connector acts as an internal T-junction.

The pin assignment is according to CiA 303-1 V1.8.0.

Pin	Assignment
Pin 1	Shield
Pin 2	Vcc
Pin 3	Gnd & CAN_GND
Pin 4	CAN_H
Pin 5	CAN_L

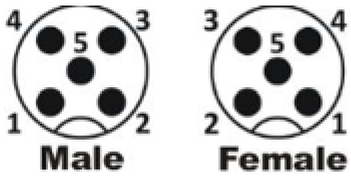


Figure 4 - Pin definition

- The maximum current for the internal T-junction is 2.5 A. This must be taken into account when using daisy-chained connections.
- The voltage supply must be dimensioned to prevent exceeding the specified voltage limits.
- The power consumption is about 50mA typical.
- This device must be connected to a class 2 power supply.
- Connect the sensor only to an approved CAN controller which must have a grounded shield. Alternative: connect the sensor housing to a grounded shield. All mentioned EMC standards that are met (see Declaration of Conformity) have been done with the housing connected to a grounded shield.

⚠ *Installation of wiring and the opening and closing of electrical connections must only be carried out in de-energized state! Short-circuits, voltage spikes, etc. can cause malfunctions and/or cause the installation to become uncontrolled, creating a serious risk of injury or damage to property.*

4.4. CAN termination

A CAN bus should be terminated properly to prevent signal reflections. The QG65D dynamic Inclinometer has an internal 120 Ohm termination resistor. By default, this is disabled, but it can be enabled with parameter index 3003h.

A separate M12 termination resistor and T-connector are available as accessories.

Figure 5 - M12 CAN terminator male 5p.
Order code: 10217

Figure 6 - M12 CAN terminator female 5p.
Order code: 10194

Figure 7 - M12 T-connector 5p.
Order code: 11822

The advantage of using a separate termination plug instead of the internal termination resistor is that an external termination plug is clearly visible. This helps to prevent an inadvertent double termination that could cause the entire CAN bus to malfunction.

5. Technical data

Please refer to the datasheet of your product.

6. Functional description

6.1. Dynamic inclination measurement principle

Conventional inclinometers measure inclination by measuring g-forces using an accelerometer. In static conditions, inclination measurement by this principle is accurate and reliable. However, the vibrations or movements present on almost all industrial machines generate undesirable g-forces. These dynamic g-forces accumulate and overlay the static g-forces, causing a 'dirty' inclination output that includes spurious or noise components.

In certain applications a low-pass filter can be used to stabilize the output. The downside of this filtering is that it significantly increases the reaction time (latency) of the inclinometer. In a control system this results in a limit on the speed of movements, and reduced machine efficiency.

A gyroscope measures the speed of rotation, which can be integrated to get the actual inclination value. But gyroscopes are subject to bias drift, integrating constant bias will cause angular errors and these errors will accumulate over a long term. Therefore, this calculation is only accurate for a relatively short period.

The QG65D dynamic inclinometer combines accelerometer MEMS and gyro MEMS. This device is unaffected by vibration or movement and can therefore measure the true angle at the sensor position in real time. Our smart algorithms (such as Kalman filtering) within the device can determine the balance between the accelerometer MEMS (best result in static situations) and the gyro MEMS (best result in dynamic situations).

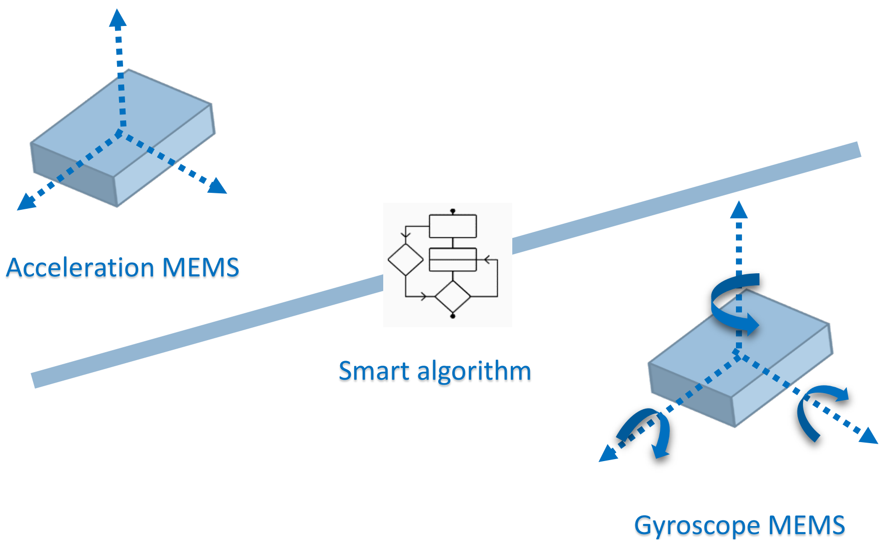


Figure 8 - Measurement principle of the dynamic inclinometer

6.2. Measuring axis and direction

6.2.1. Measuring axis and direction for Inclination

A single-axis inclinometer (vertical mount) measures the inclination in the vertical plane over the full range 0-360° (X-output). The default 0° position and the measuring direction are shown in Figure 9 - Measuring axis and direction of 1-axis inclination.

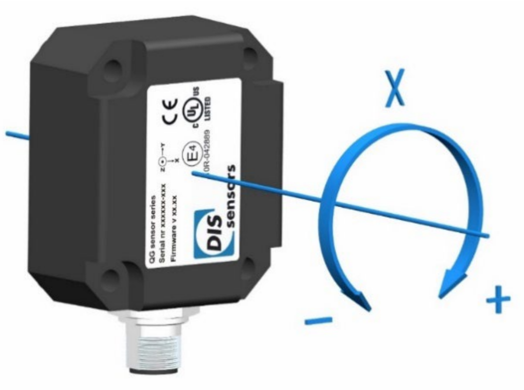


Figure 9 - Measuring axis and direction of 1-axis inclination.

A dual-axis inclinometer (horizontal mount) measures the inclination on both X and Y axis. Measuring range is up to 90°. Due to the measurement principle, only one axis may tilt more than 45°.

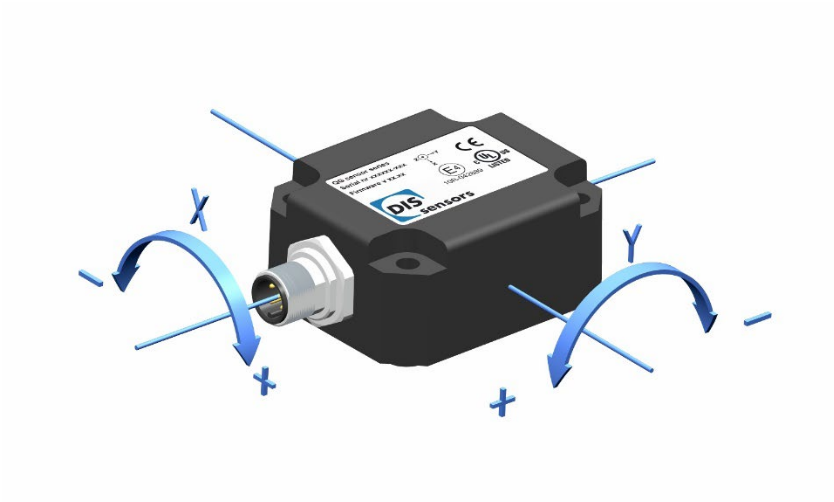


Figure 10 – Measuring axis and direction of 2-axis inclination.

