



Safety Function: Single-beam Area Access Control (AAC)

Products: Guardmaster Dual-input Safety Relay, Single-beam Area Access Control Sensors with E-stop

Safety Rating: CAT. 4, PLe to EN ISO 13849-1: 2008

LISTEN.
THINK.
SOLVE.®

Important User Information

Read this document and the documents listed in the additional resources section about installation, configuration, and operation of this equipment before you install, configure, operate, or maintain this product. Users are required to familiarize themselves with installation and wiring instructions in addition to requirements of all applicable codes, laws, and standards.

Activities including installation, adjustments, putting into service, use, assembly, disassembly, and maintenance are required to be carried out by suitably trained personnel in accordance with applicable code of practice.

If this equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.



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.




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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.
	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.
IMPORTANT	Identifies information that is critical for successful application and understanding of the product.

Labels may also be on or inside the equipment to provide specific precautions.

	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.
	ARC FLASH HAZARD: Labels may be on or inside the equipment, for example, a motor control center, to alert people to potential Arc Flash. Arc Flash will cause severe injury or death. Wear proper Personal Protective Equipment (PPE). Follow ALL Regulatory requirements for safe work practices and for Personal Protective Equipment (PPE).

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: Perform a risk assessment to make sure all task and hazard combinations have been identified and addressed. The risk assessment can 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.

Table of Contents

Important User Information	2
General Safety Information	3
Introduction	3
Safety Function Realization: Risk Assessment	4
Single-beam Area Access Control Sensor Safety Function	4
Safety Function Requirements	4
Functional Safety Description	5
Bill of Material	5
Setup and Wiring	5
Configuration	8
Calculation of the Performance Level.....	9
Verification and Validation Plan.....	13
Additional Resources	18

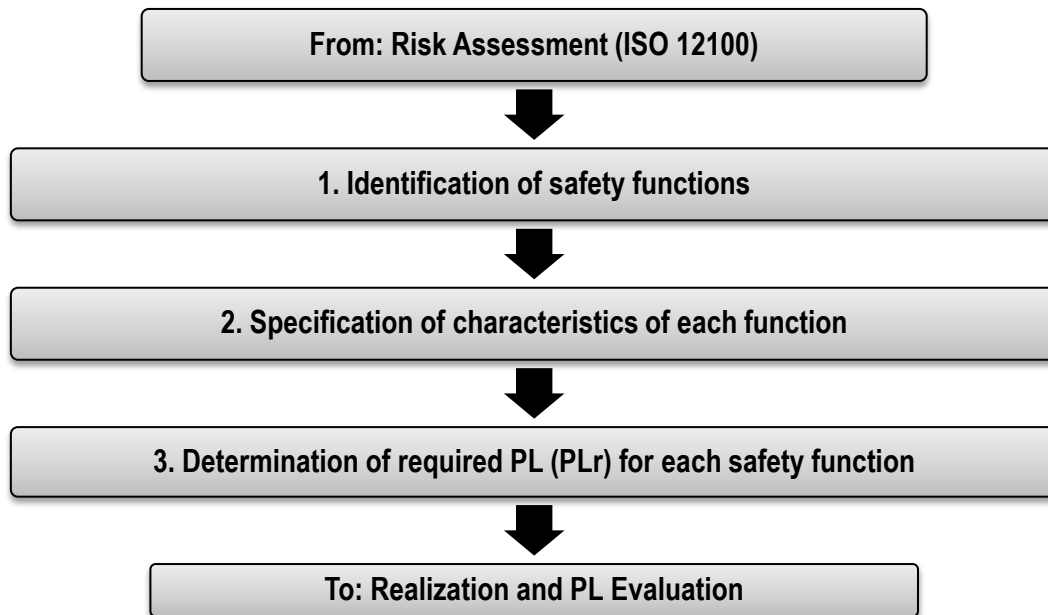
Introduction

This safety application technique explains how to wire and configure a Guardmaster® dual-input safety relay to monitor both an E-stop and single-beam area access control sensor. When an object intrudes into the sensor's field of view, the E-stop is actuated, or a fault is detected in the monitoring circuit, the relay de-energizes the final control devices, in this case, a pair of 100S safety contactors.

