Safety manual
MTL intrinsic safety solutions

August 2017
SM45-55-AO Rev 3

CROUSE-HINDS
SERIES

MTL4500/MTL5500 range

Analogue Output Modules

SIL 2 IEC 61508:2010 HFT = 0
SIL 3 IEC 61508:2010 HFT = 1 *

MTL4545Y, MTL4546, 4546C, 4546Y MTL5546, 5546Y
MTL4549, 4549C, 4549Y MTL5549, 5549Y

FSM FUNCTIONAL SAFETY MANAGEMENT IEC 61508:2010

FUNCTIONAL SAFETY MANAGEMENT

These products are for use as elements within a Safety System conforming to the requirements of IEC 61508:2010 and enable a Safety Integrity Level of up to SIL2 to be achieved for the instrument loop in a simplex architecture.

Eaton Electric Ltd, Luton is a certified Functional Safety Management company meeting the requirements of IEC 61508:2010 Part 1, Clause 6.

* Refer to content of this manual for details

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Analogue Output Modules

Contents

This manual supports the application of the products in functional-safety related loops. It must be used in conjunction with other supporting documents to achieve correct installation, commissioning and operation. Specifically, the data sheet, instruction manual and applicable certificates for the particular product should be consulted, all of which are available on the MTL web site.

In the interest of further technical developments, Eaton reserve the right to make design changes.

	Hardware Fault Tolerance (HFT) †	
Module type	**0**	**1**
MTL4545Y, MTL4546, MTL5546, MTL4546C, MTL4546Y, MTL5546Y, MTL4549, MTL5549, MTL4549C, MTL4549Y, MTL5549Y	SIL 2 IEC 61508:2010	SIL 3 IEC 61508:2010

† These modules have an inherent fault tolerance of 0.

Duplication of modules in a voting architecture may be used to achieve HFT=1. SIL ratings in this table apply where the required safety function is to repeat the loop current with ± 2%, and the safe state of the output is <3.6mA (downscale).

Functional Safety cass Approved Company

sira CERTIFICATION

1 INTRODUCTION

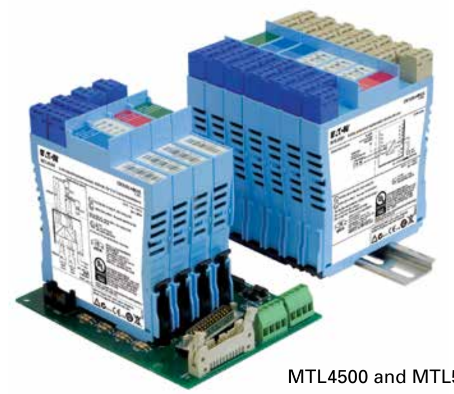
1.1 Application and function

The MTL454x and MTL554x are isolator modules which enable an analogue 4-20mA control signal to be passed to a device located in a hazardous area from a safe area. The output current available to the hazardous area is limited to comply with the requirements of the process explosion hazard. The modules are also designed and assessed according to IEC 61508 for use in safety instrumented systems up to SIL2 when the required function is to repeat the loop current within ±2%, and the safe state of the output is <3.6mA (downscale). Higher integrity levels for a SIF can be achieved by using the modules in a voting architecture.

For 'smart' valve positioners using the HART protocol the units allow bi-directional communications superimposed on the 4-20mA signal current.

There are no configuration switches or operator controls to be set on the modules – they perform a fixed function related to the model selected. The MTLx546 models are single channel while the MTLx549 models are dual channel, although both channels must not be used in the same safety instrumented function.

These modules are members of the MTL4500 and MTL5500 range of products.



MTL4500 and MTL5500 range

1.2 Variant Description

Functionally the MTL4500 and MTL5500 range of modules are the same but differ in the following way:

- the MTL4500 modules are designed for backplane mounted applications
- the MTL5500 modules are designed for DIN rail mounting.

In both models the hazardous area field-wiring connections (terminals 1-2, and 4-5) are made through the removable blue connectors on the top of the modules, but the safe area and power connections for the MTL454x modules are made through the connector on the base, while the MTL554x uses the removable grey connectors on the top and side of the module.

Note that the safe-area connection terminal numbers differ between the backplane and DIN-rail mounting models.

The analogue output models covered by this manual are:

MTL4545Y	**single channel, open cct LFD**
MTL4546 and MTL5546	**single channel, open and short cct LFD**
MTL4546C, MTL4546Y, and MTL5546Y	**single channel, open cct LFD**
MTL4549, and MTL5549	**dual channel, open and short cct LFD**
MTL4549C, MTL4549Y, and MTL5549Y	**dual channel, open cct LFD**

Note: To avoid repetition, further use of MTLx54x in this document can be understood to include both DIN-rail and backplane models. Individual model numbers will be used only where there is a need to distinguish between them.

