D5290-078

SIL3 Relay Out Module for 5 A NE/ND Loads

Models D5290-078

INSTRUCTION AND SAFETY MANUAL

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SUMMARY OF CONTENT

1. CHARACTERISTICS

General Description:
The D5290S-078 is a relay module suitable for the switching of safety related circuits, up to SIL 3 level according to IEC 61508:2010 Ed. 2 for high risk industries. It provides isolation between input channel and output contacts.
Three mutually exclusive (by DIP-Switch programming) monitoring circuits are provided:

- line input monitoring, to allow DCS/PLC line monitoring function: when enabled, the module permits a wide compatibility towards different DCS/PLC. Driving line pulse testing, executed by DCS/PLC, is permitted by a dedicated internal circuit, to prevent relay and LED flickering.
- low voltage input monitoring: when enabled, the module reflects a high impedance state to the control unit when the driving voltage is below the specified threshold.
- short circuit fault detection (only for Functional Safety applications with NE Relay condition): when enabled, it allows DCS/PLC to detect short circuit fault of module.

This relay module is not suitable for low-current consumption applications (system-to-system signalling, driving LEDs, etc.).
See the following pages for Functional Safety applications with related SIL value.

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Mounting on standard DIN-Rail or on customized Termination Boards, in Safe Area / Non Hazardous Location or in Zone 2 / Class I, Division 2 or Class I, Zone 2.

Functional Safety Management Certification:
G.M. International is certified by TUV to conform to IEC61508:2010 part 1 clauses 5-6 for safety related systems up to and included SIL3.

2. TECHNICAL DATA

Input: 24 Vdc nom (21.6 to 27.6 Vdc) reverse polarity protected, ripple within voltage limits ≤ 5 Vpp.

The following monitoring circuits are mutually exclusive:

1) Line input monitoring (DIP-Switch selectable): to allow DCS/PLC line monitoring function (pulse test).

2) Voltage monitoring (DIP-Switch selectable): ≥ 21.6 Vdc for normal operation, ≤ 17 Vdc reflects a high impedance (≤ 10 mA consumption) to the control device.

3) Short circuit fault detection (DIP-Switch selectable and only for Functional Safety applications with NE Relay condition): to allow DCS/PLC to detect short circuit fault of module.

Current consumption @ 24 V: 60 mA with relay energized, typical.

Power dissipation: 1.5 W with 24 V input voltage, relay energized, typical.

Isolation (Test Voltage): Input / All Outputs: 2.5 KV; Out S_1 & Out P_1 / Out S_3 & Out P_2, Out S_2, Out S_4: 500 V; Out S_3 & Out P_2 / Out S_2, Out S_4: 500 V; Out S_2 / Out S_4: 500 V.

Output: 2 voltage free SPDT (= NO contact + parallel of 2 NC contacts) relay contacts identified with outputs: Out S_1 & Out P_1 and Out S_3 & Out P_2;
2 voltage free SPST (NO) relay contacts identified with: Out S_2 and Out S_4.

Terminals 13-14 (Out S_1), 15-16 (Out S_2), 21-22 (Out S_4) and 23-24 (Out S_3) are: open when relay is de-energized, closed in energized relay condition.
Terminals 17-18 (Out P_1) and 19-20 (Out P_2) are: closed when relay is de-energized, open in energized relay condition.

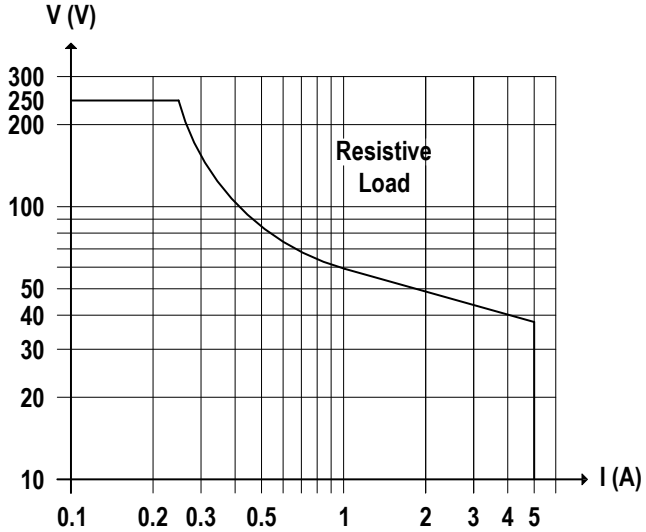
Contact material: Ag Alloy (Cd free) or $AgSnO_2$.

Contact rating: 5 A 250 Vac 1250 VA, 5 A 250 Vdc 175 W (resistive load).

Contact inrush current: 8 A at 30 Vdc, 250 Vac.

Contact min. switching current: 100 mA.

DC Load breaking capacity:



Mechanical / Electrical life: 10 * 10^6 / 5 * 10^4 operation, typical.

Operate / Release time: 55 / 25 ms, typical.

Frequency response: 10 Hz maximum.

Compatibility:

CE mark compliant, conforms to Directive: 2014/34/EU ATEX, 2014/30/EU EMC, 2014/35/EU LVD, 2011/65/EU RoHS.

Environmental conditions:

Operating: temperature limits - 40 to + 60 °C, relative humidity 95 %, up to 55 °C.

Storage: temperature limits - 45 to + 80 °C.

Max altitude: 2000 m a.s.l.

Safety Description:

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ATEX: II 3G Ex ec nC IIC T4 Gc
IECEx / INMETRO: Ex ec nC IIC T4 Gc
FM: NI / I / 2 / ABCD / T4, I / 2 / AEx nA nC / IIC / T4
FMC: NI / I / 2 / ABCD / T4, I / 2 / Ex nA nC / IIC / T4
EAC-EX: 2Ex ec nC IIC T4 Gc X.
CCC: Ex ec nC IIC T4 Gc
PESO: Ex ec nC IIC T4 Gc
non-sparking electrical equipment. -40 °C ≤ Ta ≤ 60 °C.

Approvals:

BVS 10 ATEX E 114 conforms to EN60079-0, EN60079-7, EN60079-15,
IECEx BVS 10.0072 X conforms to IEC60079-0, IEC60079-7, IEC60079-15.
INMETRO DNV 13.0109 X conforms to ABNT NBR IEC60079-0, ABNT NBR IEC60079-7, ABNT NBR IEC60079-15.
FM 3046304 and FMC 3046304C conforms to Class 3600, 3611, 3810, ANSI/ISA-60079-0, ANSI/ISA-60079-15, C22.2 No.142, C22.2 No.213, C22.2 No. 60079-0, C22.2 No. 60079-15.
EAЭC RU C-IT.AA87.B.01310/24 conforms to GOST 31610.0, GOST 31610.7, GOST 31610.15.
CCC n. 2020322316000978 conforms to GB/T 3836.1, GB/T 3836.3, GB/T 3834.8
PESO P652307 conforms to IEC60079-0, IEC60079-7, IEC60079-15.
TUV Certificate No. TUV IT 25 SIL 0631, SIL 2 / SIL 3 conforms to IEC61508:2010 Ed. 2.
SIL 3 Functional Safety TÜV Certificate conforms to IEC61508:2010 Ed.2, for Management of Functional Safety.
DNV No. TAA00001U0 and KR No. MIL20769-EL002 Certificates for maritime applications.

Mounting:

EN/IEC60715 TH 35 DIN-Rail or on customized Termination Board.
Weight: about 145 g.
Connection: by polarized plug-in disconnect screw terminal blocks to accomodate terminations up to 2.5 mm^2.
Location: installation in Safe Area/Non Hazardous Locations or Zone 2, Group IIC T4 or Class I, Division 2, Group A,B,C,D, T4 or Class I, Zone 2, Group IIC, T4.
Protection class: IP 20. ***Dimensions:*** Width 22.5 mm, Depth 123 mm, Height 120 mm.

3. ORDERING INFORMATION

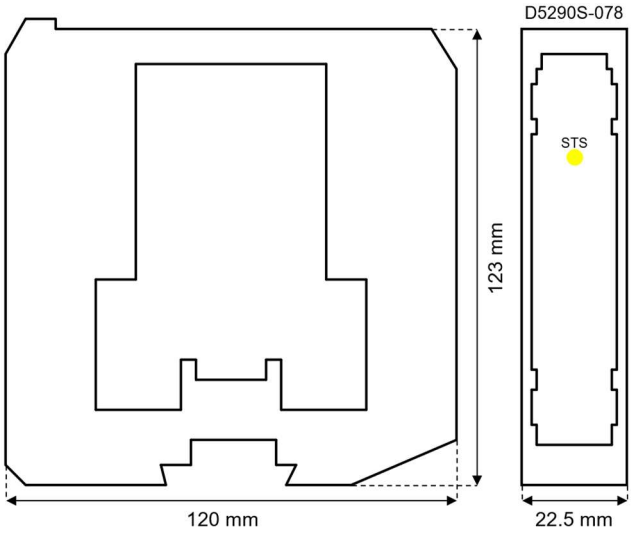
3.1 Ordering codes

D5290S-078: 1 channel

3.2 Accessories

DIN-Rail stopper MCHP196.

