R67059.0002 - 4

Manual

Inclinometer IN88

SAE J1939

pulses for automation

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1 Document

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2 General Information

Please read this document carefully before working with the product, mounting it or starting it up.

2.1 Target Group

The device may only be planned, mounted, commissioned and serviced by persons having the following qualifications and fulfilling the following conditions:

- Technical training.
- Briefing in the relevant safety guidelines.
- Constant access to this documentation.
- In case of electrical equipment for potentially explosive atmospheres, the specialized personnel needs knowledge about the ignition protection category concept.
- For facilities in potentially explosive atmospheres, the authorized person must comply with the applicable country-specific regulations.

2.2 Symbols used / Classification of the Warnings and Safety instructions

⚠ DANGER	**Classification:** This symbol, together with the signal word **DANGER** , warns against immediately imminent threat to life and health of persons. The non-compliance with this safety instruction will lead to death or severe adverse health effects.
⚠ WARNING	**Classification:** This symbol, together with the signal word **WARNING** , warns against a potential danger to life and health of persons. The non-compliance with this safety instruction may lead to death or severe adverse health effects.
⚠ CAUTION	**Classification:** This symbol, together with the signal word **CAUTION** , warns against a potential danger for the health of persons. The non-compliance with this safety instruction may lead to slight or minor adverse health effects.

ATTENTION	**Classification:** The non-compliance with the **ATTENTION** note may lead to material damage.
NOTICE	**Classification:** Additional information relating to the operation of the product, and hints and recommendations for efficient and trouble-free operation.

3 Product Description

3.1 Technical Data

Operating, storage and transport temperature range	-40 °C … +85 °C
Supply Voltage and Current Consumption	10 … 30 VDC 70 mA at 10 VDC 30 mA at 24 VDC 6 mA at 30 VDC
2-axes sensor Measuring range per axis	±85.00°
1-axes sensor: Measuring range	0 … 359.99°
Internal process data cycle	20 ms
Function display	Triple LED (red/green/blue)
Bus connection	1 x M12 or 2 x M12
Sensor	MEMS system interface
Resolution	14 bits
Standard scale factor	Scaling off

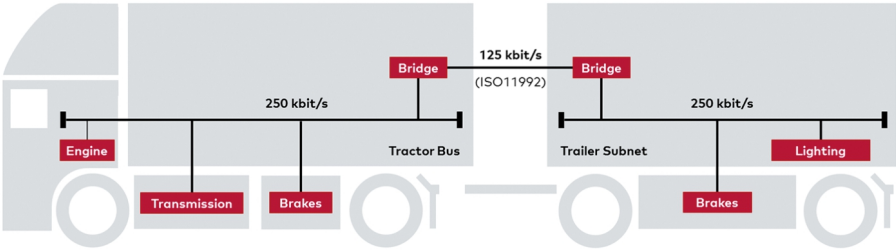
Output	SAE J1939
Communication parameters	250 kbit/s (switchable to 500 kbit/s) 8 data bytes BAM CMDT
Interface	RS485 CAN High-Speed according to ISO 11898, CAN Specification 2.0 B

3.2 Interface Description SAE J1939

SAE J1939 is an open standard for networking and communication in the utility vehicles.sector. Among possible applications, focus is set on the networking of the powertrain.

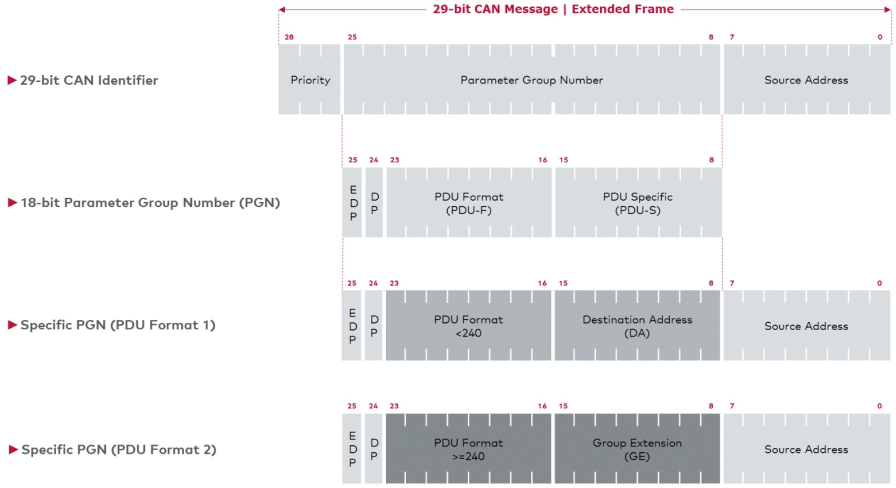
The use of the CAN technology for networking and communication and a manufacturer-independent interoperability are characteristic for J1939. The J1939 protocol comes from the international Society of Automotive Engineers (SAE) and operates on the physical layer with CAN Highspeed according to ISO 11898.

The SAE J1939 protocol uses CAN (Controller Area Network, ISO 11898-1 and ISO 11898-2) as the physical transmission layer. The CAN protocol plays a major role in the automotive networking and is a common method for the bit-serial communication between control units (Electronic Control Unit - ECU).
Typical control units are for example: the engine, transmission or brake control unit



IMG-ID: 118862859

Messages with a length exceeding 8 bytes are too large to suit in a single CAN data frame. So they must be divided in single packets by the transmitter to be then transmitted each in a CAN message. The receiver must reassemble the single fragments in the original order. A framework is provided in the J1939 standard for this purpose: a so-called transport protocol.



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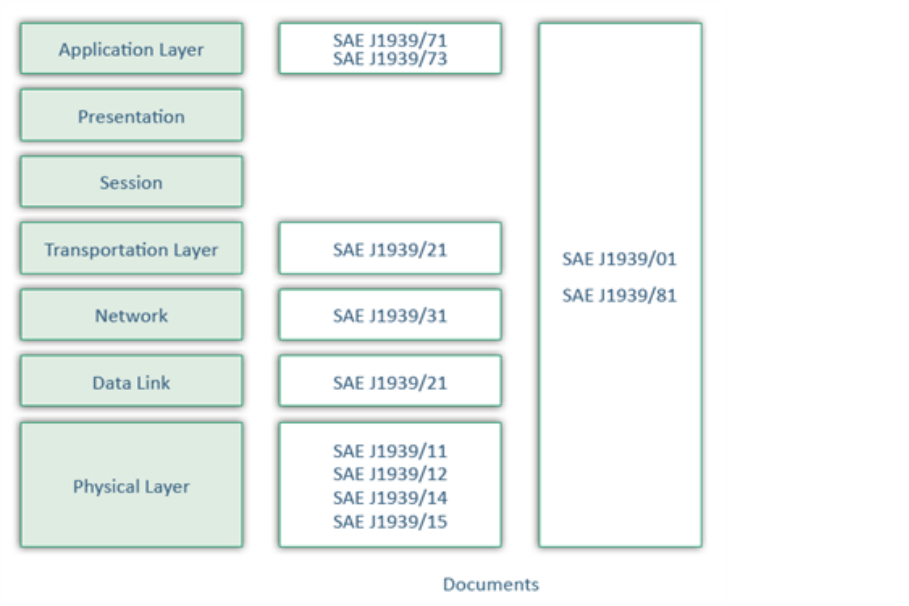
Before a CA uses an address, it must claim this address in the network. This procedure is called ADDRESS CLAIMING (ACL). The unique device name is used to solve conflicts during address allocation: the smaller the numerical value, the higher the priority.