E-stops are required in most applications' safety systems that require a sensing device, like a single-beam area access control sensor, and an E-stop combination. The relay, with its dual inputs, makes this easy to implement in a single safety relay.

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. In this application, the performance level required (PLr) by the risk assessment is Category 3, Performance Level d (CAT. 3, PLd), for each safety function. A safety system that achieves CAT. 3, PLd, or higher, can be considered control reliable. Each safety product has its own rating and can be combined to create a safety function that meets or exceeds the PLr.



Single-beam Area Access Control Sensor Safety Function

The safety system described in this application has two safety functions:

- Safety-related stop initiated by intrusion into the single-beam area access control sensor field
- Emergency stop initiated by actuation of an emergency button

This system executes a Stop Category 0 stop. Power is immediately removed and motion coasts to a stop.

Safety Function Requirements

The single-beam area access control sensor must be installed at a distance from the hazardous motion such that a user cannot reach the hazard before the motion has stopped. This distance is called the Safety Distance and is addressed later in this application technique. An object intruding into the sensor's field of view stops the hazardous motion by removing power to the motor. The system cannot be reset while an object is in the field of view. Once the object has left the field of view, the Reset button is pressed and released (a separate action), which resumes hazardous motion.

Pressing the E-stop button stops hazardous motion by removing power to the motor. Releasing the E-stop button does not restart hazardous motion. Pressing and releasing the Reset button after the E-stop has been reset and all faults are cleared, results in the restoration of hazardous motion.

A fault at the sensor, wiring, or safety relay is not detected before the next safety demand. The safety system described in this application technique is capable of connecting and interrupting power to motors rated up to 9 A, 600V AC. The safety functions in this application technique each meet or exceed the requirements for Category 3, Performance Level d (CAT. 3, PLd), per EN ISO 13849-1 and control reliable operation per ANSI B11.19.

Functional Safety Description

When an object interrupts the safety single-beam area access control sensor's field of view, hazardous motion is stopped and prevented from restarting until the field of view is restored.

Likewise, when the E-stop button is pressed and released, hazardous motion is stopped and prevented from restarting until the Reset button is pressed and released.

Bill of Material

This application uses these products.

Cat. No.	Description	Quantity
440L-T4F2070-Q	Single-beam sensor, 0...70 m range, terminal chamber with cable gland (PG 13.5 thread)	1
440L-R4F0020-Q	Single-beam sensor, 0.5...20 m range, 24V DC, terminal chamber with cable gland (PG 13.5 thread)	1
800F-1YP8	800F 1-hole enclosure E-stop station, plastic, PG, twist-to-release 60 mm, non-illuminated, 1 N.O. contact, 2 N.C. contacts	1
800FM-G611MX10	800F push button - metal, guarded, blue, R, metal latch mount, 1 N.O. contact, 0 N.C. contact, standard pack (quantity 1)	1
100S-C09ZJ23C	MCS 100S-C safety contactor, 9 A, 24V DC	2
440R-D22R2	Guardmaster dual-input safety relay, 2 dual-channel universal inputs, 1 N.C. contact, solid-state auxiliary outputs	1

Setup and Wiring

For detailed information on installing and wiring, refer to the product manuals listed in the [Additional Resources](#).

System Overview

When an object intrudes into the single-beam area access control sensor's field of view, the sensor opens its two N.C. contact outputs. The safety relay responds by opening its two output relays, removing 24V DC from the coils of the two safety contactors, whose contacts open, and thereby removing power to the motor. The motor coasts to a stop (Stop Category 0).

The sensor's outputs turn back on once its field of view is no longer interrupted. The Guardmaster dual-input safety relay's pulse-test outputs (S11 and S21) are run through the two N.C. contacts of the sensor to inputs S32 and S42, respectively.

The relay's pulse-test outputs (S11 and S21) are run through the two N.C. contacts of the E-stop to inputs S12 and S22, respectively. When the E-stop is pressed and released, these circuits are interrupted. Interruption of the area access sensor beam or actuation of the E-stop results in a change of status of the input signals to the safety relay. The motor coasts to a stop (Stop Category 0).

