

User manual

Inclinometer
with Analog-RS232-Interface

IK360



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1 General Safety Advice

Read these instructions carefully and have a look at the equipment to become familiar with the device before trying to install, operate or maintain it.

The following special messages may appear throughout this documentation & on the equipment to warn of potential hazards or to call attention towards information that clarifies / simplifies a procedure.



The addition of this symbol to a Danger or Warning safety label indicates that an electrical hazard exists, which will result in personal injury, if the instructions are not followed.



This is the safety alert symbol. It is used for alerting, in case of potential personal injury or hazards. Obey all safety messages that follow this symbol to avoid possible injury or death.

Please Note

Electrical equipment should be serviced only by qualified personnel. No responsibility is assumed by SIKO for any consequences arising out of the use of this material. This document is not intended as an instruction manual for untrained persons.

About this manual

This user manual explains how to install and configure the IK360 inclinometer with a Analog (Voltage or Current) and RS232 interface by illustrations.

2 Introduction

2.1 IK360

IK360 inclinometers sense and measure the angle of tilt (Inclination/Slope/Elevation) of an object with respect to the force of gravity. The angle is measured with the relative change in electrical capacitance.

The basic principle behind this IK360 inclinometer is a Micro-Electro-Mechanical Systems (MEMS) sensor cell, that is embedded to a fully molded ASIC. A simplified version of the sensor consists of two electrodes, one is fixed, and the other is flexible (connected with spring elements). When the inclinometer is parallel to the surface of measurement, a corresponding capacitance is measured. If the sensor is tilted, the flexible electrode will change its position relative to the fixed electrode. This results in a change of the capacitance between the two electrodes, which is measured by the sensor cell. The change of the capacitance is converted to a corresponding inclination value.

Absolute inclinometers identify all the points of a movement by means of an unambiguous signal. Due to their capacity to give clear and exact values to all inclinations positions, inclinometers have become one of the interesting alternatives to singleturn absolute (and incremental) encoders and a link between the mechanical and control systems.

2.2 Analog interface

The analog interface is one of the most common and simplest of the interfaces. It is compatible from simple multimeters to complex control systems and PLCs.

An analog signal is a *continuous* signal which is analogous i. e. comparable to another time varying signal. In our case the variation of current or voltage signal from IK360 is analogous to the variation of measured position.

In IK360, the position related output from MEMS based capacitance transducer measurement is converted to its analogous current or voltage signals with suitable electronics.

An analog signal virtually has infinite resolution. In practice an analog signal is always subjected to noise and a finite *slew rate*. Therefore, analog systems are subject to limitations in resolution and bandwidth.

Noise and unwanted variation in signals can create losses upon transmission and re-transmission over long distances and for long time. Electrically, these losses can be reduced by shielding, good connections and several cable types.

2.3 IK360 Analog

The IK360 Analog inclinometer is a simple, compact and a very low cost inclination measurement device capable of measuring precise absolute position in single axis.

It is compatible to almost all the analog measurement devices and includes a RS232 digital interface too. This RS232 interface can be used either to read the corresponding position output or for configuring the IK360 according to the need of the application.

Electrically, IK360 consists of a highly integrated circuit in SMD technology, temperature compensation, active linearization and the only variation is the analog interface. Customized scaling of analog output is also possible.

Electrically, like all other IK360 variants it consists of a highly integrated circuit in SMD technology, temperature compensation, active linearization and the only variation is the analog interface. Customized scaling of analog output is also possible.

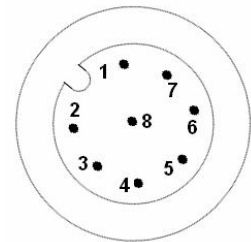
It is protected against polarity inversion and over voltage peak protection. In addition to that, the fully molded plastic housing provides an high resistance to shock/ vibration and environmental protection of up to IP69K, when used with appropriate connectors.

3 Installation

3.1 Pin assignment

The inclinometer is connected via a 8 pin round M12 connector (Standard M12, male connector on IK360, female connector at connection cable).

Pin	Description für IK360 with voltage analog output	Description für IK360 with current analog output
1	10-30 VDC	12-30 VDC
2	RxD (RS232 Receive)	
3	TxD (RS232 Transmit)	
4	Ground	
5	Z – Axis Analog Output	
6	Pins do not connect	
7		
8		



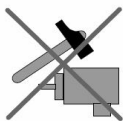
3.2 Installation precautions



ATTENTION !!!
Do not remove or mount while the inclinometer is under power!



Avert any modifications to the plastic molding!



Avoid mechanical load!

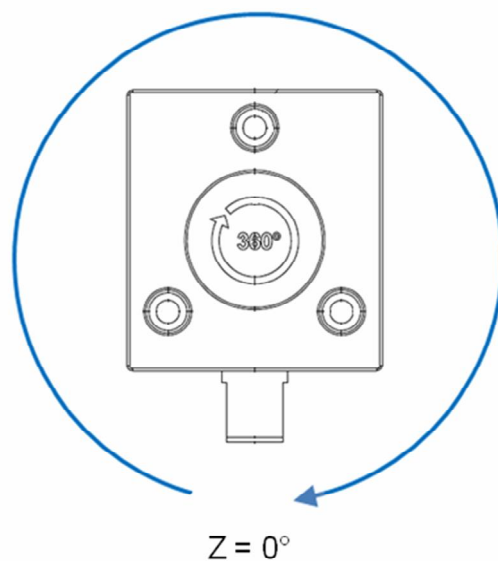
3.3 Mounting instructions

IK360 is a pre-calibrated device, which can be put into immediate operation, upon simple and easy installation with a three point mount and setting of preset. Its compact design and installation “anywhere” makes it versatile.

