

Safety Function: Door Monitoring Products: SensaGuard™ / GSR DI

Safety Rating: PLe, Cat. 4 to EN ISO 13849.1 2008







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#### Introduction

This Safety Function application note explains how to wire and configure a SensaGuard non-contact, latching interlock and an E-Stop as input devices, a GSR DI as the Logic/Control and two 100S safety contactors as the output devices to create an integrated safety system.

## **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 <a href="http://www.rockwellautomation.com/literature">http://www.rockwellautomation.com/literature</a>) 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.

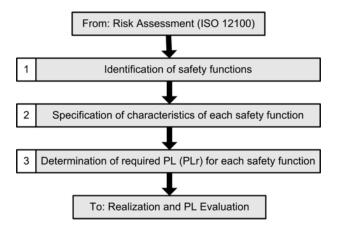
The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, Rockwell Automation, Inc. cannot assume responsibility or liability for actual use based on the examples and diagrams.

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

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### **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 PLe, Category 4. A safety system that achieves PLe, Category 4, or higher, can be considered control reliable.



## **Interlock Safety Function**

This Safety Function application note provides two Safety Functions:

- 1. A door monitoring function—the removal of power from the hazard when the safety system detects that the door has been opened.
- 2. An E-Stop function—the removal of power from the hazard when the safety system detects that the E-Stop has been actuated.

## **Safety Functional Requirements**

Opening of a guard door will stop and prevent hazardous motion by removal of power to the motor. Upon closing of the door, hazardous motion and power to the motor will not resume until a secondary action (reset button depressed and released) occurs. Pressing the E-Stop button will stop and prevent hazardous motion by removal of power to the motor. The motor coasts to a stop: a Stop Category 0. Upon releasing the E-Stop, hazardous motion and power to the motor will not resume until a secondary action (reset button depressed and released) occurs. Faults at the door interlock switch, wiring terminals or safety controller will be detected before the next safety demand. The safety functions in this example are capable of connecting and interrupting power to motors rated up to 9 A, 600V AC.

Both these safety functions will meet the requirements (PLr) Performance Level "e", for Category 4 (PLe, Cat 4), per ISO 13849-1, and SIL3 per IEC 62061, and control reliable operation per ANSI B11.19.

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



## **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.   |
|-----------|--|
| Δ         | 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. |

## **Functional Safety Description**

**Door monitoring function:** When the door is opened the SensaGuard turns off its OSSD outputs. The GSR DI responds to the SensaGuard outputs turning off 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 door is closed, and then the reset button is pressed and released.

**E-Stop function:** The pulsed outputs of the GSR DI (terminals S11 and S21) are run separately through the two E-Stop contacts to the input terminals S12 and S22 respectively. When the 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.

#### Bill of Material

| Catalog Number | Description   |   |  |
|----------------|---|---|--|
| 800F-1YP3      | 800F 1-hole Enclosure E-Stop Station, Plastic, PG, Twist-to-Release 40 mm, Non-illuminated, 2 N.C.                                    | 1 |  |
| 800F-BX10      | NO Status Contact (add to 800F-1YP3)  |   |  |
| 440N-Z21SS3PA  | SensaGuard, Plastic with Integrated Latch, 2 x PNP, 0.2 A, max Safety Output, 3 m (9.84 ft) Cable                                     | 1 |  |
| 800FM-G611MX10 | 800F Push Button - Metal, Guarded, Blue, R, Metal Latch Mount, 1 N.O. Contact(s), 0 N.C. Contact(s), Standard, Standard Pack (qty. 1) |   |  |
| 440R-D22R2     | Guardmaster® Safety Relay, 2 Dual Channel Universal Inputs, 1 N.C. Solid State Auxiliary Outputs                                      | 1 |  |
| 100S-C09EJ23C  | MCS 100S-C Safety Contactor, 9 A, 24V DC  | 2 |  |

## **Setup and Wiring**

For detailed information on installing and wiring, refer to the product manuals listed in the <u>Additional Resources</u>.

