

MTL4500/MTL5500 range

Analogue Input Modules



MTLx541, MTL4541Y, MTLx541S, MTLx544, MTLx544S,
MTLx544D



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 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 IEC61508:2010 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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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
MTL4541, MTL4541Y MTL5541, MTL4544, MTL5544, MTL4541S, MTL5541S, MTL4544S, MTL5544S, MTL4544D, MTL5544D	



† These modules have an inherent fault tolerance of 0.
Duplication of modules in a voting architecture may be used to achieve HFT=1

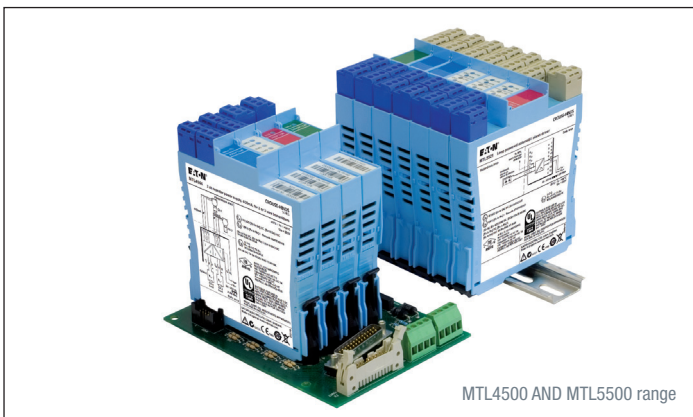
1 INTRODUCTION

1.1 Application and function

The analogue input modules, MTLx541 (single channel) and MTLx544 (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 SIL3, without hardware redundancy.

Each module provides a fully-floating dc supply for energising conventional 2-wire or 3-wire 4-20mA process transmitters while repeating the current flowing in the field loop into another floating circuit to drive the safe area load. The MTLx544D repeats the current flowing in a single field loop into two isolated safe area loads. For 'smart' 2-wire transmitters 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.

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 1-3, and 4-6) are made through the removable blue connectors, 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 the DIN-rail mounting models.

The analogue input models covered by this manual are:

MTL4541 and MTL5541	Single channel, safe area current source
MTL4544 and MTL5544	Dual channel, safe area current source
MTL4541S and MTL5541S	Single channel, safe area current sink
MTL4544S and MTL5544S	Dual channel, safe area current sink
MTL4544D and MTL5544D	Single channel, two safe area current source outputs

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.

Note: The MTL4541B and MTL4544B are versions of the standard MTL4541 and MTL4544 respectively, which have the negative terminal of the safe area current output(s) internally connected to the negative terminal of the power supply. This simplifies replacement of older MTL4041B and MTL4044 items. For functional safety applications the assessment for the MTL4541B is the same as for the MTL4541, and that for the MTL4544B is the same as for the MTL4544.

All the analogue input modules have the same connectivity for the field signals, supporting two- and three-wire process transmitters, as well as accepting signals from separately powered current sources. 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 SIS.

