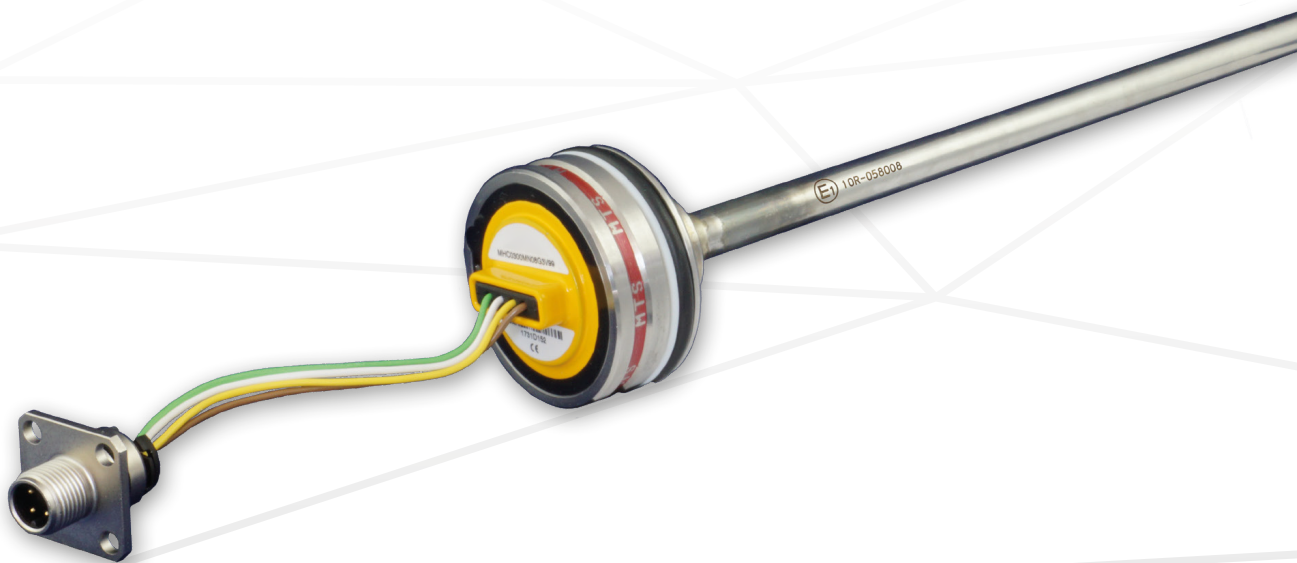# Temposonics
AN AMPHENOL COMPANY

## Data Sheet / Safety Manual

# MH Safety Analog / CANopen
## Magnetostrictive Linear Position Sensors

▌ Stroke range up to 2500 mm

▌ Linearity < 0.04 % F.S. / Resolution typ. 0.1 mm

▌ High reliability due to EMC, shock & vibration resistance

▌ E1 type approval according to UNECE Regulation 10 available

# MEASURING TECHNOLOGY

The absolute, linear position sensors provided by MTS Sensors rely on the company's proprietary Temposonics® magnetostrictive technology, which can determine position with a high level of precision and robustness. Each Temposonics® position sensor consists of a ferromagnetic waveguide, a position magnet, a strain pulse converter and supporting electronics. The magnet, connected to the object in motion in the application, generates a magnetic field at its location on the waveguide. A short current pulse is applied to the waveguide. This creates a momentary radial magnetic field and torsional strain on the waveguide. The momentary interaction of the magnetic fields releases a torsional strain pulse that propagates the length of the waveguide. When the ultrasonic wave reaches the end of the waveguide it is converted into an electrical signal. Since the speed of the ultrasonic wave in the waveguide is precisely known, the time required to receive the return signal can be converted into a linear position measurement with both high accuracy and repeatability.
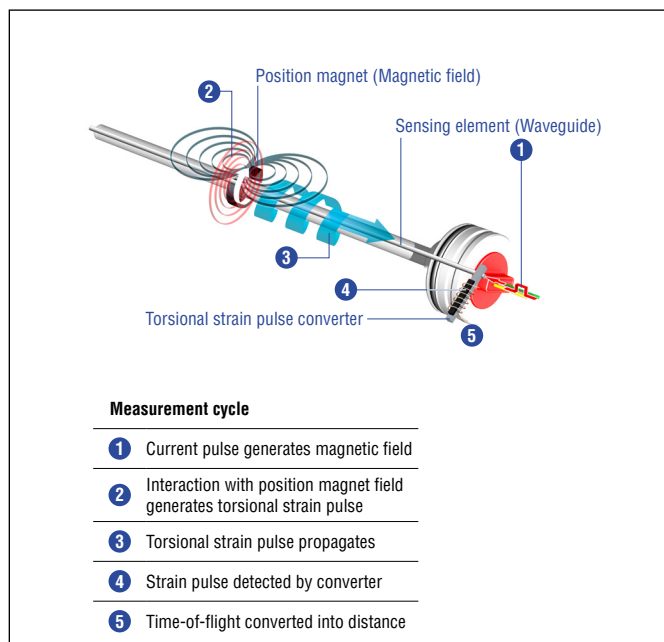


| | Measurement cycle |
|---|---|
| 1 | Current pulse generates magnetic field |
| 2 | Interaction with position magnet field generates torsional strain pulse |
| 3 | Torsional strain pulse propagates |
| 4 | Strain pulse detected by converter |
| 5 | Time-of-flight converted into distance |

*Fig. 1: Time-of-flight based magnetostrictive position sensing principle*

# MH SAFETY SENSOR

The Temposonics® MH Safety sensors are specifically designed for direct stroke measurement in hydraulic cylinders. The MH-Series sensors can be fully sealed and embedded in a cylinder which provides excellent protection against the environment and EMI and ensures a long operating life. The MH-Series sensors can be installed from the head side or the rod side of the cylinder depending on the cylinder design. A MTS M12 connector system ensures protection to IP69K. 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. E1 option is available for approved applications as per UN/ECE Reg 10 and Straßenverkehrs-Zulassungs-Ordnung (StVZO).



