MICRO-EPSILON

Operating Instructions

inertialSENSOR INC5701

INC5701S
INC5701D

1-axis inclination sensor

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1. Safety

System operation assumes knowledge of the operating instructions.

1.1 Symbols Used

The following symbols are used in these operating instructions:

⚠ CAUTION	Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.
NOTICE	Indicates a situation that may result in property damage if not avoided.
➪	Indicates a user action.
i	Indicates a tip for users.

1.2 Warnings

⚠ CAUTION

Connect the power supply and the display/output device according to the safety regulations for electrical equipment.
> Risk of injury

> Damage to or destruction of the sensor

NOTICE

The supply voltage must not exceed the specified limits.
> Damage to or destruction of the sensor

No sharp or heavy objects should be allowed to affect the cables. Avoid folding the cables. Do not bend more tightly than the minimum bending radius of the cables.
> Damage or destruction of the cable, failure of the measuring device

Do not crush the cable. Protect the sensor cable against damage.
> Damage or destruction of the cable, failure of the measuring device, data loss

Ensure that the coupling nuts of the connectors are firmly tightened.
> Damage or destruction of the cable, failure of the measuring device

1.3 Notes on CE Marking

The following apply to the INC5701:

- EU Directive 2014/30/EU
- EU Directive 2011/65/EU

Products which carry the CE mark satisfy the requirements of the EU directives cited and the European harmonized standards (EN) listed therein. The EU Declaration of Conformity is available to the responsible authorities according to EU Directive, article 10, at:

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The measuring system is designed for use in industrial environments and meets the requirements.

1.4 Intended Use

The INC5701 is designed for use in industrial applications. It is used for

- measuring angles
- determination of orientation
- measuring the position of manoeuvrable components

- The system must only be operated within the limits specified in the technical data, see 2.3.
- The sensor must be used in such a way that no persons are endangered or machines and other material goods are damaged in the event of malfunction or total failure of the sensor.
- Take additional precautions for safety and damage prevention in case of safety-related applications.

1.5 Proper Environment

- Protection class: [1] IP 67
- Operating temperature: -40 ... +85 °C (-40 ... +185 °F)
- Storage temperature: -40 ... +85 °C (-40 ... +185 °F)
- Ambient pressure: Atmospheric pressure

1) with M12 connector

2. Functional Principle, Technical Data

2.1 Functional Principle

With the inclination principle, inertial or gravitational forces are measured depending on the position of the sensor and transformed to an absolute angular value.

Therefore the sensor is mounted on the manoeuvrable component to be measured. The change of inclination is output as an absolute value relative the environment.

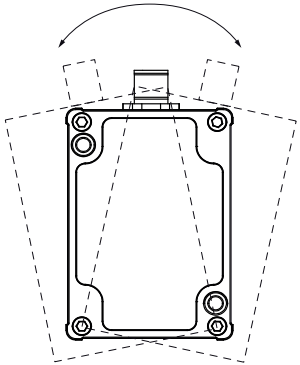


Fig. 1 One axis inclination sensor

2.2 Structure and Electrical Connection

Two variants of the sensor are offered. INC5701S [1] with a low-pass filter and INC5701D [2] using SensorFUSION with an additional dynamic extension.

Both versions are available with analog output (current, voltage and switching output) as well as RS485 for configuration of the sensor using the software sensorTOOL.

Power supply and signal output are effected through a 8-contact (M12) connector on the sensors housing.