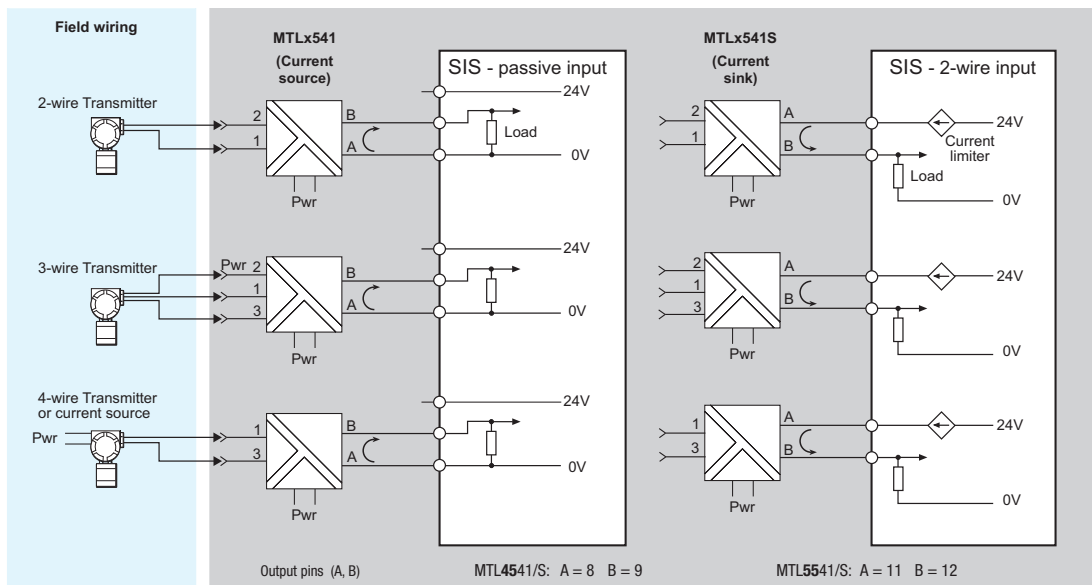
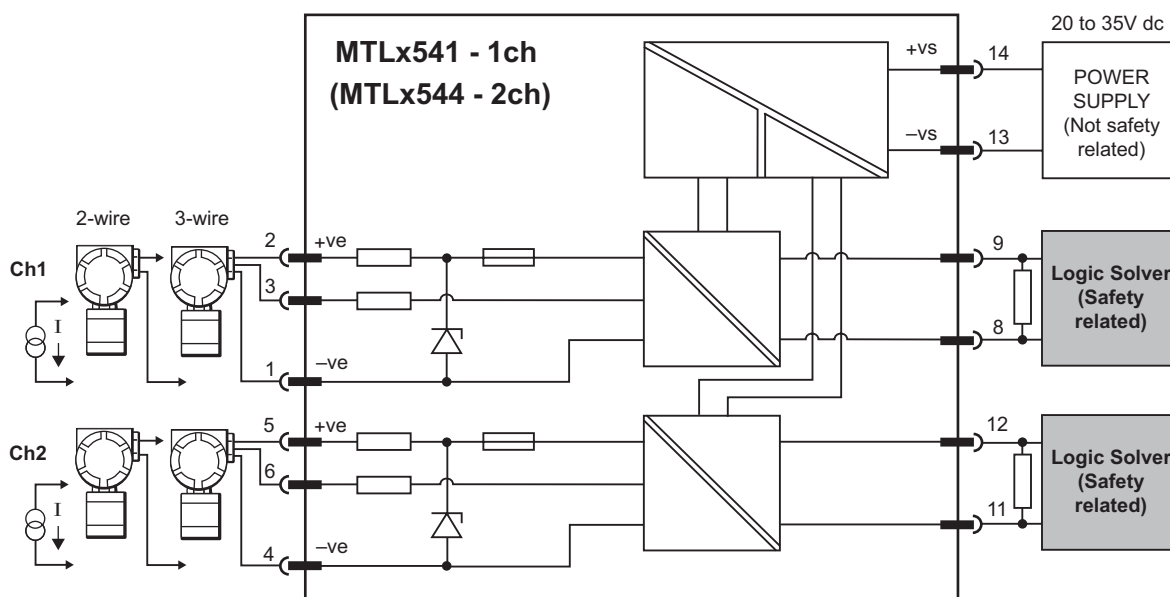


Figure 1.1 – Analogue Input Connections

2 System configuration

An MTLx54x module may be used in single-channel (1oo1) safety functions up to SIL3. The worked example in this manual is for a SIL3 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.



The MTLx54x modules are designed to power 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 MTLX544 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. A similar concern applies to the MTLX544D where only one of the output channels can be used in a safety loop, not both channels.

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 MTLx54x module is a component 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 verified for use in functional safety applications.

The instrumentation or control equipment shall have a current input with a normal operating range of 4-20mA but be capable of working over the extended range of 3 to 22mA for under- and over-range. It shall have the ability to detect and signal input currents higher than the threshold of 21mA and lower than the threshold of 3.6mA to determine out-of-range conditions.

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 240ohms.

3 Selection of product and implications

The output signal from the MTLx54x 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 is short-circuit then the loop current will rise to a value greater than 21mA.

For the modules that source the current in the safe area circuit, i.e. MTLX541/44/44D, then if the connection between the isolator and logic solver is shorted, the current seen by the logic solver will be less than 3.6mA and close to zero. For the MTLX541S/44S modules that control the current supplied by the logic solver input, if the connection between the isolator and logic solver is shorted, the current seen by the logic solver will rise to a value greater than 21mA. In both cases, the fault condition should be detected by the logic solver. This includes power supply failures which cause the output of the isolator to fall to zero mA.

Using a process transmitter 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. The transfer of HART communications through the isolator is not considered as part of the safety function of the isolator.