The IK360 inclinometer can be mounted in any number of fashions, depending on the situation. The mounting surface must be plane and free of dust and grease. It is absolutely necessary, that the IK360 inclinometer is connected to potential equalization in a workmanlike manner. For mounting we recommend cheese head screws with metrical thread M4 or UNC bolts #6 for the best possible and secure mounting. Use all the 3 screws for mounting, but restrict the tightening torque in the range of 1,5 – 2,5 Nm for the screws. The M12 connectors are to be perfectly aligned and screwed till the end with a tightening torque in the range of 0,4 -0,6 Nm. Use all the three screws for mounting and also note to use the same tightening torque for all the screws. An appropriate and well secured counter connector is also an important constraint for attaining the stated IP69K protection.

Prior to installation, please check for all connection and mounting instructions to be complied with. Please also observe the general rules and regulations on low voltage technical devices, for safety and sustainability of IK360 Inclinometers over long period of time.

3.4 Measurement axis



Initial starting Point (Factory Settings)

**Measurement axis and mid angle position
(factory setting ~ connector facing down)**

4 IK360 Software Configuration

The IK360 - Analog Inclinometer is a very flexible device and can be easily configured using the RS232 interface.

4.1 Important factory settings

Description	Value
Operational Mode	Continuous Mode
Resolution	0.01°
Output Transmission Rate	100ms
Baud Rate	9600 bd
Moving Average Filter	20
Angle Offset	0

Note: The factory settings should be noted carefully upon installation. Few of the parameters have to be re-programmed in order to make the IK360 inclinometers compatible with the measurement device, or optimize the measurement.

4.2 Modes of Operation

- **Continuous Mode**

Continuous Mode or free running mode of an IK360 is the operational output mode in which the position value is sent cyclically (regular, adjustable intervals according to the output transmission rate) using the RS232 interface.

- **Polled Mode**

Polled Mode or the query mode of an IK360 is the operational mode, where the continuous sending of angle values are stopped and the position value is transmitted only upon request. In this mode, other instructions can also be sent to the IK360 for execution and configuration, using the RS232 interface.

4.3 Programmable parameters

Modes of Operation	IK360 can be switchen between Polled Mode or Continuous Mode
Baud rate	The Baud rate can be programmed to lie between ranges of 2400 bd and 115200 bd.
Output Transmission Rate	The transmission rate of angular values can be adjusted to lie between 62.5ms and 10 seconds per value.
Moving Average Filter	Used to calculate the output position value as an average over last N values, where N varies from 2-100 measurements.
Resolution Per 1°¹	The parameter resolution per degree is used to program the desired number of angular divisions per 1° of rotation.
Preset Value	The current position value is set to the mid angle position by the parameter preset.

The parameters of IK360 can be mostly re-configured using the RS232 interface.

¹ The resolution programming functionality is not yet fully operational.

5 RS232 Digital Interface – Setup and Programming

The RS232 interface of IK360 gives flexibility to the Inclinator by providing easily accessible direct positional values and a simple interface for setup and configuration.

5.1 Hardware Setup

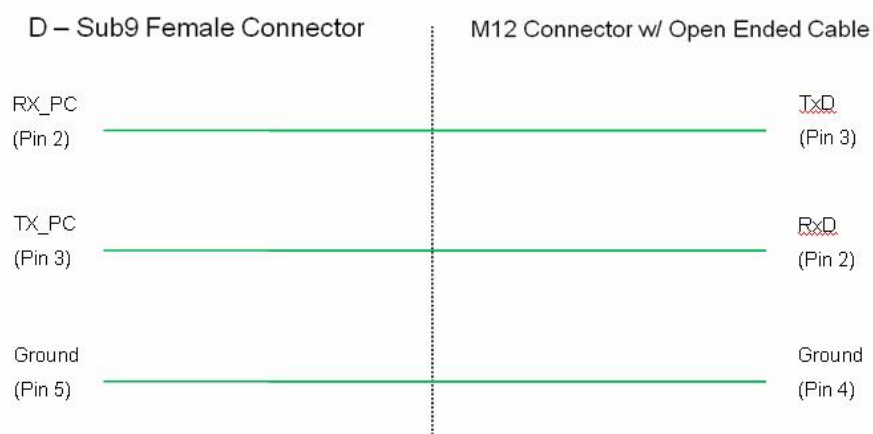
5.1.1 Accessories Required

- IK360 Inclinator
 - 8- Wire open ended connection cable with M12 8-pin female connector
 - D-Sub9 Female Connector
- } Preparation of IK360 RS232 Communication Cable

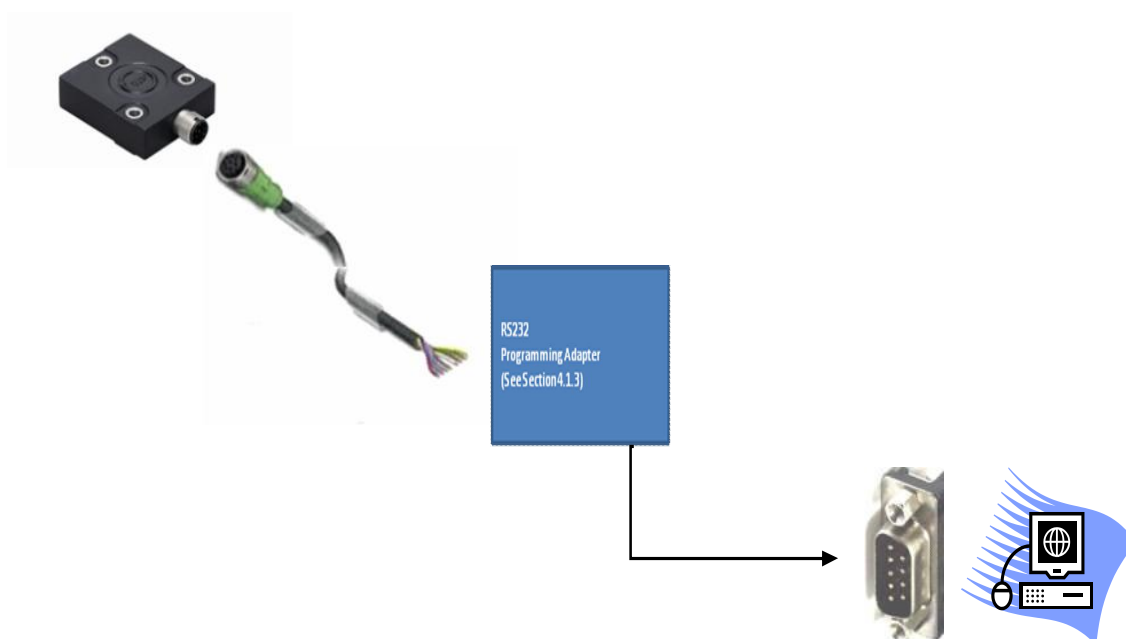
5.1.2 RS232 Communication – Pin Configuration