1) = Standard
2) = Dynamic/SensorFUSION

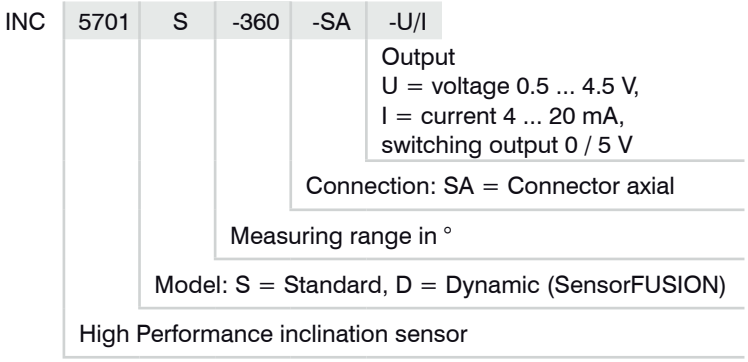
2.3 Technical Data

Model		INC5701S	INC5701D
Number of axes		1	
Adjustable filters		Low-pass (0.3 … 30 Hz)	Low-pass (0.3 … 30 Hz), SensorFUSION
Measuring range		0° … 360° (configurable)	
Resolution	Digital	0.0002°	
	Analog	Current: 0.0069°, voltage: 0.0083°	
Accuracy [1]	Digital	≤ ± 0.04°	
	Analog	≤ ± 0.12°	
Sensitivity (analog output)	Current	0.044 mA / °	
	Voltage	0.011 V / °	
Sampling frequency		250 Hz	
Temperature stability	Digital	0.0013°/ K	
	Analog	0.0083°/ K	
Supply voltage		5 … 32 VDC	
Power consumption		< 1 W	
Temperature range	Operating	-40 … +85 °C (-40 ... +185 °F)	
	Storage	-40 … +85 °C (-40 ... +185 °F)	
Digital interface		RS485	
Analog output		Current 4 … 20 mA (max. 390 Ω) Voltage 0.5 … 4.5 V (min. 1 kΩ)	
Switching output		0 / 5 V (min. 1 kΩ)	
Protection class		IP 67 (plugged state)	
Max. angular velocity		Unlimited	± 300° / s

Model	INC5701S	INC5701D
Shock	DIN EN 60068-2-27 (1500 g, 0.5 ms, half-sine shock, 3 x in each direction)	
Weight	Approx. 250 g	
Material	Die-cast aluminum	
Installation	Screw connection via mounting holes (M4)	
Connection	M12 connector, 8-pin	

All information valid under TA = 25 °C
1) Accuracy based on full measuring range with vertical installation

Article designation



2.4 Low-pass Filter

Both sensor variants operate with a low-pass filter which can be freely adjusted from 0.3 Hz to 30 Hz. Depending on the chosen cut-off frequency, the sensor signal is stabilized against undesired, short-term mechanical interferences like shocks or vibration. The lower the cut-off frequency is chosen, the more stable the signal but the higher the signal delay.

The filter has influence to the analog output as well as to the digital output.

2.5 SensorFUSION Filter

For the dynamic variant (INC5701D) an additional filter can be chosen. The combination of the low-pass filter with the additional dynamic extension is known as SensorFUSION. The SensorFUSION technology enables these sensors to be used even in vibrating environments, while providing reliable and accurate measurement results. The advantage of the SensorFUSION in comparison to the low-pass filter is shown in Figure below, see Fig. 2.

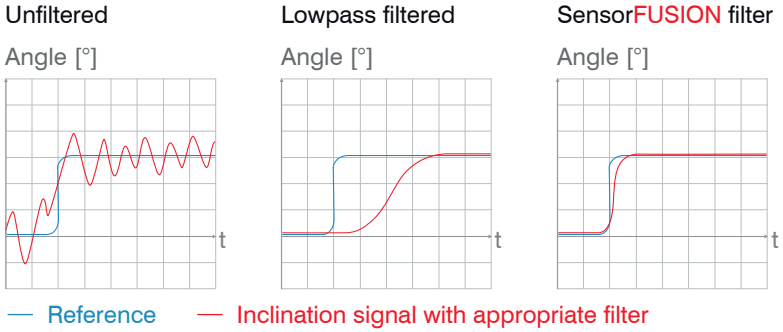


Fig. 2 Advantage of the SensorFUSION filter in comparison to the low-pass filter

3. Delivery

3.1 Unpacking, Included in Delivery

1 Sensor INC5701
1 Operating Instructions
1 Measurement protocol of the final test

- Carefully remove the components of the measuring system from the packaging and ensure that the goods are forwarded in such a way that no damage can occur.
- Check the delivery for completeness and shipping damage immediately after unpacking.
- If there is damage or parts are missing, immediately contact the manufacturer or supplier.

Optional accessories are available in the appendix, see A 1.

3.2 Storage

Storage temperature:	-40 ... +85 °C (-40 ... +185 °F)
Humidity:	5 - 95 % (non-condensing)

4. Installation and Assembly

4.1 Sensor Cable Assembly

NOTICE

No sharp or heavy objects should be allowed to affect the cables. Avoid folding the cables. Do not bend more tightly than the minimum bending radius of the cables.
> Damage or destruction of the cable, failure of the measuring device

Do not crush the cable. Protect the sensor cable against damage.
> Damage or destruction of the cable, failure of the measuring device

Ensure that the coupling nuts of the connectors are firmly tightened.
> Damage or destruction of the cable, failure of the measuring device

4.2 Sensor Assembly

The sensor is fixed with two M4 screws. After the sensor has been attached to the component, the position of rest (angular value = 0°) is freely adjustable with the software tool of Micro Epsilon.

