MTS SENSORS

Temposonics®

Magnetostrictive Linear Position Sensors

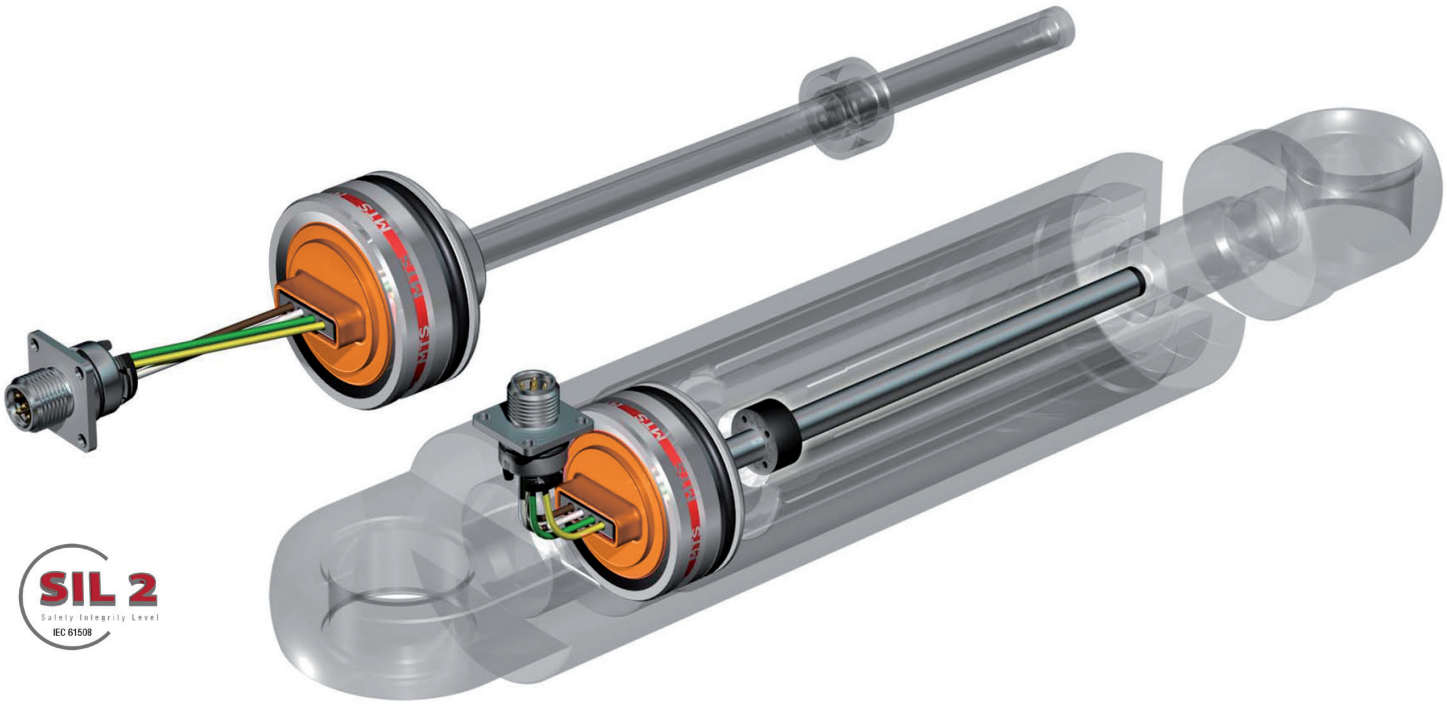
Magnetostrictive Linear Sensors with SIL 2 Specification

Technical Data / Safety Manual

– Linearity ≤ 0.04 % F.S.

– Resolution typ. 0.1 mm

– SIL 2 rated according to IEC / EN 61508



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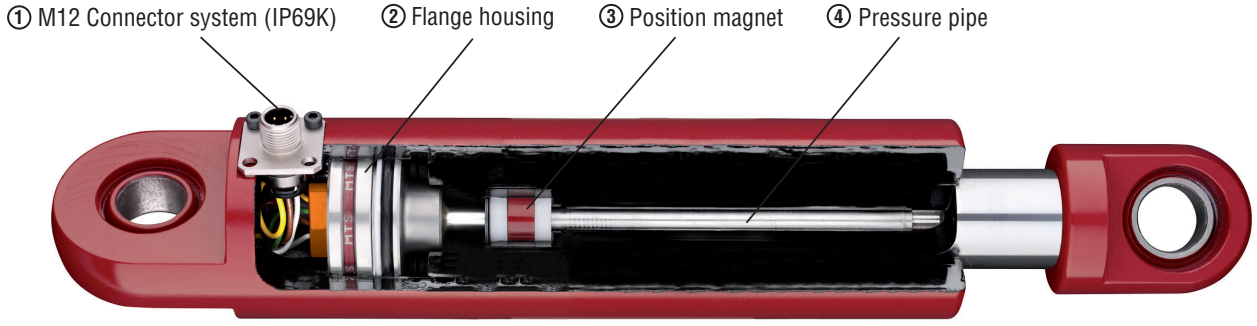
1. Product description and technology

Temposonics® sensors can be used in versatile mobile machines without any restriction and replace contact-based linear sensors like potentiometers. Highly dynamic systems are controlled safely by means of Temposonics® sensors, thus enhancing the productivity, availability and quality of the working process of the machine. Insensitive to vibration, shocks, dust and weathering influence and electromagnetic disturbances. Temposonics® MH Series sensors are successfully used in front axle and articulated frame steering cylinders, hydraulic jacks and in steering systems for hydraulic units on agricultural and construction machinery.



Simple mechanics

The extremely robust sensor consists of the following main parts:

① The innovative connector system which is easy to install in a few seconds, any soldering or crimping needless, dust-and waterproof up to IP69K.

② The flange housing with built-in electronics and signal converter.

③ The position magnet as only moving part, which is assembled into the piston bottom. This permanent magnet travels wear-free and contactless along the pressure pipe and measures the actual position.

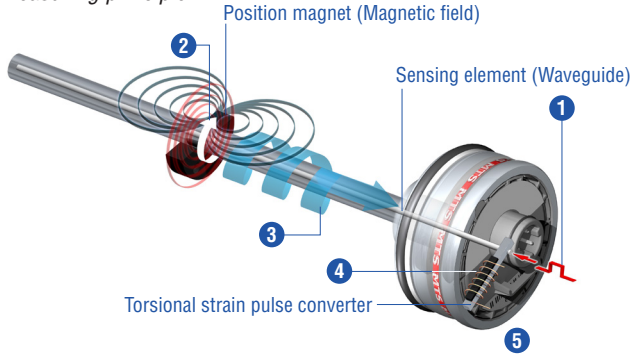
④ The pressure pipe placed within the drilled piston rod contains the protected magnetostrictive sensing element.

- Due to small dimensions MH sensors require only little space
- Suitable for operating pressures up to 350 bar
- Unaffected by surrounding media such as ageing or foaming oil
- Insensitive to shock and vibration
- Designed for all current supply voltages (12/24 VDC)
- Temposonics® sensors offer all common used output signals:
  - Analog: VDC, mA
  - Digital: CANopen Safety

Magnetostriction

For position measurement, the absolute, linear position Temposonics® sensors make use of the properties offered by the specially designed magnetostrictive waveguide. Inside the sensor a torsional strain pulse is induced in the waveguide by momentary interaction of two magnetic fields. The interaction between these two magnetic fields produces a strain pulse, which is detected by the converter at the sensor electronics housing. One field is produced by a moving position magnet, which travels along the sensor rod with the waveguide inside. The other field is generated by a current pulse applied to the waveguide. The position of the moving magnet is determined precisely by measuring the time-of-flight between the application of the current pulse and the arrival of the strain pulse at the sensor electronics housing. The result is a reliable position measurement with high accuracy and repeatability.