The relay monitors the E-stop circuit and the sensor for faults. Open circuit fault, shorts to 24V DC, shorts to GND, contact-weld fault, and channel-cross faults are detected. When a fault is detected, the relay responds by opening its mechanically-linked safety contacts, removing 24V DC power from the 100S contactor coils and thereby removing power to the motor. The motor coasts to a stop (Stop Category 0).

Two N.C. contacts, one from each of the safety contactors, are connected as part of the reset circuit. The safety relay can be reset only if both safety contactors are in a proper de-energized state.

The safety relay cannot be reset while the E-stop remains actuated or while the sensor's contact outputs are off. Once the E-stop has been released and/or the sensor's contact outputs turn on, and the Reset button is pressed and released (a separate, deliberate action), hazardous motion resumes. The Reset button must be pressed between 0.25...3 seconds. Both a shorter press and a longer press are ignored.

The safety relay checks itself for internal faults, faults on its inputs and wiring, and monitors the safety contactors, via the contactors N.C. contacts, in the reset circuit.

No single fault results in the safety system failing to perform its safety function. A single fault is detected before the next demand on the safety system. The system cannot be reset until the fault is corrected.

Installation

Refer to the installation instructions and user manuals for guidance on installing and maintaining the different parts of this system.

A single-beam area access control sensor provides no physical barrier between personnel and the hazardous motion. The sensor must be installed at a sufficient distance from the hazardous motion to make sure that an operator putting a hand through the sensor cannot reach the hazard before it has stopped. This distance is referred to as the Safety Distance. Two mirrors are used with the sensor to create two beam paths, at different heights, across the guarded area.

The Safety Distance (Ds) required varies from installation to installation, and therefore must be calculated for each specific application. This application technique uses EN ISO 13855 for calculations as shown on [page 7](#).

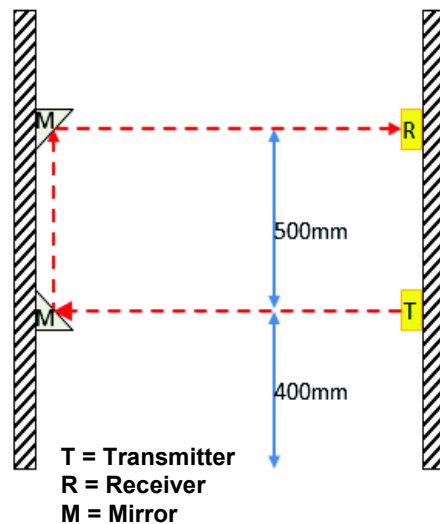
Formula: $S = (K \times T) + C$

Symbol	Definition
S	Minimum distance, in millimeters (mm)
K	Parameter, in millimeters per second (mm/s), derived from data on approach speeds of the body or parts of the body
T	Overall stopping performance in seconds
C	Intrusion distance in millimeters (mm)

In this application technique example, the values are as follows.

K	1600 mm/s
T	972 ms (Machine Stopping Time + Reaction time of LC + Reaction time of DI and contactors K1/K2)
C	850 mm
S	$1600 \times 972 + 850 = 2405.2$ Conclusion: The single-beam area access control sensor must not be mounted closer than 2405.2 mm (94.7 in.) from the hazardous motion that is being guarded against.

The above calculation is based on the following mounting consideration, with two separate beams, deduced from the risk assessment for reduction of the risk.



With reference to the EN ISO 13855: 2010, Appendix E standard, for two-beam applications, the two mounting heights are 400 mm and 900 mm from the ground or panel level that correspond to adequate risk reduction and application practice.

