January 2020
SM5314 rev 1

MTL5314 Trip amplifier

4/20mA, for 2- or 3-wire transmitters

SIL 2 *

FSM FUNCTIONAL SAFETY MANAGEMENT IEC 61508:2010

FUNCTIONAL SAFETY MANAGEMENT

This product is for use as an element within a Safety System conforming to the requirements of IEC 61508: 2010 and enables 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 specific operating conditions. Refer to content of this manual for details.

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Powering Business Worldwide

Trip Amplifier for 2- or 3-wire transmitters

Contents

This manual supports the application of the product in functional-safety related loops. It must be used in conjunction with other supporting documents to achieve correct installation, commissioning and operation. Specifically, the product data sheet, instruction manual and applicable certificates for the 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**
MTL4541	SIL 2

† This module has an inherent fault tolerance of 0.

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1 INTRODUCTION

1.1 Application and function

The Trip Amplifier module type MTL5314 is intended for use with intrinsically safe 4-20mA process measuring instruments located in a hazardous area of a process plant. It is also designed and assessed according to IEC 61508: 2010 for use in safety instrumented systems up to SIL 2.

The MTL5314 connects to a 2- or 3-wire 4-20mA intrinsically safe transmitter located in the hazardous area. It can also receive a 4-20mA signal from an intrinsically safe current source, such as the output from a 4-wire process instrument. The module provides one or two configurable alarm signals to the non-hazardous (safe) area via changeover relays. Each relay may be configured individually to signal an alarm condition (relay de-energised) when the input signal from the transmitter or current source is greater than or less than a pre-set value.

The trip-points are adjusted by the user via multiturn potentiometers accessible on the top of the unit. Switches on top of the unit also set whether the trip-points are 'High trip' or 'Low trip'. The module is a member of the MTL5000 range of products, and is intended for mounting within a secure equipment cabinet on 35mm DIN rail complying with EN 50022. Electrical connections to the module are made via pluggable connectors on the top and side of the module.

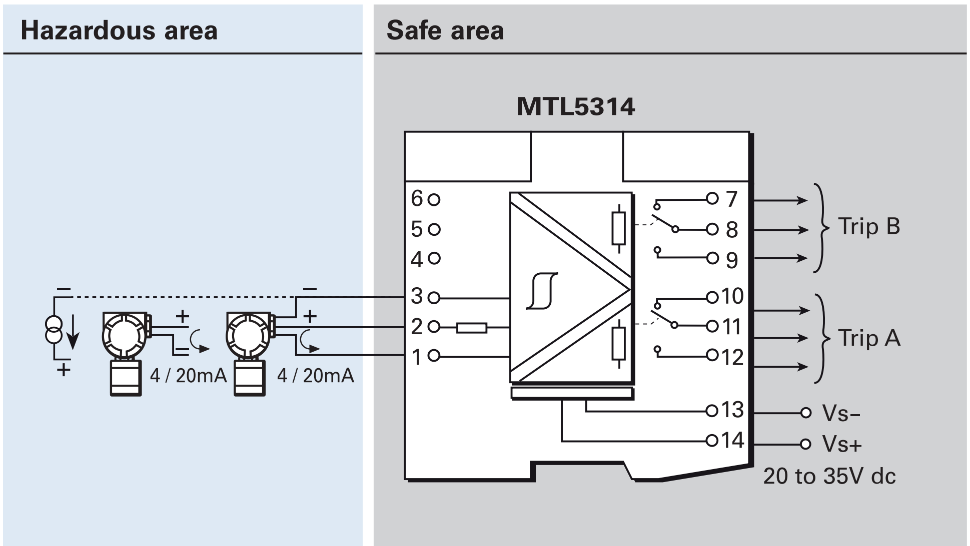
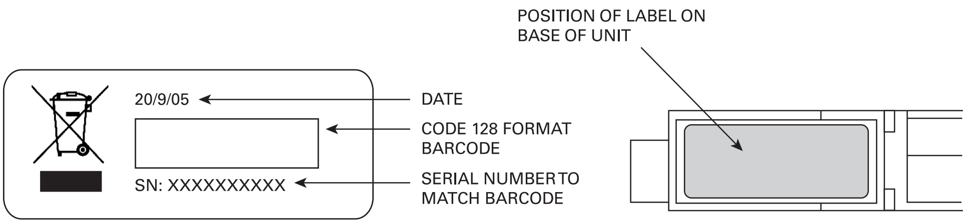


