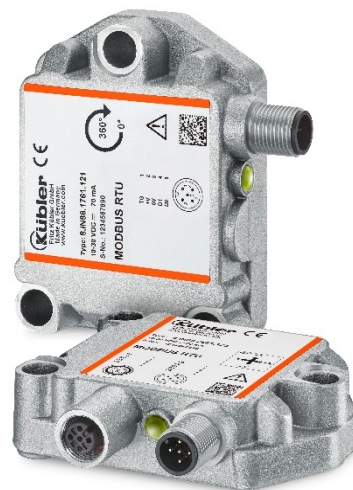


# Manual

## Inclinometer IN88

Inclinometer 1-dimensional  
Inclinometer 2-dimensional



|                            |   |
|----------------------------|---|
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## List of Abbreviations

| Abbreviation | Meaning                       |
|--------------|-------------------------------|
| CRC          | Cyclical Redundancy Check     |
| CRLF         | Carriage Return – Line Feed   |
| ERR          | Error                         |
| HEX          | Hexadecimal                   |
| LRC          | Longitudinal Redundancy Check |
| PDU          | Protocol Data Unit            |
| RTU          | Remote Terminal Unit          |

# 1. Contents

This manual contains information about the IN88 inclinometers on the following topics:

- Firmware and device file versions
- Technical details and inclinometer characteristics
- Supply voltage and current consumption
- Hardware characteristics
- Supported Standards and Protocols
- Implemented profile

Identification and maintenance functionality

- Hardware installation
- Electrical installation
- Status LEDs
- Quick Start Guide
- Modbus implementation
- Troubleshooting
- Release information

|               |  |
|---------------|--|
| <b>NOTICE</b> | These operating instructions do not contain information about the installation. You will find these in separate installation instructions. |
|---------------|--|

## 2. Identification and maintenance functionality

- Hardware installation Electrical installation
- Status LEDs
- Quick Start Guide
- **Modbus** implementation
- Troubleshooting
- Release information

This manual does not contain information about the installation. You will find these in separate installation instructions.

## 3. Technical details and characteristics

### 3.1 Working temperature range

-40...+85°C

### 3.2 Supply voltage and current consumption

Output:

|             |                 |
|-------------|-----------------|
| 10...30 VDC | 70 mA at 10 VDC |
|             | 30 mA at 24 VDC |
|             | 26 mA at 30 VDC |

### 3.3 Hardware characteristics

|   |               |
|---|---------------|
| <b>2-axes sensor</b> Measuring range per axis | +/- 85.00°    |
| <b>1-axis sensor</b> Measuring range          | 0 ... 359.99° |
| Internal process data cycle                   | 20 ms         |
|   |               |

### 3.4 Function display and diagnostics

Triple LED (red/green/blue)

### 3.5 Supported Standards and Protocols

- MODBUS APPLICATION PROTOCOL SPECIFICATION V1.1b3
- MODBUS over Serial Line Specification and Implementation Guide V1.02

The **Modbus** inclinometer supports the current **MODBUS APPLICATION PROTOCOL SPECIFICATION V1.1b3**. In addition, device-specific registers are available.

The additional services integrated allow performing node number allocation and Modbus bit rate configuration directly via the Modbus.

## 3.6 Orientation

### 1-dimensional 0 ... 360°

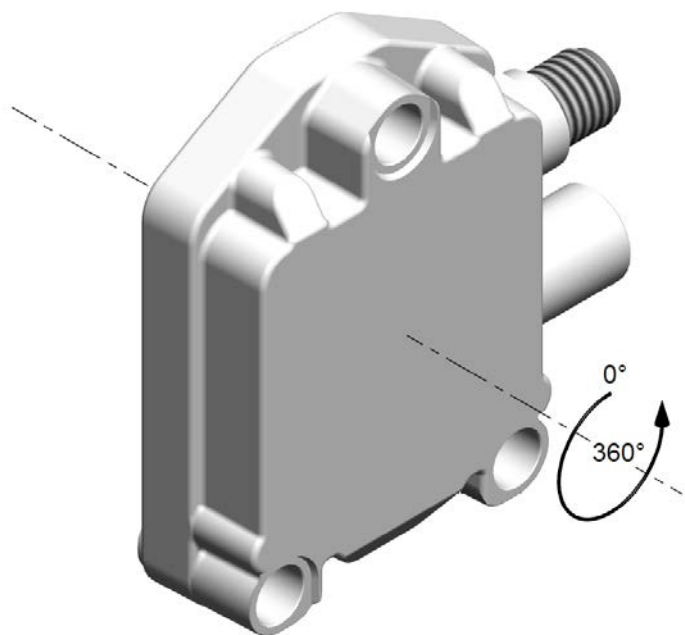


Figure 1

### 2-dimensional $\pm 85^\circ$

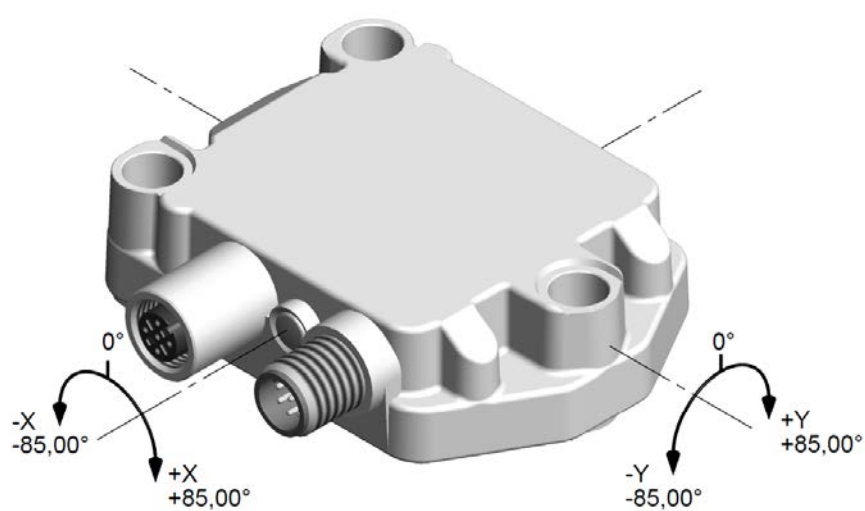


Figure 2

### 3.7 Operating modes

The Polled Mode operating mode can be selected. Moreover, scaling, preset values and many other additional parameters can be programmed via the Modbus. When switching the appliance on, all parameters are loaded from a flash memory. These parameters have previously been stored in a zero-voltage secure manner. The output values can combine in a very variable way e. g. **the angle of the measurement axes, the temperature and the position as read-holding registers.**

### 3.8 Modbus access point

Termination at both ends

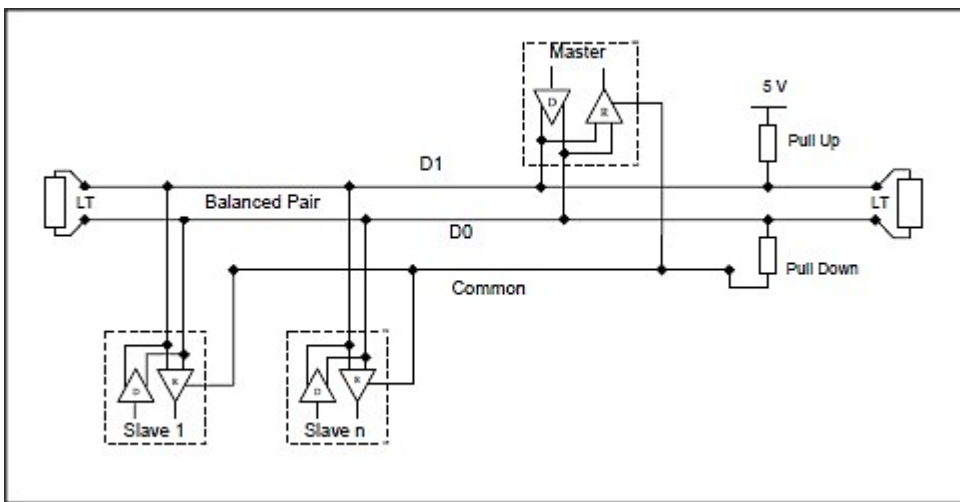


Figure 3

Bus termination can be configured by means of a register. It allows connecting a **120 ohm** resistor.

## 4. Electrical installation - Supply voltage and Modbus

This chapter contains information about the electrical installation, configuration and commissioning of the inclinometer.


### NOTICE

#### Switch off the plant!

Make sure that the whole plant remains switched off during the electrical installation.

Electrical installation requires connectors or connection cables (see data sheet).

### 4.1 Terminal assignment

| Schnittstelle | Anschlussart | 1 x M12 Stecker, 5-polig |        |     |    |    |    |   |
|---------------|--------------|--------------------------|--------|-----|----|----|----|---|
| 6             | 1            |                          | Bus IN |     |    |    |    |  |
|               |              | Signal:                  | +V     | 0 V | D0 | D1 | TG |   |
|               |              | Pin:                     | 2      | 3   | 5  | 4  | 1  |   |

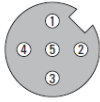

| Schnittstelle | Anschlussart | 2 x M12 Stecker, 5-polig |         |     |    |    |    |   |
|---------------|--------------|--------------------------|---------|-----|----|----|----|---|
| 6             | 3            |                          | Bus OUT |     |    |    |    |  |
|               |              | Signal:                  | +V      | 0 V | D0 | D1 | TG |   |
|               |              | Pin:                     | 2       | 3   | 5  | 4  | 1  |   |
|               |              |                          | Bus IN  |     |    |    |    |  |
|               |              | Signal:                  | +V      | 0 V | D0 | D1 | TG |   |
|               |              | Pin:                     | 2       | 3   | 5  | 4  | 1  |   |

Figure 4

### NOTICE

#### Connect the shield to the inclinometer housing

If possible, mount all cables with traction relief.