Pin	Description
2	Receive data
3	Transmit data
5	Common Ground

5.1.3 Wiring & Connection



5.1.4 Connection Setup



IK360 Analog → M12 Connector → RS232 Connector → PC RS232

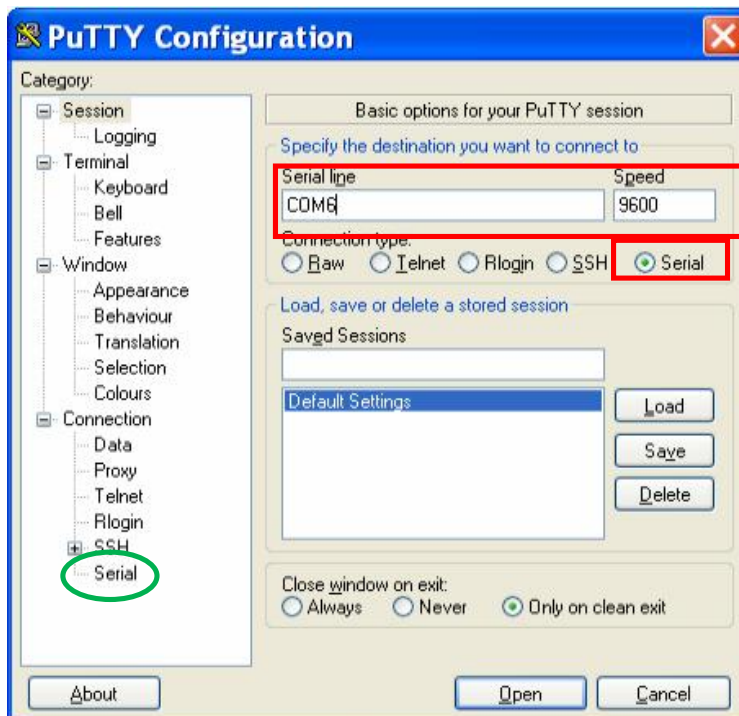
5.2 Software Communication Setup

Once the hardware is connected, the RS232 interface communication has to be setup using HyperTerminal or any other terminal programming client software. Communication with the sensor is done through a standardized RS232 interface. Data transmission is effected in duplex mode.

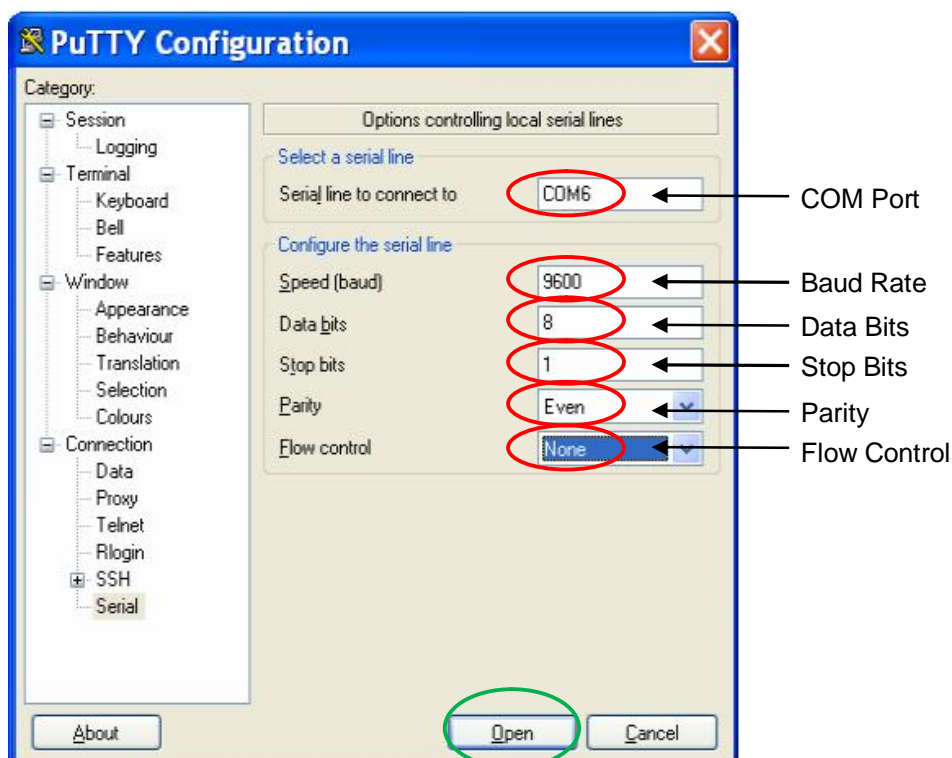
RS232 Interface Parameters are:

- Baud Rate: 9600 bd
- Data Bits: 8 Bits
- Parity: Even Parity
- Stop Bits: 1 Bit
- Flow Control: None

Step 1: Open the executable file of PuTTY - A Telnet/SSH client freeware. Please click on Serial in **Connection type** and then type in the appropriate COM port in the **Serial line** column and the current Baud rate in the **Speed** dialog box. Then select, **SSH -> Serial** to setup the parameters for interface communication.