Figure 1.1- Input and Output connections

1.2 Product build information covered by this manual

The information provided in this manual is valid for all product build revisions having a product build label as shown below. This is found on the underside of the product.



Example: MTwwyyzzzzzzz

ww	=	week
yy	=	year
z	=	7 digit serial number

2 SYSTEM CONSIDERATIONS

2.1 Permitted configurations

This manual describes two different configurations in which the MTL5314 may be used in functional safety applications:

a) The MTL5314 is used in a "stand-alone" mode, in which the hazardous area terminals are connected to a 4-20mA transmitter or current source, and the non-hazardous relay terminals are connected to a digital input card in a Logic Solver or to an alarm sounder or beacon that is part of the Safety Instrumented System. No other apparatus is connected into the 4-20mA current loop on the hazardous area side of the module.

b) The MTL5314 is used in conjunction with an Analogue Input module, which transfers the 4-20mA signal to the non-hazardous area for connection to receiving equipment that is not part of the Functional Safety system. In this configuration, the hazardous area input terminals of the Analogue Input module are connected in series with the 4-20mA loop current being passed by the transmitter, but power for the loop is provided by the MTL5314. The non-hazardous terminals of the MTL5314 are connected to a digital input card in a Logic Solver or to an alarm sounder or beacon that is part of the Safety Instrumented System.

These options are shown in Figure 2.0 (a) and Figure 2.0 (b), and are described in more detail in Section 3 of this manual. The diagrams show the safety-rated and non-safety related system components, and are intended to support an understanding of the application.

In both configurations, the MTL5314 module may be used in single-channel (1oo1) safety functions up to SIL 2.

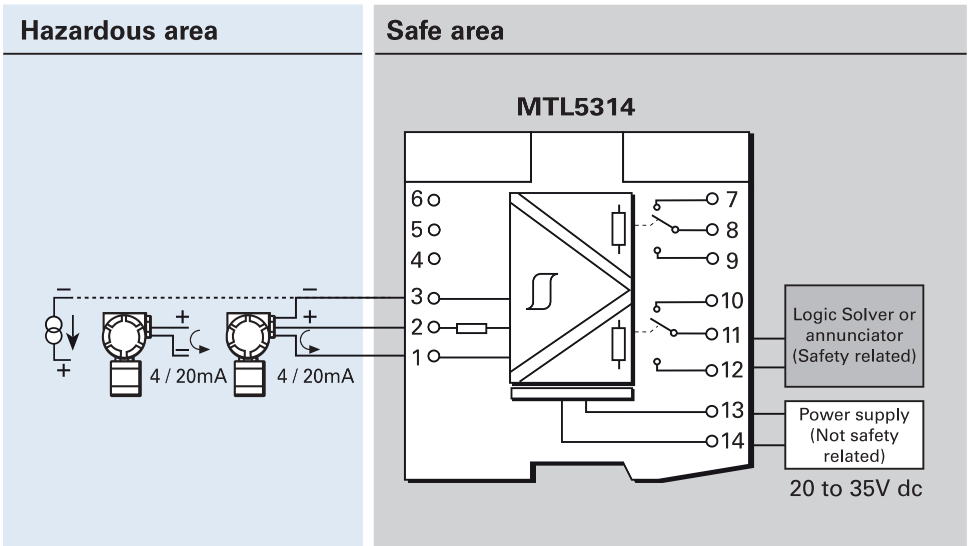


Figure 2.0 (a) - System Configuration: Stand-alone Trip function mode
(Logic Solver shown connected to Trip A)