From the position of rest the sensor measures an angle of up to 180 ° in each direction of rotation (clockwise and counterclockwise). The measurement range is shown in Figure below, see Fig. 3.

i To ensure most precise measurement the sensor should be positioned without tilting as shown, see Fig. 4.

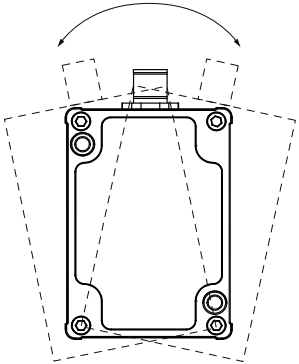


Fig. 3 Measurement range ±180 °

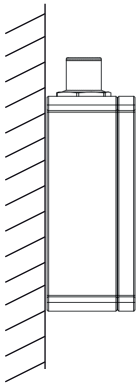


Fig. 4 Standard mounting position with most precise measurement without tilting of the sensor

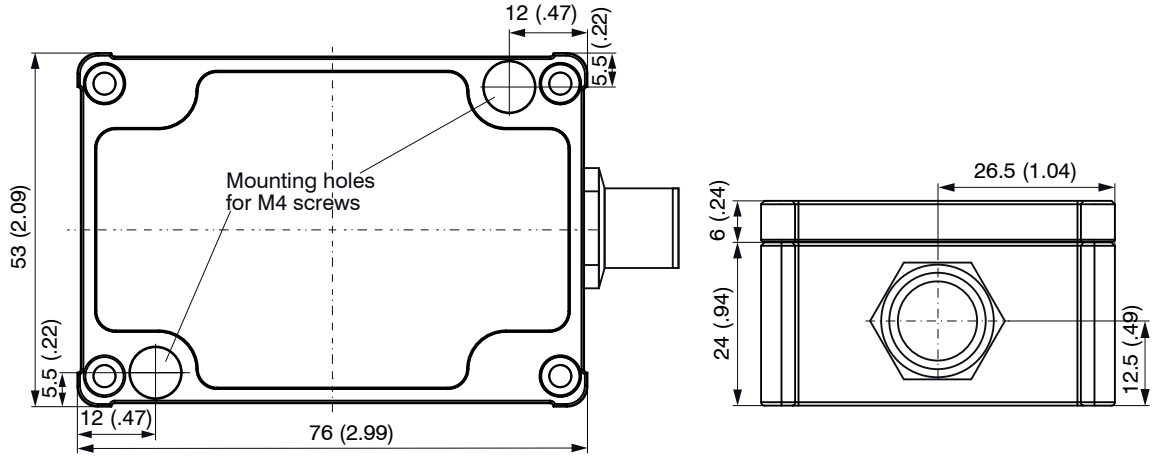
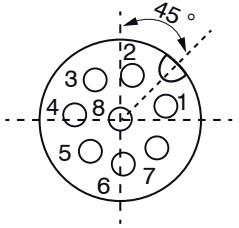


Fig. 5 Dimensional drawing, dimensions in mm (inches), not to scale

4.3 Pin Assignment

Connect the open cable end in accordance with the color coding, see Fig. 6.

Pin [1]	Color [2]	Description
1	White	Voltage output (angle)
2	Brown	GND (current output)
3	Green	Current output (angle)
4	Yellow	RS485+
5	Gray	GND (signal voltage output)
6	Black/pink	GND (supply)
7	Blue	RS485-
8	Red	Supply +



View of solder pin side, 8-pin, A-coded, female connector

Fig. 6 Pin assignment of the 8-pin, A-coded, female connector

1) - SA - Connector
2) PCx/8-M12 power supply and output cable, see A 1.

4.4 Current and Voltage Output

The sensor makes the angular value available as analog output variable either as current or voltage value on separate pins, depending on the configuration of the sensor using the software tool of Micro-Epsilon.

4.4.1 Continuous Operation Mode

In this process, the symmetrical measurement range in the unit angular degrees is scaled to the respective analogue range.

The sensitivity increases with decreasing measurement range as only a small angular rang is scaled to the same output range.