Step 2: The appropriate parameters for the RS232 interface communication and please click on **Open** to create a new terminal program for IK360 RS232 interface communication.



Power Off – Power On for getting a boot-up message on startup.

5.3 RS232 Commands

There are two working levels for IK360 in RS232:

The **User Level** is where the user can activate or deactivate different modes and read out position values directly in degrees.

The **Setup Level** is where the user can configure the settings of the IK360 according to the application requirements.

After Power On the sensor is always in the User Level. In factory setting (Continuous Mode) every 100ms the current angle values are continuously output with a baud rate of 9600 bd.

In the Setup Level several settings can be changed permanently like Polled or Continuous Mode, output rate, baud rate and angle offset/Preset.

If Polled Mode, instead of Continuous Mode, is set, the sensor will send boot up information with the current settings only after Power On and no angular values will be displayed after the boot up message.

5.3.1 IK360 Output – Programming Index

The following table is of the character and its corresponding decimal/ hexadecimal equivalents to assist a user in the output programming.

CHAR	D0	D1	D2	D3	D4	D5	D6	D7
ASCII	X	X	X	.	X	X	CR	LF
DEC	Variable Numerical Values			46	Variable Numerical Values		13	10
HEX				0x2e			0x0d	0x0a

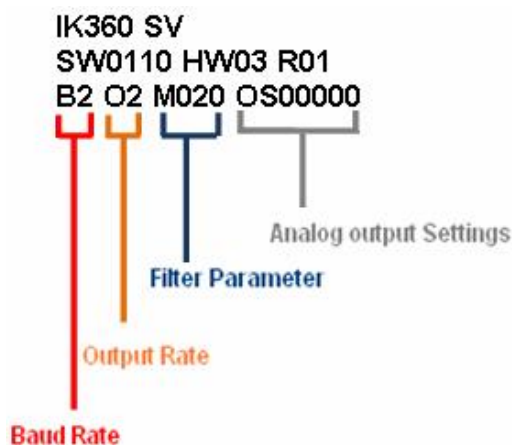
IK360 Output Display: <D0.....D5 D6 D7>

<CR> <LF> is a program analogy to indicate end of current line and start of a new line in a program.

(CR: Carriage Return; LF: Line Feed)

5.3.2 Boot-Up Message Representation

In the bootup messages most important features like the baud rate, output rate and filter parameters will be included.



5.3.3 Table 1: Instructions at User Level

Instruction	To the sensor	Response from sensor
Activate temporary Polling Mode	f	f <CR> <LF> xxx.xx <CR> <LF> (or) f <CR> <LF>
Activate temporary Continuous Mode	F	F <CR> <LF> xxx.xx <CR> <LF> xxx.xx <CR> <LF>
Read angle value for one-time ²	R	xxx.xx <CR> <LF>
Switch to the Setup Level ³	prog	P <CR> <LF>
Software Reset ⁴	Q	<CR> <LF> Boot-up Message

Setup Level

After going into Setup Level, changes can be done to the IK360 parameters as mentioned in table 2. The Setup Level is active until "Power Off" or Software Reset. All settings taken in the Setup Level are stored in the EEPROM and permanent available, also after Power down. After power cycle the IK360 starts up in the User Level with the saved settings.

² Preferred to be used only in Polling Mode.

³ Change to Setup Level. The „prog„ must be sent within a span of 3 seconds and please wait for 2-3 seconds for the output "P" after sending. Upon output, the IK360 is in Setup Level.
p →(<400 ms) r →(<400 ms) o →(<400 ms) g

⁴ After reset, in either mode, the IK360 reboots in the User Level giving a start-up/boot-up message. When the IK360 is in Setup Level, it saves all the settings and then reboots in the User Level with boot-up message.

5.3.4 Table 2: Instructions at Setup Level

Instruction	To the sensor	Response from sensor
Activate permanent Polling Mode ⁵	f	f <CR> <LF>
Activate permanent Continuous Mode ⁵	F	F <CR> <LF>
Set preset ⁶	Pt	Pt <CR> <LF>
Reset offset adjust / Disable preset adjust	N	N <CR> <LF>
Set rate of data transmission for Continuous Mode ⁷	O (after response) <Code transmission rate>	O or E ⁸ <CR> <LF>
Set baud rate ⁹	B (after response) <Code Baud rate>	B or E ⁸ <CR> <LF>
Software Reset ¹⁰	Q	<CR> <LF> Boot-up Message
Deactivate Moving Average Filter	M0¹¹	M0 <CR> <LF>
Activate Moving Average Filter	M1	M1 <CR> <LF>
Moving Average Filter Configuration ¹²	MP (after response) <N value>	N= <CR> <LF>
Restore to factory settings	rest → Y ~ Restore ¹³ → N ~ Software Reset ¹³	rest <CR> <LF> Y/N <CR> <LF>

ATTENTION	<ul style="list-style-type: none"> • A reset of the baud rate to a default value is not possible. If the user forgets the adjusted baud rate, the new value must be detected by testing only. • A power cycle (power off-on) or a software reset is required for saving all the settings configured in the Setup Level. • Detailed illustrations of the commands and their implementation are provided in the next section.
------------------	--

⁵ Mode Setup for User Level upon startup/boot-up.

⁶ Reset the current angular value to mid angle position. If preset is already set, you have to disable the "old" preset, before setting the "new" preset.

⁷ See Table 3 for defined code transmission rates.

⁸ E for Error – Code input is outside of defined values.