Measuring principle



Measurement Cycle	
1	Current pulse generates magnetic field
2	Interaction with position magnet field generates torsional strain pulse
3	Torsional strain pulse propagates
4	Strain pulse detected by converter
5	Time-of-flight converted into distance

2. Functional safety for linear position sensing

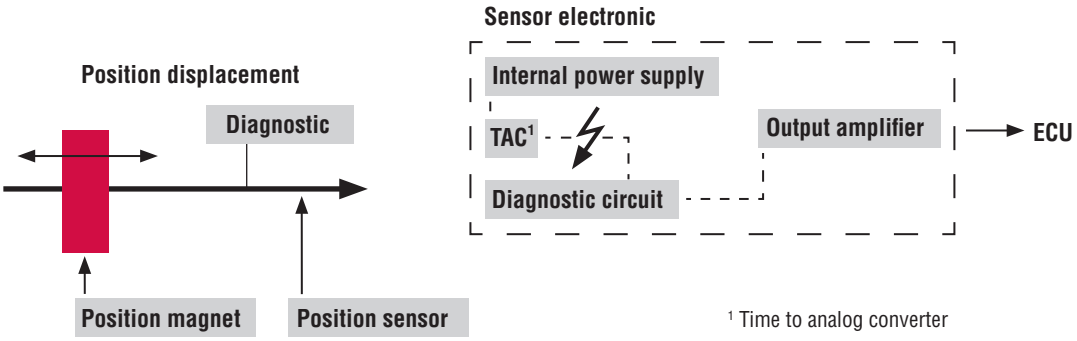
Temposonics® linear displacement sensors “MH Safety” are based on the magnetostrictive technology and designed according to the requirements out of IEC/EN 61508 and rated with SIL 2 safety level. Developed for use in safety circuits/safety functions for measuring linear position as part of the functional safety of machinery and equipment it is also possible to use them up to PLd according to ISO 13849.

Operating with internal diagnostics consisting of evaluation electronics in order to detect a fail function relevant failure status will transmitted to the ECU. Critical safety function is evaluated in the ECU- emergency stop or emergency run will enable a safe operation after detecting the failure. Main areas of application are as linear sensor in safety oriented systems such as steering systems, load torque limitation in truck-mounted cranes (outrigger cylinders) and boom lifting and tilting cylinders in working platforms.

The design is a single architecture (Cat2) PLd according to ISO 13849

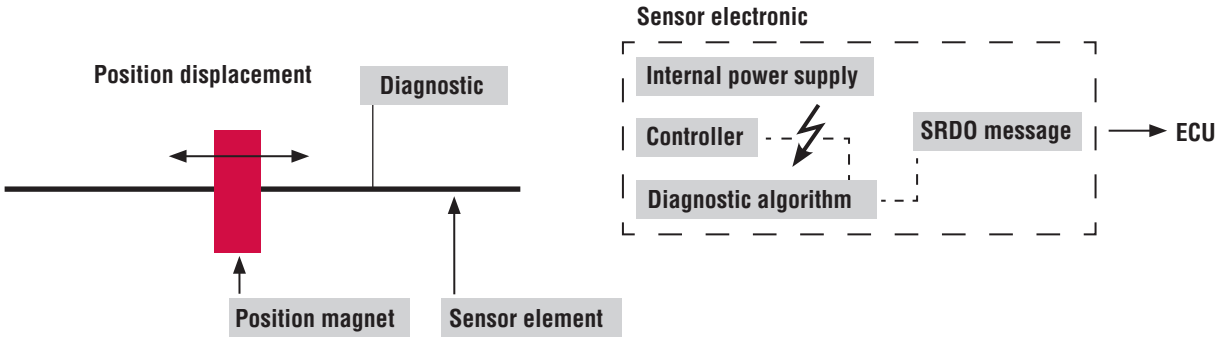
The user has two alternatives at his disposal:

1. MH Analog Safety
Position sensor with an isolated three-wire analog output. Classified as type B according to IEC 61508. The sensor contains a self-diagnostic circuit. In an event of a detected failure, the sensor sends a defined output of 0 VDC.



[1] Time to analog converter

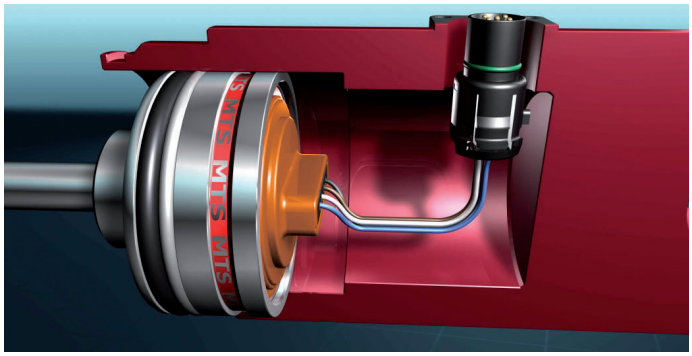
2. MH CANopen Safety
CANopen based position sensor classified as type B according to IEC 61508 sends safety relevant data objects. In an event of a detected failure, the internal diagnostic algorythm sends a safety relevant data object (SRDO) which includes the corresponding emergency status information to the ECU. This will ensure to perform the requested functional safety.



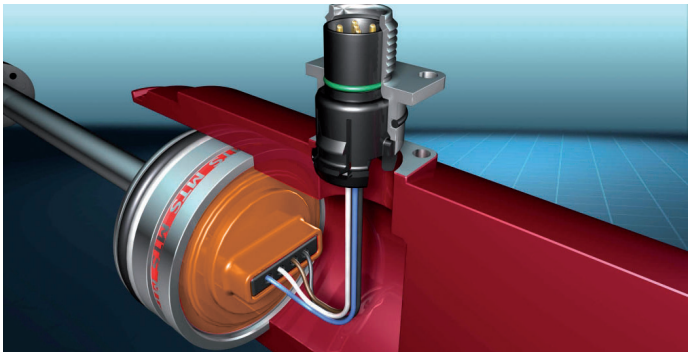
3. MTS Sensors connector system M12

MTS Sensors presents the innovative connector system for Temposonics® MH-Series

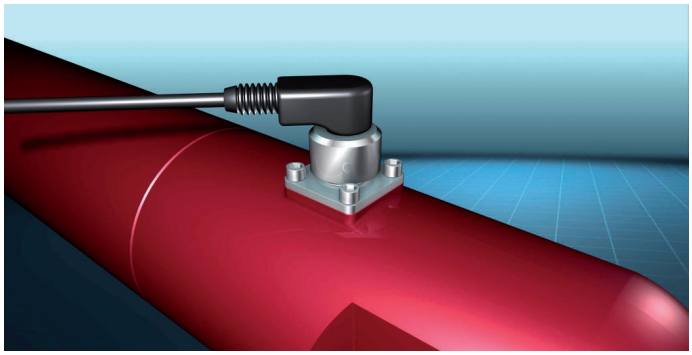
The M12 connector system meets the highest protection requirements important for a harsh environment in mobile hydraulic applications. Protection type IP69K performs water and dust proof. In addition it is even resistive against high pressure water cleaning.



1 The MH sensor is delivered by MTS together with the new connector system:
The connector insert carrier is already connected to the sensor conductors, i.e. no soldering, any color or connection mistake.



2 The connector insert is taken out of the cylinder through a bore hole. The flange can easily be clicked in position from outside.

