USER MANUAL

QG65D CANopen Dynamic Inclinometer (Type H)

V1.0, 2020/12/7

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Contents

1. Safety information

1.1. Intended use

The QG65D CANopen Dynamic Inclinometer is a MEMS-based inclination sensor with CANopen 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 CANopen.
- 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.
- An emergency message with sensor error information is detected. (→ 6.8 Emergency message)

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 CANopen dynamic inclinometer (Type H) with the following model designations:

- QG65D-KIXv-360H-CAN-C(F)M-UL —— 1 axis, measuring range ± 180°, vertical mounting
- QG65D-KDXYh-090H-CAN-C(F)M-UL —— 2 axes, measuring range ± 90°, horizontal mounting
- QG65D-KDXYh-030H-CAN-C(F)M-UL —— 2 axes, measuring range ± 30°, horizontal mounting

DIS product code can be identified here.

2.2. Document revision control

Version	Date	Revision
V1.0	20201127ss	1st release

Table 1 - Document revision

2.3. 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

2.4. Copyright

3. Quick reference

General

- 1-axis ± 180° and 2-axes ± 30°/± 90° dynamic inclinometer
- Output type: CANopen
- Inclination, acceleration, gyroscope outputs defined by Function modes (→ object 3007_h)
- 4 application profiles for inclination measurement in specific applications (→ object 3004_h)
- Sensor outputs can be customised using TPDO mapping parameters (→ object $1A00_h$)
- Internal sample rate MEMS: 1000Hz; output rate: 100 Hz
- Dynamic inclination application limitations: max. acceleration 1.5 g, max. angle rate 500°/s
- Output filter: adjustable 1st order LPF (→ sub 06_h of object 3021_h to 3024_h or object $300E_h$)
- Moving average filter: averaging time interval adjustable from 10 ms to 100 ms (→ sub 07_h of object 3021_h to 3024_h or object $300D_h$)
- An optional configurator is available on request

CAN, CANopen

- CAN interface: CAN2.0 A/B (compliant with ISO11898-1&2)
- CANopen application layer and communication profile: EN50325-4 (CiA301 v4.0 and 4.2.0)
- CANopen device profile for inclinometer: CiA410
- LSS (Layer Setting Service) implemented
- TPDO1 (CAN-ID: 180_h + Node ID) and TPDO2 (CAN-ID: 280_h + Node ID)
- Outputs: inclination X-axis (longitudinal) in object 6010_h; inclination Y-axis (lateral) in object 6020_h
- Internal switchable CAN termination resistor: default off (→ object 3003_h)
- CAN bus bit rate: default 250 kbit/s (→ object 3001_h)
- Node ID: default 01_h (→ object 3000_h range: 01_h – $7F_h$, max. 127 nodes)
- Heartbeat: default on, 2 s (→ object 1017_h)
- Two modes of PDO transmission (→ object 1800_h / 1801_h)
  - Event mode: default on, event timer default 100 ms (range 10 ms – 500 ms)
  - Sync mode: default off
- Vendor ID DIS: $000001BD_h$ (→ object 1018_h)
- Firmware version available via CAN Object Dictionary (→ object 1018_h)
- Serial number format: xxxxxx-xxx (→ object 1018_h)
- Zero adjustment of inclination available via CAN Object Dictionary (→ object $300F_h$).
- Pre-set inclination setting available via CAN Object Dictionary (→ objects 6012_h and 6022_h).
- Bootup in NMT Operational state (→object $1F80_h$)
- Negative values: two's complement
- Byte-sequence on CAN bus: little-endian (least significant byte first)

4. Installation guide

4.1. Mechanical drawing

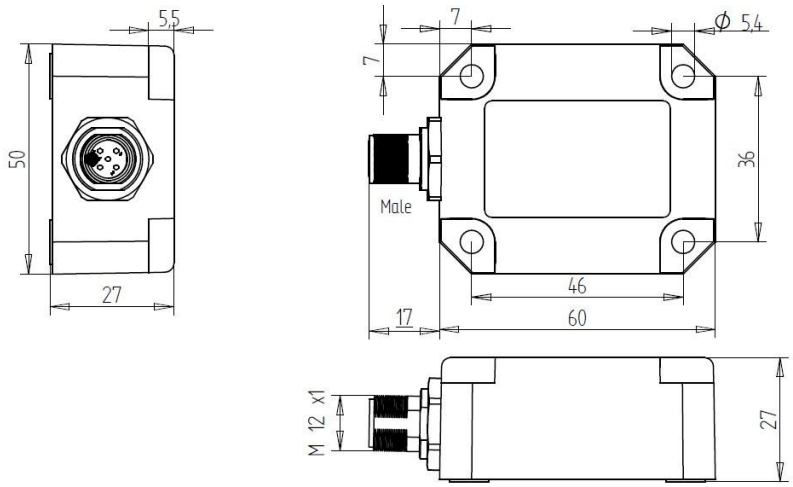


Figure 1 - Mechanical drawing of QG65D with a male M12.

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

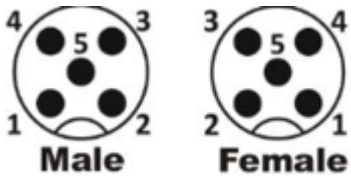


Figure 4 - Pin definition

- 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.
- The power supply must be IEC Class 2 protected.
- 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 CANopen dynamic Inclinometer has an internal 120 Ohm termination resistor. By default, this is disabled, but it can be enabled with object 3003_h.

A separate M12 termination resistor and T-connector are also available as accessories for CANopen devices.

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 male 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. It therefore measures inclination perfectly in dynamic situations, but in static situations it is useless, due to bias drift.

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).

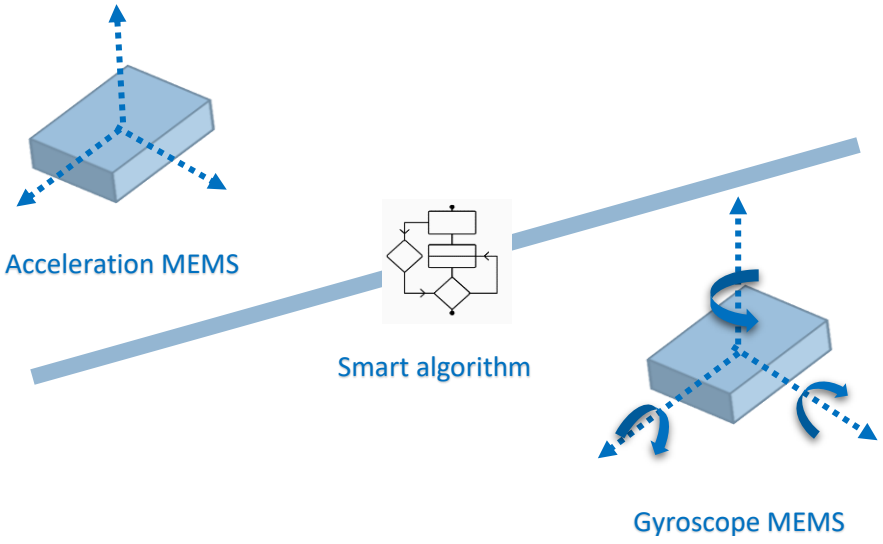


Figure 8 - Measurement principle of the dynamic inclinometer

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.

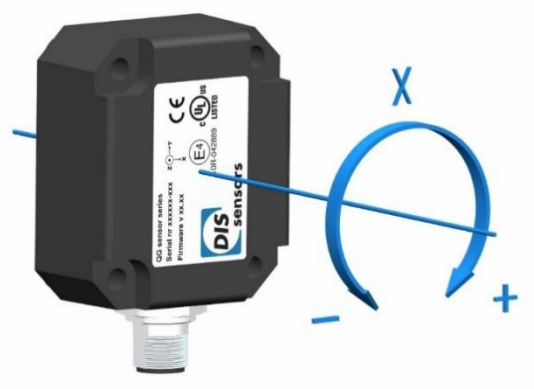


Figure 9 - Measuring axis and direction of 1-axis inclination.

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°.

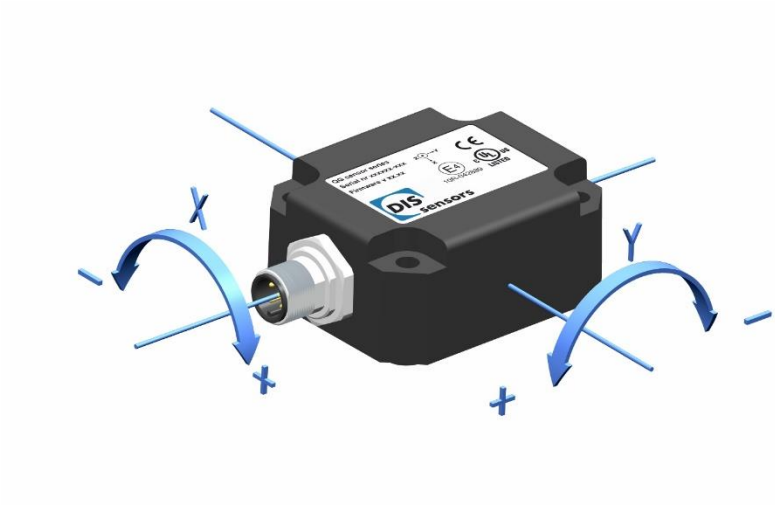


Figure 10 – Measuring axis and direction of 2-axis inclination.

⚠ *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 CAN 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°. In addition, an EMCY message will also be sent, in which the last 5 bytes (00 00 00 00 01/02$_h$) specifies the cross-tilt error on the X or Y axis (→Object 1002h Manufacturer status register).*

6.2.2. Measuring axis and direction for acceleration

In acceleration mode (→6.4 Function mode**)**, 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.

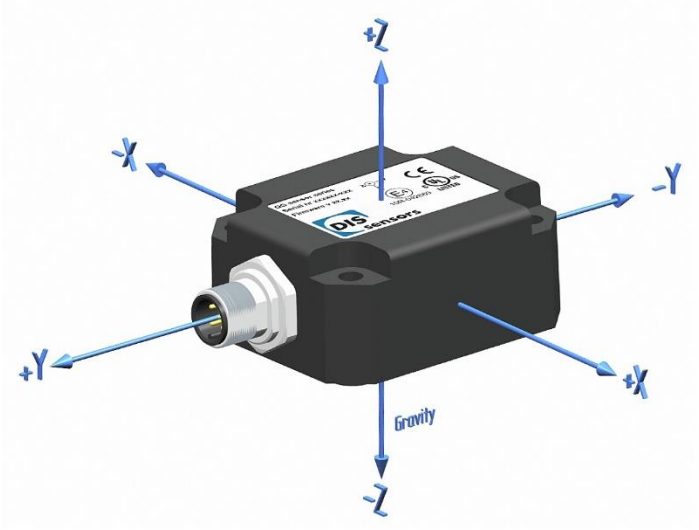


Figure 11 – Measuring axis and direction of acceleration

6.2.3. Measuring axis and direction for gyroscope

In gyroscope mode (→6.4 Function mode**)**, the sensor measures the angular rate on all 3 axes. The measuring direction of three axes in the factory default setting is shown in Figure 12.