When starting up, the CA transmits an ADDRESS CLAIM PGN (ACL, PGN 00EE00h) and waits a defined time for a response. If no other CA claims this address during this time, it can start with the normal communication.

Several documents apply for SAE J1939 according to the OSI layer model. The document number respectively refers to the assigned layer in the layer model. As practically all field bus protocols, layers 5 and 6 are not required by SAE J1939 and are therefore not specified. With J1939, the network management is organized decentrally, i. e. every control device must implement a minimum functionality. Since the network management can be considered as a separate unit, which accesses up to the hardware (layer 1), it is represented as an independent functional block on the right side of the picture..



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3.3 Supported Standards and Protocols

SAE J1939 with two PGs:

- Configuration-receive PG (via CMDT transport protocol)
- Position and status transmit PG (without transport protocol)

The configuration PG allows performing node number allocation and CAN bit rate configuration directly via the CANbus. Alternatively, the node address can also be modified by means of the J1939 Commanded Address PG.

Moreover, scaling, preset values and some other additional parameters can be programmed via the CANbus. When transmitting the configuration-receive PG to the sensor, the configuration is immediately saved in the Flash memory of the microcontroller included in the sensor. The configuration remains preserved after switching off the operating voltage.

When switching on, all parameters are loaded from the Flash memory. The distribution of the data bytes among the transmit PG (the layout or mapping of the transmit PG) is defined in the device.

NOTICE	**PG Configuration** The numbers of the J1939 PGs for sending the measured values and for configuration receipt are permanently stored in the device. On request, Kübler can also provide the devices with modified PG numbers.

4 Installation

4.1 Electrical Installation

4.1.1 General Information for the Connection

ATTENTION	**Destruction of the device** Before connecting or disconnecting the signal cable, always disconnect the power supply and secure it against switching on again.
NOTICE	**General safety instructions** Make sure that the whole plant remains switched off during the electrical installation. Make sure that the operating voltage is switched on or off simultaneously for the device and the downstream device.
NOTICE	**Traction relief** Always mount all cables with traction relief.
NOTICE	**Interference susceptibility** Proceed as follows: • Connect the shield to the device housing. • Comply with the maximum cable length for stub lines and for the total length of the bus network. • Check the maximum supply voltage on the device.

4.1.2 Information for EMC-Compliant Installation

Requirements for cables

- Use exclusively shielded twisted-pair cables to connect the device.
- Comply with the maximum permissible connection cables length.

EMC acc. to EN 61326-1	Criterion A The device operates trouble-free, user data transmission proceeds without disturbance, internally stored data and configurations remain preserved	Criterion B During a failure, a disturbed transmission of the user data is allowed, internally stored data and configurations remain preserved
Interference immunity	Is achieved with a shielded line	Is not achieved with a shielded line
	Class A Industrial environment The device has a radiation according to Class A	Class B Living area The device has a radiation according to Class B
Radiation	Is not achieved with a shielded line	Is achieved with a shielded line

Shielding and equipotential bonding

- Apply the cable shield on a large contact area - ideally 360°. Use e. g. a shield terminal to this purpose.
- Pay attention to proper cable shield fastening.
- Preferably connect the shield on both sides with low impedance to the protective earth (PE), e.g.on the device and/or on the evaluation unit. In the event of potential differences, the shield must only be applied on one side.
- If shielding is not possible, appropriate filtering measures must be taken.
- If the protective earth should be connected to the shield on one side only, it must be made sure that no short-time overvoltages can appear on the signal and supply voltage lines.
- For the large-area connection of the cable shield, use the shield terminal for top hat rail mounting provided for this purpose.

IMG-ID: 9007199375147403

Order code	8.0000.4G06.0312
Material	Spring steel, galvanized
Shield diameter	3.0 … 12.0 mm

Kübler offers a wide range of connection cables in various versions and lengths, see www.kuebler.com/connection technology.

Kübler offers various solutions for EMC-compliant installation, e.g. shield terminals for the electrical cabinet, see www.kuebler.com/accessories.

4.1.3 Connection Color Coding

Part of the cables are identified by a color coding, part of them by a numerical coding. Abbreviation of the colors :

Abbreviation	Color	Abbreviation	Color
WH	White	BU	Blue
BN	Brown	RD	Red
GN	Green	BK	Black
YE	Yellow	VT	Violet
GY	Gray	GY-PK	Gray-Pink
PK	Pink	RD-BU	Red-Blue

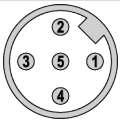
ATTENTION	Destruction of the electronics
	When confectioning the sensor cable, always take care to ensure sufficient ESD protection.

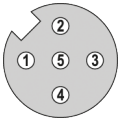
4.1.4 Connection Legend

+V:	Supply voltage +V DC
0V:	Ground GND (0V)
CAN_H:	Positive CAN Signal (Dominant High)
CAN_L:	Negated CAN-Signal (Dominant Low)
CAN_GND:	CAN-Ground
PH ⏚:	Connector housing (cable shield is applied on the connector housing), protective earth

4.1.5 Terminal Assignment

Isolate unused wires individually before commissioning.

Interface	Type of connection	1 x M12 connector, 5-pin						Pin arrangement
3	1		Bus IN					
		Signal	+V	0V	CAN_GND	CAN_H	CAN_L	
		Pin	2	3	1	4	5	

Inter-face	Type of connec-tion	2 x M12 connector, 5-pin						Pin arrange-ment
3	3		Bus OUT					
		Signal	+V	0V	CAN_GND	CAN_H	CAN_L	
		Pin	2	3	1	4	5	
3	3		Bus IN					
		Signal	+V	0V	CAN_GND	CAN_H	CAN_L	
		Pin	2	3	1	4	5	

NOTICE	**Connect the shield to the inclinometer housing**
	• If possible, mount all cables with traction relief. • Check the maximum supply voltage on the device.

4.1.6 Electrical Features

Display	LEDs
Interface	SAE J1939 (CAN)
Bus connection	1x M12 or 2x M12
Supply voltage	10 … 30 VDC max. 20 mA

NOTICE	**Comply with the maximum cable length for stub lines and for the total length of the bus system.**
	• If possible, mount all cables with traction relief. • Check the maximum supply voltage on the device.

4.2 Mechanical Installation

4.2.1 General Information for the Mounting of Inclinometers

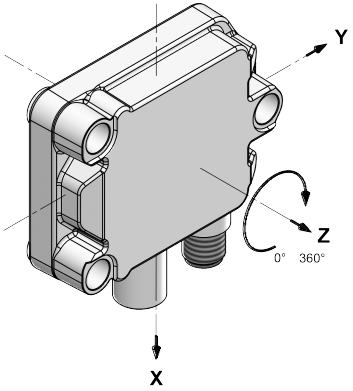
NOTICE	**Do not disassemble or open the inclinometer**
	Inclinometer function may be lost partly or entirely. • In no case disassemble the inclinometer entirely or partly. • Do not modify the inclinometer.

NOTICE	**Do not expose the device to impact stress.**
	This would impair inclinometer accuracy and MEMS reliability. • Do not use a hammer to align the inclinometer. • Avoid impact stress.