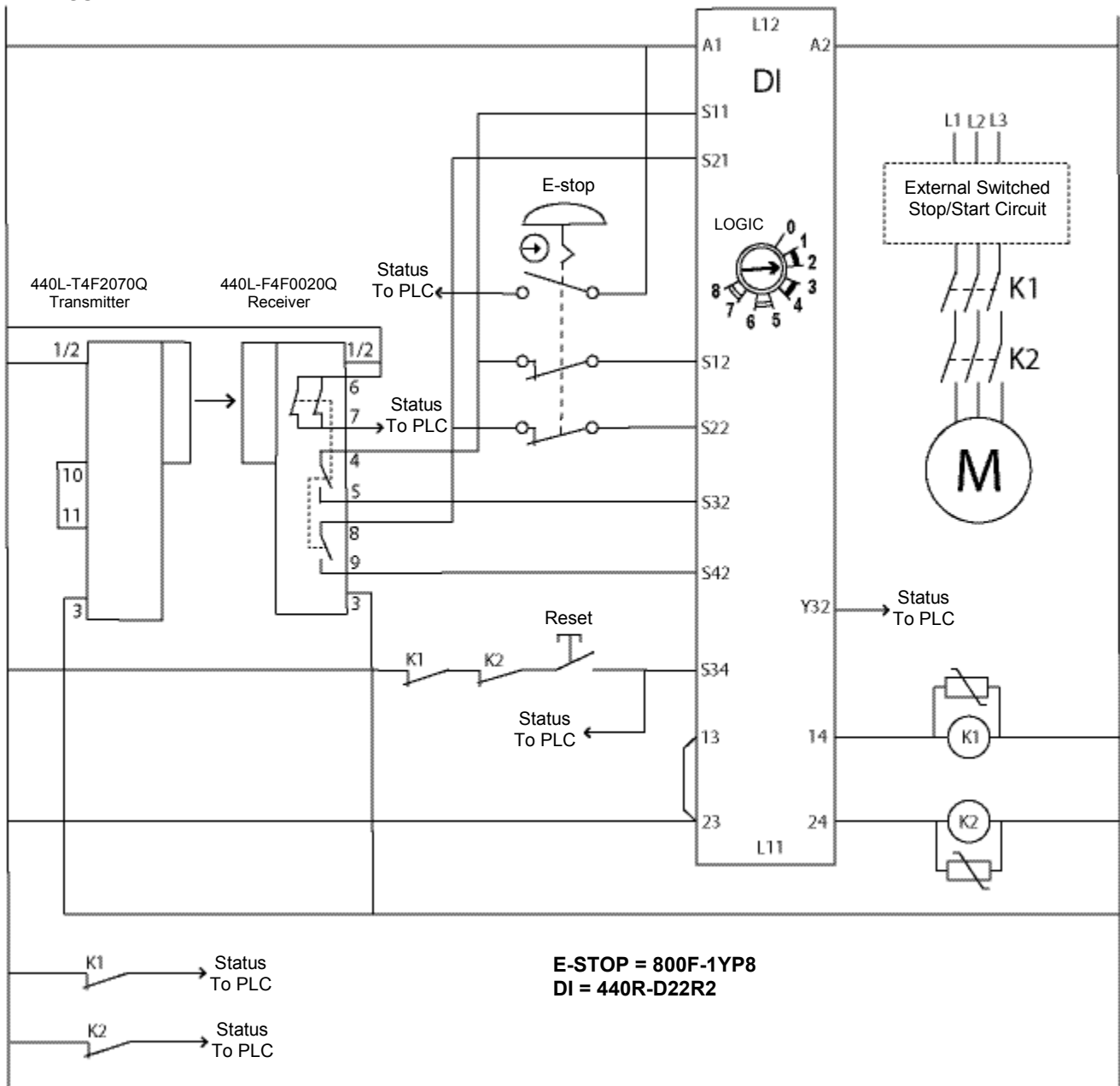
Therefore, in applying the multiple separated beam, the following formula is used:
 $S = 1600 \times T + 850$.

According to EN ISO 13855:2010, Appendix E, the two-beam application of the lowest height of 400 mm can be used only when the risk assessment allows.

Electrical Schematic

24V DC SUPPLY

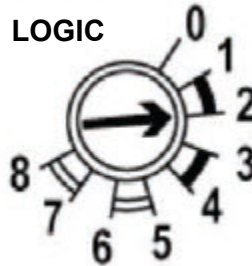
24V DC COM



Configuration

The 440L single-beam area access control sensor needs no settings; only alignment of the transmitter and receiver is necessary.

The 440R-D22R2 safety relay must be configured for LOGIC 2, (L12) or (IN 1 and IN 2), per the installation instructions, publication [10000175129 ver. 00](#).



