Safety Function: E-Stop String
Products: GSR SI

Safety Rating: PLd, Cat. 3 to EN ISO 13849.1 2008

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Introduction

This Safety Function application note explains how to wire and configure a string of three E-Stops to a GSR SI Safety Relay. When the three E-Stops are pressed the GSR SI safety relay responds by opening its safety contacts removing 24V from the coils of the two 100S safety contactors. The 100S contactors open removing power from the hazardous motion. The hazardous motion coasts to a stop (a Stop category 0).

Important User Information

Solid state equipment has operational characteristics differing from those of electromechanical equipment. Safety Guidelines for the Application, Installation and Maintenance of Solid State Controls (publication **SGI-1.1** available from your local Rockwell Automation® sales office or online at **http://www.rockwellautomation.com/literature**) describes some important differences between solid state equipment and hard-wired electromechanical devices. Because of this difference, and also because of the wide variety of uses for solid state equipment, all persons responsible for applying this equipment must satisfy themselves that each intended application of this equipment is acceptable.

In no event will Rockwell Automation, Inc. be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, Rockwell Automation, Inc. cannot assume responsibility or liability for actual use based on the examples and diagrams.

No patent liability is assumed by Rockwell Automation, Inc. with respect to use of information, circuits, equipment, or software described in this manual.

Throughout this manual, when necessary, we use notes to make you aware of safety considerations.

	**WARNING:** Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.
IMPORTANT	Identifies information that is critical for successful application and understanding of the product.
	**ATTENTION:** Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard, and recognize the consequence.
	**SHOCK HAZARD:** Labels may be on or inside the equipment, for example, a drive or motor, to alert people that dangerous voltage may be present.
	**BURN HAZARD:** Labels may be on or inside the equipment, for example, a drive or motor, to alert people that surfaces may reach dangerous temperatures.

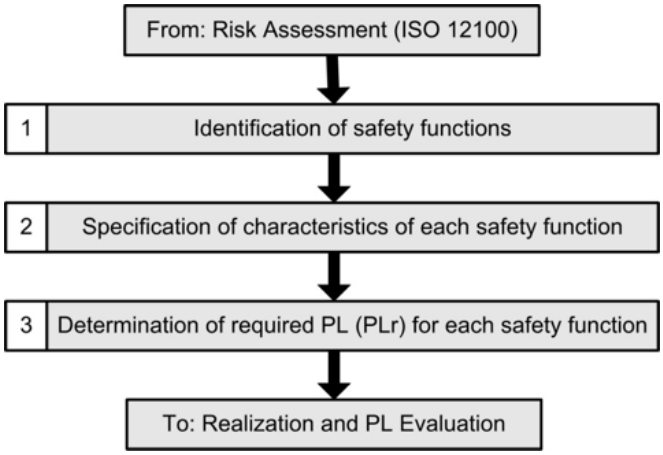
General Safety Information

Contact Rockwell Automation to find out more about our safety risk assessment services.

IMPORTANT	This application example is for advanced users and assumes that you are trained and experienced in safety system requirements.
	**ATTENTION:** A risk assessment should be performed to make sure all task and hazard combinations have been identified and addressed. The risk assessment may require additional circuitry to reduce the risk to a tolerable level. Safety circuits must take into consideration safety distance calculations which are not part of the scope of this document.

Safety Function Realization: Risk Assessment

The required performance level is the result of a risk assessment and refers to the amount of the risk reduction to be carried out by the safety-related parts of the control system. Part of the risk reduction process is to determine the safety functions of the machine. For the purposes of this document the assumed required performance level is PLd, Category 3. A safety system that achieves PLd, Category 3, or higher, can be considered control reliable.



Emergency Stop Safety Function

Safety Function: The removal of power from the hazard when the safety system detects that the E-Stop has been actuated.

ISO 13849-1 directs that when devices are connected in series such as the three E-Stops in this Safety Function application the function of each device is evaluated as a separate safety function.