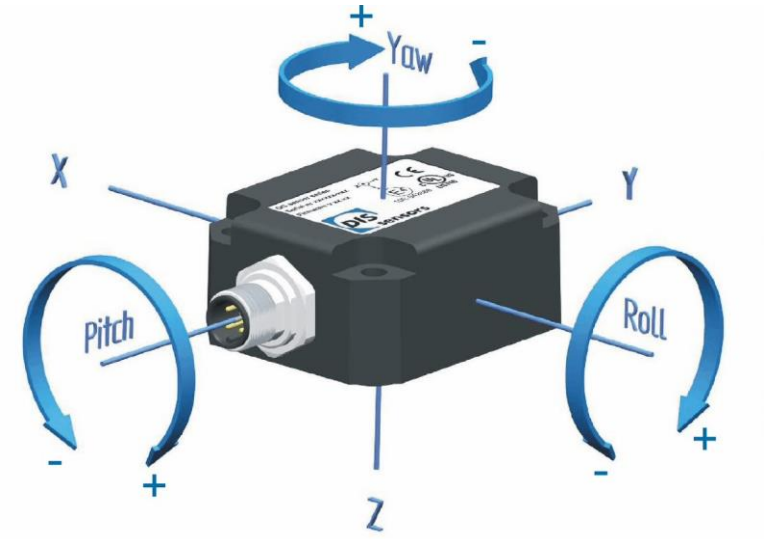
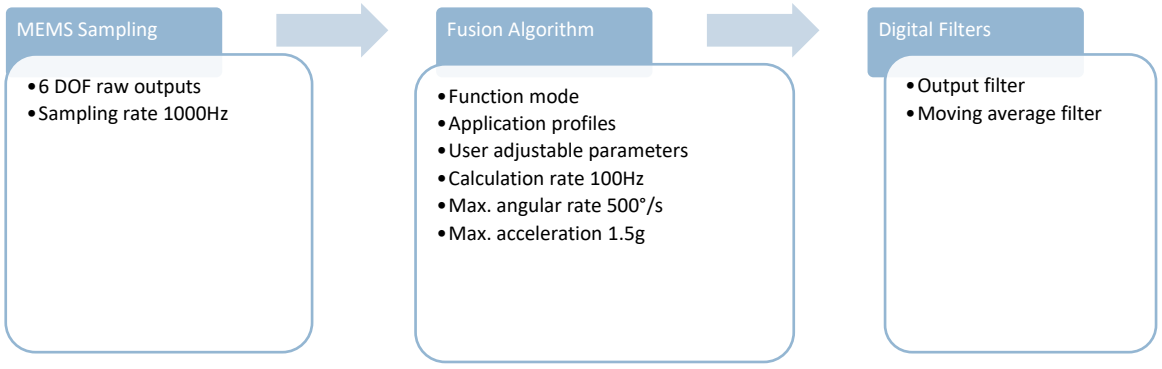


Figure 12 - Measuring axis and direction of gyroscope

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. Based on the selected function mode, application profile and user-adjustable parameters, 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 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. In each application profile, those filters can be enabled and configured using the DIS QG65D configurator, or with the CAN object dictionary.

Output filter

A 1st order low-pass filter is implemented for reduction of bandwidth and filtering noise. Each application profile has its own default filter settings, which can be set via subindex 06_h of CAN object 3021_h to 3024_h. Another way to control the filter settings for the current active application profile is via object $300E_h$. The value you set with $300E_h$ will also be written to the corresponding object for that active application profile (object 3021_h ~ 3024_h). The filter settings are effective on all sensing axes, but by default they are disabled.

By setting a time-constant τ (time in which the output changes to 70% of the step after a step response), the -3 dB frequency can be calculated by the formula $f = 1 / (2\pi*\tau)$. A longer filter time results in a narrower bandwidth and therefore less noise, but also causes a longer phase delay.

⚠ *This -3 dB frequency is independent of TPDO event time. However, when the output filter time-constant is set to a value lower than the TPDO event time, the output filter is automatically disabled. For example, if TPDO event time is set to 100 ms, and output filter time is set to 50 ms, this filter will not work.*

Moving average filter

The final inclination output is an average of the last N samples. The sampling rate of this filter is 10 ms. The various application profiles have different default filter settings. This filter can be controlled via CAN object 3021_h subindex 07_h to 3024_h subindex 07_h. It can also be controlled for the active application profile via CAN object $300D_h$. In this case the sensor will update the correct object of the active application profile (in the range 3021_h subindex 07_h to 3024_h subindex 07_h). The moving average filter is disabled in the factory default application profile 1.

N must be a number from 0_d-10_d. Setting the N to 0_d and 1_d will disable this filter.

The TPDO event timer decides the cycle time of the TPDO message. By default, the sensor sends a new TPDO every 100 ms. This TPDO message contains an inclination measurement which is an average of the preceding N x 10ms samples and is totally independent of the TPDO event time.

Example:
TPDO event timer = 50 ms, N = 7: every 50 ms, a new average inclination value from the previous 70 ms samples will be supplied in the TPDO message.

6.4. Function mode

The QG65D can measure inclination, acceleration and rotation. By selecting the function mode via **object 3007$_h$**, the sensor is configured to function as an inclinometer, accelerometer, gyroscope or a fusion sensor. Once a function mode is selected, the TPDO mapping parameters (→8.1.12, page 31) are automatically configured with the predefined objects and object entries. The user can also define the TPDO mapping objects manually; the function mode is then changed to Mode FF$_h$ (user defined mode).

Function mode	Output	TPDO mapping objects
Mode 0 (default)	**Inclination (CiA410)**	TPDO1: 6010$_h$ - 00$_h$ (1-axis model) TPDO1: 6010$_h$ - 00$_h$, 6020$_h$ - 00$_h$ (2-axis model) TPDO2: disabled
Mode 1	**Inclination (CiA410) alternative orientation**	TPDO1: 6010$_h$ - 00$_h$ (1-axis model inverted) TPDO1: 6020$_h$ - 00h, 6010h - 00h (2-axis model with X and Y swapped, X and Y inverted) TPDO2: disabled
Mode 2	**Inclination (CiA410) + Temperature**	TPDO1: 6010$_h$ - 00$_h$, 6511$_h$ (1-axis model) TPDO1: 6010$_h$ - 00$_h$, 6020$_h$ - 00$_h$, 6511$_h$ – 10$_h$ (2-axis model) TPDO2: disabled
Mode 3	**Acceleration (3 axes)** (Pure acceleration without dynamic effects compensation)	TPDO1: 6401$_h$ - 01$_h$, 6401$_h$ - 02$_h$, 6401$_h$ - 03$_h$ TPDO2: disabled
Mode 4	**Gyroscope (3 axes)**	TPDO1: 6010$_h$ - 07$_h$, 6010$_h$ - 08$_h$, 6010$_h$ - 09$_h$ TPDO2: disabled
Mode 5	**Mode 0 + Mode 3 + Mode 4** (Inclination + Acceleration + gyroscope)	TPDO1: 6010$_h$ - 00$_h$, 6020$_h$ - 00$_h$, 6401$_h$ - 01$_h$, 6401$_h$ - 02$_h$ TPDO2: 6401$_h$ - 03$_h$, 6401$_h$ - 07$_h$, 6401$_h$ - 08$_h$, 6401$_h$ - 09$_h$
Mode FF	**User defined mode** (Output defined by user)	TPDO1: user defined TPDO2: user defined

Table 2 – Sensor output configuration in different function modes.

6.5. Application profiles

The use of application profiles is the best practice for inclination measurement in various applications. Each profile has a unique combination of parameters that balance the processing between acceleration MEMS and gyroscope MEMS, to produce the best measurement quality for that application.

Four application profiles are provided that can be configured via CAN object 3004h. As they are intended to improve the inclination measurement, the profiles are only effective in a function mode where the inclination outputs are valid (mode 0, 1, 2, 5 and FF). For each profile, two parameters are available for optimisation of the outputs.

Application profile	Applications	User adjustable parameters
Profile 0 **Static**	Non-dynamic applications (Gyroscope is disabled)	Output filter (default 100 ms) Moving average filter (default 10)
Profile 1 **Dynamic (fast mode)** **(factory default)**	Dynamic applications with moderate to fast movements/vibrations such as excavation, start/stop driving, rotation, etc.	Output filter (default disabled / 0ms) Moving average filter (default disabled / 0)
Profile 2 **Dynamic (slow mode)**	Dynamic applications with slow movements/vibrations such as cranes, platforms, scissor lifts etc.	Output filter (default 50 ms) Moving average filter (default 10)
Profile 3 **Dynamic (platform levelling)**	Dynamic applications with minor movements/vibrations such as platform levelling, etc.	Output filter (default 100 ms) Moving average filter (default 10)

Table 3 - Application Profiles

User adjustable parameters	Function	Value
Output Filter (subindex 06_h)	1st order LPF filter for all sensing axes. (→ 6.3.3 Digital filters)	Value range: 0_d ~ $10\,000_d$ (ms) A longer filter time results in a smoother reaction on peaks/accelerations, but also a slower reaction to physical movements.
Moving average filter TPDO1, TPDO2 (subindex 07_h, 08_h)	Moving average filter for filtering noise. (→ 6.3.3 Digital filters)	N value range: 0_d – 10_d A greater N (number of samples) results in less noise and a smoother output, but also a slower reaction to physical movements.

Table 4 – User adjustable parameters for application profiles.

The user adjustable parameters can be fine-tuned for the existing application profiles via CAN object 3021_h ~ 3024_h, while objects 3025_h ~ 3027_h are reserved for future profiles.

These parameters are also easily adjusted in the configuration panel of the QG65D configurator (Figure 13).

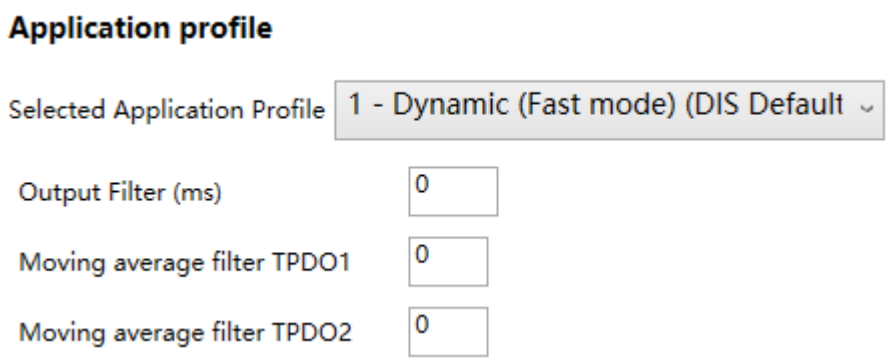


Figure 13 - Application profile in configuration panel

6.6. Output format

Inclination output format: CAN output = 100*α. (α = angle in °, factory default resolution is 0.01°). CAN outputs are sent with PDOs (→7.3 PDO (Reading sensor output).

For example:

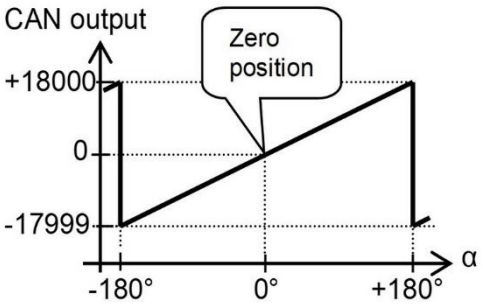


Figure 14 - Output 1-axis ±180° sensor

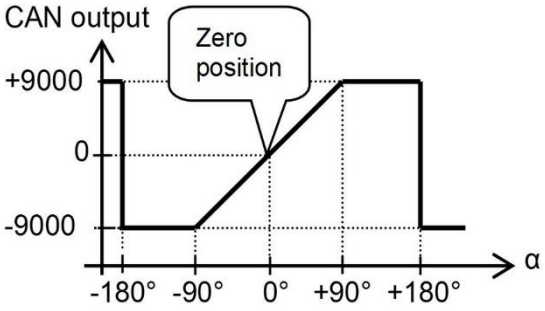


Figure 15 - Output 2-axis ±90° sensor

In Figure 14, the sensor sends 1 axis inclination output with 2 Bytes Integer (Table 5).

Byte1	Byte0
23_h	82_h
Inclination output: $2382_h = 9090_d = 90.9°$	

Table 5 - Output 1-axis ±180° sensor

In Figure 15, the sensor sends 2 axis inclination outputs with 4 bytes integer. The 1st two bytes are the X inclination and the 2nd two bytes are the Y inclination (Table 6).

Byte3	Byte2	Byte1	Byte0
Y inclination		**X inclination**	
00_h	82_h	$0B_h$	$C8_h$
$0080_h = 130_d = 1.3°$		$0BC8_h = 3016_d = 30.16°$	

Table 6 - TPDO1 of QG65D-KDXYh-090H-CAN-C(F)M

Besides inclination values, the device also provides acceleration, angular rate and device temperature. The user can customise the device outputs by changing the TPDO mapping parameters. (→Object $1A00_h$, $1A01_h$ TPDO Mapping parameter). For example, 1st two bytes are the device temperature, the 2nd two bytes are the inclination output (Table 7).