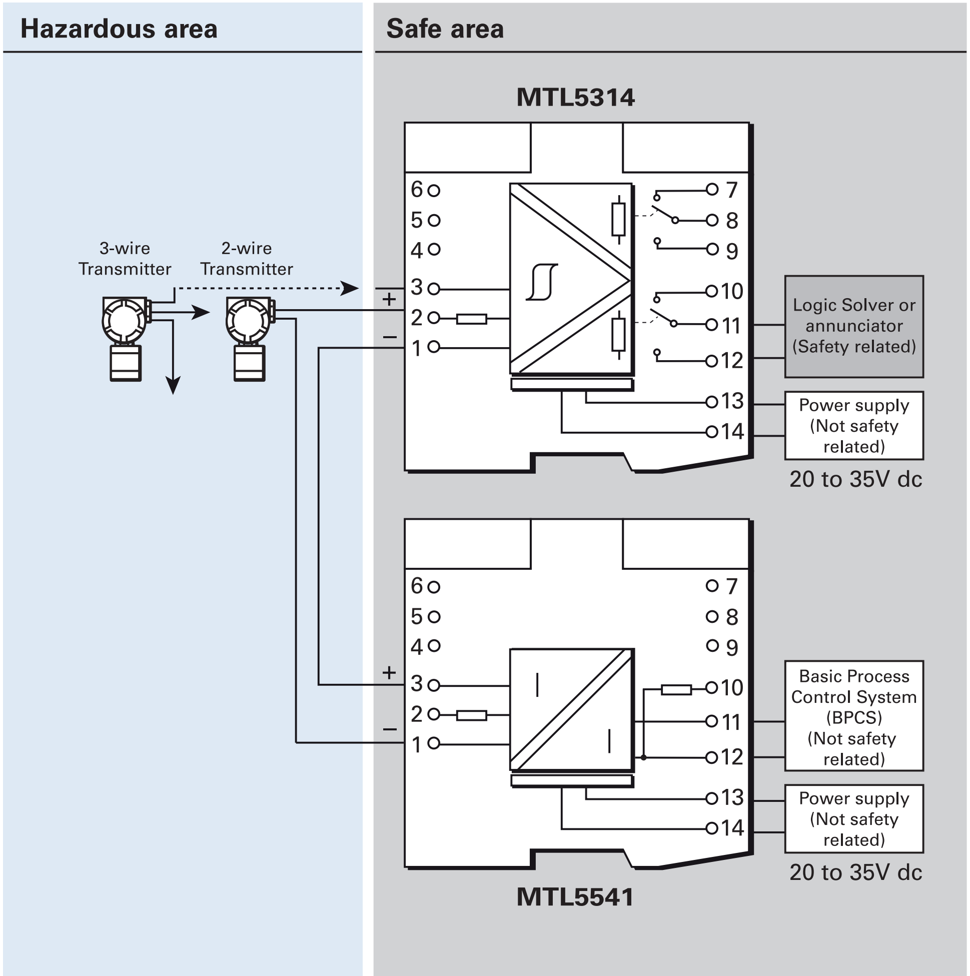


Figure 2.0 (b) - System Configuration: Trip function with 4-20mA current repeated to non-hazardous area (Logic Solver shown connected to Trip A)

The shaded areas in each diagram 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 Trip Amplifier output.

2.2 Associated System Components

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

In Functional Safety applications, the MTL5314 Trip Amplifier module provides an interface between a safety-related process transmitter and a safety-related control system. The transmitter must be suitable for the process conditions and have been assessed and independently verified for use in a Safety Instrumented Function. The process transmitter shall have a normal operating range of 4-20mA but shall ideally be capable of working over an extended range of 3 to 22mA to allow for applications where the trip points are set outside the nominal range.

The Digital Input card in the Logic Solver shall have the ability to detect the status of the relays in the MTL5314 module. Although the MTL5314 module can be configured to provide two independent alarms, each of which can be set as a high or low trip point, the safety analysis presented in this manual assumes that only one trip output is used in the Safety Instrumented Function, meaning that the MTL5314 is set to trip either on a low input signal (Low Trip application) or on a high input signal (High Trip application).