Check the maximum supply voltage on the device.

## 4.2 Electrical Inclinometer Features

|  |  |
|--|--|
| 2-axes sensor:<br>Measuring range per axis | +/- 85.00°   |
| 1-axis sensor:<br>Measuring range per axis | 0 ... 359.99°  |
| Internal process data cycle                | 20 ms  |
| Output:                                    | Modbus Protocol RTU                                      |
| Communication RTU:                         | 9600 ... 115200 baud, 8 data bits, no parity, 1 stop bit |
| Display:                                   | LED's  |
| Interface:                                 | RS-485 for Modbus  |
| Bus connection:                            | 1 or 2 M12   |
| Sensor                                     | MES system interface                                     |
| Resolution:                                | 14-bit resolution +/- 85.00°                             |
| Default Scaling:                           | 14-bit resolution    Scaling off                         |
| 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 Modbus.**

If possible, mount all cables with traction relief.

Check the maximum supply voltage on the device.

## 5. Function and status LED







A **3-color LED** signals the operating and error status of the Modbus.

The device is equipped with a **triple LED** for displaying status and error messages

**Green** = Modbus BUS status

**Red** = Modbus ERR display

**Blue** = Calibration mode in combination with Green and Red

| Display                             | LED   | Meaning  | Error cause   | Addition  |
|-------------------------------------|---|--|---|---|
| All LEDs off                        |    | No connection to the master <sup>2</sup>   | Data line interruption<br>Wrong baud rate<br>Interchanged data line<br>No voltage | Observe the combination with the ERR LED If ERR LED is also off, check the voltage supply.          |
| Green Flashing about 250 ms         |   | Device ready for operation   |   | Communication is active   |
| Red off                             |  | Device operates error-free   |   | Observe the combination with the green LED  |
| Green flashing Blue flashing        |   | Transmission over Modbus active  | Combination with bus status   | Bus LED flashing green<br>Transmission running  |
| ERR flashing                        |  | Failure  | Modbus signaled a system error  |   |
| Blue flashing 300 ms                |  | Calibration Mode<br>Device is neither 6-point calibrated nor temperature-compensated |   | Perform 6-point calibration<br>Perform temperature calibration<br>Adjust 30 VDC at the power supply |
| Blue and Red flashing alternatingly |  | Calibration Mode<br>Device is 6P calibrated, but not temperature-compensated yet     |   | Perform temperature calibration<br>Adjust 30 VDC at the power supply                                |

## 6. Quick-Start Guide - General settings on the appliance

### NOTICE

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

| Function   | Register     | Designation                |
|--|--------------|----------------------------|
| Switch the appliance on                            |              |                            |
| Set the Modbus parameters using the register table |              |                            |
| Setting of the required baud rate                  | Register 300 | Baud rate                  |
| Setting of the node address                        | Register 304 | Node address               |
| Setting of the termination                         | Register 305 | Termination                |
| Setting of the resolution                          | Register 310 | Resolution                 |
| Saving the bus parameters                          | Register 360 | Save all Modbus Parameters |
| Appliance on/off cycle                             |              |                            |

### 6.1 Register 300

Baud rate Default setting: **19200 bit/s** (Entry 2)

The baud rate can be modified **with a Modbus software on Register 300**. Input value: 1...5

| Value | Baud rate in Kbit/s |
|-------|---------------------|
| 1     | 9600                |
| 2     | 19200               |
| 3     | 38400               |
| 4     | 57600               |
| 5     | 115200              |

### NOTICE

To be taken into consideration for the corresponding baud rate:  
For all baud rates, general cycle time at least **20ms**

## 6.2 Register 304

Node address Default setting: **0x3F** (63 decimal).

The node number can also be modified **with a Modbus software on Register 304**.

**Node number 00** is reserved for broadcast messages and shall not be used by any node.

The resulting node numbers are in the range **1...7Fh** hexadecimal (1...127 decimal). Register 360 stores the value permanently.

## 6.3 Register 305

Termination Default setting: **0x2** (on).

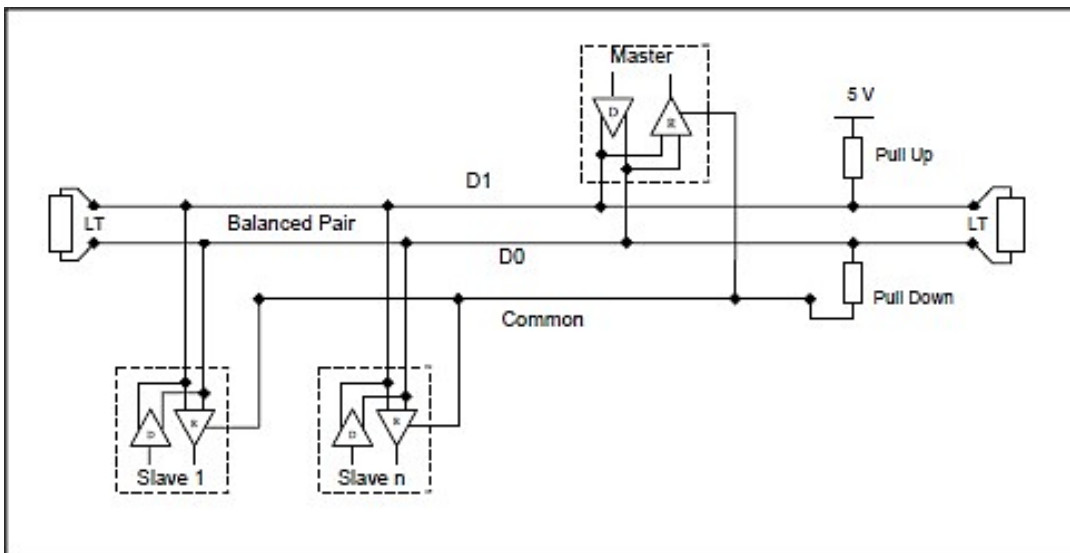


Figure 5

Modbus 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 (or 121) ohm terminating resistor in order to prevent reflections. This is necessary even in case of very short line lengths!

The termination can also be modified **with a Modbus software on Register 305**.

**Termination value 1** switches the terminating resistor off. **Termination value 2** switches the terminating resistor on.

## 6.4 Register 310

Resolution Default setting **0xA** (10d)

Default setting sensor: 10d = 0.01 ° Resolution

| Value        | Definition           |
|--------------|----------------------|
| 1d (01h)     | 0.001° not supported |
| 10d (0Ah)    | <b>0.01°</b>         |
| 100d (64h)   | 0.1°                 |
| 1000d (3E8h) | 1.0°                 |
| other        | not supported        |

### NOTICE

Parameter "310 Resolution" influences measuring axes **long16** and **lateral16** and **Euler angle Y!**

## 6.5 Register 360

Saving the parameters

This parameter (**Register 360**) saves all Modbus parameters **permanently** in the Flash memory. Only targeted saving with parameter "**save**" (**hexadecimal 1010**) will save permanently all **Modbus parameters** and bus parameters such as **baud rate, node address and termination**.

### NOTICE

The new values are only taken over after a power off/on sequence.

|     |     |   |     |                                 |                           |
|-----|-----|---|-----|---------------------------------|---------------------------|
| 300 | VAR | W | U16 | Baudrate                        | 19200 Baud (2)            |
| 301 | VAR | W | U16 | Parity                          | 1=none, 2 = even , 3 =odd |
| 302 | VAR | W | U16 | Stopbit                         | 1= 1 Stopbit, 3=2 Stopbit |
| 304 | VAR | W | U16 | Node Number                     | 0x3F                      |
| 305 | VAR | W | U16 | Termination                     | 2 = ON , 1 =Off           |
| 310 | VAR | W | U16 | Resolution of all axis          | 10                        |
| 360 | VAR | W | U16 | Save All Application Parameters | 0x1010                    |

Figure 6

## 7. Operating modes

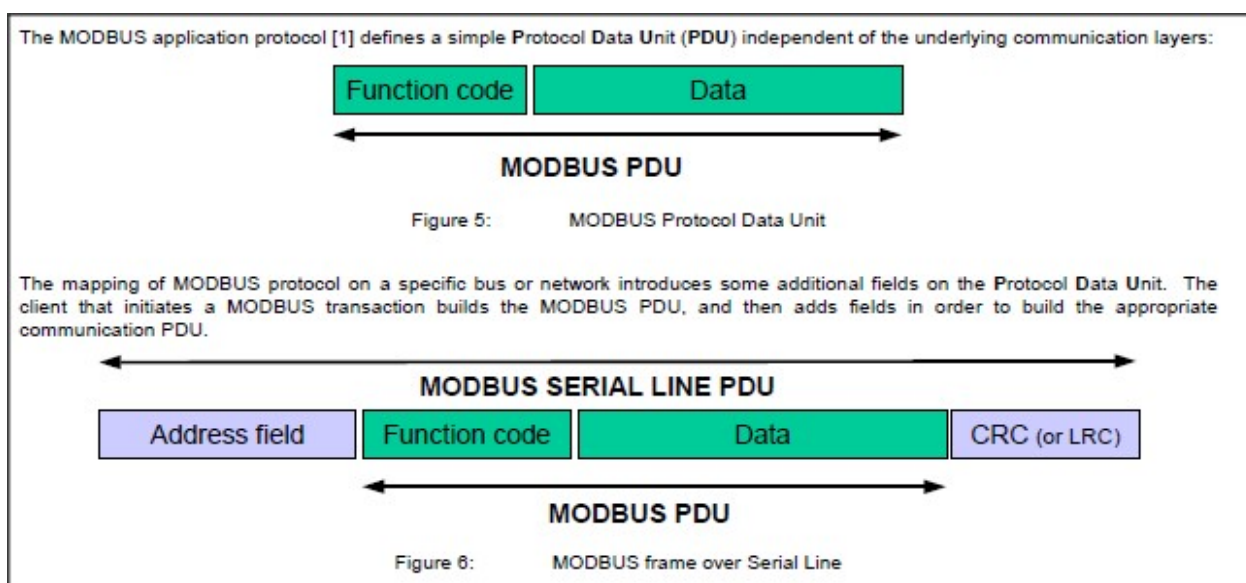


Figure 7

### 7.1 MODBUS Message RTU Framing

In RTU mode, messages start with a silent interval of at least 3.5 character times.