2 System configuration

An MTLx54x module may be used in single-channel (1oo1) safety functions up to SIL2.

The figure below shows the system configuration and specifies detailed interfaces to the safety related and non safety-related system components. It does not aim to show all details of the internal module structure, but is intended to support understanding for the application.

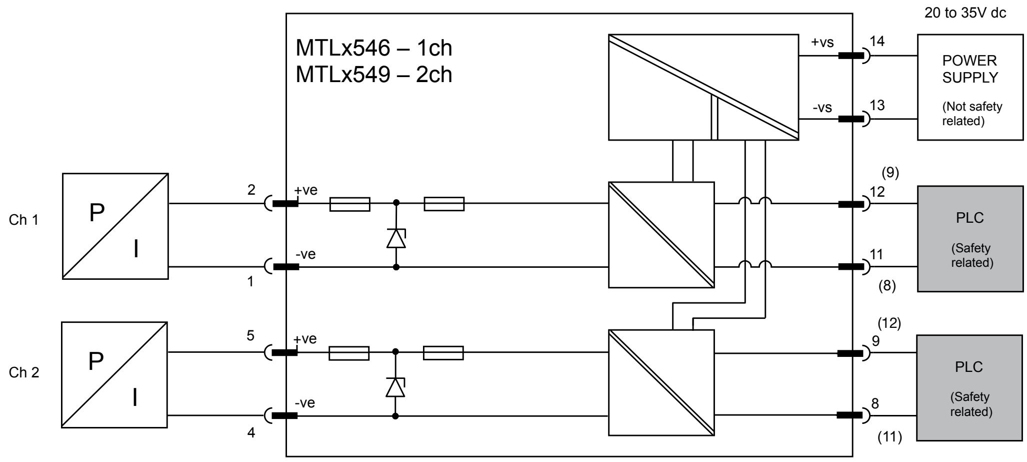


Figure 2.1 – Analogue Output module system configuration – see the 'Note' in the text regarding use of dual channel modules

The MTLx54x modules are designed to repeat the current signal from a safe-area source to a field device such as a current-to-pneumatic converter or valve positioner in the hazardous area. The shaded area indicates the safety relevant system connection, while the power supply connections are not safety-related. For simplicity the term 'PLC' has been used to denote the safety system performing the driving function of the process loop.

Note: When using the MTLx549 dual-channel modules, **it is not appropriate** for both channels to be used in the same loop, or the same safety function, as this creates concerns of common-cause failures. Consideration must also be made of the effect of common-cause failures when both loops of a dual-channel module are used for different safety functions.

2.1 Associated System Components

There are many parallels between the loop components that must be assessed for intrinsic safety as well as functional safety where in both situations the contribution of each part is considered in relation to the whole.

The MTLx54x module is a component in the signal path between safety-related actuators and safety-related control systems.

The current to pressure converter, valve positioner, or other field device, must be suitable for the process and have been assessed and verified for use in functional safety applications as well as its certification for hazardous area mounting.

The safety system PLC shall have a current output with a normal operating range of 4-20mA but capable of working over the extended range of 3 to 22mA for under- and over-range. Such controllers will normally also include a readback facility to enable the detection of open or short circuits in the wiring.

The transmission of HART data is not considered as part of the safety function and is excluded from this analysis.

3 Selection of product and implications

The analogue signal levels employed by the MTLx54x are within the operating range of 4-20mA under normal conditions.

If the wiring between the isolator and field device are open circuit then the line-fault detect (LFD) operation of the isolator forces the current taken into the input terminals to fall to a low value, which is less than the expected under-range value of 3.6mA. The MTLx546 and MTLx549 models also detect when the resistance in the field wiring is less than fifty ohms indicating a short circuit condition, and this also is reflected into a low input current value.

This diagnostic aspect can be used by logic solvers that include a readback facility to monitor the output current from their output cards or modules. Thus the ability to detect that the actual current being passed is not the desired value can be used to determine the health of the instrument function. The same condition of the actual loop current falling to a low level will also occur if the wiring between the logic solver and the isolator is open circuit.

Using a field device and logic controller, as defined in section 2, with an MTLx54x then a system-loop can be implemented that applies functional safety together with intrinsic safety to meet the requirements of protection against explosion hazards. Note that the transfer of HART communications through the isolator is not considered as part of the safety function of the isolator.