3 SELECTION OF PRODUCT AND IMPLICATIONS

3.1 Stand-alone Trip function mode

In this mode of operation, the MTL5314 Trip Amplifier forms part of a high- or low-level Safety Instrumented Function (SIF), using the 4-20mA output from a field transmitter that is measuring a process variable such as pressure, temperature, flow or level. Refer to Figure 2.0 (a). The MTL5314 provides a single alarm trip to a Logic Solver, using the Trip A or Trip B relay connections. The 'Normally open' relay contacts must be used (ie terminals 11 & 12 for Trip A or terminals 8 & 9 for Trip B); this ensures that the SIF fails to a safe condition if the wiring between the Logic Solver and relay contacts is broken, or if power to the MTL5314 is lost.

In most applications, the trip point will be set within the nominal 4-20mA range. However, if the trip point is set outside this range but within the 0.5 to 22mA range of the MTL5314, care must be taken to ensure that the process transmitter is capable of reaching the trip value.

Use of the MTL5314 in two separate Safety Instrumented Functions (for example with Trip A set as a High Alarm and Trip B set as a Low Alarm) is permissible only where special consideration has been given to common-cause failures that may affect both SIFs. The second trip relay may however be used to provide a non safety-related input to the basic process control system.

3.2 Trip function with 4-20mA current repeated to non-hazardous area

In this mode of operation, an MTL 4-20mA Analogue Input module is used in addition to the MTL5314, to transfer the hazardous area loop current to receiving equipment in the non-hazardous area, as described in Figure 2.0 (b). The MTL5314 trip function continues to act on the loop current, and to communicate the pre-configured alarm conditions to the Logic Solver. The requirements stated below apply in addition to those in 3.1 above.

The MTL Analogue Input module is declared as "Non-interfering" in respect of the Safety Instrumented Function that comprises the field instrument, MTL5314 Trip Amplifier and Logic Solver.

The MTL Analogue Input module must be one of the following types in the MTL4500 or MTL5500 ranges:

- MTLx541
- MTLx541S
- MTLx544
- MTLx544S
- MTLx541
- MTLx541S
- MTLx544
- MTLx544S

In order to ensure that the Alarm Trip Safety Instrumented Function continues to operate in the event that the power supply to the MTL Analogue Input isolator fails, the user must ensure that the transmitter voltage available from the MTL5314 (stated in the product data sheet as >17V @ 20mA) is at least 1.5V greater than the total voltage developed across the transmitter and associated field wiring at 20mA.

The Analogue Input module must not itself be part of a Safety Instrumented Function. Its non-hazardous 4-20mA output signal may be part of the basic process control system, but must not be used as part of the Safety Instrumented System. Note that HART communications are not supported on the 4-20mA signal.

Note:

- The MTL5314 is capable of operating in conjunction with MTL Analogue Input modules (such as MTL5541) that provide power for the hazardous area current loop, where the MTL5314 is connected in series with the process transmitter. This configuration also provides a means of transferring the loop current to the non-hazardous area in addition to the trip alarms, and is shown in other MTL documentation such as the MTL5314 product data sheet. However, this configuration is different to that described in 2.1 above, and has not been assessed for Functional Safety applications.

4 ASSESSMENT OF FUNCTIONAL SAFETY

4.1 Hardware Safety Integrity

The hardware safety integrity stated in this manual is drawn from a Failure Modes, Effects and Diagnostic Analysis (FMEDA) for the MTL5314 Trip Amplifier, conducted on behalf of Eaton-MTL by Exida (Exida report no. MTL 05/05-26 R007, version V1, revision R1). Minor amendments have been made in this manual where appropriate, to ensure that the calculation of Safe Failure Fraction (SFF) is in compliance with IEC 61508-2: 2010.