In this safety function application note the three S-Stops are evaluated as three identical, E-Stop safety functions.

Safety Function Requirements

Pressing of any one of the series wired E-Stops will stop and prevent hazardous motion by removal of power to the motor. Upon resetting the E-Stop pushbutton, hazardous motion and power to the motor will not resume until a secondary action (start button depressed) occurs. Faults at the E-Stop button, wiring terminals or safety controller will be detected before the next safety demand. This Emergency Stop function is complementary to any other safeguards on the machine and shall not reduce the performance of other safety related functions. The safety function in this example is capable of connecting and interrupting power to motors rated up to 9A, 600VAC. The safety function will meet the requirements for Category 3, Performance Level “d” (Cat. 3, PLd), per ISO 13849-1, and SIL3 per IEC 62061, and control reliable operation per ANSI B11.19.

Functional Safety Description

Three E-stop push buttons are connected in series to the GSR SI Safety Relay. One channel runs through the three E-Stops between pulsed output S11 and input S12 and the other channel between pulsed output S21 and input S22. The Safety Relay monitors the pulse stream at each input to confirm that each E-Stop channel is in a proper state. When any E-Stop is pressed these two circuits are interrupted. GSR DI responds to this circuit interruption by opening its safety contacts (13 to 14 and 23 to 24) de-energizing the coils of K1 and K2. With power removed the hazardous motion coasts to a stop (Stop Category 0). The hazardous motion cannot be started until the E-Stop is released, and then the reset button is pressed and released.

To confirm the proper state of the two 100S Safety contactors before permitting a start/reset 24V is run in series through an NC auxiliary contact on each 100S to the Reset button of the GSR SI. If a safety contact of one (or both) 100S is welded closed the corresponding auxiliary NC contact is held open breaking the 24V circuit to the Reset button.

The GSR SI in this application is configured for Monitored Manual (MM) reset. When the E-Stop inputs are in the proper state and the two 100s are properly de-energized, pressing and releasing the Reset button will result in the GSR SI energizing the two 100S Safety Contactors. If the Reset button is pressed for less than .250 seconds or longer than 3 seconds the GRS will not reset. This is to prevent unintentional reset and thwart “tie down” of the Reset button.

Bill of Material

Catalog Number	Description	Quantity
800F-1YP3	800F 1-Hole Enclosure E-Stop Station, Plastic, PG, Twist-to-Release 40mm, Non-Illuminated, 2 N.C.	3
800FM-G611MX10	800F Push Button - Metal, Guarded, Blue, R, Metal Latch Mount, 1 N.O. Contact(s) - Reset	3
440R-S12R2	Guardmaster® Safety Relay, 1 Dual Channel Universal Input, 1 N.C. Solid State Auxiliary Output	1
100S-C09ZJ23C	MCS 100S-C Safety Contactor, 9A, 24V DC	2

Setup and Wiring

For detailed information on installing and wiring, refer to the product manuals listed in the **Additional Resources**.

