SC22-3/-3E Safety Controller Instruction Manual

BANNER ®

Contents

1 About This Document

1.1 Important . . . Read This Before Proceeding!

It is the responsibility of the machine designer, controls engineer, machine builder and/or maintenance electrician to apply and maintain this product in full compliance with all applicable regulations and standards. The product can provide the required safeguarding function only if it is properly installed, properly operated, and properly maintained. This manual attempts to provide complete installation, operational, and maintenance instruction. *Reading the manual completely is highly recommended.* Please direct any questions regarding the application or use of the product to the Banner Engineering Applications at the locations listed here.

For more information regarding U.S. and international institutions that provide safeguarding application and safeguarding product performance standards, see the following sections.

WARNING: . . . User Responsibility

The user is responsible to:

- **Carefully read, understand and follow** the information in all documentation for this product.
- **Perform a risk assessment** of the specific machine guarding application.
- **Determine what safeguarding devices and methods** are appropriate per the requirements defined in ISO 13849-1 and other appropriate standards.
- **Create and confirm each configuration** and then verify that the entire safeguarding system (including input devices and output devices) is operational and working as intended.
- **Periodically re-verify** as needed, that the entire safeguarding system is working as intended.

Failure to follow any of these recommendations can potentially create a dangerous condition that may lead to serious injury or death.

1.1.1 Use of Warnings

Warnings are intended to remind the machine designer, control engineer, machine builder, maintenance electrician, or end user how to avoid misapplication of this product and effectively apply the Safety Controller to meet the various safeguarding application requirements. *Reading and abiding by the warnings is highly recommended.*

1.2 EC Declaration of Conformity (DOC)

Banner Engineering Corp. herewith declares that the **SC22-3 Series Safety Controller** is in conformity with the provisons of the Machinery Directive (Directive 98/37/EEC) and all essential health and safety requirements have been met. For more information, visit *www.bannerengineering.com/SC22*.

1.3 Standards and Regulations

The list of standards below is included as a convenience for users of this Banner product. Inclusion of the standards below does not imply that the product complies specifically with any standard, other than those specified in the Specifications section of this manual.

1.3.1 U.S. Application Standards

ANSI B11.0 Safety of Machinery, General Requirements, and Risk Assessment

ANSI B11.1 Mechanical Power Presses

ANSI B11.2 Hydraulic Power Presses

ANSI B11.3 Power Press Brakes

ANSI B11.4 Shears

ANSI B11.5 Iron Workers

ANSI B11.6 Lathes

ANSI B11.7 Cold Headers and Cold Formers

ANSI B11.8 Drilling, Milling, and Boring

ANSI B11.9 Grinding Machines

ANSI B11.10 Metal Sawing Machines

ANSI B11.11 Gear Cutting Machines

ANSI B11.12 Roll Forming and Roll Bending Machines

ANSI B11.13 Single- and Multiple-Spindle Automatic Bar and Chucking Machines

ANSI B11.14 Coil Slitting Machines

ANSI B11.15 Pipe, Tube, and Shape Bending Machines

ANSI B11.16 Metal Powder Compacting Presses

ANSI B11.17 Horizontal Extrusion Presses

ANSI B11.18 Machinery and Machine Systems for the Processing of Coiled Strip, Sheet, and Plate

ANSI B11.19 Performance Criteria for Safeguarding

ANSI B11.20 Manufacturing Systems

ANSI B11.21 Machine Tools Using Lasers

ANSI B11.22 Numerically Controlled Turning Machines

ANSI B11.23 Machining Centers

ANSI B11.24 Transfer Machines

ANSI/RIA R15.06 Safety Requirements for Industrial Robots and Robot Systems

ANSI NFPA 79 Electrical Standard for Industrial Machinery

ANSI/PMMI B155.1 Package Machinery and Packaging-Related Converting Machinery — Safety Requirements

1.3.2 OSHA Regulations

OSHA Documents listed are part of: Code of Federal Regulations Title 29, Parts 1900 to 1910

OSHA 29 CFR 1910.212 General Requirements for (Guarding of) All Machines

OSHA 29 CFR 1910.147 The Control of Hazardous Energy (lockout/tagout)

OSHA 29 CFR 1910.217 (Guarding of) Mechanical Power Presses

1.3.3 International/European Standards

ISO 12100-1 & -2 (EN 292-1 & -2) Safety of Machinery – Basic Concepts, General Principles for Design