⁹ See Table 4 for defined baud rates.

¹⁰ After reset, in either mode, the IK360 reboots in the User Level giving a startup/ boot-up message. When the IK360 is in Setup Level, it saves all the settings and then reboots in the User Level with boot-up message.

¹¹ For Clarification, M0 is M(zero)0 and not MO.

¹² Filter Configuration:

Possible values: N = 2 to 100, with N = 0 for deactivation of moving average filter

Output values = average over last N values

Factory setting: moving average filter is activated with N = 20

¹³ After either Y/N the IK360 is rebooted. If Y, IK360 is restored to factory settings and if N, the IK360 is just re-started.

5.3.5 Table 3: Code Transmission Rates

Input Character to Sensor	Output Transmission Rate (in ms)
1	62,5
2	100 ¹⁴
3	200
4	500
5	1000
6	5000
7	10000

5.3.6 Table 4: Baud rates

Input Character to Sensor	Baud rate (in bd)
0	2400
1	4800
2	9600 ¹⁴
3	19200
4	38400
5	57600
6	115200

ATTENTION	An output "E" appears as a response from the sensor on entering characters, which are out of the range of defined values as shown in the above tables.
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5.3.7 Detailed Illustrations

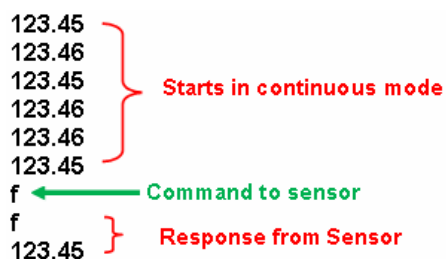
- To view the commands sent to the sensor via terminal program, please select Local Echo – ASCII Configuration.
- Initially the IK360 is in factory settings.

5.3.8 User Level

- **Activate temporary Polling Mode**

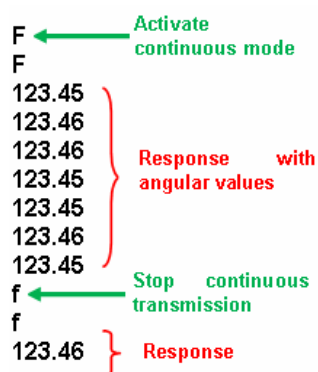
The activation of Polling Mode, when the IK360 is in Continuous Mode, gives an output of "f" with a single angular output. The continuous sending of angular values are stopped and single instructions can be sent to the sensor. The activation of Polling Mode when IK360 is already in Polling Mode gives an output of just "f".

¹⁴ Default factory settings



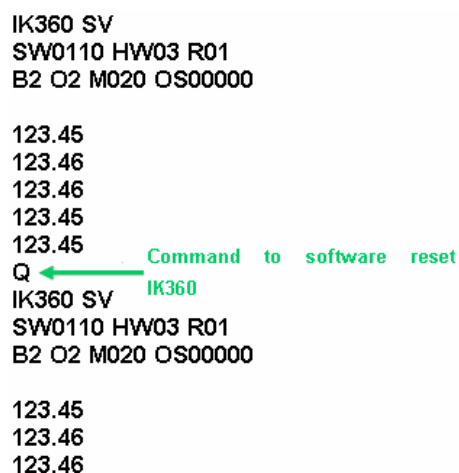
- **Activate temporary Continuous Mode**

The activation of Continuous Mode in the User Level is followed by an response “F” and then continuous angular values in intervals of 100ms (factory setting) or according to the set code transmission or output transmission rate (see 4.3.3 Table 3). To stop this you need to send command “f” as illustrated and explained above.



- **Software Reset**

The Software Reset is used in the User Level to just re-boot the IK360. In the below illustration the IK360 is started up with a power on, and then it sends continuous angles. Upon giving the command “Q” for software reset, the IK360 re-boots again and then continues sending the angular values. When used in the Setup Level the command “Q” saves all the settings configured and then re-boots the IK360 with the new settings (Shown in the next section).



5.3.9 Setup Level

Once, in the setup level various parameters of IK360 can be configured and saved permanently. Please note, that all the settings configured in this level, will be saved and executed only upon a software reset or Power cycle.

- **Activate permanent Polling Mode**

This command is used to set the IK360's mode to polling mode upon new startup/boot up.

```

prog } Setup Level
P
f ← Command to change to permanent polling mode
f → Response from sensor
Q
IK360 SV
SW0110 HW03 R01 } Software Reset and Re-boot
B2 O2 M020 OS00000
} No continuous angular values after boot

```

- **Activate permanent Continuous Mode**

This command is used to set the IK360's mode to Continuous Mode or free running mode after boot-up. This is generally the factory setting of an IK360.

```

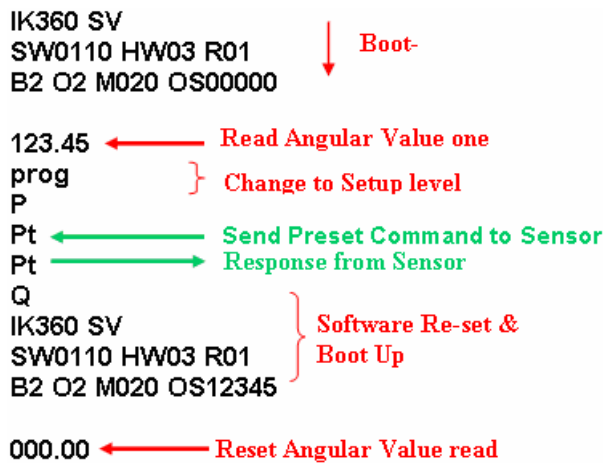
prog } Setup Level
P
F ← Command to change to permanent continuous mode
F → Response from sensor
Q
IK360 SV
SW0110 HW03 R01 } Software Reset and Re-boot
B2 O2 M020 OS00000

123.46
123.45 } Continuous angular values after boot up
123.46
123.46
123.45