4. OVERALL DIMENSIONS



5. TERMINAL BLOCK CONNECTIONS

5.1 Field Side

13: Normally Open (NO) contact (Out S_1)

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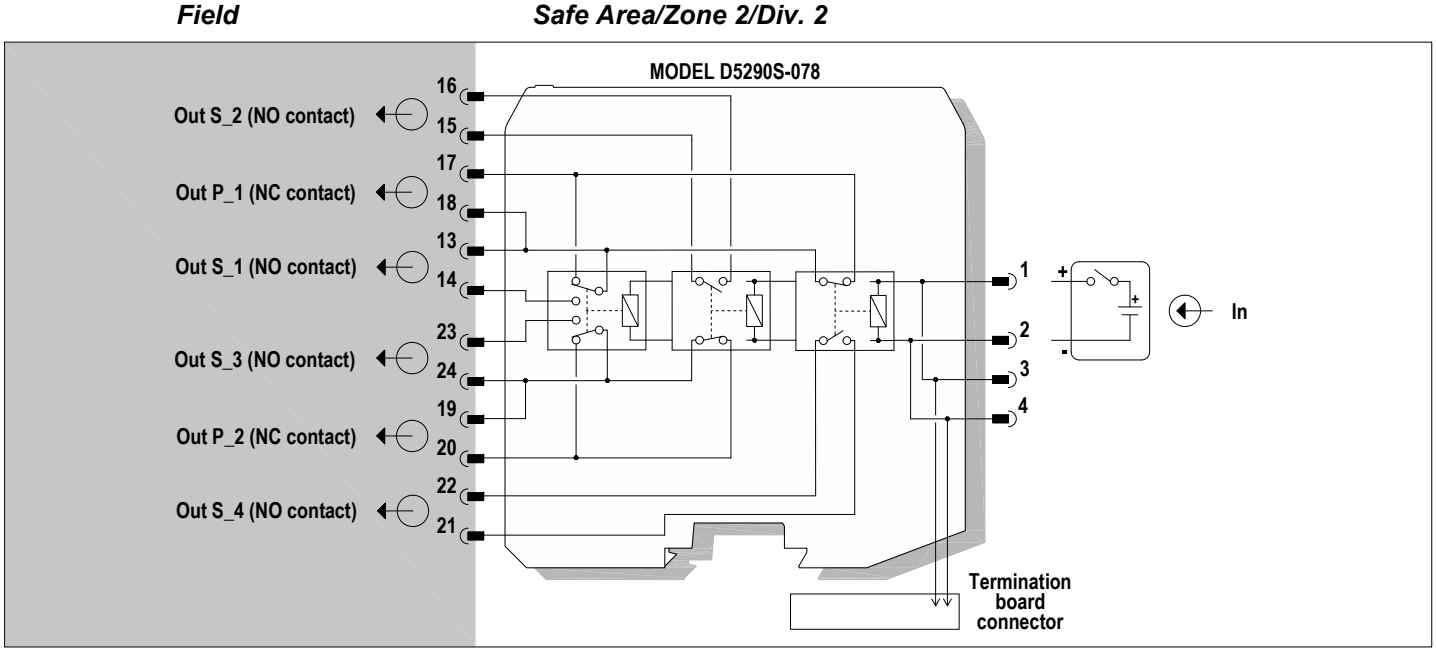
14: Normally Open (NO) contact (Out S_1)
15: Normally Open (NO) contact (Out S_2)
16: Normally Open (NO) contact (Out S_2)
17: Normally Closed (NC) contact (Out P_1)
18: Normally Closed (NC) contact (Out P_1)
19: Normally Closed (NC) contact (Out P_2)
20: Normally Closed (NC) contact (Out P_2)
21: Normally Open (NO) contact (Out S_4)
22: Normally Open (NO) contact (Out S_4)
23: Normally Open (NO) contact (Out S_3)
24: Normally Open (NO) contact (Out S_3)

5.2 System Side

1: Input +
2: Input -
3: Input +
4: Input -

6. FUNCTION DIAGRAM



Relay contacts shown in de-energized position. Terminals 13-14, 15-16, 21-22 and 23-24 are open. Terminals 17-18 and 19-20 are closed.
To prevent relay contacts from damaging, connect an external protection (fuse or similar), chosen according to the relay breaking capacity diagram.

7. WARNING

D5290S-078 is an electrical apparatus installed into standard EN50022 T35 DIN-Rail located in Safe Area or Zone 2, Group IIC, Temperature Classification T4, Hazardous Area (according to EN/IEC60079-15) within the specified operating temperature limits Tamb - 40 to +60 °C.

D5290S-078 must be installed, operated and maintained only by qualified personnel, in accordance to the relevant national/international installation standards (e.g. IEC/EN60079-14

Electrical apparatus for explosive gas atmospheres - Part 14: Electrical installations in hazardous areas (other than mines)), following the established installation rules.

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De-energize power source (turn off power supply voltage) before plug or unplug the terminal blocks when installed in Hazardous Area or unless area is known to be nonhazardous.

Warning: substitution of components may impair Intrinsic Safety and suitability for Zone 2.

Warning: de-energize main power source (turn off power supply voltage) and disconnect plug-in terminal blocks before opening the enclosure to avoid electrical shock when connected to live hazardous potential.

Explosion Hazard: to prevent ignition of flammable or combustible atmospheres, disconnect power before servicing or unless area is known to be nonhazardous.

Failure to properly installation or use of the equipment may risk to damage the unit or severe personal injury. The unit cannot be repaired by the end user and must be returned to the manufacturer or his authorized representative. Any unauthorized modification must be avoided.

8. OPERATION

D5290S-078 relay module is suitable for the switching of safety related circuits, providing isolation between the input and output contacts. See the proper section for Functional Safety applications with related SIL value. A “RELAY STATUS” yellow led lights when input is powered, showing that relay is energized.

9. INSTALLATION

D5290-078 series is a relay output module housed in a plastic enclosure suitable for installation on EN/IEC60715 TH 35 DIN-Rail or on customized Termination Board.

D5290-078 series can be mounted with any orientation over the entire ambient temperature range.

Electrical connection are accommodated by polarized plug-in removable screw terminal blocks which can be plugged in/out into a powered unit without suffering or causing any damage **(for Zone 2 installations check the area to be nonhazardous before servicing)**. Connect only one individual conductor per each clamping point, use conductors up to 2.5 mm² (13 AWG) and a torque value of 0.5-0.6 Nm. The wiring cables have to be proportionate in base to the current and the length of the cable.

On the section “Function Diagram” and enclosure side a block diagram identifies all connections.

Identify the function and location of each connection terminal using the wiring diagram on the corresponding section, as an example (n° 1 application):

- Connect positive input at terminal “1” and negative input at “2” (positive input at terminal “3” and negative input at “4” are provided for daisy chain connection to the next module).
- For Load A and its service load:
  - connect positive or AC load supply line to terminals “13” and “18”;
  - connect SIL 3 Normally Energized (NE) Load between terminals “14” and “16”;
  - connect Not SIL Service Load between terminal “17” and negative or AC load supply line;
  - connect terminal “15” to negative or AC load supply line.
- For Load B and its service load:
  - connect positive or AC load supply line to terminals “19” and “24”;
  - connect SIL 3 Normally Energized (NE) Load between terminals “23” and “21”;
  - connect Not SIL Service Load between terminal “20” and negative or AC load supply line;
  - connect terminal “22” to negative or AC load supply line.

Installation and wiring must be in accordance to the relevant national or international installation standards (e.g. IEC/EN60079-14 Electrical apparatus for explosive gas atmospheres Part 14: Electrical installations in hazardous areas (other than mines)), make sure that conductors are well isolated from each other and do not produce any unintentional connection.

Connect SPST relay contacts checking the load rating to be within the contact maximum rating (5 A 250 Vac 1250 VA, 5 A 250 Vdc 175 W (resistive load)).

To prevent relay contacts from damaging, connect an external protection (fuse or similar), chosen according to the relay breaking capacity diagram on data sheet.