Byte3	Byte2	Byte1	Byte0
23_h	82_h	00_h	$1A_h$
Inclination output: $2382_h = 9090_d = 90.9°$		Device temperature: $001A_h = 26_d$ °C	

Table 7 - Customised TPDO message

6.7. Boot-up procedure

When the device is powered on, it automatically enters NMT Initialisation state. In this state, the device will be initialised with the default parameters of the manufacturer-specific profile area and of the standardized device profile area. When initialisation is complete, a bootup message 00_h will be sent with the heartbeat (700_h + Node ID). If an error is detected during the boot up, an emergency message with the error information will be sent.

6.8. Emergency message

When the device detects an internal error, an emergency object (80_h+Node ID) with 8-bytes message is transmitted. The error code is inserted at the location of object 1003h (pre-defined error field), and the device enters the error state which is defined in Object 1029_h Error Behaviour (default: NMT pre-operational state).

The first 3 bytes indicates the error code specified in CiA301 and error register specified in Object 1001_h. The remaining 5 bytes indicate the manufacturer-specific error specified in Object 1002_h.

Byte8 Byte7 Byte6 Byte5 Byte4	Byte3	Byte2 Bye1
Manufacturer-specific error (1002_h) 00 00 00 00 00_h = no error 00 00 00 00 01_h = X-axis Cross-Tilt Error 00 00 00 00 02_h = Y axis Cross-Tilt Error 00 00 00 00 08_h = EEPROM error More: → 8.1.2 Object 1002h Manufacturer status register	**Error register (1001_h)** 00_h = no error 01_h = Generic error 05_h = Voltage error 81_h = Manufacturer specific error More: → 8.1.1 Object 1001h Error register	**EMCY error code (CiA301)** 00 00_h = No error. Always sent at start-up 10 xx_h = Generic error 50 00_h = Voltage error 50 30_h = Error during sensor initialization 60 00_h = Watchdog error 62 00_h = Device software error 80 00_h = Sent at every change of the manufacturer status register 81 xx_h = CANopen stack message 82 xx_h = CANopen stack message FF 20_h = EEPROM error

Table 8 – format EMCY message

Examples:

00 00 00 00 01 05 50 00_h – Voltage error detected during initialization

00 00 00 00 01 81 80 00_h – Cross-tilt error on X axis

When all errors are corrected, the device enters the error-free state and transmits an emergency object with the error code 'reset error / no error' containing all 0 s.

6.9. LSS (Layer Setting Service, according to CiA305-DSP)

Layer setting services (LSS) and protocols are used to request or change the settings of three parameters of the physical layer, data link layer and application layer on a CANopen device via the CAN network. It is supported only in NMT stop mode or pre-operational mode.

The QG65D device is serviced as a CAN device, and a CAN master such as a PLC can detect and configure those three parameters with LSS:

- Node ID (→object 3000_h)
- CAN bus bit rate (→object 3001_h)
- LSS address: 128-bit number to identify each node uniquely, consisting of the vendor ID, product code, revision number and serial number with 32 bits each (→object 1018_h)

After changing parameters using LSS, a save action must be performed. Normally your LSS tool can be configured to perform an automatic save (store), as shown below:

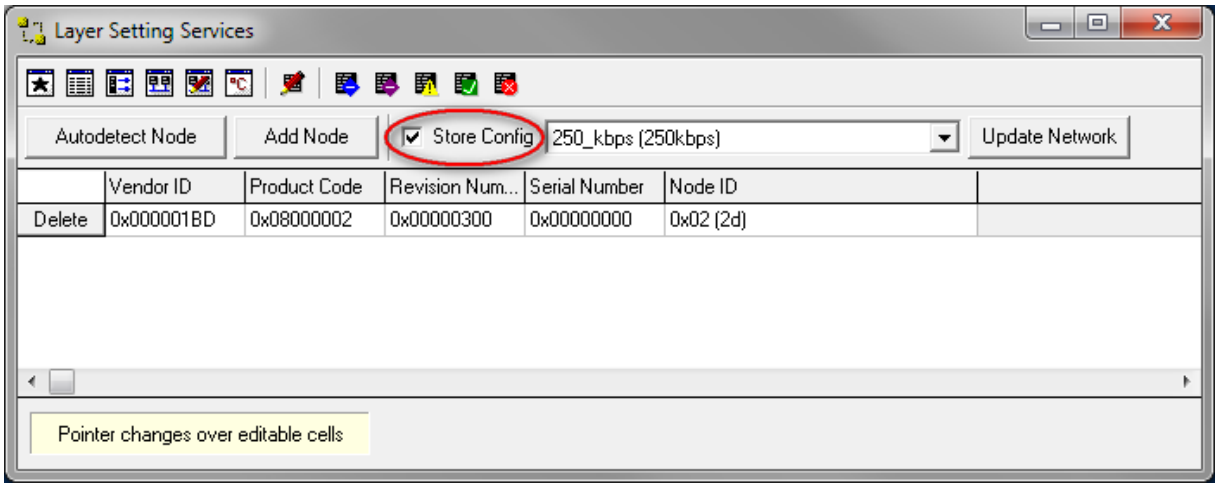


Figure 16 - LSS save action

6.10. Firmware management

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

Figure 17 - Firmware version

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

⚠ *The currently-installed firmware version might vary from the version on the sticker due to a firmware update. Always check the actual version in the object dictionary.*

It will soon be possible to update the firmware via the DIS configuration tool. This tool can check the current firmware version in your device and upload the new firmware to the device. The user can upload the new firmware to the device by simply clicking a button (Figure 18).

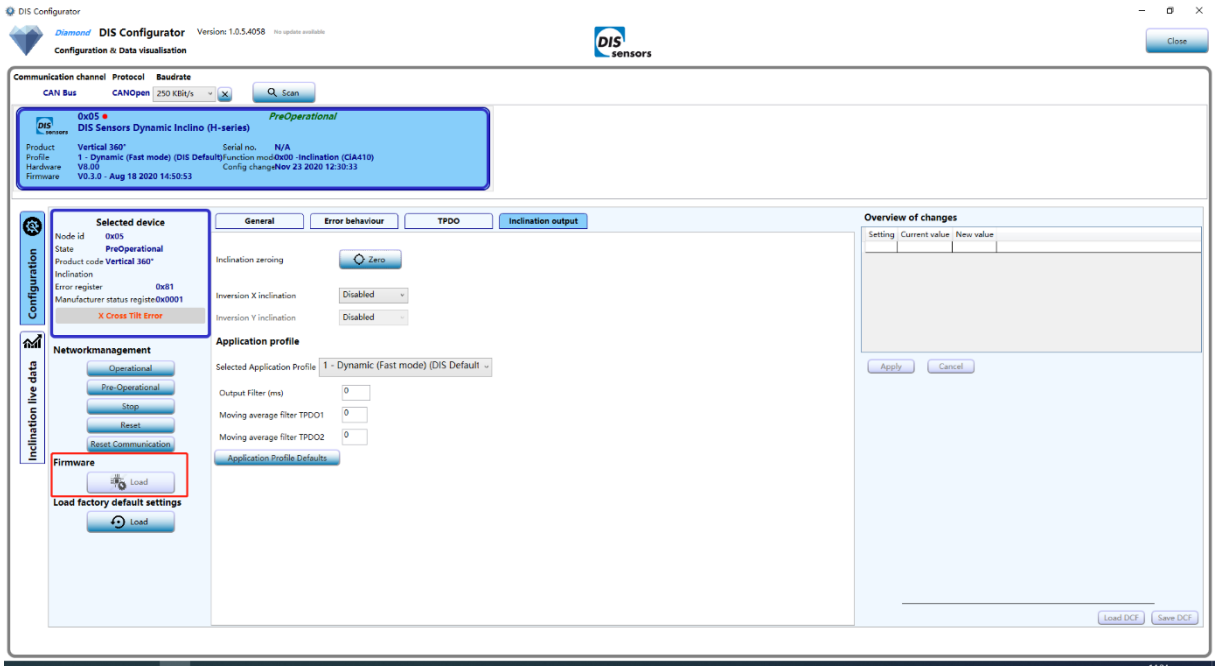


Figure 18 - Firmware update via configurator

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

6.11. 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 object 1011_h, 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 standard factory default - communication parameters

Parameters	Object	DIS standard default value
COB-ID SYNC	1005_h	00000080_h
Communication Cycle Period	1006_h	00_h
Guard Time	$100C_h$	00_h

Life Time factor	$100D_h$	00_h
COB-ID EMCY	1014_h	00000081_h
Emergency Inhibit Time	1015_h	00_h
Producer heartbeat time	1017_h	2000_d – 2000 ms
Error behaviour	1029_h	00_h - Switch to pre-operational
NMT Start-up behaviour	$1F80_h$	00000000_h – Start in operational
Node ID	3000_h	01_h
Baud Rate	3001_h	03_h - 250 kBit/s
Termination resistor	3003_h	00_h - Disabled
Error masks	$301E_h$	$80001D40_h$

Table 9 – DIS standard factory default communication parameters

DIS standard factory default - application parameters

Parameters	Object	DIS standard default value
Application Profile	3004_h	01_h – Profile1: Dynamic (fast mode)
Function mode	3007_h	00_h – Inclination (CiA 410)
Moving Average filtering	3022_h sub 07_h and $300D_h$	00_h – Moving Average filtering OFF
Output Filter time	3022_h sub 06_h and $300E_h$	00_h – Output filter OFF
Operating parameters	6011_h, 6021_h	02_h
Pre-set values (zero values)	6200_h	00_h

Table 10 – DIS standard factory default application parameters

6.12. 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 → Object 6013_h, 6023_h Offset inclination value. (page 39)

Zero adjustment can be done in 2 ways, and can be repeated at any time.

1. **Via → Object 300Fh Zero adjustment.**
   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 object 300Fh. The offset value will be stored permanently in the device without "save" to object 1010_h.
2. **Via → Object 6012h, 6022h Pre-set inclination value.**
   To set the output of X/Y axis to 0°, write 0000_h to object 6012_h / 6022_h at your desired 0° position. The

offset will be stored in Object 6013_h, 6023_h Offset inclination value. Those parameters must be saved to the device (→ 8.1.6 Object 1010_h Store parameters.)

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°.

6.13. EDS & DCF

The "Electronic Data Sheet" (EDS file) is a file format that describes the communication behaviour and the object dictionary entries of a device. In fact, it is a template. This allows tools such as CAN configuration tools to handle the device properly. The file format is described in CiA306 V1.3.0.

The EDS file contains all possible settings and functions for the device by describing the CAN object dictionary for the device to be set by CAN commands.

The EDS file does not contain a customer specific configuration description (the values of the object dictionary, such as the chosen baud rate, TPDO1 event time, Node ID, etc.). For this purpose, the customer can generate a DCF file (Device Configuration File) with all customer specific settings in the same format as the EDS file. The DCF file is in fact an emulation of the EDS file.

After loading the DCF file into the device, the settings can be stored permanently into the EEPROM. (→ 8.1.6 Object 1010_h Store parameters)

The EDS files are available at www.dis-sensors.com under "downloads".

7. CANopen specification

The QG65D series of devices communicates with the CANopen interface according to CiA 301. The device profile CiA 410 is implemented. All parameters and measured values can be accessed by the Object dictionary. More knowledge of CANopen sensors can be found in our **Knowledgebase**.

7.1. CANopen Communication Objects (COB)

A CANopen device contains a communication module that provides communication objects and the appropriate functionality to transport data items via the underlying network structure. In other words: objects that you send or receive from the device for different communication purposes.

The communication objects are described by the services and protocols. Objects we often use:

Common COBs	Description
SDO	Service Data Object provides direct access to object entries of a CANopen device's object dictionary
PDO	Process Data Object is used to transfer real-time data
NMT	Network Management object is used to execute network management services to initialize, monitor, restart or stop the sensor
SYNC	Synchronization object provides the basic network synchronization mechanism
EMCY	Emergency object is used to indicate internal errors
Heartbeat	Heartbeat is produced by the device to indicate its status. It Is one of the error control services in CANopen.
LSS	Layer Setting Service (LSS) enables the LSS master to modify the LSS slaves' node-ID and to switch the entire network from one data rate to another.