```

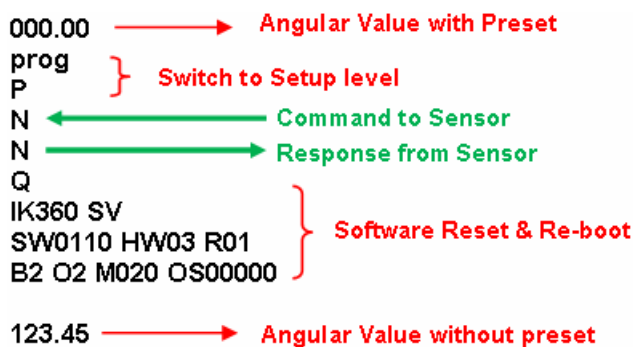
- **Set Preset**

“Pt” command is used to reset the current position to the mid angle position. If a preset value is already set, it is necessary to reset offset adjust, before you make a new preset.



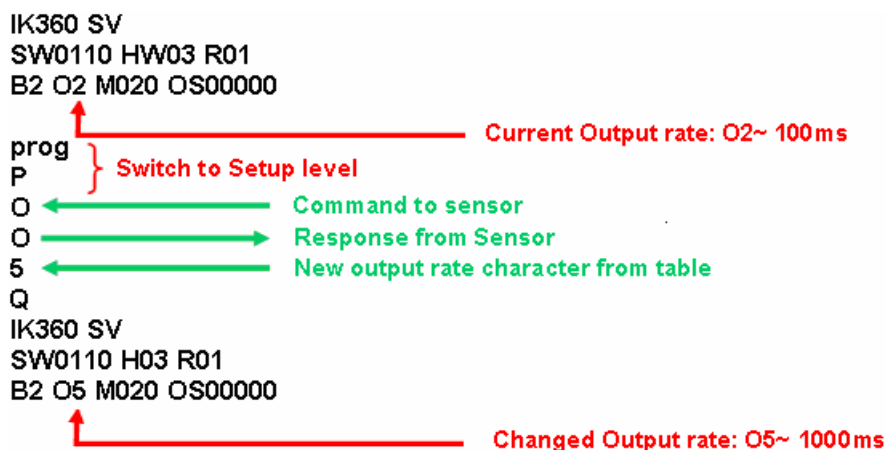
- Reset offset adjust / Disable preset adjust

The command "N" is used to disable the preset and bring back the offset adjustments to the factory settings.



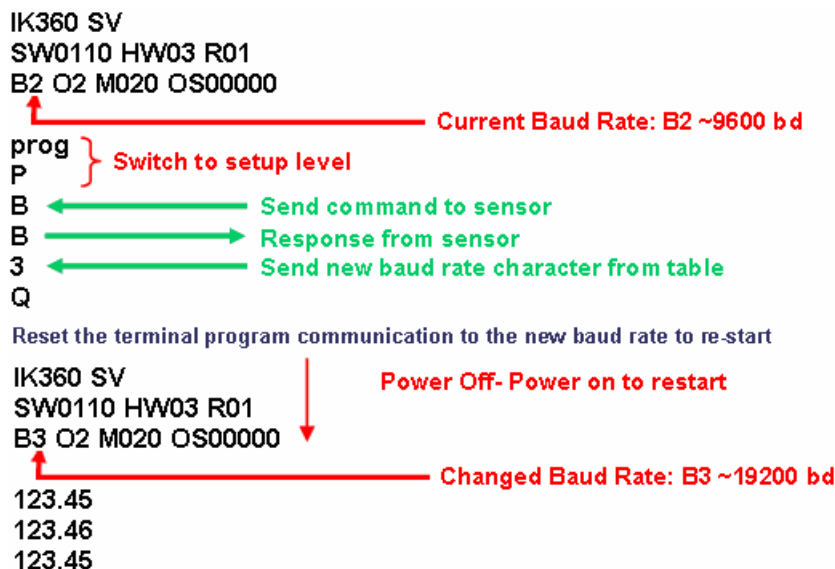
- Set rate of data transmission for Continuous Mode

This is used to set the intervals between two consecutive angular outputs in Continuous. The rates of transmission are given in table 3 of chapter 4.3.3. The default setting is O2 (~100ms).



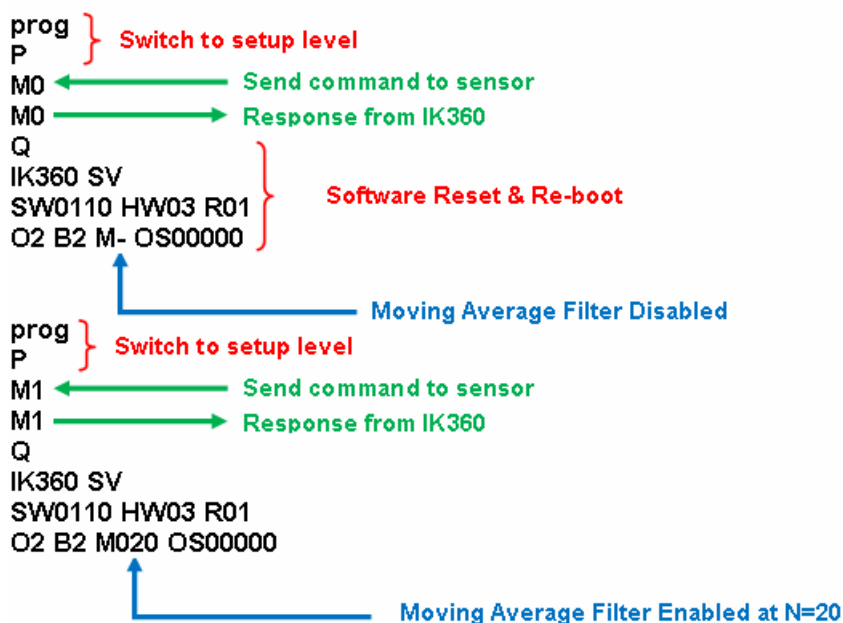
- Set Baud rate

This command is used to change the baud rate of IK360 RS232 Interface. A reset of the baud rate to a default value is not possible. So, the following sequence must be always followed. The factory setting is 9600bd. The code for the baud rate is given in table 4.