ISO 13857 Safety Distances . . . Upper and Lower Limbs

ISO 13850 (EN 418) Emergency Stop Devices, Functional Aspects – Principles for Design

ISO 14121 (EN 1050) Principles of Risk Assessment

ISO 14119 (EN 1088) Interlocking Devices Associated with Guards – Principles for Design and Selection

IEC 60204-1 Electrical Equipment of Machines Part 1: General Requirements

ISO 13851 (EN 574) Two-Hand Control Devices – Functional Aspects – Principles for Design

ISO 62061 Functional Safety of Safety-Related Electrical, Electronic and Programmable Control Systems

ISO 13849-1 (EN 954-1) Safety-Related Parts of Control Systems

ISO 13855 (EN 999) The Positioning of Protective Equipment in Respect to Approach Speeds of Parts of the Human Body

IEC 61496 Electro-sensitive Protection Equipment

IEC 60529 Degrees of Protection Provided by Enclosures

IEC 60947-1 Low Voltage Switchgear – General Rules

IEC 60947-5-1 Low Voltage Switchgear – Electromechanical Control Circuit Devices

IEC 60947-5-5 Low Voltage Switchgear – Electrical Emergency Stop Device with Mechanical Latching Function

1.3.4 Sources of Standards and Regulations

These and other standards are available from:

OSHA Documents: *http://www.osha.gov* (Tel: 202.512.1800)

American National Standards Institute (ANSI): *http://www.ansi.org* (Tel: 212.642.4900)

Robotics Industries Association (RIA): *http://www.robotics.org* (Tel: 734.994.6088)

National Fire Protection Association (NFPA): *http://www.nfpa.org* (Tel: 800.344.3555)

NSSN National Resource for Global Standards : *http://www.nssn.org/* (Tel: 212.642.4980)

IHS Standards Store: *http://www.global.ihs.com/* (Tel: 303.397.7956, 800.854.7179)

Document Center: *http://www.document-center.com/home.cfm* (Tel: 650.591.7600)

1.4 Contact Us

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2 Overview

The Banner models **SC22-3** / **SC22-3E** Safety Controller (the Safety Controller or the Controller) are easy-to-use, configurable, 24V dc safety modules designed to monitor multiple safety and non-safety input devices and control up to three independent machine primary control elements (MPCEs). They provide safety stop and start functions for machines with hazardous motion. The Safety Controller can replace multiple safety relay modules in applications that include such safety input devices as E-stop buttons, gate interlocking switches, safety light curtains, and other safeguarding devices. It also can be used in place of safety PLCs and other safety logic devices when they are excessive for the application.

Configurations are created using an Onboard LCD and push-button interface, or using a PC connected to the Safety Controller via a USB port.
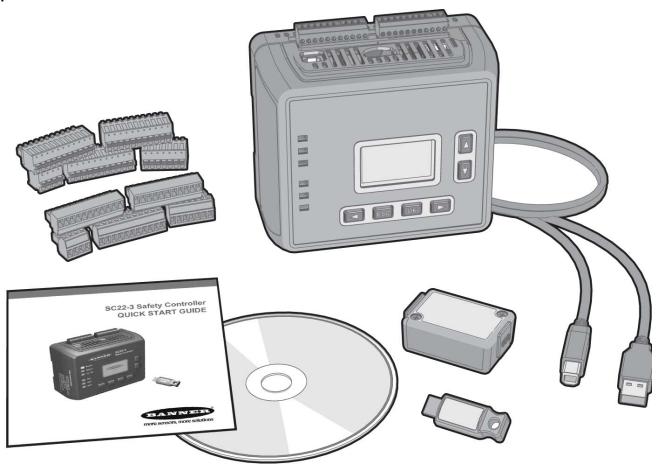
2.1 Ethernet-Compatible Model

The model **SC22-3E** provides the same features of the **SC22-3**, and in addition provides the ability to interface to Ethernet (for example to a PLC or HMI human interface touch panel), using Modbus/TCP or EtherNet/IP™ protocols.

Modbus/TCP is an open standard protocol developed by the Modbus IDA. It is similar to Modbus RTU, except that it uses standard Internet communication protocols, just like Web communications or email. The master is referred to as the "client," and the slave is the "server." (The **SC22-3E** is a "server.") Modbus/TCP follows the same structure as Modbus RTU: clients initiate all communication, servers can only respond.