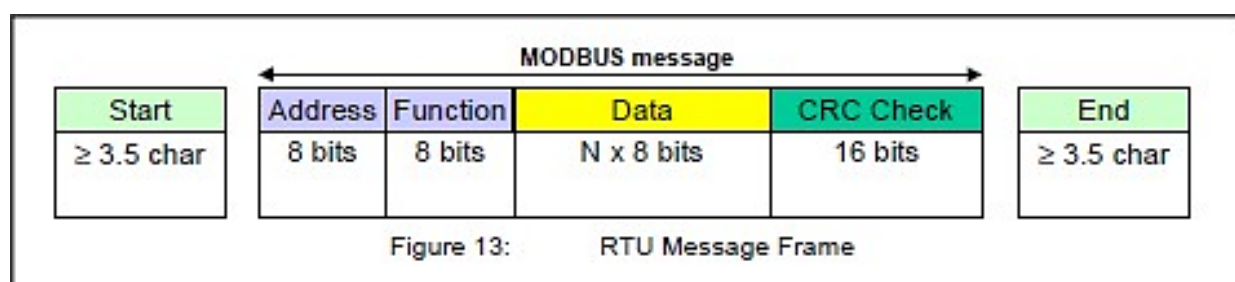


Figure 8

This is most easily implemented as a multiple of character times at the baud rate that is being used on the network. The **first field** then transmitted is the device address in the range of **01...0xF7 (247) (248-255 reserved by Modbus)**. The allowable characters transmitted for all fields are hexadecimal 0–9, A–F.

Networked devices monitor the network bus continuously, including during the 'silent' intervals. When the first field (the address field) is received, the inclinometer decodes it to find out if it is the addressed device.

Following the last transmitted character, a similar interval of at least 3.5 character times marks the end of the message. A new message **can begin after** this interval.

The entire message frame must be transmitted as a continuous stream. If a silent interval of more than 1.5 character times occurs before completion of the frame, the receiving device flushes the incomplete message and assumes that the next byte will be the address field of a new message.

Similarly, if a new message begins earlier than 3.5 character times following a previous message, the receiving device will consider it a continuation of the previous message. This will **set an error**, as the value in the final CRC field will **not be valid for** the combined messages.

## 7.2 RTU Transmission Mode

In RTU mode, messages start with a silent interval of at least 3.5 character times. This is most easily implemented as a multiple of character times at the baud rate that is being used on the network (shown as T1–T2–T3–T4 in the figure below). The first field then transmitted is the device address. The allowable characters transmitted for all fields are hexadecimal 0–9, A–F. Networked devices monitor the network bus continuously, including during the ‘silent’ intervals. When the first field (the address field) is received, each device decodes it to find out if it is **the addressed** device.

Following the last transmitted character, a similar interval of at least 3.5 character times marks the end of the message. A new message can begin after this interval. The entire message frame must be transmitted as a continuous stream. If a silent interval of more than 1.5 character times occurs before completion of the frame, the receiving device flushes the incomplete message and assumes that the next byte will be the address field of a new message. Similarly, if a new message begins earlier than 3.5 character times following a previous message, the receiving device will consider it a continuation of the previous message. This will set **an error**, as the value in the final CRC field will not be valid for the combined messages. A typical message frame is shown below.

| START       | ADDRESS | FUNCTION | DATA              | CRC CHECK | END         |
|-------------|---------|----------|-------------------|-----------|-------------|
| T1–T2–T3–T4 | 8 BITS  | 8 BITS   | $n \times 8$ BITS | 16 BITS   | T1–T2–T3–T4 |

Figure 9

## 7.3 LRC Checking

In ASCII mode, messages include an error-checking field that is based on a Longitudinal Redundancy

Checking (**LRC**) calculation is performed on the message contents, exclusive of the beginning 'colon' and terminating CRLF pair characters. It is applied regardless of any parity checking method used for the individual characters of the message.

The LRC field is one byte, containing an 8-bit binary value. The LRC value is calculated by the device that emits, which appends the LRC to the message. The device that receives calculates an LRC during receipt of the message, and compares the calculated value to the actual value it received in the LRC field. If the two values are not equal, an error results.

The LRC is calculated by adding together successive 8-bit bytes of the message, discarding any carries, and then two's complementing the result. It is performed on the bytes of the message, before the encoding of each byte in the two ASCII characters corresponding to the hexadecimal representation of each nibble. The computation does not include the 'colon' character that begins the message, and does not include the CRLF pair at the end of the message.

## 7.4 Modbus Communication Defaults

**Standard communication parameters are:**

The resulting baud rate numbers lie in the range 9600 ... 115200 Baud.

**Modbus RTU Default: 19200 baud, 8 data bits, no parity, 1 stop bit**

## 7.5 Modbus Node number

**Node number 0** is reserved and must not be used by any node.

The resulting node numbers lie in the range **1...F7h** hexadecimal (1...247 decimal, 248-255 res).

**Node ID      Default: 0x3F**

## 7.6 Data Model

MODBUS bases its data model on a series of tables that have distinguishing characteristics. The four primary tables

| Primary tables    | Object type | Type of    | Comments  |
|-------------------|-------------|------------|---|
| Discretes Input   | Single bit  | Read-Only  | This type of data can be provided by an I/O system.           |
| Coils             | Single bit  | Read-Write | This type of data can be alterable by an application program. |
| Input Registers   | 16-bit word | Read-Only  | This type of data can be provided by an I/O system            |
| Holding Registers | 16-bit word | Read-Write | This type of data can be alterable by an application program. |

Figure 10

The distinctions between inputs and outputs, and between bit-addressable and word-addressable data items, do not imply any application behavior.

## 7.7 Data Addresses in Modbus Messages

All data addresses in Modbus messages are referenced to zero.

- Holding register **40001 is addressed as register 0001 in the data address field** of the message. The function code field already specifies a 'holding register' operation. Therefore the '4XXXX' reference is implicit.
- Holding register **40014 is addressed as register 000D hex (14 decimal)**.

## 8. Read Holding Register

### 1 Read Holding Register Function code 03

Reads the binary contents of holding registers (4XXXX references) in the inclinometer slave.  
**Broadcast** is **not** supported.

#### READ HOLDING REGISTERS FUNCTION CODE 03

| Register | Data Name             | ATT | Value                       | Default        |
|----------|-----------------------|-----|-----------------------------|----------------|
| 00001    | LOTWINKEL X-ACHSE     | I16 | Inclination angle in 0.01 ° | -85.00..+85.00 |
| 00002    | LOTWINKEL Y-ACHSE     | I16 | Rotation angle in 0.01 °    | -85.00..+85.00 |
| 00003    | EULERWINKEL X-ACHSE   | I16 | Euler angle (1 axis)        | 0 ... 180.99°  |
| 00004    | EULERWINKEL Y-ACHSE   | U16 | Euler angle (1 axis)        | 0 ... 359.99°  |
| 00007    | VERSORGUNG VCC        | U16 | VCC in 0.1 VDC              | 240            |
| 00008    | TEMPERATURE IN 0.1 °C | U16 | Temp. in 0.1°               | 210            |
| 00016    | SIDEVIEW              | U16 | Back = 0, Front = 1         | 0              |
| 00023    | SYSTEM STATE          | U16 | No errors = 0               | 0              |
| 00140    | BAUDRATE              | U16 | Current baud rate           | 19200 Baud (2) |
| 00144    | NODE-ID               | U16 | Current node address        | 63             |
| 00145    | TERMINIERUNG          | U16 | Termination on/off          | 2 (on)         |
| 00146    | FILTER AKTIVIERUNG    | U16 | Filter on/off               | 1 (on)         |
| 00147    | FILTER EINSTELLUNG    | F32 | Filter value in HZ          | 5.0            |
| 00148    | SERIENNUMMER          | U32 | Serial number               | 16DDNNNNNN     |
| 00149    | PRODUCT CODE          | U32 | Device type                 | 0x88616100     |
| 00150    | AUFLÖSUNG             | U16 | Resolution X/Y axis         | 0.01 ° (10)    |
| 00151    | OPERATING PARAMETER   | U16 | Setting X axis              | 0              |
| 00152    | PRESET X-ACHSE        | U16 | Preset X axis               | 0              |

|       |                        |     |                     |   |
|-------|------------------------|-----|---------------------|---|
| 00153 | OFFSET X-ACHSE         | U16 | Offset X axis       | 0 |
| 00154 | DIFF.OFFSET X-ACHSE    | U16 | Differential offset | 0 |
|       |                        |     |                     |   |
| 00155 | OPERATING<br>PARAMETER | U16 | Setting Y axis      | 0 |
| 00156 | PRESET Y-ACHSE         | U16 | Preset Y axis       | 0 |
| 00157 | OFFSET Y-ACHSE         | U16 | Offset Y axis       | 0 |
| 00158 | DIFF.OFFSET Y-ACHSE    | U16 | Differential offset | 0 |
| 00159 | OFFSET EULERWINKEL     | U16 | Offset after preset | 0 |

**Query**

The query message specifies the starting register and quantity of registers to be read.