System Overview

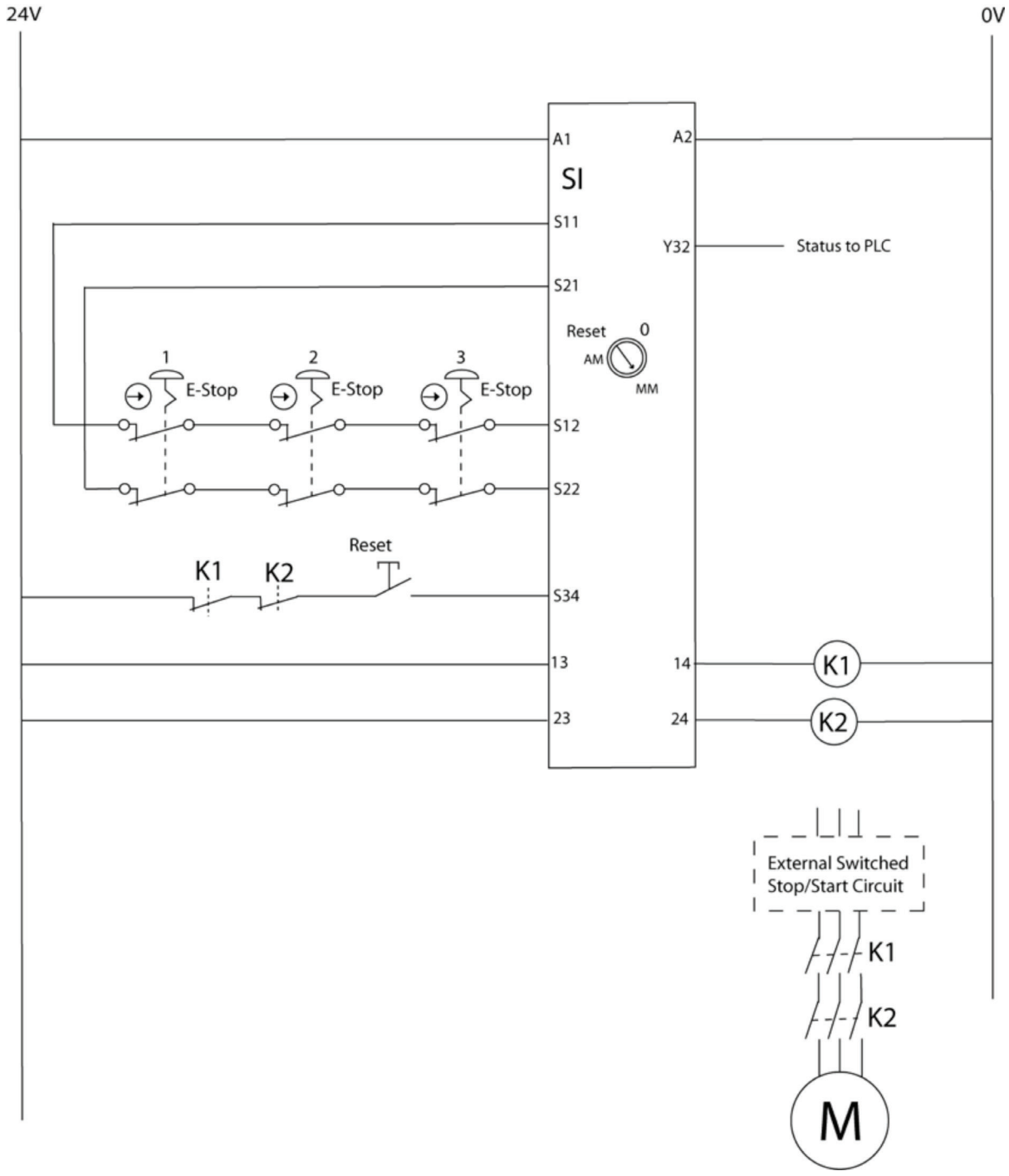
The pulsed outputs of the GSR DI (terminals S11 and S21) are run separately through the two E-Stop contact strings (E-Stop 1 to E-Stop 2 to E-Stop 3) to input terminals S12 and S22 respectively. This enables the GSR DI to detect loose wire, short to 24V, short to GND and cross channel faults. There is the possibility that a contact in one of the E-Stop's could fail closed and that this failure could be masked by the operation of the other E-Stops. For this reason the three E-Stops in the string are calculated as having a Cat. 3 structure.

The GSR DI responds to E-Stop inputs and, detected E-Stop circuit faults by opening its safety contacts (13 to 14 and 23 to 24) de-energizing the coils of K1 and K2. The GSR SI cannot be reset until the E-Stop(s) is released or fault is corrected. In some cases the E-Stop may have to be pressed and released before the GSR SI can be reset. After some faults the GSR SI must be power cycled once the fault is cleared before it can be reset.