*Fig. 2: Typical application*

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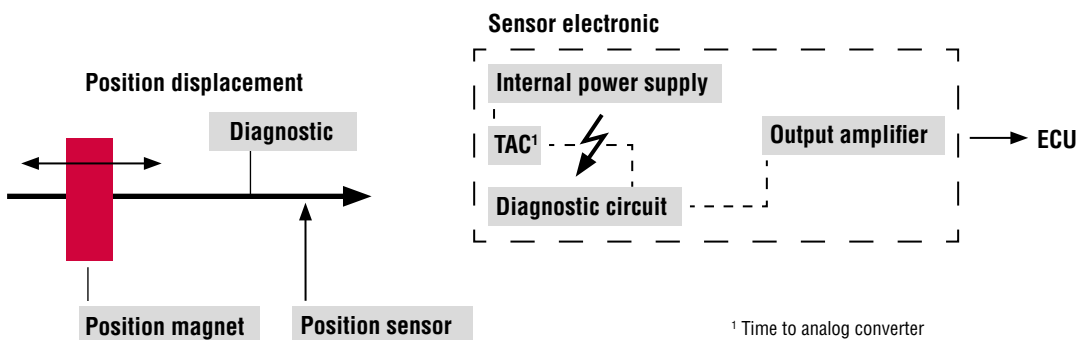
**The design is a single architecture (Cat2) PLd according to ISO 13849**

The user has two alternatives at his disposal:
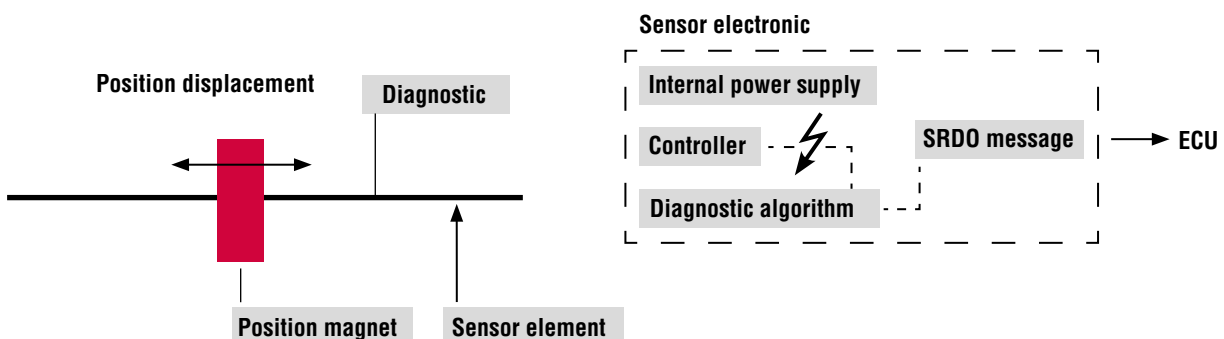
**1. MH Analog Safety**
Position sensor with an isolated three-wire analog output. Classified as type B according to IEC 61508. The sensor contains a self-diagnostic circuit.
In an event of a detected failure, the sensor sends a defined output of 0 VDC for output V99 or 0 mA for output A99.

**Position displacement**

**Diagnostic**

**Position magnet**    **Position sensor**

**Sensor electronic**

**Internal power supply**

**TAC[1]**    **Output amplifier** → **ECU**

**Diagnostic circuit**

[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.

**Position displacement**

**Diagnostic**

**Position magnet**    **Sensor element**

**Sensor electronic**

**Internal power supply**

**Controller**    **SRDO message** → **ECU**

**Diagnostic algorithm**

# TECHNICAL DATA – ANALOG

| 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 |
| Measured value | Position | | |

| Measurement parameters | | | |
|---|---|---|---|
| Resolution | Typ. 0.1 mm | | |
| Power uptime | Typ. 250 ms | | |
| Linearity | 0050…0250 mm | 0255…2000 mm | 2005…2500 mm |
| | ≤ ±0.1 mm | ±0.04 % (F.S.) | ≤ ±0.8 mm |
| Hysteresis | ±0.1 mm | | |
| Internal sample rate | 1 ms | | |
| Setpoint tolerance | ≤ 1 mm | | |

