Safety manual
MTL intrinsic safety solutions

April 2024
SM4541A/AS, 5541A/AS,
4544A/AS, 5544A/AS rev 2

CROUSE-HINDS
SERIES

MTL4500/MTL5500 range

SIL 2 IEC 61508:2010 *

Analogue Input Modules with passive input for 4-wire separately powered transmitters

MTL4541A, MTL4541AS, MTL5541A, MTL5541AS,
MTL4544A, MTL4544AS, MTL5544A, MTL5544AS

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 SIL 2 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 IEC61508:2010 Part 1, Clause 6.

* Subject to special conditions for detection of out-of-range signal currents. Refer to content of this manual for details.

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Analogue Input Modules with passive input for 4-wire transmitters

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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**
MTL4541A, MTL4541AS, MTL5541A, MTL5541AS, MTL4544A, MTL4544AS, MTL5544A, MTL5544AS	SIL 2 IEC 61508:2010

† These modules have an inherent fault tolerance of 0.

1 INTRODUCTION

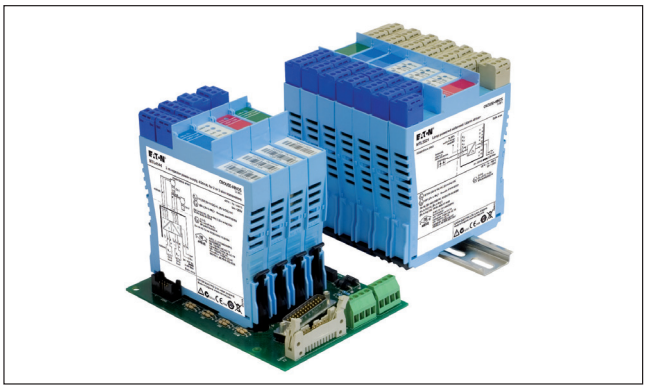
1.1 Application and function

The Analogue Input module types MTLx541A/MTLx541AS (single channel) and MTLx544A/MTLx544AS (dual channel) are intrinsic safety isolators that interface with process measurement transmitters located in a hazardous area of a process plant. They are also designed and assessed according to IEC 61508 for use in safety instrumented systems up to SIL 2.

The MTLx541A provides an input for a separately-powered 4/20mA transmitter located in a hazardous area, and repeats the transmitter current into a load in the safe area. The MTLx544A supports two identical channels for use with two separate transmitters. The MTLx541AS and MTLx544AS versions act as a current sink for the safe area connection rather than driving the current into the load.

All the modules allow bi–directional transmission of HART communication signals superimposed on the 4/20mA loop current, so that the transmitter can be interrogated either from the operator station or by a hand-held communicator (HHC).

There are no configuration switches or operator controls to be set on the modules. These modules are members of the MTL4500 and MTL5500 range of products.



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 optionally 4,5) are made through the removable blue connectors, but the safe area and power connections for the MTL454xA/MTL454xAS modules are made through the connector on the base, while the MTL554xA/MTL554xAS modules use 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 the DIN-rail mounting models.

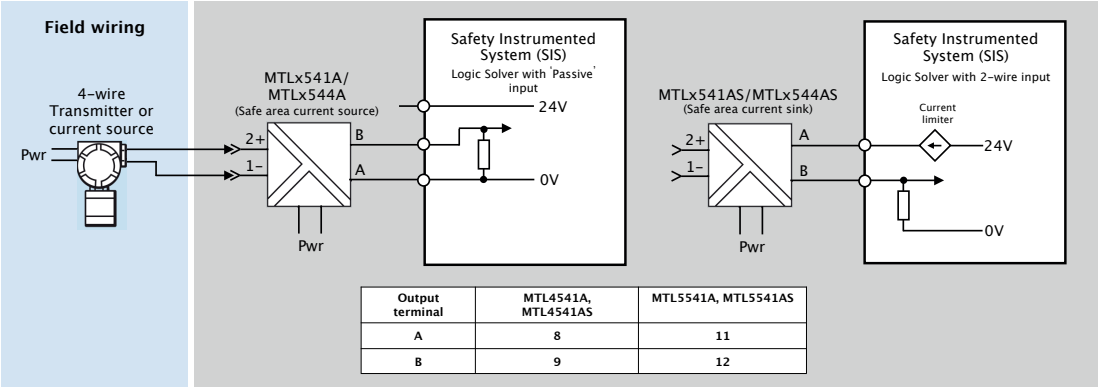
The analogue input models covered by this manual are:

Module type	Number of channels	Safe area connection
MTL4541A and 5541A	1	Current source
MTL4541AS and 5541AS	1	Current sink
MTL4544A and 5544A	2	Current source
MTL4544AS and 5544AS	2	Current sink

Note: *To avoid repetition, further use of MTLx54xA and MTLx54xAS 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.*

All the module types described in this manual have the same connectivity for the field signals, supporting 4-wire process transmitters or currents sourced in the hazardous area. The connection of the repeated current signals into the input measurement channels for the safety logic system follows the arrangement shown in the following diagram. When the input channels of the Safety Instrumented System (SIS) are providing power for the loop, the 'S' variants of the isolator modules are used to 'sink' the measuring current.

In the other cases the isolator modules 'source' the measuring current that flows into a load resistor inside the input card of the Safety Instrumented System.



Output terminal	MTL4541A, MTL4541AS	MTL5541A, MTL5541AS
A	8	11
B	9	12

Figure 1.1 – Input and output connections

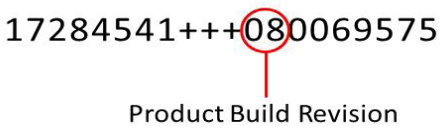
1.3 Product build revisions covered by this manual

The information provided in this manual is valid for the product build revisions listed in the following table:

Model Type	Product build revision covered by this manual
MTL4541A	Up to and including 08
MTL4541AS	Up to and including 08
MTL5541A	Up to and including 08
MTL5541AS	Up to and including 08
MTL4544A	Up to and including 08
MTL4544AS	Up to and including 08
MTL5544A	Up to and including 08
MTL5544AS	Up to and including 08

The product build revision is identified by the field 'CC' in the module Product Identification Number that appears at the bottom left-hand corner of the side label:

The CC field immediately precedes the 7-digit Serial Number field, DDDDDDD. Example:



2 System configuration

An MTLx54x module may be used in single-channel (1oo1) safety functions up to SIL 2. The worked example in this manual is for a SIL 2 application.

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.

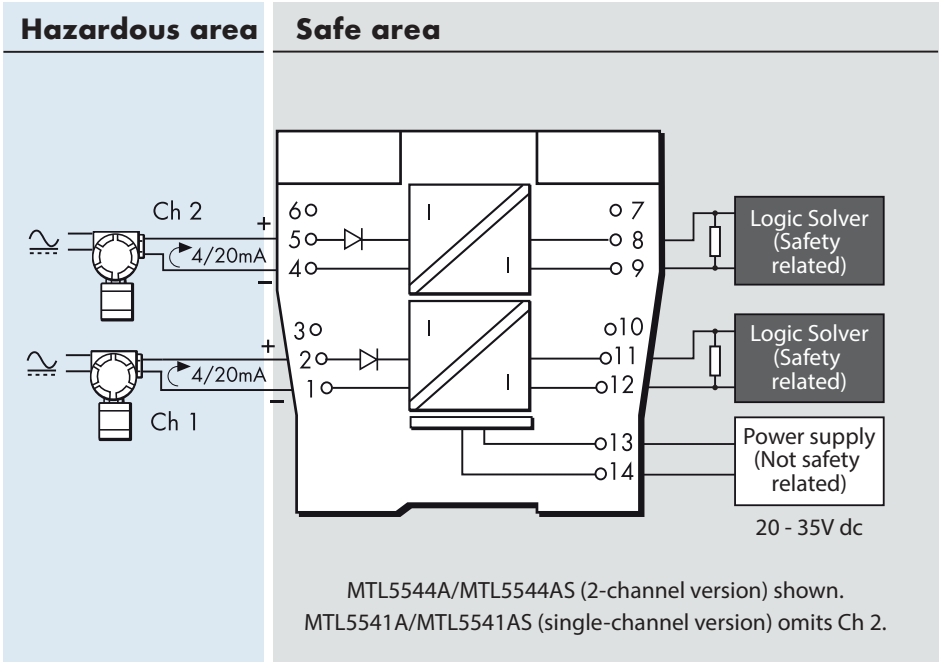


Figure 2 – System Configuration

The MTLx54xA/MTLx54xAS modules are designed to receive an active 4-20mA signal from separately powered process transmitters in the hazardous area and to repeat the current flowing in the field loop to the safe-area load. The shaded area indicates the safety-related system connection, while the power supply connections are not safety-related. The term 'Logic Solver' has been used to denote the safety system performing the monitoring function of the process loop variable.