It is important that the effect of electromagnetic interference on the operation of any safety function is reduced where possible. For this reason it is recommended that the cable connections from the logic solver to the isolator modules be a maximum of 30 metres and are not exposed to possible induced surges, keeping them inside a protected environment.

Similarly, operation of the equipment outside of its environmental ratings induces component stress and temperature above the normal ambient of 60°C is to be avoided to ensure required performance and reliability.

4 Assessment of Functional Safety

4.1 Hardware Safety Integrity

The hardware assessment shows that MTLx54x analogue output modules:

- have a hardware fault tolerance of 0
- are classified as Type A devices ("Non-complex" component with well-defined failure modes)
- have no internal diagnostic elements

The definitions for product failure of the modules at maximum ambient temperature of 45°C were determined as follows:-

Analogue output isolator modules

Failure mode	Failure rate (FIT)	
	MTL4545Y, MTLx546, MTL4546C, MTLx546Y	MTLx549, MTL4549C, MTLx549Y
Output current >21mA (upscale)	2	2
Output current <3.6mA (downscale)	199	223
Output current within range but >2% in error	42	60
Output current correct within ±2%	135	148
LFD not signaled in line fault condition	10	11
LFD signaled when no fault	21	24

(FITs means failures per 10^9 hours or failures per thousand million hours)

The above failure rates apply primarily to the analogue signal transfer only. The information for the line fault detection function is provided for consideration in respect of the diagnostic capabilities of the safety logic-solver.

- Reliability data for this analysis is taken from IEC TR 62380:2004 Reliability Data Handbook.
- Failure mode distributions are taken principally from IEC 62061:2005 Safety of Machinery.

It is assumed that the module is powered from a nominal 24Vdc supply. The product has been assumed to operate at a maximum ambient temperature of 45°C under normal conditions.

4.2 Systematic Safety Integrity

The modules covered by this safety manual have a systematic safety integrity measure of SC 3.

Note: Earlier versions of this manual (Revisions 1 and 2) inferred a systematic safety integrity of SC 2. Subsequent independent assessment of the design features and techniques/measures used to avoid systematic faults has allowed the modules to be awarded SC 3. No change has been made to the product designs; the SC 3 systematic integrity measure therefore applies retrospectively to modules installed under previous revisions of this manual.

4.3 SIL Capability

Considering both the hardware safety integrity and the systematic capability, this allows the modules to be used in safety functions up to SIL2 in a simplex architecture (HFT=0), or in SIL 3 applications with hardware redundancy (HFT = 1 or greater), provided SFF >60% for the application.

Note: Independent of hardware architecture and systematic capability considerations, the hardware probability of failure for the entire safety function needs to be calculated for the application to ensure the required PFH (for a high or continuous demand safety function) or PFD_{AVG} (for a low demand safety function) for the SIL is met.

4.4 Example of use in a safety function

In this example the application context is assumed to be:

- The safety function is to repeat current within ±2%
- The safe state of the output is <3.6mA (downscale)
- The logic solver will diagnose input currents below 3.6mA as faults and take appropriate action. (Here, it is important to understand that when the MTL module detects a line fault, it forces the input current to <0.9mA).

The failure modes shown above can then be defined as:

Failure mode	Category	Comment
Output current >21mA (upscale)	Dangerous undetected, λ_{du}	
Output current <3.6mA (downscale)	Safe undetected, λ_{su}	These failures do not trigger the MTL module's line fault detection. Hence they do not cause the input current to fall below 3.6mA and are undetected by the logic solver
Output current within range but >2% in error	Dangerous undetected, λ_{du}	
Output current correct within ±2%	No effect, λ_{ne}*	These failures are categorised as no-effect because the module is still performing its published safety function
LFD not signaled in line fault condition	Safe undetected, λ_{su}	In the event of a line fault (ie open or short circuit), the output fails to a downscale (safe) value; hence these failures are safe but undetected
LFD signaled when no fault	Safe detected, λ_{sd}	In this example where the logic solver diagnoses input currents below 3.6mA as faults, these failures cause a spurious trip of the safety function

Consequently, the failure rates for these categories are then (FITs):

Model	λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	λ_{ne}*
MTL4546 or MTL5546	21	209	0	44	135

In this example the Safe Failure Fraction is 83.9%. *λne is not used in the calculation of Safe Failure Fraction.

4.5 EMC

The MTL4500 and MTL5500 modules are designed for operation in normal industrial electromagnetic environment but, to support good practice, modules should be mounted without being subjected to undue conducted or radiated interference, see Appendix A for applicable standards and levels.