The hardware assessment shows that MTL5314 module:

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

The failure rates derived by the FMEDA for the MTL5314 are stated as FITs (failures per 10^9 hours, or failures per thousand million hours) in the table below:

Model	λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	λ_{ne*}	SFF
MTL5314, Low Trip	0	156	0	50	165	75.7%
MTL5314, High Trip	0	151	0	56	165	72.9%

The Safe Failure Fraction (SFF) shown in the table is calculated as $(\lambda_{dd} + \lambda_{sd} + \lambda_{su}) / (\lambda_{du} + \lambda_{dd} + \lambda_{sd} + \lambda_{su})$, and stated as a percentage.

For both trip modes, the calculated SFF is between 60 and 90%, and therefore meets the requirements for SIL 2 according to Table 2 of IEC 61508-2: 2010, for a hardware fault tolerance of 0.

*** Note** that "No-effect" failures (λ_{ne}) are not used in the calculation of SFF. No-effect failures are defined in IEC 61508-4: 2010 as failures of elements (or components) that are part of the safety function but have no effect on the safety function.

4.2 Assumptions

The following assumptions have been made during this analysis:

- The fail safe state is defined as the alarm relay in the MTL5314 being de-energised.
- Only one trip output is used in the Safety Instrumented Function.
- A single failure will fail the entire product.
- Failure rates are constant; wear-out mechanisms are not considered.
- Propagation of failures is not relevant.
- All components that are not part of the safety function and cannot influence the safety function are excluded.
- The stress levels are typical for an industrial environment and can be compared to the Ground Fixed classification of MIL-HDBK-217F. This is similar to Class C (sheltered location) as defined in IEC 60654-1, with temperature and humidity levels within those stated in the product data sheet and Section 4.6 of this manual, and an average long-term temperature of 40°C.
- The module is powered from a nominal 24V dc supply.
- Power supply failure rates are not considered.

4.3 Systematic Safety Integrity

The MTL5314 module has 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.

4.4 SIL Capability

Considering both the hardware safety integrity and the systematic capability, this allows the module to be used in safety functions up to SIL 2 in a simplex architecture (HFT=0). 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.

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 PFDavg (for a low demand safety function) for the SIL is met.

4.5 EMC

The MTL5314 module is designed for operation in normal industrial electromagnetic environment but, to support good practice, the module should be mounted without being subjected to undue conducted or radiated interference. See Appendix A for applicable standards and levels.

4.6 Environmental

The MTL5314 module is designed for operation over the temperature range from-20°C to +60°C, and at up to 95% non-condensing relative humidity.

The module is intended to be mounted in a normal industrial environment without excessive vibration, as specified for the MTL5500 product range. 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 aspects of safety that must be considered when installing the MTL5314 module. These are:

- Functional safety
- Intrinsic safety

To comply with intrinsic safety requirements, reference should be made to the relevant sections in the instruction manual INM5500, which is available to download from the Eaton-MTL website. In many countries there are also specific codes of practice and industry guidelines, which must also be adhered to.

Provided that these installation requirements are followed then there are no additional environmental 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 mounting location should provide equivalent protection such as inside an equipment cabinet.

6 MAINTENANCE

To follow the guidelines relating 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 performed at least once every three years.

Refer to Appendix B for the proof testing procedure for the MTL5314 module.

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

If an MTL5314 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 Eaton-MTL office. Where appropriate, a Customer Incident Report (CIR) will be notified by Eaton to enable the unit to be returned to the factory for analysis. If the unit is within the warranty period and the failure is due to defective components or manufacture, 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 MTL5314 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 module are detected in service, 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: 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)

Note that other standards are referenced in Exida report no. MTL 05/05-26 R007, version V1, revision R1, which was used for the derivation of failure rates used in this manual.

7.2 Appendix B : Proof Test Procedure, MTL5314 Module

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.

Observe normal anti-static precautions when handling equipment during device testing. Remove the MTL5314 from the target system and observe the following test sequence:

1. Select a variable current source or sink, according to which is most representative of the actual field device in the Safety Instrumented Function. A current sink is representative of typical 2 or 3-wire field transmitters, whereas a current source is representative of the 4-20mA output from 4-wire transmitters. The current source or sink should have a traceable calibration history.