- **Activate / Deactivate Moving average filter**

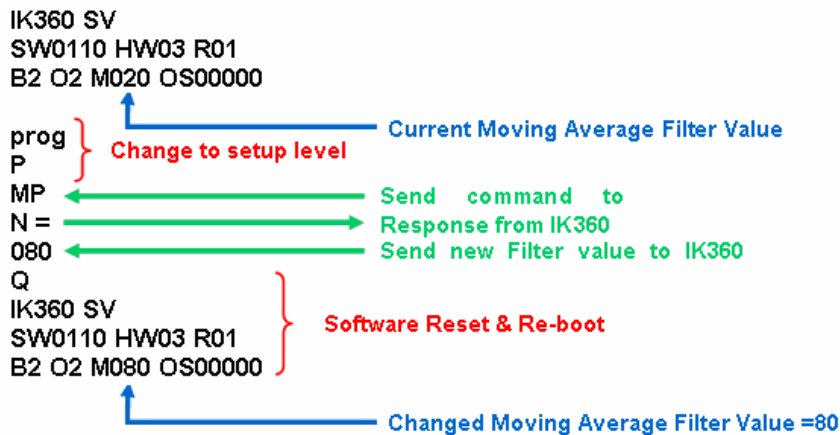
Command “M0” is used to disable the averaging of output values and the command “M1” is used to enable the averaging of output values.



The moving average filter can be modified, when the filter is enabled or disabled. The “N” value of the moving average filter is not active, when the filter is in disabled state.

- **Setting Moving Average Filter**

The command "MP" is used to set the appropriate number of samples for averaging.

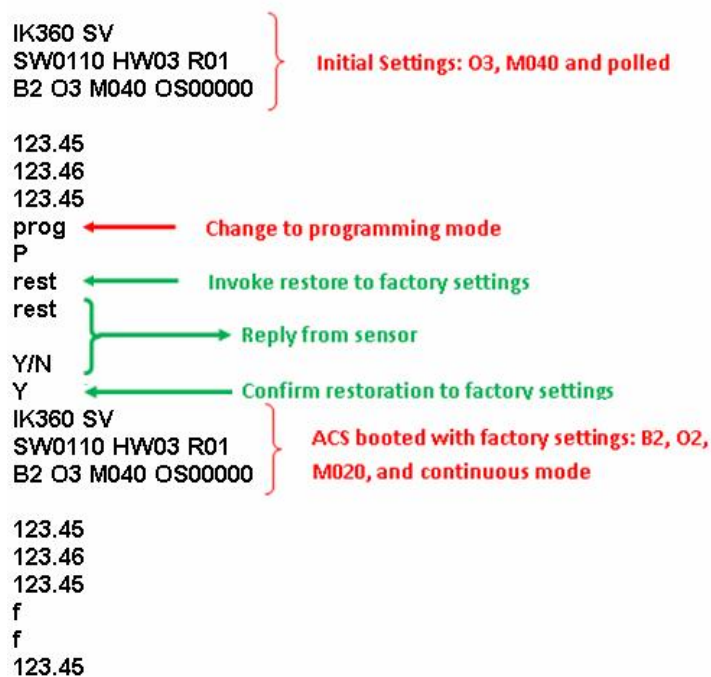


Filter Configuration:

Possible values: N = 2 to 100, with N = 0 for deactivation of moving average filter
Output values = Average over last N values
Factory setting: moving average filter is activated with N = 20

- **Restore to factory settings**

The command "rest" is used to restore the IK360 to its factory settings upon confirmation from the user.



- **Errors**

When parameters are defined beyond the programmable limits, then the IK360 gives an error “E” output. We know, that the code transmission rate is defined only till 7 (~10000 ms) and baud rate up to 6 (~115200 bd). So the following examples show error displays.

Example 1: Code Transmission Rate

```
IK360 SV
SW0110 HW03 R01
B2 O2 M020 OS00000
```

123.45

prog

P

O

O

8

E

} **When code transmission is set to 8 then an error is displayed**

Example 2: Baud rate

```
IK360 SV
SW0110 HW03 R01
B2 O2 M020 OS00000
```

123.45

prog

P

B

B

9

E

} **When baud rate is set to 9 then an error is displayed**

Important Points for programming:

- Always power off - power on for saving the settings changed in the setup level. Else, do software reset with command “Q” to save the settings.
- Make sure to switch to setup level, before trying to configure the settings/parameters of IK360.
- Wait for 2-3 seconds for response from IK360 every time you send an instruction to it.
- The use of preset in the digital interface will affect the analog output too. So, when using both the interfaces simultaneously take appropriate precautions.
- While changing the baud rate, please make sure to note it down before rebooting. A reset of the baud rate to a default value is not possible. If the user forgets the adjusted baud rate, the new value must be detected by testing only.

6 Analog Interface

The output signal from the IK360 analog interface can be directly connected to devices for immediate processing. The calibration of the signals can be easily done, since the signals are linear.

6.1 Output Types

6.1.1 IK360 - Voltage

Connect the corresponding (voltage analog output pin 5) open end of the connection cable to the measurement system.