The GSR SI monitors itself for any internal faults. When a fault is detected the GSR SI responds by opening its safety contacts (13 to 14 and 23 to 24) de-energizing the coils of K1 and K2. Some internal faults can be cleared by power cycling the GSR SI. In other cases the GSR SI must be replaced.

The GSR SI monitors the 100S contactors for welded contacts via two NC contacts in series, one from each 100S, in its reset circuit. If a contact of a 100S is welded the NC contact is held Open, breaking the reset circuit.

Electrical Schematic



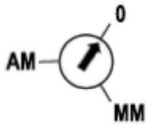
Configuration

Configuration

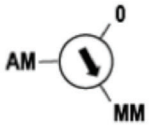
C The following procedure sets the function of the device:

1. Start configuration/overwrite: with power off, turn rotary switch to position "0" and unit is powered up. After power-up test, "PWR" LED will flash red.
2. Set configuration: turn rotary switch to "MM" (Montired Manual).. IN 1 LED blinks new setting.
   NOTE: Position is set when "PWR" LED is solid green.
3. Lock in configuration by cycling unit power.
4. Configuration must be confirmed before operation. A white space on face of device is provided to record unit setting.

❶ Enable program mode



❷ Set operation mode

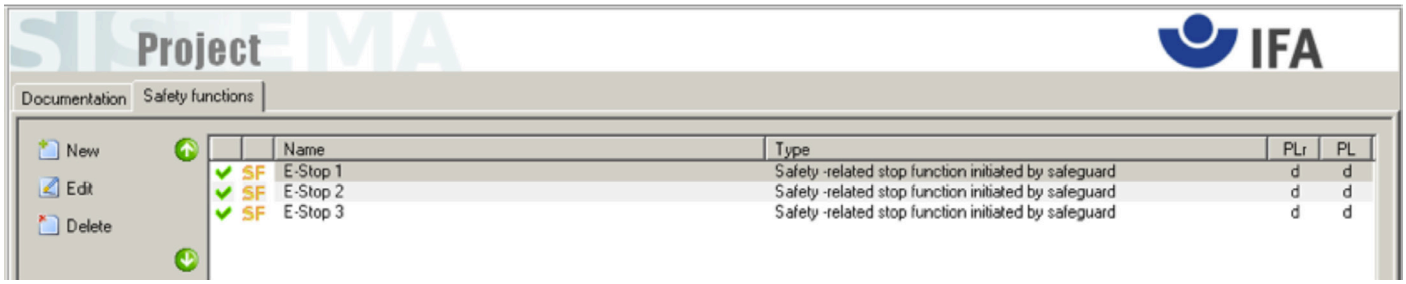


❸ Cycle power to store

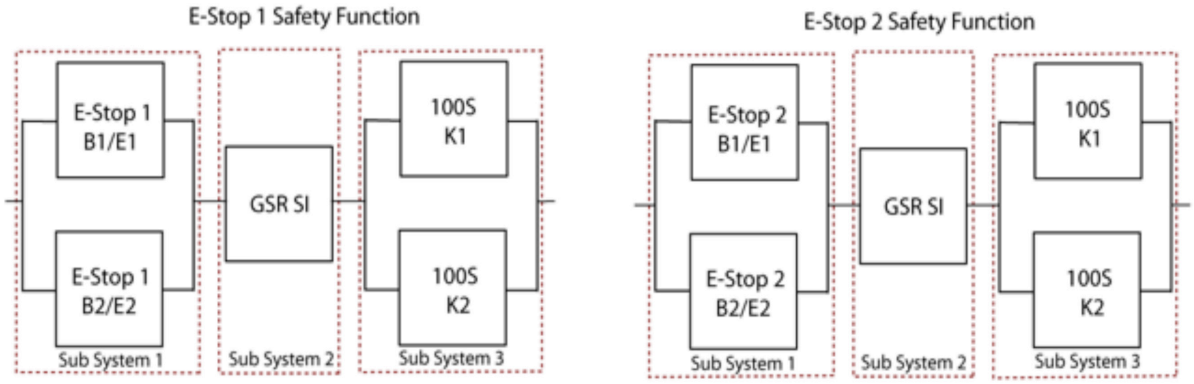
Calculation of the Performance Level

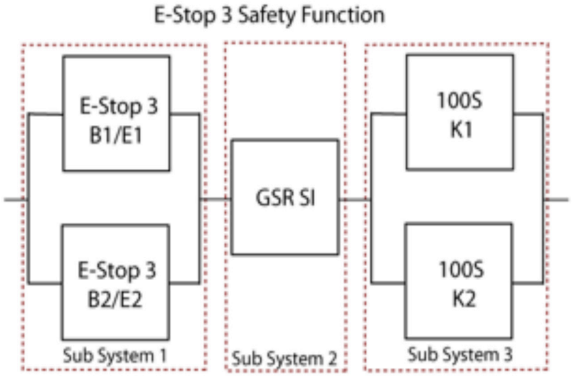
The Functional Safety Specifications of the project call for a Performance Level on PLd (minimum) and a structure of Cat 3 (minimum). A PFHd of less than 1.0 E-06 for the overall safety function is required for PLd.

When configured and installed properly, each of the three-Stop Safety Functions of this safety system, emergency stop of hazardous motion initiated by an E-Stop button, can achieve the Performance Level required, PLd, Cat. 3 according to EN ISO 13849.1 2008. as calculated using the SISTEMA tool.



The entire E-Stop Project can be modeled as follows:





The Functional Safety data for the E-Stop Input subsystem in each Safety Function is the same as in E-Stop 1:

SB E-Stop 1	
PL	d
PFH [1/h]	1.01E-7
Cat.	3
MTTFd [a]	100 (High)