⚠ *Cross-tilt error: when the cross axis (axis perpendicular to the measuring axis) tilts more than 45° during the measurement, the measuring axis will be disabled. The sensor will send a fixed output to indicate that the sensor is now at a cross-tilt error position (→Knowledgebase): 20000$_d$ (200°) for the measuring range ±180°, ±30°/ ±90°, and 40000$_d$ (400°) for the measuring range 0°-360°.*

6.2.2. Measuring axis and direction for acceleration

The device measures the acceleration values on all 3 axes. The measuring direction of three axes in the factory default setting is shown in Figure 11. Raw acceleration value range are up to ±1.5/±2.0 g with resolution of 0.001g.

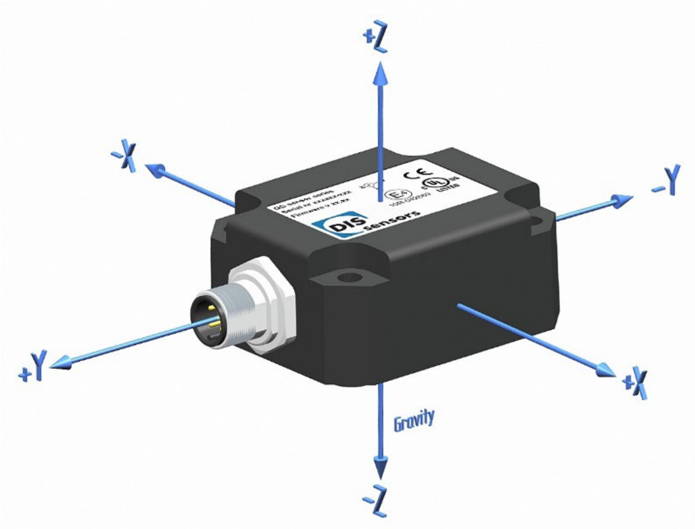
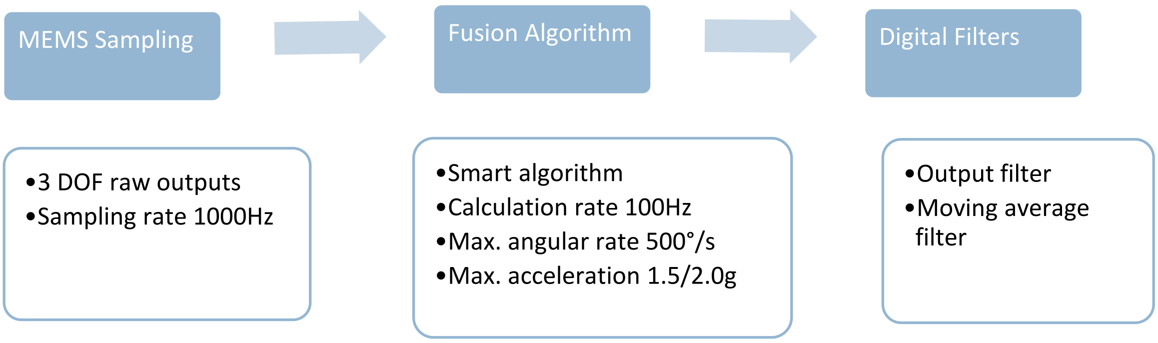


Figure 11 – Measuring axis and direction of acceleration

6.3. Signal processing



6.3.1. Sampling rate

Each axis of the acceleration and gyroscope MEMS is sampled by the internal microcontroller at a rate of 1000 Hz. Those samples are then processed and fed into the sensor fusion algorithm.

6.3.2. Sensor fusion algorithm

The sensor fusion algorithm transforms the raw MEMS outputs into a reliable inclination value. The smart algorithm will combine the accelerometer and gyroscope outputs in a balanced way optimised for your application. The limitations for the sensor fusion algorithm are: acceleration max 1.5 / 2.0 g, angular rate max. 500°/s. The calculation rate, and therefore also the output rate, is 100 Hz.

6.3.3. Digital Filters

To eliminate noise or reduce the bandwidth, the inclination values can be further processed with extra digital filters. The value are predefined by DIS.

6.4. Boot-up procedure

When the device is powered on, the device will be initialised with the last-stored parameters. When initialisation is complete, an Address Claim Message (ACM) containing the address used and NAME will be sent. (→7.5 NAME and ACM (PGN 60928))

Bus	CAN-ID (h...	Type	Prio.	PGN	PGN (hex)	Len...	Symbol	Data	Source	Source (hex)
1	18EEFF80	J1939	6	60928	EE00h	8	ACM	NAMEOfControllerApplication = 9223533667373223231 IdentityNumber = 199999 ManufacturerCode = DIS Sensors B.V. ECUInstance = 0 FunctionInstance = 0 Function = 147 VehicleSystem = 0 VehicleSystemInstance = 0 IndustryGroup = Global, applies to all ArbitraryAddressCapable = CA is capable	128	80h

Figure 12 – example ACM at boot-up

The CAN-ID 18EEFF80 shows that the sensor has a default source address of 80_h.

The data of the ACM is

Hex View: Rx, Bus 1, 18EEFF80h (ACM), DLC 8, Length 8

```
0 | 3F 0D A3 89 00 93 00 80
```

Figure 13 - ACM data

This is the 64-bit device NAME for DIS sensors which contains the following fields:

MSB				64 bits					LSB
1 bit	3 bit	4 bit	7 bit	1 bit	8 bit	5 bit	3 bit	11 bit	21 bit
Arbitrary Address Capable	Industry group	Vehicle system Instance	Vehicle System	Reserved	Function	Function Instance	ECU Instance	Manufacturer Code	Identify Number
1	*000*	*0000*	*0000000*	*0*	*10010011*	*00000*	*000*	*10001001101*	*000110000110100111111*

Table 2 – NAME definition and data example

Bit length	Definition	Data	Meaning
21 bits	Identify Number	000110000110100111111_b	The least 21 bits of the 32-bit serial number of the sensor
11 bits	Manufacturer Code	$10001001101_b = 1101_d$	DIS Sensors B.V.
3 bits	ECU Instance	000_b	
5 bits	Function Instance	00000_b	
8 bits	Function	$10010011_b = 147_d$	Inertial Sensor
1 bit	Reserved	0_b	
7 bits	Vehicle System	0000000_b	
4 bits	Vehicle system Instance	0000_b	
3 bits	Industry group	000_b	Global, applies to all industries
1 bit	Arbitrary Address	1_b	yes