**Response**

The register data in the response message is packed as two bytes per register, with the binary contents right-justified within each byte. For each register, the first byte contains the high order bits and the second contains the low order bits.

## 9. Write Holding Register

### 2 Write Holding Register Function code 16 [0x10]

#### Description

Write values into a sequence of holding registers (4XXXX references). When **broadcast**, the function presets the same register references in **all** attached inclinometer slaves.

#### Note

The function will override the **Inclinometer memory protect state**.

The programmed values will remain valid in the registers **during the complete power-cycle** and some functions will achieve immediately.

The register values will remain and stored in a **non volatile** memory, independently of whether they are programmed in the controller's logic or not.

Write Holding Register Function code 16 [0x10]

| Register | Value | R/W | Format | Content                             | Default                     |
|----------|-------|-----|--------|-------------------------------------|-----------------------------|
| 300      | VAR   | W   | U16    | Baud rate                           | 19200 baud (2)              |
| 301      | VAR   | W   | U16    | Parity                              | 1=none, 2 = even, 3 =odd    |
| 302      | VAR   | W   | U16    | Stopbit                             | 1=1 Stop bit, 3=2 Stop bits |
| 304      | VAR   | W   | U16    | Node Number                         | 0x3F (63d)                  |
| 305      | VAR   | W   | U16    | Termination                         | 2 = ON , 1 =Off             |
| 306      | VAR   | W   | U16    | Digital Filter Active               | 1 = ON                      |
| 307      | VAR   | W   | F32    | Digital Filter Coefficient          | 5.0                         |
|          |       |     |        |                                     |                             |
| 310      | VAR   | W   | U16    | Resolution of axis                  | 10                          |
| 311      | VAR   | W   | U16    | Slope long16 operating parameter    | 0                           |
| 312      | VAR   | W   | I16    | Slope long16 preset value           | 0                           |
| 313      | VAR   | W   | I16    | Slope long16 offset                 | 0                           |
| 314      | VAR   | W   | I16    | Differential Slope long16 offset    | 0                           |
|          |       |     |        |                                     |                             |
| 315      | VAR   | W   | U16    | Slope lateral16 operating parameter | 0                           |

|            |     |   |     |  |        |
|------------|-----|---|-----|--|--------|
| <b>316</b> | VAR | W | I16 | <b>Slope lateral16 preset value</b>          | 0      |
| <b>317</b> | VAR | W | I16 | <b>Slope lateral16 offset</b>                | 0      |
| <b>318</b> | VAR | W | I16 | <b>Differential Slope lateral16 offset</b>   | 0      |
| <b>320</b> | VAR | W | U16 | <b>Preset Euleraxis (only 0)</b>             | 0      |
| <b>261</b> | VAR | W | U16 | <b>Delaytime for Transmission</b>            | 1      |
|            |     |   |     |  |        |
| <b>360</b> | VAR | W | U16 | <b>Save All Application Parameters</b>       | 0x1010 |
| <b>361</b> | VAR | W | U16 | <b>Load All Parameters (Factory default)</b> | 0x1011 |

## 10. Supported Modbus Function Codes in Project

### 10.1 Function 03 Read Holding Registers General Description

#### Query

The query message specifies the starting register and quantity of registers to be read. Registers are addressed starting at zero: registers 1–16 are addressed as 0–15. Here is an example of a request to read registers 40108–40110 from slave device

| QUERY                    |               |
|--------------------------|---------------|
| Field Name               | Example (Hex) |
| Slave Address            | 11            |
| Function                 | 03            |
| Starting Address Hi      | 00            |
| Starting Address Lo      | 6B            |
| No. of Points Hi         | 00            |
| No. of Points Lo         | 03            |
| Error Check (LRC or CRC) | —             |

Figure 14 Read Holding Registers – Query

Figure 11

#### Response

The register data in the response message is packed as two bytes per register, with the binary contents right justified within each byte. For each register, the first byte contains the high order bits and the second contains the low order bits. The response is returned when the data is completely assembled.

### 10.2 FUNCTION 16 (10 HEX) PRESET MULTIPLE REGISTERS

#### Query

The query message specifies the register references to be preset. Registers are addressed starting at zero: register 1 is addressed as 0.

Here is an example of a request to preset **two registers** starting at 40002 to 00 0A and 01 02 hex, in slave device 17 (0x11):

| QUERY                    |               |
|--------------------------|---------------|
| Field Name               | Example (Hex) |
| Slave Address            | 11            |
| Function                 | 10            |
| Starting Address Hi      | 00            |
| Starting Address Lo      | 01            |
| No. of Registers Hi      | 00            |
| No. of Registers Lo      | 02            |
| Byte Count               | 04            |
| Data Hi                  | 00            |
| Data Lo                  | 0A            |
| Data Hi                  | 01            |
| Data Lo                  | 02            |
| Error Check (LRC or CRC) | —             |

Figure 30 Preset Multiple Registers – Query

Figure 12

## Response

The normal response returns the slave address, function code, starting address, and **quantity of registers preset**.

Here is an example of a response to the query shown above.

| RESPONSE                 |               |
|--------------------------|---------------|
| Field Name               | Example (Hex) |
| Slave Address            | 11            |
| Function                 | 10            |
| Starting Address Hi      | 00            |
| Starting Address Lo      | 01            |
| No. of Registers Hi      | 00            |
| No. of Registers Lo      | 02            |
| Error Check (LRC or CRC) | —             |

Figure 31 Preset Multiple Registers – Response

Figure 13

Example: Node ID 3F **Read 8 Register** starting with register 1 up to register 8 (temperature)

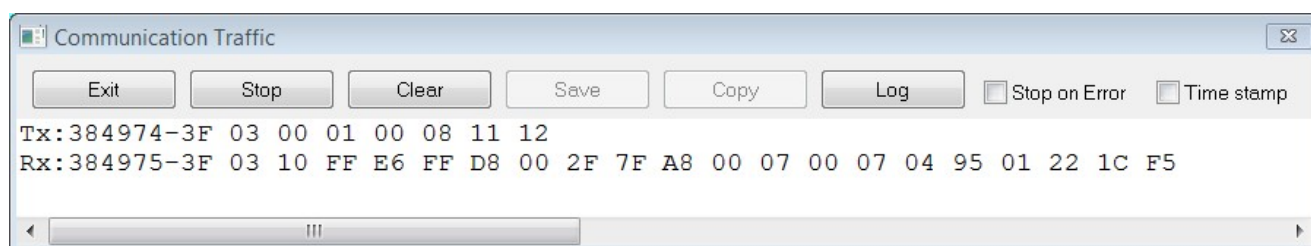


Figure 14

# 11. Function code 03

## 3 Function code 03 Read Holding Registers

### Description

Reads the binary contents of holding registers (4X references) in the slave.

Broadcast is **not** supported

READ HOLDING REGISTERS

FUNCTION CODE 03

| REGISTER | DATA NAME             | ATT | Value                       | Value           |
|----------|-----------------------|-----|-----------------------------|-----------------|
| 00001    | LOTWINKEL X-ACHSE     | I16 | Inclination angle in 0.01 ° | -85.00..+85.00  |
| 00002    | LOTWINKEL Y-ACHSE     | I16 | Rotation angle in 0.01 °    | -85.00..+85.00  |
| 00003    | EULERWINKEL X-ACHSE   | I16 | Euler angle (1 axis)        | 0 ... 180.99° * |
| 00004    | EULERWINKEL Y-ACHSE   | U16 | Euler angle (1 axis)        | 0 ... 359.99° * |
|          |                       |     |                             |                 |
| 00007    | VERSORGUNG VCC        | U16 | VCC in 0.1 VDC              | 240             |
| 00008    | TEMPERATURE IN 0.1 °C | U16 | Temp. in 0.1°               | 210             |
| 00016    | SIDEVIEW              | U16 | Back = 0, Front = 1         | 0               |
| 00023    | SYSTEM STATE          | U16 | No errors = 0               | 0               |
|          |                       |     |                             |                 |
| 00140    | BAUDRATE              | U16 | Current baud rate           | 19200 baud (2)  |
| 00144    | NODE-ID               | U16 | Current node address        | 63              |
| 00145    | TERMINIERUNG          | U16 | Termination on/off          | 2 (on)          |
| 00146    | FILTER AKTIVIERUNG    | U16 | Filter on/off               | 1 (on)          |
| 00147    | FILTER EINSTELLUNG    | F32 | Filter value in HZ          | 5.0             |
| 00148    | SERIENNUMMER          | U32 | Serial number               | 16DDNNNNNN      |
| 00149    | PRODUCT CODE          | U32 | Device type                 | 0x88616100      |
|          |                       |     |                             |                 |
| 00150    | AUFLÖSUNG             | U16 | Resolution X/Y axis         | 0.01 ° (10)     |
| 00151    | OPERATING PARAMETER   | U16 | Setting X axis              | 0               |