Table 11 – Common communication objects

7.2. Predefined CAN-IDs

Every CAN message on the bus starts with a CAN-ID. A CAN device that uses 11-bit identifiers is commonly called CAN 2.0 A and a CAN device that uses 29-bit identifiers is commonly called CAN 2.0B. For CANopen sensors, DIS Sensors implements an 11-bit CAN-ID which consists of a 4-bit function code and 7-bit Node ID.

Examples:

Object SYNC has function code 0001b, resulting CAN-ID 000,1000,0000b=080h.

Object TPDO1 has function code 0011b, resulting CAN-ID 001,1000,0000b=180h.

CiA has pre-defined CAN-IDs for common CAN objects as below:

CAN objects	CAN-ID
NMT	000_h
SYNC	080_h
Emergency	080_h + Node ID
TPDO1	180_h + Node ID
TPDO2	280_h + Node ID
SDO tx (server -> client)	580_h + Node ID
SDO rx (client -> server)	600_h + Node ID
Heartbeat	700_h + Node ID

Table 12 – Predefined CAN-ID of common objects.

7.3. PDO (Reading sensor output)

The Process Data Object (PDO) is used to process real time data. The measured values such as inclination, temperature, etc. are sent with TPDOs. PDOs are transmitted in the NMT operational state only and may be transmitted when a mapped process data item changes.

A DIS device supports 2 TPDOs. In factory default mode, TPDO1 sends the sensor output, TPDO2 is disabled. The communication parameters of TPDOs can be configured with object 1800_h and 1801_h. The data transmitted with TPDOs can be configured with TPDO mapping parameters object $1A00_h$ and $1A01_h$.

7.4. SDO (configuring Object Dictionary)

The Service Data Object (SDO) is used to set and request values from the object dictionary. There are three types of SDO services used to transmit data. In this context, the device is considered as a server (owner of the object dictionary) and communication is viewed from the server.

SDO Services	Description	SDO Request (600_h + Node ID)	SDO Response (580_h + Node ID)
SDO upload	Read from device Server -> Client	40_h = Expedited Read	43_h = Read reply 4 bytes 47_h = Read reply 4 bytes $4B_h$ = Read reply 4 bytes $4F_h$ = Read reply 4 bytes
SDO download	Write to device Client -> Server	23_h = Expedited Write, 4 Bytes 27_h = Expedited Write, 3 Bytes $2B_h$ = Expedited Write, 2 Bytes $2F_h$ = Expedited Write, 1 Byte	60_h = Write Reply
SDO abort transfer	Indicates error		80_h = Error/Abort code

Table 13 - Expedited SDO transfer command specifier

Common SDOs to configure sensors and SDO abort codes can be found in the knowledge base.

7.5. NMT state

CANopen devices are initialized, started, monitored, reset or stopped using NMT services. The NMT state of the device can be set by applications such as PLC software. Table 14 shows the communication objects that exist in each NMT state.

NMT State	PDO	SDO	SYNC	EMCY	Heartbeat	Description
Pre-operational	✗	✓	✓	✓	✓ $7F_h$	Configuration mode: PDOs do not exist. This is the recommended mode for configuration of PDOs.
Operational	✓	✓	✓	✓	✓ 05_h	Take care with configuration in this mode, as some objects are protected and may not be changed in this mode.
Stopped	✗	✗	✗	✗	✓ 04_h	All communication is forced to stop except the heartbeat/node guarding.
Bootup	✗	✗	✗	✗	✓ 00_h	Device is initialised with default power-on values

Table 14 – NMT states and communication objects

7.6. Object Dictionary (device parameters)

The object dictionary is a collection of data items that influence the behaviour of the application objects, the communication objects and the state machine used on this device. Each object is addressed using a 16-bit index and an 8-bit subindex.

Index Range	Object	Description
1000_h – $1FFF_h$	Communication profile area	Parameters for communication such as SDO, PDO, NMT etc.
2000_h – $5FFF_h$	Manufacturer-specific profile area	Parameters for device-specific features such as function mode, etc.
6000_h – $9FFF_h$	Standardized profile area	Parameters that are common for inclinometers.
Other	Reserved for factory use	Do not use

Table 15 – Structure of object dictionary

All parameters in the object dictionary can be accessed with SDOs.

See also 8. CAN Object dictionary overview.

8. CAN Object dictionary overview

8.1. Communication profile (Index 1000h - 1FFFh)

Index	Subindex	Data Type	Access	Object Name and description	Factory Default	Detail
1000h	00h	U32	r	**Device type** (QG65D complies with device profile CiA410)	0101019Ah – 1-axis inclination 0102019Ah – 2-axis inclination	
1001h	00h	U8	r	**Error register** 00h – No error 81h – Error detected	00h	8.1.1
1002h	00h	U8	r	**Manufacturer status register**	00000000h – No error	8.1.2
1003h	00h	U32		**Number of errors**. Range: 00h to FEh	00h	8.1.3
	01h...FEh	U32	r	**Error Code**	NA	
1005h	00h	U32	rw	**COB-ID SYNC**	00000080h	8.1.4
1006h	00h	U32	r	**Communication cycle period**	00000000h – No SYNC transmission	8.1.5
1008h	00h	VSTR	const	**Manufacturer device name**	"DIS Sensors Dynamic Inclino Sensor"	
1009h	00h	VSTR	const	**Manufacturer hardware version**	Depends on sensor. e.g. "V8.00"	
100Ah	00h	VSTR	const	**Manufacturer software version**	Depends on sensor. e.g. "V1.0.0"	
1010h				**Store parameters**	Write "save" to subindex 01h to 03h	8.1.6
	00h	U8	const	highest subindex supported	04h	
	01h	U32	rw	Save all parameters	01h	
	02h	U32	rw	Save communication parameters.	01h	
	03h	U32	rw	Save application parameters	01h	
1011h				**Restore default parameters**	Write "load" to subindex 01h to 03h	8.1.8
	00h	U8	const	Highest subindex supported	04h	
	01h	U32	rw	Restore all parameters	01h	
	02h	U32	rw	Restore communication parameters	01h	
	03h	U32	rw	Restore application parameters	01h	
1013h	00h	U32	rw	**High Resolution Timestamp**	00h	
1014h	00h	U32	rw	**COB-ID EMCY**	00000081h (80h + Node ID)	8.1.9
1017h	00h	U16	rw	**Producer heartbeat time**	7D0h – 2000 ms	
1018h				**Identity object**		
	00h	U8	const	Highest subindex supported	04h	
	01h	U32	r	Vendor ID	000001BDh	
	02h	U32	r	Product code	08000001h – 1-axis inclination 360 08000002h – 2-axes inclination ±90 08000003h – 2-axes inclination ±30	
	03h	U32	r	Revision number	00000208h – V0.2.8	
	04h	U32	r	Serial number	e.g. 77542822h = 2002004-002d	
1020h				**Verify configuration**		8.1.9
	00h	U8	const	Highest subindex supported	02h	
	01h	U32	rw	Configuration date	number of whole days since 1-1-1984	
	02h	U32	rw	Configuration time	number of ms since midnight	
1029h				**Error behaviour**		8.1.11
	00h	U8	const	Highest subindex supported	02h	
	01h	U8	rw	Communication error 00h – switches to pre-operational 01h – does not change state 02h – switches to stopped 03h ... FFh – reserved	00h	
	02h	U8	rw	Profile- or manufacturer-specific error 00h – switches to pre-operational	00h	

Index	Subindex	Data Type	Access	Object Name and description	Factory Default	Detail
				01h – does not change state 02h – switches to stopped 03h … FFh – reserved		
1800h				**TPDO1 communication parameter**		8.1.11
	00h	U8	const	Highest subindex supported	05h	
	01h	U32	rw	COB-ID used by TPDO1 40000181h – TPDO1 enabled C0000181h – TPDO1 disabled	40000181h (CAN-ID of TPDO1: 180h + Node ID)	
	02h	U8	rw	Transmission type FFh – event-driven 00h – sync	FFh	
	03h	U16	rw	Inhibit time	0000h	
	05h	U16	rw	Event timer	0064h – TPDO1 event time 100 ms	
1801h				**TPDO2 communication parameter**		8.1.11
	00h	U8	const	Highest subindex supported	05h	
	01h	U32	rw	COB-ID used by TPDO2 40000281h – TPDO2 enabled C0000281h – TPDO2 disabled	C0000281h (CAN-ID of TPDO2: 280h + Node ID)	
	02h	U8	rw	Transmission type FFh – event-driven 00h – sync	FFh	
	03h	U16	rw	Inhibit time	0000h	
	05h	U16	rw	Event timer	0064h – TPDO2 event time 100 ms	
1A00h				**TPDO1 mapping parameter**		8.1.13
	00h	U8	rw	Number of mapped application objects in TPDO	01h – 1 axis ±180° 02h – 2 axes ±30°/±90°	
	01h	U32	rw	Mapping object1	60100010h	
	02h	U32	rw	Mapping object2	60200010h	
	03h	U32	rw	Mapping object3	00000000h	
	04h	U32	rw	Mapping object4	00000000h	
1A01h				**TPDO2 mapping parameter**		8.1.13
	00h	U8	rw	Number of mapped application objects in TPDO	00h – Disabled	
	01h	U32	rw	Mapping object1	64010110h	
	02h	U32	rw	Mapping object2	64010210h	
	03h	U32	rw	Mapping object3	64010310h	
	04h	U32	rw	Mapping object4	00000000h	
1F80h	00h	U32	rw	**NMT Start-up behaviour** 00000004h: start in state pre-operational 00000000h: start in state operational	00000000h	8.1.13

Table 16 - Communication Profile

To permanently save communication parameters in the EEPROM of the device, use only CAN Object 1010h, 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.

8.1.1. Object 1001_h Error register

This object indicates the type of a detected error. This is a part of the EMCY message (→6.8 Emergency message).

Bit	Error type	Example
0	Generic error	00_h - No error (this bit is set to 1 whenever another error bit is set)
1	Current	03_h
2	Voltage	05_h
3	Temperature	09_h
4	Communication error	11_h
5	Device profile specific	21_h
6	Reserved, always 0	
7	Manufacturer-specific	81_h - Manufacturer error detected

Table 17 – Error register

8.1.2. Object 1002_h Manufacturer status register

This object defines the manufacturer error codes. Each bit represents a specific type of error. When an error is detected, the bit will be set to 1. This is a part of the EMCY message (→ 6.8 Emergency message).

Value	Error
00000000_h	No error
00000001_h	Inclination X axis (longitudinal) cross tilt error
00000002_h	Inclination Y axis (lateral) cross tilt error
00000004_h	Inclination X axis (longitudinal) out of range indication
00000008_h	Inclination Y axis (lateral) out of range indication
00000010_h	Temperature Under operational limit (e.g. T < -40°C, specified in the datasheet.)
00000020_h	Temperature Over operational limit (e.g. T > +85°C, specified in the datasheet.)
00000040_h	Actual power error (e.g. supply voltage too low)
00000080_h	Power error since last reset (memorized)
00000100_h	EEPROM Error
00000200_h	Flash Error
00000400_h	Sensor element Error
00000800_h	Watchdog Error
00001000_h	Error handler activated Error
00002000_h - 80000000_h	Unused Error bits

Table 18 - Manufacturer error code

The error code can be mapped into the TPDO message via Object $301F_h$.

8.1.3. Object 1003h Predefined error field

This object provides an error history of the device. The error codes are saved in the subindex starting with 01h. The most recent error is always shown on the top. These error codes are transmitted with the emergency object.

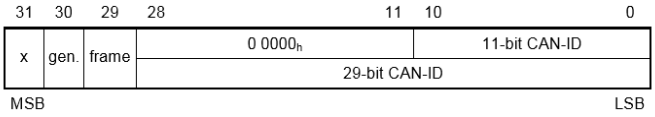
- Subindex 00h indicates the number of existing errors that are recorded in the array starting at subindex 01h.
- If an error is detected, the error code will be stored in subindex 01h and higher. Same error code will also be sent via the emergency object. In doing so it provides an error history.