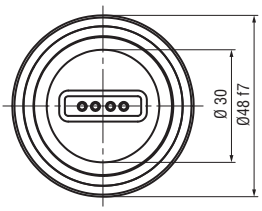


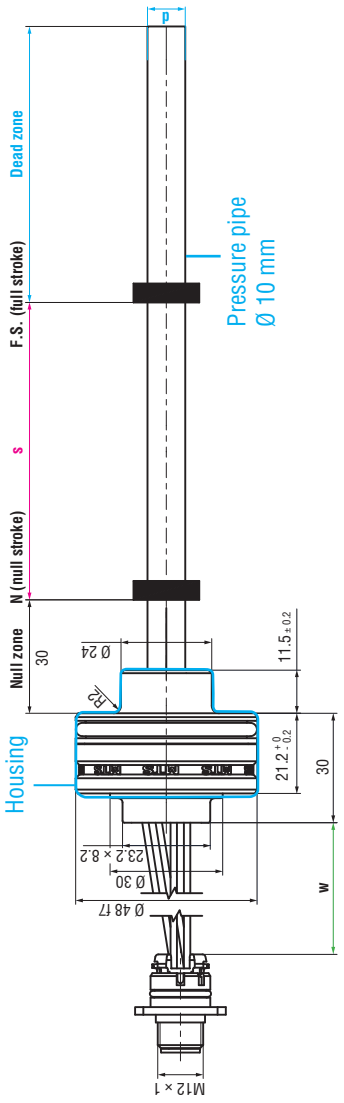
3 Four standard screws must be tightened to mount the connector system on the cylinder. In case of using angled type connectors the connector insert can be rotated inside the flange in 45° steps.

4 With a corresponding mating plug the connector system fulfills an IP rating of IP69K.

- Absolutely easy and safe installation.
- No brazing or crimping of connecting leads is required.

4. Dimensions





Model no.

MH	C	–	2	0	0	0	M	–	N	1	2		H	–	3	–	V99		
																	A99		
																	S01	2	40
																	F		

Mechanical configurations

Form factor	C	Z = 63.5 mm (s ≤ 2.500 mm)
Stroke length	s	50…2500 mm
Wire length	w	60…240 mm

e.g.: s = 2000 mm

e.g.: w = 120 mm

Electrical configurations

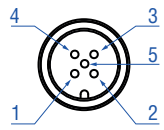
MH Analog	H	1 = VDC 3 = GND 2 = Sig 4 = n.c.
MH Digital	F	2 = VDC 3 = GND 4 = CAN HI 5 = CAN LO 1 = n.c.
MH Analog	V99	0.50…4.50 VDC
	A99	4…20 mA
MH Digital	S01	CANopen Safety

Baudrate	2	500 kbit/sec
Node ID	40	40 hex

All dimensions in mm

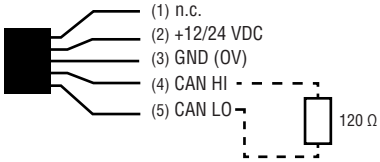
5. Electrical installation

MH Digital
PIN assignment digital 5 pin

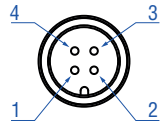


Pin	F
1	n.c.
2	VDC
3	GND
4	CAN HI
5	CAN LO

Pin assignment "F"

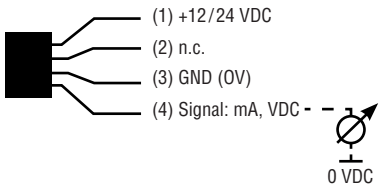


MH Analog
PIN assignment analog 4 pin

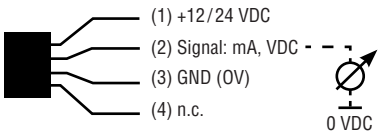


Pin	G	H
1	VDC	VDC
2	n.c.	Signal
3	GND	GND
4	Signal	n.c.

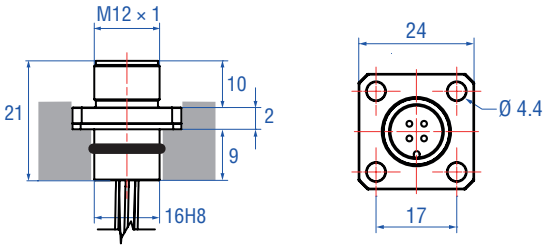
Pin assignment "G"



Pin assignment "H"

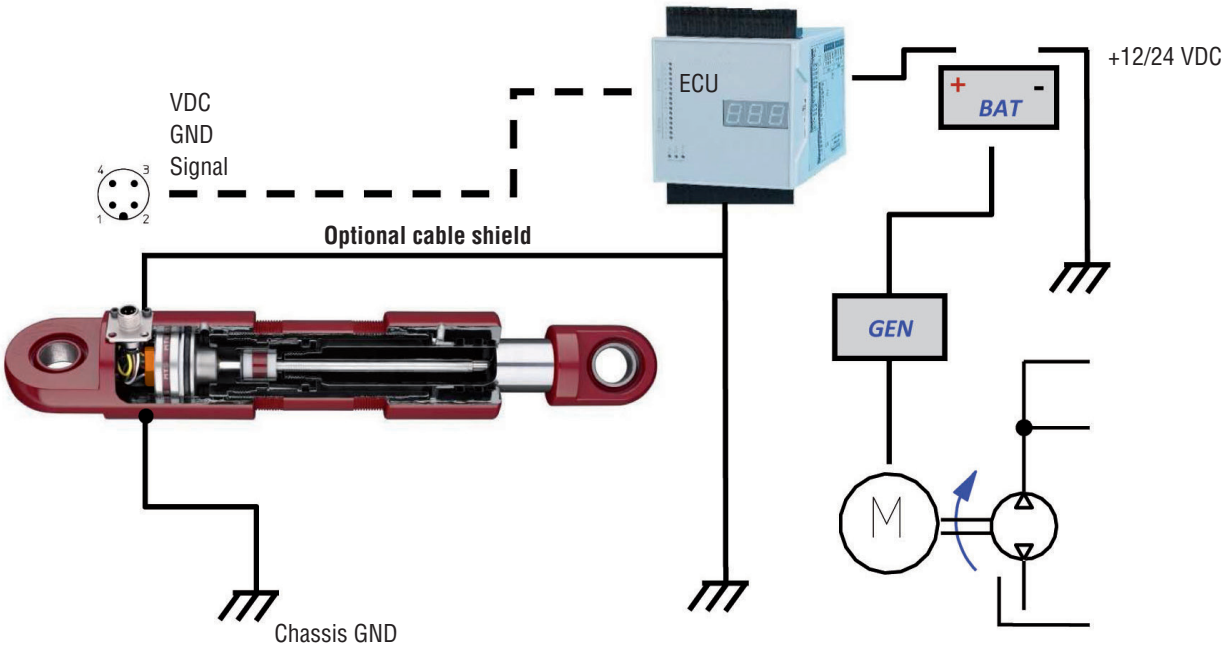


M12 flange



Please pay attention to operation manual

Connecting schematics on vehicle electronics:



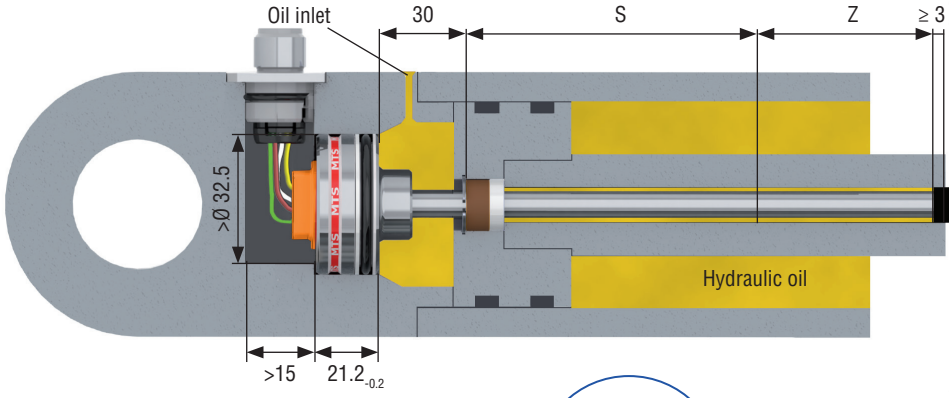
All dimensions in mm

6. In cylinder assembly

Mechanical installation

The robust Temposonics® MH sensor is designed for direct stroke measurement in hydraulic cylinders.
The Temposonics® MH sensor can be installed from the head side or the rod side of the cylinder depending on the cylinder design.