DCavg [%]	60 (Low)
CCF	65 (fulfilled)

The Functional Safety data for the GSR DI Logic subsystem in each Safety Function is the same as in E-Stop 1:

SB Monitoring Safety Relay: GSR-SI	
PL	e
PFH [1/h]	3.98E-9
Cat.	4
MTTFd [a]	*not relevant*
DCavg [%]	*not relevant*
CCF	*not relevant*

The Functional safety data for the 100S Output subsystem in each Safety Function is the same as in E-Stop 1:

SB 100S Safety Contactor	
PL	e
PFH [1/h]	2.47E-8
Cat.	3
MTTFd [a]	100 (High)
DCavg [%]	99 (High)
CCF	65 (fulfilled)

Note that the E-Stop and Safety Contactors data includes MTTFd, DCavg, and CCF data. This is because these are electromechanical devices. Electromechanical devices functional safety evaluations include how frequently they are operated, whether they are effectively monitored for faults and properly specified and installed.

SISTEMA calculates the MTTFd using B10d data provided for the contactors along with the estimated frequency of use entered during the creation of the SISTEMA project. This application example presumes that the E-Stop is operated or tested at least once per day, i.e. 365 times a year.

The DCavg (99%) for the contactors was selected from the Output Device table of EN ISO 13849-1 Annex E. “Direct Monitoring”.

The DCavg (99%) for the E-Stop was selected from the Input Device table of EN ISO 13849-1 Annex E. “Cross Monitoring”. However as these are connected in series we have reduced the DC to 60%.

The (CCF) value is generated using the scoring process outlined in Annex F of ISO 13849-1. The complete CCF scoring process must be done when actually implementing an application. A minimum score of 65 points must be achieved. A CCF of 65 was entered for practical purposes in each case for Calculations are based on 1 operation of the safety guard door per hour; therefore 8,760 operations of contactors per year.

The measures against Common Cause Failure (CCF) are quantified using the scoring process outlined in Annex F of ISO 13849-1. For the purposes of the PL calculation, the required score of 65 needed to fulfill the CCF requirement is considered to be met. The complete CCF scoring process must be done when implementing this example.