4 Assessment of Functional Safety

4.1 Hardware Safety Integrity

The hardware assessment shows that MTLx54x Repeater Power Supplies:

- 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 definitions for product failure of the modules at an ambient temperature of 45°C are as follows:-

Failure mode	Failure rate (FIT)				
	MTLx541/Y	MTLx541S	MTLx544	MTLx544S	MTLx544D
Output current >21mA (upscale)	7	16	7	16	7
Output current <3.6mA (downscale)	203	210	238	243	227
Output current within range but >2% in error	17	19	20	21	22
Output current correct within ±2%	116	120	131	141	153

(FITs means failures per 10⁹ 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 3.

Note: *Earlier versions of this manual (Revisions 1 and 2) inferred a systematic safety integrity for MTLx54x 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 MTLx54x 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 SIL3 in a simplex architecture (HFT=0), provided SFF ≥ 90% is the case for the application. (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 PF_{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 MTLx541 for these categories are then (FITs):

Model	λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	λ_{ne}
MTL4541 or MTL5541	0	0	210	17	116

In this example, the safe failure fraction (SFF) is 92.5%.

* λ_{ne} is not used in the calculation of SFF. Defining the "output current correct within $\pm 2\%$ " 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 95%.

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

Model	λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	λ_{ne}	SFF
MTLx541/Y	0	0	210	17	116	92.5%
MTLx541S	0	0	226	19	120	92.2%
MTLx544	0	0	245	20	131	92.5%
MTLx544S	0	0	259	21	141	92.5%
MTLx544D	0	0	234	22	153	91.4%

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 $+60^{\circ}\text{C}$, 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 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

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
IEC 61511 Ed. 2	Functional safety - Safety instrumented systems for the process industry sector
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
EN 60068-2-27	Environmental testing. Test Ea and guidance. Shock. (Criterion FS)

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

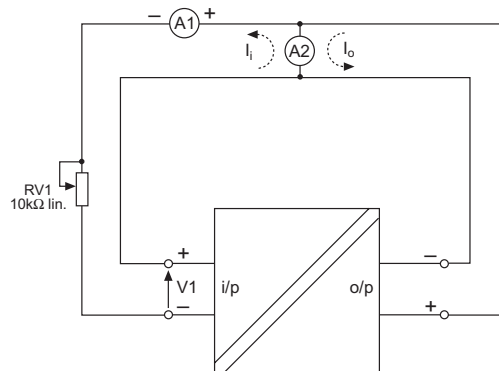
Confirmation, through testing, that a safety function will operate as designed, is a necessary periodic activity to ensure that the probability of failure upon demand (PFD_{avg}) is maintained.

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.

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 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 appropriate, in the manner shown in Figure 7.2. Please note, that it is also acceptable to leave the unit in the target system but only after ensuring that the terminals 1, 2, 3, 8 and 9 or 11 and 12 are disconnected from the system and available for test. Alternatively, for the backplane mounted MTL4500 range modules, a separate backplane can be used 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).