The enclosure provides, according to EN60529, an IP20 minimum degree of protection (or similar to NEMA Standard 250 type 1). The equipment shall only be used in an area of at least pollution degree 2, as defined in IEC 60664-1. When installed in EU Zone 2, the unit shall be installed in an enclosure that provides a minimum ingress protection of IP54 in accordance with IEC 60079-0. The enclosure must have a door or cover accessible only by the use of a tool. The end user is responsible to ensure that the operating temperature of the module is not exceeded in the end use application.

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Units must be protected against dirt, dust, extreme mechanical (e.g. vibration, impact and shock) and thermal stress, and casual contacts.

If enclosure needs to be cleaned use only a cloth lightly moistened by a mixture of detergent in water.

Electrostatic Hazard: to avoid electrostatic hazard, the enclosure of D5290-078 series must be cleaned only with a damp or antistatic cloth.

Any penetration of cleaning liquid must be avoided to prevent damage to the unit. Any unauthorized card modification must be avoided.

All circuits connected to D5290-078 series must comply with the overvoltage category II (or better) according to EN/IEC60664-1.

Warning: de-energize main power source (turn off power supply voltage) and disconnect plug-in terminal blocks before opening the enclosure to avoid electrical shock when connected to live hazardous potential.

10. START-UP

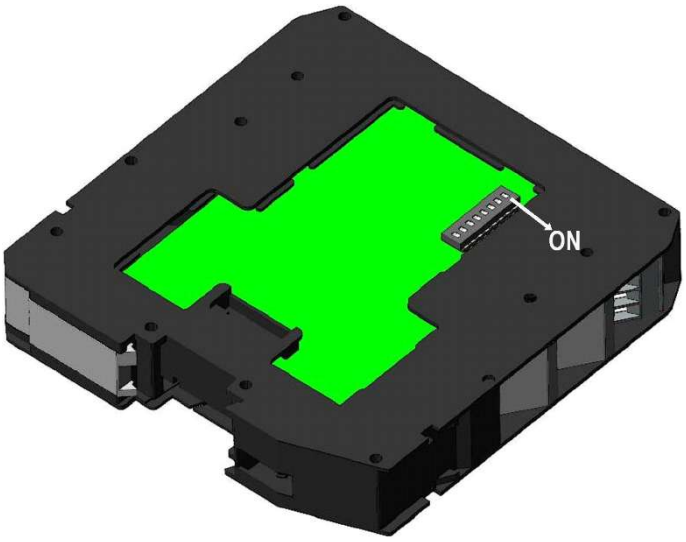
Before powering the inputs of unit check that all wires are properly connected, also verifying their polarity. Check conductors for exposed wires that could touch each other causing dangerous unwanted shorts. Enabling input, the “RELAY STATUS” yellow led must be lit, all relays must be energized, so that: contacts of terminals “13”-”14” (Out S_1), “15”-”16” (Out S_2), “21”-”22” (Out S_4) and “23”-”24” (Out S_3) must be closed, while contacts of terminals “17”-”18” (Out P_1) and “19”-”20” (Out P_2) must be open. Instead, disabling input, the “RELAY STATUS” yellow led must be turned off, all relays must be de-energized, so that: contacts of terminals “13”-”14” (Out S_1), “15”-”16” (Out S_2), “21”-”22” (Out S_4) and “23”-”24” (Out S_3) must be open, while contacts of terminals “17”-”18” (Out P_1) and “19”-”20” (Out P_2) must be closed.

11. CONFIGURATION

An eight position DIP Switch is located on component side of pcb in order to set four mutually exclusive configurations:

1) line input monitoring, to allow DCS/PLC line input monitoring function (driving line pulse testing);
2) low voltage input monitoring (UVLO—under voltage lock out): module reflects a high impedance state to the control unit when the driving voltage is below the specified threshold;
3) short circuit fault detection: it allows DCS/PLC to detect short circuit fault of module;
4) T-proof relay testing.

11.1 D5290S-087



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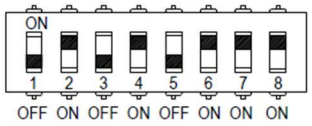
DIP switch configurations:

1) line input monitoring:

This is factory settings

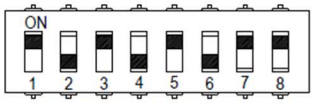
2) low voltage input monitoring:

3) short circuit fault detection:



Can be used only for Functional Safety applications n° 1, 2, 3, 4 with NE Relay condition
Must not used for Functional Safety applications n° 5, 6 with ND Relay condition!

4) T-proof relay testing:



T-proof relays (dip1 = relay1; dip3 = relay2; dip5 = relay3)

T-proof relays enable

Normal Operation

Please, see proper section testing procedure at T-proof.
WARNING: after T-proof test, dip-switch 1-3-5 must be set to “OFF” position for normal operation.

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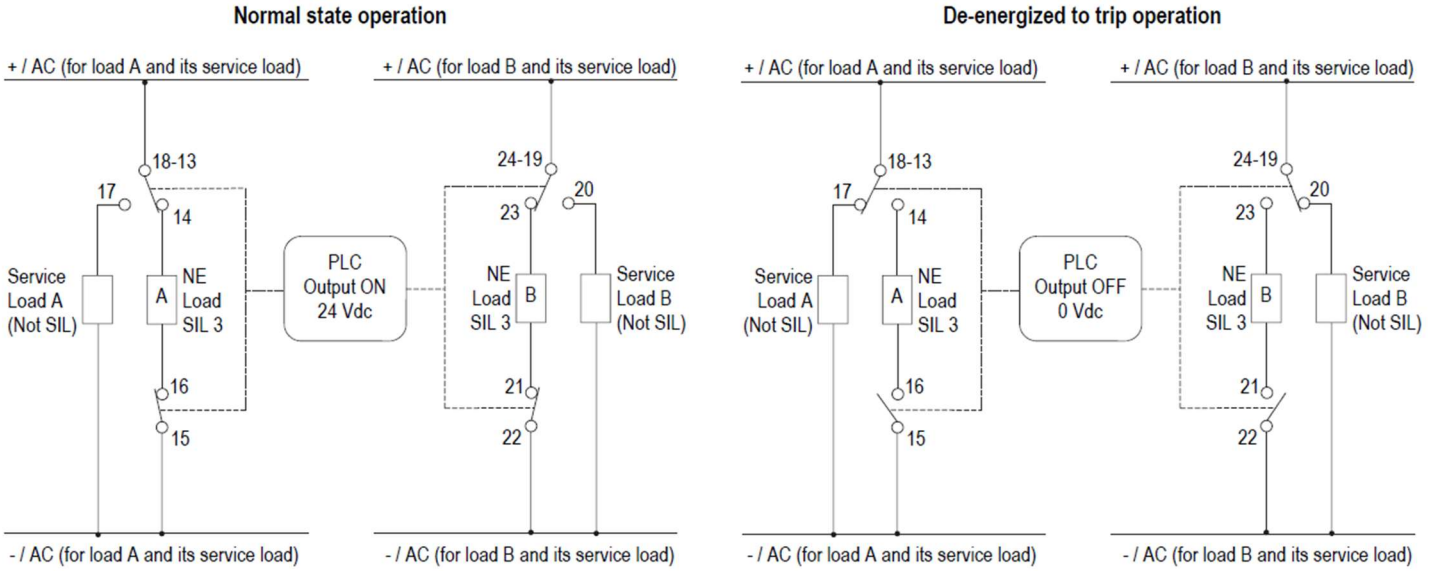
12. FUNCTIONAL SAFETY MANUAL AND APPLICATION

12.1 Application D5290S-078 - SIL 3 Load Normally Energized Condition (NE) and Normally Energized Relay: one common driving signal from PLC for both NE loads (A and B), with interruption of both load supply lines



Description:

Input Signal from PLC/DCS is normally High (24 Vdc) and is applied to pins 1-2 or 3-4 in order to Normally Energize (NE) the internal relays. Input Signal from PLC/DCS is Low (0 Vdc) during “de-energize to trip” operation, in order de-energize the internal relays.

Load A (and Load B if present) is Normally Energized (NE) therefore its safe state is to be de-energized. Disconnection of Loads A and B is done on both supply lines. Service Load A (and Service Load B if present) is normally de-energized, therefore it energizes during “de-energize to trip” operation.