| Operating conditions | |
|---|---|
| Operating temperature electronics | –40…+100 °C |
| Storage temperature | –20…+65 °C |
| Fluid temperature | –30…+85 °C |
| Humidity | EN 60068-2-30, 90 % rel. humidity, no condensation |
| Ingress protection – M12 connector | EN 60529 – IP69K (correctly fitted) |
| Ingress protection – Sensor housing | EN 60529 – IP67 |
| 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.) Ø 10 mm pressure pipe (10…2000 Hz) – resonance frequencies excluded |
| EMC test | UNECE Regulation 10 Rev 5: Electromagnetic Compatibility<br>ISO 14982 Agricultural and forest machines<br>EN 13309  Construction machines<br>　　　　　　Immunity:　　　ISO 11452-2 (200 V/m Antenna), ISO 11452-4 (200 mA BCI)<br>　　　　　　Emissions:　　　CISPR 25<br>　　　　　　Transiente Impulses: ISO 7637-1/2<br>　　　　　　E.S.D.:　　　　　ISO/TR 10605<br>The sensor meets the requirements of the EC directives and is marked with CE |
| Pressure (according to DIN EN ISO 19879)* | Ø 10 mm pressure pipe |
| PN (nominal operating) | 350 bar |
| PMAX (max. overload) | 450 bar |
| PSTATIC (proof pressure) | 625 bar |

| Design / Material | |
|---|---|
| Sensor electronics housing | 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 |
| Sensor rod | Stainless steel 1.4306 (AISI 304L) |
| 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 |
| Stroke length | 50…2500 mm |

| Mechanical mounting | |
|---|---|
| Mounting position | Any |
| Mounting instruction | Please consult the technical drawings |

| Electrical installation | | |
|---|---|---|
| Connector | M12 male connector | |
| Supply voltage | **12 VDC (8…32 VDC)** | **24 VDC (16…32 VDC)** |
| Current consumption | Typ. ≤ 100 mA | Typ. ≤ 50 mA |
| Load (output VDC) | $R_L$ > 10 kΩ | $R_L$ > 10 kΩ |
| Load current (output VDC) | Typ. 0.5 mA | Typ. 0.5 mA |
| Load (output mA) | $R_L$ < 250 Ω | $R_L$ < 500 Ω |
| Inrush current | Max. 2.5 A/2 ms | Max. 4.5 A / 2 ms |
| Supply voltage ripple | < 1 % PP | |
| Power drain | < 1 W | |
| Over voltage protection (GND - VDC) | Up to +36 VDC | |
| Polarity protection (GND - VDC) | Up to –36 VDC | |
| Insulation Resistance | R ≥ 10 MΩ @ 60 sec | |
| Electric strength | 500 VDC (DC GND to chassis GND) | |

**\*/ According to calculations under use of the FKM guideline**

| Cycles | Ø 10 mm sensor rod |
|---|---|
| Dynamic pressure: < 2 × 10$^6$ pressure cycles | 350 bar |
| Static pressure: < 2 × 10$^4$ pressure cycles | 450 bar |
| Proof pressure: Maximum 5 minutes testing time for cylinder pressure test | 625 bar |

## TECHNICAL DATA – CANopen SAFETY

| Output | | | |
|---|---|---|---|
| Signal characteristic | CANopen Safety according to EN 50325-5, device profile DS-406 V3.2 | | |
| Measured value | Position & velocity | | |
| **Measurement parameters** | | | |
| Resolution (position) | 0.1 mm | | |
| Resolution (velocity) | 1 mm/s | | |
| Boot up time | Typ. 400 ms | | |
| Linearity | 0050…0250 mm | 0255…2000 mm | 2005…2500 mm |
| | ≤ ±0.1 mm | ±0.04 % (F.S.) | ≤ ±0.8 mm |
| Hysteresis | ±0.1 mm | | |
| Internal sample rate | 1 ms | | |
| Setpoint tolerance | ±0.2 mm | | |
| Refresh-Time default | 25 ms | | |
| **Operating conditions** | | | |
| Operating temperature electronics | –40…+100 °C | | |
| Storage temperature | –20…+65 °C | | |
| Fluid temperature | –30…+85 °C | | |
| Humidity | EN 60068-2-30, 90 % rel. humidity, no condensation | | |
| Ingress protection – M12 connector | EN 60529 – IP69K (correctly fitted) | | |
| Ingress protection – Sensor housing | EN 60529 – IP67 | | |
| 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.) Ø 10 mm pressure pipe (10…2000 Hz) – resonance frequencies excluded | | |
| EMC test | UNECE Regulation 10 Rev 5: Electromagnetic Compatibility<br>ISO 14982 Agricultural and forest machines<br>EN 13309  Construction machines<br>Immunity:  ISO 11452-2 (200 V/m Antenna), ISO 11452-4 (200 mA BCI)<br>Emissions:  CISPR 25<br>Transiente Impulses: ISO 7637-1/2<br>E.S.D.:  ISO/TR 10605<br>The sensor meets the requirements of the EC directives and is marked with CE | | |
| Pressure (according to DIN EN ISO 19879)* | Ø 10 mm pressure pipe | | |
| PN (nominal operating) | 350 bar | | |
| $P_{MAX}$ (max. overload) | 450 bar | | |
| $P_{STATIC}$ (proof pressure) | 625 bar | | |
| **Design / Material** | | | |
| Sensor electronics housing | 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 | | |
| Sensor rod | Stainless steel 1.4306 (AISI 304L) | | |
| 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 | | |
| Stroke length | 50…2500 mm | | |
| **Mechanical mounting** | | | |
| Mounting position | Any | | |
| Mounting instruction | Please consult the technical drawings | | |
| **Electrical installation** | | | |
| Connector | M12 male connector | | |
| 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 % $_{PP}$ | | |
| Power drain | < 1.5 W | | |
| Over voltage protection (GND - VDC) | Up to +36 VDC | | |
| Polarity protection (GND - VDC) | Up to –36 VDC | | |
| Insulation Resistance | R ≥ 10 MΩ | | |
| Electric strength | 500VDC (DC ground to machine ground) @ 60 sec | | |

