Safety manual
MTL intrinsic safety solutions

June 2017
SM45-55-SAD Rev 3

CROUSE-HINDS
SERIES

MTL4500/MTL5500 range

Solenoid / Alarm Drivers

SIL 3 IEC 61508:2010 HFT = 0 LOOP-POWERED MODULES

SIL 2 IEC 61508:2010 HFT = 0 SEPARATELY-POWERED MODULES *

MTL4521, 4521L, 5521, 5522, 4523L, 5525
MTL4523, 4523R, 4523V, 4523VL, 4523Y, 5523V, 523VL,
MTL5523, 5524, 4524, 4524S, 4525

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 IEC61508:2010 or IEC61511-1:2016 and enable a Safety Integrity Level of up to SIL3 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 IEC61508 Part1:clause 6

* Refer to content of this manual for details

EATON
Powering Business Worldwide

Solenoid / Alarm Drivers

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**
Loop-powered **MTLx521, MTL4521L, MTL4523L, MTL5522, MTL5525**	SIL 3	N/A
Separately-powered **MTLx523/x23x/x23VL, MTL4523Y, MTLx524, MTL4524S, MTL4525**	SIL 2	SIL 3

† 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 stated in this table apply where the required element safety function is to de-energise the output. Where the required element safety function is to energise the output, a rating of SIL 1 is achieved for all module types.

1 INTRODUCTION

1.1 Application and function

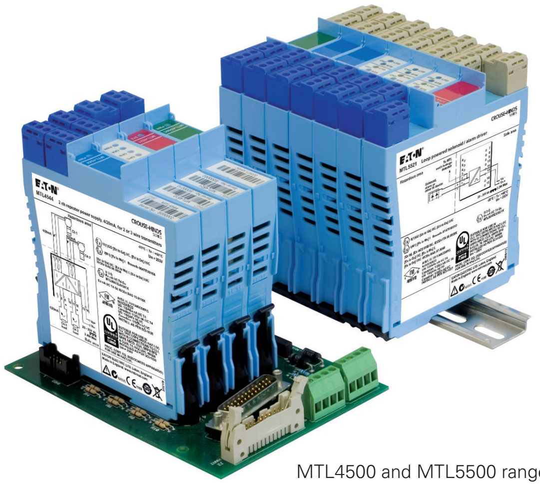
The MTL452x and MTL552x are isolator modules which enable a device located in the hazardous area to be controlled from the safe area. Some models are simply loop-powered while others have additional input logic signals to enable power to be supplied to the output. The output current available to the hazardous area is limited to comply with the requirements of the process explosion hazard. They are also designed and assessed according to IEC 61508 for use in safety instrumented systems up to SIL2 or in loop-powered variant up to SIL3 when the required function is to **de-energise** the output.

When used in a safety instrumented function where the required operation is to **energise** the output on demand then a SIL1 rating is achieved for all module types, without hardware redundancy.

The modules can drive a certified intrinsically safe low-power load, such as a solenoid valve or a non-energy-storing simple apparatus such as an LED lamp.

There are no configuration switches or operator controls to be set on the modules - they perform a fixed function related to the model selected. Use of the phase-reversal link on the MTL5524 is not recommended in functional safety applications and has not been considered in this manual.

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 1-3, and 4-6) are made through the removable blue connectors on the top of the modules, but the safe area and power connections for the MTL**45**2x modules are made through the connector on the base, while the MTL**55**2x 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 solenoid/alarm driver output models covered by this manual are:

MTL4521, MTL4521L, and MTL5521	**loop powered, IIC gas group output**
MTL5522	**loop powered, IIB gas group output**
MTL4523, MTL4523R, and MTL5523	**powered, with LFD output**
MTL4523L	**loop powered, with LFD output**
MTL4523V, MTL4523VL, MTL5523V, MTL5523VL and MTL4523Y	**powered, with LFD output**
MTL4524, and MTL5524	**powered, two control inputs**
MTL4524S	**powered, switch and voltage controls**
MTL4525, and MTL5525	**low power output**