Subindex	Description	Value
00h	Number of errors detected	No error: 00h
01h	The latest error code	See 6.8 Emergency message
02h … 10h	Oldest error - highest subindex A maximum of 16 errors (emergency messages) are stored.	

⚠ *Writing 00h to subindex 00h will delete the entire error history.*

8.1.4. Object 1005h COB-ID SYNC message

The structure of the COB-ID of SYNC object is specified as below:



QG65D series devices are configured with a default COB-ID of 00000080h, which means:

- 11-bit CAN-ID is valid by default
- CAN-ID of SYNC is 080h

8.1.5. Object 1006h Communication cycle period

This object defines the SYNC interval. The value must be supplied as a multiple of µs. If the value is set to 0000 0000h the transmission of SYNC messages will be disabled.

8.1.6. Object 1010_h Store parameters

Use this object to save the customised settings such as Node ID, baud rate, etc. to the internal EEPROM. User can store parameters in both NMT operational and pre-operational state.

Procedures:

- Write “save” to sub-index 01h = All parameters will be stored.
- Write “save” to sub-index 02h = Parameters of communication profile (Index from 1000h to 1FFFh) will be stored.
- Write “save” to sub-index 03h = Parameters of application profile (Index from 6000h to 9FFFh) will be stored.
- Write “save” in ASCII or “65766173h” have the same effect.

⚠ *An NMT request or a new power cycle is required to enable the stored settings.*

8.1.7. Object 1011_h Restore factory default parameters

Use this object to restore the factory default values for the parameters of the communication profile, device profile and application profile. The factory default values of standard DIS devices are specified in Table 9, Table 10 and the object dictionary overview tables. Customised devices may have different factory default values, which may deviate from this manual. See the datasheet of your customized product for these customized factory default values. You can restore the factory default in both NMT operational and pre-operational state.

Procedures:

- Write “load” to sub-index 01h = All parameters will be restored.
- Write “load” to sub-index 02h = Parameters of communication profile (Index from 1000h to 1FFFh) will be restored.
- Write “load” to sub-index 03h = Parameters of application profile (Index from 6000h to 9FFFh) will be restored.
- Write “load” in ASCII or “64616F6Ch” have the same effect.

⚠ *A direct NMT restart or 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 (see 8.1.6 above).*

8.1.8. Object 1014_h COB-ID EMCY

This object configures the COB-ID for the EMCY write service. The factory default COB-ID of EMCY is 00000081_h, which indicates:

- EMCY exists
- 11-bit CAN-ID is valid
- CAN-ID of EMCY is 81_h (default: 80_h + Node ID 01_h)

⚠ *It is not recommended to change the CAN-ID of EMCY to a different value.*

8.1.9. Object 1020_h verify configuration

This object provides the downloaded configuration date and time. It is used by configuration tools to compare the current device configuration date with their DCF files and determine whether reconfiguration is necessary.

8.1.10. Object 1029_h error behaviour

This object configures the device to enter the selected NMT state when a serious failure is detected. By default, subindex 01h and 02h are both preconfigured with the default value of 00h, which means the device shall autonomously enter pre-operational state.

Subindex	Error type	Error behaviour
01h	Communication error	00_h – Change to NMT state pre-operational (only if currently in NMT state Operational) 01_h – No change of the NMT state 02_h – Change to NMT state Stopped 03_h … FF_h – reserved
02h	Profile- or manufacturer-specific error	

Table 19 – Object 1029_h error behaviour

Failures include the following communication errors:

- Bus-off state of the CAN interface
- Life guarding event with the state ‘occurred’ and the reason 'time out'
- Heartbeat event with state ‘occurred’ and the reason 'time out"
- Device internal failures

8.1.11. Object 1800_h, 1801_h TPDO communication parameter

The QG65D series device supports 2 TPDOs: object 1800h configures the communication parameters of TPDO1; object 1801h configures those of TPDO2.

Subindex	Description	Value
01h	**Defines the COB-ID of TPDO** Default CAN-ID of TPDO1 = 180h + Node ID. Default CAN-ID of TPDO2 = 280h + Node ID.	4000181_h – Enable TPDO1 $C000181_h$ – Disable TPDO1
02h	**TPDO transmission type** Synchronous: TPDO is transmitted after the SYNC Event-driven: TPDO is transmitted at any time based on the occurrence of an internal event.	00_h – synchronous FF_h – event-driven (default)
03h	**Inhibit time**	0000_h – Disabled
05h	**Event timer** defines the interval of TPDO. The value is defined as multiple of 1 ms.	0064_h – TPDO1 event time 100 ms 0000_h – Disabled.

Table 20 - TPDO communication parameter

8.1.12. Object $1A00_h$, $1A01_h$ TPDO Mapping parameter

Object $1A00_h$ contains the mapping parameters for TPDO1.

Object $1A01_h$ contains the mapping parameters for TPDO2.

The value indicates the index, subindex of the mapped object, and the data length.

For example, with factory default settings:
- TPDO1 mapping parameter of a 1-axis ±180° inclinometer is configured as in Table 21
- TPDO1 mapping parameter of a 2-axis ±30°/±90° inclinometer is configured as in Table 22
- TPDO2 mapping is disabled by default.

$1A00_h$	TPDO1 mapping parameter	Object description	
00_h	Number of mapped application objects in TPDO1	01_h	TPDO1 consists of value from only 1 object.
01_h	Mapping object1	60100010_h	Index: 6010_h, subindex: 00_h, data length: 10_h=16bits. Inclination X-axis (longitudinal)

Table 21 – Default mapping parameters of TPDO1 1-axis ±180°

$1A00_h$	TPDO1 mapping parameter	Object description	
00_h	Number of mapped application objects in TPDO1	02_h	TPDO1 consists of value from 2 objects.
01_h	Mapping object1	60100010_h	Index: 6010_h, subindex: 00_h, data length: 10_h=16bits. Inclination X-axis (longitudinal)
01_h	Mapping object1	60200010_h	Index: 6020_h, subindex: 00_h, data length: 10_h=16bits. Inclination Y-axis (lateral)

Table 22 – Default mapping parameters of TPDO1 2-axis ±30°/±90°

TPDO mapping procedure

The following procedure must be used for re-mapping, which may take place during either of the NMT states Pre-operational and Operational.

Step	Description	Value example
1	Disable TPDO	$1800_h.01_h = C0000181_h$ $1801_h.01_h = C0000281_h$
2	Disable TPDO mapping	$1A00_h.00_h = 00_h$ $1A01_h.00_h = 00_h$
3	Modify mapping by changing the values of the corresponding subindices.	$1A00_h.01_h = 60100010_h$ $1A00_h.02_h = 60200010_h$ $1A01_h.01_h = 64011010_h$
4	Enable mapping by setting subindex 00h to the number mapped objects.	$1A00_h.00_h = 02_h$ $1A01_h.00_h = 01_h$
5	Enable TPDO	$1800_h.01_h = 40000181_h$ $1801_h.01_h = 40000281_h$

Table 23 – Procedure for configuring TPDO mapping parameters

The TPDO mapping parameters various according to the user-selected Function Mode.

8.1.13. Object $1F80_h$ NMT start-up behaviour

This object configures the NMT start-up state. In factory default configuration, the device enters NMT Operational state after it passes all internal tests. In this state, device output will be sent with TPDO1, and a heartbeat with value "05_h" will be sent indicating that the sensor is now in "Operational" state. To have the device start instead in "Pre-operational" state, write "00000004_h" to this object.

Value	Description
00000000h	Start in state Operational (default setting for DIS devices)
00000004h	Start in state Pre-operational

Table 24 – NMT start-up state configuration

8.2. Manufacturer-specific profile (2000h - 5FFFh)

Index	Subindex	Data type	Access	Object name and description	Factory default	Detail
3000h	**00h**	U8	rw	**Node ID** (Range: 01h - 7Fh)	01h	
3001h	**00h**	U8	rw	**Baud Rate** 00h = 1000 kBit/s 01h = 800 kBit/s 02h = 500 kBit/s 03h = 250 kBit/s 04h = 125 kBit/s 05h = 100 kBit/s 06h = 50 kBit/s 07h = 20 kBit/s 08h = 10 kBit/s	03h	
3003h	**00h**	U8	rw	**CAN bus termination resistor 120Ohm** 00h: Disable 01h: Enable	00h	4.4
3004h	**00h**	U8	rw	**Application Profile** 00h = Profile0 01h = Profile1 02h = Profile2 03h = Profile3 04h = Profile4 (future use) 05h = Profile5 (future use) 06h = Profile6 (future use)	01h	8.2.1
3007h	**00h**	U8		**Function Mode**	00h	8.2.2
			rw	00h = Mode 0		
			rw	01h = Mode 1		
			rw	02h = Mode 2		
			rw	03h = Mode 3		
			rw	04h = Mode 4		
			rw	05h = Mode 5		
			r	FFh = Mode FF (user defined mode)		
300Dh				**Moving average filter**		6.3.3
	00h	U8	r	Highest subindex supported		
	01h	U8	rw	Moving average number N for TPDO 1	00h	
	02h	U8	rw	Moving average number N for TPDO 2	00h	
300Eh	**00h**	U16	rw	**Output filter**	00h	6.3.3
300Fh	**00h**	U8	rw	**Zero adjustment Inclination** 01h Start zero adjustment X-axis 02h Start zero adjustment Y-axis 03h Start zero adjustment X and Y axis	00h	8.2.3
301Eh	**00h**	U32	rw	**Manufacturer status register error mask** mask which bits will trigger the manufacturer-specific error behaviour.		8.2.4
301Fh				**Manufacturer status register mapping**		8.2.5
	00h	U8	r	Highest subindex supported		
	01h	U8	r	Manufacturer Status Register bits 0 - 7		
	02h	U8	r	Manufacturer Status Register bits 8 - 15		
	03h	U8	r	Manufacturer Status Register bits 16 - 23		
	04h	U8	r	Manufacturer Status Register bits 24 - 31		
3021h				**Parameters for application profile 0**		
	00h	U8	r	Highest subindex supported	08h	

Index	Subindex	Data type	Access	Object name and description	Factory default	Detail
	01_h - 05_h	S8	rw	Reserved	0_d	
	06_h	U16	rw	Output filter	100_d	8.2.7
	07_h	U8	rw	Moving average filter TPDO1	10_d	8.2.8
	08_h	U8	rw	Moving average filter TPDO2	0_d	
3022_h				**Parameters for Application Profile 1**		
	00_h	U8	r	Highest subindex supported	08_h	
	01_h - 05_h	S8	rw	Reserved	0_d	
	06_h	U16	rw	Output filter	0_d	8.2.7
	07_h	U8	rw	Moving average filter TPDO1	0_d	8.2.8
	08_h	U8	rw	Moving average filter TPDO2	0_d	
3023_h				**Parameters for Application Profile 2**		
	00_h	U8	r	Highest subindex supported	08_h	
	01_h - 05_h	S8	rw	Reserved	0_d	
	06_h	U16	rw	Output filter	50_d	8.2.7
	07_h	U8	rw	Moving average filter TPDO1	10_d	8.2.8
	08_h	U8	rw	Moving average filter TPDO2	0_d	
3024_h				**Parameters for Application Profile 3**		
	00_h	U8	r	Highest subindex supported	08_h	
	01_h - 05_h	S8	rw	Reserved	0_d	
	06_h	U16	rw	Output filter	100_d	8.2.7
	07_h	U8	rw	Moving average filter TPDO1	10_d	8.2.8
	08_h	U8	rw	Moving average filter TPDO2	0_d	
3025h				**Parameters for Application Profile 4 (future use)**		
	00h	U8	r	Highest subindex supported	08h	
	01_h - 08_h	S8	rw	Reserved	0_d	
3026h				**Parameters for Application Profile 5 (future use)**		
	00h	U8	r	Highest subindex supported	08h	
	01_h - 08_h	S8	rw	Reserved	0_d	
3027h				**Parameters for Application Profile 6 (future use)**		
	00h	U8	r	Highest subindex supported	08h	
	01_h - 08_h	S8	rw	Reserved	0_d	
3028h				**Parameters for Application Profile 7(future use)**		
	00h	U8	r	Highest subindex supported	08h	
	01_h - 08_h	S8	rw	Reserved	0_d	

Table 25 – Application-specific profile

⚠ *To permanently save application-specific parameters in the EEPROM of the device, use only CAN Object 1010h, 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.*

8.2.1. Object 3004h Application profile

Use object index 3004h, subindex 00h, to select an application profile (→ 6.5 Application profiles). Configure user-adjustable parameters via objects 3021h ~ 3027h.