EtherNet/IP (EtherNet Industrial Protocol) is an open standard protocol developed by Allen-Bradley, but managed by the ODVA. Ether-Net/IP is an adaptation of the DeviceNet serial fieldbus protocol, using Internet communications protocols. EtherNet/IP is DeviceNet over Ethernet. Compatible devices supported are:

- EtherNet/IP connection (using the CIP protocol) to the Allen-Bradley ControlLogix family of PLCs. Both implicit and explicit messaging is supported.
- EtherNet/IP connection (using the PCCC protocol) to the Allen-Bradley SLC and PLC5 families of PLCs.
- Modbus/TCP connection to any compatible PLCs, HMIs, or devices.

2.2 Applications

The Safety Controller can be used wherever safety modules are used. The Safety Controller is well suited to address many types of applications, including, but not limited to:

- Two-hand control with mute function
- Robot weld/processing cells with dual-zone muting
- Material-handling operations that require multiple inputs and by-pass functions
- Manually loaded rotary loading stations
- Multiple two-hand-control station applications
- Lean manufacturing stations
- Dynamic monitoring of single- or dual-solenoid valves or press safety valves
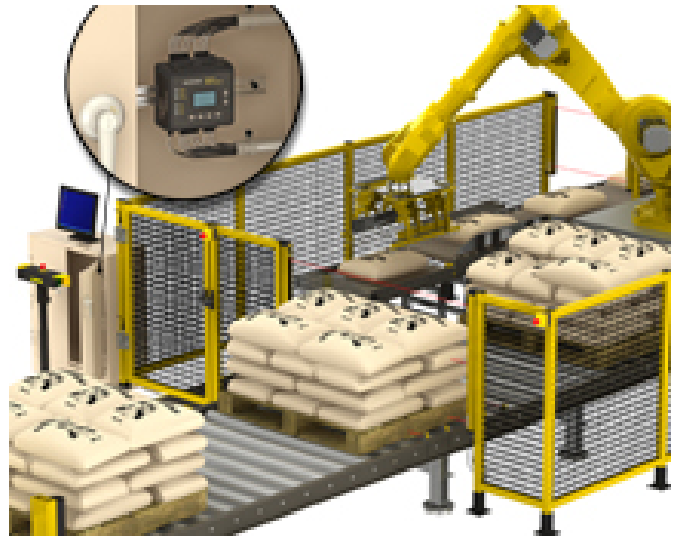
Figure 1. A palletizing application with multiple safeguarding controlled by the Safety Controller

2.3 Design and Testing

The Safety Controller was designed for up to Category 4 PL e (ISO 13849-1) and Safety Integrity Level 3 (IEC 61508 and IEC 62061) safeguarding applications. It has been extensively tested to ensure that it meets the UL, IEC, and ISO product performance requirements for both safety functionality and operational reliability. This self-checking Controller incorporates:

- Redundant microcontrollers,
- Redundant input signal detection circuitry, and
- Redundant Safety Output control circuitry.

The safety circuit performance (e.g., categories) of a specific safety or safeguarding device(s) will be determined primarily by the devices used and their interconnection to the Safety Controller.

See section *10 Input Device and Safety Category Reference* on page 90 for specific information about integrating devices with the Controller.

2.4 Components

The Safety Controller Starter Kit includes:

- 1 Safety Controller (model **SC22-3** or **SC22-3E**)
- 1 set of removable terminals (choose screw or clamp type)
- 1 **SC-XM1** external memory (XM) card
- 1 USB A/B cable (Ethernet models)
- 1 **SC-XMP** XM card programming tool (some models)
- 1 CD containing PCI software, instruction manual, and configuration tutorials (p/n 134534)
- 1 Quick Start Guide

Ethernet connection cables (for model **SC22-3E**) are user-supplied.

2.4.1 PC System Requirements

Operating system: Microsoft Windows® XP, Windows 2000, Vista®, Windows 7

Hard drive space: 100 MB (plus up to 280 MB for Microsoft .NET 2.0, if not already installed)

Third-party software: Microsoft .NET 2.0, included and installed with PCI, if not already on computer Adobe® Reader® for Windows version 7.0 or newer

USB port: USB 1.1 or 2.0 type A port

2.4.2 USB Connections

The Safety Controller is connected to a PC by way of a USB A/B cable. The cable is also used to connect the PC to the SC-XMP programming tool, in order to download a configuration to the XM card.