The following table describes the status (open or closed) of each output contact when input signal is High or Low:

Operation	Input Signal Pins 1-2 or 3-4	Pins 13-14	Pins 15-16	Pins 23-24	Pins 21-22	NE Load A (SIL3) Pins 14-16	NE Load B (SIL 3) Pins 23-21
Normal	High (24 Vdc)	Closed	Closed	Closed	Closed	Energized	Energized
Trip	Low (0 Vdc)	Open	Open	Open	Open	De-Energized	De-Energized

Pins 17-18	Pins 19-20	Service Load A	Service Load B
Open	Open	De-Energized	De-Energized
Closed	Closed	Energized	Energized

Safety Function and Failure behavior:

D5290S-078 is considered to be operating in Low Demand mode, as a Type A module, having Hardware Fault Tolerance (HFT) = 0. In the 1st Functional Safety application, the normal state operation of relay module is energized, with NE (Normally Energized) loads. In case of alarm or request from process, the relay module is de-energized (safe state), de-energizing loads.

The failure behaviour of relay module is described by the following definitions:

- fail-Safe State: it is defined as the output load being de-energized;
- fail Safe: this failure causes the system to go to the defined fail-safe state without a process demand;
- fail Dangerous: failure mode that does not respond to a demand from the process (i.e. being unable to go to the defined fail-safe state), so that the output load remains energized. In addition, there are other definitions of failure behaviours which are not safety-related:
- fail “No effect”: failure mode of a component that plays a part in implementing the safety function but is neither a safe failure nor a dangerous failure;

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- fail “Not part”: failure mode of a component which is not part of the safety function but part of the circuit diagram and is listed for completeness. When calculating the SFF this failure mode is not taken into account. It is also not considered for the total failure rate evaluation.

Failure rate data: taken from Siemens Standard SN29500.

Failure rate table:

Failure category	Failure rates (FIT)
λ_{dd} = Total Dangerous Detected failures	0.00
λ_{du} = Total Dangerous Undetected failures	1.60
λ_{sd} = Total Safe Detected failures	0.00
λ_{su} = Total Safe Undetected failures	190.02
$\lambda_{tot\ safe}$ = Total Failure Rate (Safety Function) = λ_{dd} + λ_{du} + λ_{sd} + λ_{su}	**191.62**
MTBF (safety function, single channel) = (1 / $\lambda_{tot\ safe}$) + MTTR (8 hours)	**595 years**
$\lambda_{no\ effect}$ = “No effect” failures	92.38
$\lambda_{not\ part}$ = “Not Part” failures	0.60
$\lambda_{tot\ device}$ = Total Failure Rate (Device) = $\lambda_{tot\ safe}$ + $\lambda_{no\ effect}$ + $\lambda_{not\ part}$	**284.60**
MTBF (device, single channel) = (1 / $\lambda_{tot\ device}$) + MTTR (8 hours)	**401 years**
$MTTF_S$ (Total Safe) = 1 / (λ_{sd} + λ_{su})	600 years
$MTTF_D$ (Dangerous) = 1 / λ_{du}	71347 years

Failure rates table according to IEC 61508:2010 Ed.2:

λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	SFF
0.00 FIT	190.02 FIT	0.00 FIT	1.60 FIT	99.17%

PFDavg vs T[Proof] table (assuming Proof Test coverage of 99%), with determination of SIL supposing module contributes ≤10% of total SIF dangerous failures:

T[Proof] = 1 year	T[Proof] = 10 years
PFDavg = 7.01 E-06 - Valid for SIL 3	PFDavg = 7.01 E-05 - Valid for SIL 3

PFDavg vs T[Proof] table (assuming Proof Test coverage of 99%), with determination of SIL supposing module contributes >10% of total SIF dangerous failures:

T[Proof] = 20 years
PFDavg = 1.40 E-04 - Valid for SIL 3

Systematic capability SIL 3.

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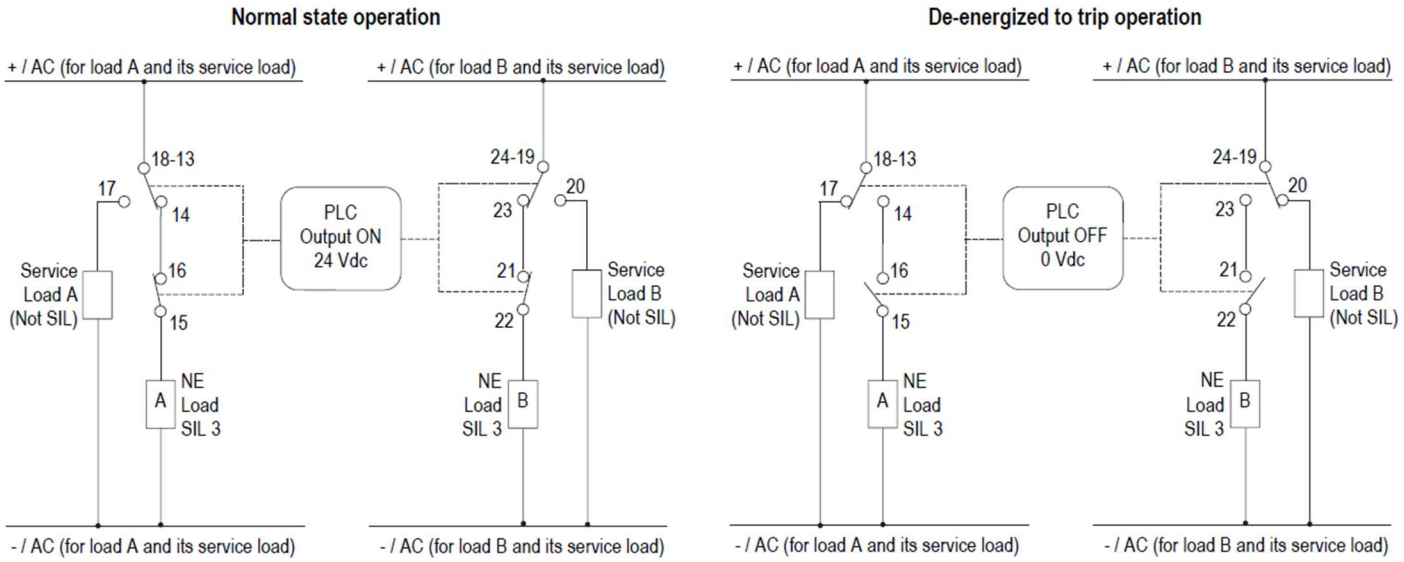
12.2 Application D5290S-078 - SIL 3 Load Normally Energized Condition (NE) and Normally Energized Relay: one common driving signal from PLC for both NE loads (A and B), with interruption of only one load supply line



Description:

Input Signal from PLC/DCS is normally High (24 Vdc) and is applied to pins 1-2 or 3-4 in order to Normally Energize (NE) the internal relays. Input Signal from PLC/DCS is Low (0 Vdc) during “de-energize to trip” operation, in order de-energize the internal relays. Load A (and Load B if present) is Normally Energized (NE) therefore its safe state is to be de-energized. Disconnection of Loads A and B is done by disconnecting one supply line via two separate contacts. Service Load A (and Service Load B if present) is normally de-energized, therefore it energizes during “de-energize to trip” operation.

The following table describes the status (open or closed) of each output contact when input signal is High or Low.:

Operation	Input Signal Pins 1-2 or 3-4	Pins 13-14	Pins 15-16	Pins 23-24	Pins 21-22	NE Load A (SIL3) Pins 15-Supply	NE Load B (SIL 3) Pins 22-Supply
Normal	High (24 Vdc)	Closed	Closed	Closed	Closed	Energized	Energized
Trip	Low (0 Vdc)	Open	Open	Open	Open	De-Energized	De-Energized

Pins 17-18	Pins 19-20	Service Load A	Service Load B
Open	Open	De-Energized	De-Energized
Closed	Closed	Energized	Energized

Safety Function and Failure behavior:

D5290S-078 is considered to be operating in Low Demand mode, as a Type A module, having Hardware Fault Tolerance (HFT) = 0. In the 2nd Functional Safety application, the normal state operation of relay module is energized, with NE (Normally Energized) loads. In case of alarm or request from process, the relay module is de-energized (safe state), de-energizing loads.

The failure behaviour of relay module is described by the following definitions:

- fail-Safe State: it is defined as the output load being de-energized;
- fail Safe: this failure causes the system to go to the defined fail-safe state without a process demand;
- fail Dangerous: failure mode that does not respond to a demand from the process (i.e. being unable to go to the defined fail-safe state), so that the output load remains energized. In addition, there are other definitions of failure behaviours which are not safety-related;
- fail “No effect”: failure mode of a component that plays a part in implementing the safety function but is neither a safe failure nor a dangerous failure;
- fail “Not part”: failure mode of a component which is not part of the safety function but part of the circuit diagram and is listed for completeness. When calculating the SFF this failure mode is not taken into account. It is also not considered for the total failure rate evaluation.

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Failure rate data: taken from Siemens Standard SN29500.