4.2.2 Axes Orientation

1 dimensional - Rotation angle

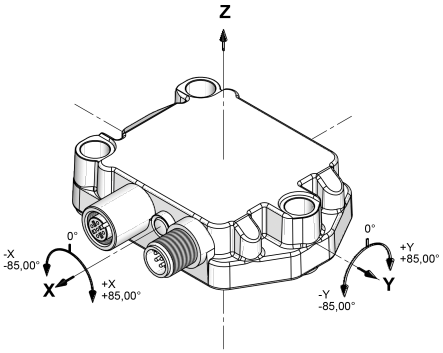
Z axis: Longitudinal (long) 0 … 360°



2 dimensional - Orientation angle

X axis: Longitudinal (long) ±85°

Y axis: Lateral (lat) ±85°



5 Commissioning and Operation

5.1 Function and Status LED

A multicolored LED signals the bus, operating and error status of the sensor.

Green = BUS status
Blue = BUS internal ERR display
Red = BUS ERR display

Display	LED	Meaning	Error cause	Addition
LED off		no voltage		
Green		J1939 Address claimed Device operates error-free	no error Connection interrupted (see annex)	An interruption of the connection cannot be detected in non-cyclic operation.
LED Red flashing (500 ms)		J1939 Address claimed Configuration error, sensor provides no measured data		Signal IN88_Error of the transmitted measured data has value 0xe, the other measured data is filled up with binary 1
Red (constantly on)		BUS OFF status J1939 Address conflict J1939 Address claim lost Cyclic transmission interrupted	Short-circuit on the J1939 bus or wrong baud rate, no ACK on the J1939 Bus, address conflict on the J1939 bus	Device sends no data on the bus
Blue flickering (100 ms)		Internal error in the sensor Sensor provides no measured data (Measured data is filled up with binary 1)	Send the device to the Kübler support for servicing.	Signal IN88_Error of the transmitted measured data has value 0xd, the other measured data is filled up with binary 1

5.2 Quick Start Guide

5.2.1 Default Settings

The sensor has been set in the factory as follows:

Signal name	Standard value
Resolution	100 (for 1-axis variant) 10 (for 2-axes variant)
LongOperatingPar	0x02 (Scaling ON, Inversion OFF)
LatOperatingPar	0x02 (Scaling ON, Inversion OFF)
SensorCycleTime	100 (100 ms)
BitRate	0 (250 kbps)
CANBusTermination	1 (ON)
J1939 address	0x20 (dec. 32)
FilterConfig	0x06 (10 Hz)

NOTICE	**Resetting to the delivery condition**
	The device has no special function for resetting to the delivery condition, since all adjustable and storable parameters are set anew when sending the configuration PG. A separate frame must be sent to the sensor to reset the sensor to the delivery condition. Example: Resetting to Factory Settings [▷ 31].

5.2.2 Changing the Parameters

At start-up, the sensor sends a J1939 address claim message including, among others, its device address and the least significant bits of its serial number.

✓ Carry out the electrical installation (voltage supply, bus connection).

a) Switch the device on

b) Have the address claiming carried out.

⇨ Display lights red: Check of the CAN communication (CAN_H, CAN_L), active CAN node must be present, termination, baud rate (default: 250kbit/s or 500 kbit/s).

⇨ Display lights green: J1939 address claim and configuration carried out properly.

NOTICE	**Sensor setting time**
	The measured values of the sensors require a setting time of approximately 500 ms after firmware start. Setting is necessary for all signals between 0 and 0x06, which are configured to a value with CFG_Filter_Config.

The sensor starting phase is structured as follows:

- The sensor starts its firmware after applying the power supply.
- The sensor sends the address claim as soon as the CAN bus is available.

- As specified in the J1939 protocol specification, the sensor waits 250 ms for a response to the address claim (e. g. in case its address is already occupied).
- The sensor waits additional 250 ms for the setting of the internal measured values in order to avoid possible strong fluctuations of the measured values at the beginning (independent of CFG_Filter_Config).
- The sensor transmits frames with measured values in the configured cycle time.

The configuration PG allows setting the following parameters:

- Resolution
- Scaling
- Preset
- Cycle time
- Device address
- Bit rate
- Termination
- Filter

The device address of the sensor can be modified by sending the COMMANDED ADDRESS (CA) PGN to the sensor. The new address is stored in non-volatile manner in the Flash memory of the sensor. The sensor restarts with the new address and sends its address claim and, if any, measured values from the new address.

ATTENTION	**Service life of the Flash memory**
	Every sensor configuration by sending the configuration PG to the sensor causes the sensor to write its configuration in the Flash memory. This is also the case if already set configuration values are written again. The Flash memory used in the sensor is specified for at the maximum 10,000 writing cycles. The service life of the Flash memory is reached when exceeding 10,000 writing cycles, which may lead to sensor malfunction. In the event of a fault, contact our support. Contact [▶ 34]

5.3 Protocol Features

5.3.1 Data Transmission

All of the data is transmitted per device with a specific identifier - CAN-ID. The CAN-ID precedes every message transmitted or received by the device and is composed as follows:

Priority	PGN	Target address	Source address
0x18	0xEB00	0x20	0x05

This results for example in the following CAN-ID: 0x18EB2005

The priority determines which messages are processed first. In the event of a conflict – when two messages are transmitted simultaneously – the message with the lowest priority value is processed first. If two devices transmit with the same priority, the message of the device closest to the control in the topology is processed first.

NOTICE	**CAN-ID priority**
	The default priority preset in the device for all messages is 18. If other priorities are required, this must be implemented in a separate firmware.

As standard, the sensor uses the following J1939 PGN for data transmission:

- Receive configuration or End of Message message: PGN : 0xEF00 through transport protocol CMDT
- Process data transmission: PGN : 0xFFAB
- Configuration transmission 0xEB00
- TPCM through CMDT: 0xEC00
- Assembled configuration (is not transmitted via the BUS): 0xEF00

NOTICE	**PGN (PG number) determination**
	Upon customer request, other PG numbers can be set during sensor production, according to a special agreement with Kübler. Form sheet for configuration: kuebler.com/konfiguration_IN88

The configuration data is transmitted through J1939 CMDT transfer - as specified in document SAE J1939/21.

To transmit the data in the configuration data PG to the sensor, you can use a tool such as e. g. Vector CANoe, CANalyzer or a J1939 software stack. A configuration is However also possible without J1939 stack or without a suitable tool.