IK360 with voltage output

Calculation of angle from IK360 voltage:

$$\text{Position angle (in } ^\circ) = (V_{\text{out}} - 0.5 \text{ V}) \div (0.0111 \text{ Volts per } ^\circ)$$

For example:

$$1. V_{\text{out}} = 1.166 \text{ V}$$

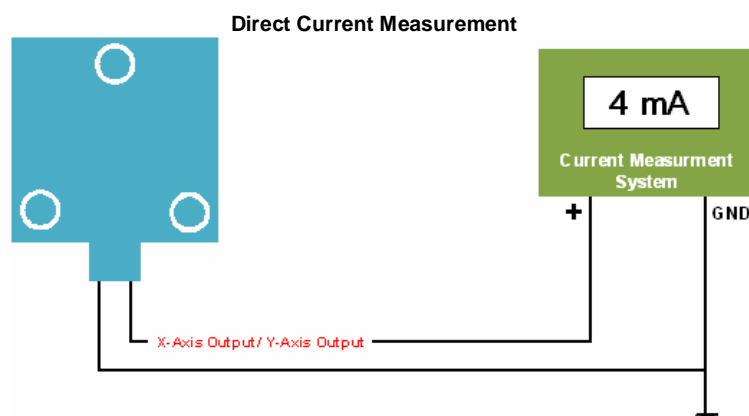
$$\text{Position Angle} = (1.166 - 0.5 \text{ V}) / (0.0111 \text{ V per } ^\circ) = 60^\circ$$

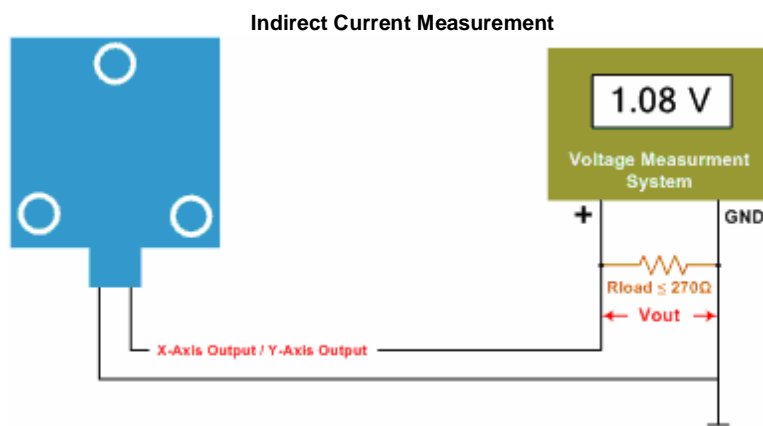
$$2. V_{\text{out}} = 2.866 \text{ V}$$

$$\text{Position Angle} = (2.866 \text{ V} - 0.5 \text{ V}) / (0.0111 \text{ V per } ^\circ) = 213.15^\circ$$

6.1.2 IK360 – Current

Connect the corresponding (current analog output Pin 5) open end of the connection cable to the measurement system. IK360 output current, I_{out} can be directly measured or indirectly measured as voltage, using a shunt resistor (Note: $R_{\text{Load}} \leq 270 \Omega$).





Calculation of angle from IK360 current:

$$\text{Position angle (in } ^\circ) = (I_{\text{out}} - 4 \text{ mA}) \div (0.0444 \text{ mA per } ^\circ)$$

For example:

1. $I_{\text{out}} = 8.31 \text{ mA}$

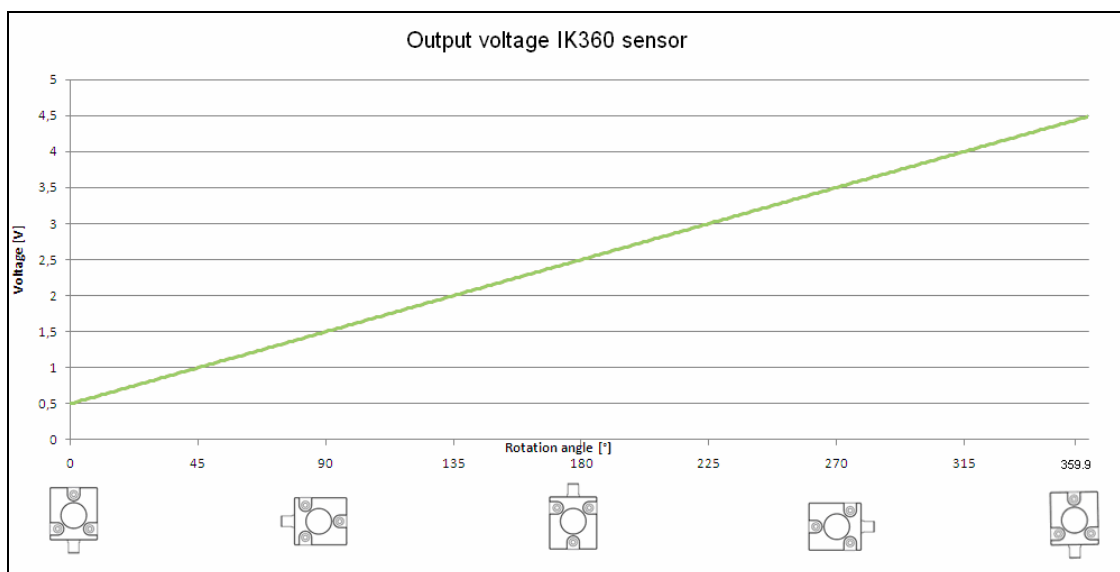
Position Angle = $(8.31 \text{ mA} - 4 \text{ mA}) / (0.0444 \text{ mA per } ^\circ) = 97.07^\circ$

2. $I_{\text{out}} = 11.6 \text{ mA}$

Position Angle = $(11.6 \text{ mA} - 4 \text{ mA}) / (0.0444 \text{ mA per } ^\circ) = 171.17^\circ$

7 IK360 - Analog Output Graphs

7.1 IK360 - Voltage



7.2 IK360 - Current