Calculation of the Performance Level

The Performance Level required from the risk assessment is Category 3, Performance Level d (CAT. 3, PLd). When properly implemented, the safety functions described here can achieve a Category 4, Performance Level e (CAT. 4, PLe), according to EN ISO 13849-1: 2008, as calculated by using the SISTEMA tool. Calculations are based on each safety function being operated once an hour, 24 hours a day, 365 days a year, for a total of 8760 operations a year. The 100S contactors are used in both safety functions, therefore, their calculations are based on 17,520 operations per year.

SISTEMA

Project

IFA

Documentation

Safety functions

New

Edit

Delete

Status

Type

Name

Type

PLr

PL

✓

SF

AAC Safety Function

d

e

✓

SF

Estop SafetyFunction

d

e

This safety system includes two safety functions: single-beam area access control sensor safety function and an E-stop safety function.

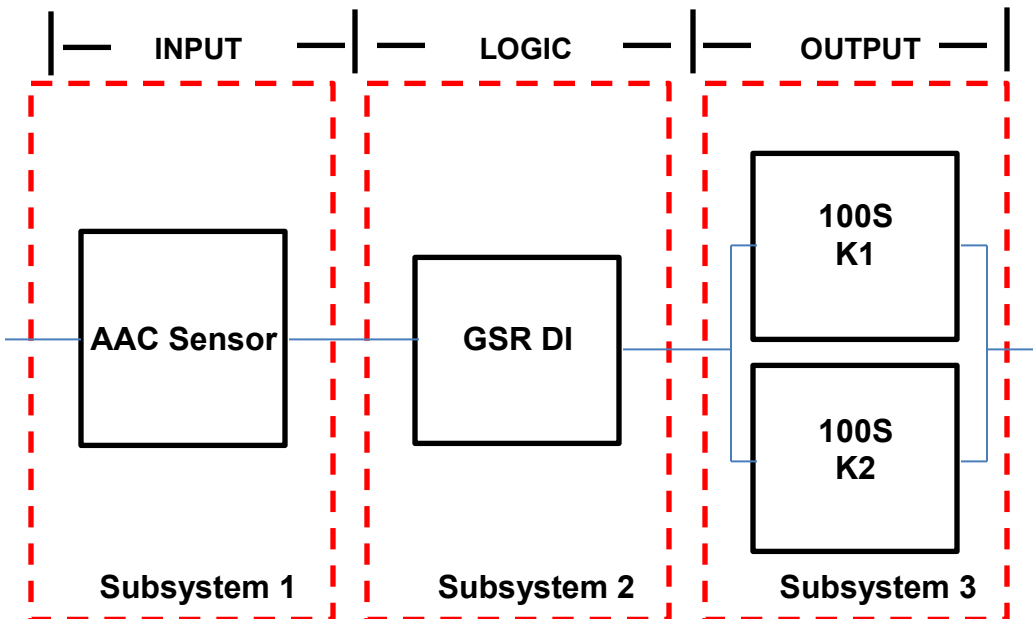
AAC Sensor Safety Function Data

Safety function											
Documentation PLr PL Subsystems											
Status	Type	Name	PL	PFH [1/h]	CCF score	DCavg [%]	MTTFd [a]	Category	Requirements of the category		
✓	SB	Safety Single Beam 440L-R/T	e	1.43E-8	not relevant	not relevant	not relevant	4	fulfilled		
✓	SB	Monitoring Safety Relay: GSR-DI	e	4.35E-9	not relevant	not relevant	not relevant	4	fulfilled		
✓	SB	Contactors	e	2.47E-8	65 (fulfilled)	99 (High)	100 (High)	4	fulfilled		

E-stop Safety Function Data

Safety function											
Documentation PLr PL Subsystems											
Status	Type	Name	PL	PFH [1/h]	CCF score	DCavg [%]	MTTFd [a]	Category	Requirements of the category		
✓	SB	E-Stop Switch: 800FP-MT44, 800FM-MT44 - Twist to release	e	2.47E-8	65 (fulfilled)	99 (High)	100 (High)	4	fulfilled		
✓	SB	Monitoring Safety Relay: GSR-DI	e	4.35E-9	not relevant	not relevant	not relevant	4	fulfilled		
✓	SB	Contactors	e	2.47E-8	65 (fulfilled)	99 (High)	100 (High)	4	fulfilled		

The single-beam area access control sensor safety function is represented below.