5.3.2 Layout of the Configuration Data PG

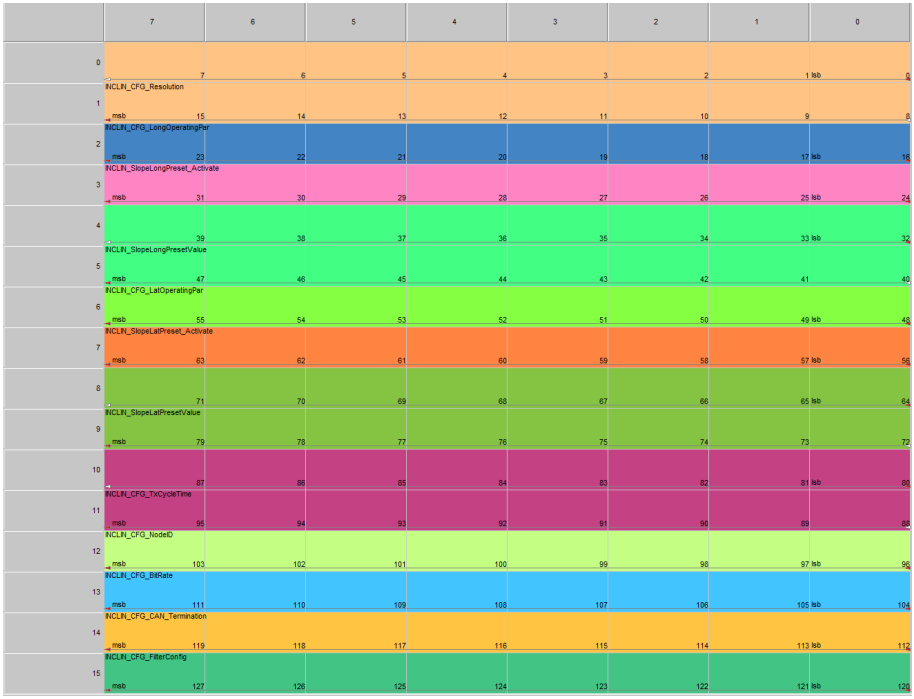
The configuration data is - as shown in the figure - structured in blocks.

Rows (horizontal)

Bytes no. 0 to 15 of the PG

Columns (vertical)

Bits 0 to 7 of every byte



NOTICE	**The following signals are not used for the 2-axes sensor:** - INCLIN_CFG_LatOperatingPar - INCLIN_CFG_LatPresetActivate - INCLIN_CFG_LatPresetValue Please fill their values up with zeros.

5.3.3 Layout of the Process Data PG

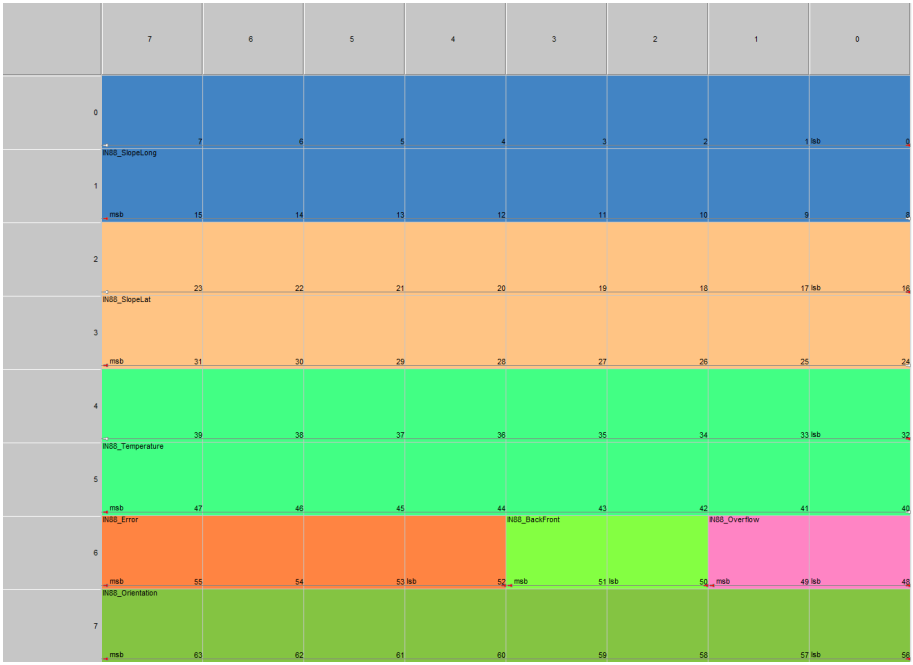
The process data is structured in blocks, as shown in the figure. The inclinometer transmits the process data on PGN 0xFFAB, which results in CAN-ID 0x18FFAB20 (Extended).

Rows (horizontal)

Bytes no. 0 to 7 of the PG

Columns (vertical)

Bits 0 to 7 of every byte



5.4 Configuration Parameters Description

5.4.1 Cycle Time - INCLIN_CFG_TxCycleTime

This signal allows setting in milliseconds the cycle time with which the process data (measured values) of the sensor is transmitted on the bus as a CAN frame.

A value 0xFFFF retains the value stored so far in the sensor unchanged. A value 0 deactivates the cyclic process data transmission.

5.4.2 Bit Rate - INCLIN_CFG_BitRate

This signal allows modifying the CAN bit rate of the inclinometer. If the set value is different from the previous value, the inclinometer saves the settings and restarts after some milliseconds with the new bit rate.

NOTICE	**Changing the bit rate during network operation**
	If possible, the bit rate should not be modified when the network is in operation. The selected cycle time (INCLIN_CFG_TxCycleTime) must be longer than the bus transmission time of a measured values frame, so that the measured data PGN can be transmitted error-free on the bus.

Value	Bit rate in kBit/s
0	250 (default)
1	500
0xFF	Maintain the currently active bit rate

5.4.3 Node ID - INCLIN_CFG_NodeID

This signal allows modifying the J1939 node address of the sensor and saving it immediately in non-volatile manner in the sensor.

The node address does not change if value 0xFF is set or if the current node address is set again.

If another value is set, the sensor accepts the new value as its node address, saves it and re-starts the firmware with the new node address. Alternatively, the node address can by modified with J1939 COMMANDED ADDRESS PGN (CA).

5.4.4 Termination - INCLIN_CFG_CAN_Termination

CAN is a 2-wire bus system in which all participants are connected in parallel (that is to say with short stub lines). The bus must be terminated at both ends with a 120 ohm terminating resistor in order to prevent reflections. This is necessary even in case of very short line lengths.

The 120 ohm terminating resistor can be activated and deactivated electronically.

Setting the value 1 activates the termination, setting value 0 deactivates it.

Value 0xFF maintains the current setting unchanged.

5.4.5 Resolution - INCLIN_CFG_Resolution

This signal sets the resolution of the inclinometer for all axes.
Parameter "INCLIN_CFG_Resolution" influences measuring axes long16 and lateral16.

Value	Axis(axes) resolution	Value range of axis IN88_SlopeLong for the 1-axis sensor	Value range of axes IN88_SlopeLong and IN88_SlopeLat for the 2-axes sensor
10 (hex 0x0A)	0.01°	not supported for the 1-axis sensor	-8500 to +8500
100 (hex 0x64)	0.1°	0 to 3599	-850 to +850
1000 (hex 0x3E8)	1.0°	0 to 359	-85 to +85
others	not supported		

5.4.6 X Axis Scaling - INCLIN_CFG_LongOperatingPar

This signal allows enabling or disabling the scaling, taking into account the preset of the measured values of the longitudinal axis and the inversion of the measured values (inversion, e.g. when the sensor is mounted upside down).

The following permissible values result from this:

- 0x0: Scaling off, Inversion off
- 0x01: Scaling off, Inversion on

- 0x02: Scaling on, Inversion off
- 0x03: Scaling on, Inversion on

Field	Value	Description
ms	0	Manufacturer-specific, must always be set to 0.
r	0	reserved
s (scaling)	0 1	Scaling off Scaling enabled
i (Inversion)	0 1	Inversion off Inversion enabled

Scaling

If scaling is enabled, the measured value is calculated first:
The sensor thus takes into account a possibly set preset value when calculating the measured value. If scaling is disabled, the measured value corresponds to the physically measured value.