|              |                                |     |                     |                |
|--------------|--------------------------------|-----|---------------------|----------------|
| <b>00152</b> | <b>PRESET X-ACHSE</b>          | U16 | Preset X axis       | 0              |
| <b>00153</b> | <b>OFFSET X-ACHSE</b>          | U16 | Offset X axis       | 0              |
| <b>00154</b> | <b>DIFF.OFFSET X-ACHSE</b>     | U16 | Differential offset | 0              |
|              |                                |     |                     |                |
| <b>00155</b> | <b>OPERATING<br/>PARAMETER</b> | U16 | Setting Y axis      | 0              |
| <b>00156</b> | <b>PRESET Y-ACHSE</b>          | U16 | Preset Y axis       | 0              |
| <b>00157</b> | <b>OFFSET Y-ACHSE</b>          | U16 | Offset Y axis       | 0              |
| <b>00158</b> | <b>DIFF.OFFSET Y-ACHSE</b>     | U16 | Differential offset | 0              |
| <b>00159</b> | <b>OFFSET EULERWINKEL</b>      | U16 | Offset after preset | 0 <sup>1</sup> |

#### **Lotwinkel X-Achse Value Query Register 40001 (16-bit access)**

Position values depending on the scaling factor set.

|   |  |
|---|--|
| <b>Lotwinkel X-Achse resolution 0.01°</b> | <b>-85.00 ... +85.00</b>               |
| Deterministic position delay time:        | 40μs                                   |
| Position Jitter:                          | +/- 1μs                                |
| Total response delay for position values: | 40μs + process time for response frame |
| Estimated response delay for position:    | 10μs                                   |
| Minimum cycle time for position update:   | 20ms (timeout t3.5 + 300μs)            |

#### **Lotwinkel Y-Achse Value Query Register 40002 (16-bit access)**

Position values depending on the scaling factor set.

|   |  |
|---|--|
| <b>Lotwinkel Y-Achse resolution 0.01°</b> | <b>-85.00 ... +85.00</b>               |
| Deterministic position delay time:        | 40μs                                   |
| Position Jitter:                          | +/- 1μs                                |
| Total response delay for position values: | 40μs + process time for response frame |
| Estimated response delay for position:    | 10μs                                   |
| Minimum cycle time for position update:   | 20ms (timeout t3.5 + 300μs)            |

---

<sup>1</sup> Only for 1-axis system

**Eulerwinkel X-Achse Value Query Register 40003 (16-bit access)**

Position values depending on the scaling factor set.

**Eulerwinkel resolution 0.01°                      0... 180.0°**

**Eulerwinkel Y-Achse Value Query Register 40004 (16-bit access)**

Position values depending on the scaling factor set.

**Eulerwinkel resolution 0.01°                      0... 359.9°**

Deterministic position delay time:                      40µs

Total response delay for position values:                      40µs + process time for response frame

Estimated response delay for position:                      100µs

Minimum cycle time for position update:                      20ms (timeout t3.5 + 300µs)

**Actual VCC Voltage Query Register 40007:**

**Value in 0.1 VDC steps**

Actual VCC Value

Example

Value = 245

**VCC = 24.5 VDC**

**Actual Sensor Temperature Query Register 40008:**

Sensor temperature values: *in 0.1°C*

Default:                      25 °C (*ambient temperature*)

Temperature range                      -40°C ... 100°C

Temperature Critical Level                      90°C

**Update Rate:                      60 sec**

**Example**

**Value = 332**

**Temperature = 33.2°C**

**Actual System State Query Register 40023:**

Default:

**No errors = 0x0000****Others\***

see table for details

**ERRORFREE = 0**

INIT\_ERR = 1,

SENSOR\_ERR = 2,

EPS\_INIT\_ERR = 3,

EPS\_FUNC\_ERR = 4

**Actual Baud rate State Query Register 40140:**

Stored values:

Actual result of internal baud rate table

To be taken into consideration for the corresponding baud rate

For all baud rates, general cycle time at least **20ms**

| Value    | Baud rate in Kbit/s |
|----------|---------------------|
| <b>1</b> | <b>9600</b>         |
| <b>2</b> | <b>19200</b>        |
| <b>3</b> | <b>38400</b>        |
| <b>4</b> | <b>57600</b>        |
| <b>5</b> | <b>115200</b>       |

**Actual Node ID State Register 40144:****Node ID Value:****0x3F (63) default****NOTICE**The node number can be modified **on Register 304**.**Node number 0** is reserved and shall not be used by any node.The resulting node numbers are in the range **1...7Fh** hexadecimal (1...127 decimal).

**Actual Bus Termination State Query Register 40145:**

Bus termination off = 1

12. Bus termination on = 2

**Actual Digital Filter State Query Register 40146:**

|                 |   |                                 |
|-----------------|---|---------------------------------|
| Filter active   | 1 | default                         |
| Filter disabled | 0 | Update Rate: <i>immediately</i> |

**Actual Filter Parameter Register 40147 (32-bit access Butterworth)**

|                      |                    |         |
|----------------------|--------------------|---------|
| Filter Coeff values: | 0.1 .... 10.0      |         |
| Default:             | 5.0                | default |
| Update Rate:         | <i>immediately</i> |         |

**Serial Number Register 400148 (32-bit access)**

|                    |  |                                 |
|--------------------|--|---------------------------------|
| Allowed values:    | Actual Serial Number in following format |                                 |
|                    | 0xYYDDDDNNNNN                            |                                 |
|                    | 0xYY                                     | Year (last 2 Digits)            |
|                    | 0xDDD                                    | actual day of the year (1..365) |
| Low Word SN Number | 0xNNNNN                                  | continuously number 1...65535   |

**Product Code Register 400149 (32-bit access)**

|                 |   |                        |
|-----------------|---|------------------------|
| Allowed values: | Actual Product code in following format |                        |
|                 | 0xTTDD                                  |                        |
| 0x88266100      | 0xTT                                    | Product code           |
|                 | 0xDD                                    | Interface 61= Modbus   |
| Low Word Number | 0x6100                                  | <b>Modbus standard</b> |

## 13. Function code 16

### 4 Function code 16 (10 Hex) WRITE Multiple Registers

| Write Holding Register Function code 16 [0x10] |       |     |        |  |                                    |
|--|-------|-----|--------|--|------------------------------------|
| Register                                       | Value | R/W | Format | Content                                    | Default                            |
| <b>300</b>                                     | VAR   | W   | U16    | <b>Baud rate</b>                           | <b>19200 baud (2)</b>              |
| <b>301</b>                                     | VAR   | W   | U16    | <b>Parity</b>                              | <b>1=none, 2 = even, 3 =odd</b>    |
| <b>302</b>                                     | VAR   | W   | U16    | <b>Stopbit</b>                             | <b>1=1 Stop bit, 3=2 Stop bits</b> |
| <b>304</b>                                     | VAR   | W   | U16    | <b>Node Number</b>                         | <b>0x3F</b>                        |
| <b>305</b>                                     | VAR   | W   | U16    | <b>Termination</b>                         | <b>2 = ON , 1 =Off</b>             |
| <b>306</b>                                     | VAR   | W   | U16    | <b>Digital Filter Active</b>               | <b>1 = ON</b>                      |
| <b>307</b>                                     | VAR   | W   | F32    | <b>Digital Filter Coefficient</b>          | <b>5.0</b>                         |
|  |       |     |        |  |                                    |
| <b>310</b>                                     | VAR   | W   | U16    | <b>Resolution of axis</b>                  | <b>10</b>                          |
| <b>311</b>                                     | VAR   | W   | U16    | <b>Slope long16 operating parameter</b>    | <b>0</b>                           |
| <b>312</b>                                     | VAR   | W   | I16    | <b>Slope long16 preset value</b>           | <b>0</b>                           |
| <b>313</b>                                     | VAR   | W   | I16    | <b>Slope long16 offset</b>                 | <b>0</b>                           |
| <b>314</b>                                     | VAR   | W   | I16    | <b>Differential Slope long16 offset</b>    | <b>0</b>                           |
|  |       |     |        |  |                                    |
| <b>315</b>                                     | VAR   | W   | U16    | <b>Slope lateral16 operating parameter</b> | <b>0</b>                           |
| <b>316</b>                                     | VAR   | W   | I16    | <b>Slope lateral16 preset value</b>        | <b>0</b>                           |
| <b>317</b>                                     | VAR   | W   | I16    | <b>Slope lateral16 offset</b>              | <b>0</b>                           |
| <b>318</b>                                     | VAR   | W   | I16    | <b>Differential Slope lateral16 offset</b> | <b>0</b>                           |
| <b>320</b>                                     | VAR   | W   | U16    | <b>Preset Euler axis Y</b>                 | <b>0</b>                           |
|  |       |     |        |  |                                    |
| <b>261</b>                                     | VAR   | W   | U16    | <b>Delaytime for Transmission</b>          | <b>1</b>                           |
|  |       |     |        |  |                                    |

|            |     |   |     |  |        |
|------------|-----|---|-----|--|--------|
| <b>360</b> | VAR | W | U16 | <b>Save All App Parameters</b>                       | 0x1010 |
| <b>361</b> | VAR | W | U16 | <b>Load All Bus Parameters<br/>(Factory default)</b> | 0x1011 |

**NOTICE**

**All Holding Register in green needs a power off/on cycle**  
**All input values for communication and other functionality will be checked on plausibility.** Other values as defined are not allowed and will be cause an error message

Uxx = UNSIGNED, lxx = SIGNED, Fxx = FLOAT

VAR = Variable

ARRAY = Array of variables

RW = Read/Write

RO = Read only

Const = Constant

Name = Register name

M/O = Mandatory or Optional.