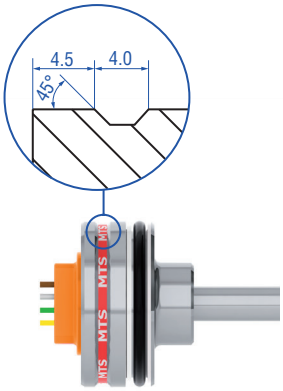
Example



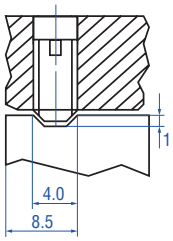
Sensor installation

The method of installation is entirely dependent on the cylinder design. While the most common method of installation is from the rod side of the cylinder, an installation from the head side of the cylinder is also possible. In both installation methods, the hermetic sealing of the cylinder is given by an O-ring with additional back-up ring.

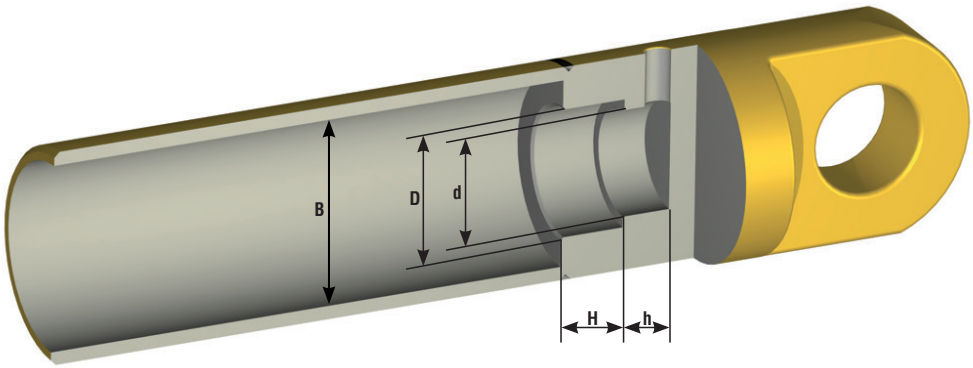
Please pay attention:
- The position magnet shall not touch the pressure pipe.
- Do not exceed operating pressure.
- Piston rod drilling:
  Depth: S + Z + 3 mm
  Diameter: Ø 13 mm minimum



Flange housing with O-ring and back-up ring



Example:
e.g. retaining with set screw DIN 913 M5×10 (with flat point!) max. torque 0.5 Nm



Type	B - Ø Cylinder	D - Ø min.	H - Depth	d - Ø min.	h - Depth
MH	52	48	21.2	> 32.5 < 40	> 15

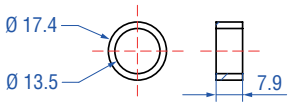
NOTICE

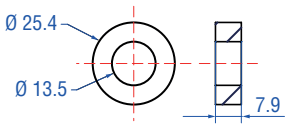
For correct sensor installation and technical support please contact our application team
(See last page for contact information)

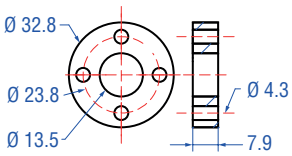
All dimensions in mm

6.1 Position magnets

Position magnets (please order separately)



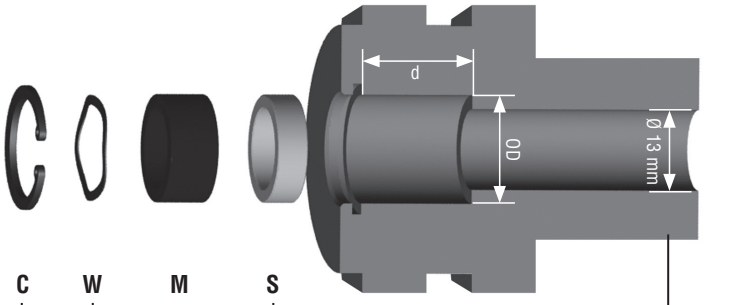




Name	OD17.4 Ring magnet	OD25.4 Ring magnet	OD33 Ring magnet
Part no.	**401 032**	**400 533**	**201 542-2**
Dimensions			
OD_M	17.4 mm	25.4 mm	32.8 mm
ID_M	13.5 mm	13.5 mm	13.5 mm
Height	7.9 mm	7.9 mm	7.9 mm
Characteristics			
Material	PA neobind	PA ferrite	PA ferrite GF20
Weight	ca. 5 g	ca. 10 g	ca. 14 g
Operating temperature	–40…+100 °C	–40…+100 °C	–40…+100 °C
Surface pressure	max. 20 N/mm²	max. 40 N/mm²	max. 40 N/mm²
Fastening torque for M4 screws	–	–	max. 1 Nm

*max. mechanical burden, e.g. by circlip, lock washers etc.

6.2 Position magnet (M) and magnet assembly with spacer (S) in piston



$S = OD \times 5 \times ID_M$

Part no.	401 032	400 533	201 542-2
OD	17.4 mm	25.4 mm	32.8 mm
d	13.5 mm	13.5 mm	13.5 mm
	P_A* 10 N/mm²	P_A* 40 N/mm²	P_A* 40 N/mm²