Figure 2. USB connections: PC to SC-XMP programming tool connection

Figure 3. USB connections: PC to Safety Controller USB port connection

2.4.3 Ethernet Connections

Ethernet connections are made using an ethernet cable from the **SC22-3E** Ethernet port to a network switch or the user's control device. The **SC22-3E** supports use of either standard or crossover-style cables. Shielded cable may be needed in high-noise environments.

Legend

1 USB port

2 XM card port

3 Ethernet port

Figure 4. Safety Controller external memory card (XM card) and Ethernet (some models) connections

2.4.4 SC-XMP Programming Tool

The programming tool is a handy device that can be used to transfer a configuration from a PC (running the PCI software) to an XM card or from an XM card to the PC, without requiring a Safety Controller. It connects to the PC via the USB A/B cable and the PC's USB port.

2.4.5 SC-XM1 External Memory (XM) Card

The model **SC-XM1** external memory (XM) card is a removable memory module that can store or be used to transfer a single configuration. The XM card has a write-on label on its reverse side where a configuration name or a machine identification can be noted.

The XM card can be used to:

- Keep a backup copy of the Safety Controller's configuration (to minimize downtime in the case of a hardware failure that may require a Controller replacement).
- Transfer configurations from one Safety Controller to another Safety Controller.
- Send (download) identical configurations into multiple Safety Controllers.
- Transfer configurations between the Safety Controller and a personal computer.

Store a configuration on the XM card in one of two ways:

- Send a copy to the XM card using the PC Interface (PCI) and the **SC-XMP** programming tool.
- Send a copy from the Controller to the XM card, using the Onboard Interface (OBI).

NOTES:

1. A configuration can be stored permanently in an XM card, if the "lock" function is performed. However, once the card is locked, it cannot be unlocked (it becomes "read-only").
2. Configurations on an XM card do NOT contain any network settings. The PCI software must be used to change network settings.

2.5 Configuring the Safety Controller

Building a configuration for the Safety Controller is a simple process, using one of two interfaces: the push buttons and display on the Controller itself (the Onboard Interface, or OBI) or the PCI software program included on the enclosed CD (p/n 134534). The process comprises three main steps:

1. Define the safeguarding application (risk assessment).

    - Determine the required devices.
    - Determine the required level of safety.
2. Build the configuration.

    - Select safety input device types and circuit connections.
    - Map each input to one or more Safety Outputs, or to other input devices.
    - Set optional Safety Output ON- or OFF-time delays.
    - Select non-safety input device types and circuit connections, if needed.
    - Assign Status Output signals, if needed.
    - Create configuration name, file name, date, and author name.
3. Confirm the configuration.

    - Controller verifies that the desired configuration is valid.
    - User confirms that the configuration is what is expected.

2.5.1 Onboard Interface (OBI)

The Safety Controller can be configured using its built-in push buttons and LCD screen, the Onboard Interface (OBI). The LCD display provides I/O device and system status information for any event that causes one or more of the Safety Outputs to turn OFF. The display is used in conjunction with the six push buttons to:

- Create or modify password-protected configurations,
- Retrieve fault log information,
- Review device wiring detail and I/O logic relationships,
- Display I/O device fault details and likely remedial steps, and
- Display configuration checksum.

NOTES:

1. Onboard Interface functions are covered in more detail in Section 5 and the OBI tutorial, located separately on the disk.
2. The OBI cannot be used to change network settings; the PCI must be used for that function.

Legend:

1. **Moves cursor to the left or selects settings.**
2. **Moves cursor to the pre-established point in the program to re-establish a menu reference point.**
3. **Enters/stores the item highlighted in the display as the intended selection or toggles a setting.**
4. **Moves cursor to the right or selects settings.**
5. **Moves cursor down or moves through a list to display individual list items. Also used to select settings.**
6. **Moves cursor up or moves through a list to display individual list items. Also used to select settings.**
7. **Ethernet connector indicators (Yellow and Green; Ethernet models only)**
8. **Status indicators**
9. **LCD display**

Figure 5. Onboard Interface, including push buttons, LCD display and status indicators (model SC22-3E shown)