**\*/ According to calculations under use of the FKM guideline**

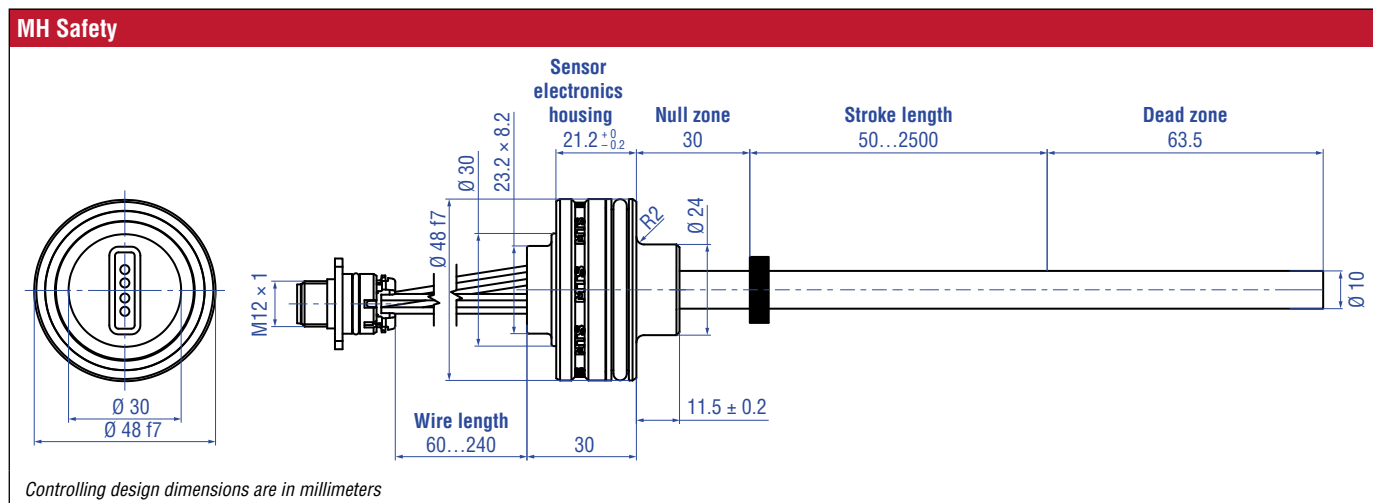| Cycles | Ø 10 mm sensor rod |
|---|---|
| Dynamic pressure: < $2 \times 10^6$ pressure cycles | 350 bar |
| Static pressure: < $2 \times 10^4$ pressure cycles | 450 bar |
| Proof pressure: Maximum 5 minutes testing time for cylinder pressure test | 625 bar |

# TECHNICAL DRAWING

**MH Safety**



Sensor electronics housing
Null zone
Stroke length
Dead zone

$21.2 ^{+0}_{-0.2}$
30
50…2500
63.5

$23.2 \times 8.2$
Ø 30
Ø 48 f7
M12 × 1
Ø 24
R2

Ø 30
Ø 48 f7

Wire length
60…240
30
$11.5 \pm 0.2$

Ø 10

*Controlling design dimensions are in millimeters*

*Fig. 3: Temposonics® MH Safety with ring magnet*

# CONNECTOR WIRING

| Analog Safety | | |
|---|---|---|
| **M12 connector** | **N…G** | **N…H** |
| **Pin** | **Function** | |
| 1 | VDC | VDC |
| 2 | do not connect | SIG |
| 3 | GND | GND |
| 4 | SIG | do not connect |

View on connector

*Fig. 4: Connector wiring of M12 connector*

| CANopen Safety | |
|---|---|
| **M12 connector** | **N…F** |
| **Pin** | **Function** |
| 1 | do not connect |
| 2 | VDC |
| 3 | GND |
| 4 | CAN_H |
| 5 | CAN_L |