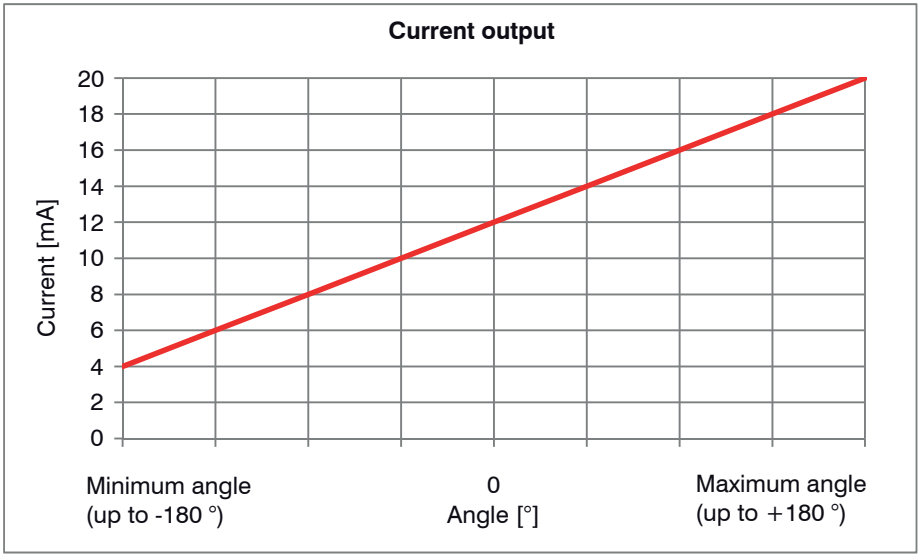


Fig. 7 Scaling of the angular measurement range to analog output variable current

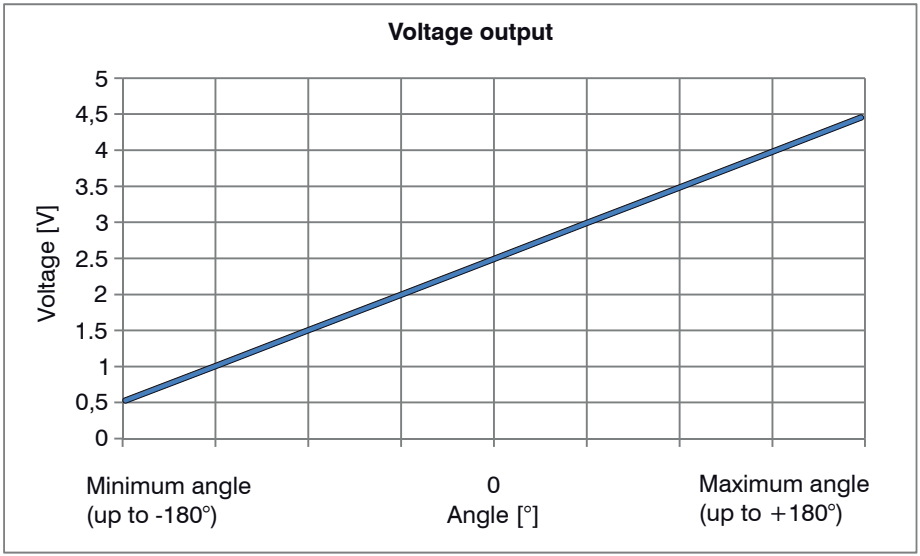


Fig. 8 Scaling of the angular measurement range to analog output variable voltage

4.4.2 Switching Operation Mode

The switching mode, configurable via Software, switches the analog voltage output to 5 V when the inclination value reaches the trigger-level “on-level“ and switches back to 0 V when the inclination value falls below the “off-level“, see Fig. 9.

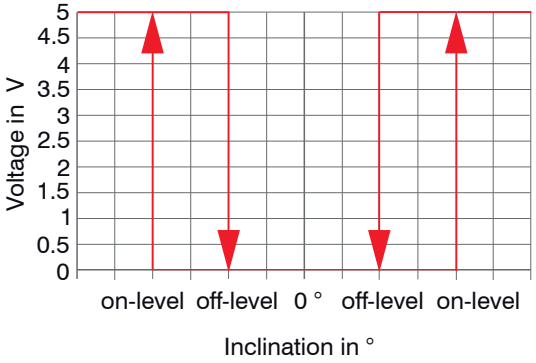


Fig. 9 Hysteresis of the trigger-levels in switching operation

That functionality can be used, for example, as safety feature which switches off a machine if a certain inclination angle is exceeded. The duration of the rising and falling edge is t < 10 µs, see Fig. 10.