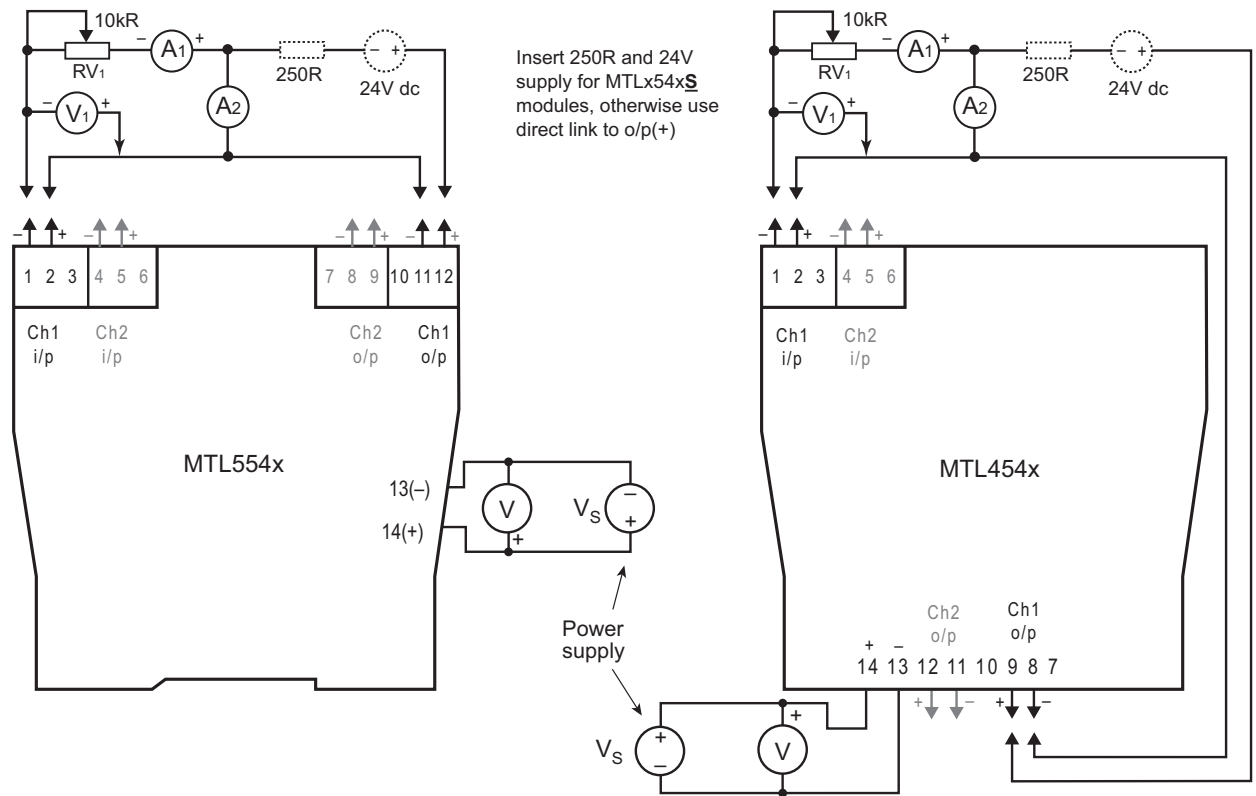


Figure 7.2- Connections for testing the MTL554x and MTL454x modules

Measurements

Note: do not connect the voltmeter (V1 in Figure 7.2) across the module input terminals until requested in step 6 below, otherwise

the current measurements may be affected.

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

1. Adjust resistor RV1 to vary the current (A1) through the range 4 to 20mA. (Tests 1- 5 in table)
2. The measured current imbalance (A2) over this range should not exceed $\pm 50\mu\text{A}$.
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 $\pm 200\mu\text{A}$
5. Adjust RV1 for a 20mA current reading on A1. (Test 8 in table)
6. The voltage V1 measured across the channel input should be $\geq 16.5\text{V}$.
7. Record the supply voltage V_s .

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 V_s : _____ V dc

Module type: _____

Serial No: _____

Channel 1

Test #	Description	Actual	Target
1	Current imbalance (A_2) at loop current (A_1) = 4mA		< $\pm 50\mu A$
2	Current imbalance (A_2) at loop current (A_1) = 8mA		< $\pm 50\mu A$
3	Current imbalance (A_2) at loop current (A_1) = 12mA		< $\pm 50\mu A$
4	Current imbalance (A_2) at loop current (A_1) = 16mA		< $\pm 50\mu A$
5	Current imbalance (A_2) at loop current (A_1) = 20mA		< $\pm 50\mu A$
6	Current imbalance (A_2) at loop current (A_1) = 3.5mA		< $\pm 200\mu A$
7	Current imbalance (A_2) at loop current (A_1) = 21.5mA		< $\pm 200\mu A$
8	Input voltage (V_1) at loop current (A_1) = 20mA		$\geq 16.5V$

Channel 2

Test Step#	Description	Actual	Target
1	Current imbalance (A_2) at loop current (A_1) = 4mA		< $\pm 50\mu A$
2	Current imbalance (A_2) at loop current (A_1) = 8mA		< $\pm 50\mu A$
3	Current imbalance (A_2) at loop current (A_1) = 12mA		< $\pm 50\mu A$
4	Current imbalance (A_2) at loop current (A_1) = 16mA		< $\pm 50\mu A$
5	Current imbalance (A_2) at loop current (A_1) = 20mA		< $\pm 50\mu A$
6	Current imbalance (A_2) at loop current (A_1) = 3.5mA		< $\pm 200\mu A$
7	Current imbalance (A_2) at loop current (A_1) = 21.5mA		< $\pm 200\mu A$
8	Input voltage (V_1) at loop current (A_1) = 20mA		$\geq 16.5V$

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