NOTICE

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All dimensions in mm

7. MH Analog Safety: Technical data / Model configurator

Input			
Measured value	Position		
Stroke range	50…2500 mm (in 5 mm steps)		
Output			
Signal characteristic	Continuously analog output restricted by noise or A/D converter of control unit		
Voltage	0.5…4.5 VDC with failure signal	< 0.5 VDC LO	> 4.5 VDC HI
Current	4…20 mA with failure signal	< 4.0 mA LO	> 20 mA HI
Resolution	Typ. 0.1 mm		
Power uptime	< 2 s		
Null zone	30 mm		
Dead zone	63.5 mm		
Accuracy			
Linearity	50…250 mm ≤ ±0.1 mm 255…2000 mm ±0.04 % (F.S.) 2005…2500 mm ≤ ±0.8 mm		
Hysteresis	±0.1 mm		
Internal sample rate	2 ms		
Setpoint tolerance	±2 mm		
Operating conditions			
Fitting position	Any		
Operating temperature electronics	–40…+105 °C		
Storage temperature	–20…+65 °C		
Fluid temperature	–40…+105 °C		
Dew point, humidity	EN 60068-2-30, 90 % rel. humidity, no condensation		
Pressure			
Operating pressure ratings	pressure pulse test according to DIN EN ISO 19879		
PN	350 bar		
Pmax	450 bar		
Pstatic	625 bar		
IP rating			
M12 connector	EN60529 (IP69K), plugged		
Sensor housing	EN60529 (IP67)		
Environmental testing			
Shock test	IEC 60068-2-27, 100 g (6 ms) single shock, 50 g (11 ms) at 1000 shocks per axis		
Vibration test	IEC 60068-2-64, ε < ±1.25 % F.S. for vibration 20 g (r.m.s.) 10…2,000 Hz		
EMC test	ECE R10 Rev. 3: Road vehicles ISO 14982 Agricultural and forest machines EN 13309 Construction machines Immunity: ISO 11452-2 (200 V/m Antenna), ISO 11452-4 (200 mA BCI) Emissions: CISPR 25 Transiente Impulses: ISO 7637-1/2 E.S.D.: ISO/TR 10605		
Materials and dimensions			
Pressure Pipe (Ø 10 mm)	Stainless steel 1.4306 / AISI 304L		
Housing, flange (Ø 48 mm)	Stainless steel 1.4305 / AISI 303		
Sealing	O-ring 40.87 × 3.53 mm NBR 80, back-up ring 42.6 × 48 × 1.4 PTFE		
M12 connector insert	Material: polyamide reinforces; O-ring 7 × 1.35 mm NBR 70; pins: brass with gold plated pins		
M12 flange	Brass nickel-plated with O-ring 13 × 1.6 NBR 70		
Electrical installation			
Connector	M12 male plug		
Supply voltage	**12 VDC (8…32 VDC)**		**24 VDC (8…32 VDC)**
Current consumption	Typ. ≤ 100 mA		Typ. ≤ 50 mA
Load (output VDC)	R_L > 10 kΩ		R_L > 10 kΩ
Load (output mA)	235 Ω < R_L < 265 Ω		235 Ω < R_L < 265 Ω
Inrush current	Max. 2.5 A / 2 ms		Max. 4.5 A / 2 ms
Supply voltage ripple	< 1 % p-p		
Power drain	< 1 W		
Over voltage protection (GND – VDC)	Up to +36 VDC		
Polarity protection (GND – VDC)	Up to –36 VDC		
Dielectric strength	500 VDC (DC GND to chassis GND)		

Temposonics® Model configurator

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
M	H	C					M	N				3		9	9
a		b	c					d			e	f	g		

a	Sensor model
M H	Flange housing (Ø 48 mm)

b	Form factor
C	Pressure pipe (Ø 10 mm)

c	Stroke range
	0050…2500 mm (in 5 mm steps)

d	Electrical wiring
N	60…240 mm 4 single wires (in 20 mm steps) *Example: N06 = 60 mm, N08 = 80 mm, N24 = 240 mm*

e	Pin assignment
G	M12 IP69K, 4 pin (pin assignment 1-3-4)
H	M12 IP69K, 4 pin (pin assignment 1-3-2)

f	Supply voltage
3	+12 / 24 VDC

g	Output
V 9	9 0.5…4.5 VDC
A 9	9 4…20 mA

Scope of delivery:
Position sensor, O-ring, backup-ring, M12 connector system

Please order magnets separately!

Accessories (selection)	Part no.
OD17.4 Ring magnet	401 032
OD25.4 Ring magnet	400 533
OD33 Ring magnet	201 542-2

MH Testkit	Part no.
Hardware Scope of delivery: • MH-Series Analog / PWM Tester • 12 VDC battery charger with adapter (adapter main plug EU, adapter main plug UK) • cable with M12 connector • cable with pigtailed wires • carrying case	280 618

8. MH Digital Safety: Technical data / Model configurator

Input		
Measured value	Position & velocity	
Stroke range	50…2500 mm (in 5 mm steps)	
Output		
Signal characteristic	EN 50325-5: bus-protocol according to CiA DS-304 CANopen Safety, device profile DS-406 V3.1	
Resolution (position)	0.1 mm	
Resolution (velocity)	1 mm/s	
Boot up time	Typ. 400 ms	
Cycle time	25 ms	
Null zone	30 mm	
Dead zone	63.5 mm	
Accuracy		
Linearity	50…250 mm ≤ ±0.1 mm 255…2000 mm ±0.04 % (F.S.) 2005…2500 mm ≤ ±0.8 mm	
Hysteresis	±0.1 mm	
Internal sample rate	1 ms	
Setpoint tolerance	±0.2 mm	
Operating conditions		
Mounting position	Any	
Operating temperature electronics	–40…+100 °C	
Storage temperature	–20…+65 °C	
Fluid temperature	–30…+85 °C	
Dew point, humidity	EN60068-2-30, 90 % rel. humidity, no condensation	
Pressure		
Operating pressure ratings	Pressure pulse test according to DIN EN ISO 19879	
PN	350 bar	
Pmax	450 bar	
Pstatic	625 bar	
IP rating		
M12 connector	EN60529 (IP69K), plugged	
Sensor housing	EN60529 (IP67)	
Environmental testing		
Shock test	IEC 60068-2-27, 100 g (6 ms) single shock, 50 g (11 ms) at 1000 shocks per axis	
Vibration test	IEC 60068-2-64, 20 g (r.m.s.) (10…2000 Hz) resonance frequencies excluded	
EMC test	ECE R10 - Rev. 3: Road vehicles ISO 14982 Agricultural and forest machines EN 13309 Construction machines Immunity: ISO 11452-2 (200 V/m Antenna), ISO 11452-4 (200 mA BCI) Emissions: CISPR 25 Transiente Impulses: ISO 7637-1/2 E.S.D.: ISO/TR 10605	
Materials and dimensions		
Pressure pipe (Ø 10 mm)	Stainless steel 1.4306 / AISI 304L	
Housing, flange (Ø 48 mm)	Stainless steel 1.4305 / AISI 303	
Sealing	O-ring 40.87 × 3.53 mm NBR 80, back-up ring 42.6 × 48 × 1.4 PTFE	
M12 connector insert	Material: polyamide reinforces; O-ring 7 × 1.35 mm NBR 70; pins: brass with gold plated pins	
M12 flange	Brass nickel-plated with O-ring 13 × 1.6 NBR 70	
Electrical installation		
Connector	M12 male plug	
Supply voltage	**12 VDC (8…32 VDC)**	**24 VDC (8…32 VDC)**
Current consumption	Typ. ≤ 100 mA	Typ. ≤ 50 mA
Inrush current	1.0 A / 2 ms	1.5 A / 2 ms
Bus termination (HI-LO) (external)	120 Ω	
Supply voltage ripple	< 1 % p-p	
Power drain	< 1.5 W	
Over voltage protection (GND – VDC)	Up to +36 VDC	
Polarity protection (GND – VDC)	Up to –36 VDC	
Dielectric strength	500 VDC (DC GND to chassis GND)	

Temposonics® Model configurator

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
M	H	C					M	N			F	3	S	0	1			
a		b	c					d			e	f	g			h	i	

a	Sensor model
M H	Flange housing (Ø 48 mm)

b	Form factor
C	pressure pipe (Ø 10 mm)

c	Stroke range
	0050…2500 mm (in 5 mm steps)

d	Electrical wiring
N	60…240 mm 4 single wires (in 20 mm steps) *Example: N06 = 60 mm, N08 = 80 mm, N24 = 240 mm*

e	Pin assignment
F	M12 IP69K, 4 pin (pin assignment 2-3-4-5)

f	Supply voltage
3	+12 / 24 VDC

g	Output
S 0 1	CANopen Safety, cycle time 25 ms (default setting)

h	Baud rate
0	1000 kbit/sec
1	800 kbit/sec
2	**500 kbit/sec (default setting)**
3	250 kbit/sec
4	125 kbit/sec
6	50 kbit/sec

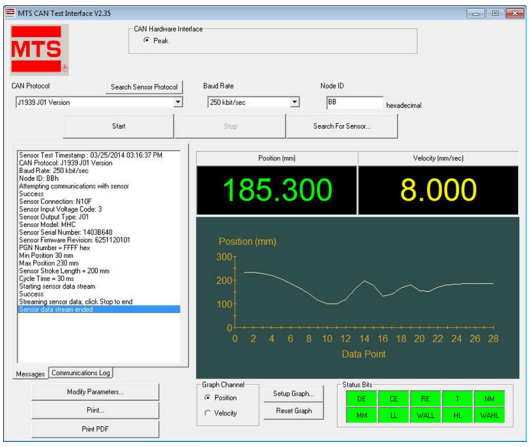
i	Node-ID
	CANopen Safety: hex 01…40 (default setting: 40)

Scope of delivery
Position sensor, O-ring, back-up ring, M12 connector system

Please order magnets separately!