It is important that the effect of electromagnetic interference on the operation of any safety function is reduced where possible. For this reason it is recommended that the cable connections from the logic solver to the isolator modules be a maximum of 30 metres and are not exposed to possible induced surges, keeping them inside a protected environment.

Any maintenance or other testing activity should only be conducted when the field loop is not in service, to avoid any possibility of introducing a transient change in the field signal.

4.6 Environmental

The MTL4500 and MTL5500 modules operate over the temperature range from-20°C to +60°C, and at up to 95% non-condensing relative humidity.

The modules are intended to be mounted in a normal industrial environment without excessive vibration, as specified for the MTL4500 & MTL5500 product ranges. See Appendix A for applicable standards and levels.

Continued reliable operation will be assured if the exposure to temperature and vibration are within the values given in the specification.

5 Installation

There are two particular aspects of safety that must be considered when installing the MTL4500 or MTL5500 modules and these are:

- **Functional safety**
- **Intrinsic safety**

Reference must be made to the relevant sections within the instruction manual for MTL4500 range (INM4500) or MTL5500 range (INM5500) which contain basic guides for the installation of the interface equipment to meet the requirements of intrinsic safety. In many countries there are specific codes of practice, together with industry guidelines, which must also be adhered to.

Provided that these installation requirements are followed then there are no additional factors to meet the needs of applying the products for functional safety use.

To guard against the effects of dust and water the modules should be mounted in an enclosure providing at least IP54 protection degree, or the location of mounting should provide equivalent protection such as inside an equipment cabinet.

In applications using MTL4500 range, where the environment has a high humidity, the mounting backplanes should be specified to include conformal coating.

6 Maintenance

To follow the guidelines pertaining to operation and maintenance of intrinsically safe equipment in a hazardous area, yearly periodic audits of the installation are required by the various codes of practice.

In addition, proof-testing of the loop operation to conform with functional safety requirements should be carried out at the intervals determined by safety case assessment.

Proof testing must be carried out according to the application requirements, but it is recommended that this be carried out at least once every three years.

Refer to Appendix B for the proof testing procedure of the MTL4500 or MTL5500 modules.

Note that there may also be specific requirements laid down in the E/E/PE operational maintenance procedure for the complete installation.

If an MTL4500 or MTL5500 module is found to be faulty during commissioning or during the normal lifetime of the product then such failures should be reported to the MTL office. When appropriate, a Customer Incident Report (CIR) will be notified to enable the return of the unit to the factory for analysis. If the unit is within the warranty period then a replacement unit will be sent.

Consideration should be made of the normal lifetime for a device of this type which would be in the region of ten years.

7 Appendices

7.1 Appendix A: Summary of applicable standards

This annex lists all standards referred to in the previous sections of this document:

IEC 61508:2010	Functional safety of electrical/electronic/programmable electronic safety-related systems. Parts 1 and 2 as relevant.
EN 61131-2:2003	Programmable controllers – Part 2: Equipment requirement and tests (EMC requirements).
EN 61326-1:2006	Electrical equipment for measurement, control and laboratory use – EMC requirements. (Criterion A).
IEC 61326-3-1:2008	Electrical equipment for measurement, control and laboratory use- EMC requirements- Part 3-1: Immunity requirements for equipment performing or intended to perform safety-related functions (functional safety)- General industrial applications. (Criterion FS).
NE21 : 2007	Electromagnetic Compatibility of Industrial Process and Laboratory Control Equipment. (Criterion A).
Lloyds Register Type Approval System : 2002, Test Specification Number 1.	(Specifically vibration: 1.0mm displacement @ 5 to 13.2Hz and 0.7G acceleration @13.2Hz to 100Hz per IEC60068-2-6, test Fc).
IEC 60068-2-6	Environmental testing- Part 2-6: Tests- Test Fc: Vibration (sinusoidal)
IEC 60068-2-27	Environmental testing- Part 2-27: Tests- Test Ea and guidance: Shock

7.2 Appendix B : Proof Test Procedure, MTL45/5500 Analogue Output Modules

1. System –Normal operation test
2. Input / Output characteristic functional safety test.
3. System- Normal operation test

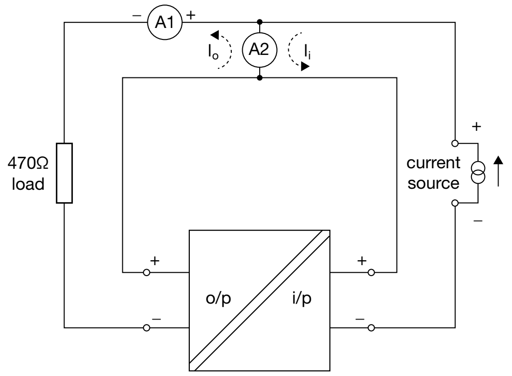
Confirmation, through testing, that a safety function will operate as designed, is a necessary periodic activity to ensure that the probability of failure upon demand (PFDavg) is maintained.