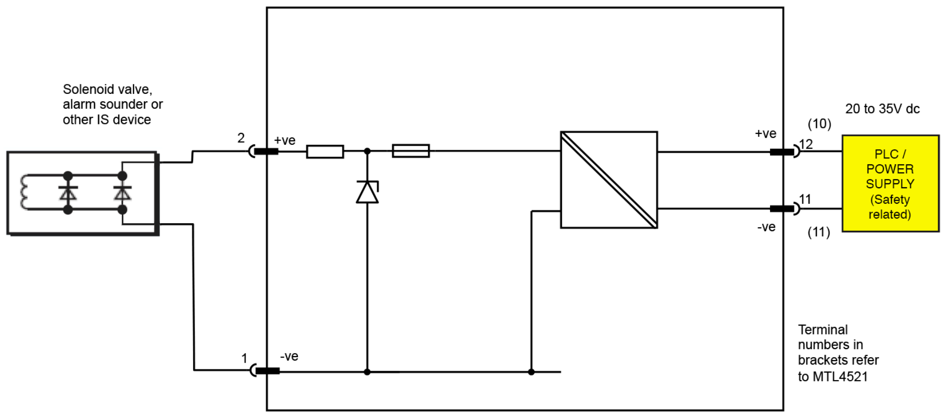
Note: To avoid repetition, further use of **MTLx52x** *in this document can be understood to include both DIN-rail and backplane models. Individual model numbers will be used only where there is a need to distinguish them.*

2 System configuration

An MTLx52x loop-powered module may be used in single-channel (1oo1) safety functions up to SIL3 and an MTLx52x separately powered module may similarly be used up to SIL2 where the safe state is to de-energise the output.

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.

Loop powered modules e.g. MTL4521/5521



The MTLx52x modules are designed to power a field device such as a solenoid valve in the hazardous area and are driven from a safe-area source. The yellow (hatched) area shows the safety relevant system connection when using the loop-powered configuration. For simplicity the term 'PLC' has been used to denote the safety system performing the driving function of the process loop.

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 MTLx52x module is a component in the signal path between safety-related actuators and safety-related control systems.

The solenoid valve, 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.

3 Selection of Product and Implications

For the loop-powered modules there is only one function: to energize the output when power is applied to the input. This may be used as a safety function, preferably with power off as the safe state, i.e de-energise to safe.

When the module is loop powered, the output cannot be energised if the input is de-energised.

There is no significant energy storage within the module that could delay the de-energising of the output. The module can be considered as a dc transformer where the output will de-energise to within 10% of its final value within 100ms with a load up to 4kΩ.

Thus, when used in a de-energise to safe function, as identified in the next section the dangerous undetected failures rate λ_{du} for the loop-powered MTL4/5521 modules is less than the maximum failure rate normally applied for SIL3 systems with 1oo1 architecture.

This is considering the hardware failure rate only and the user must consider the systematic implications of applying this equipment in safety functions where a number of safety-related subsystem channels are implemented to achieve the requisite hardware fault tolerance.

For the separately powered modules which are controlled by a logic signal, the hardware failure rate and systematic considerations indicate limiting the use of such modules to simplex (1oo1) loops achieving up to SIL2 for a de-energise to safe function.

Note: When using the modules that are not loop-powered it is important that the solenoids being driven be chosen to ensure that the residual field current that flows in the module OFF state does not cause the solenoid to remain energised. A small field current is used by some module types to determine the line condition and some low-power solenoids are capable of remaining in their energised state, once energised, with very small loop currents. If the safe state of the loop is for the solenoid to be OFF then it must be able to drop out, despite the monitoring of line state.

It is therefore advisable to avoid this risk by selecting module types that do not support line fault monitoring, unless this function is specifically required by the application.

Similarly, operation of the equipment outside of its environmental ratings induces component stress and in particular temperatures below-20ºC are to be avoided to ensure required performance.

4 Assessment of Functional Safety

4.1 Hardware Safety Integrity

The hardware assessment shows that MTLx52x solenoid/alarm drivers:

- 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 an ambient temperature of 45°C were determined as follows:-

Loop-powered modules

Failure mode	Failure rate (FIT)				
	MTLx521	MTL4521L	MTL4523L	MTL5522	MTL5525
Output stuck ON	0	0	0	0	0
Output stuck OFF (no output)	189	194	191	228	201
Output uncertain (OK or OFF)	17	17	17	24	18
Correct operation but reduced output voltage when ON	49	50	50	60	50
Correct operation (failures have no effect)	100	101	73	108	103

Separately-powered modules

Failure mode	Failure rate (FIT)		
	MTLx523/23x/23VL	MTLx524/4524S	MTL4525
Output stuck ON	8	20	21
Output stuck OFF (no output)	234	227	241
Output uncertain (OK or low) when ON	23	28	30
Correct operation but reduced output voltage when ON	50	50	51
Correct operation (failures have no effect)	100	111	116

The above failure rates apply to the hazardous area output only. The line fault detection function is not included in these figures.