Table 3 - NAME explanation

6.5. Output format

The device supports 2 different parameter groups (Tx PGNs):

- Proprietary B Tx PGN1 65280 for Longitudinal, Lateral Inclination (Availability of lateral information depends on sensor type)
- Proprietary B Tx PGN2 65283 for X, Y, Z Acceleration

6.5.1. Inclination outputs PGN 65280 (FF00h).

PGN	Name	Priority	SPN position(bit)	SPN Width(bit)	Resolution	Offset	Data Range
65280_d FF00$_h$	X axis (Longitudinal)	3	0	16	0.01°/bit	–	-90° - +90°
	Y axis (Lateral)	3	16	16	0.01°/bit	–	-90° - +90°

Table 4 – Transmit PGN1 inclination 2-axis

PGN	Name	Priority	SPN position(bit)	SPN Width(bit)	Resolution	Offset	Data Range
65280_d FF00$_h$	X axis (Longitudinal)	3	0	16	0.01°/bit	–	-180° - +180°

Table 5 - Transmit PGN1 inclination 1-axis

The angle can be calculated with formula: α = J1939 output / 100. (α = angle in degrees, factory resolution is 0.01°)

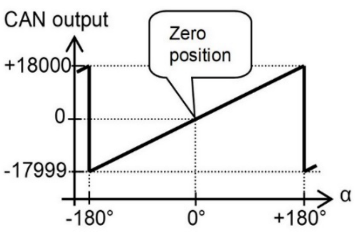


Figure 14 - Output 1-axis ±180° sensor

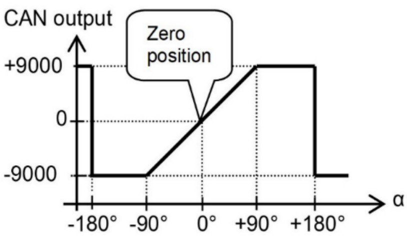


Figure 15 - Output 2-axis ±90° sensor

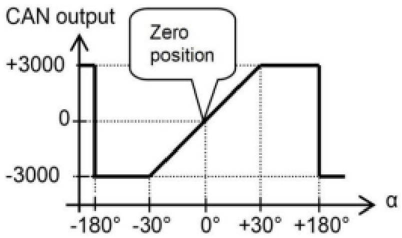


Figure 16 - Output 2-axis ±30° sensor

Example – Inclination output of a 1-axis sensor.

Time (rel.)	Bus	ID (hex.)	Symbol	Rx/Tx	Type	Prio	PGN	SA	DA	Length	Data (hex.)
0,1217	1	0CFF0080	Inclination Output	Rx	Data	3	65280	128	255	8	0A 0A FF FF FF FF FF FF
0,2217	1	0CFF0080	Inclination Output	Rx	Data	3	65280	128	255	8	30 0A FF FF FF FF FF FF
0,3217	1	0CFF0080	Inclination Output	Rx	Data	3	65280	128	255	8	44 0A FF FF FF FF FF FF

The first 2 bytes are the angle value, the rest 6 bytes are not used..

Byte0	Byte1
0A$_h$	0A$_h$
Inclination output: 0A0A$_h$ = 2570_d = 25.70°	

Table 6 - Output 1-axis ±180° sensor explanation

Example – Inclination output of a 2-axis sensor

Time (diff.)	Bus	ID (hex.)	Symbol	Rx/Tx	Type	Prio	PGN	SA	DA	Length	Data (hex.)
-	1	00FF0080	Inclination Output	Rx	Data	0	65280	128	255	8	8E FC 4B 08 FF FF FF FF
0,1000	1	00FF0080	Inclination Output	Rx	Data	0	65280	128	255	8	F4 FB 7A 08 FF FF FF FF

The first 2 bytes are X inclination, and the second 2 bytes are Y inclination. The rest 4 bytes are not used.

Byte0	Byte1	Byte2	Byte3
X inclination		**Y inclination**	
$8E_h$	FC_h	$4B_h$	08_h
$FC8E_h = -882_d = -8.82°$		$084B_h = 2123_d = 21.23°$	

Table 7 – Output 2-axis 90° sensor explanation

6.5.2. Acceleration outputs PGN 65283 (FF03h).

PGN	Name	Priority	SPN position(bit)	SPN Width(bit)	Resolution	Offset	Data Range
65283_d $FF03_h$	X axis (Longitudinal)	3	0	16	0.001g/bit	–	H series: -1.5g to +1.5g Std. series: -2.0g to +2.0g
	Y axis (Lateral)		16	16	0.001g/bit	–	H series: -1.5g to +1.5g Std. series: -2.0g to +2.0g
	Z axis (Vertical)		32	16	0.001g/bit	–	H series: -1.5g to +1.5g Std. series: -2.0g to +2.0g

Table 8 - Transmit PGN2 acceleration

Acceleration can be calculated with formula: a = J1939 output / 1000. (a = acceleration in g, factory resolution is 0.001g)

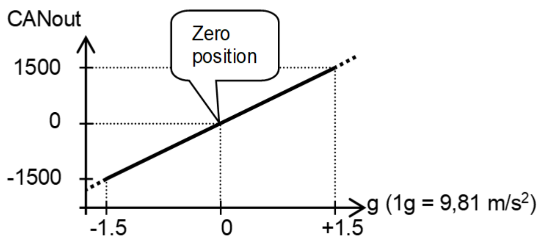


Figure 17 - Output acceleration high accuracy series

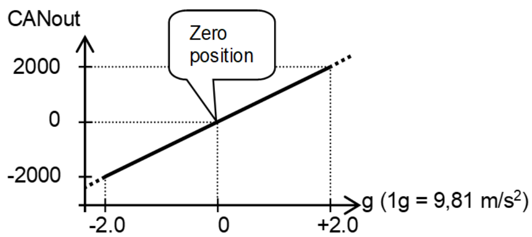


Figure 18 - Output acceleration std. accuracy series

For example:

Time (diff.)	Bus	ID (hex.)	Symbol	Rx/Tx	Type	Prio	PGN	SA	DA	Length	Data (hex.)
-	1	00FF0380	Acceleration Output	Rx	Data	0	65283	128	255	8	EA FF 0A 00 18 FC FF FF
0,1000	1	00FF0380	Acceleration Output	Rx	Data	0	65283	128	255	8	EA FF 0A 00 18 FC FF FF

Figure 19 - Acceleration output trace

The 6 bytes data are defined as below.

Byte0	Byte1	Byte2	Byte3	Byte4	Byte5
X acceleration		**Y acceleration**		**Z acceleration**	
EA_h	FF_h	$0A_h$	00_h	18_h	FC_h
$FFEA_h = -22_d = -0.022g$		$000A_h = 10_d = 0.010g$		$FC18_h = -1000_d = -1.000g$	

6.6. Sensor configuration (PGN 61184)

For reading and writing the sensor configuration, Prop A PGN 61184 ($EF00_h$) (->PGN (Parameter Group Number)) is used.