Status Indicator	Condition	Indicates Controller Status
All Indicators OFF	—	Initiation Mode
Power	ON Green	Power ON
	OFF	Power OFF
Status (Controller Mode)	ON Red	Configuration mode
	Flashing Red	Lockout mode
	OFF	Run mode
USB or Tx/Rx (depending on model)	Flashing Green	Transmitting or receiving data (a link is established with the PC)
	OFF	Not transmitting or receiving data
Safety Output SO1, SO2, SO3	ON Green	Safety Output ON
	ON Red	Safety Output OFF
	Flashing Red	Safety Output fault detected
	Flashing Green	Safety Output waiting for reset
Ethernet Connector (model SC22-3E only)	Yellow OFF	No link
	Yellow ON	Link OK
	Green OFF	No activity
	Green ON or flashing	Activity detected

Accessing Fault Codes

Fault codes are displayed in the last line of the OBI fault diagnostics menu (see example at right). Refer to OBI Configuration and Trouble-shooting sections for more information.

```
ES01
Simultaneity
Fault
< Cycle Input >
Code: 2.2
```
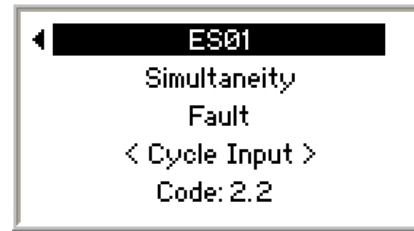
2.5.2 Personal Computer Interface (PCI)

The Safety Controller can also be configured using a Windows®-based computer and the Safety Controller PC Interface (PCI) program. This user-friendly interface makes use of icons and circuit symbols to simplify the selection of device properties during configuration. The configuration wiring and ladder logic diagrams develop automatically as the configuration progresses.

Creating a configuration is simple. Once a configuration is created, it::

- Can be stored to a computer file for archiving and future use, or
- Can be emailed to a remote location as an attachment, or
- Can be sent directly to another Safety Controller or to the plug-in external memory card.

The PCI can be used to create a configuration, save it and send it as described above, and also monitor the function of a Controller using the live display, as well as monitor the fault log for troubleshooting purposes.

To access the Ethernet functionality of the model **SC22-3E**, click on the Network Settings icon and check the Enable Network Interface box. The Virtual Status Outputs will appear on the I/O Properties menu, as will additional tabs above the document section of the screen, as shown in the following figure.
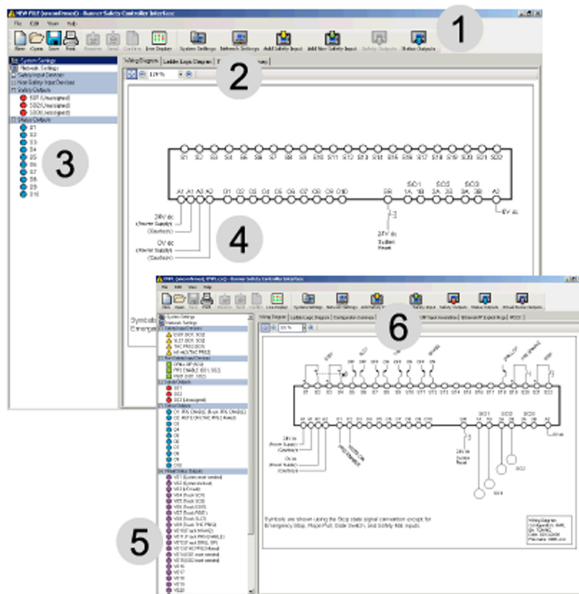
Legend:

1. **Toolbar**
2. **Network settings**
3. **I/O properties**
4. **Document (in this case, Wiring Diagram)**
5. **Virtual Status Outputs (These outputs become visible after the Enable Network Interface box is checked under the Network Settings tab.)**
6. **New tab selections also become visible.**

Figure 6. PC User Interface (PCI) main screens

- PC Interface functions are covered in more detail in section *5.1 PC Interface (PCI) Overview* on page 53 and in the PCI tutorial.
- PC Interface network functions are covered in more detail in sections *4.9 Virtual Status Outputs* on page 52 and *11 Ethernet Reference* on page 124.

PCI Software Compatibility

To identify the version of your PCI software (i.e., PC Interface), click on the "**Help**" tab located on the top tool bar and then click on "**Compatibility Information**." The information contained in the pop-up window identifies what PCI software version is running and lists when a feature was added or changed.