Value	Profile
00h	Profile 0 – Static
01h	Profile 1 – Dynamic (fast mode) (factory default)
02h	Profile 2 – Dynamic (slow mode)
03h	Profile 3 – Dynamic (platform levelling)
04h - 06h	Profile 4 ~ 6 – Reserved for future use

Table 26 – Object 3004h Application profile

8.2.2. Object 3007h Function mode

Use this object to select a function mode (→ 6.4. Function mode).

Access	Value	Function Mode	Description
rw	00h	Mode 0	**Inclination (CiA410)**
rw	01h	Mode 1	**Inclination (CiA410) alternative orientation** (X and Y swapped, X and Y inverted)
rw	02h	Mode 2	**Inclination (CiA410) + Temperature**
rw	03h	Mode 3	**Acceleration (3 axes)** (Pure acceleration without dynamic effects compensation)
rw	04h	Mode 4	**Gyroscope (3 axes)**
rw	05h	Mode 5	**Mode 0 + Mode 3 + Mode 4** (Inclination + Acceleration + gyroscope)
r	FFh	Mode FF	**User defined mode** (Output defined by user)

Table 27 - Object 3007h 00h -function mode

8.2.3. Object 300Fh Zero adjustment Inclination

To perform a zero adjustment, write the corresponding value to subindex 00h (→ 6.12 Zero adjustment).

Write to 300Fh 00h		Response by reading 300Fh 00h
01h	Start zero adjustment X-axis - inclination	00h = Successful; FFh = Failed
02h	Start zero adjustment Y axis - inclination	00h = Successful; FEh = Failed
03h	Start zero adjustment X and Y axis - inclination	00h = Successful; FDh = Failed

Table 28 – Object 300Fh entries description

8.2.4. Object 301Eh Manufacturer status register error mask

Use the error mask to select the error bit in object 1002h that triggers the manufacturer-specific error behaviour. Set this bit to 1 to trigger the error behaviour, or 0 to ignore the error.

Bit	Error
0	Inclination X axis (Longitudinal) Cross Tilt Error
1	Inclination Y axis (Lateral) Cross Tilt Error
2	Inclination X axis (Longitudinal) Out of Range indication
3	Inclination Y axis (Lateral) Out of Range indication

4	Temperature under operational Limit (e.g. T < -40°C, specified in the datasheet.)
5	Temperature over operational Limit (e.g. T > +85°C, specified in the datasheet.)
6	Actual power error (e.g. Supply voltage too low)
7	Power error since last reset (memorized)
8	EEPROM error
9	Flash error
10	Sensor element error
11	Watchdog error
12	Error handler activated error
13 ~ 30	Unused error bits
31	ON/OFF sending of EMCY message '0x8000 Monitoring' at every change of the manufacturer status register bits.

Table 29 – object 1002_h Error bit

The factory default value is $80001D40_h$ ($10000000000000000001110101000000_b$), which includes following errors:

- Bit 6: Actual power error.
- Bit 8: EEPROM error
- Bit 10: Sensor element error
- Bit 11: Watchdog error
- Bit 12: Error handler activated error
- Bit 31: Send EMCY message

The error behaviour is set via → Object 1029_h error behaviour.

8.2.5. Object $301F_h$ Manufacturer status register mapping

Use object $301F_h$ to map the manufacturer error code (→ 8.1.2 Object 1002_h Manufacturer status register) into the TPDO messages.

Subindex	Manufacturer status register mapping
00h	Highest subindex supported
01h	Manufacturer status register bits 0 - 7
02h	Manufacturer status register bits 8 - 15
03h	Manufacturer status register bits 16 - 23
04h	Manufacturer status register bits 24 - 31

Table 30 – Manufacturer status register mapping object

For example, to get the first 8 bits of the manufacturer error code in the TPDO output, set the TPDO1 mapping parameters to $301F0108_h$ (→ Object $1A00_h$, $1A01_h$ TPDO Mapping parameter).

8.2.6. Object 3021_h ~ 3027_h User adjustable parameters for application profile

In each application profile, a group of parameters are used to improve the measurement of inclination values. Currently only 3 parameters are implemented, and other subindices are reserved for future use (→ 6.5 Application profiles).

Subindex	Parameter name	Data type	Value range
01_h - 05_h	Reserved	S8	
06_h	Output filter	U16	0_d ~ 10000_d

07_h	Moving average filter TPDO1	U8	0_d ~ 10_d
08_h	Moving average filter TPDO2	U8	0_d ~ 10_d

Table 31 – Parameters for application profile

8.2.7. Subindex 06_h Output filter

Use subindex 06_h of objects 3021_h – 3027_h to set the filter time τ for a **1st order LPF** for all sensing axes in a specific application profile (→6.3.3 Digital filters). Use object $300E_h$ if you also wish to set this filter for the active application profile.

The cut-off frequency is calculated using this formula: $\mathbf{F_{-3\ dB} = 1/2\pi\tau}$.

τ is the time-constant with a value range of 0ms (off) ~ 10000 ms.

8.2.8. Subindex 07_h, 08_h Moving average filter TPDO1 and TPDO2

Use subindex 07_h and 08_h of objects 3021_h ~ 3027_h to set the average number N for the moving average filter for the TPDOs in a specific application profile (→6.3.3 Digital filters).
Use object $300D_h$ if you also wish to set this filter for the current active application profile.

Value Range	Description
00_h	Moving average filter disabled (factory default)
01_h	Moving average filter disabled.
02_h – $0A_h$	Output is averaged with the last 20 ms – 100 ms samples.

Table 32 – moving average filter TPDO

8.3. Standardized device profile (6000h – 9FFFh) (CiA410)

Index	Subindex	Type	Access	Object name and description	Factory default	Detail
6000_h	**00_h**	U16	r	**Resolution** 1_d=0.001, 10_d=0.01, 100_d=0.1, 1000_d=1.0	10_d	
6010_h	**00_h**	S16	r	**Inclination X-axis (longitudinal)** Output X-axis. Inclination [°] with the resolution in object 6000_h	No	
6011_h	**00_h**	U8	rw	**Operating parameter for Inclination X-axis (longitudinal)** bit0 = 1: inverted; 0: normal bit1 = 1: pre-set value included; 0: pre-set value excluded.	02_h	8.3.1
6012_h	**00_h**	S16	rw	**Pre-set Inclination X-axis**	0000_h	8.3.2
6013_h	**00_h**	S16	rw	**Offset Inclination X-axis**	0000_h	8.3.3
6020_h	**00_h**	S16	r	**Inclination Y-axis (lateral)** Output Y axis. Inclination [°] with the resolution in object 6000_h	No	
6021_h	**00_h**	U8	rw	**Operating parameter for Inclination Y-axis (lateral)** bit0 inversion = 1: inverted; 0: normal bit1 scaling = 1: enable; 0: disable	02_h	8.3.1
6022_h	**00_h**	S16	rw	**Pre-set Inclination Y-axis**	0000_h	8.3.2
6023_h	**00_h**	S16	rw	**Offset Inclination Y-axis**	0000_h	8.3.3
6401_h				**Sensor Outputs**		8.3.4
	00_h	U8	r	Highest subindex supported	0Fh	
	01_h	S16	r	X acceleration [mg]		
	02_h	S16	r	Y acceleration [mg]		
	03_h	S16	r	Z acceleration [mg]		
	04_h	S16	r	X inclination scale ±180° [0.01°]		
	05_h	S16	r	Y inclination scale ±180° [0.01°]		
	06_h	S16	r	Reserved		
	07_h	S16	r	X rotation [0.01°/s]		
	08_h	S16	r	Y rotation [0.01°/s]		
	09_h	S16	r	Z rotation [0.01°/s]]		
	$0A_h$	S16	r	Temperature [0.1 °C]	Realtime e.g. 251h	
	$0B_h$	S16	r	X acceleration dynamic compensated [0.1 mg]		
	$0C_h$	S16	r	Y acceleration dynamic compensated [0.1 mg]		
	$0D_h$	S16	r	Z acceleration dynamic compensated [0.1 mg]		
	$0E_h$	U16	r	X inclination scale 0°-360° [0.01°]		
	$0F_h$	U16	r	Y inclination scale 0°-360° [0.01°]		
6511_h	**00_h**	S16	r	**Device Temperature [1°C]**	No	

Table 33 - Standardized device profile

⚠ *To permanently save application-specific parameters permanent in the EEPROM of the device, use only CAN Object 1010h, otherwise the changes will be lost after a power cycle.*

8.3.1. Object 6011_h, 6021_h Operating parameter

Use the operating parameter to set the +/- direction of measurement, and whether the pre-set value should be calculated (scaling).

Index	Subindex	Value			
6011_h **6021_h**	00_h	Bit 0	Inversion	0 1	Disable (DIS default) Enable (inverted)
		Bit 1	Scaling	0 1	Disable Enable

Table 34 - Operating parameter

If scaling is enabled, the actual output will be calculated with the pre-set value in Object 6012_h and 6022_h. (see below).

If scaling is disabled, the actual output is the unscaled physically measured inclination value.

8.3.2. Object 6012_h, 6022_h Pre-set inclination value

Use these objects to store pre-set inclination values for the X and Y axis at a certain position, with the resolution given in object 6000_h. The outputs will be then adjusted to the stored pre-set value. The offset is stored in Object 6013_h, 6023_h Offset inclination value.

Index	Value	Example
6012_h	Pre-set inclination X-axis	0000_h - 0°
6022_h	Pre-set inclination Y axis	0100_h- 1°

Table 35 – Object 6012_h/6022_h Pre-set inclination value

2-axis ±30°/±90° sensors can only be pre-set in a horizontal position within an offset limit of ±5°.

8.3.3. Object 6013_h, 6023_h Offset inclination value

These objects store the offset inclination values for the X and Y axis after the pre-set is done.

Index	Value	Example
6013_h	Pre-set inclination X-axis	-9007_d (1-axis Sensor pre-set at -90.07° position)
6023_h	Pre-set inclination Y axis	$+0200_d$ (2-axis Sensor pre-set at Y=+2.00° position)

Table 36 – Object 6013_h/6023_h Offset inclination value

8.3.4. Object 6401_h Sensor outputs

Various types of outputs are stored in object 6401_h. These values can be mapped into TPDOs (→8.1.12 Object $1A00_h$, $1A01_h$ TPDO Mapping parameter).

Subindex		Output Types	Description
00_h	U8	Highest subindex supported	$0F_h$
01_h	S16	X acceleration [mg]	Acceleration value without dynamic effects compensation.
02_h	S16	Y acceleration [mg]	
03_h	S16	Z acceleration [mg]	
04_h	S16	X inclination scale ±180° [0.01°]	X inclination output on a scale of -180° to +180°.
05_h	S16	Y inclination scale ±180° [0.01°]	
06_h	S16	reserved	
07_h	S16	X rotation (Roll) [0.01°/s]	Angular rate from gyro MEMS on a scale of -327°/s to +327°/s, with clipping outside this range.
08_h	S16	Y rotation (Pitch) [0.01°/s]	
09_h	S16	Z rotation (Yaw) [0.01°/s]]	
$0A_h$	S16	Temperature [0.1 °C]	Temperature measured by internal MEMS sensing element.
$0B_h$	S16	X acceleration dynamic compensated [0.1 mg]	Acceleration value with dynamic effects compensation.
$0C_h$	S16	Y acceleration dynamic compensated [0.1 mg]	
$0D_h$	S16	Z acceleration dynamic compensated [0.1 mg]	
$0E_h$	U16	X inclination scale 0°-360° [0.01°]	X inclination output on a scale of 0° to 360° (0 - 36000). The same value as object 6010h.
$0F_h$	U16	Y inclination scale 0°-360° [0.01°]	Y inclination output on a scale of 0° to 360° (0 - 36000). The same value as object 6010h.