Inversion

If inversion is enabled, the measured value of the axis is output inverted. The inversion is independent of the orientation of the device, it merely changes the sign of the output value.

NOTICE	**Preset behavior in the event of inversion**
	Also the preset value is inverted when inversion is enabled. If e. g. the value 40 is entered, it will be taken over as -40.

5.4.7 Preset Activation X Axis - INCLIN_SlopeLongPresetActivate

If "INCLIN_SlopeLongPresetActivate" is set to 1, the preset function is triggered once immediately upon receipt of the configuration PG and the value contained in "INCLIN_SlopeLongPresetValue" is used for triggering the preset function.

For all other values of "INCLIN_SlopeLongPresetActivate", "INCLIN_SlopeLongPresetValue" is ignored and the preset function is not triggered.

NOTICE	**Taking the preset into account**
	The preset setting is only taken into account when the scaling is enabled in INCLIN_CFG_LongOperatingPar.

5.4.8 Preset Value X Axis - INCLIN_SlopeLongPresetValue

Signal INCLIN_SlopeLongPresetValue allows setting the measured value IN88_Slope_Long to a desired angle value within the value range (PRESET).

Calculation of the measured value IN88_Slope_Long:

Slope long16 = physically measured angle + Difference slope long16 offset + Slope long16 offset

NOTICE	Triggering the preset
	The preset is only triggered when INCLIN_SlopeLongPresetActivate is set to 1.

After triggering the preset, the preset value is saved in a non-volatile manner in the sensor. The preset value also remains preserved when the power supply is switched off and on.

5.4.9 Y Axis Scaling - INCLIN_CFG_LatOperatingPar

This signal allows enabling or disabling the scaling, taking into account the preset of the measured values of the lateral axis and the inversion of the measured values (inversion, e.g. when the sensor is mounted upside down).

Field	Value	Description
ms	0	Manufacturer-specific, must always be set to 0.
r	0	reserved
s (scaling)	0 1	Scaling not enabled Scaling enabled
i (Inversion)	0 1	Inversion not enabled Inversion enabled

The following permissible values result from this:

- 0x0: Scaling off, Inversion off
- 0x01: Scaling off, Inversion on
- 0x02: Scaling on, Inversion off
- 0x03: Scaling on, Inversion on

Scaling

If scaling is enabled, the measured value is calculated first. The sensor thus takes into account a possibly set preset value when calculating the measured value.
If scaling is disabled, the measured value corresponds to the physically measured value.

Inversion

If inversion is enabled, the measured value of the axis is output inverted. The inversion is independent of the orientation of the device, it merely changes the sign of the output value.

✓ This signal is ignored for the 1-axis variant of the inclinometer.

a) Recommendation: set this signal to 0 for the 1-axis variant.

NOTICE	Preset behavior in the event of inversion
	Also the preset value is inverted when inversion is enabled. If e. g. the value 40 is entered, it will be taken over as -40.

5.4.10 Preset Activation Y Axis – INCLIN_SlopeLatPresetActivate

If INCLIN_SlopeLatPresetActivate is set to 1, the preset function is triggered once for the lateral axis immediately upon receipt of the configuration PG and the value contained in INCLIN_SlopeLatPresetValue is used for triggering the preset function.

For all other values of INCLIN_SlopeLatPresetActivate, INCLIN_SlopeLatPresetValue is ignored and the preset function is not triggered.

NOTICE	**Taking the preset into account**
	The preset setting is only taken into account when the scaling is enabled in INCLIN_CFG_LatOperatingPar. This signal is ignored for the 1-axis variant of the inclinometer. Recommendation: set this signal to 0 for the 1-axis variant.

5.4.11 Preset Value Y Axis - INCLIN_SlopeLatPresetValue

Signal INCLIN_SlopeLatPresetValue allows setting the measured value IN88_Slope_Lat to a desired angle value (PRESET).

The desired angle value is transmitted as a signed 16-bit value, taking into consideration the resolution set in Signal INCLIN_CFG_Resolution.

After triggering the preset, the preset value is saved in a non-volatile manner in the sensor. The preset value also remains preserved when the power supply is switched off and on.
This signal is ignored for the 1-axis variant of the inclinometer.

Recommendation: set this signal to 0 for the 1-axis variant.

NOTICE	**Taking the preset into account**
	The preset is only triggered when INCLIN_SlopeLatPresetActivate is set to 1.

5.4.12 Filter setting - INCLIN_CFG_FilterConfig

This signal allows setting a low-pass filter. The starting point of the stop band frequency of the filter can be modified, or the filter can be totally disabled.

The filter lets pass signal portions with frequencies lower than the limit frequency almost without attenuation. In contrast, it attenuates signal portions with higher frequencies

The default value of this setting is 0x06, i.e. the filter is enabled with a 10 Hz limit frequency.

Value (hex)	Filter enabled/disabled	Starting point of the stop band frequency of the filter
0x80	Filter disabled	--
0	Filter enabled	0.1 Hz
0x1	Filter enabled	0.3 Hz
0x2	Filter enabled	0.5 Hz
0x3	Filter enabled	1 Hz
0x4	Filter enabled	2 Hz
0x5	Filter enabled	5 Hz
0x6 (default)	Filter enabled	10 Hz
0xFF	Maintain the setting already saved	Maintain the setting already saved

A low filter frequency (e. g. value 0 or 1) leads to a strong smoothing of the measured values. When the sensor is tilted, this also means a sluggish approach of the values transmitted on the bus to the angle value measured by the sensor. Jumps in the measured values are smoothed.

On the contrary, a high filter frequency (e. g. value 5 or 6) means that the measured values will only be little smoothed. In addition, jumps and quick changes in the measured values transmitted to the bus can become visible. Description of the filter Sensor filter [▶ 36]

When the filter is disabled (value 0x80), the measured values are passed through directly and without delay. Measurement-related jumps in the values must possibly be expected.

NOTICE	**Relation between filter and transmission cycle time**
	Note that the transmission cycle time must be set at a low value to allow transmitting also fast measured value changes on the bus (e. g. 10 ms).

5.5 Process Data Description

5.5.1 Angle Longitudinal - IN88_Slope_Long

1-axes variant

The inclinometer returns the value measured by the Z axis LONGITUDINAL16. The measured value depends on the settings of the configuration signals and on the sensor type. These values influence the calculation and the result.

NOTICE	**Take care to the orientation of the device**
	The Z axis of the 1-axis sensor must be oriented as perpendicular as possible to the gravity vector. Otherwise, undefined measured values may occur. If the gravity vector and the Z axis are parallel, the Euler angle cannot be calculated.

Byte 0	Byte 1
2^7 … 2^0	2^{15} … 2^8

Values range

As indicated under INCLIN_CFG_Resolution. Resolution - INCLIN_CFG_Resolution [▶ 21]

Internal update rate of the measured value

20 ms

2-axes variant

The inclinometer returns the value measured by the Y axis LONGITUDINAL16. The measured value depends on the settings of the configuration signals and on the sensor type. These values influence the calculation and the result.

Byte 0	Byte 1
2^7 … 2^0	2^{15} … 2^8

Values range

As indicated under INCLIN_CFG_Resolution. Resolution - INCLIN_CFG_Resolution [▶ 21]

Internal update rate of the measured value

20 ms

5.5.2 Angle Lateral - IN88_Slope_Lat

1-axes variant

With the 1-axis inclinometer, signal IN88_Slope_Lat is fixedly filled with value 0xFFFF.