Accessories (selection)	Part no.
OD17.4 Ring magnet	401 032
OD25.4 Ring magnet	400 533
OD33 Ring magnet	201 542-2

MH Testkit	Part no.
Software	625 129
Hardware Scope of delivery: • USB CAN-modul kit: - USB CAN modul - USB connector cable • Cable with MTS M12 connector and RS232 connector • Cable with core cable ends and RS232 connector • Carrying case • 12 V charger with adapter	254 267



MH Test-Software

MTS SENSORS

Temposonics®

Magnetostrictive Linear Position Sensors

Magnetostrictive Linear Sensors with SIL 2 Specification

Safety Manual

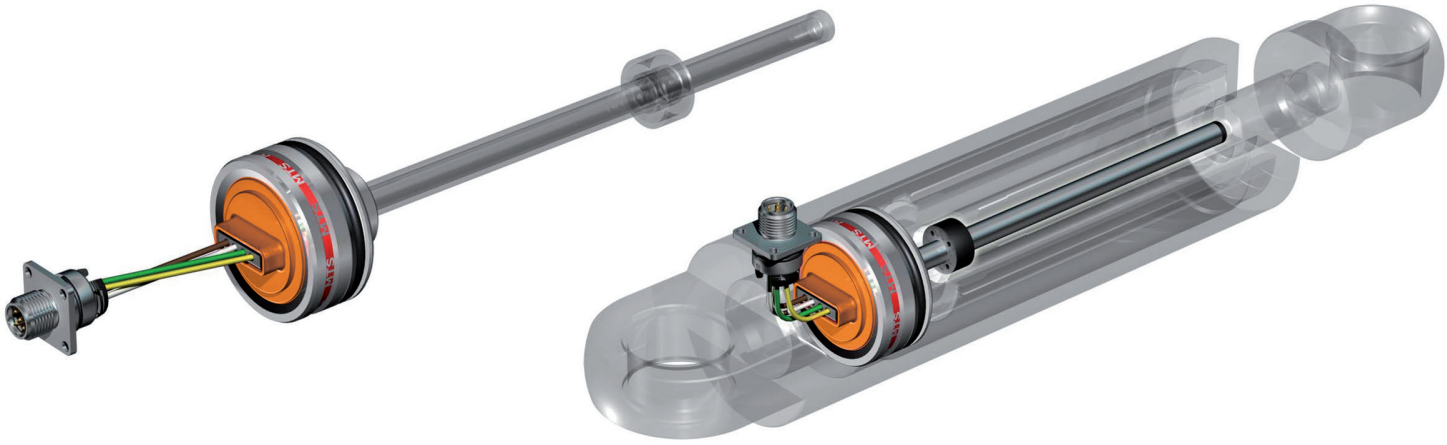


Table of contents

B. Safety manual

1. Introduction

This manual provides electrical installation and operation guidelines for the Temposonics® MH Safety models with analog and digital outputs in safety related applications to the user. The MH Safety models are SIL (Safety Integrity Level) certified according to IEC 61508, they have a performance Level (PL) in accordance with ISO 13849-1, and meet the EN 954-1 standard.

ISO 13849	Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design
IEC 61508	Functional safety of electrical/electronic/programmable electronic safety-related systems

At present the new machine safety standards – the ISO 13849-1 and the IEC 61508 for machines are about to deal with the usage of safety related functions on machines. The purpose of this revision of machine safety standards is obvious: the EN 954-1 has an immediate need to include software components in terms of safety, especially regarding the potential risk of breakdowns caused by software failures. To include these aspects, the standardization committee defines the ISO 13849-1, which is based on the IEC 61508, which comprises programmable products such as safety control units with microcontrollers. MTS Sensors will have a SIL (Safety Integrity Level) category according to the IEC 61508 and a Performance Level (PL) according to the ISO 13849-1 in addition to the existing categories of the EN 954-1.

For manufacturers this means that, independent of which standard their products must meet, MTS products can easily be taken into consideration. Besides the SIL and the PL can be compared easily. The EN 13849 will cover all technologies like mechanical, electrical, pneumatic and hydraulic parts, so this standard would be most important for machine manufacturers.

2. Device specific notes

2.1 Determination and intend to use

The MH Safety model is a magnetostrictive linear-position sensor, which is designed for in-cylinder assembly and dedicated to mobile hydraulic applications. The MH Safety model is certified according to IEC61508 for single input in low and high demand, SIL 2 Safety Instrumented Systems and to ISO 13849 performance level d for single channel architectures. Dual channel architectures are realized by 2 sensors used in 2 cylinder applications “left/right” or “front/rear”. The sensor measures the relative position of a travelling magnet relative to its null position. The output signal is transmitted to an external controller (ECU) and processed according to its requirements.

2.2 Mechanical and electrical installation

No special or additional sensor installation requirements exist beyond the standard installation practices documented in the actual MH-Series installation manual. Environmental operating specifications are applicable as published in the specifications section in the model MH Safety product specification.

2.3 Operating and OFFLINE PROOF tests

For complete information regarding performance, installation, operation, and specifications of MH Safety models, please refer to our product specification and available manuals. All installation recommendations as documented in the operating manual of MH sensors are applicable. Functional tests of safety relevant circuits will give a reliable statement about all components in use (sensor, controller and acting device). The user is responsible for applying an OFFLINE PROOF test (check interval is 1 year).

2.4 Maintenance and repair

The MH safety sensor is maintenance free. The MH safety models are not field repairable; device repairs must be performed by MTS Sensors. The electronic is encapsulated within a protective housing. All terminal faults[1] which are not followed by 10 consecutive startups without terminal faults must be reported. In the event of a failure please contact MTS Sensors.

[1] Please look at 2.8 for the description of terminal faults

2.5 Illegal and safety critical operation modes

All operating modes outside given specifications are not allowed. The specific limits are valid and they shall not be exceeded. All valid manuals and specifications need to be considered. Especially the programming manual and the operating manual need to be considered. No firmware changes are permitted nor authorized.against contamination from those environments.

2.6 Common cause failure

The following CCF issues from annex F of the ISO 13849-1 standard have been considered in the design of the MH Safety models and can be used in overall system CCF analysis:

1. Physical separation between signal paths.
2. The sensor is protected against over-voltage, up to max. pressure rating, miswiring (VDC – GND).
3. The FMEDA is available and the results of the FMEDA were taken into account for CCF analysis.
4. The designers of this sensor have been trained to understand the causes and consequences of common cause failure.
5. The sensor has been tested for:
   EMC (emission and immunity), Mechanical loads (e.g. vibration, temperature, pressure, fluid ingress) and environmental influences like fluid ingress and temperature. The sensor is compatible within these environments and is intended to be used in these conditions while it is sealed against contamination from those environments.