#### **System Overview**

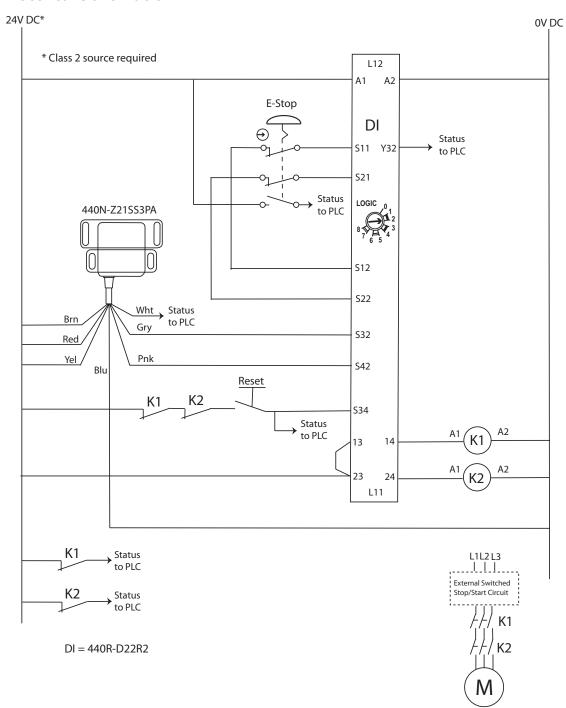
The SensaGuard monitors its OSSD outputs for loose wire, wire shorted to 24V, wire shorted to GND and cross channel faults. When a fault is detected the SensaGuard responds by turning both its OSSD outputs off. The SensaGuard will not turn its OSSD outputs on again until the faults are corrected and the door is closed. In some cases, after the fault is corrected, the SensaGuard must be power cycled before it will turn on its OSSD outputs.

The pulsed outputs of the GSR DI (terminals S11 and S21) are run separately through the two E-Stop contacts to the input terminals S12 and S22 respectively. This enables the GSR DI to detect loose wire, contact failed closed, short to 24V, short to GND and cross channel faults. The GSR DI responds to faults by opening its safety contacts (13 to 14 and 23 to 24) de-energizing the coils of K1 and K2. The GSR DI cannot be reset until the fault is removed. In some cases the E-Stop may have to be pressed and released before the GSR DI can be reset. After some faults the GSR DI must be power cycled once the fault is cleared before it can be reset.

The GSR DI monitors itself for any internal faults. When a fault is detected the GSR DI 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 DI. In other cases the GSR DI must be replaced.

The GSR DI 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

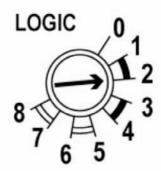
## **Configure the DI**

- The following procedure sets the function of the device:
- 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.
- Set configuration: turn rotary switch to position "2". IN 1 LED blinks new setting.

**NOTE:** Position is set when "PWR" LED is solid green.

- 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.

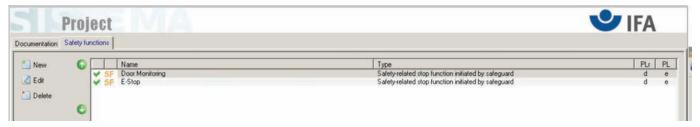
Logic "2" = L12 OR (IN 1 AND IN 2)



#### **Calculation of the Performance Level**

When configured correctly, the three Safety Functions in this project all achieve the PLr of PLd, (Cat. 4) or better.

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.



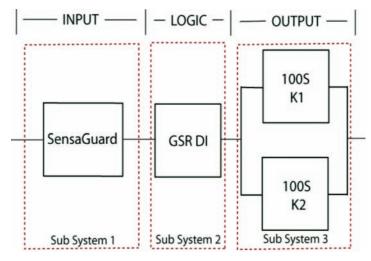
The Door Monitoring Safety Function's Functional safety data are:



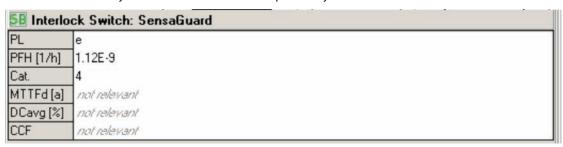
The E-Stop Safety Function's Functional safety data are:



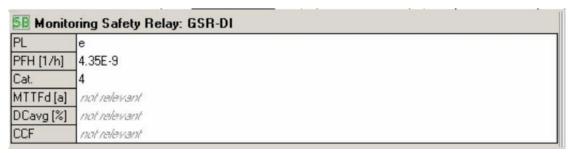
The Door Monitoring Safety Function can be modeled as follows:



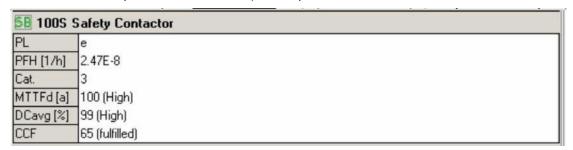
The Functional Safety data for the SensaGuard Input subsystem is:



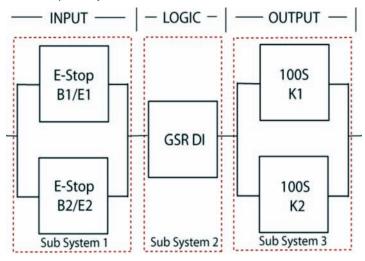
The Functional Safety data for the GSR DI Logic subsystem is:



The Functional Safety data for the 100S Output subsystem is:



The E-Stop Safety Function can be modeled as follows:



The Functional Safety data for the E-Stop Input subsystem is:

```
        PL
        e

        PFH [1/h]
        2.47E-8

        Cat.
        4

        MTTFd [a]
        100 (High)

        DCavg [%]
        99 (High)

        CCF
        65 (fulfilled)
```

The Functional Safety data for the GSR DI Logic subsystem is:

| 58 Monitoring Safety Relay: GSR-DI |              |  |  |
|------------------------------------|--------------|--|--|
| PL                                 | e            |  |  |
| PFH [1/h]                          | 4.35E-9      |  |  |
| Cat.                               | 4            |  |  |
| MTTFd[a]                           | not relevant |  |  |
| DCavg [%]                          | not relevant |  |  |
| CCF                                | not relevant |  |  |

The Functional Safety data for the 100S Output subsystem is:

| 5B 100S Safety Contactor |                |  |  |
|--------------------------|----------------|--|--|
| PL                       | е              |  |  |
| 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 once per day ie 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".

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. 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.

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 Door Monitoring Safety Function Verification and Val  | idation Checklis   | t                             |  |
|------------------------|---|---|--------------------|-------------------------------|--|
|                        |   | General Machinery Information   |                    |                               |  |
| Machine Nan            | ne / Model Number   |   |                    |                               |  |
| Machine Serial Number  |   |   |                    |                               |  |
| Customer Name          |   |   |                    |                               |  |
| Test Date              |   |   |                    |                               |  |
| Tester Name(s)         |   |   |                    |                               |  |
| Schematic Dr           | rawing Number   |   |                    |                               |  |
| Guardmaster            | Safety Relay Model  |   |                    |                               |  |
|                        |   | Safety Wiring and Relay Configuration Verific   | ation              |                               |  |
| Test Step              |   | Verification  | Pass/Fail          | Changes/Modifications         |  |
|                        | Visually inspect the sa   | afety relay circuit is wired as documented in the schematics.   |                    |                               |  |
|                        | Visually inspect the sa   | afety relay rotary switch settings are correct as documented.   |                    |                               |  |
| No                     | rmal Operation V  | erification - The safety relay system properly responds to all norr   | nal Start, Stop, E | stop and Reset Commands       |  |
| Test Step              |   | Verification  | Pass/Fail          | Changes/Modifications         |  |
|                        |   | and. Both contactors should energize for a normal machine run condition.<br>e status indication and safety relay LED indication.  |                    |                               |  |
|                        |   | and. Both contactors should de-energize for a normal machine Stop condition.<br>e status indication and safety relay LED indication.  |                    |                               |  |
|                        |   | the monitored guard door. Both contactors should de-energize and open for a<br>n. Verify proper machine status indication and safety relay LED indication.<br>oors.   |                    |                               |  |
|                        | While Stopped, with the guard door open, 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 door locks. |   |                    |                               |  |
|                        | Initiate Reset Command. Both contactors should remain de-energized. Verify proper machine status indication and safety relay LED indication.  |   |                    |                               |  |
| Abnor                  | mal Operation Ve  | rification - The Safety Relay system properly responds to all fores<br>Door Monitoring Input Tests  | seeable faults wi  | th corresponding diagnostics. |  |
| Test Step              | p Validation  |   | Pass/Fail          | Changes/Modifications         |  |
|                        |   | ve the Channel 1 wire from the safety relay. Both contactors should de-energize.<br>e status indication and safety relay LED indication. Repeat for Channel 2.  |                    |                               |  |
|                        | While Running, short the Channel 1 of the safety relay to +24V DC. 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 (-) 0V DC. 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         |  |
|                        | system. All contactors  | ve the single wire safety connection between two adjoining safety relays in the<br>s should de-energize. Verify proper machine status indication and safety relay LED<br>r all safety connections. This test is not applicable for single relay circuits. |                    |                               |  |
|                        |   | the logic rotary switch on the safety relay. All contactors should remain<br>proper machine status indication and safety relay LED indication. Repeat for all<br>stem.  |                    |                               |  |
|                        |   | Safety Contactor Output Tests   |                    |                               |  |
| Test Step              |   | Validation  | Pass/Fail          | Changes/Modifications         |  |
|                        | energized. Initiate a S   | ve the contactor feedback from the safety relay. All contactors should remain<br>Stop Command followed by a Reset Command. The relay should not restart or reset.<br>e status indication and safety relay LED indication.                                 |                    |                               |  |