\*Raw Slope long16 High Resolution with a resolution of 0.01°.

## 13.1 Register 300: Baud rate

This register allows modifying the baud rate by software. As a standard, the value is set to 2, i.e. 19,200 bits/s.

| Value    | Baud rate in Kbit/s |
|----------|---------------------|
| <b>1</b> | <b>9600</b>         |
| <b>2</b> | <b>19200</b>        |
| <b>3</b> | <b>38400</b>        |
| <b>4</b> | <b>57600</b>        |
| <b>5</b> | <b>115200</b>       |

**NOTICE**

To be taken into consideration for the corresponding baud rate:  
for all baud rates, general cycle time at least **20ms**

A new baud rate is only taken into consideration at the following booting (Reset/Power-on) of the device. All other settings in the register table remain retained.

Example: Node ID 3F **Change baud rate for 115200**

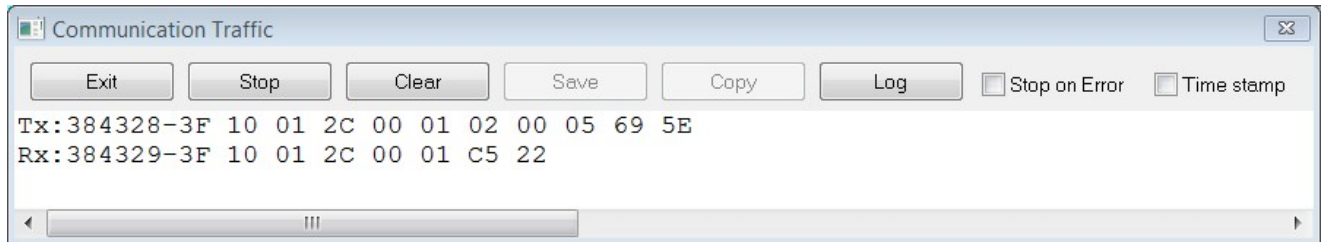


Figure 15

## 13.2 Register 301: Parity setting

This register allows modifying the parity setting by software. As a standard, this value is set to **1 (no parity)**. If the value is set to 2 (even parity) or 3 (odd parity) and the parameter is saved using **Register 360 Save All Bus Parameters**, the device boots with the modified parity settings at the next start-up or Reset Node.

Value Range

**1 = no parity, 2 = even parity, 3 = odd parity**

## 13.3 Register 302: Stop bit setting

This register allows modifying the stop bit setting by software. As a standard, this value is set to **1 (1 stop bit)**. If the value is set to 3 (2 stop bits) and the parameter is saved using **Register 360 Save All Bus Parameters**, the device boots with the modified stop bit settings at the next start-up or Reset Node.

Value range:

**1 = 1 Stop bit**

**3 = 2 Stop bits**

## 13.4 Register 304: Node address

This register allows modifying the node address by software. As a standard, the value is set to 0x3Fh, i.e. Node ID= 0x3F. If the value is set between 1..127 and the parameter is saved using **Register 360 Save All Bus Parameters**, the device boots with the modified node address at the next start-up or Reset Node.

Values range **1 ...127 or 1..7Fh**

**Node number 0** is reserved and shall not be used by any node.

The resulting node numbers are in the range **1...7Fh** hexadecimal or (1...127). A new node number is only taken over at the following booting (reset/power-on). All other settings in the register table remain retained.

Example: Node ID 3F **Change node address for 02**

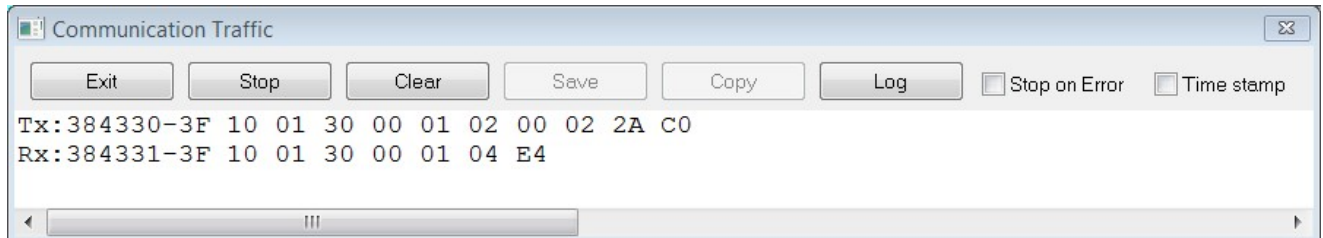


Figure 16

## 13.5 Register 305: Modbus bus termination off/on

This register allows switching the bus termination on by software. As a standard, this value is set to 2, i.e. the termination is **switched on**.

Values range 1,2

**\*for devices with cable outlet and a Modbus connection = 2**

Example: Node ID 3F **Switch termination off (01)**

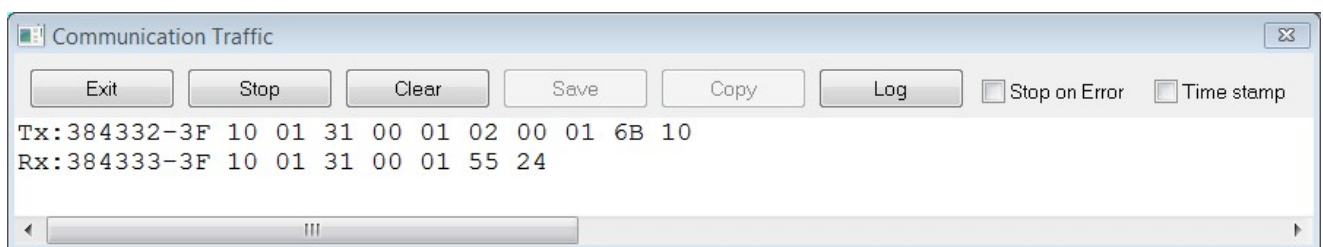


Figure 17

## 13.6 Register 306: Low-pass filter on/off

**Low-pass filter on 0x1**

**Low-pass filter off 0x0**

Description chapter 14

## 13.7 Register 307: Filter coefficient

| Value | Hexadecimal Value |
|-------|-------------------|
| 0.1   | 3D CC CC CD       |
| 0.3   | 3E 99 99 9A       |
| 0.5   | 3F 00 00 00       |
| 1.0   | 3F 80 00 00       |
| 2.0   | 40 00 00 00       |
| 5.0   | 40 A0 00 00       |
| 10.0  | 41 20 00 00       |

Standard setting: **Filter operating frequency b** Value **5.0**

Possible settings:

**0.1, 0.3, 0.5, 1.0, 2.0, 5.0, 10.0 Hz**

**Other values are set by default to 5.0Hz.**

Values range: Real32      **0.1 ... 10.0 Hz**

Example: Node ID 3F **Change filter setting for 0.3Hz**

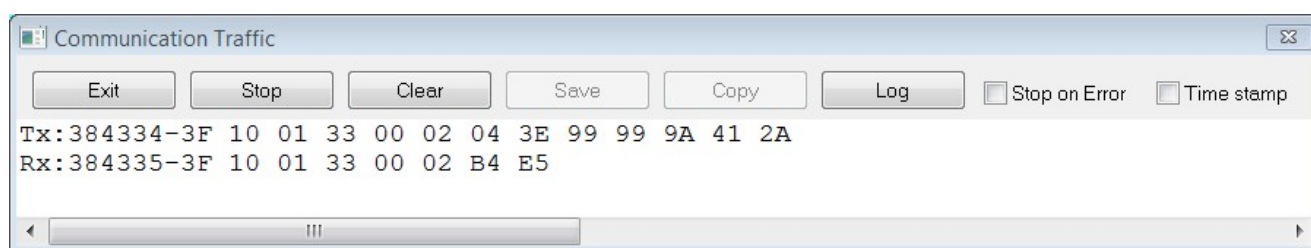


Figure 18

## 13.8 Register 360: Save All Modbus Parameters

This parameter saves the desired bus parameters (registers 2100h, 2101h, 2102h) permanently in the Flash memory. This register serves as an additional protection against accidental changes of the baud rate and node address.

Only targeted saving with parameter "**save**" (**hexadecimal 0x1010**) will save permanently all Modbus parameters.