Verification and Validation Plan

Verification and Validation play an important role in the avoidance of faults throughout the safety system design and development process. ISO/EN 13849-2 sets the requirements for verification and validation. It calls for a documented plan to confirm all the Safety Functional Requirements have been met.

Verification is an analysis of the resulting safety control system. The Performance Level (PL) of the safety control system is calculated to confirm it meets the Required Performance Level (PLr) specified. The SISTEMA software tool is typically utilized to perform the calculations and assist with satisfying the requirements of ISO 13849-1.

Validation is a functional test of the safety control system to demonstrate that it meets the specified requirements of the safety function. The safety control system is tested to confirm all of the safety related outputs respond appropriately to their corresponding safety related inputs. The functional test should include normal operating conditions in addition to potential fault inject of failure modes. A checklist is typically used to document the validation of the safety control system.

When configured and installed properly, each of the three-Stop Safety Functions of this safety system, emergency stop of hazardous motion initiated by an E-Stop button, can achieve the Performance Level required, PLd, Cat. 3 according to EN ISO 13849.1 2008 as calculated using the SISTEMA tool.

Prior to validating the GSR Safety Relay system, it is necessary to confirm the GSR Relay has been wired and configured in accordance with the Installation Instructions.

GSR Emergency Stop Safety Function Verification and Validation Checklist			
General Machinery Information			
Machine Name / Model Number			
Machine Serial Number			
Customer Name			
Test Date			
Tester Name(s)			
Schematic Drawing Number			
Guardmaster Safety Relay Model			
Safety Wiring and Relay Configuration Verification			
Test Step	**Verification**	**Pass/Fail**	**Changes/Modifications**
	Visually inspect the safety relay circuit is wired as documented in the schematics.		
	Visually inspect the safety relay rotary switch settings are correct as documented.		
Normal Operation Verification - The safety relay system properly responds to all normal Start, Stop, Estop and Reset Commands			
Test Step	**Verification**	**Pass/Fail**	**Changes/Modifications**
	Initiate a Start Command. Both contactors should energize for a normal machine run condition. Verify proper machine status indication and safety relay LED indication.		
	Initiate a Stop Command. Both contactors should de-energize for a normal machine Stop condition. Verify proper machine status indication and safety relay LED indication.		
	While Running, press the E-Stop pushbutton. Both contactors should de-energize and open for a normal safe condition. Verify proper machine status indication and safety relay LED indication. Repeat for all E-Stop pushbuttons.		
	While Stopped, press the E-Stop pushbutton, initiate a Start Command. Both contactors should remain de-energized and open for a normal safe condition. Verify proper machine status indication and safety relay LED indication. Repeat for all E-Stop pushbuttons.		
	Initiate Reset Command. Both contactors should remain de-energized. Verify proper machine status indication and safety relay LED indication.		
Abnormal Operation Verification - The Safety Relay system properly responds to all foreseeable faults with corresponding diagnostics. E-Stop Input Tests			
Test Step	**Validation**	**Pass/Fail**	**Changes/Modifications**
	While Running, remove the Channel 1 wire from the safety relay. Both contactors should de-energize. Verify proper machine status indication and safety relay LED indication. Repeat for Channel 2.		
	While Running, short the Channel 1 of the safety relay to +24VDC. Both contactors should de-energize. Verify proper machine status indication and safety relay LED indication. Repeat for Channel 2.		
	While Running, short the Channel 1 of the safety relay to (-) 0VDC. Both contactors should de-energize. Verify proper machine status indication and safety relay LED indication. Repeat for Channel 2.		
	While Running, short Channels 1 & 2 of the safety relay. Both contactors should de-energize. Verify proper machine status indication and safety relay LED indication.		
GSR Logic Solver Tests			
Test Step	**Validation**	**Pass/Fail**	**Changes/Modifications**
	While Running, remove the single wire safety connection between two adjoining safety relays in the system. All contactors should de-energize. Verify proper machine status indication and safety relay LED indication. Repeat for all safety connections. This test is not applicable for single relay circuits.		
	While Running, turn the logic rotary switch on the safety relay. All contactors should remain de-energized. Verify proper machine status indication and safety relay LED indication. Repeat for all safety relays in the system.		
Safety Contactor Output Tests			
Test Step	**Validation**	**Pass/Fail**	**Changes/Modifications**
	While Running, remove the contactor feedback from the safety relay. All contactors should remain energized. Initiate a Stop Command followed by a Reset Command. The relay should not restart or reset. Verify proper machine status indication and safety relay LED indication.		