2-axes variant

The inclinometer returns the value measured by the X axis LATERAL16. The measured value depends on the settings of the configuration signals and on the sensor type. These values influence the calculation and the result.

Byte 0	Byte 1
2^7 … 2^0	2^{15} … 2^8

Values range

As indicated under INCLIN_CFG_Resolution. Resolution - INCLIN_CFG_Resolution [▶ 21]

Internal update rate of the measured value

20 ms

5.5.3 Temperature - IN88_Temperature

This signal indicates the current temperature inside of the sensor as a signed 16-bit hexadecimal value. This value allows checking the current temperature of the device.

The signal value is provided in tenths of a degree and must be divided by 10 to give the temperature value in °C.

Byte 0	Byte 1
$2^7 \dots 2^0$	$2^{15} \dots 2^8$

Values range

00…FFFFh

Example

0x103 corresponds to + 25.9 °C

Internal update rate of the measured value:

The temperature value is updated every 2 s.

Accuracy

Accuracy is ± 0.2 °C, measurement takes place inside of the sensor electronics.

5.5.4 Overflow - IN88_Overflow

1-axis variant

For the 1-axis inclinometer, this signal has no relevance and can be ignored.

2-axes variant

Returns the overflow status.

Value	Meaning
0	Sensor positioned within the valid measuring range > -85.00° & <+85.00°
1	Sensor positioned outside of the positive measuring range > +85.00°
2	Sensor positioned outside of the negative measuring range < -85.00°

5.5.5 Position - IN88_BackFront

Returns the position of the sensor.

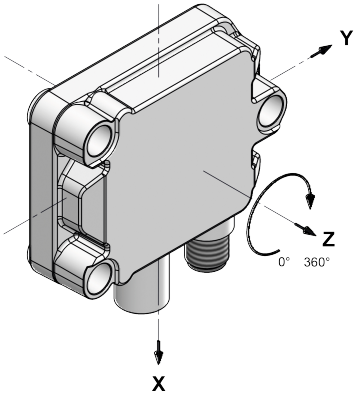
Value	Meaning
0	Sensor upside down
1	Sensor in normal position/installation position

5.5.6 Orientation - IN88_Orientation

The orientation value returns the quadrant in which the sensor is generally tilted. The quadrants always refer to the position of the respective sensor type (see drawing).

1-axes variant

For the 1-axis sensor, the values of the respective quadrants return the complete 360° measuring range.

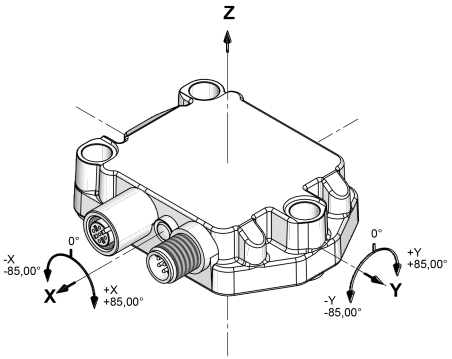


IMG-ID: 9007199377709835

Value	Meaning
0	Q1 225° … 315°
2	Q2 315° … 45°
4	Q3 45° … 135°
6	Q4 135° … 225°

2-axes variant

For the 2-axes sensor, the quadrants refer to the 4 axis directions: +X, -X, +Y, -Y.



IMG-ID: 9007199377711755

Value	Meaning
0	Tilting in the +Y direction
2	Tilting in the -Y direction
4	Tilting in the +X direction
6	Tilting in the -X direction

5.5.7 Error - IN88_Error

Returns the internal error status of the sensor.

Value	Meaning
0	no error
0xE	Invalid configuration (e. g. invalid value for the resolution or last preset value outside of measuring range).
0xD	Reading error when accessing to the internal sensor components. The sensor provides no measured data. It can be sent to the Kübler support for servicing.

If an internal error occurs, the other measured values are set to value 0xFF (binary 1). Do not use these.

For optimal operation, the error status must be continuously checked during plant operation.

NOTICE	**Behavior in case of connection loss.**
	When resuming the connection with the sensor,it may happen that the sensor transmits a message that has not been transmitted yet because of the loss of the connection. This is a normal behavior with CAN networks, but it may lead to an error in the control.

5.6 Examples

5.6.1 Example: Setting Configuration Data

Here a fictitious example of a transmission with the listing of the raw frames on the bus when transmitting the EncoderSetup PG. This example uses fictitious values to illustrate the transmission of the data.

Configuration data	Data length in bytes	Hex value (fictitious)	Hex value converted in decimal value	Endian-converted hex value
INCLIN_CFG_Resolution	2	0x0102	258	0x0201
INCLIN_CFG_LongOperatingPar	1	0x03	3	0x03
INCLIN_CFG_SlopeLongPreset_Activate	1	0x04	4	0x04
INCLIN_CFG_SlopeLongPresetValue	2	0x0506	1286	0x0605
INCLIN_CFG_LatOperatingPar	1	0x07	7	0x07
INCLIN_CFG_SlopeLatPreset_Activate	1	0x08	8	0x08
INCLIN_CFG_SlopeLatPresetValue	2	0x090a	2314	0x0a09
INCLIN_CFG_TxCycleTime	2	0x0b0c	2828	0x0c0b
INCLIN_CFG_NodeID	1	0x0d	13	0x0d
INCLIN_CFG_BitRate	1	0x0e	14	0x0e
INCLIN_CFG_CAN_Termination	1	0x0f	15	0x0f
INCLIN_CFG_FilterConfig	1	0x10	16	0x10

The data consisting in several bytes must first be Endian-converted, thus swapped byte by byte. This is necessary because J1939 transfers the data starting with the lowest-order byte. Then the data is concatenated and transmitted as shown in the layout.

This results in the following raw data stream, which must be transmitted to the sensor (by concatenating the values in the right column of the table):

02 01 03 04 06 05 07 08 0A 09 0C 0B 0D 0E 0F 10

This data must now be distributed over several CAN frames and transmitted per CMDT transport protocol. The transport protocol is necessary because at the maximum 8 user data bytes can be transmitted per CAN frame.

All mentioned CAN frames must be transmitted and received as extended frames (29-bit identifier). There must be a dwell of at least 50 ms between the transmission of the frames.

A CMDT connection must be set up first. The requesting control device has address 0x01 and the sensor has address 0x20. The parameters coded in the transmitted packet are:

- Control byte: 0x10
- Message size: 0x10
- Total number of packets: 3
- Maximum number of packets: 0xFF
- PG number: 0xEF00
- Source address: 0x05
- Destination address: 0x20

For this purpose, the following RTS packet must be transmitted to the sensor and the CTS answer from the sensor must be waited for:

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Transmit RTS request on CAN ID: 0x18EC2005	10	10	00	03	FF	00	EF	00
Receive CTS answer on CAN ID: 0x18EC0520	11	03	01	FF	FF	00	EF	00

In the next step, the control device transmits the configuration data in three CAN frames to the sensor.

The byte 0 of the frames always contains the sequence number in the data transmission.
The bytes 1-7 consecutively contain the raw data, in this example the following data:

02 01 03 04 06 05 07 08 0A 09 0C 0B 0D 0E 0F 10

In frame 3, the last 5 unused bytes are filled up with value 0xFF.