Table 37 – Sensor outputs

8.4. Data type

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 ($-2147483648_d – +2147483647_d$)
VSTR	Visible String

Table 38 - Data type

9. Configuration tool

The QG65D CANopen dynamic Inclinometer can be easily configured using the configuration tool developed by DIS Sensors. The tool also displays live data from the sensor. The configuration tool consists of a configuration kit and PC software. The configuration kit can be ordered separately, and the software can be downloaded from our website.

The configurator runs best in full HD display mode (1920x1080p)

9.1. Configuration kit

The QG65D CANopen configuration kit comprises:

- Item 1: USB-CAN dongle. (Peak USB-CAN IPEH Interface adaptor)
- Item 2: CAN power box with power adapter connection
- Item 3: 0.3 m CAN cable for connecting the sensor
- Item 4: Power adaptor. (Figure 20)

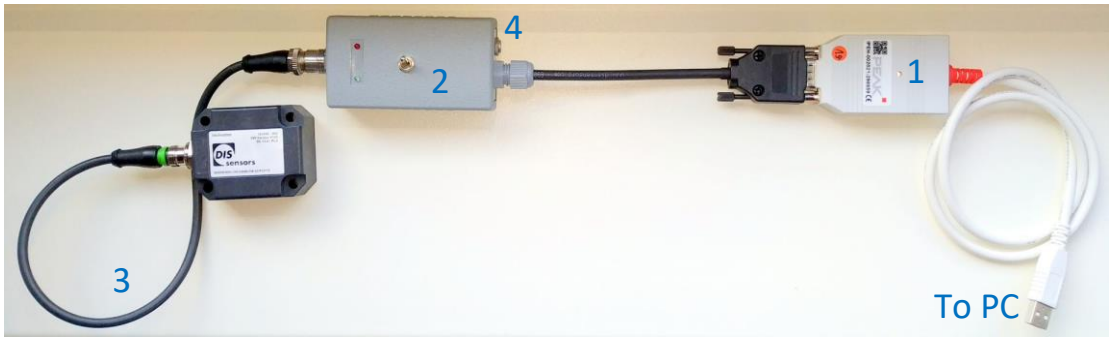


Figure 19 - Connection of QG65D configurator

The USB-CAN dongle (item 1) provides the communication between USB and CAN interface. Note that DIS has modified the Peak USB-CAN IPEH Interface adaptor to forward a 5 V power supply to the CAN power box (item 2). If a standard (unmodified) Peak USB-CAN adaptor is used, the included power adaptor (item 4) must be used.

The CAN power box (item 2) provides the voltage supply to the sensor devices. When only 1 or 2 sensors are connected, sensors can be powered via the USB-CAN dongle (item 1) by the 5 V USB power. If more than 2 sensors are connected, then the power adapter (item 4) must be used instead. This power adapter can support up to 32 dynamic Inclinometers from DIS Sensors.

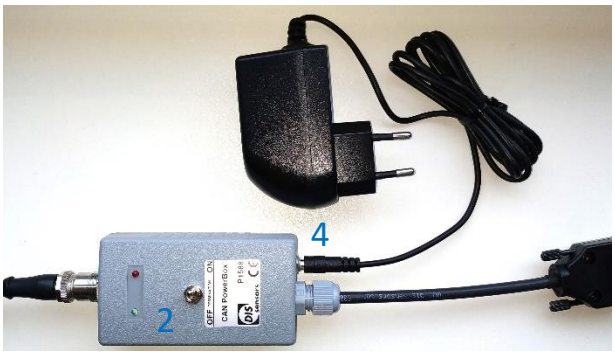


Figure 20 - Power adapter for the CAN power box

The CAN power box is also equipped with a switch to control the internal CANbus termination resistor within the CAN power box. The label clearly shows “on” and “off”.

Figure 21 - CAN power box

Two LEDs on the CAN power box indicate the power status. The green LED (connection indication) will be lit when it is connected correctly to the PC. The red LED (current overload indication) will be lit when the USB port is overloaded (max. 250 mA) to protect your PC or laptop. If you use the power adapter to supply the CAN power box, then the internal power supply and the current overload protection are disabled.

⚠ *If the CAN configurator is not used ‘stand-alone’ (i.e. only configurator + DIS sensor) but is connected to a powered CANbus system, then this CANbus system must be powered with Vcc > 20 V dc. Otherwise, the USB / DIS configurator will have to supply power to the entire CAN system chain, which can potentially harm the PC and connected items.*

⚠ *The QG65D configuration kit will supply 18Vdc on Vcc and Gnd to the connected CAN systems/CAN sensors. Connecting sensors from other brands could potentially harm the equipment.*

The configuration tool can be loaned on request free of charge for pilot testing.

The QG65D configuration kit may be used in an ambient temperature range of +10 °C to +50 °C without power adapter, or 0 °C to +40 °C with power adaptor.

9.2. PC software

The PC software and a detailed manual can be download from the DIS website free of charge. The software provides a portal for both sensor configuration and live data monitoring. The description in this chapter is based on the first released version. The changes will only be updated in the separate manual for the configurator, which you can also download from the DIS website.

Key features:

- **Sensor detection.** Click 

, the software will scan the CAN bus and find the connected sensors. Basic information such as product name, serial number, etc. will be shown as in Figure 22.

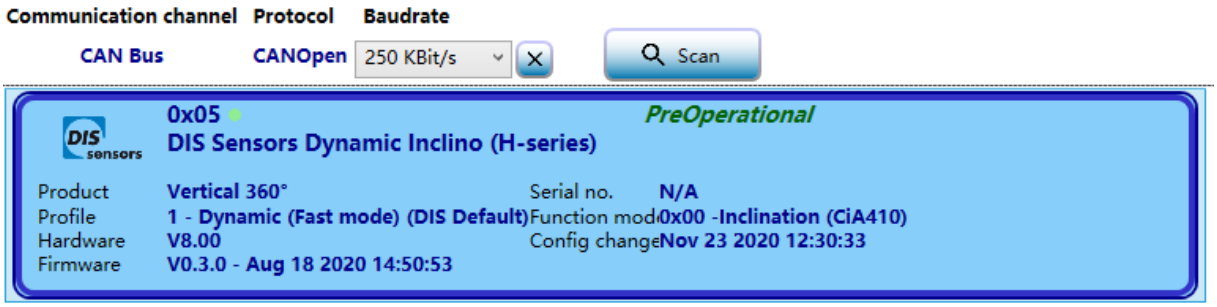


Figure 22 - Sensor detection

- Click on the displayed sensor to show a detailed configuration panel.

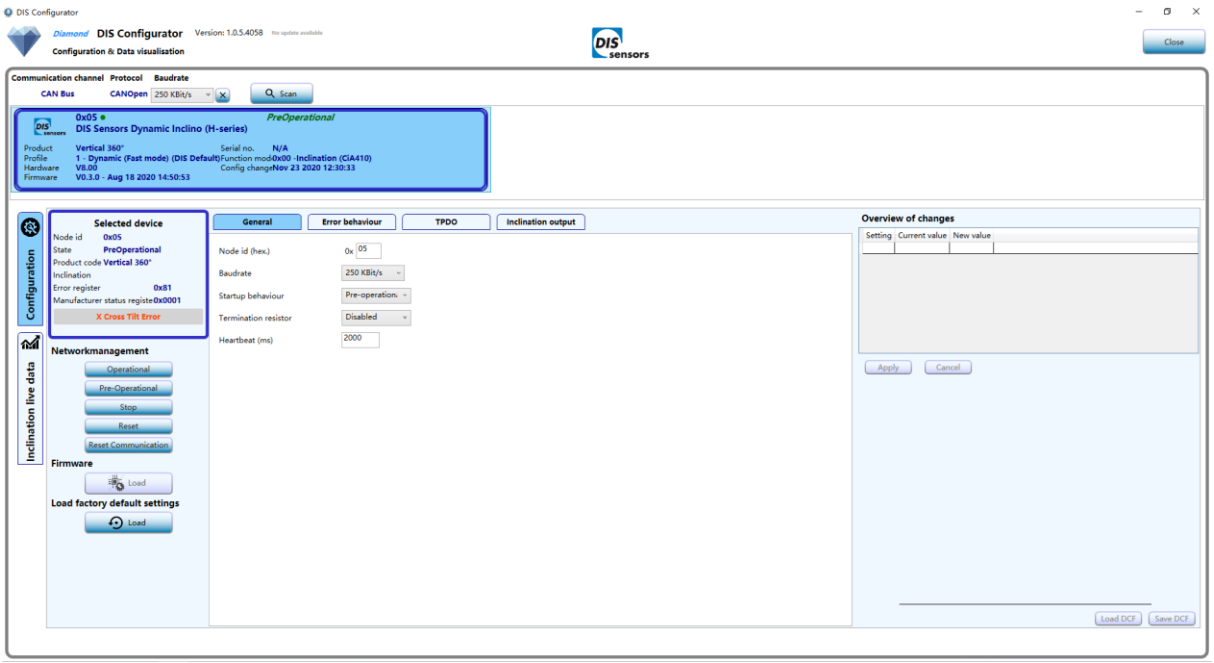


Figure 23 - Configuration panel

- The configurator keeps track of all changes you have made. Click the Apply button to save the changes to the sensor device. This can take a little time, after which the new settings will take effect.

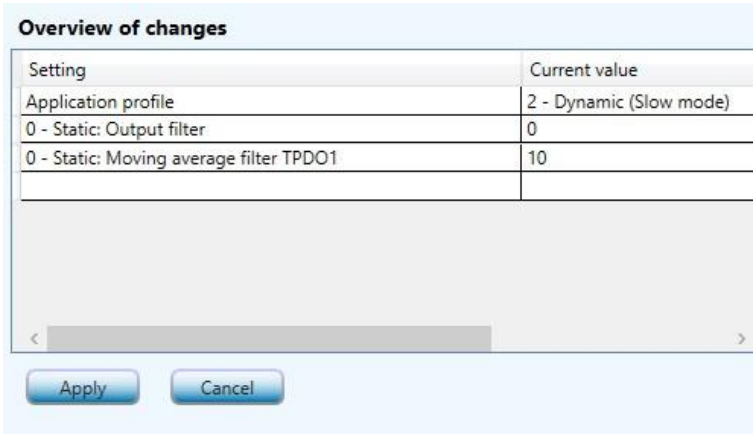


Figure 24 - Overview of changes

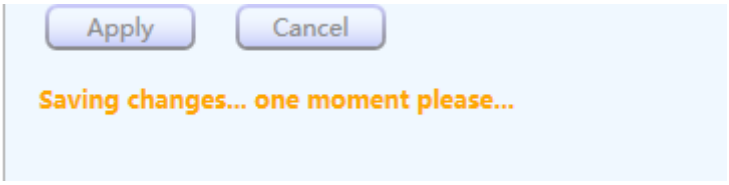


Figure 25 - Saving the changes

- General configuration, Error behaviour, TPDO parameters and parameters for inclination output can easily be configured here.