2. Set the current source or sink to 12.0mA, and connect it to the appropriate input terminals on the MTL5314 module as shown in Figure 7.2.

3. Adjust the trip potentiometers on the top of the MTL5314 module for Alarms A and B in turn, until the associated LEDs just extinguish.

4. Set the current source or sink to 11.5mA

5. Using the switches on top of the module, set both Alarms to 'Low Alarm'.

6. Confirm that the LEDs and alarm relays comply with the status shown in 'Low Alarm' column of the table below. A multi-meter set to a low ohms range can be used to check that the relays are open or closed.

7. Set both Alarms to 'High Alarm', and confirm that the LEDs and alarm relays comply with the status shown in the 'High Alarm' column of the table.

8. Set the current source or sink to 12.5mA and repeat steps 5 to 7.

<table>
<tr><th rowspan="5">Current</th><th colspan="3">High Alarm</th><th colspan="3">Low Alarm</th></tr>
<tr><th rowspan="4">LEDs</th><th colspan="2">Alarm A</th><th rowspan="4">LEDs</th><th colspan="2">Alarm A</th></tr>
<tr><th>Terminals 11 - 12</th><th>Terminals 10 - 11</th><th>Terminals 11 - 12</th><th>Terminals 10- 11</th></tr>
<tr><th colspan="2">Alarm B</th><th colspan="2">Alarm B</th></tr>
<tr><th>Terminals 8- 9</th><th>Terminals 7- 8</th><th>Terminals 8- 9</th><th>Terminals 7- 8</th></tr>
<tr><td>11.5mA</td><td>on</td><td>closed</td><td>open</td><td>off</td><td>open</td><td>closed</td></tr>
<tr><td>12.5mA</td><td>off</td><td>open</td><td>closed</td><td>on</td><td>closed</td><td>open</td></tr>
</table>

continued

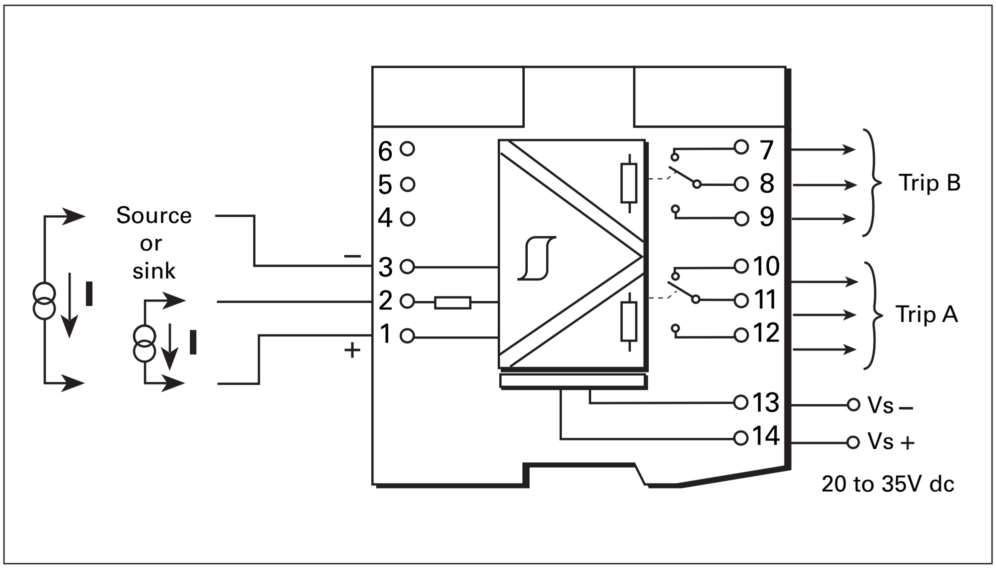


Figure 7.2 - Connections for testing MTL5314 module

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