View on connector

*Fig. 5: Cable wiring of cable outlet*

**Connection schematics**



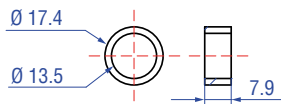+12/24 VDC
ECU
+ BAT −
GEN
M
Chassis GND
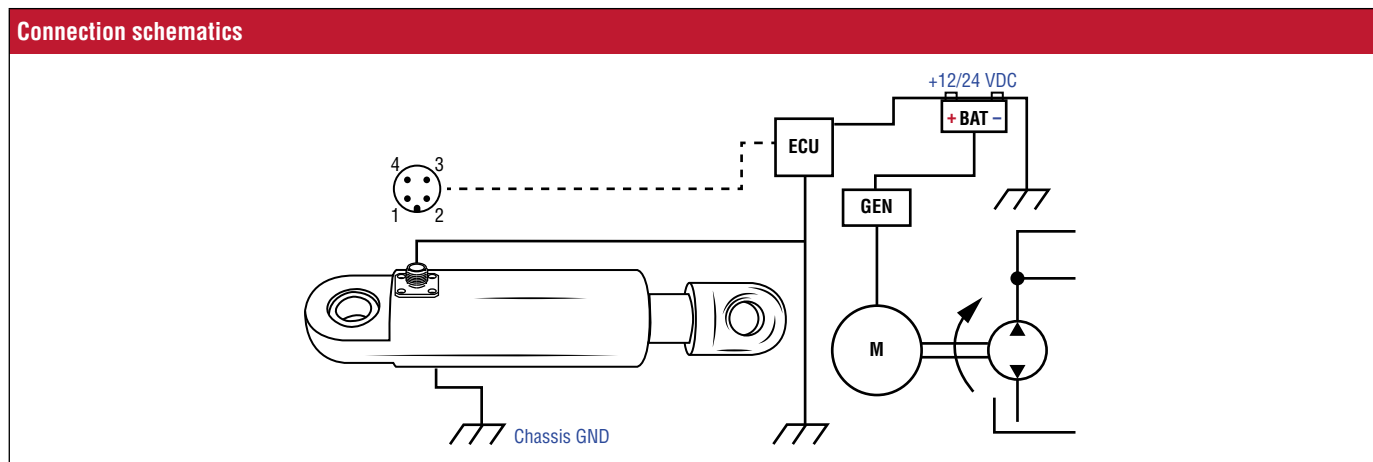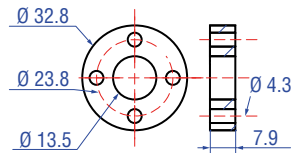
*Fig. 6: Connection schematics*

# FREQUENTLY ORDERED ACCESSORIES
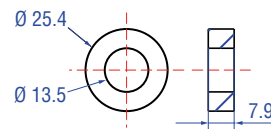
## Position magnets



**Ring magnet OD17.4**
**Part no. 401 032**

Material: PA neobond
Weight: Approx. 5 g
Surface pressure: Max. 20 N/mm²
Operating temperature:
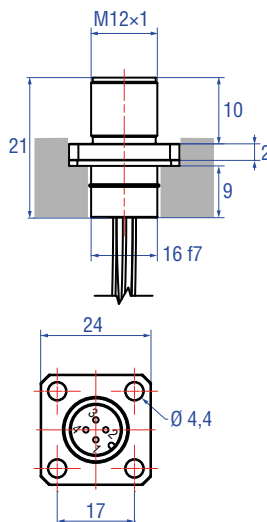–40…+105 °C (–40…+221 °F)

**Ring magnet OD33**
**Part no. 201 542-2**

Material: PA ferrite GF20
Weight: Approx. 14 g
Surface pressure: Max. 40 N/mm²
Fastening torque for M4 screws: 1 Nm
Operating temperature:
–40…+105 °C (–40…+221 °F)

**Ring magnet OD25.4**
**Part no. 400 533**

Material: PA ferrite
Weight: Approx. 10 g
Surface pressure: Max. 40 N/mm²
Operating temperature:
–40…+105 °C (–40…+221 °F)

## M12 flange                Test kit



**M12 flange**
**Part no. 253 769**

Material flange: Brass nickel-plated
Material O-ring: 13×1.6 NBR70

**MH analog test kit**
**Part no. 280 618**

**Kit includes:**
- 12 VDC battery charger with adapter (EU & UK)
- Cable with M12 connector
- Cable with pigtailed wires
- Carrying case

**MH digital test kit**
**Part no. 254 267**

**Kit includes:**
- MH-Series CANopen / J1939 Test Software installation CD
- USB CAN-modul kit:
  - USB CAN modul
  - USB CAN modul utility CD (with drives and description)
  - 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
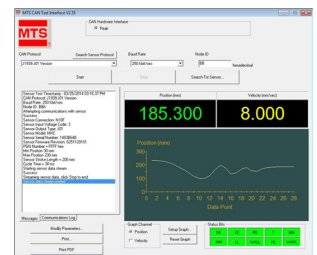
**MH digital test kit software**
**Part no. 625 129**

*Controlling design dimensions are in millimeters*

# MECHANICAL INSTALLATION

### Installation in a hydraulic cylinder

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.

In both installation methods, the sensor seals the cylinder by using an O-Ring and backup ring which is installed on the sensor housing.

Ensure that after all tolerances are applied, that the magnet stays within the specified measuring range.

> **NOTICE**
>
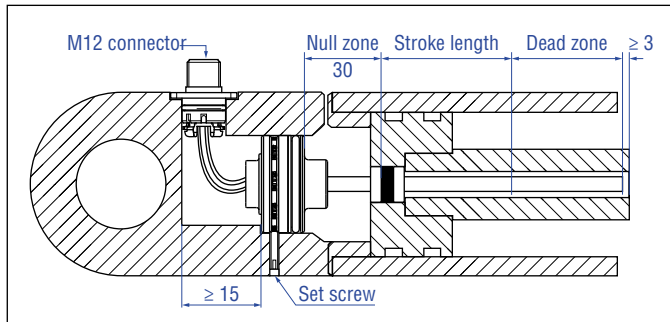> For analog sensors, the signal output will drop down to 0 VDC / 0 mA, when the position magnet travels beyond the set point.



Fig. 7: Example of In-Cylinder assembly

> **NOTICE**
>
> Use for cable outlet a cable gland with IP69K protection class.