Example – Read serial number.

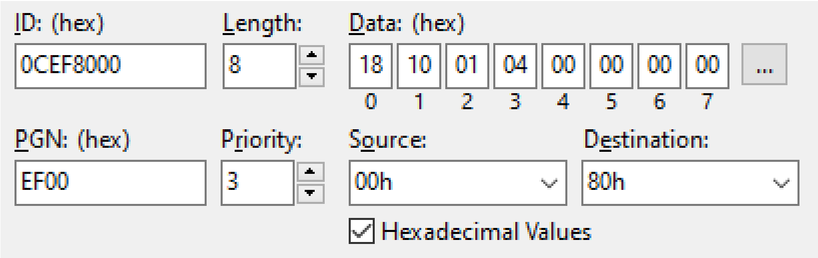


Figure 20 - CMD read serial number

The 8 bytes data are defined as below:

D0	D1	D2	D3	D4	D5	D6	D7
Parameter Index		CMD	Sub index /Status	Data0	Data1	Data2	Data3

Parameter index	Index of the PGN parameters. (→ 8 Parameter overview)
CMD	01_h = Command for read data 02_h = Command for write data
Sub Index:	message to the sensor: Sub index of the PGN parameters. (→ 8 Parameter overview) message from the sensor: Status reply
Data0 to Data3	0 to 4 data bytes (Number of valid bytes depends on the parameter)

Status reply (Sub Index):

Message	Description
00_h	Ok processing successfully
$F0_h$	Invalid index
$F1_h$	Invalid parameter, parameter out of range
$F2_h$	EEPROM error

Table 9 - PGN 61184 data definition

More configuration examples can be found in 9 Configuration examples.

6.7. Load factory default settings

Factory reset or load factory default settings allows users to restore the device to its original manufacturer settings. The customer settings which were saved to the EEPROM will be overwritten by the factory default settings.

With index 1011h, the factory default settings below can be restored. Customised products may have different factory default values, which may deviate from this manual. See the datasheet of your customized products for these customized factory default values.

DIS factory default

Parameters	Index	DIS standard default value
Device Address	3101_h	80_h
Baud Rate	3001_h	03_h - 250 kBit/s
PGN1 (65280)	3102_h	Cycle time = 100_d = Enabled
PGN2 (65283)	3103_h	Cycle time = 0_d = Disabled

Table 10 – DIS standard factory default communication parameters

Procedures:

- Write "load" to sub-index 01h = All parameters will be restored.
- Write "load" in ASCII or "64616F6Ch" have the same effect.

Example:

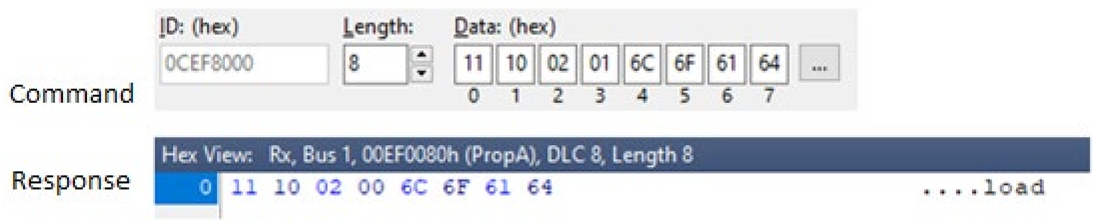


Figure 21 - Restore default settings

⚠ *A new power cycle is required to enable the factory default settings after a "load". Do not execute "save" before you restart the device, as this will cause the current working environment settings to overwrite (i.e. store) the default factory settings.*

6.8. Zero adjustment

Zero adjustment allows users to compensate for mechanical offsets of a horizontally mounted 2-axis device or set a customised 0° position of a vertically mounted 1-axis sensor. The measured inclination value at the 0° position will be stored in the device as a permanent offset, which is used to calculate the actual inclination output of the device. The zero offset value can be read from index 6013$_h$, 6023$_h$.

Zero adjustment can be done in two ways and can be repeated at any time.

1. **Via index 300F$_h$ Zero adjustment.**
   To perform a zero adjustment, write the corresponding value to index 300F$_h$ subindex 00$_h$. The zero adjustment can be done for each axis separately or for all axes at the same time. Status information of the result is available from index 300F$_h$.

Value		Response
01$_h$	Start zero adjustment X-axis - inclination	00$_h$ = Successful; FF$_h$ = Failed
02$_h$	Start zero adjustment Y axis - inclination	00$_h$ = Successful; FE$_h$ = Failed
03$_h$	Start zero adjustment X and Y axis - inclination	00$_h$ = Successful; FD$_h$ = Failed

Table 11 - Definition index 300F$_h$

For example:
Write 03$_h$ to zero both X and Y axis.

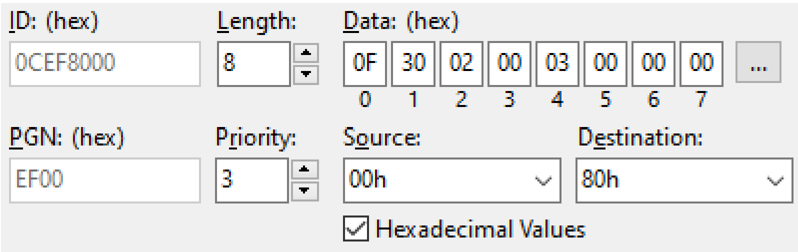


Figure 22 - commands to zero both X and Y axis

The sensor returns 00$_h$ in the data byte4 indicating that the zero adjustment is successful.

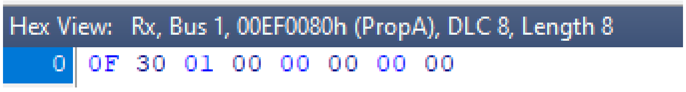


Figure 23 - response from the sensor indicating that zero is successful (data=00)

And the live output shows the sensor is indeed zeroed.

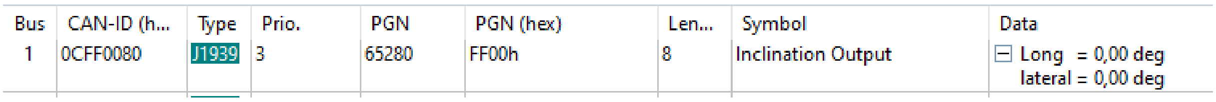


Figure 24 - sensor live output

If the sensor is zeroed at an illegal position, the response (byte4) will be FF/FE/FD$_h$

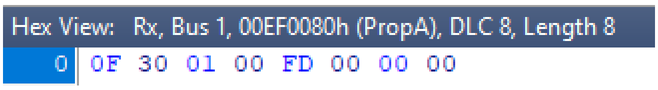


Figure 25 - response shows that zero at X and Y axis both failed.

The offset value will be stored permanently in the device without "save" to index 1010$_h$.