Figure 26 - General configuration

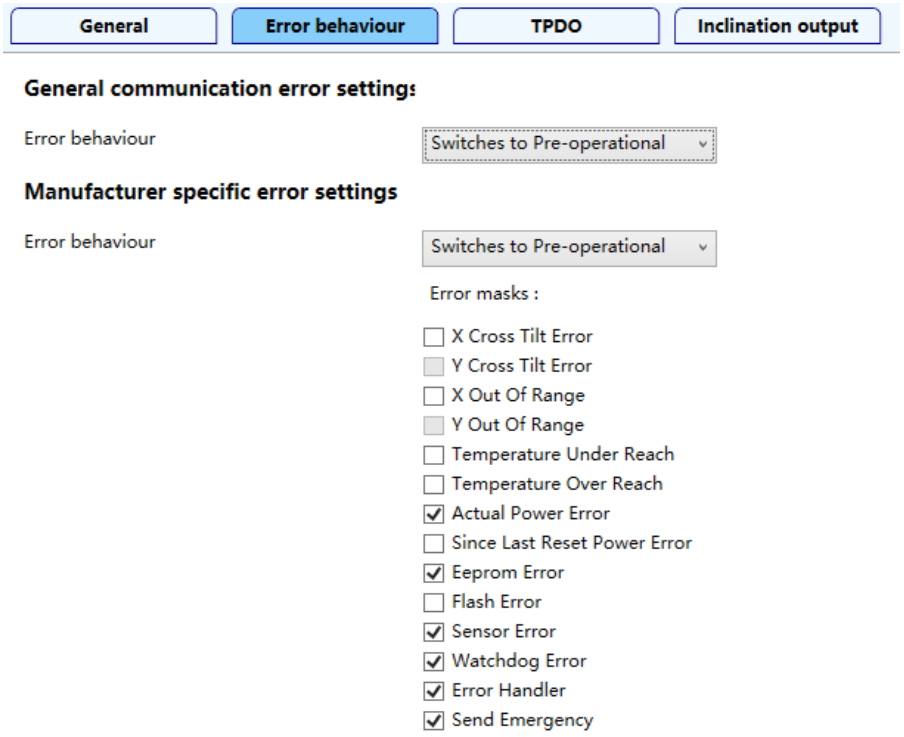


Figure 27 - Error behaviour

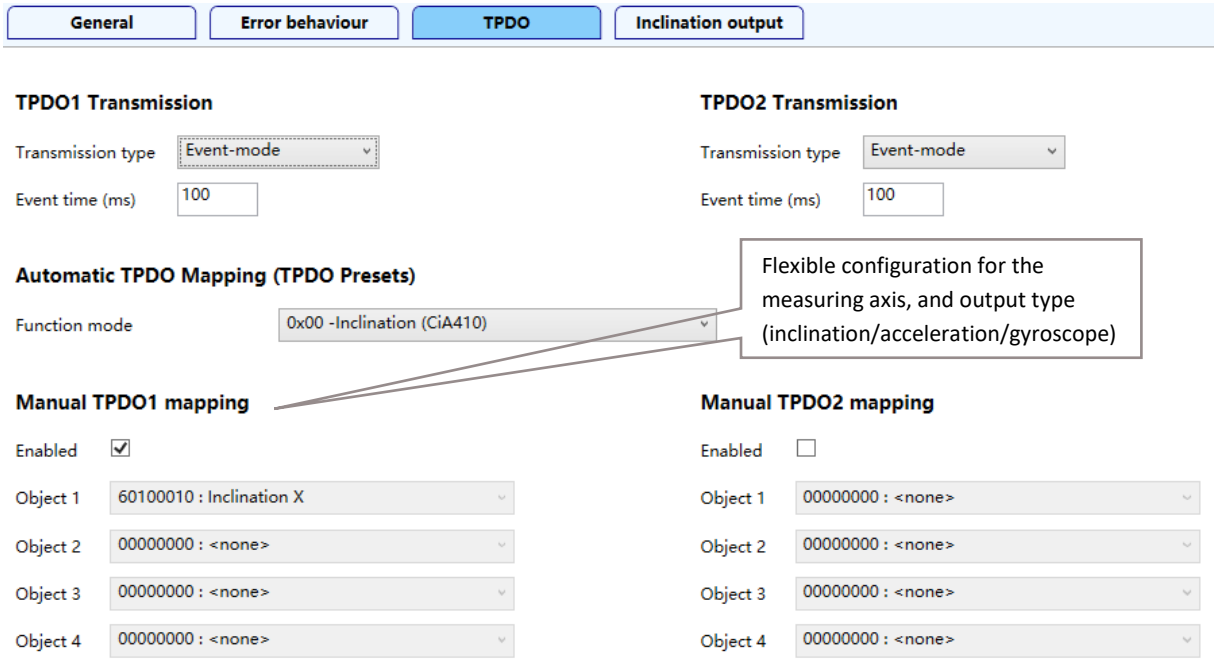


Figure 28 - TPDO mapping parameters in configuration panel

*The PC software supports **all** TPDO mapping options, including 0-360° output. This output can therefore be used by a pilot customer, as 0-360° values are transferred in the TPDO message. Device profile inclinations ±30°, ±90° and ±180° are visible only in the live data tab.*

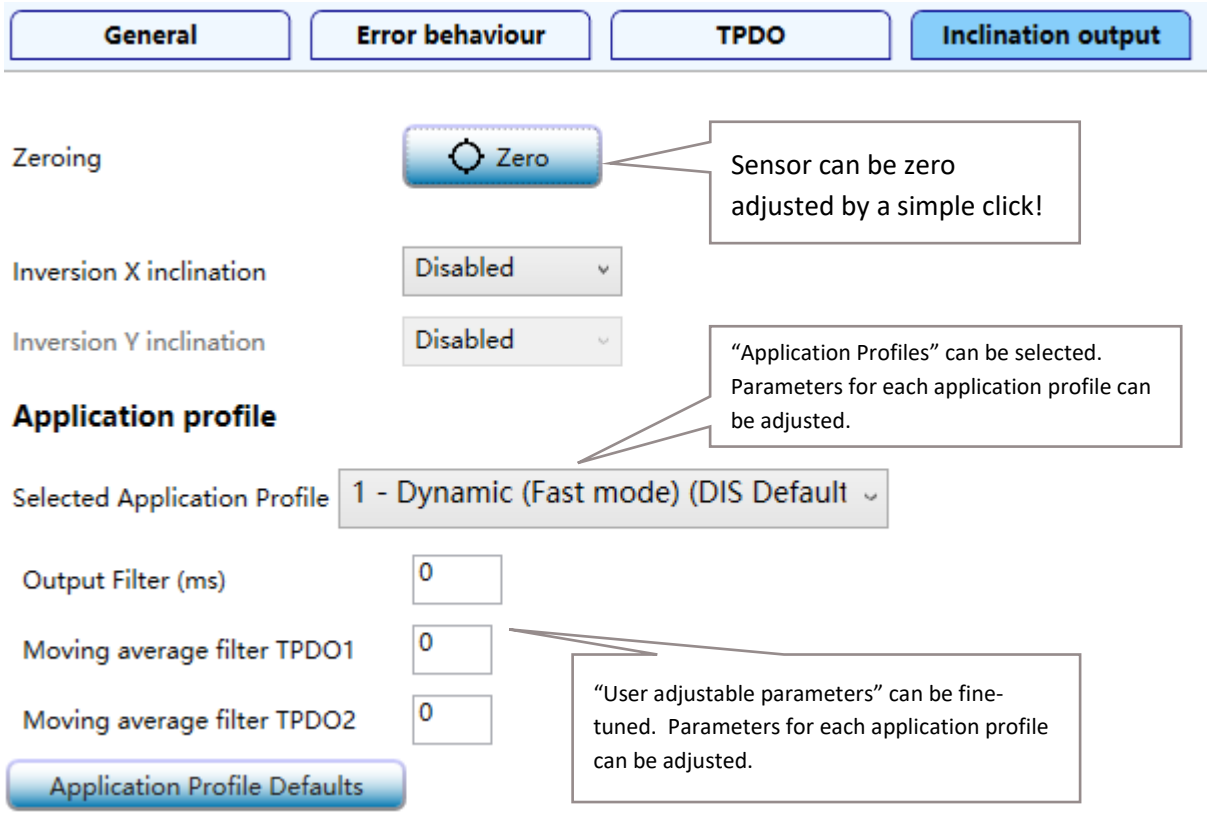


Figure 29 - Application profiles in configuration panel

- The "Live data" tab shows the real-time sensor outputs. The chart can also be c as an image.

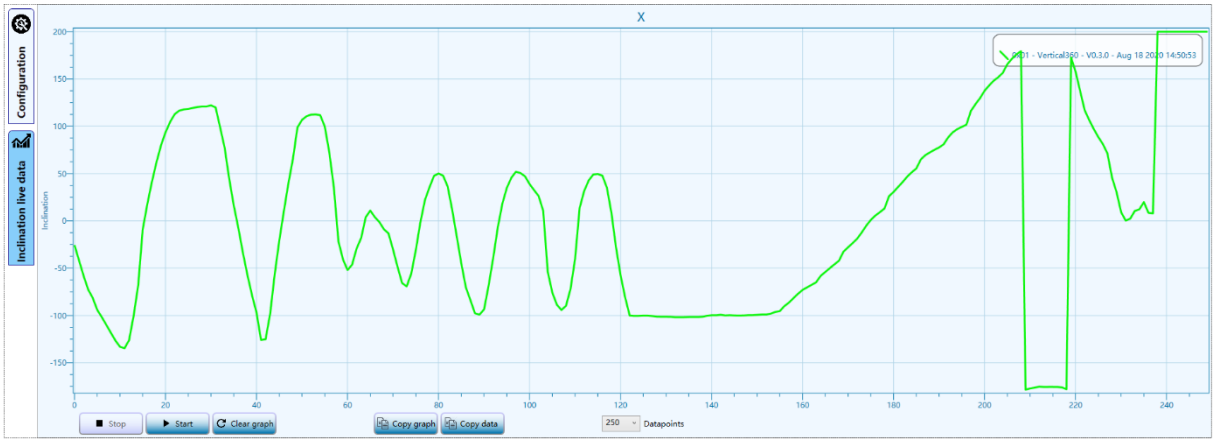


Figure 30 - Live data

- Future versions of this software will support upgrading of the firmware.

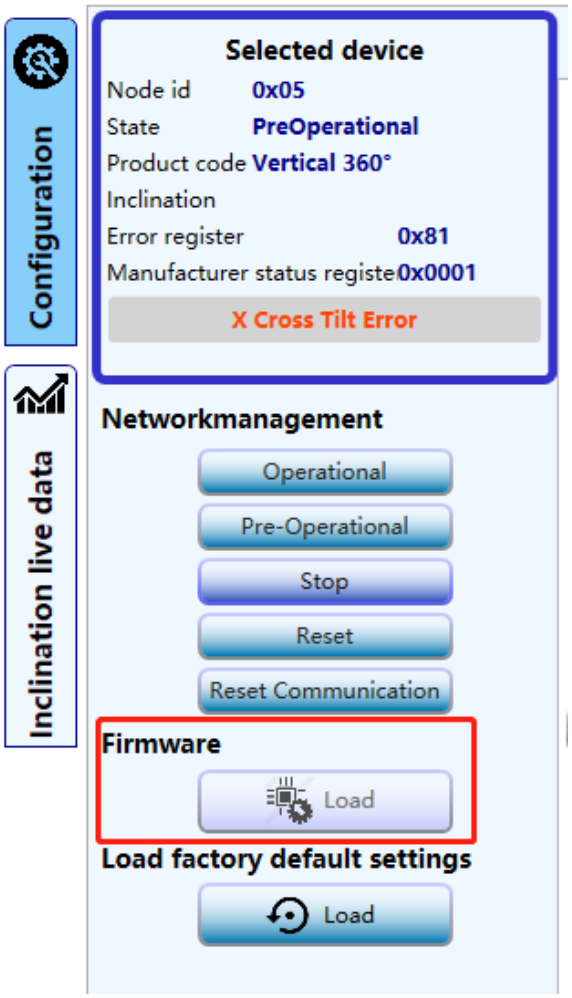


Figure 31 - Firmware update

10. Abbreviations and definitions

CAN	Controller area network
CAN-ID	CAN identifier
COB	Communication object
COB-ID	COB identifier
CRC	Cyclic redundancy check
CiA	CAN in Automation
DOF	Degrees of freedom
EDS	Electronic data sheet
EMCY	Emergency
GYRO	Gyroscope
LPF	Low-Pass Filter
MEMS	Microelectromechanical system
NMT	Network Management
PDO	Process Data Object
SDO	Service Data Object
SYNC	Synchronization
TPDO	Transmit PDO

11. Normative references

CiA301	CANopen application layer and communication profile. Version: 4.2.0
CiA303-1	Cabling and connector pin assignment. Part 1: Cabling and connector pin assignment. Version: 1.9.0
CiA305-DSP	Layer setting services (LSS) and protocols, draft standard proposal
CiA306	Electronic data sheet specification for CANopen V1.3.0
CiA410	Device profile for inclinometer. Version: 1.3.0
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