**Space requirements**

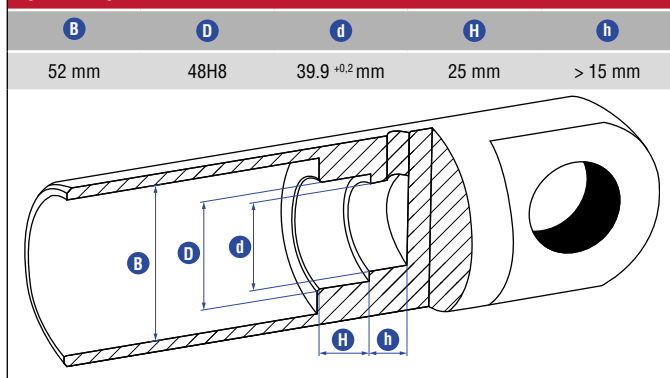| B | D | d | H | h |
|---|---|---|---|---|
| 52 mm | 48H8 | 39.9 +0,2 mm | 25 mm | > 15 mm |



Fig. 8: Space requirements for cylinder

- The position magnet shall not touch the pressure pipe.
- Do not exceed the operating pressure.
- Note the piston rod drilling:
  - Ø 10 mm rod: ≥ Ø 13 mm

> **NOTICE**
>
> The bore depth in piston:
> Null zone + Stroke length + Dead zone + > 3 mm

**Set screw**

e.g. retaining with set screw ISO 4026 M5×10 (DIN 914).
Fastening torque: 0.44 Nm to 0.50 Nm
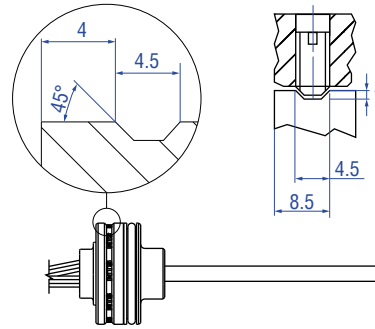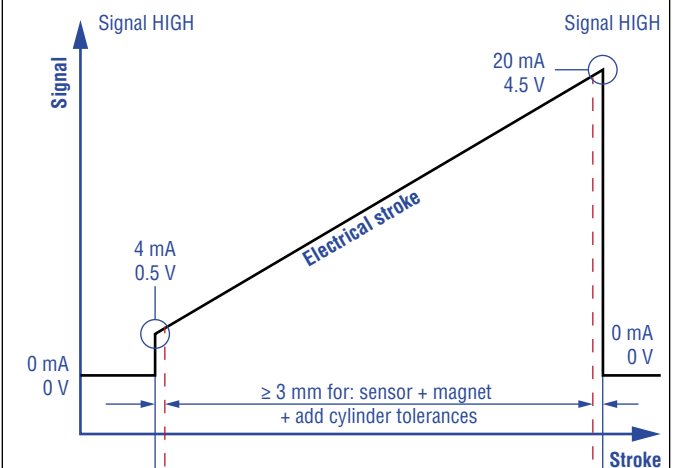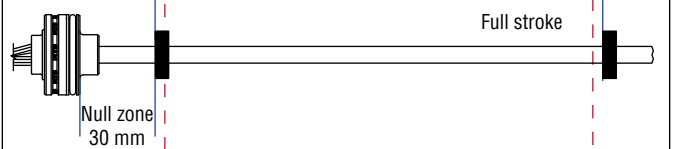**Notice:** Ensure threads are free of oil, grease and debris



Fig. 9: Set screw

**Electrical installation for analog output**
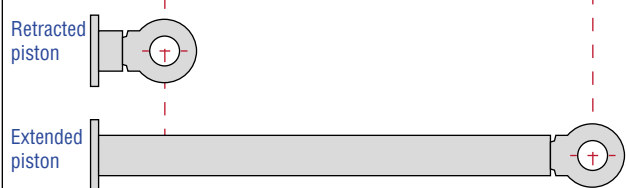


Fig. 10: Electrical installation

# MECHANICAL INSTALLATION – POSITION MAGNET

**Magnet installation for In-Cylinder applications**



| | Position magnet (Part no.) | | |
|---|---|---|---|
| | **401 032** | **400 533** | **201 542-2** |
| **1** | Circlip | | |
| **2** | Non-magnetic spacer | | |
| **3** | Position magnet | | |
| **4** | Non-magnetic spacer (≥ 5 mm) | | |
| **A** | 17.4 mm | 25.4 mm | 32.8 mm |
| **B** | ≥ 18 mm | ≥ 18 mm | ≥ 18 mm |
| **C** | Rod Ø 10 mm ➜ | Piston rod drilling ≥ Ø 13 mm | |

*Fig. 11: Dimensions for magnet mounting*

Controlling design dimensions are in millimeters
*Please refer to the installation manual for complete installation instructions!*

# ORDER CODE – MH SAFETY ANALOG (CURRENT)

| 1 | 2 | | 3 | | 4 | 5 | 6 | 7 | 8 | | 9 | 10 | 11 | | 12 | | 13 | | 14 | 15 | 16 | | 17 | 18 | 19 | | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|----|----|---|----|---|----|---|----|----|----|---|----|----|----|---|----|----|
| M | H | | C | | | | | | M | | N | | | | | | 3 | | A | 9 | 9 | | | | | | | |
| **a** | | | **b** | | **c** | | | | | | **d** | | | | **e** | | **f** | | **g** | | | | **h** | | | | **i** | |

optional

| **a** | **Sensor model** |
|---|---|
| **M H** | Flange housing Ø 48 mm |

| **b** | **Form factor** |
|---|---|
| **C** | Rod: Ø 10 mm + flat end plug |

| **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 (8…32 VDC) |

| **g** | **Output** |
|---|---|
| **A 9 9** | 4…20 mA |

| **h** | **Load resistance** |
|---|---|
| | 10…500 Ω (default value: 250 Ω) |

| **i** | **Approvals (optional)** |
|---|---|
| **E 1** | E1 type approved according to UNECE Regelung 10 |

---

***NOTICE***

Standard calibration with 250 Ω.
Contact MTS Sensors if you need another load value.