2. **Via Index 6012h, 6022h Pre-set inclination value.**
   To set the output of X/Y axis to 0°, write 0000$_h$ to index 6012$_h$ / 6022$_h$ at your desired 0° position. The offset will be stored in Index 6012$_h$, 6022$_h$. Those parameters must be saved to the device.

Index	Sub-index	Definition	Value Example
6012_h	00_h	Pre-set inclination X-axis	0000_d - 0°
6022_h	00_h	Pre-set inclination Y axis	0100_d - 1°

Table 12 - Index 6012/6022_h definition

Example - Pre-set the X axis to 0°

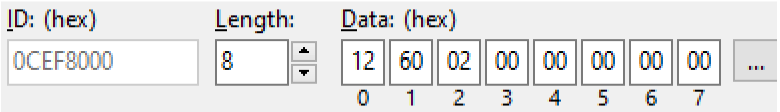


Figure 26 - commands to pre-set X axis to 0°

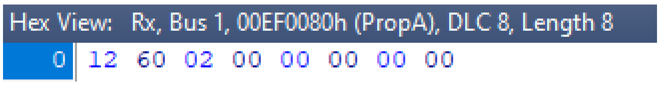


Figure 27 - response from the sensor indicating pre-set is successful (Byte3=00_h)

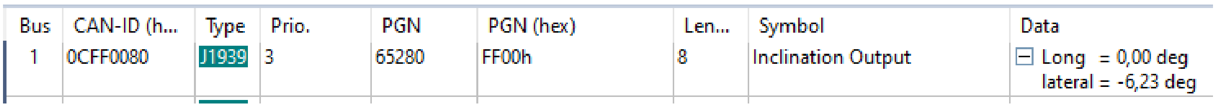


Figure 28 - sensor live output shows that The X axis is zeroed

When an out-of-range pre-set value is sent, the sensor sends “F1” as response indicating “Invalid parameter, parameter out of range” (->6.6 Sensor configuration)

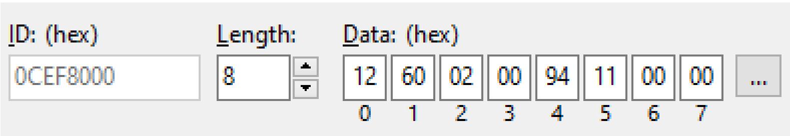


Figure 29 - pre-set X angle to 1194h/45°

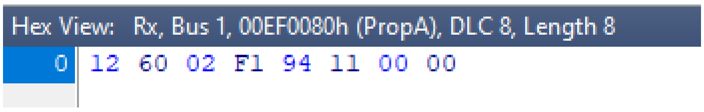


Figure 30 - response from sensor indicating that pre-set is failed. (Byte3=$F1_h$)

1-axis ±180° sensors can be zero adjusted over the full range, the position of the male connector is at customer discretion. 2-axis ±30°/±90° sensors can only be zero adjusted in a horizontal position within an offset limit of ±5°.

After you load factory default settings, the sensor will be restored with the factory zero offset, which means the pre-set inclination value will be restored to 00_h, index 6013_h and 6023_h will be rewritten to a factory default value and you need to zero your sensor again.

6.9. Firmware management

The factory-installed firmware version is stated on the device label.

Figure 31 - Firmware version

It can also be requested with index $100A_h$ sub-index 00_h Manufacturer software version. The message format is "Vx.x.x" in ASCII, for example: V1.0.0.

⚠ *The installed firmware version might vary from the version on the sticker due to a firmware update.*

The firmware release notes are available at www.dis-sensors.com under "downloads/user manuals".

7. SAE J1939 specification

The QG65D J1939 series of devices communicates with the SAE J1939 interface. SAE J1939 uses the CAN protocol to transmit a message on the network. Every message includes an identifier which defines the message priority, who sent it, and what data is contained within it.

More knowledge of J1939 can be found in our **Knowledgebase**.

7.1. PDU (Protocol Data Unit)

The Protocol Data Unit provides a framework for organizing the key information that is sent with every CAN data frame.

PDU format												
SOF	**Identifier**	**SRR**	**IDE**	**Identifier**	**RTR**	**r1**	**r0**	**DLC**	**Data**	**CRC**	**ACK**	**EOF + IFS**
1 bit	11 bits	1 bit	1 bit	18 bits	1 bit	2 bits		4 bits	0 - 8*8 bits	16 bits	2 bits	10 bits

Figure 32 - J1939 PDU format

7.2. CAN-ID (CAN Identifier)

The Extended CAN data frame (CAN 2.0B Frame) with 29-bit identifier is used in the SAE J1939 protocol.

PDU format												
SOF	**Identifier**	**SRR**	**IDE**	**Identifier**	**RTR**	**r1**	**r0**	**DLC**	**Data**	**CRC**	**ACK**	**EOF + IFS**
1 bit	11 bits	1 bit	1 bit	18 bits	1 bit	2 bits		4 bits	0 - 8*8 bits	16 bits	2 bits	10 bits

29-bit CAN-ID

28			25																	8	7							0
priority			Parameter Group Number (PGN)																		Source Address (SA)							

Table 13 - CAN-ID definition

Priority (3 bits)	Message priority during the arbitration process. 0= high and 7=low. Not used by receiver.
PGN (18 bits)	The PGN uniquely identifies the parameter group (PG) that is being transmitted in the message.
SA (8 bits)	This field defines the specific address to which the message is being sent. All other destinations should ignore this message. In the case of the global destination address (255), all devices are required to listen and respond as message recipients

Table 14 - CAN-ID explanation

0CFF0080h

28			25																	8	7							0
0	1	1	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
priority = 3			Parameter Group Number (PGN) = 0FF00h																		Source Address (SA) = 80h							

Figure 33 - Example CAN-ID of inclination output

11-bit identifier devices can be used within the same network without conflict, but it's not defined in J1939 standards.

7.3. PGN (Parameter Group Number)

The J1939 PGN comprises an 18-bit subset of the 29-bit extended CAN ID. The PGN uniquely identifies the parameter group (PG) that is being transmitted in the message. Every PG (grouping of specific parameters) has its own specific definition comprising the assignment of each parameter within an 8-byte data field (size in bytes, location of the LSB), and the transmission rate and priority of the message.