Note: When using the MTLx544A/MTLx544AS 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 regarding common-cause failures. Consideration must also be given to 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. In both situations the contribution of each part is considered in relation to the whole.

The MTLx54xA/MTLx54xAS modules are components in the signal path between safety-related process transmitters and safety-related control systems. The transmitter or other field device must be suitable for the process and have been assessed and independently verified for use in functional safety applications.

The field instrument and Analogue input card of the Logic Solver shall have a normal operating range of 4-20mA but be capable of working over an extended range of 3 to 22mA for under- and over-range. The Logic Solver shall have the ability to detect and annunciate input currents higher than the threshold of 21mA and lower than the threshold of 3.6mA to determine out-of-range conditions.

Note that the transmission of HART data is not considered as part of the safety function and is excluded from this analysis. However, for HART data communication to take place, the input impedance of the receiving equipment must be at least 240R.

3 Selection of product and implications

The safe area output signal from the MTLx541A/AS and MTLx544A/AS modules is within the operating range of 4-20mA under normal conditions. If the field wiring to the transmitter or connection between the isolator and logic solver is open-circuit then the loop current will fall to less than 3.6mA and close to zero. If the field wiring connection between the transmitter and isolator is short-circuited, the loop current will also fall to below 3.6mA.

For module types MTLx541A and MTLx544A that source the 4-20mA signal in the safe area circuit, then the current seen by the logic solver will fall to less than 3.6mA and close to zero if the connection between the isolator and logic solver is shorted.

For module types MTLx541AS and MTLx544AS that sink the 4-20mA signal in the safe area circuit, then the current seen by the logic solver will rise to a value greater than 21mA if the connection between the isolator and logic solver is shorted.

In both cases, the fault condition must be detected by the logic solver in Functional Safety applications. This should also include the detection of power supply failures which cause the output of the isolator to fall to zero mA.

4 Assessment of Functional Safety

4.1 Hardware Safety Integrity

The hardware assessment shows that MTLx541A/MTLx541AS and MTLx544A/MTLx544AS modules:

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

The failure rates of these modules at an ambient temperature of 45°C are as follows:

Failure mode	Failure rate (FIT)*			
	MTL4541A MTL5541A	MTL4541AS MTL5541AS	MTL4544A MTL5544A	MTL4544AS MTL5544AS
Output current >21mA (upscale)	3	3	3	14
Output current <3.6mA (downscale)	224	224	264	253
Output current within range but >2% in error	42	42	49	49
Output current correct within ±2%	73	73	80	81

*(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.
- Stated failure rates for dual-channel modules apply to a single channel.

It is assumed that the module is powered from a nominal 24V dc supply and operating at a maximum ambient temperature of 45°C.

4.2 Systematic Safety Integrity

The MTLx54x modules have a systematic safety integrity measure of SC 2. This has been established using compliance Route 1_S, as described in IEC 61508-2: 2010, section 7.4.2.2 c.

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 SIL 2 in a simplex architecture (HFT=0), provided SFF ≥60% is the case for the application. The hardware safety integrity assessment has been conducted according to compliance Route 1_H, as described in IEC 61508-2:2010, section 7.4.4. (See example below).

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 logic solver will diagnose currents above 21mA and below 3.6mA as faults and take appropriate action

The failure modes shown above can then be defined as:

Failure mode	Category
Output current >21mA (upscale)	Dangerous detected, λ_{dd}
Output current <3.6mA (downscale)	Dangerous detected, λ_{dd}
Output current within range but >2% in error	Dangerous undetected, λ_{du}
Output current correct within ±2%	No effect, λ_{ne}*

The failure rates of the MTL4541A and MTL5541A for these categories are then (FITs):

Model	λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	λ_{ne}*
MTL4541A or MTL5541A	0	0	227	42	73

In this example, the safe failure fraction (SFF) is 84.4%.

*λ_{ne} *is not used in the calculation of SFF. Defining the "output current correct within ±2%" failure mode as* λ_{ne} *represents a conservative approach to the calculation of SFF. Interpreting this failure mode as* λ_{su} *(safe, undetected) may also be considered and yields an SFF value of 87.7%.*

Accordingly, the SFF of all module types described in this manual, when used in the same application, are as follows:

Model	λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	λ_{ne}	SFF
MTL4541A, MTL5541A, MTL4541AS, MTL5541AS	0	0	227	42	73	84.4%
MTL4544A, MTL5544A	0	0	267	49	80	84.5%
MTL5544AS, MTL5544AS	0	0	267	49	81	84.5%

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.