- FITs means failures per 10^9 hours or failures per thousand million hours.
- 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.

Example of use in a safety function

In this example for a **loop-powered** module the application context is assumed to be:

- the safety function is to **de-energise** the output on demand

The failure modes shown above can then be defined as

Failure mode	Category
Output stuck ON	Dangerous undetected, λ_{du}
Output stuck OFF (no output)	Safe undetected, λ_{su}
Output uncertain (OK or OFF)	Safe undetected, λ_{su}
Correct operation but reduced output voltage when ON	Safe undetected, λ_{su}
Correct operation (failures have no effect)	No effect, λ_{ne}

The failure rates for these categories are then (FITs)

Model	λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	λ_{ne}*
MTL4521 or MTL5521	0	255	0	0	100

In this example, the safe failure fraction is 100%.

*Note, that λ_{ne} is not used in the calculation of SFF.

Accordingly, the SFF of all module types described in this manual are as follows, for applications where the element safety function is to de-energise the output:

Model		λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	λ_{ne}*	SFF
Loop-powered modules	MTLx521	0	255	0	0	100	100%
	MTL4521L	0	261	0	0	101	100%
	MTL4523L	0	258	0	0	73	100%
	MTL5522	0	312	0	0	108	100%
	MTL5525	0	269	0	0	103	100%
Separately-powered modules	MTLx523/23x/23VL	0	307	0	8	100	97%
	MTLx524/4524S	0	305	0	20	110	94%
	MTL4525	0	322	0	21	116	94%

4.2 Systematic Safety Integrity

The design features and techniques/measures used to avoid systematic faults give the MTLx52x modules a systematic safety integrity measure of SC 3.

Note: Earlier versions of this manual (Revisions 1 & 2) inferred a systematic safety integrity for MTLx52x modules 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 MTLx52x modules installed under previous revisions of this manual.

4.3 SIL capability

Considering both the hardware safety integrity and systematic capability, the modules may be used as follows:

4.3.1 Loop-powered modules

Loop-powered modules may be used in SIL 3 safety functions in a simplex architecture (HFT =0) where the required element safety function is to de-energise the output. In this application, loop-powered modules are inherently incapable of powering the field device if no power is applied to the input. Where the required element safety function is to energise the output, loop-powered modules may be used in SIL 1 safety functions in a simplex architecture.

4.3.2 Separately-powered modules

The Separately-powered modules may be used in SIL 2 safety functions in a simplex architecture (HFT =0) where the required element safety function is to de-energise the output. Duplication of modules in a voting architecture may be used to achieve HFT=1. Where the required element safety function is to energise the output, loop-powered modules may be used in SIL 1 safety functions in a simplex architecture.

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. The 'SIL Capability' statement assumes that no more than 10% of the probability of dangerous (undetected) failure budget is used by the MTLx52x.

4.4 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.

4.5 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 (Clause 7.1) 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 (Clause 7.2) for the proof testing procedure of the MTL4500 or MTL5500 modules.

Note that specific requirements may also be 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 local 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

The annex lists together 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 Digital Output Modules

Example MTLx521 Proof Test Procedure

Solenoid driver module Proof Test Procedure:

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 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 MTL4521 modules, use a separate backplane for this purpose to facilitate access to the power and output connections.