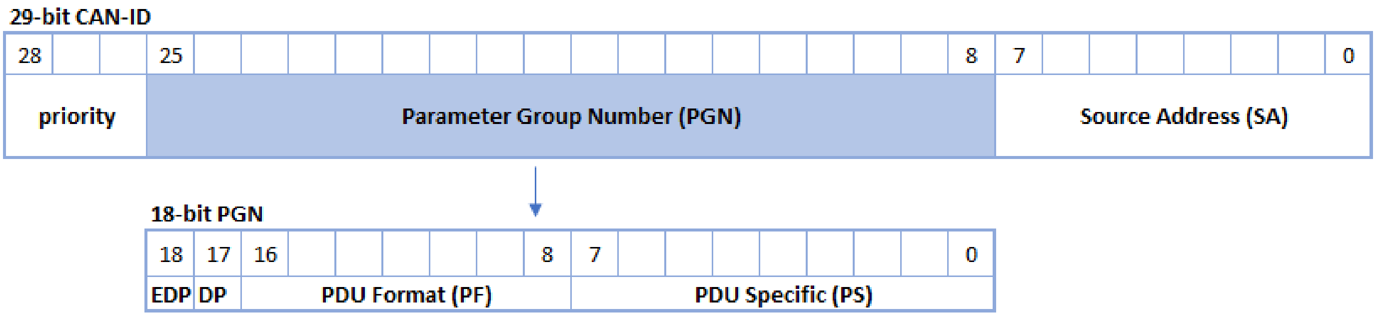


Figure 34 - PGN format

<table>
<tr><td>EDP (Extended Data Page)</td><td>Select a page for the PGNs.</td></tr>
<tr><td>DP (Data Page)</td><td>
<table>
<tr><th>EDP</th><th>DP</th><th>Definition</th></tr>
<tr><td>0</td><td>0</td><td>J1939 Page 0 PGNs</td></tr>
<tr><td>0</td><td>1</td><td>J1939 Page 1 PGNs</td></tr>
<tr><td>0</td><td>0</td><td>Reserved</td></tr>
<tr><td>0</td><td>1</td><td>Diagnostic message</td></tr>
</table>
</td></tr>
<tr><td>PDU format (PF):</td><td>Defines whether a PGN has a PDU1 or PDU2 format.
Determines the PGN assigned to the Data field.
<table>
<tr><th></th><th>Format 1</th><th>Format 2</th></tr>
<tr><td>PF value</td><td>0 – 239d/EF_h</td><td>240_d/F0_h – 255_d/FF_h</td></tr>
<tr><td>PGNs</td><td>2*240 = 480</td><td>2*16*256 = 8192</td></tr>
<tr><td>Usage</td><td>point-to-point messages
or global message</td><td>Global message only
Broadcast message etc.</td></tr>
</table>
</td></tr>
<tr><td>PS – PDU Specific</td><td>This field depends on the value of PDU Format and contains either a destination address or a group extension, depending on PDU Format.</td></tr>
</table>

18	17	16					8	7							0
EDP	DP	PDU Format 1(PF) < 240						Destination Address (DA)							

18	17	16					8	7							0
EDP	DP	PDU Format 2 (PF) >= 240						Group Extension							

DA: defines the specific address to which the message is being sent.

GE: provides extra 4096 PGNs per data page.

Table 15 - PGN definition

PGNs used by DIS J1939 sensors are explained as below:

PGN	PG Name	J1939 Definition	DIS
61184$_d$ (00EF00$_h$)	PropA	This PG uses the destination-specific PDU1 Format allowing manufacturers to direct their proprietary communications to a specific destination node. How the Data field of this message is used is up to each manufacturer.	Sensor configuration is sent with PGN 61184
65280$_d$ (00FF00$_h$)	PropB	This PG uses the PDU2 Format message allowing manufacturers to define the PS (GE) field content as they desire.	Inclination output is sent by PGN 65280.
65283$_d$ (00FF03$_h$)	PropB	This PG uses the PDU2 Format message allowing manufacturers to define the PS (GE) field content as they desire.	Acceleration output is sent by PGN 65283.
60928$_d$ (00EE00$_h$)	AC	The Address Claimed PGN may be used in two ways: to claim an address, and to announce that a CA was unable to claim an address.	ACM
59904$_d$	Request Message	The request message (PGN 59904) for the Address Claimed message (PGN 60928) is used by any CA to request the NAMEs and addresses of CAs in ECUs attached to the network.	RQST

Table 16 - PGN examples

7.4. SPN (Suspect Parameter Number)

SPN is a 19-bit identifier for the CAN signals (parameters) contained in the data. SPNs are grouped by PGNs and can be described in terms of their bit start position, bit length, scale, offset and unit - information required to extract and scale the SPN data to physical values.

The assignment of SPNs can be found in SAE J1939-21 documents. DIS sensors B.V. is using PGN 2551 for definition of inclination and acceleration outputs.

	PGN 65280 to 65535 Proprietary B	Manufacturer Defined Usage (PropB_PDU2)	2551	64 to 14280

Example – SPN 2551 by PGN 65280 Inclination output defined by DIS Sensors B.V.

PGN	Name	Priority	Position in PG	Bit Size	Resolution (scale)	Offset	Data Range
65280_d $FF00_h$	X axis (Longitudinal)	3	0	16	0.01°/bit		-90° - +90°
	Y axis (Lateral)		16	16	0.01°/bit		-90° - +90°

7.5. NAME and ACM (PGN 60928)

Every device shall have one address and an associated **NAME** to communicate on the SAE J1939 network.

SAE J1939 defines a 64-bit NAME to identify the primary function of a controller application. The NAME consists of fields shown in table below.

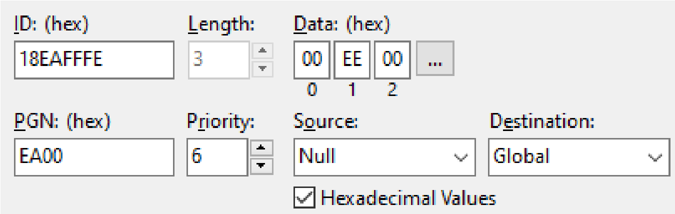
MSB					64 bits				LSB
1 bit	3 bit	4 bit	7 bit	1 bit	8 bit	5 bit	3 bit	11 bit	21 bit
Arbitrary Address Capable	Industry group	Vehicle system Instance	Vehicle System	Reserved	Function	Function Instance	ECU Instance	Manufacturer Code	Identify Number

Table 17 - NAME format

Address Claim, defined in SAE J1939-81, is the process for claiming a network address and associating the NAME, or vehicle function, to that address.

Upon power-up or whenever requested, a device must send an ACM to claim an address. Other devices must compare the newly claimed address with their own to avoid conflicts. When multiple devices claim the same address, the device with lower NAME value uses the address, the others must claim a different address or stop communicating on the network.

A device can send request for the ACM to determine whether addresses claimed by other devices. PGN 59904 (RQST) for ACM (PGN 60928) is described as below:



All requested devices send their ACMs so that you know which devices are currently on the network.

Any CA that is unable to successfully claim an address shall respond with a Cannot Claim Address message. It has the same PGN as ACM but has a source address of 254d (the NULL address).