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 MTLx541A/AS and MTLx544A/AS 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 MTLx541A/AS and MTLx544A/AS 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 by Eaton 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 given to the service lifetime for a device of this type, which is in the region of ten years. Operating an MTLx541A/AS and MTLx544A/AS module for longer than this period could invalidate the functional safety analysis, meaning that the overall safety function no longer meets its target SIL. If high failure rates of the MTL modules are detected, indicating that they have entered the 'end of life phase' of their service life, then they should be replaced promptly.

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 61326-1:2013	Electrical equipment for measurement, control and laboratory use – EMC requirements. (Criterion A)
IEC 61326-3-1:2017	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: 2015, Test Specification Number 1.	Specifically vibration: 1.0mm displacement @ 5 to 13.2Hz and
EN 60068-2-27	Environmental testing. Test Ea and guidance. Shock. (Criterion FS)

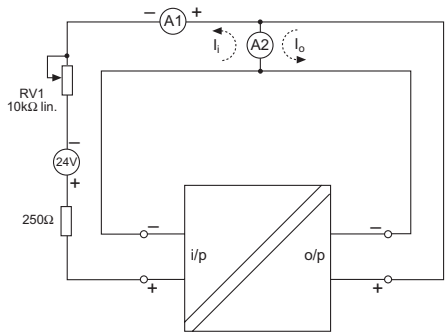
7.2 Appendix B: Proof Test Procedure, MTLx541A/AS, MTLx544A/AS Modules

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.

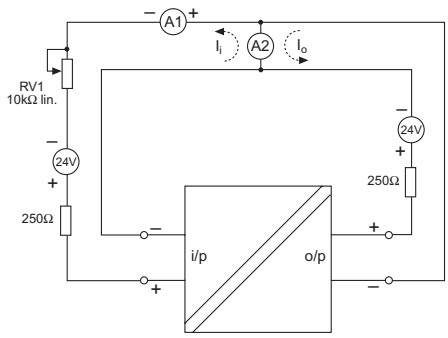
In some applications, the user may prefer to conduct a proof test on the overall safety instrumented function without dismantling or disconnecting the individual instrumentation components, in order to avoid disturbing the integrity of the installation.

However, where it is deemed desirable to perform proof testing on the MTL modules individually, the following procedure may be used. Proof tests of the other components of the loop must then be conducted in accordance with their manufacturers' instructions, to maintain the integrity of the overall safety function. Alternative proof tests may be devised and applied, provided they give a similar level of test coverage that is appropriate to the safety function.

The tests described here - see Figure 7.1 - compare the output current of the MTL isolator 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.



Modules types MTL4541A, MTL4544A, MTL5541A, MTL5544A



Modules types MTL4541AS, MTL4544AS, MTL5541AS, MTL5544AS

Figure 7.1 - Basic test arrangement

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

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 an energised mode. If the module is in a faulty or de-energised loop, restore normal fault-free and energised operation 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 it as shown in Figure 7.2. This figure shows the arrangement for the MTLx541A/AS single-channel modules; for equivalent connections for the MTLx544A/AS dual-channel modules, refer to the relevant product data sheets. Note that it is acceptable to leave the unit in the target system but only after ensuring that the all the hazardous area input and safe area output terminals have been disconnected from the system and are available for test. Alternatively, for the backplane-mounted MTL4500 range modules, a separate backplane can be used to provide access to the power and output connections.

Note that the combination of the 24V power supply and variable resistor RV1 in the hazardous area connection can be provided by a suitable industrial current simulator, which is likely to be more readily available. Also, the 250R resistor does not need to be a precision type; any value in the range 200-300R is acceptable would suffice, such as a standard value of 240R.

Where a second power supply is introduced for testing the MTLx541AS or MTLx544AS module variants, note that both power supplies must be floating and not share a common 0V connection.

During testing, a 24V nominal system power supply in the range 20.0 to 35.0V should be connected between terminals 13 and 14 (+ve to terminal 14).