Newer PCI versions are backwards compatible with earlier SC22 firmware versions, although features must be supported by the SC22 firmware version or the feature will be unavailable. If an unsupported feature is attempted to be downloaded, an error message will be displayed. The SC22 firmware version can be identified via the Onboard Interface (OBI) "Model #" menu item; see section *7.3 Display Controller Information — Onboard Interface (OBI)* on page 71. This screen identifies the Safety Controller model, the firmware versions of microprocessors A and B, and the hardware version. Contact a Banner Applications Engineer with any questions.

2.6 Input and Output Connections

2.6.1 Safety and Non-Safety Input Devices

The Safety Controller has 22 input terminals that can be used to monitor either safety or non-safety devices; these devices may incorporate either solid-state or contact-based outputs. Each of these 22 input terminals can either monitor an input signal or provide 24V dc. The function of each input circuit depends on the type of device connected to it; this function is established when the Controller is configured.

For general and specific information about input devices, their requirements, hookup options and appropriate warnings and cautions, additional installation information (e.g., Safety Distance), refer to the sections *4 System Installation* on page 26 and *10 Input Device and Safety Category Reference* on page 90, which contains hookup information and other useful information about integrating the following devices:

- Safety Circuit Integrity
- Protective (Safety) Stop
- Optical Sensors
- Safety Gate (Interlock Guard)
- Two-Hand Control
- Safety Mat (Edges)
- Emergency Stop Push Buttons
- Rope (Cable) Pull
- Enabling Devices (Pendants)
- Bypass
- Muting

For further information about connecting any devices to the Safety Controller, contact Banner Engineering.

Safety Device Hookup Considerations

The Safety Controller inputs can be configured to interface with many types of safety devices, including safeguarding devices (e.g., safety light curtains), complementary protective equipment (e.g., emergency stop push buttons), and other devices that impact the safe use of a machine (e.g., equipment protection).

The way these devices interconnect impacts their ability to exclude or detect faults that could result in the loss of the safety function. There are many standards, regulations and specifications that require certain capabilities of a safety circuit.

WARNING: . . . User Responsibility

The user is responsible for ensuring that all local, state, and national laws, rules, codes, and regulations relating to the use of this product in any particular application are satisfied. Extreme care is urged that all legal requirements have been met and that all installation, operation, and maintenance instructions contained in the product documentation are followed.

2.6.2 Safety Outputs

The Safety Outputs are designed to control final switching devices (FSDs) and machine primary control elements (MPCEs) that are the last in the control chain to control the dangerous motion. These control elements include relays, contactors, solenoid valves, motor controls and other devices that incorporate force-guided (mechanically-linked) monitoring contacts, or control-reliable signals needed for external device monitoring.

The Safety Controller has three independently controlled and redundant solid-state Safety Outputs. The Controller's self-checking algorithm ensures that the outputs turn ON and OFF at the appropriate times, in response to the assigned input signals and the system's self-checking test signals.

The Safety Outputs, SO1, SO2 and SO3, can be controlled by input devices with both automatic and manual reset operation.
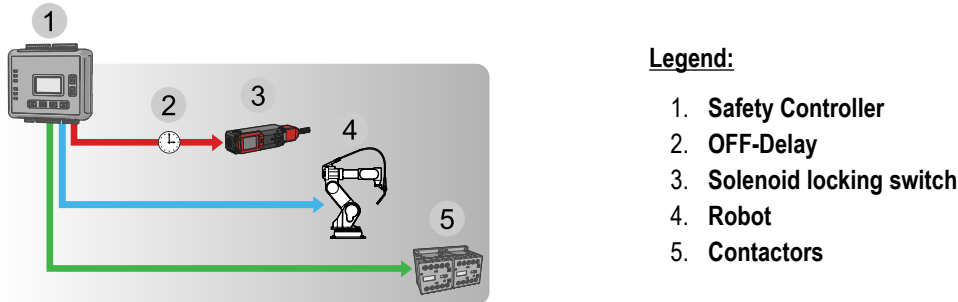
Legend:

1. **Safety Controller**
2. **OFF-Delay**
3. **Solenoid locking switch**
4. **Robot**
5. **Contactors**

Figure 7. Safety Outputs

See section for more information about configuring Safety Outputs.

Functional Stops per IEC 60204-1 and ANSI NFPA79

The Controller is capable of performing the two functional stop types:

- Category 0: an uncontrolled stop with the immediate removal of power from the guarded machine
- Category 1: a controlled stop with a delay before power is removed from the guarded machine

Delayed stops can be used in applications where, for example, machines need power for a braking mechanism to stop the hazardous motion.