Single-beam Area Access Control Sensor Safety Function Subsystem 1

SB Safety Single Beam 440L-R/T	
PL	e
PFH [1/...]	1.43E-8
Cat.	4
MTTFd ...	<i>not relevant</i>
DCavg ...	<i>not relevant</i>
CCF	<i>not relevant</i>

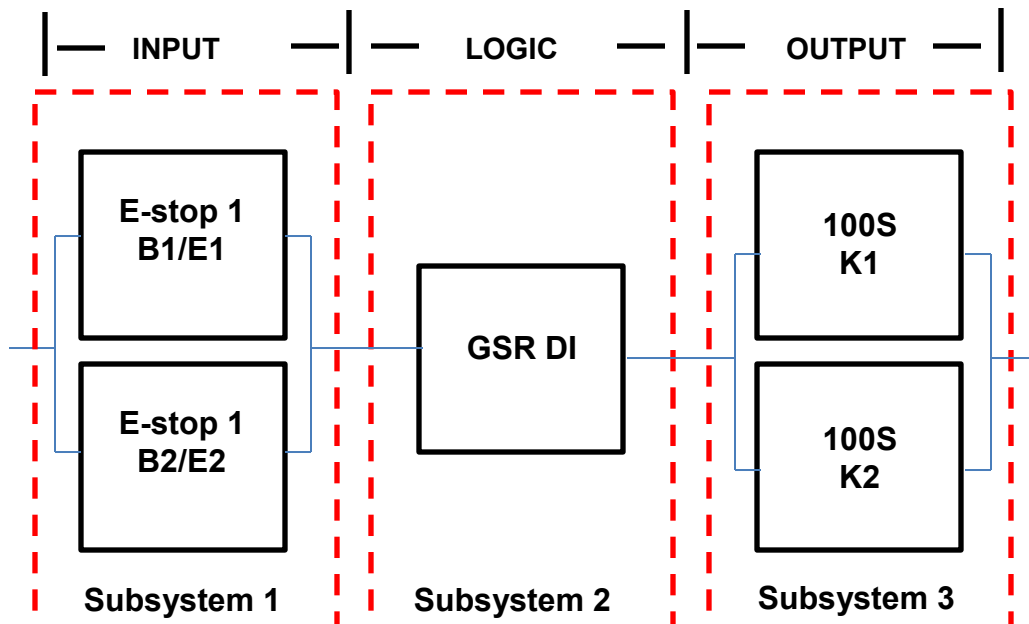
Single-beam Area Access Control Sensor Safety Function Subsystem 2

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

Single-beam Area Access Control Sensor Safety Function Subsystem 3

SB Safety Contactors	
PL	e
PFH [1/h]	2.47E-8
Cat.	4
MTTFd [a]	100 (High)
DCavg [%]	99 (High)
CCF	65 (fulfilled)

The E-stop safety function is represented below.



E-stop Safety Function Subsystem 1

SE E-Stop Switch: 800FP-MT44, 800FM-MT44 - Twist to release	
PL	e
PFH [1/...	2.47E-8
Cat.	4
MTTFd ...	100 (High)
DCavg ...	99 (High)
CCF	65 (fulfilled)

E-stop Safety Function Subsystem 2

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

E-stop Safety Function Subsystem 3

SE Safety Contactors	
PL	e
PFH [1/h]	2.47E-8
Cat.	4
MTTFd [a]	100 (High)
DCavg [%]	99 (High)
CCF	65 (fulfilled)

Because these are electro-mechanical devices, the E-stop and safety contactors data includes the following:

- Mean Time to Failure, dangerous (MTTFd)
- Diagnostic Coverage (DCavg)
- Common Cause Failure (CCF)

Electro-mechanical devices' functional safety evaluations include the following:

- How frequently they are operated
- Whether they are effectively monitored for faults
- Whether they are properly specified and installed

SISTEMA software calculates the MTTFd by using B10d data provided for the contactors along with the estimated frequency of use, which is entered during the creation of the SISTEMA project.