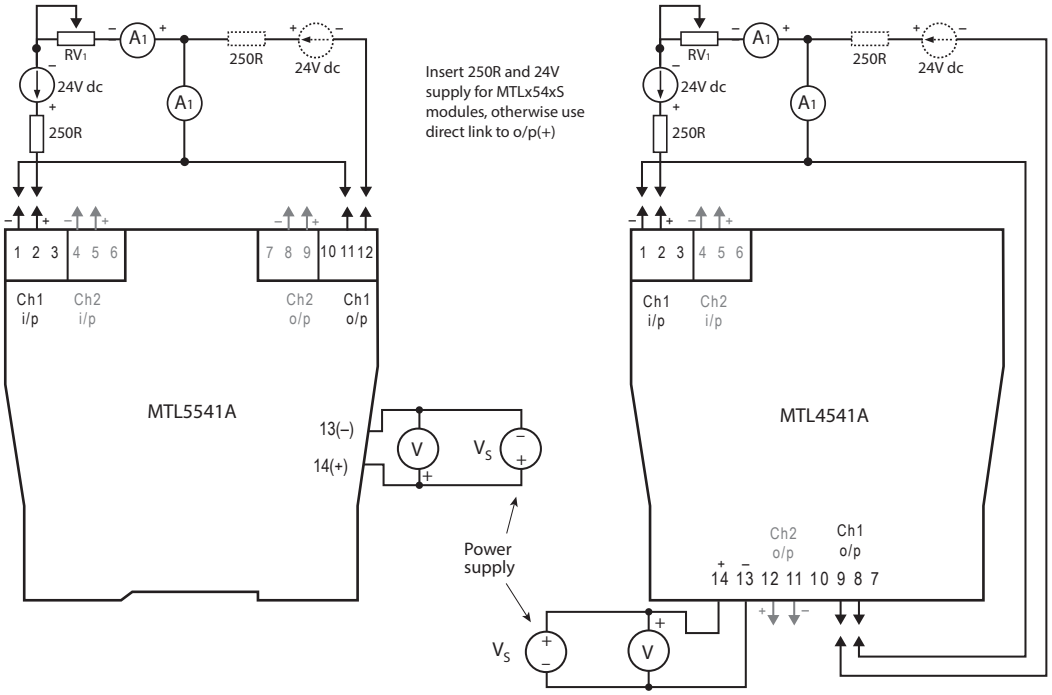


Figure 7.2 - Connections for testing the MTL5541A/AS and MTL4541A/AS modules

Measurements

Make the following measurements. It is recommended to record the results in a table such as that shown on the next page.

1. Adjust resistor RV1 to vary the loop current (measured by Ammeter A1) through the range 4 to 20mA. (Tests 1 - 5 in table)
2. The measured current imbalance (measured by Ammeter A2) over this range should not exceed ±50µA.
3. Adjust RV1 to vary the current (A1) to 3.5mA and then 21.5mA (tests 6 & 7 in table).
4. The measured current imbalance (A2) at these currents should not exceed ±200µA.
5. Record the supply voltage Vs.

If appropriate, repeat these measurements for Channel 2.

3 System - Normal operation test

Disconnect the test setup from the unit and reconnect the original system configuration. Make sure that the tested unit operates normally in the target system, as before, 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 (A2) at loop current (A1) = 4mA		<±50µA
2	Current imbalance (A2) at loop current (A1) = 8mA		<±50µA
3	Current imbalance (A2) at loop current (A1) = 12mA		<±50µA
4	Current imbalance (A2) at loop current (A1) = 16mA		<±50µA
5	Current imbalance (A2) at loop current (A1) = 20mA		<±50µA
6	Current imbalance (A2) at loop current (A1) = 3.5mA		<±200µA
7	Current imbalance (A2) at loop current (A1) = 21.5mA		<±200µA

Channel 2

Test Step#	Description	Actual	Target
1	Current imbalance (A2) at loop current (A1) = 4mA		<±50µA
2	Current imbalance (A2) at loop current (A1) = 8mA		<±50µA
3	Current imbalance (A2) at loop current (A1) = 12mA		<±50µA
4	Current imbalance (A2) at loop current (A1) = 16mA		<±50µA
5	Current imbalance (A2) at loop current (A1) = 20mA		<±50µA
6	Current imbalance (A2) at loop current (A1) = 3.5mA		<±200µA
7	Current imbalance (A2) at loop current (A1) = 21.5mA		<±200µA

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AUSTRALIA
Eaton Electrical (Australia) Pty Ltd,
10 Kent Road, Mascot, New South Wales, 2020, Australia
Tel: +61 1300 308 374 Fax: +61 1300 308 463
E-mail: mtlsalesanz@eaton.com