2.7 Measures against foreseeable misuse

The measures that have been taken against the foreseeable misuse of the MH Safety are:

1. Detailed instructions in the installation manual on methods to prevent damage to the sensor during installation.
2. Checking the function of the sensor after installation will mitigate the possibility of damage to the sensor after it has been damaged during the installation process

2.8 Fault failure action plan

If the sensor diagnostics system recognizes a fault condition it will switch the output into a state that allows the machine controller to act accordingly:

- MH Analog Safety:
  Failure signal output is LO < 0.5 VDC or HI > 4.5 VDC
  Failure signal output is LO < 4.0 mA or HI > 20 mA

- MH CANopen Safety:
  The failure status byte within the received SRDO message is incorrect. The machine controller interprets this as an error and reacts in a certain manner.

The sensors diagnosis system classifies diagnosed malfunctions into auto-recoverable faults and terminal faults. On auto-recoverable faults the sensor will revert to the regular position output as soon as the fault condition is no longer detected. No additional measures are necessary.

On terminal faults the sensor will maintain the failure signal output until the sensor undergoes a power up cycle. After exhibiting a terminal fault the following procedure must be exercised:

- Initiate 10 consecutive starts combined with an output signal observation that allows judgement whether the sensor became operational after each power up.

If the sensor response passes this test in all of the 10 cycles it can be put to use again. If it at least one time did not resume operation or if the test cannot be administered the sensor needs to be returned to MTS Sensors for further analysis.

2.9 Product identification

The model number of the sensor preceeds the the output type (Voltage / Current / CANopen Safety).

Example:

MH Analog Safety:	MHC-xxxxM-NyyH-3-V99
MH Analog Safety:	MHC-xxxxM-NyyG-3-A99
MH CANopen Safety:	MHC-xxxxM-NyyF-3-S01-2-40

3. MH Analog Safety

3.1 Functional description

The MH Analog safety position sensor is classified according to IEC 61508 type B and ISO 13849. Its design is based on isolated a three wire. The sensor performs self-diagnostics and enters a fail-safe state upon the detection of a failure, indicating the safety function cannot be performed. For the sensor output to be considered valid value must be in the electrical output range of 10 consecutive milliseconds. If the sensor output value ever lies outside of this range, and therefore in a fault condition, the fault condition shall be considered presently until the output is in the valid range of 10 consecutive milliseconds.

ONLINE PROOF test : The conditions that will trigger a fault are

- Missing or damaged position magnet
- Internal hardware failure
- Invalid checksum of parameter memory
- Magnet position is outside the valid measuring range
- Invalid checksum of program memory

3.2 Device parameter

Because of the applied operating mode and its influence on the safety of the complete system, safety critical parameters need to setup within the application. Please make sure that the software within the ECU is protected against non authorized access to the safety relevant parameters.

3.3 OFFLINE PROOF test: Method for checking the safety function in which the sensor must be removed from the cylinder

The OFFLINE PROOF test can be applied in order to check the safety function of the sensor. The safety function of the MH Safety sensor is internally checked but the diagnostic coverage of the sensor can be increased by checking the function of the sensor externally.
The recommended method for checking the function is:

1. Set the sensor to its zero position.
2. Stroke the sensor to its full-span position to confirm full range of motion and continuous output along full range.
3. Return the sensor to its zero position.
4. Perform a 3 point calibration verification of the sensor over the full-span of the sensor.
5. Move the magnet beyond the stroke range (NULL < 20 mm on F.S. > 70 mm) and make sure that the output voltage drops < 0.5 volts / < 4 mA.
6. Remove position magnet to see signal drop < 0.5 volts / < 4.0 mA.

All applied methods and results of the proof test have to be written in a test report. When the functional test is negative, the device and the system need to be shut down. The process has to be kept in a safe mode due to appropriate actions. Please pay attention to the valid technical literature:

Assembly and installation manual (document no. 551 289)
Operating manual (electrical operation and installation), (document no. 551 290)

Please use MH Analog Testkit MTS p/n 280618

3.4 Safety tolerance (analog)

Please review the MH Safety product specification for the operating accuracy of the sensor. The safety accuracy of the MH Analog Safety is 2.5 % full stroke. An example of the calculations necessary for determining the maximum safe position of the sensor magnet proceeds:

	Cylinder electrical stroke	Magnet (piston) speed	Actual magnet (piston) position
	400 mm	100 mm/s	200 mm

Safety Tolerance	400 mm × 2.5 %	100 mm/s × 10 ms	200 mm – 10 mm – 1.0 mm
@safe position	= 10 mm	= 1.0 mm	= 189 mm

3.5. Certification and failure rate data

The failure rates are considered to the FMEDA according to IEC 61805. Calculations based on the failure rates of electronic components according to SN29500. The FMEDA is available for review.
Two different failure outputs will be indicated:

a. Failure signal “HI” > 4.5 VDC or > 20 mA
b. Failure signal “LO” < 0.5 VDC or < 4.0 mA

Following assumptions are valid:

- The sensor operates in low and high demand mode
- Failure rates of external power supplies are not considered
- Please refer to FMEDA-report for mentioned SFF and PFH values
- The MH Analog Safety will enter a fail-safe state in the event of a failure
- The controller device needs to interpret the failure signal in the correct manner.
- The ambient conditions follow the specifications out of the valid data sheets.
- PFD_{avg} value is calculated assuming a 1-year OFFLINE PROOF test interval.

MTS MH Sensor with analog safety output
Model No. MHC-xxxxM-NyyH-3-V99 / MHC-xxxxM-NyyG-3-A99

MTS Sensors hereby confirms as manufacturer that all above mentioned requirements are fulfilled by safety related applications and design according to IEC/ EN 61508. Safety relevant parameters approved as follows:

	MH SIL 2 voltage output	MH SIL 2 current output
Classification according to IEC 61508	SIL 2 (Device type B)	SIL 2 (Device type B)
Classification according to ISO 13849	PLd-Cat2	PLd-Cat2
Safe output range	0.5 V ≤ Vout ≤ 4.5 V	4 mA ≤ Iout ≤ 20 mA
Failure state output	Vout < 0.5 V or Vout > 4.5 V	Iout < 4 mA or Iout > 20 mA
Diagnostic response time	≤ 10 ms	≤ 10 ms
Safety tolerance	±2.5 % (F.S.)	±2.5 % (F.S.)
Proof test coverage	45 %	48 %
PFD_{avg} [1]	6.88E-04	6.82E-04

1/ The PFD_{avg} was calculated for a mission time of 10 years. The Mean-Time-To-Restauration is assumed to be 24 hrs. Climate profile C3 from IEC 60654-1 was applied.

The Failure rates for 'Fail Safe Detected', 'Fail Safe Undetected', 'Fail Dangerous Detected' and 'Fail Dangerous Undetected' are:

		λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}
40 °C[2]	MH SIL2 voltage output	0.0 FIT	42.0 FIT	394.0 FIT	26.0 FIT
	MH SIL2 current output	0.0 FIT	43.0 FIT	430.0 FIT	27.0 FIT
60 °C[2]	MH SIL2 voltage output	0.0 FIT	105.0 FIT	985.0 FIT	65.0 FIT
	MH SIL2 current output	0.0 FIT	107.5 FIT	1075.0 FIT	67.5 FIT
80 °C[2]	MH SIL2 voltage output	0.0 FIT	210.0 FIT	1970.0 FIT	130.0 FIT
	MH SIL2 current output	0.0 FIT	215.0 FIT	2150.0 FIT	135.0 FIT

2/ The Temperatures in the table above are long term average temperatures used to calculate the corresponding failure rates. For details of this component level analysis see Siemens standard SN29500

4. MH CANopen Safety

4.1 Functional description

The linear position sensor MH CANopen Safety is specified according to IEC 61508 classified as type B. It contains self-diagnostics and is programmed to send safety relevant data objects (SRDO). The sensor is based on a single channel design. In an event of a detected failure, the max. diagnostic response time and the max. safety tolerance must be considered.