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

The DCavg (99%) for the E-stop is selected from the Input Device table of EN ISO 13849-1 Annex E, Cross Monitoring.

The CCF value is generated by using the scoring process outlined in Annex F of EN ISO 13849-1. The complete CCF scoring process must be performed when actually implementing an application. A minimum score of 65 must be achieved.

Verification and Validation Plan

Verification and validation play important roles in the avoidance of faults throughout the safety system design and development process. EN ISO 13849-2 sets the requirements for verification and validation. The standard calls for a documented plan to confirm all of 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 that the system meets the required Performance Level (PLr) specified. The SISTEMA software is typically used to perform the calculations and assist with satisfying the requirements of EN ISO 13849-1.

Validation is a functional test of the safety control system to demonstrate that the system meets the specified requirements of the safety function. The safety control system is tested to confirm that all of the safety-related outputs respond appropriately to their corresponding safety-related inputs. The functional test includes 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 Guardmaster Safety Relay (GSR) system, you must confirm that the Guardmaster safety relay has been wired and configured in accordance with the installation instructions.

Guardmaster Dual-input Safety Relay (GSR DI) Single-beam Area Access Control Sensor Safety Function Verification and Validation Checklist

General Machinery Information			
Machine Name/Model 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 to verify that it is wired as documented in the schematics.		
	Visually inspect the area access control safety switch to verify that it is wired as documented.		
	Visually inspect the safety relay rotary switch settings to verify that they are correct as documented.		
Normal Operation Verification			
The safety relay system properly responds to all normal Start, Stop, AAC Sensor Input, and Reset commands.			
Test Step	Verification	Pass/Fail	Changes/Modifications
	Initiate a Start command. Both contactors energize for a normal machine run condition. Verify proper machine-status indication and safety-relay status indication.		
	Initiate a Stop command. Both contactors de-energize for a normal machine Stop condition. Verify proper machine-status indication and safety-relay status indication.		
	While the system is running, interrupt the single-beam area access control sensor safety switch. Both contactors de-energize and open for a normal safe condition. Verify proper machine-status indication and safety-relay status indication. Repeat for all sensors.		
	While the system is stopped, interrupt the single-beam area access control sensor and initiate a Start command. Both contactors remain de-energized and open for a normal safe condition. Verify proper machine-status indication and safety-relay status indication.		
	Initiate a Reset command. Both contactors remain de-energized. Verify proper machine-status indication and safety-relay status indication.		

**GSR DI Single-beam Area Access Control Sensor Safety Function Verification and Validation Checklist
(continued)**

Abnormal Operation Validation			
The safety relay system properly responds to all foreseeable faults with corresponding diagnostics.			
Single-beam Area Access Control Sensor Safety Switch Input Tests			
Test Step	Validation	Pass/Fail	Changes/Modifications
	While the system is running, remove the channel 1 wire from the safety relay. Both contactors de-energize. Verify proper machine-status indication and safety-relay status indication. Repeat for channel 2.		
	While the system is running, short channel 1 of the safety relay to 24V DC. Both contactors de-energize. Verify proper machine-status indication and safety-relay status indication. Repeat for channel 2.		
	While the system is running, short channel 1 of the safety relay to 0V DC. Both contactors de-energize. Verify proper machine-status indication and safety-relay status indication. Repeat for channel 2.		
	While the system is running, short channels 1 and 2 of the safety relay. Both contactors de-energize. Verify proper machine-status indication and safety-relay status indication.		
GSR Logic Solver Tests			
Test Step	Verification and Validation	Pass/Fail	Changes/Modifications
	While the system is running, remove the single wire safety connection between two adjoining safety relays in the system. All contactors de-energize. Verify proper machine-status indication and safety-relay status indication. Repeat for all safety connections. This test is not applicable for single relay circuits.		
	While the system is running, turn the logic rotary switch on the safety relay. All contactors remain energized. Verify proper machine-status indication and safety-relay status indication. Repeat for all safety relays in the system.		
Safety Contactor Output Tests			
Test Step	Validation	Pass/Fail	Changes/Modifications
	While the system is running, remove the contactor feedback from the safety relay. All contactors remain energized. Initiate a Stop command followed by a Reset command. The relay does not restart or reset. Verify proper machine-status indication and safety-relay status indication.		