BeNeLux
MTL Instruments BV
Ambacht 6, 5301 KW Zaltbommel
The Netherlands
Tel: +31 (0)418 570290 Fax: +31 (0)418 541044
E-mail: mtl.benelux@eaton.com

CHINA
Cooper Electric (Shanghai) Co. Ltd
955 Shengli Road, Heqing Industrial Park
Pudong New Area, Shanghai 201201
Tel: +86 21 2899 3817 Fax: +86 21 2899 3992
E-mail: mtl-cn@eaton.com

FRANCE
MTL Instruments sarl,
7 rue des Rosiéristes, 69410 Champagne au Mont d'Or
France
Tel: +33 (0)4 37 46 16 53 Fax: +33 (0)4 37 46 17 20
E-mail: mtlfrance@eaton.com

GERMANY
MTL Instruments GmbH,
Heinrich-Hertz-Str. 12, 50170 Kerpen, Germany
Tel: +49 (0)22 73 98 12 - 0 Fax: +49 (0)22 73 98 12 - 2 00
E-mail: csckerpen@eaton.com

INDIA
MTL India,
No.36, Nehru Street, Off Old Mahabalipuram Road
Sholinganallur, Chennai - 600 119, India
Tel: +91 (0) 44 24501660 /24501857 Fax: +91 (0) 44 24501463
E-mail: mtlindiasales@eaton.com

ITALY
MTL Italia srl,
Via San Bovio, 3, 20090 Segrate, Milano, Italy
Tel: +39 02 959501 Fax: +39 02 95950759
E-mail: chmninfo@eaton.com

JAPAN
Cooper Crouse-Hinds Japan KK,
MT Building 3F, 2-7-5 Shiba Daimon, Minato-ku,
Tokyo, Japan 105-0012
Tel: +81 (0)3 6430 3128 Fax: +81 (0)3 6430 3129
E-mail: mtl-jp@eaton.com

NORWAY
Norex AS
Fekjan 7c, Postboks 147,
N-1378 Nesbru, Norway
Tel: +47 66 77 43 80 Fax: +47 66 84 55 33
E-mail: info@norex.no

RUSSIA
Cooper Industries Russia LLC
Elektrozavodskaya Str 33
Building 4
Moscow 107076, Russia
Tel: +7 (495) 981 3770 Fax: +7 (495) 981 3771
E-mail: mtlrussia@eaton.com

SINGAPORE
Eaton Electric (Singapore) Pte Ltd
100G Pasir Panjang Road
Interlocal Centre
#07-08 Singapore 118523
#02-09 to #02-12 (Warehouse and Workshop)
Tel: +65 6 645 9888 ext 9864/9865
Fax: +65 6 645 9811
E-mail: sales.mtlsing@eaton.com

SOUTH KOREA
Cooper Crouse-Hinds Korea
7F. Parkland Building 237-11 Nonhyun-dong Gangnam-gu,
Seoul 135-546, South Korea.
Tel: +82 6380 4805 Fax: +82 6380 4839
E-mail: mtl-korea@eaton.com

UNITED ARAB EMIRATES
Cooper Industries/Eaton Corporation
Office 205/206, 2nd Floor SJ Towers, off. Old Airport Road,
Abu Dhabi, United Arab Emirates
Tel: +971 2 44 66 840 Fax: +971 2 44 66 841
E-mail: mtlgulf@eaton.com

UNITED KINGDOM
Eaton Electric Ltd,
Great Marlings, Butterfield, Luton
Beds LU2 8DL
Tel: +44 (0)1582 723633 Fax: +44 (0)1582 422283
E-mail: mtlenquiry@eaton.com

AMERICAS
Cooper Crouse-Hinds MTL Inc.
3413 N. Sam Houston Parkway W.
Suite 200, Houston TX 77086, USA
Tel: +1 281-571-8065 Fax: +1 281-571-8069
E-mail: mtl-us-info@eaton.com

Powering Business Worldwide

Eaton Electric Limited,
Great Marlings, Butterfield, Luton
Beds, LU2 8DL, UK.
Tel: + 44 (0)1582 723633 Fax: + 44 (0)1582 422283
E-mail: mtlenquiry@eaton.com
www.eaton.com

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EUROPE (EMEA):
+44 (0)1582 723633
mtlenquiry@eaton.com

THE AMERICAS:
+1 800 835 7075
mtl-us-info@eaton.com

ASIA-PACIFIC:
+65 6 645 9888
sales.mtlsing@eaton.com

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