Failure rate table:

Failure category	Failure rates (FIT)
λ_{dd} = Total Dangerous Detected failures	0.00
λ_{du} = Total Dangerous Undetected failures	1.60
λ_{sd} = Total Safe Detected failures	0.00
λ_{su} = Total Safe Undetected failures	190.02
$\lambda_{tot\ safe}$ = Total Failure Rate (Safety Function) = λ_{dd} + λ_{du} + λ_{sd} + λ_{su}	**191.62**
MTBF (safety function, single channel) = (1 / $\lambda_{tot\ safe}$) + MTTR (8 hours)	**595 years**
$\lambda_{no\ effect}$ = “No effect” failures	92.38
$\lambda_{not\ part}$ = “Not Part” failures	0.60
$\lambda_{tot\ device}$ = Total Failure Rate (Device) = $\lambda_{tot\ safe}$ + $\lambda_{no\ effect}$ + $\lambda_{not\ part}$	**284.60**
MTBF (device, single channel) = (1 / $\lambda_{tot\ device}$) + MTTR (8 hours)	**401 years**
$MTTF_S$ (Total Safe) = 1 / (λ_{sd} + λ_{su})	600 years
$MTTF_D$ (Dangerous) = 1 / λ_{du}	71347 years

Failure rates table according to IEC 61508:2010 Ed.2:

λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	SFF
0.00 FIT	190.02 FIT	0.00 FIT	1.60 FIT	99.17%

PFDavg vs T[Proof] table (assuming Proof Test coverage of 99%), with determination of SIL supposing module contributes ≤10% of total SIF dangerous failures:

T[Proof] = 1 year	T[Proof] = 10 years
PFDavg = 7.01 E-06 - Valid for SIL 3	PFDavg = 7.01 E-05 - Valid for SIL 3

PFDavg vs T[Proof] table (assuming Proof Test coverage of 99%), with determination of SIL supposing module contributes >10% of total SIF dangerous failures:

T[Proof] = 20 years
PFDavg = 1.40 E-04 - Valid for SIL 3

Systematic capability SIL 3.

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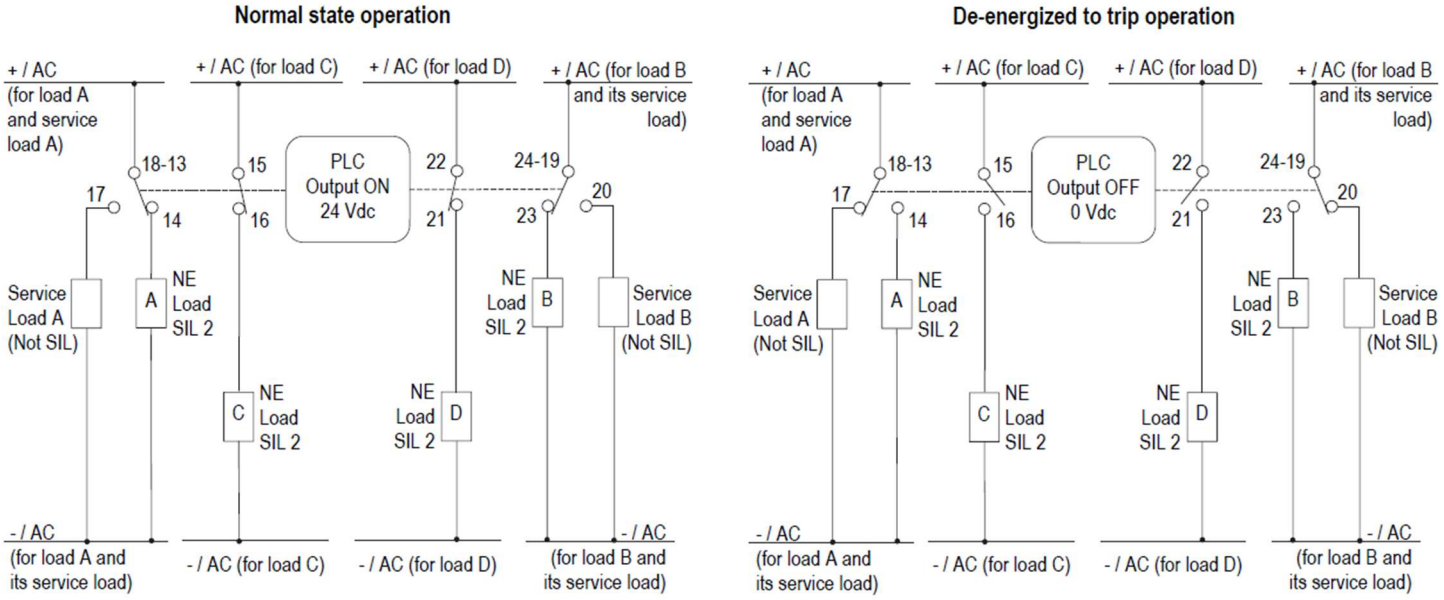
12.3 Application D5290S-078 - SIL 2 Load Normally Energized Condition (NE) and Normally Energized Relay: one common driving signal from PLC for all NE loads (A, B, C and D), with interruption of only one load supply line



Description:

Input Signal from PLC/DCS is normally High (24 Vdc) and is applied to pins 1-2 or 3-4 in order to Normally Energize (NE) the internal relays. Input Signal from PLC/DCS is Low (0 Vdc) during “de-energize to trip” operation, in order de-energize the internal relays. Load A (and Load B, C, D if present) is Normally Energized (NE) therefore its safe state is to be de-energized. Disconnection of Loads A, B, C, D is done by disconnecting one supply line. Service Load A (and Service Load B if present) is normally de-energized, therefore it energizes during “de-energize to trip” operation.

The following table describes the status (open or closed) of each output contact when input signal is High or Low.

Operation	Input Signal Pins 1-2 or 3-4	Pins 13-14	Pins 15-16	Pins 21-22	Pins 23-24	NE Load A (SIL 2) Pins 14-Supply	NE Load C (SIL 2) Pins 16-Supply	NE Load D (SIL 2) Pins 21-Supply	NE Load B (SIL 2) Pins 23-Supply
Normal	High (24 Vdc)	Closed	Closed	Closed	Closed	Energized	Energized	Energized	Energized
Trip	Low (0 Vdc)	Open	Open	Open	Open	De-Energized	De-Energized	De-Energized	De-Energized

Pins 17-18	Pins 19-20	Service Load A	Service Load B
Open	Open	De-Energized	De-Energized
Closed	Closed	Energized	Energized

Safety Function and Failure behavior:

D5290S-078 is considered to be operating in Low Demand mode, as a Type A module, having Hardware Fault Tolerance (HFT) = 0. In the 3rd Functional Safety application, the normal state operation of relay module is energized, with NE (Normally Energized) loads. In case of alarm or request from process, the relay module is de-energized (safe state), de-energizing loads.

The failure behaviour of relay module is described by the following definitions:

- fail-Safe State: it is defined as the output load being de-energized;
- fail Safe: this failure causes the system to go to the defined fail-safe state without a process demand;

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- fail Dangerous: failure mode that does not respond to a demand from the process (i.e. being unable to go to the defined fail-safe state), so that the output load remains energized. In addition, there are other definitions of failure behaviours which are not safety-related;
- fail “No effect”: failure mode of a component that plays a part in implementing the safety function but is neither a safe failure nor a dangerous failure;
- fail “Not part”: failure mode of a component which is not part of the safety function but part of the circuit diagram and is listed for completeness. When calculating the SFF this failure mode is not taken into account. It is also not considered for the total failure rate evaluation.

Failure rate data: taken from Siemens Standard SN29500.

Failure rate table:

Failure category	Failure rates (FIT)
λ_{dd} = Total Dangerous Detected failures	0.00
λ_{du} = Total Dangerous Undetected failures	32.00
λ_{sd} = Total Safe Detected failures	0.00
λ_{su} = Total Safe Undetected failures	63.84
$\lambda_{tot\ safe}$ = Total Failure Rate (Safety Function) = λ_{dd} + λ_{du} + λ_{sd} + λ_{su}	**95.84**
MTBF (safety function, single channel) = (1 / $\lambda_{tot\ safe}$) + MTTR (8 hours)	**1191 years**
$\lambda_{no\ effect}$ = “No effect” failures	70.16
$\lambda_{not\ part}$ = “Not Part” failures	0.60
$\lambda_{tot\ device}$ = Total Failure Rate (Device) = $\lambda_{tot\ safe}$ + $\lambda_{no\ effect}$ + $\lambda_{not\ part}$	**166.60**
MTBF (device, single channel) = (1 / $\lambda_{tot\ device}$) + MTTR (8 hours)	**685 years**
$MTTF_S$ (Total Safe) = 1 / (λ_{sd} + λ_{su})	1788 years
$MTTF_D$ (Dangerous) = 1 / λ_{du}	3567 years

Failure rates table according to IEC 61508:2010 Ed.2:

λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	SFF
0.00 FIT	63.84 FIT	0.00 FIT	32.00 FIT	66.61%

PFDavg vs T[Proof] table (assuming Proof Test coverage of 99%), with determination of SIL supposing module contributes ≤10% of total SIF dangerous failures:

T[Proof] = 1 year	T[Proof] = 7 years
PFDavg = 1.40 E-04 - Valid for SIL 2	PFDavg = 9.81 E-04 - Valid for SIL 2

PFDavg vs T[Proof] table (assuming Proof Test coverage of 99%), with determination of SIL supposing module contributes >10% of total SIF dangerous failures:

T[Proof] = 20 years
PFDavg = 2.80 E-03 - Valid for SIL 2

Systematic capability SIL 3.

