Temposonics
AN AMPHENOL COMPANY

Safety Manual

MH-Series SAFETY Analog

Magnetostrictive Linear Position Sensors

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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) capable according to EN IEC 61508-2:2010. They have a performance Level (PL) in accordance with EN ISO 13849-1:2006.

EN ISO 13849-1:2006	Safety of machinery -- Safety-related parts of control systems -- Part 1: General principles for design
EN IEC 61508-2:2010	Functional safety of electrical/electronic/programmable electronic safety-related systems

The machine safety standards – the EN ISO 13849-1:2006 and the EN IEC 61508-2:2010 for machines deal with the usage of safety related functions on machines.

To include these aspects, the standardization committee defines the EN ISO 13849-1:2006, which is based on the EN IEC 61508-2:2010, which comprises programmable products such as safety control units with microcontrollers. Temposonics will have a SIL (Safety Integrity Level) category according to the EN IEC 61508-2:2010 and a Performance Level (PL) according to the EN ISO 13849-1:2006. For manufacturers this means that, independent of which standard their products must meet, Temposonics® products can easily be taken into consideration. Besides the SIL and the PL can be compared easily. The EN ISO 13849-1 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 capable according to EN IEC 61508-2:2010 for single input in low and high demand, SIL2 Safety Instrumented Systems and to EN ISO 13849-1:2006 performance level d for single channel architectures. 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 Temposonics. 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 Temposonics.

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 EN ISO 13849-1:2006 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 SAFETY Analog:**
  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

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 Temposonics for further analysis.

2.9 Product identification

The model number of the sensor preceeds the the output type (Voltage / Current).
Example:
MH Analog (Voltage) Safety: MHC-xxxxM-NyyH-3-V99
MH Analog (Current) Safety: MHC-xxxxM-NyyG-3-A99-ZZZ

3. MH SAFETY Analog

3.1 Functional description

The MH SAFETY Analog position sensor is classified as type B according to EN IEC 61508-2:2010 and EN ISO 13849-1:2006. 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)

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 EN IEC 61508-2:20105. 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.

Temposonics® MH Sensor with analog safety output:
Analog - Voltage output: MHC-xxxxM-NyyH-3-V99
Analog - Current output: MHC-xxxxM-NyyG-3-A99-ZZZ

Temposonics hereby confirms as manufacturer that all above mentioned requirements are fulfilled by safety related applications and design according to EN IEC 61508-2:2010. Safety relevant parameters approved as follows:

	MH SAFETY Analog (Voltage) output	MH SAFETY Analog (Current) output
Classification according to EN IEC 61508-2:2010	SIL2 (Device type B)	SIL2 (Device type B)
Classification according to EN ISO 13849-1:2006	PLd Category 2	PLd Category 2
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	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}
40 °C [3]	MH SIL2 voltage output	0 FIT	42 FIT	394 FIT	26 FIT
	MH SIL2 current output	0 FIT	43 FIT	430 FIT	27 FIT
60 °C [3]	MH SIL2 voltage output	0 FIT	105 FIT	985 FIT	65 FIT
	MH SIL2 current output	0 FIT	107.5 FIT	1075 FIT	67.5 FIT
80 °C [3]	MH SIL2 voltage output	0 FIT	210 FIT	1970 FIT	130 FIT
	MH SIL2 current output	0 FIT	215 FIT	2150 FIT	135 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. Terms and abbreviations

C	
Category	Safety category according to EN ISO 13849-1:2006
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_D	Probability of Failure per Hour
PL	Performance Level according to EN ISO 13849-1:2006
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 EN IEC 61508-2:2010
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 EN IEC 61508-2:2010 Clause 7.4.4.1.2
Type B component	“Complex” component (using micro controllers or programmable logic); for details see EN IEC 61508-2:2010 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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Document Part Number:
552235 Revision A (EN) 08/2025

UK CA CE ISO 9001 CERTIFIED

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