---

# DELIVERY

- Position sensor
- O-ring
- backup-ring
- M12 connector system (optional)

Accessories have to be ordered separately

**Manuals, Software & 3D models available at:**
**www.mtssensors.com**

# ORDER CODE – MH SAFETY ANALOG (VOLTAGE)

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|
| M | H | C | | | | | M | N | | | | 3 | V | 9 | 9 | | |
| a | | b | | c | | | | d | | | e | f | g | | | i | |

optional

| a | **Sensor model** |
|---|---|
| **M** **H** | Flange housing Ø 48 mm |

| b | **Form factor** |
|---|---|
| **C** | Rod: Ø 10 mm + flat end plug |

| 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 (8…32 VDC) |

| g | **Output** |
|---|---|
| **V** **9** **9** | 0.5…4.5 VDC |

| h | **Approvals (optional)** |
|---|---|
| **E** **1** | E1 type approved according to UNECE Regelung 10 |

# DELIVERY

• Position sensor
• O-ring
• backup-ring
• M12 connector system (optional)

Accessories have to be ordered separately

**Manuals, Software & 3D models available at: www.mtssensors.com**

# ORDER CODE – MH SAFETY CANopen SAFETY

| 1 | 2 | | 3 | | 4 | 5 | 6 | 7 | 8 | | 9 | 10 | 11 | | 12 | | 13 | | 14 | 15 | 16 | | 17 | | 18 | 19 | | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|----|----|---|----|---|----|---|----|----|----|---|----|---|----|----|---|----|----|
| M | H | | C | | | | | | M | | N | | | | F | | 3 | | S | 0 | 1 | | | | | | | | |
| **a** | | | **b** | | **c** | | | | | | **d** | | | | **e** | | **f** | | **g** | | | | **h** | | **i** | | | **j** | |

optional

| **a** | **Sensor model** | |
|---|---|---|
| **M** | **H** | Flange housing Ø 48 mm |

| **b** | **Form factor** |
|---|---|
| **C** | Rod: Ø 10 mm + flat end plug |

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

| **d** | **Electrical wiring** |
|---|---|
| **N** | 60…240 mm 4 single wires (in 20 mm steps)<br>(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 (8…32 VDC) |

| **g** | **Output** | |
|---|---|---|
| **S** | **0** | **1** | CANopen Safety (default refresh time: 25 ms) |

| **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** |
|---|---|
| | Hex 01…40 (default setting: 40) |

| **j** | **Approvals** | |
|---|---|---|
| **E** | **1** | E1 type approved according to UNECE Regelung 10 |

# DELIVERY

- Position sensor
- O-ring
- backup-ring
- M12 connector system (optional)

Accessories have to be ordered separately

**Manuals, Software & 3D models available at:**
**www.mtssensors.com**

# Temposonics®

Magnetostrictive Linear Position Sensors

**MH Safety Analog / CANopen**
Safety Manual

**Temposonics® MH Safety Analog / CANopen**
Data Sheet

## Table of contents

# 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). If the application requires an offline proof test, the user is responsible for applying the test (recommended 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.

## 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.

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

## 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:**
  Analog (Voltage):
  Failure signal output is LO < 0.5 VDC or HI > 4.5 VDC
  Analog (Current):
  Failure signal output is LO < 4.0 mA or HI > 20 mA
• **MH CANopen Safety:**
  The failure status byte within the received SRDO message reports an error. 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 (Voltage) Safety: MHC-xxxxM-NyyH-3-V99
MH Analog (Voltage) Safety: MHC-xxxxM-NyyH-3-V99-E1
MH Analog (Current) Safety: MHC-xxxxM-NyyG-3-A99-250
MH Analog (Current) Safety: MHC-xxxxM-NyyG-3-A99-250-E1
MH CANopen Safety: MHC-xxxxM-NyyF-3-S01-2-40
MH CANopen Safety: MHC-xxxxM-NyyF-3-S01-2-40-E1

## 3.  MH Safety Analog

### 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

The OFFLINE PROOF test is not a hard requirement due to the
sufficient and good rating of all components in regards to reliability.
It can be applied as an additional measure to increase reliability. If
regular proofing tests are required for a system and its safety-related
components, then use following method to check the safety function
of the sensor.

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
   fullspan 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 drops < 0.5 volts /
   < 4.0 mA.

Suggested OFFLINE-PROOF test interval is one year.

All applied methods and results of the proof test must 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.

Offline proof tests can be avoided if the application will recognize
a sensor position error greater than 25% of the sensor's full stroke
and if the sensor is not powered continuously. In that case 1,000,000
measurement cycles combined with 10 power-on cycles achieve a
diagnostic coverage similar or greater to that of 1 offline proof test.

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*

| NOTICE |
| --- |
| Use MH Analog Testkit (part no. 280 618) |

**Temposonics® MH Safety Analog / CANopen**
Data Sheet

### 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/sec | 200 mm |

| Safety Tolerance | 400 mm × 2.5 % | 100 mm/sec × 10 msec | 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.