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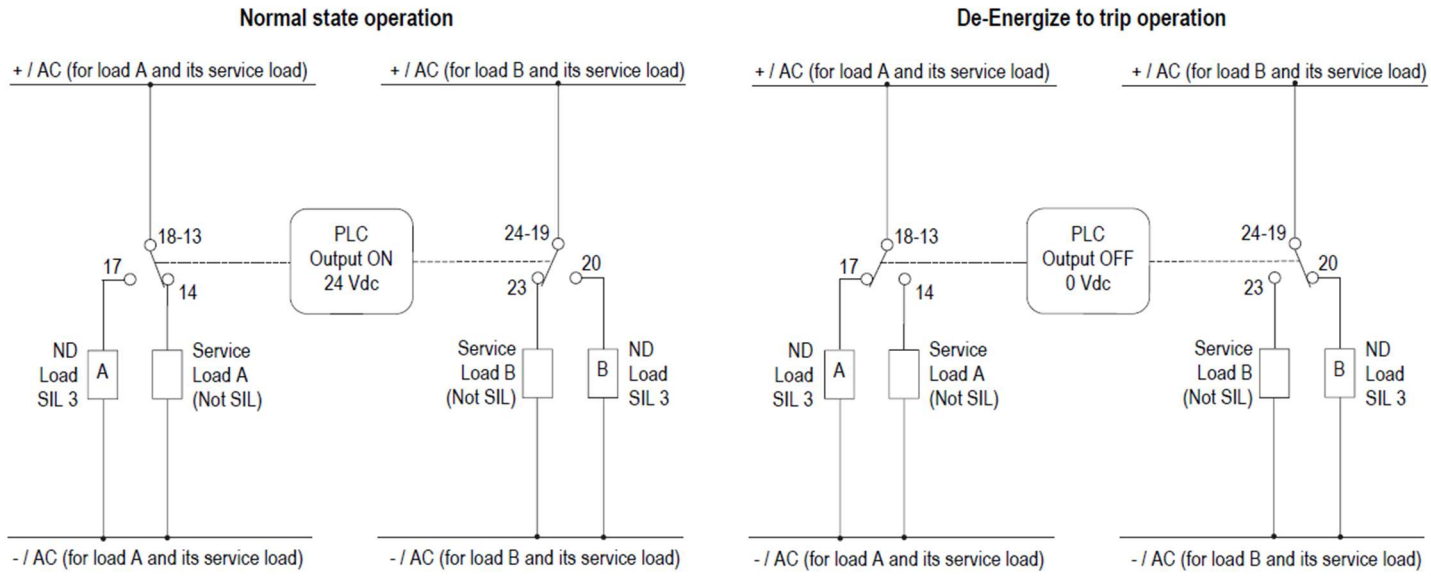
12.4 Application D5290S-078 - SIL 3 Load Normally De-energized Condition (ND) and Normally Energized Relay: one common driving signal from PLC for both ND loads (A and B), with interruption of only one load supply line



Description:

Input Signal from PLC/DCS is normally High (24 Vdc) and is applied to pins 1-2 or 3-4 in order to Normally Energize (NE) the internal relays. Input Signal from PLC/DCS is Low (0 Vdc) during “de-energize to trip” operation, in order de-energize the internal relays. Load A (and Load B if present) is Normally De-Energized (ND) therefore its safe state is to be energized. Disconnection of Loads A and B is done by disconnecting one supply line. Service Load A (and Service Load B if present) is normally energized, therefore it de-energizes during “de-energize to trip” operation.

The following table describes the status (open or closed) of each output contact when input signal is High or Low.

Operation	Input Signal Pins 1-2 or 3-4	Pins 17-18	Pins 19-20	ND Load A (SIL3) Pins 17- Supply	ND Load B (SIL 3) Pins 20- Supply
Normal	High (24 Vdc)	Open	Open	De-Energized	De-Energized
Trip	Low (0 Vdc)	Closed	Closed	Energized	Energized

Pins 13-14	Pins 23-24	Service Load A	Service Load B
Closed	Closed	Energized	Energized
Open	Open	De-Energized	De-Energized

Safety Function and Failure behavior:

D5290S-078 is considered to be operating in Low Demand mode, as a Type A module, having Hardware Fault Tolerance (HFT) = 0.In the 4th Functional Safety application, the normal state operation of relay module is energized, with ND (Normally De-energized) loads. In case of alarm or request from process, the relay module is de-energized (safe state), energizing loads.

The failure behaviour of all relay modules here considered is described by the following definitions:

- fail-Safe State: it is defined as the output load being energized;
- fail Safe: this failure causes the system to go to the defined fail-safe state without a process demand;
- fail Dangerous: failure mode that does not respond to a demand from the process (i.e. being unable to go to defined fail-safe state), so that output load remains de-energized.

In addition, there are other definitions of failure behaviours which are not safety-related:

- fail “No effect”: failure mode of a component that plays a part in implementing the safety function but is neither a safe failure nor a dangerous failure;
- fail “Not part”: failure mode of a component which is not part of the safety function but part of the circuit diagram and is listed for completeness. When calculating the SFF this failure mode is not taken into account. It is also not considered for the total failure rate evaluation.

Failure rate data: taken from Siemens Standard SN29500.

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Failure rate table:

Failure category	Failure rates (FIT)
λ_{dd} = Total Dangerous Detected failures	0.00
λ_{du} = Total Dangerous Undetected failures	1.60
λ_{sd} = Total Safe Detected failures	0.00
λ_{su} = Total Safe Undetected failures	190.02
$\lambda_{tot\ safe}$ = Total Failure Rate (Safety Function) = λ_{dd} + λ_{du} + λ_{sd} + λ_{su}	**191.62**
MTBF (safety function, single channel) = (1 / $\lambda_{tot\ safe}$) + MTTR (8 hours)	**595 years**
$\lambda_{no\ effect}$ = “No effect” failures	92.38
$\lambda_{not\ part}$ = “Not Part” failures	0.60
$\lambda_{tot\ device}$ = Total Failure Rate (Device) = $\lambda_{tot\ safe}$ + $\lambda_{no\ effect}$ + $\lambda_{not\ part}$	**284.60**
MTBF (device, single channel) = (1 / $\lambda_{tot\ device}$) + MTTR (8 hours)	**401 years**
$MTTF_S$ (Total Safe) = 1 / (λ_{sd} + λ_{su})	600 years
$MTTF_D$ (Dangerous) = 1 / λ_{du}	71347 years

Failure rates table according to IEC 61508:2010 Ed.2:

λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	SFF
0.00 FIT	190.02 FIT	0.00 FIT	1.60 FIT	99.17%

PFDavg vs T[Proof] table (assuming Proof Test coverage of 99%), with determination of SIL supposing module contributes ≤10% of total SIF dangerous failures:

T[Proof] = 1 year	T[Proof] = 10 years
PFDavg = 7.01 E-06 - Valid for SIL 3	PFDavg = 7.01 E-05 - Valid for SIL 3

PFDavg vs T[Proof] table (assuming Proof Test coverage of 99%), with determination of SIL supposing module contributes >10% of total SIF dangerous failures:

T[Proof] = 20 years
PFDavg = 1.40 E-04 - Valid for SIL 3

Systematic capability SIL 3.