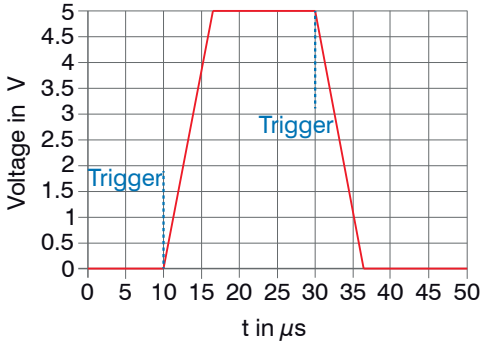


Fig. 10 Rising and falling edge of the voltage output in switching mode, t < 10 µs

Two different modes are selectable:

- Edge triggered, i.e. immediate switching when reaching the trigger-level.
- Edge triggered with delay, i.e. switching after specified time during which the trigger-level is reached permanently (debouncing).

The output values at the digital interface in switching mode are either zero or equal to the “on-level” as long as the trigger condition is met, see Fig. 11.

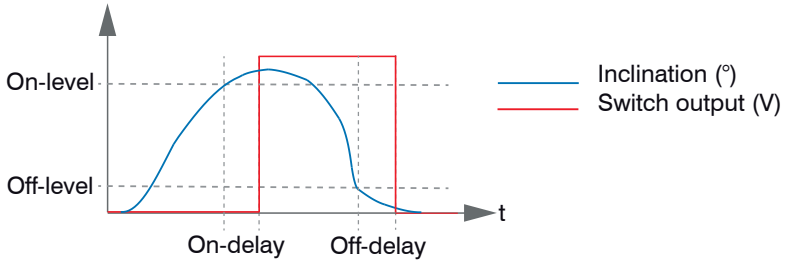


Fig. 11 Edge-triggered with delay (debouncing)

The debouncing (switching delay) can be adjusted in a wide range independently for the rising edge and the falling edge by the parameters “on-delay” and “off-delay”. The switch output will change only if the trigger level is reached or exceeded permanently during the delay duration. That ensures that the switch output will change only in stable signal conditions and will prevent undesired frequent switching in case of signal fluctuations or vibrations, see Fig. 12.

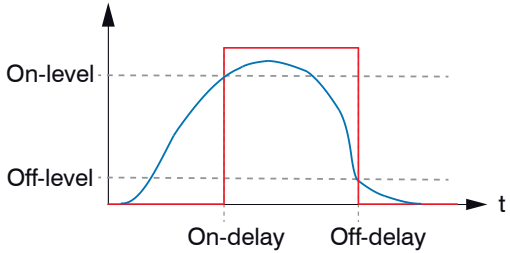


Fig. 12 Edge-triggered (immediate switching)

4.5 Digital Output RS485

You can read out the measured data in digital form using the RS485 interface. The PC software sensorTOOL, see A 2, permits configuration of the sensor and the visualization of the measured data, see A 1.

The bus protocol required to read out the measured data in your own applications is described, see A 4.

Additionally, you can use the IF1032/ETH interface converter by MICRO-EPSILON MESSTECHNIK GmbH & Co. KG, to read out the measured data via Ethernet.

5. Operation

The measurement device is already calibrated when delivered. Calibration by the user is not necessary. After connection to the operating voltage, the sensor is immediately ready for operation and independently initiates the measurement.

Additionally, the digital RS485 interface is ready to react to enquiries by the master (periodic retrieval of measured data).

For sensor configuration please use the power supply and output cable with USB/RS485 converter, see A 1, as well as the software of MICRO-EPSILON.

Allow the sensor to warm up for approximately 10 minutes after connection of the voltage supply.

6. Liability for Material Defects

All components of the device have been checked and tested for functionality at the factory. However, if defects occur despite our careful quality control, MICRO-EPSILON or your dealer must be notified immediately.

The liability for material defects is 12 months from delivery.

Within this period, defective parts, except for wearing parts, will be repaired or replaced free of charge, if the device is returned to MICRO-EPSILON with shipping costs prepaid. Any damage that is caused by improper handling, the use of force or by repairs or modifications by third parties is not covered by the liability for material defects. Repairs are carried out exclusively by MICRO-EPSILON.