GSR DI Single-beam Area Access Control Sensor Safety Function Verification and Validation Checklist (continued)

General Machinery Information			
Machine Name/Model 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 to verify that it is wired as documented in the schematics.		
	Visually inspect the single-beam area access control sensor safety switch to verify that it is wired as documented.		
Normal Operation Verification			
The safety relay system properly responds to all normal Start, Stop, E-stop, and Reset commands.			
Test Step	Verification	Pass/Fail	Changes/Modifications
	Initiate a Start command. Both contactors energize for a normal machine run condition. Verify proper machine-status indication and safety-relay status indication.		
	Initiate a Stop command. Both contactors de-energize for a normal machine Stop condition. Verify proper machine-status indication and safety-relay status indication.		
	While the system is running, press the E-stop button. Both contactors de-energize and open for a normal safe condition. Verify proper machine-status indication and safety-relay status indication. Repeat for all E-stop buttons.		
	While the system is stopped, press the E-stop button and initiate a Start command. Both contactors remain de-energized and open for a normal safe condition. Verify proper machine-status indication and safety-relay status indication. Repeat for all E-stop buttons.		
	Initiate a Reset command. Both contactors remain de-energized. Verify proper machine-status indication and safety-relay status indication.		

**GSR DI Single-beam Area Access Control Sensor Safety Function Verification and Validation Checklist
(continued)**

Abnormal Operation Validation			
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 the system is running, remove the channel 1 wire from the safety relay. Both contactors de-energize. Verify proper machine-status indication and safety-relay status indication. Repeat for channel 2.		
	While the system is running, short channel 1 of the safety relay to 24V DC. Both contactors de-energize. Verify proper machine-status indication and safety-relay status indication. Repeat for channel 2.		
	While the system is running, short channel 1 of the safety relay to 0V DC. Both contactors de-energize. Verify proper machine-status indication and safety-relay status indication. Repeat for channel 2.		
	While the system is running, short channels 1 and 2 of the safety relay. Both contactors de-energize. Verify proper machine-status indication and safety-relay status indication.		
GSR Logic Solver Tests			
Test Step	Verification and Validation	Pass/Fail	Changes/Modifications
	While the system is running, remove the single wire safety connection between two adjoining safety relays in the system. All contactors de-energize. Verify proper machine-status indication and safety-relay status indication. Repeat for all safety connections. This test is not applicable for single relay circuits.		
	While the system is running, turn the logic rotary switch on the safety relay. All contactors remain energized. Verify proper machine-status indication and safety-relay status indication. Repeat for all safety relays in the system.		
Safety Contactor Output Tests			
Test Step	Validation	Pass/Fail	Changes/Modifications
	While the system is running, remove the contactor feedback from the safety relay. All contactors remain energized. Initiate a Stop command followed by a Reset command. The relay does not restart or reset. Verify proper machine-status indication and safety-relay status indication.		

Additional Resources

Refer to these publications for more information about related products from Rockwell Automation.

Resource	Description
GuardMaster Safety Relay DI Installation Instruction, publication 10000175129 Ver. 00	Provides information on installing, operating, and maintaining 440R-D22R2 safety relays.
Guardmaster Safety Relays Application and Wiring Diagrams, publication SAFETY-WD001	Provides functional descriptions, guidance, and wiring for a typical safety relay.
Area Access Control Safety Single Beam User Manual, publication 10000104186/00EN	Provides Information on installing, operating, and maintaining of 440L-T4F2070Q/440L-R4F0020Q.
Safety Product Catalog, publication S117-CA001A	Provides an overview of products, product specifications, and application examples.

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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Asia Pacific: Rockwell Automation, Level 14, Core F, Cyberport 3, 100 Cyberport Road, Hong Kong, Tel: (852) 2887 4788, Fax: (852) 2508 1846

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