- CANopen communication profile DS301 V4.02
- Encoder profile DS406 V3.2
- LSS service DS305 V2.1.1
- Framework for safety relevant communication DS304 V1.01
- Time delayed shifted messages (SRDO) will be sent bit inverted to the controller
- Counter for each transmitted CAN message (positive and inverted datas) enables the unique assignment of each position value.
- Error status message

The CAN message consists of the following bytes:
4 bytes (position), 2 bytes (velocity), 1 byte (status) and 1 byte (counter).

ONLINE PROOF test The conditions that will trigger a fault are:

- Missing or damaged position magnet
  Emergency message
- Internal hardware failure
  Emergency message
- Invalid checksum of parameter memory
  SRDO message
- Magnet position is outside of the valid measuring range
  SRDO message
- Electronic temperature > 100 °C
  SRDO message

4.2 Device parameter

Because of the applied operating mode and its influence on the safety of the complete system, the sensor must be protected against non authorized access to the safety relevant parameters.

Please use MH Digital Testkit MTS p/n 280618 and MH Digital Testsoftware p/n 551288

4.3 OFFLINE PROOF test: Method for checking the safety function in which the sensor must be removed from the cylinder

The OFFLINE PROOF test can be applied in order to check the safety function of the sensor. Within the OFFLINE test recommended functional tests: Please run the tests with activated password protection to avoid a parameter change by mistake.
The recommended method for checking the safety function is:

1. Set the sensor to its zero position.
2. Stroke the sensor to its full-span position to confirm full range of motion and continuous output along full range.
3. Return the sensor to its zero position.
4. Perform a 3 point calibration verification of the sensor over the full-span of the sensor.
5. Move the magnet beyond the stroke range (NULL < 20 mm on F.S. > 70 mm) and make sure that the error flags in the CAN message will appear.
6. Remove the position magnet and check error flags transmitted within CAN messages.
   The time monitoring of the controller software must give an error message as well.
   This is related to the time shift of complemented and inverted CAN messages.
7. Change safety relevant parameter setting by transmission wrong checksum to the sensor.
   To check if the corresponding failure flag is set within the respond CAN message of the sensor.

All applied methods and results of the proof test have to be written in a test report. When the functional test is negative, the device and the system need to be shut down. The process has to be kept in a safe mode due to appropriate actions. Please pay attention to the valid technical literature:
Assembly and installation manual (document no. 551 289)
Programming manual (document no. 901 492)
Operating manual (electrical operation and installation) (document no. 551 291)

Please use MH Digital Testkit MTS p/n 280618 and MH Digital Testsoftware p/n 551288

4.4 Safety tolerance (digital)

Please review the MH Safety product specification for the operating accuracy of the sensor. The safety accuracy of the MH Analog Safety is 2.5 % (F.S.). An example of the calculations necessary for determining the maximum safe position of the sensor magnet proceeds:

	Cylinder electrical stroke	Magnet (piston) speed	Actual magnet (piston) position
	400 mm	100 mm/s	200 mm

Safety Tolerance	**400 mm × 2.5 %**	**a. 100 mm/s × 5 ms** **b. 100 mm/s × 25 ms**	**a. 200 mm – 10 mm – 0.5 mm** **b. 200 mm – 10 mm – 2.5 mm**
@safe position	10 mm	a. 0.5 mm b. 2.5 mm	a. 189.5 mm b. 187.5 mm

a. in the event of emergency message
b. in the event of SRDO message

4.5 Safety relevant characteristics MH CANopen Safety

The failure rates are considered to the FMEDA according to IEC 61508. Calculations based on the failure rates of electronic components according to SN29500. Following assumptions are valid:

- In an event of an failure the relevant SRDO message will be send to the ECM
- The sensor operates in low and high demand mode
- Failure rates of external power supplies are not considered
- Please refer to FMEDA report for mentioned SFF and PFH_{avg} values
- The communication via CANopen Safety protocol will be performed according to CiA 304.
  In an event of a failure the controller software must verify the received CAN messages and set the system into a safe state.
- The controller device needs to interpret this signal in a correct matter.
- The ambient conditions follow the specifications out of the valid data sheets.
- The sensor will be protected against non authorized settings (password protection)
- In addition to check the error flags, the software must implement a time out monitoring of received CAN messages, too.
  MTS MH Sensor with CANopen safety protocol (S01) Model No. MHC-xxxxM-NyyF-3-S01-2-40

MTS Sensors hereby confirms as manufacturer that all above mentioned requirements fulfilled by safety related applications and design according to IEC/ EN 61508. The data protocol follows the guidelines of CiA standard 304. Safety relevant parameters approved as follows:

	MH SIL2 CANopen SAFETY			
	IEC 61508		ISO 13849	
Safety level	SIL 2		PLd-Cat2	
Diagnostic coverage	SFF 98 %		DC 97 %	
Device type	B		n.a.	
Output	CANopen Safety protocol CiA DS304- Device profile DS-406 V3.1			
$MTTF_d$ (years) 60 °C	10.75×10^3			
$MTTF_d$ (years) 80 °C	4.53×10^3			
PFH-60 °C (1/h)	0.108×10^{-7}			
PFH-80 °C (1/h)	0.255×10^{-7}			
Diagnostic response time	5 ms (Emergency messages) 25 ms (SRDO messages)			
Safety tolerance	2.5 % F.S.			
Fail signal	SRDO messages: Safety relevant data objects			
FIT Output	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}
FIT 60 °C	0	269	365	11
FIT 80 °C	0	577	821	25

5. Terms and abbreviations

C	
Cat.	Safety category according to EN 954-1
E	
E/E/PE	Electrical/Electronic/Programmable Electronic
F	
FIT	Failure in time (1×10-9 failures per hour)
FMEDA	Failure Mode, Effects and Diagnostic Analysis
FSM	Functional Safety Management
H	
HFT	Hardware Fault Tolerance, HFT = x where x is the number of faults that the design can tolerate without losing its safety function.
High demand mode	High demand or continuos mode of operation (PFH) Probability of a dangerous failure per hour
L	
Low demand mode	Low demand mode of operation (PFD_{avg}) (Average probability of failure to perform its design function on demand)
P	
PFD_{AVG}	Probability of Failure on Demand (Average)
PFH	Probability of Failure per Hour
P_L	Performance Level according to ISO 13849
S	
SFF	Safe failure fraction summarizes the fraction of failures, which lead to a safe state and the fraction of failures which will be detected by diagnostic measures and lead to a defined safety action.
SIF	Safety Instrumented Function
SIL	Safety Integrity Level according to IEC 61508
SIS	Safety Instrumented System – Implementation of one or more Safety Instrumented Functions. A SIS is composed of any combination of device(s), logic solver(s), and final element(s).
SLC	Safety Lifecycle
T	
Type A component	“Non-complex” component (using discrete elements); for details see 7.4.3.1.3 of IEC 61508-2
Type B component	“Complex” component (using micro controllers or programmable logic); for details see 7.4.3.1.3 of IEC 61508-2
V	
V&V	Verification and Validation
Verification	The demonstration for each phase of the life-cycle that the (output) deliverables of the phase meet the objectives and requirements specified by the inputs to the phase. The verification is usually executed by analysis and / or testing.
Validation	The demonstration that the safety-related system(s) or the combination of safety-related system(s) and external risk reduction facilities meet, in all respects, the Safety Integrity Requirements Specification. The validation is usually executed by testing.

MTS®
SENSORS

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