In many safety applications, where practical, the user may well prefer that these proof tests are conducted on the instrument loop as a whole, without dismantling or disconnecting the parts. This will help to ensure the integrity of the installation is continued after commissioning, but the disturbance to plant operations may not be acceptable.

The tests given in this section of the manual will enable only the function of the isolator component of the safety loop to be proved. Proof tests of the other components of the loop must be conducted at the requisite intervals to maintain availability of the safety function. Alternative proof tests may be devised and applied provided they give a similar level of test that is appropriate to the safety function.

The tests described here- see Figure 7.1- compare the output current with the input current (A1) over the required range of operation, and measure the "error current" i.e. the difference between the two- as indicated on A2.
The tests should be employed per channel, as appropriate.

Figure 7.1
Basic test arrangement



Ammeter A2 must be capable of handling either polarity of signal. If it is not an auto-ranging instrument, set it to a high range before switch on, then adjust sensitivity to obtain the required reading.

Example MTLx54y Proof Test Procedure

Test sequence:

1. System- Normal operation test
2. Input /Output characteristic functional safety test
3. System- Normal operation test

1 System - Normal operation test

Make sure that the module to be tested is operating normally in the target system, without errors and in energised mode. If the module is connected in a faulty or de-energised loop, restore normal fault free and energised conditions before testing.

2 Input/Output characteristic functional safety test

Observe normal anti-static precautions when handling equipment during device testing.

Remove the unit from the target system and connect as shown in Figure 7.1

Please note, that it is acceptable to leave the unit in the target system, when it is secured, that the terminals are disconnected from the system and available for test. Alternatively, for the backplane mounted MTL4500, use a separate backplane for this purpose to facilitate access to the power and output connections.

During testing, the power supply, Vs- nominal 24.0V, min/max. range 20.0 to 35.0V- should be connected between terminals 13 and 14 (+ve to terminal 14)

Make the following measurements and, it is recommended, record the results in a table such as that shown on the next page.

The chosen “load” resistor can be any value between 100 and 800Ω

Output Measurements

1. Adjust the current source to set the current (A1) through the range 4 to 20mA.
2. The measured current imbalance (A2) over this range should not exceed ± 50 μA.
3. Adjust the current source to set the current (A1) to 3.5mA, and then 21.5mA.
4. The measured current imbalance (A2) over this range should not exceed ± 200 μA.
5. Adjust the current source to set the current (A1) to 20mA.
6. Apply a voltmeter to the product input port + and- terminals.
7. The measured voltage (V1) at the product input port should not exceed +6V.

3 System - Normal operation test

Disconnect the test setup from the unit and connect the original system configuration. Make sure, that the tested unit is operating normally in the target system, without errors and in energised mode.

Date: ______/______/__________ Supply voltage Vs: ______________V dc

Module type: _________________ Serial No: ______________________________

Channel 1

Test #	Description	Actual	Target
1	Current imbalance (A_2) at loop current (A_1) = 4mA		<±50μA
2	Current imbalance (A_2) at loop current (A_1) = 8mA		<±50μA
3	Current imbalance (A_2) at loop current (A_1) = 12mA		<±50μA
4	Current imbalance (A_2) at loop current (A_1) = 16mA		<±50μA
5	Current imbalance (A_2) at loop current (A_1) = 20mA		<±50μA
6	Current imbalance (A_2) at loop current (A_1) = 3.5mA		<±200μA
7	Current imbalance (A_2) at loop current (A_1) = 21.5mA		<±200μA
8	Input voltage (V_1) at loop current (A_1) = 20mA		<6V

Channel 2

Test Step#	Description	Actual	Target
1	Current imbalance (A_2) at loop current (A_1) = 4mA		<±50μA
2	Current imbalance (A_2) at loop current (A_1) = 8mA		<±50μA
3	Current imbalance (A_2) at loop current (A_1) = 12mA		<±50μA
4	Current imbalance (A_2) at loop current (A_1) = 16mA		<±50μA
5	Current imbalance (A_2) at loop current (A_1) = 20mA		<±50μA
6	Current imbalance (A_2) at loop current (A_1) = 3.5mA		<±200μA
7	Current imbalance (A_2) at loop current (A_1) = 21.5mA		<±200μA
8	Input voltage (V_1) at loop current (A_1) = 20mA		<6V

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