Values range: "**save**" in hexadecimal **0x1010**

**The new values are only taken over after a power off/on sequence.**

Example: Node ID 3F **Save all parameters**

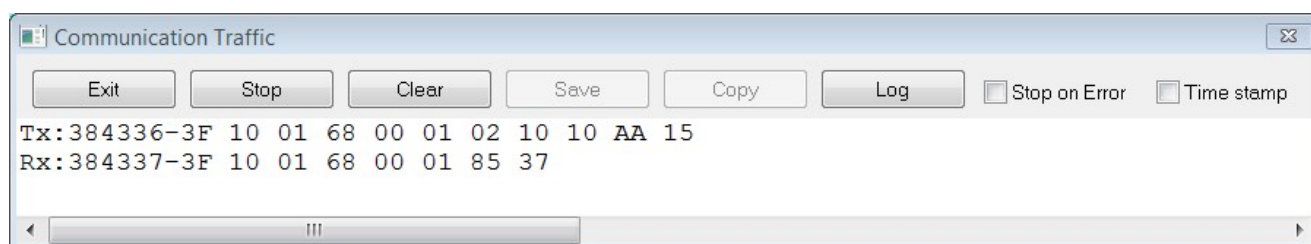


Figure 19

## 13.9 Register 361: Load Factory default Parameters

This parameter loads the standard bus parameters permanently in the Flash memory. Only targeted loading with parameter **"load"** (hexadecimal **0x1011**) will load the comprehensive standard Modbus parameters and simultaneously save them as default..

Values range: **"load"** in hexadecimal **0x1011**

Example: Node ID 3F **Load the default values**

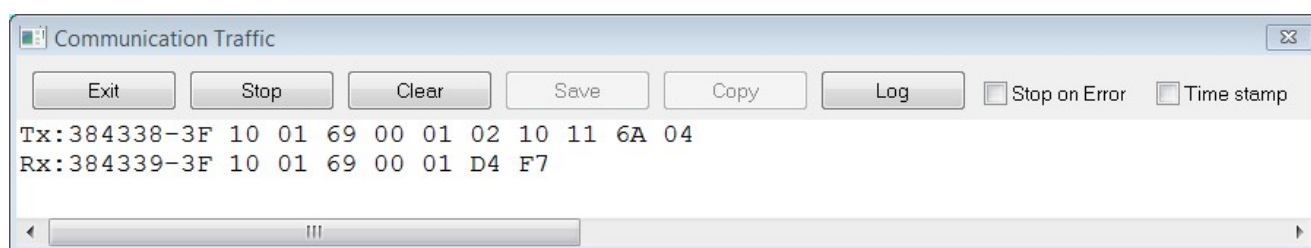


Figure 20

Register 310: Resolution

Default setting sensor: 10d = 0.01 ° Resolution

| Value        | Definition           |
|--------------|----------------------|
| 1d (01h)     | 0.001° not supported |
| 10d (0Ah)    | <b>0.01°</b>         |
| 100d (64h)   | 0.1°                 |
| 1000d (3E8h) | 1.0°                 |
| other        | not supported        |

### NOTICE

Parameter "310 Resolution" influences measuring axes **long16** and **lateral16**!

## 13.10 Register 311: Slope long16 Operating parameter

This register allows switching on and off the scaling with Offset/Preset of registers 6012h-6014h and the measurement value inversion of Slope long16 in Register 6010h.

| Field                | Value                            | Definition                                 |       |
|----------------------|----------------------------------|--|-------|
| <i>ms</i>            |                                  | Manufacturer-specific                      |       |
| <i>r</i>             | 0 <sub>b</sub>                   | reserved                                   |       |
| <i>s</i> (scaling)   | 0 <sub>b</sub><br>1 <sub>b</sub> | Scaling not enabled<br>Scaling enabled     | Bit 1 |
| <i>i</i> (inversion) | 0 <sub>b</sub><br>1 <sub>b</sub> | Inversion not enabled<br>Inversion enabled | Bit 0 |

Figure 21

### Scaling:

If scaling is switched on, the measured value is calculated as follows:

$$\text{Slope long16} = \text{physically measured angle} + \text{Differential slope long16 offset} + \text{Slope long16 offset}$$

Figure 22

If scaling is switched off, the measured value corresponds to the physically measured value.

Inversion: If inversion is switched on, the measured value is output inverted.

## 13.11 Register 312: Slope long16 preset value

Register 312 allows setting the measured value to a desired angle value (PRESET). The desired angle value is transmitted as a signed 16-bit value, taking into consideration the resolution set previously.

The differential offset of register 6014h is included in the Preset calculation.

The angle offset calculated by the Preset value in 6012h can be read or modified via register 313.

### Angle offset calculation:

$$\text{Slope long16 offset} = \text{Slope long16 preset value at } t_{acc} - \text{slope physical measured at } t_{acc} - \text{Differential slope long16 offset}$$

$t_{acc}$  = time when accessing object 6012<sub>h</sub>

Figure 23

**Measured value calculation:**

$$\text{Slope long16} = \text{physically measured angle} + \text{Differential slope long16 offset} + \text{Slope long16 offset}$$

Figure 24

**Example:**

The measured value is to be set to +45.00°. The resolution in register 300 is set to 0.01° = 10d:

**2-axes sensor:**

Values range: 0 ... +/-85.00°. Example: +45.00° = 4500 (SIGNED16)

**1-axis sensor:**

Values range: 0 ... 360.0°. Example: 45.0° = 450 (SIGNED16)

**NOTICE**

The input must be adapted to the selected resolution in register 310!

**13.12 Register 313: Slope long16 offset**

Register 313 allows transferring directly an angle offset that will be used with the measured value in the calculation. The angle offset is transferred with a signed 16 bit value, depending on the resolution set in register 310. Values range:

**2-axes sensor:**

+/-180.00°. Example: +45.00° = 4500 (SIGNED16)

**1-axis sensor:**

+/-360.0°. Example: +45.0° = 450 (SIGNED16)

**CAUTION!** The input must be adapted to the selected resolution in register 300!

$$\text{Slope long16} = \text{physically measured angle} + \text{Differential slope long16 offset} + \text{Slope long16 offset}$$

Figure 25

### 13.13 Register 314: Differential Slope long16 offset

Register 314 allows shifting the measuring range with an offset regardless of registers 312 Preset and 313 Offset. To that purpose, a signed 16-bit angular value, depending on the resolution set in register 310, can be transferred in register 314.

Values range:

**2-axes sensor:**

+/-85.00°. Example: +45.00° = 4500 (SIGNED16)

**1-axis sensor:**

+/-360.0°. Example: +45.0° = 450 (SIGNED16)

**CAUTION!** The input must be adapted to the selected resolution in register 310!

$$\text{Slope long16} = \text{physically measured angle} + \text{Differential slope long16 offset} + \text{Slope long16 offset}$$

Figure 26

### 13.14 Register 315: Slope lateral16 operating parameter

This register allows switching on and off the scaling with Offset/Preset of registers 315 and 316 and the measurement value inversion.

| Field                | Value          | Definition            |       |
|----------------------|----------------|-----------------------|-------|
| <i>ms</i>            |                | Manufacturer-specific |       |
| <i>r</i>             | 0 <sub>b</sub> | reserved              |       |
| <i>s</i> (scaling)   | 0 <sub>b</sub> | Scaling not enabled   | Bit 1 |
|                      | 1 <sub>b</sub> | Scaling enabled       |       |
| <i>i</i> (inversion) | 0 <sub>b</sub> | Inversion not enabled | Bit 0 |
|                      | 1 <sub>b</sub> | Inversion enabled     |       |

Figure 27

**Scaling:**

If scaling is switched on, the measured value is calculated as follows:

$$\text{Slope lateral16} = \text{physically measured angle} + \text{Differential slope lateral16 offset} + \text{Slope lateral16 offset}$$

Figure 28

If scaling is switched off, the measured value corresponds to the physically measured value.

**Inversion:**

If inversion is switched on, the measured value is output inverted.

## 13.15 Register 316: Slope lateral16 preset value

Register 316 allows setting the measured value to a desired angle value (PRESET). The desired angle value is transmitted as a signed 16-bit value, taking into consideration the resolution set previously.

The differential offset of register 318 is included in the Preset calculation.

The angle offset calculated by the Preset value in 316 can be read or modified via register 313.

Angle offset calculation:

$$\text{Slope long16 offset} = \text{Slope long16 preset value at } t_{acc} - \text{slope physical measured at } t_{acc} - \text{Differential slope long16 offset}$$

$t_{acc}$  = time when accessing object 6012<sub>h</sub>

Figure 29

Measured value calculation:

$$\text{Slope long16} = \text{physically measured angle} + \text{Differential slope long16 offset} + \text{Slope long16 offset}$$

Figure 30

Example:

The measured value is to be set to +45.00 °. The resolution in register 300 is set to 0.01° = 10d: **2-axes sensor:**

Values range: 0 ... +/-85.00°. Example: +45.00° = 4500 (SIGNED16)

**1-axis sensor:**

Values range: 0 ...360.0°. Example: 45.0° = 450 (SIGNED16)

The input must be adapted to the selected resolution in register 310!

### 13.16 Register 317: Slope lateral16 offset

Register 317 allows transferring directly an angle offset that will be used with the measured value in the calculation. The angle offset is transferred with a signed 16 bit value, depending on the resolution set in register 300.

Values range: +/-180.00°. Example: +45.00° = 4500 (SIGNED16)

$$\text{Slope lateral16} = \text{physically measured angle} + \text{Differential slope lateral16 offset} + \text{Slope lateral16 offset}$$

Figure 31

### 13.17 Register 318: Differential Slope lateral16 offset

Register 318 allows shifting the measuring range with an offset regardless of registers 316 Preset and 317 Offset. To that purpose, a signed 16-bit angular value, depending on the resolution set in register 300, can be transferred in register 318.