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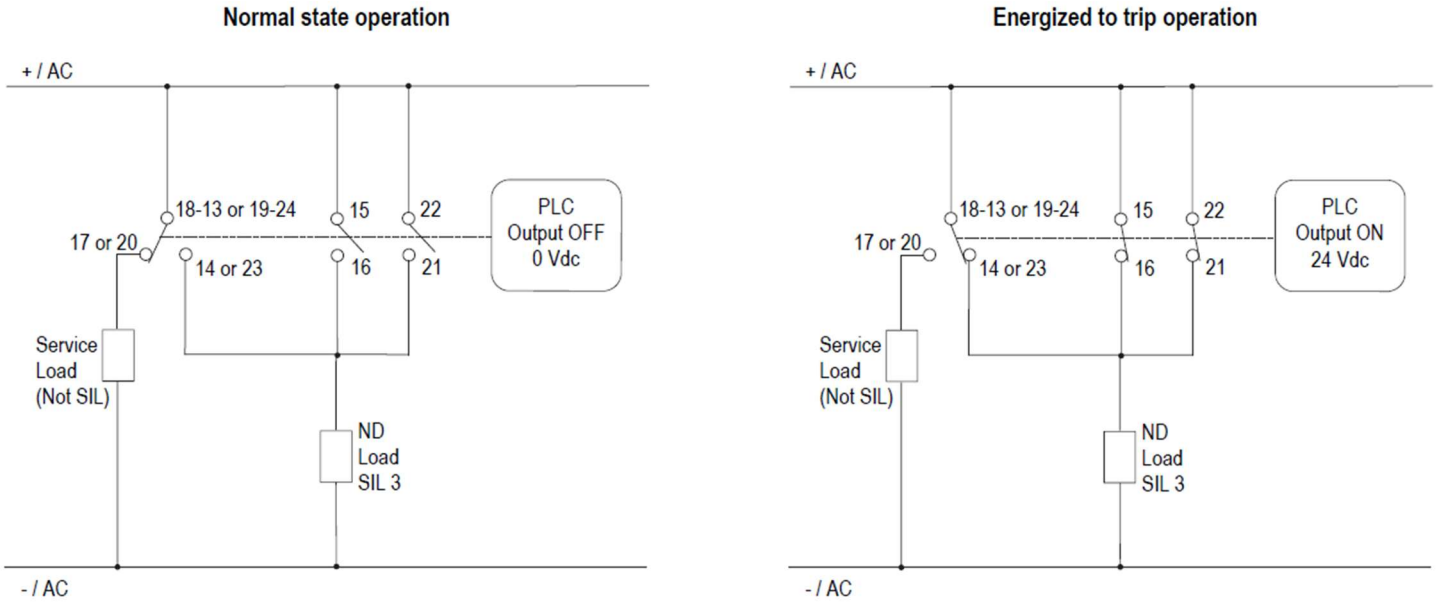
12.5 Application D5290S-078 - SIL 3 Load Normally De-energized Condition (ND) and Normally De-energized Relay, with interruption of only one load supply line



Description:

Input Signal from PLC/DCS is normally Low (0 Vdc) and is applied to pins 1-2 or 3-4 in order to Normally De-energize (ND) the internal relays. Input Signal from PLC/DCS is High (24 Vdc) during “energize to trip” operation, in order energize the internal relays. Load is Normally De-Energized (ND) therefore its safe state is to be energized. Load is connected in parallel to pins 14 (or 23) and 16 and 21. Disconnection of Load is done by disconnecting one supply line via three separate contacts in parallel. Service Load is normally energized, therefore it de-energizes during “energize to trip” operation.

The following table describes the status (open or closed) of each output contact when input signal is High or Low.:

Operation	Input Signal Pins 1-2 or 3-4	Pins 13-14 or 23-24	Pins 15-16	Pins 21-22	ND Load (SIL 3) Pins 14 (or 23), 16,21-Supply
Normal	Low (0 Vdc)	Open	Open	Open	De-Energized
Trip	High (24 Vdc)	Closed	Closed	Closed	Energized

Pins 17-18 or 19-20	Service Load
Closed	Energized
Open	De-Energized

Safety Function and Failure behavior:

D5290S-078 is considered to be operating in Low Demand mode, as a Type A module, having Hardware Fault Tolerance (HFT) = 0. In the 5th Functional Safety application, the normal state operation of relay module is de-energized, with ND loads. In case of alarm or request from process, the relay module is energized (safe state), energizing loads.

The failure behaviour of all relay modules here considered is described by the following definitions:

- fail-Safe State: it is defined as the output load being energized;
- fail Safe: this failure causes the system to go to the defined fail-safe state without a process demand;
- fail Dangerous: failure mode that does not respond to a demand from the process (i.e. being unable to go to defined fail-safe state), so that output load remains de-energized.

In addition, there are other definitions of failure behaviours which are not safety-related:

- fail “No effect”: failure mode of a component that plays a part in implementing the safety function but is neither a safe failure nor a dangerous failure;
- fail “Not part”: failure mode of a component which is not part of the safety function but part of the circuit diagram and is listed for completeness. When calculating the SFF this failure mode is not taken into account. It is also not considered for the total failure rate evaluation.

Failure rate data: taken from Siemens Standard SN29500.

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Failure rate table:

Failure category	Failure rates (FIT)
λ_{dd} = Total Dangerous Detected failures	0.00
λ_{du} = Total Dangerous Undetected failures	3.60
λ_{sd} = Total Safe Detected failures	0.00
λ_{su} = Total Safe Undetected failures	299.70
$\lambda_{tot\ safe}$ = Total Failure Rate (Safety Function) = λ_{dd} + λ_{du} + λ_{sd} + λ_{su}	**303.30**
MTBF (safety function, single channel) = (1 / $\lambda_{tot\ safe}$) + MTTR (8 hours)	**376 years**
$\lambda_{no\ effect}$ = “No effect” failures	99.30
$\lambda_{not\ part}$ = “Not Part” failures	0.00
$\lambda_{tot\ device}$ = Total Failure Rate (Device) = $\lambda_{tot\ safe}$ + $\lambda_{no\ effect}$ + $\lambda_{not\ part}$	**402.60**
MTBF (device, single channel) = (1 / $\lambda_{tot\ device}$) + MTTR (8 hours)	**283 years**
$MTTF_S$ (Total Safe) = 1 / (λ_{sd} + λ_{su})	380 years
$MTTF_D$ (Dangerous) = 1 / λ_{du}	31709 years

Failure rates table according to IEC 61508:2010 Ed.2:

λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	SFF
0.00 FIT	299.70 FIT	0.00 FIT	3.60 FIT	98.81%

PFDavg vs T[Proof] table (assuming Proof Test coverage of 99%), with determination of SIL supposing module contributes ≤10% of total SIF dangerous failures:

T[Proof] = 1 year	T[Proof] = 6 years
PFDavg = 1.58 E-05 - Valid for SIL 3	PFDavg = 9.46 E-05 - Valid for SIL 3

PFDavg vs T[Proof] table (assuming Proof Test coverage of 99%), with determination of SIL supposing module contributes >10% of total SIF dangerous failures:

T[Proof] = 20 years
PFDavg = 3.15 E-04 - Valid for SIL 3

Systematic capability SIL 3.

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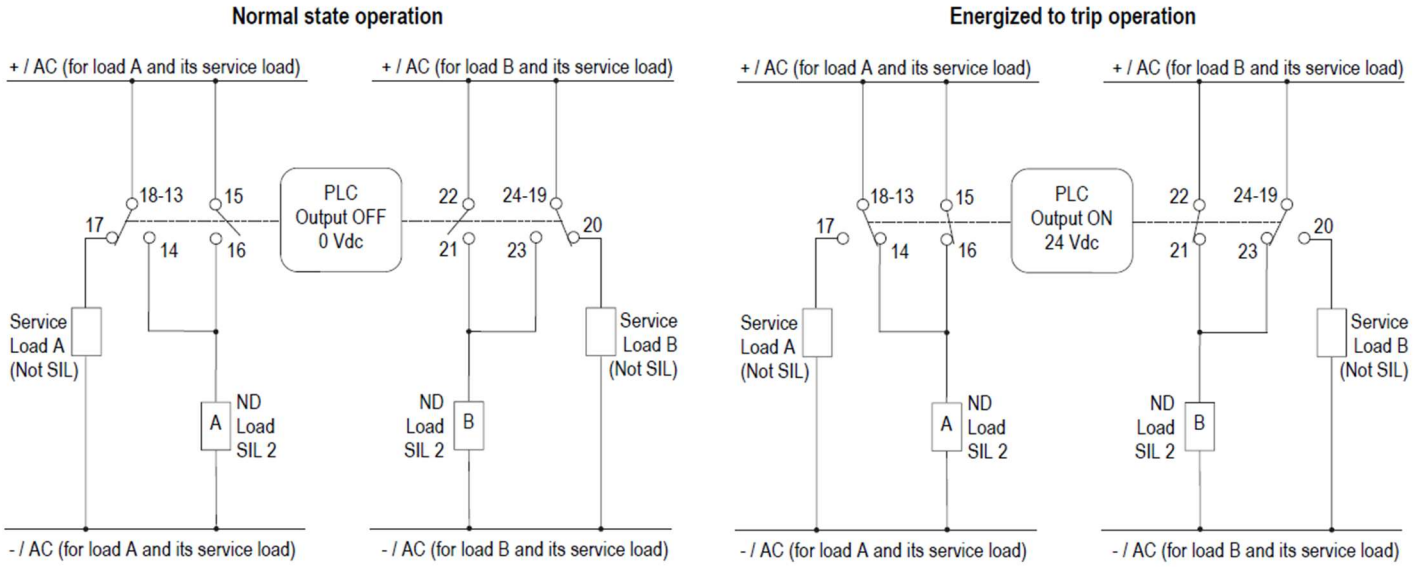
12.6 Application D5290S-078 - SIL 2 Load Normally De-energized Condition (ND) and Normally De-energized Relay: one common driving signal from PLC for both ND loads (A and B), with interruption of only one load supply line