8. Parameter overview

Like CANopen, parameters of J1939 sensors are also configured via various parameter index. Use PGN 61184 to read/write those parameters. (→ 6.6 Sensor configuration (PGN 61184))

Index	Subindex	Data Type	Access	Parameter Name and description	Factory Default	Detail
1010$_h$	**01$_h$**			**Save all parameters** Write “save” or “65766173$_h$”		9.4
1011$_h$	**01$_h$**			**Restore all parameters** Write “load” or “64616F6C$_h$”		9.5
1018$_h$				**Identity**		
	00$_h$	U8	const	Highest subindex supported	04$_h$	
	01$_h$	U32	r	Vendor ID	000001BD$_h$	
	02$_h$	U32	r	Product code	08000001$_h$ = 1-axis inclination 360° 08000002$_h$ = 2-axes inclination ±90° 08000003$_h$ = 2-axes inclination ±30°	
	03$_h$	U32	r	Revision number	00010000$_h$ = V1.0.0	
	04$_h$	U32	r	Serial number		
3001$_h$	**00$_h$**	U8	rw	**Baud Rate** 02$_h$ = 500 kBit/s 03$_h$ = 250 kBit/s	03$_h$	9.2
3003$_h$	**00$_h$**	U8	rw	**CAN bus termination resistor 120Ω** 00$_h$ = Disable 01$_h$ = Enable	00$_h$	
300F$_h$	**00$_h$**	U8	rw	**Zero adjustment Inclination** 01$_h$ | Zero X-axis | 00$_h$=successful FF$_h$=failed 02$_h$ | Zero X-axis | 00$_h$=successful FE=failed 03$_h$ | Zero X and Y axis | 00$_h$=successful FD$_h$=failed **Zero adjustment Acceleration** 01$_h$ | Zero X-axis | 00$_h$=successful FF$_h$=failed 02$_h$ | Zero Y-axis | 00$_h$=successful FE=failed 03$_h$ | Zero Z-axis | 00$_h$=successful FD$_h$=failed 07$_h$ | Zero all axis | 00$_h$=successful F9$_h$=failed		6.8
3101$_h$	**00$_h$**	U8	rw	**J1939 Address** (Range: 0$_d$ – 254$_d$)	80$_h$	9.1

Index	Subindex	Data Type	Access	Parameter Name and description	Factory Default	Detail
3102$_h$				**PGN 65280 Angle output**		6.5.1
	01$_h$	U32	r	Priority (range: 0-7)	03$_h$	
	02$_h$	U32	r	Cycle time [ms] 0 = deactivated	0064$_h$ = 100ms	
3103$_h$				**PGN 65283 Acceleration output**		6.5.2
	01$_h$	U32	r	Priority (range: 0-7)	03$_h$	
	02$_h$	U32	r	Cycle time [ms] 0 = deactivated	0064$_h$ = 100ms	
6000$_h$	**00$_h$**	U16	r	**Resolution** 10$_d$ = 0.01°, 100$_d$ = 0.1°, 1000$_d$ = 1.0°	10d = 0.01°	
6012$_h$	**00h**	S16	rw	**Pre-set Inclination X-axis**	0000h	
6013$_h$	**00$_h$**	S16	rw	**Offset Inclination X-axis**	0000h	
6022$_h$	**00$_h$**	S16	rw	**Pre-set Inclination Y-axis**	0000h	
6023$_h$	**00$_h$**	S16	rw	**Offset Inclination Y-axis**	0000h	

⚠ *Use 1010h to permanently save communication parameters in the EEPROM of the device, otherwise the changes will be lost after a power cycle. All indices and/or subindices not described in the table are reserved exclusively for factory use.*

Data types used in the application layers are explained in the following table.

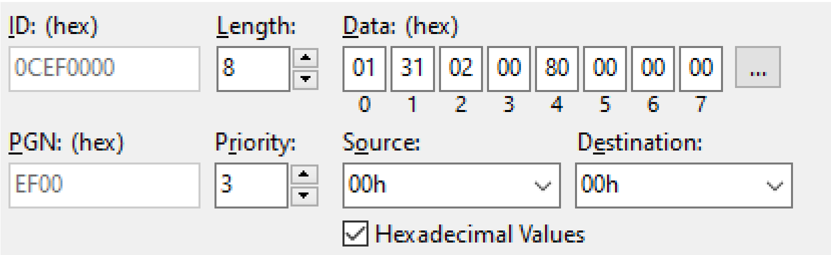
Data type	Definitions
U8	Unsigned 8-bit number (0 – 255$_d$)
U16	Unsigned 16-bit number (0 – 65535$_d$)
U32	Unsigned 32-bit number (0 – 4294967295$_d$)
S8/Integer 8	Signed integer 8-bit number (-128$_d$ – +127$_d$)
S16/Integer 16	Signed integer 16-bit number (-32768$_d$ – +32767$_d$)
S32/Integer 32	Signed integer 16-bit number (-2147483648$_d$ – +2147483647$_d$)

Table 18 - Data type

9. Configuration examples

9.1. Change device address

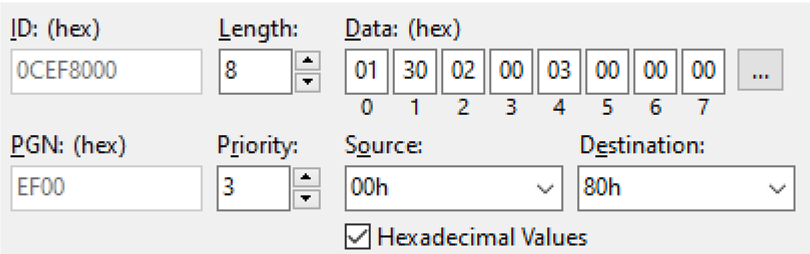
Use index 3101_h sub-index 00_h to change the device address.



Byte 0-1	Index = 3101_h
Byte 2	CMD = 02_h, write to the sensor.
Byte 3	Sub index = 00_h
Byte 4	New Device address = 80_h
Byte 5-7	00 = Not used

9.2. Change baud rate

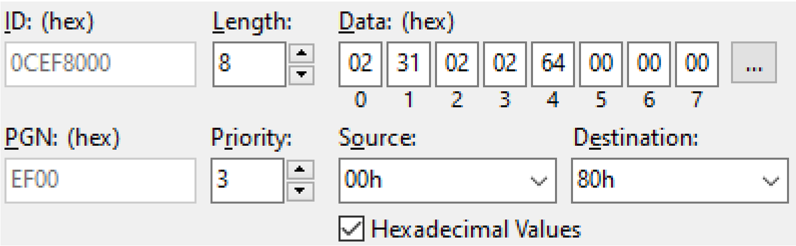
Use index 3001_h sub-index 00_h to change the baud rate.



Byte 0-1	index = 3001_h
Byte 2	CMD = 02_h, write to the sensor.
Byte 3	sub index = 00_h
Byte 4	03_h = 250 kbit/s 02_h = 500 kbit/s
Byte 5-7	00 = Not used

9.3. Enable/Disable/Set cycle time PGNs

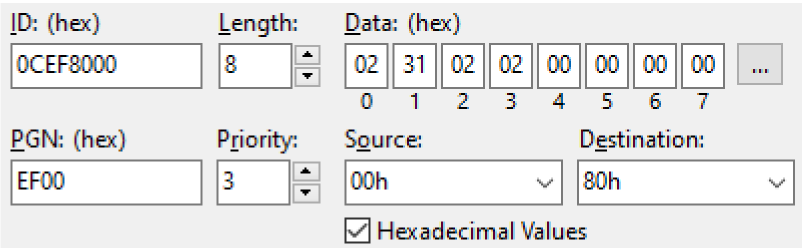
Use PGN cycle time to enable or disable PGNs. Index 3102_h is used for PGN 65280 and Index 3103_h is used for PGN 65283. Below is an example for PGN 65280.