Values range: +/-85.00°. Example: +45.00° = 4500 (SIGNED16)

$$\text{Slope lateral16} = \text{physically measured angle} + \text{Differential slope lateral16 offset} + \text{Slope lateral16 offset}$$

Figure 32

### 13.18 Register 320: Euler axis Y Preset value

Register 320 allows inputting a **zero setting position** (PRESET).

Example:

The measured value is 60° - After a preset, the value is set to zero 0°.

#### 1-axis sensor:

Values range: 0 ... 359.99°.

Only value 0 is accepted!

## 13.19 Register 261: Transmission Delay time

This register allows modifying by software a **time delay of the emitter after receiving a message**. As a standard, this value is set to 1. The value is therefore multiplied by **n**.

Example: Input 5      Baud rate = 19200      **Delay = 5\* 2.2ms = 11ms**

| Value    | Baud rate in Kbit/s | Delay time standard |
|----------|---------------------|---------------------|
| <b>1</b> | <b>9600</b>         | <b>5.0 ms</b>       |
| <b>2</b> | <b>19200</b>        | <b>2.2 ms</b>       |
| <b>3</b> | <b>38400</b>        | <b>1.9 ms</b>       |
| <b>4</b> | <b>57600</b>        | <b>1.9 ms</b>       |
| <b>5</b> | <b>115200</b>       | <b>1.8 ms</b>       |

A new delay time is taken over immediately after the input. Saving with **Register 360** is possible.

## 14. 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 operating frequency b:** **Filter on/off**  
**defines the starting point of the stop band**  
**(area 0.1 ... 10.0 Hz)**

### Filter description 2nd order:

An IIR filter 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  $w_0(n)$ , as well as of the two coefficients  $a_{01}$ ,  $a_{02}$  in the recursive portion and the three coefficients  $b_{00}$ ,  $b_{01}$  and  $b_{02}$ .

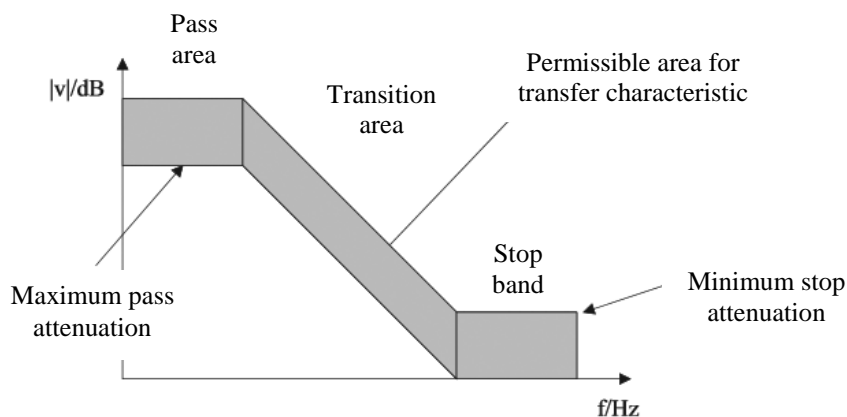


Figure 33

### 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.

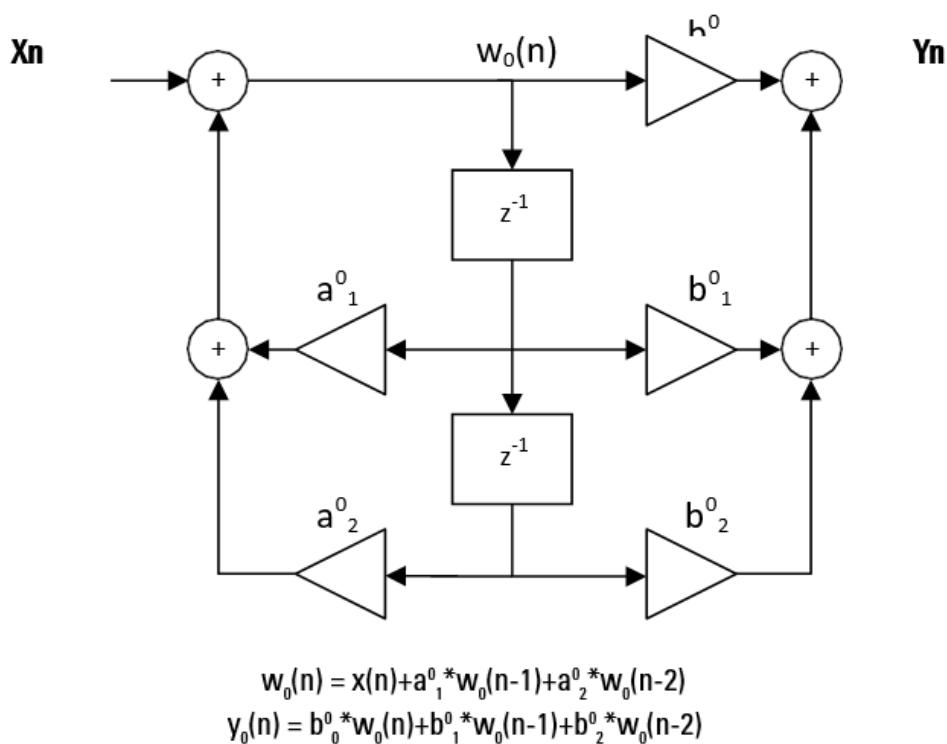


Figure 34

$X_n$  is here the input signal,  $Y_n$  is the filter output and simultaneously the input of another subsystem.

## 15. (11 Hex) Report Slave ID

### 5 17 (11 Hex) Report Slave ID

#### Description

Returns a description of the type of inclinometer present at the slave address and other information specific to the slave device. Broadcast is **not** supported.

#### Response

The format of a normal response is shown below. The data contents are specific to each type of inclinometer. They are listed on the following pages.

#### **A Summary of Slave IDs**

These are the Slave ID codes returned by Kuebler inclinometers in the first byte of the data field:

The Kuebler Modbus inclinometer returns a byte count of 31 as follows:

#### Byte Contents

|       |   |
|-------|---|
| 1     | Slave address (actual device)   |
| 2     | Function code   |
| 3     | Byte length   |
| 4     | Slave ID  |
| 5     | RUN indicator status (0 = Modbus OFFline (Diagnostic), 0xFF = Modbus Operational) |
| 6-27  | System information    Inclinometer type, Hardware Name, SW-Version (ASCII Format) |
| 28,29 | Error Counter   |
| 30,31 | CRC   |

6..27    21 Byte   ASCII-Format   02,FF, "IN88\_MB\_V103 IN88\_V1.28"

## 16. UNSUPPORTED MODBUS FUNCTION CODES

Not part of the implementation are following function codes:

1. *Read Coil Status*
2. *Read Input Status*
3. *Read Input Registers*
4. *Force Single Coil*
5. *Preset Single Register*
6. *Read Exception Status*
7. *(0B Hex) Fetch Comm Event Ctr*
8. *(0C Hex) Fetch Comm Event Log*
9. *15 (0F Hex) Force Multiple Coils*
10. *(14Hex) Read General Reference*
11. *(15Hex) Write General Reference*
12. *(16Hex) Mask Write 4X Register*
13. *(17Hex) Read/Write 4X Registers*
14. *(18Hex) Read FIFO Queue*

## 17. MODBUS EXCEPTION CODES

### Code Name Meaning

- **01 ILLEGAL FUNCTION**
  - The function code received in the query is not an allowable action for the slave. If a Poll Program Complete command was issued, this code indicates that no program function preceded it.
- **02 ILLEGAL DATA ADDRESS**
  - The data address received in the query is not an allowable address for the slave.
- **03 ILLEGAL DATA VALUE**
  - A value contained in the query data field is not an allowable value for the slave.
- **04 SLAVE DEVICE FAILURE**
  - An unrecoverable error occurred while the slave was attempting to perform the requested action.
- **05 ACKNOWLEDGE**
  - The slave has accepted the request and is processing it, but a long duration of time will be required to do so. This response is returned to prevent a timeout error from occurring in the master. The master can next issue a Poll Program Complete message to determine if processing is completed.
- **06 SLAVE DEVICE BUSY**
  - The slave is engaged in processing a long-duration program command. The master should retransmit the message later when the slave is free.

## 18. Angle calculations

### 18.1 2-axes inclinometer

#### Orientation angles

Indicating the two orientation angles describes the inclination of the coordinates 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 X". 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 Y". This value corresponds to the angle [°] formed by the gravity vector with the zx plane of the sensor.

$$\text{Orientation angle} = \sin^{-1} \left( \frac{x}{\sqrt{x^2 + y^2 + z^2}} \right)$$

$$\text{Orientation angle} = \sin^{-1} \left( \frac{y}{\sqrt{x^2 + y^2 + z^2}} \right)$$

Figure 35

### 18.2 1-axis inclinometer

#### Euler angles

In this setting, both angle values output are to be interpreted as Euler angles. The current sensor position is given by two revolutions performed consecutively, based on its horizontally aligned position. The "Eulerwinkel Z" indicates the angle [°] by which the z axis of the sensor is deflected. The "Eulerwinkel XY" corresponds to the angle [°] by which the sensor has then been rotated around the (deflected) z axis.

$$\text{Eulerwinkel Z} = \cos^{-1} \left( \frac{z}{\sqrt{x^2 + y^2 + z^2}} \right)$$

$$\text{Eulerwinkel Z} = \tan^{-1} (x, y)$$

Figure 36

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