a) Loop powered modules: MTL4521, 4521L, 5521, 5522, 4523L, 5525

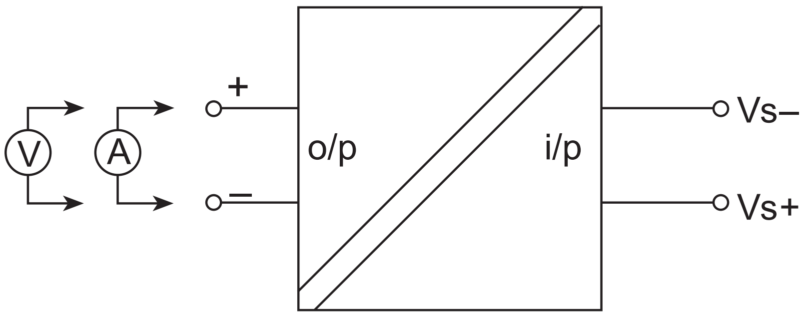


Figure 1 Basic test arrangement- loop powered

1 Connect a voltmeter between the + &- output terminals of the module, observing polarity.
2 Apply 24V dc between the input drive terminals.
3 The voltmeter on the output terminals should indicate a value between 22.2 and 24 volts.
4 Switch off the power to the module.
5 Connect an ammeter between the + and – output terminals of the module, observing polarity.
6 Apply 24V dc between the input drive terminals.
7 The ammeter should indicate a value of at least 48mA and a maximum of 60mA (76mA for MTL5522)

Operate the test sequence and confirm expected operation of the module.
It is recommended that the results are recorded in a table such as that shown on page 11.

b) Powered modules: MTLx523, 4523R, x523V, x523VL, x524, 4524S, 4525

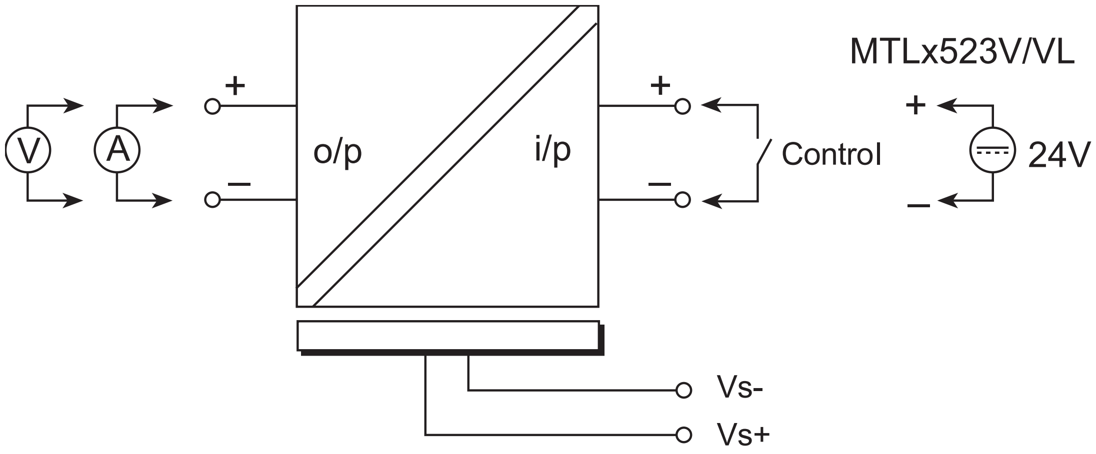


Figure 2 Basic test arrangement- separately powered

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).

1 Connect a voltmeter between the + & – output terminals of the module, observing polarity.
2 Apply 24V between the supply terminals Vs+, Vs–.
3 Close the Control switch, or apply the 24V source for the MTLx523V/VL.
4 The voltmeter should now indicate a value between 22.2 and 24 volts.
5 Switch off the power to the module.
6 Connect an ammeter between the + & – output terminals of the module, observing polarity.
7 Close the Control switch, or apply the 24V source for the MTLx523V/VL.
8 The ammeter should indicate between 48mA and 60mA.
9 Switch off the power to the module.

Operate the test sequence and confirm expected operation of the module.
It is recommended that the results are recorded in a table such as that shown overleaf.

3. System - Normal operation test

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

Loop Powered Modules:

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

Module type: _________________ Serial No: ______________________________

Test step #	Description	Actual	Target
1	Output voltage, off state		0V
2/3	Output voltage, on state		21.4 to 24V
5	Output current, off state		0mA
6/7	Output current, on state		>48mA and <76mA

Separately Powered Modules:

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

Module type: _________________ Serial No: ______________________________

Test step #	Description	Actual	Target
2	Output voltage, off state		<4V
3/4	Output voltage, on state		21.4 to 24V
6	Output current, off state		<22mA
7/8	Output current, on state		>48mA and <60mA

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