Further claims can not be made. Claims arising from the purchase contract remain unaffected. In particular, MICRO-EPSILON shall not be liable for any consequential, special, indirect or incidental damage. In the interest of further development, MICRO-EPSILON reserves the right to make design changes without notification.

For translations into other languages, the German version shall prevail.

7. Service, Repair

If the sensor is defective, please send us the affected parts for repair or exchange.

If the cause of a fault cannot be clearly identified, please send the entire measuring system to:

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info@micro-epsilon.de
www.micro-epsilon.com

8. Decommissioning, Disposal

➡ Remove the power and output cable from the sensor.

Incorrect disposal may cause harm to the environment.

➡ Dispose of the device, its components and accessories, as well as the packaging materials in compliance with the applicable country-specific waste treatment and disposal regulations of the region of use.

Appendix

A 1 Accessories

Designation	Description
PC3/8-M12	Power supply and output cable, 3 m long
PC5/8-M12	Power supply and output cable, 5 m long
PC10/8-M12	Power supply and output cable, 10 m long
PC10/8-M12	Power supply and output cable, drag chain suitable, 10 m long
PC15/8-M12	Power supply and output cable, 15 m long
PC2/8-Sub-D	Power supply and output cable with USB/RS485 converter, 2.8 m long

A 2 PC Software sensorTOOL

You will find the software for the sensor for free at:
www.micro-epsilon.com

A 3 Factory Settings

Low-pass filter: 0.7 Hz

Gyro-effect: 63 %

Current measurement range: 360 °

Current measurement start: -180 °

Output signal: 4 ... 20 mA

Analog Output Signal: Signal 2 (SensorFUSION)

A 4 Digital Interface RS485

A 4.1 Hardware Interface

The interface is a half-duplex RS485 interface, which means that one cable pair is jointly used for sending and receiving.

Baud rate	230400 b/s
Data format	1 start bit, 8 data bits, 1 parity bit even, 1 stop bit
Bus address	126

Fig. 13 Settings of the RS485 interface

A terminating resistance of 120 Ω is required between the A- and B-line of the RS485 interface at the beginning and the end of the RS485 bus. A terminating resistor of the RS485 line is not incorporated in the sensor. It is therefore allowed to connect several sensors to one bus cable.

A 4.2 Protocol

INC5701 acts as RS485 slave. As the system uses a half-duplex protocol, only the master can initiate communication. Each device at the RS485 bus requires its own address. The master sends an enquiry with the destination address to the bus and only the slave with this address answers accordingly. At any given moment, the digital output signal of INC5701D contains the output values of the low-pass filter and the SensorFUSION filter, independent of the filter configuration. The user can therefore directly compare both filter principles at any time. The configuration merely switches the analog output to the respective filter type.

A 4.2.1 Reading Measurement Data

Master: Request data						
Byte:	SD	DA	SA	FC	FCS	ED
Value:	0x10	x	x	0x4C	x	0x16
		FCS				

Slave: Response data										
Byte:	SD	LE	LE rep	SD rep	DA	SA	FC	Data[]	FCS	ED
Value:	0x68	x	x	0x68	x	x	0x08	x	x	0x16

Designations	
SD	Start Delimiter (0x10: datagram without data, 0x68: datagram with variable length)
LE	Length (number of bytes without SD, LE, LE rep, SD rep, FCS, ED)
LE rep	LE repeated
SD rep	SD repeated
DA	Destination Address (default 0x7E = 126)
SA	Source Address (e. g. 0x01)
FC	Function Code
FCS	Checksum (sum of all bytes without SD, LE, LE rep, SD rep, FCS, ED, overflow at 256)
ED	End Delimiter
Data[]	Measurement data, variable number, little endian

The measurement data consists of one status byte, one measured values counter, number of measured values, and the measured data. The measured values counter increases continuously with each sampled value. It represents the number of measured values buffered in the sensor since the last enquiry by the master and therefore represents the number of the measured values transmitted in this package (floats).

The internal sampling at 250 Hz generates a new measured value every 4 ms. The maximum number of measured values which can be held within the sensor is

- 58 for INC5701S and
- 29 for INC5701D (contains SensorFUSION and low-pass filter).

Therefore, an enquiry by the master must reach the sensor within
58 * 4 ms = 232 ms or 29 * 4 ms = 116 ms, respectively, in order to read the content from the internal memory and ensure uninterrupted sampling (periodic enquiry). If the enquiries are not made in time, error flag 0x01 is set in the status byte.