Byte 0-1	Index = 3102_h (parameter used for PGN 65280)
Byte 2	CMD = 02_h, write to the sensor.
Byte 3	Sub index = 02_h
Byte 4	PGN cycle time = 64_h = 100ms Setting PGN cycle time to a non-zero value will enable PGN
Byte 5-7	00 = Not used

Table 19 - Example enable PGN 65280

Disable PGN

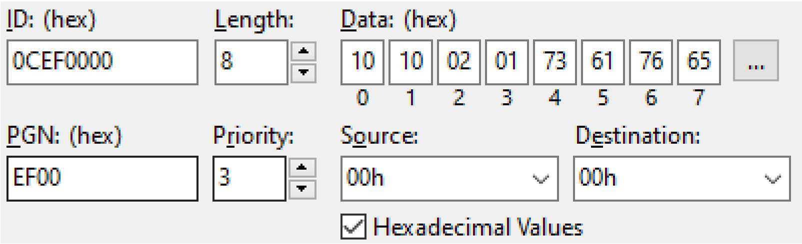


Byte 0-1	Index = 3102_h
Byte 2	CMD = 02_h, write to the sensor.
Byte 3	Sub index = 02_h
Byte 4	PGN cycle time = 00_h Setting PGN cycle time to zero will disable PGN
Byte 5-7	00 = Not used

Table 20 - Example disable PGN 65280

9.4. Save changes to the sensor

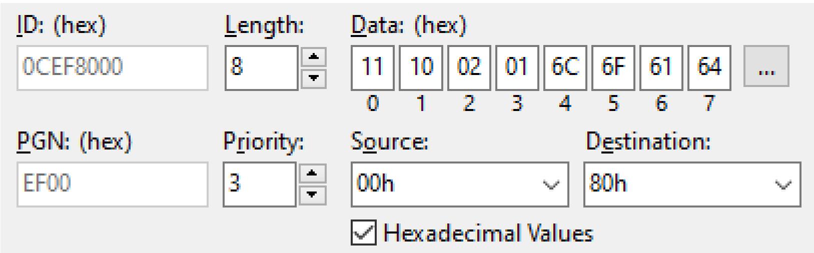
Use Index 1010_h sub-index 01_h



Byte 0-1	Index = 1010_h
Byte 2	CMD = 02_h, write to the sensor.
Byte 3	Sub index = 01_h
Byte 4-7	Write 65766173_h (save)

9.5. Restore factory default

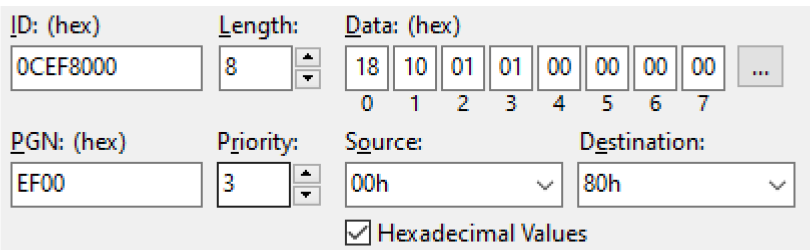
Use Index 1011_h sub-index 01_h



Byte 0-1	Index = 1011_h
Byte 2	CMD = 02_h, write to the sensor.
Byte 3	Sub index = 01_h
Byte 4-7	Write $64616F6C_h$ (load)

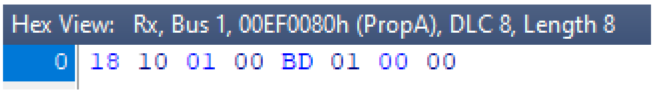
9.6. Read vendor ID

Vendor ID can be read by Index 1018_h sub-index 01_h



Byte 0-1	Index = 1018_h
Byte 2	CMD = 01_h, read sensor
Byte 3	Sub index = 01_h
Byte 4-7	00_h = Not used

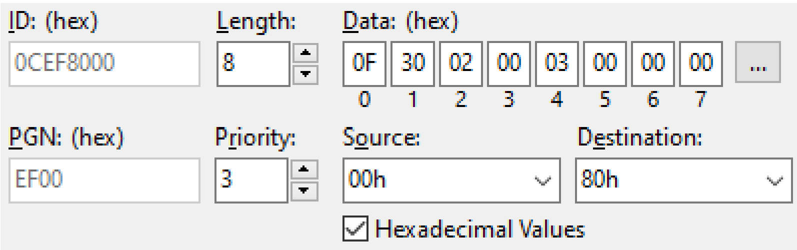
The status reply from the sensor is



Byte 0-1	Index = 1018_h
Byte 2	CMD = 01_h, read sensor
Byte 3	Status reply = 00_h = Read successful
Byte 4-7	Data = $000001BD_h$ = DIS Sensors B.V.

9.7. Zero adjustment

Use index $300F_h$ sub-index 00_h to zero the sensor. Below is an example of zeroing X and Y axis for a 2-axis sensor.



Byte 0-1	Index = $300F_h$
Byte 2	CMD = 02_h, write to the sensor
Byte 3	Sub-index = 00_h
Byte 4-7	Data = 03_h = Inclination Zero adjustment for X and Y axis. **Zero adjustment Inclination** 01_h Zero X-axis 00_h=successful FF_h=failed 02_h Zero Y-axis 00_h=successful FE=failed 03_h Zero X and Y axis 00_h=successful FD_h=failed **Zero adjustment Acceleration** 01_h Zero X-axis 00_h=successful FF_h=failed 02_h Zero Y-axis 00_h=successful FE=failed 03_h Zero Z-axis 00_h=successful FD_h=failed 07_h Zero all axis 00_h=successful $F9_h$=failed

10. Abbreviations and definitions

ACM	Address Claimed Message
CAN	Controller Area Network
CAN-ID	CAN Identifier
PGN	Parameter Group Number
PDU	Protocol Data Unit
SPN	Suspect Parameter Number
MEMS	Microelectromechanical system
DOF	Degrees of freedom
PropA	Proprietary A, PGN 61184
PropB	Proprietary B

11. Normative references

ISO11898-1	Controller area network (CAN) —Data link layer and physical signalling
ISO11898-2	Controller area network (CAN) —High-speed medium access unit
SAE J1939	SAE's family of standards relating to the Controller Area Network (CAN) for heavy-duty vehicles.
IEC 61076-2-101	Connectors for electronic equipment - Part 2-101: Circular connectors – Detail specification for circular connectors M8 with screw- or snap-locking, M12 with screw locking for low voltage applications