**MTS MH Sensor with analog safety output:**
**Analog - Voltage output: MHC-xxxxM-NyyH-3-V99**
**Analog - Voltage output: MHC-xxxxM-NyyH-3-V99-E1**
**Analog - Current output: MHC-xxxxM-NyyG-3-A99-250**
**Analog - Current output: MHC-xxxxM-NyyG-3-A99-250-E1**

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 Safety Analog (Voltage) output | MH Safety Analog (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 % |
| $PFD_{AVG}$ [2] | 6.88E-04 | 6.82E-04 |
| Life cycle | 25 years | 25 years |

**2/** 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:

| Temperature | Sensor type | $\lambda_{SD}$ | $\lambda_{SU}$ | $\lambda_{DD}$ | $\lambda_{DU}$ |
|---|---|---|---|---|---|
| **40 °C** [3] | MH SIL 2 voltage output | 0.0 FIT | 42.0 FIT | 394.0 FIT | 26.0 FIT |
| | MH SIL 2 current output | 0.0 FIT | 43.0 FIT | 430.0 FIT | 27.0 FIT |
| **60 °C** [3] | MH SIL 2 voltage output | 0.0 FIT | 105.0 FIT | 985.0 FIT | 65.0 FIT |
| | MH SIL 2 current output | 0.0 FIT | 107.5 FIT | 1075.0 FIT | 67.5 FIT |
| **80 °C** [3] | MH SIL 2 voltage output | 0.0 FIT | 210.0 FIT | 1970.0 FIT | 130.0 FIT |
| | MH SIL 2 current output | 0.0 FIT | 215.0 FIT | 2150.0 FIT | 135.0 FIT |

3/ 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 Safety CANopen

### 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.

| *NOTICE* |
|---|
| Use MH Digital Testkit (part no. 254267) and MH Digital Testsoftware (part no. 551288) |

## 4.3 OFFLINE PROOF test: Method for checking the safety function

The OFFLINE PROOF test is not a hard requirement due to the sufficient and good rating of all components in regards to reliability. It can be applied as an additional measure to increase reliability. If regular proofing tests are required for a system and its safety-related components, then use following method to check the safety function of the sensor.

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.
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.

*Suggested OFFLINE-PROOF test interval is one year.*

*All applied methods and results of the proof test must 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 part no. 551 289*
***Protocol manual:***
*Document part no. 901 492*
***Operating manual (electrical operation and installation):***
*Document part no. 551 291*

| **NOTICE** |
| --- |
| Use MH Digital Testkit (part no. 254267) and MH Digital Testsoftware (part no. 551288) |

## 4.4 Safety tolerance (CANopen Safety)

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/sec | 200 mm |
| Safety Tolerance | 400 mm × 2.5 % | a. 100 mm/sec × 5 msec<br>b. 100 mm/sec × 25 msec | a. 200 mm – 10 mm – 0.5 mm<br>b. 200 mm – 10 mm – 2.5 mm |
| @safe position | 10 mm | a. 0.5 mm<br>b. 2.5 mm | a. 189.5 mm<br>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 EN 50325-5.
  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 EN 50325-5. Safety relevant parameters approved as follows:

| MH SIL2 CANopen SAFETY | | |
|---|---|---|
| | IEC 61508 | ISO 13849 |
| Safety level | SIL2 | PLd-Cat2 |
| Dignostic coverage | SFF 98 % | DC 97 % |
| Device type | B | n.a. |
| Output | CANopen Safety protocol EN 50325-5<br>Device profile DS-406 V3.2 | |
| $MTTF_D$ (years) 60 °C | $10.75 \times 10^3$ | |
| $MTTF_D$ (years) 80 °C | $4.53 \times 10^3$ | |
| $PFH_D$-60 °C (1/h) | $0.108 \times 10^{-7}$ | |
| $PFH_D$-80 °C (1/h) | $0.255 \times 10^{-7}$ | |
| Diagnostic response time | 5 msec (Emergency messages) | |
| | 25 msec (SRDO messages) | |
| Safety tolerance | 2.5 % F.S. | |
| Fail Signal | SRDO messages:<br>Safety relevant data objects | |

| FIT Output | $\lambda_{SD}$ | $\lambda_{SU}$ | $\lambda_{DD}$ | $\lambda_{DU}$ |
|---|---|---|---|---|
| FIT 60 °C | 0 | 269 | 365 | 11 |
| FIT 80 °C | 0 | 577 | 821 | 25 |

| | |
|---|---|
| Life cycle | 25 years |

## 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 ($1 \times 10^{-9}$ 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)<br>Probability of a dangerous failure per hour |

| L | |
|---|---|
| Low demand mode | Low demand mode of operation ($PFD_{avg}$)<br>(Average probability of failure to perform its design function on demand) |

| P | |
|---|---|
| $PFD_{AVG}$ | Probability of Failure on Demand (Average) |
| $PFH_D$ | 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.<br>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 IEC 61508 part 2 Clause 7.4.4.1.2 |
| Type B component | "Complex" component (using micro controllers or programmable logic); for details see IEC 61508 part 2 Clause 7.4.4.1.3 |

| U | |
|---|---|
| UNECE Regulation 10 Rev 5 | Uniform provisions concerning the approval of vehicles with regard to electromagnetic compatibility |

| 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. |

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