There must be a dwell of at least 50 ms between the transmission of the frames.

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Transmit TP, sequence number: 1 CAN-ID: 0x18EB2005	01	02	01	03	04	06	05	07

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Transmit TP, sequence number: 2 CAN-ID: 0x18EB2005	02	08	0a	09	0c	0b	0d	0e

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Transmit TP, sequence number: 3 CAN-ID: 0x18EB2005	03	0F	10	FF	FF	FF	FF	FF

At the end of the transmission, the sensor confirms the successful transmission:

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Receipt EoMA, CAN-ID: 0x18EC0520	13	10	00	03	FF	00	EF	00

The receipt of the confirmation completes the configuration of the sensor.

5.6.2 Example: Resetting to Factory Settings

In this example, the sensor is set to the default settings. Also the preset values of both axes are set to 0.

Configuration data	Data length in bytes	Hex value	Hex value converted in decimal value	Endian-converted hex value
INCLIN_CFG_Resolution	2	0x0064	100	0x6400
INCLIN_CFG_LongOperatingPar	1	0x02	2	0x02
INCLIN_CFG_SlopeLongPreset_Activate	1	0x01	1	0x01
INCLIN_CFG_SlopeLongPresetValue	2	0x0000	0	0x0000
INCLIN_CFG_LatOperatingPar	1	0x02	2	0x02
INCLIN_CFG_SlopeLatPreset_Activate	1	0x01	1	0x01
INCLIN_CFG_SlopeLatPresetValue	2	0x0000	0	0x0000
INCLIN_CFG_TxCycleTime	2	0x0032	50	0x3200
INCLIN_CFG_NodeID	1	0x20	32	0x20
INCLIN_CFG_BitRate	1	0x00	0	0x00
INCLIN_CFG_CAN_Termination	1	0x01	1	0x01
INCLIN_CFG_FilterConfig	1	0x06	6	0x06

The data consisting in several bytes must first be Endian-converted, thus swapped byte by byte. This is necessary because J1939 transfers the data starting with the lowest-order byte. Then the data is concatenated and transmitted as shown in the layout.

This results in the following raw data stream, which must be transmitted to the sensor (by concatenating the values in the right column of the table):

64 00 02 01 00 00 02 01 00 00 32 00 20 00 01 06

This data must now be distributed over several CAN frames and transmitted per CMDT transport protocol. The transport protocol is necessary because at the maximum 8 user data bytes can be transmitted per CAN frame.

All mentioned CAN frames must be transmitted and received as extended frames (29-bit identifier).

There must be a dwell of at least 50 ms between the transmission of the frames.

A CMDT connection must be set up first. The requesting control device has address 0x01 and the sensor has address 0x20. The parameters coded in the transmitted packet are:

- Control byte: 0x10
- Message size: 0x10
- Total number of packets: 3
- Maximum number of packets: 0xFF
- PG number: 0xEF00
- Source address: 0x01
- Destination address: 0x20

For this purpose, the following RTS packet must be transmitted to the sensor and the CTS answer from the sensor must be waited for:

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Transmit RTS request on CAN ID: 0x18EC2001	10	10	00	03	FF	00	EF	00
Receive CTS answer on CAN ID: 0x18EC0120	11	03	01	FF	FF	00	EF	00

In the next step, the control device transmits the configuration data in three CAN frames to the sensor.

The byte 0 of the frames always contains the sequence number in the data transmission.
The bytes 1-7 consecutively contain the raw data, in this example the following data:

64 00 02 01 00 00 02 01 00 00 32 00 20 00 01 06

In the last frame, the unused data bytes are filled up with the value 0xFF.

There must be a dwell of at least 50 ms between the transmission of the frames.

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Transmit TP, sequence number: 1 CAN-ID: 0x18EB2001	01	64	00	02	01	00	00	02
Transmit TP, sequence number: 2 CAN-ID: 0x18EB2001	02	01	00	00	32	00	20	00
Transmit TP, sequence number: 3 CAN-ID: 0x18EB2001	03	01	06	FF	FF	FF	FF	FF

At the end of the transmission, the sensor confirms the successful transmission:

	Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7
Receipt EoMA, CAN-ID: 0x18EC0120	13	10	00	03	FF	00	EF	00

The receipt of the confirmation completes the configuration of the sensor.

6 Contact

You want to contact us:

Technical advice

Kübler's worldwide applications team is available on site all over the world for technical advice, analysis or installation support.

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Kübler USA +1 855 583 2537

Repair service / RMA form

In case of returns, please package the product sufficiently and attach the completed "Returns form".

www.kuebler.com/rma

Please send your return to the address below.

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Fax +49 7720 21564

info@kuebler.com
www.kuebler.com

7 Annex

7.1 Angle calculation

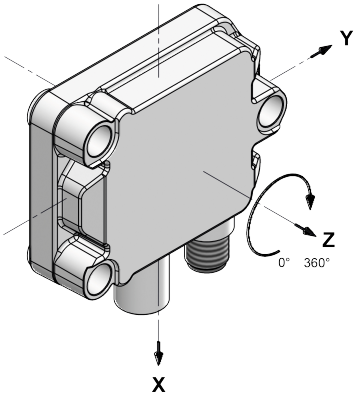
7.1.1 1-axis inclinometer

Rotation angle

In this setting, the output angle value is to be interpreted as a rotation angle. The "Rotation angle Z" corresponds to the angle [°] by which the sensor has been rotated around the Z axis.

NOTICE	**Comply with the maximum Z axis deflection.**
	The sensor also outputs the angle around the Z axis if the Z axis, which normally is at 90° with respect to the gravity vector, is deflected with respect to the gravity vector. However, this is only possible up to the horizontal sensor position. In horizontal position, the Z rotation angle cannot be determined.

Z axis: Longitudinal (long)



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7.1.2 2-axes inclinometer

Orientation angles

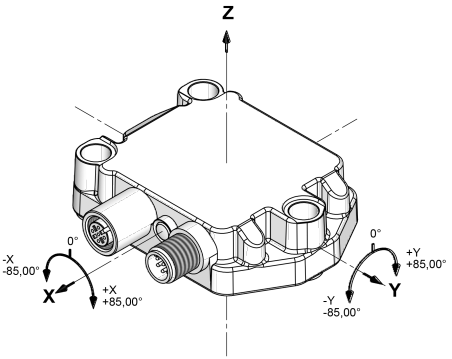
Indicating the two orientation angles describes the inclination of the coordinate system of the sensor with respect to the gravitational direction.

The first value output corresponds to a rotation around the Y axis of the sensor and is called "Orientation angle Y". This value corresponds to the angle [°] formed by the gravity vector with the YZ plane of the sensor.

The second value output corresponds to a rotation around the X axis of the sensor and is called "Orientation angle X". This value corresponds to the angle [°] formed by the gravity vector with the XZ plane of the sensor.