Additional Resources

For more information about the products used in this example refer to these resources.

Document	Pub. No.	Description
Guard Locking Switch Installation Instructions	440G-IN007	How to install, commission, operate and maintain the 440G-TZS21UPRH
Guardmaster Safety Relay Installation Instructions	10000175129	How to install, commission, operate and maintain the 440R-D22R2 Safety Relays
Guardmaster Safety Relay Troubleshooting Guide	440R-TG002	How to troubleshoot the 440RD22R2 Safety Relays
Guardmaster Expansion Relay Installation Instructions	440R-IN045	How to install, commission, operate and maintain the 440R-EM4R2D Expansion Relay
Guardmaster Expansion Relay Troubleshooting Guide	440R-TG001	How to install, commission, operate and maintain the 440R-EM4R2D Expansion Relay
Safety Products Catalog	S117-CA001A	Overview of Safety products, product specifications, and application examples
GuardShield Type 4 User Manual	440L-UM003	How to install, operate, and maintain the 440L Safety Light Curtains
Next Generation Guardmaster Safety Relays	SAFETY-WD001	Functional descriptions, guidance, and wiring for Safety Relays
Heavy Duty Guard Interlock Switch Installation Instructions	440K-IN008	How to install, configure, commission, operate, and maintain MT-GD2 Interlock Switches
Trojan T15 Interlock Switch Installation Instructions	440K-IN003	How to install, configure, commission, operate, and maintain Trojan T15 Interlock Switches
Safety Interlock Switches Brochure	EUSAFE-BR001	Overview of Interlock Switches
Guardmaster Safety Relay SI Installation Instructions	440R-IN042	How to install, configure, commission, operate, and maintain GSR SI Safety Relays
Guardmaster Safety Relays Selection Guide	440R-SG001	Overview of Guardmaster Safety Relays
RightSight Photoelectric Sensor Installation Instructions	42EF-IN003	How to install, commission, operate, and maintain 42EF Photoelectric Sensors
MSR42 Control Module User Manual	440R-UM008	How to install, commission, operate, and maintain MSR42 Systems
MSR45E Safety Relay Expansion Module User Manual	440R-UM007	How to install, commission, operate, and maintain the MSR45E Expansion Module
SensaGuard Integrated Latch Unique Coded Installation Instructions	440N-IN011	How to install, commission, operate, and maintain the SensaGuard
Touch Button and Guard Installation Instructions	800Z-IN001-MU	How to install and mount the 800Z Touch Button
Zero-Force Touch Buttons Family Brochure	800Z-BR002	Brochure that describes all 800Z Palm Buttons
MSR12T Safety Relays Installation Instructions	MINOTR-IN010	How to install, configure, commission, operate, and maintain the MSR 12T Safety Relays
Guardmaster Safety Relay Installation Instructions	440R-IN042	How to install, commission, operate and maintain the 440R-S12R2 Safety Relays

You can view or download publications at **http://www.rockwellautomation.com/literature**. To order paper copies of technical documentation, contact your local Allen-Bradley® distributor or Rockwell Automation sales representative.

For More Information on Safety Function Capabilities, visit:

discover.rockwellautomation.com/safety

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