This error flag is deleted automatically as soon as the master resumes its periodic enquiries. The analog output remains unaffected by this. The first measurement value in the Data[] package is the oldest measured value. A measured value is represented as 4-byte float data type in the unit angular degrees [°].

Byte	Meaning	Data format
Data[0]	Status byte (contains error flags, normally 0x00	8 bit
Data[1]	Long term values counter [bit 0:7]	Uint 32 bit
Data[2]	Long term values counter [bit 8:15]	
Data[3]	Long term values counter [bit 16:23]	
Data[4]	Long term values counter [bit 24:31]	
Data[5]	Number of measured values in this package	8 bit
Data[6]	Padding byte	8 bit
Data[7]	Padding byte	8 bit
Data[8]	Measured value 1 [bit 0:7]	Float 32 bit
Data[9]	Measured value 1 [bit 8:15]	
Data[10]	Measured value 1 [bit 16:23]	
Data[11]	Measured value 1 [bit 24:31]	
Data[12]	Measured value 2 [bit 0:7]	Float 32 bit
Data[13]	Measured value 2 [bit 8:15]	
Data[14]	Measured value 2 [bit 16:23]	
Data[15]	Measured value 2 [bit 24:31]	

Fig. 14 Encoding of Measured Data in the Transmission Protocol, INC5701S

Byte	Meaning	Data format
Data[0]	Status byte (contains error flags, normally 0x00)	8 bit
Data[1]	Long term values counter [bit 0:7]	Uint 32 bit
Data[2]	Long term values counter [bit 8:15]	
Data[3]	Long term values counter [bit 16:23]	
Data[4]	Long term values counter [bit 24:31]	
Data[5]	Number of measured values in this package	8 bit
Data[6]	Padding byte	8 bit
Data[7]	Padding byte	8 bit
Data[8]	Measured value 1 LP [1] [bit 0:7]	Float 32 bit
Data[9]	Measured value 1 LP [1] [bit 8:15]	
Data[10]	Measured value 1 LP [1] [bit 16:23]	
Data[11]	Measured value 1 LP [1] [bit 24:31]	
Data[12]	Measured value 2 LP [1] [bit 0:7]	Float 32 bit
Data[13]	Measured value 2 LP [1] [bit 8:15]	
Data[14]	Measured value 2 LP [1] [bit 16:23]	
Data[15]	Measured value 2 LP [1] [bit 24:31]	
...	...	...
Data[n] n=8+(4*Data [5])	Measured value 2 SF [2] [bit 0:7]	Float 32 bit
Data[n + 1]	Measured value 2 SF [2] [bit 8:15]	
Data[n + 2]	Measured value 2 SF [2] [bit 16:23]	
Data[n + 3]	Measured value 2 SF [2] [bit 24:31]	
Data[n + 4]	Measured value 2 SF [2] [bit 24:31]	Float 32 bit
Data[n + 5]	Measured value 2 SF [2] [bit 24:31]	
...	...	

Fig. 15 Encoding of Measured Data in the Transmission Protocol, INC5701D

1) LP = Low pass filter 2) SF = SensorFUSION filter

A 4.2.2 Example Transmission of a Measurement Value

Master: Request data						
Byte:	SD	DA	SA	FC	FCS	ED
Value:	0x10	0x7E	0x01	0x4C	0xCB	0x16
		FCS				

DA = Destination Address = 0x7E = 126 (Slave)

SA = Source Address = 0x01 (Master)

FCS = Checksum = 0x7E + 0x01 + 0x4C = 0xCB

= 126 + 1 + 76 = 203 (no overflow)

Slave: Response data										
Byte:	SD	LE	LE rep	SD rep	DA	SA	FC	Data[]	FCS	ED
Value:	0x68	1B	1B	0x68	0x01	0x7E	0x08	x	0x67	0x16
					FCS					

4 measured values = 4 x float = 4 x 4 bytes = 16 data bytes

LE = Length = 16 data bytes + 11 bytes (DA, SA, FC, 1xstatus, 4xstatus, 4xcounter, 1xnumber, 2xpadding byte) = 0x1B =27

DA = Destination Address = 0x01 (Master)

SA = Source Address = 0x7E = 126 (Slave)

FCS = Checksum = 0x01 + 0x7E + 0x08 + 0x00 (status) + 0x04 (counter) ... = 0x67 (note overflow at 256 each time = reset sum to zero)

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