X axis: Longitudinal (long)

Y axis: Lateral (lat)



IMG-ID: 9007199377711755

7.2 Sensor filter

Filter description 1st order

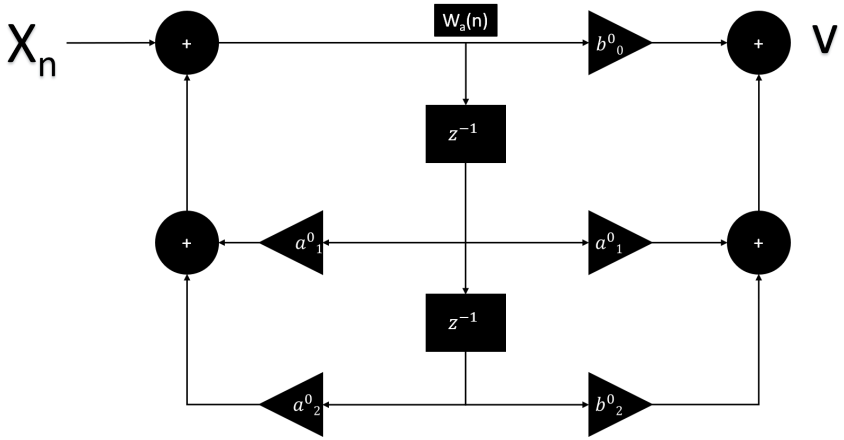
In electronics, low-pass filters are filters that let pass signal portions with frequencies lower than their limit frequency almost without attenuation and attenuate signal portions with higher frequencies.
Setting possibilities: Filter on/off
Filter operating frequency b: defines the starting point of the stop band (range 0.1 … 10.0 Hz)

Filter description 2nd order

An IIRfilter is generally realized with the help of 2nd order subsystems in direct form.
The following picture shows the corresponding block diagram. A subsystem consists of 2 delay elements or memory elements that contain the intermediate values w0(n) as well as of the two coefficients a^0_1, a^0_2 in the recursive portion and the three coefficients b^0_0, b^0_1 and b^0_2.

Functioning

The second index (j) is used for differentiation in case of several subsystems. A subsystem is described by equations, see below. The device uses 4 2nd order subsystems, resulting in an 8th order Butterworth filter.
x_n is here the input signal, y_n is the filter output and simultaneously the input of another subsystem.



IMG-ID: 151303947

$$w_0(n) = x(n) + a^0{}_1 \times w_0(n-1) + a^0{}_2 \times w_0(n-2)$$

$$y_0(n) = b^0{}_0 \times w_0(n) + b^0{}_1 \times w_0(n-1) + b^0{}_2 \times w_0(n-2)$$

7.3 Decimal / Hexadecimal conversion table

Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex
0	*0*	51	*33*	102	*66*	153	*99*	204	*CC*
1	*1*	52	*34*	103	*67*	154	*9A*	205	*CD*
2	*2*	53	*35*	104	*68*	155	*9B*	206	*CE*
3	*3*	54	*36*	105	*69*	156	*9C*	207	*CF*
4	*4*	55	*37*	106	*6A*	157	*9D*	208	*D0*
5	*5*	56	*38*	107	*6B*	158	*9E*	209	*D1*
6	*6*	57	*39*	108	*6C*	159	*9F*	210	*D2*
7	*7*	58	*3A*	109	*6D*	160	*A0*	211	*D3*
8	*8*	59	*3B*	110	*6E*	161	*A1*	212	*D4*
9	*9*	60	*3C*	111	*6F*	162	*A2*	213	*D5*
10	*0A*	61	*3D*	112	*70*	163	*A3*	214	*D6*
11	*0B*	62	*3E*	113	*71*	164	*A4*	215	*D7*
12	*0C*	63	*3F*	114	*72*	165	*A5*	216	*D8*
13	*0D*	64	*40*	115	*73*	166	*A6*	217	*D9*
14	*0E*	65	*41*	116	*74*	167	*A7*	218	*DA*
15	*0F*	66	*42*	117	*75*	168	*A8*	219	*DB*
16	*10*	67	*43*	118	*76*	169	*A9*	220	*DC*
17	*11*	68	*44*	119	*77*	170	*AA*	221	*DD*
18	*12*	69	*45*	120	*78*	171	*AB*	222	*DE*
19	*13*	70	*46*	121	*79*	172	*AC*	223	*DF*
20	*14*	71	*47*	122	*7A*	173	*AD*	224	*E0*
21	*15*	72	*48*	123	*7B*	174	*AE*	225	*E1*
22	*16*	73	*49*	124	*7C*	175	*AF*	226	*E2*
23	*17*	74	*4A*	125	*7D*	176	*B0*	227	*E3*
24	*18*	75	*4B*	126	*7E*	177	*B1*	228	*E4*
25	*19*	76	*4C*	127	*7F*	178	*B2*	229	*E5*
26	*1A*	77	*4D*	128	*80*	179	*B3*	230	*E6*
27	*1B*	78	*4E*	129	*81*	180	*B4*	231	*E7*
28	*1C*	79	*4F*	130	*82*	181	*B5*	232	*E8*
29	*1D*	80	*50*	131	*83*	182	*B6*	233	*E9*
30	*1E*	81	*51*	132	*84*	183	*B7*	234	*EA*

Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex	Dec	Hex
31	*1F*	82	*52*	133	*85*	184	*B8*	235	*EB*
32	*20*	83	*53*	134	*86*	185	*B9*	236	*EC*
33	*21*	84	*54*	135	*87*	186	*BA*	237	*ED*
34	*22*	85	*55*	136	*88*	187	*BB*	238	*EE*
35	*23*	86	*56*	137	*89*	188	*BC*	239	*EF*
36	*24*	87	*57*	138	*8A*	189	*BD*	240	*F0*
37	*25*	88	*58*	139	*8B*	190	*BE*	241	*F1*
38	*26*	89	*59*	140	*8C*	191	*BF*	242	*F2*
39	*27*	90	*5A*	141	*8D*	192	*C0*	243	*F3*
40	*28*	91	*5B*	142	*8E*	193	*C1*	244	*F4*
41	*29*	92	*5C*	143	*8F*	194	*C2*	245	*F5*
42	*2A*	93	*5D*	144	*90*	195	*C3*	246	*F6*
43	*2B*	94	*5E*	145	*91*	196	*C4*	247	*F7*
44	*2C*	95	*5F*	146	*92*	197	*C5*	248	*F8*
45	*2D*	96	*60*	147	*93*	198	*C6*	249	*F9*
46	*2E*	97	*61*	148	*94*	199	*C7*	250	*FA*
47	*2F*	98	*62*	149	*95*	200	*C8*	251	*FB*
48	*30*	99	*63*	150	*96*	201	*C9*	252	*FC*
49	*31*	100	*64*	151	*97*	202	*CA*	253	*FD*
50	*32*	101	*65*	152	*98*	203	*CB*	254	*FE*
								255	*FF*

Glossary

BAM

Broadcast Announce Message

CA

Commanded Address

CAN

Controller Area Network

CAN-ID

CAN Identifier - Assembled messages identifier per device

CFG

Configuration

CMDT

Connection Mode Data Transfer

CTS

Clear To Send

Diag

Diagnostic

EMC

Electromagnetic compatibility

EoMA

End of Message Acknowledge

GND

Ground

IIR

Infinite Impulse Response (filter)

LED

Light Emitting Diode

MEMS

Micro-Electro-Mechanical Systems

PE

Protective Earth

PELV

Protective Extra Low Voltage. Functional extra-low voltage with electrically safe isolation

PG

Parameter Group

PGN

Parameter Group Number

RTS

Request To Send

TPCM

Transport Protocol Connection Management

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