Description:

Input Signal from PLC/DCS is normally Low (0 Vdc) and is applied to pins 1-2 or 3-4 in order to Normally De-energize (ND) the internal relays. Input Signal from PLC/DCS is High (24 Vdc) during “energize to trip” operation, in order energize the internal relays. Load A (and Load B if present) is Normally De-energized (ND) therefore its safe state is to be energized. Disconnection of Loads A and B is done by disconnecting one supply line via two separate contacts in parallel.

Service Load A (and Service Load B if present) is normally energized, therefore it de-energizes during “energize to trip” operation.

The following table describes the status (open or closed) of each output contact when input signal is High or Low.

Operation	Input Signal Pins 1-2 or 3-4	Pins 13-14	Pins 15-16	ND Load A (SIL 2) Pins 14,16-Supply	ND Load B (SIL 2) Pins 21,23-Supply
Normal	Low (0 Vdc)	Open	Open	De-Energized	De-Energized
Trip	High (24 Vdc)	Closed	Closed	Energized	Energized

Pins 17-18	Pins 19-20	Service Load A	Service Load B
Closed	Closed	Energized	Energized
Open	Open	De-Energized	De-Energized

Safety Function and Failure behavior:

D5290S-078 is considered to be operating in Low Demand mode, as a Type A module, having Hardware Fault Tolerance (HFT) = 0. In the 6th Functional Safety application, the normal state operation of relay module is de-energized, with ND loads. In case of alarm or request from process, the relay module is energized (safe state), energizing loads.

The failure behaviour of all relay modules here considered is described by the following definitions:

- fail-Safe State: it is defined as the output load being de-energized;
- fail-Safe State: it is defined as the output load being energized;
- fail Safe: this failure causes the system to go to the defined fail-safe state without a process demand;
- fail Dangerous: failure mode that does not respond to a demand from the process (i.e. being unable to go to defined fail-safe state), so that output load remains de-energized.

In addition, there are other definitions of failure behaviours which are not safety-related:

- fail “No effect”: failure mode of a component that plays a part in implementing the safety function but is neither a safe failure nor a dangerous failure;
- fail “Not part”: failure mode of a component which is not part of the safety function but part of the circuit diagram and is listed for completeness. When calculating the SFF this failure mode is not taken into account. It is also not considered for the total failure rate evaluation.

Failure rate data: taken from Siemens Standard SN29500.

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Failure rate table:

Failure category	Failure rates (FIT)
λ_{dd} = Total Dangerous Detected failures	0.00
λ_{du} = Total Dangerous Undetected failures	3.52
λ_{sd} = Total Safe Detected failures	0.00
λ_{su} = Total Safe Undetected failures	200.68
$\lambda_{tot\ safe}$ = Total Failure Rate (Safety Function) = λ_{dd} + λ_{du} + λ_{sd} + λ_{su}	**204.20**
MTBF (safety function, single channel) = (1 / $\lambda_{tot\ safe}$) + MTTR (8 hours)	**559 years**
$\lambda_{no\ effect}$ = “No effect” failures	80.40
$\lambda_{not\ part}$ = “Not Part” failures	0.00
$\lambda_{tot\ device}$ = Total Failure Rate (Device) = $\lambda_{tot\ safe}$ + $\lambda_{no\ effect}$ + $\lambda_{not\ part}$	**284.60**
MTBF (device, single channel) = (1 / $\lambda_{tot\ device}$) + MTTR (8 hours)	**401 years**
$MTTF_S$ (Total Safe) = 1 / (λ_{sd} + λ_{su})	568 years
$MTTF_D$ (Dangerous) = 1 / λ_{du}	32430 years

Failure rates table according to IEC 61508:2010 Ed.2:

λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	SFF
0.00 FIT	200.68 FIT	0.00 FIT	3.52 FIT	98.28%

PFDavg vs T[Proof] table (assuming Proof Test coverage of 99%), with determination of SIL supposing module contributes ≤10% of total SIF dangerous failures:

T[Proof] = 1 year	T[Proof] = 20 years
PFDavg = 1.54 E-05 - Valid for SIL 2	PFDavg = 3.08 E-04 - Valid for SIL 2

Systematic capability SIL 3.

12.7 Testing procedure at T-proof

The proof test shall be performed to reveal dangerous faults which are undetected by diagnostic. This means that it is necessary to specify how dangerous undetected faults, which have been noted during the FMEDA, can be revealed during proof test. The Proof test consists of the following steps:

Steps	Action
1	Bypass the safety-related PLC or take other appropriate action to avoid a false trip when removing the unit for test.
2	Verify the input-to-output functionality, considering the input signal and each relay output contact state: • Out S_1 (NO contact) at terminals “13”-“14”: when input is energized, Out S_1 must be closed; while shutdown of the input channel, Out S_1 must be open; • Out S_2 (NO contact) at terminals “15”-“16”: when input is energized, Out S_2 must be closed; while shutdown of the input channel, Out S_2 must be open; • Out P_1 (2 NC contacts in parallel connection) at terminals “17”-“18”: when input is energized, Out P_1 must be open; while shutdown of the input channel, Out P_1 must be closed; • Out S_3 (NO contact) at terminals “23”-“24”: when input is energized, Out S_3 must be closed; while shutdown of the input channel, Out S_3 must be open; • Out S_4 (NO contact) at terminals “21”-“22”: when input is energized, Out S_4 must be closed; while shutdown of the input channel, Out S_4 must be open; • Out P_2 (2 NC contacts in parallel connection) at terminals “19”-“20”: when input is energized, Out P_2 must be open; while shutdown of the input channel, Out P_2 must be closed. The channel functionality must be verified for a min to max input voltage change (21.6 to 27.6 Vdc). In addition is possible to check the Out P_1 and Out P_2 (which are the parallel connection of 2 NC contacts), imposing (by internal DIP-switches n° 1, 3, 5) the short circuit of each single relay coil and to verify the ohmic continuity of the contacts, as described in the following procedure.

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Steps	Action
	Do not supply the input channel (terminals “1”-“2”, or “3”-“4”) of module under test and verify that the ohmic continuity at the output contact terminals “17”-“18” (Out P_1) or “19”-“20” (Out P_2) is present (i.e. the parallel connection of the 2 NC contacts is closed: the 1st requisite is verified).But this condition could also be true if only one contact is closed and other is blocked (for welding) into closed or open position: this will be verified testing the channel when input is supplied (see the 2nd point). Instead, the absence of ohmic continuity implies that all relay contacts are blocked (for welding) into open position. • Supply the input channel (terminals “1”-“2”, or “3”-“4”) of module under test and verify that the ohmic continuity at the output contacts terminals “17”-“18” (Out P_1) or “19”-“20” (Out P_2) is absent (i.e. the parallel connection of the 2 NC contacts is open: the 2th requisite is verified). • The presence of ohmic continuity implies that at least one relay contact is blocked (for welding) into closed position: this could only be verified after disassembling and individually testing each relay. Instead, to verify if a contact is blocked (for welding) into open position, use internal DIP-switches (n°1, 3, 5) to put in short circuit one relay coil at a time (starting with the 2nd coil by DIP-switch n°3, then going on with the 3rd one by DIP-switch n°5 (for “17”-“18” Out P_1) or with the 1st one by DIP-switch n°1 (for “19”-“20” Out P_2)), verifying that the ohmic continuity is always present between terminals “17”-“18” (Out P_1) or “19”-“20” (Out P_2). In this situation, the absence of ohmic continuity implies that a relay contact (the only one with de-energized coil) is blocked (for welding) into open position.
3	Remove the bypass from the safety-related PLC or restore normal operation inserting the unit.

This test reveals almost 99% of all possible Dangerous Undetected failures in the relay module.

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