|              |  | GSR Emergency Stop Safety Function Verification and Val   | idation Checklis  | t                             |  |  |
|--------------|--|---|-------------------|-------------------------------|--|--|
|              |  | General Machinery Information   |                   |                               |  |  |
| Machine Nan  | ne / Model Number  |   |                   |                               |  |  |
| Machine Seri | al Number  |   |                   |                               |  |  |
| Customer Na  | me   |   |                   |                               |  |  |
| Test Date    |  |   |                   |                               |  |  |
| Tester Name( |  |   |                   |                               |  |  |
|              | awing Number   |   |                   |                               |  |  |
| Guardmaster  | Safety Relay Model   | Safety Wiring and Relay Configuration Verific   | ation             |                               |  |  |
| Test Step    |  | Verification  | Pass/Fail         | Changes/Modifications         |  |  |
| rest step    | Visually inspect the sa  | afety relay circuit is wired as documented in the schematics.   | 1 433/1 411       | changes/mounteations          |  |  |
|              |  | afety relay rotary switch settings are correct as documented.   |                   |                               |  |  |
| No           |  | erification - The safety relay system properly responds to all norn   | aal Start Stan Er | ston and Poset Commands       |  |  |
|              | illiai Operation v   | Verification  Verification  | Pass/Fail         | Changes/Modifications         |  |  |
| Test Step    | Initiate a Charat Commun   |   | Pass/Fall         | Changes/Modifications         |  |  |
|              | Verify proper machine  | and. Both contactors should energize for a normal machine run condition.<br>e status indication and safety relay LED indication.  |                   |                               |  |  |
|              |  | and. Both contactors should de-energize for a normal machine Stop condition.<br>e 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.   |   |                   |                               |  |  |
| Abnor        | mal Operation Ve   | rification - The Safety Relay system properly responds to all fores<br>E-Stop Input Tests   | eeable faults wi  | th corresponding diagnostics. |  |  |
| Test Step    |  | Validation  | Pass/Fail         | Changes/Modifications         |  |  |
|              |  | ve the Channel 1 wire from the safety relay. Both contactors should de-energize.<br>e status indication and safety relay LED indication. Repeat for Channel 2.  |                   |                               |  |  |
|              | While Running, short the Channel 1 of the safety relay to +24V DC. 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 (-) 0V DC. 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         |  |  |
|              | system. All contactors   | ve the single wire safety connection between two adjoining safety relays in the s should de-energize. Verify proper machine status indication and safety relay LED all safety connections. This test is not applicable for single relay circuits. |                   |                               |  |  |
|              |  | he logic rotary switch on the safety relay. All contactors should remain<br>proper machine status indication and safety relay LED indication. Repeat for all<br>stem.   |                   |                               |  |  |
|              |  | Safety Contactor Output Tests   |                   |                               |  |  |
| Test Step    |  | Validation  | Pass/Fail         | Changes/Modifications         |  |  |
|              | energized. Initiate a S  | ve the contactor feedback from the safety relay. All contactors should remain itop Command followed by a Reset Command. The relay should not restart or reset. e 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   |
| <b>Guardmaster Safety Relay SI Installation Instructions</b>       | 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              |

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# For More Information on Safety Function Capabilities, visit:

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