ON-Delays and OFF-Delays

Each Safety Output can be configured to function with a time delay. There are two types of time delays: ON-delay and OFF-delay, where the outputs turn ON or OFF only after the time limit has elapsed. The ON and OFF time delay limit options are from 100 milliseconds to 5 minutes, in 100 millisecond increments.

Safety Output ON-delays are sometimes used when a machine operation must be delayed before a safe machine startup is permitted. An example application would be a robot weld cell.

⚠️ **WARNING: . . . Turning a Delayed Output ON/OFF**

If an input that is mapped to both an immediate Safety Output and a delayed Safety Output opens and then closes before the delay time of the delayed output has expired, the immediate Safety Output will turn OFF and remain OFF while the delay time is running.

At the end of the delay time, the delayed output will also turn OFF. Both outputs will then remain OFF for about 500 ms, before they will turn back ON. This will happen either automatically, if configured for auto reset, or after a valid manual reset signal, if configured for manual reset.

2.6.3 Status Outputs

The Safety Controller has 10 configurable Status Outputs, used to send non-safety status signals to programmable logic controllers (PLCs) or to human machine interfaces (HMIs), or they may be used to power indicator lights. These outputs can be configured to report on the status of input devices, Safety Outputs, or the Controller itself. See section *4.8.1 Status Output Signal Conventions* on page 50 for more information.

Signal Convention

The Status Output signal convention can be configured to be 24V dc or 0V dc to indicate:

- When an input is in the Run state,
- When a Safety Output is in the ON state (see Note 1),
- When a Safety Output is in a logical ON state (ON or in an ON-delay; see Note 1),
- When the system is in a Lockout condition,
- When an I/O fault is present (see Note 2),
- When a system reset is needed,
- When a Safety Output needs a reset (see Note 3),
- When a Safety Input is muted,
- Which Safety Input, of a defined group of Safety Inputs, turned OFF first,
- When a Safety Input is bypassed,
- When a Safety Input has a Fault condition, or
- When a Safety Output's OFF-delay can be cancelled.

NOTES:

1. Only Safety Outputs that have inputs mapped to them can be mapped to a Status Output.
2. An I/O fault is a failure of one or more Safety Inputs, Safety Outputs, or Status Outputs.
3. Only Safety Outputs mapped to inputs configured with manual reset logic can have a Status Output configured to indicate a reset is needed.

⚠️ **WARNING: . . . Status Outputs**

The Status Outputs are not Safety Outputs and can fail in either the ON or OFF state. **They must never be used to control any safety-critical applications. If a Status Output is used to control a safety-critical application, a failure to danger is possible and could lead to serious injury or death.**

Monitored Mute Lamp Outputs

Status Outputs O9 and O10 can be configured to create a monitored mute lamp function for a mute operation. When the mute lamp is ON, the Controller monitors for a short circuit in the load. When the lamp is OFF, it monitors for an open circuit in the load. If an open circuit occurs before the start of a mute cycle, the next mute cycle will be prevented. If an open circuit occurs during a mute cycle, that mute cycle will finish, but the next mute cycle will be prevented. If a short occurs before or during a mute, that mute cycle will start and finish, but the next mute cycle will be prevented. If not used to monitor a mute lamp, these outputs may be used in the same ways as outputs O1–O8.

IMPORTANT: **Only terminals O9 and O10 have the extra monitoring circuitry needed for a monitored mute lamp.** If monitoring of the mute lamp is not required (depending on applicable standards), any of the Status Outputs (O1–O10) may be used to indicate a mute condition. **Because of this feature, these Status Outputs will always appear ON with no load** (see *Specifications* on page 23).

2.6.4 Virtual Status Outputs

Using the PCI, the model **SC22-3E** (only) can configure up to 32 Virtual Status Outputs. These outputs can communicate the same information as the Status Outputs, but over a network.

> ⚠️ **WARNING: . . . Virtual Status Outputs**
>
> The Virtual Status Outputs are not Safety Outputs and can fail in either the ON or the OFF state. **They must never be used to control any safety-critical applications. If a Virtual Status Output is used to control a safety-critical application, a failure to danger is possible and could lead to serious injury or death.**

2.6.5 I/O Mapping: the I/O Control Relationship

The term "map" implies a control logic relationship between an input and an output or between an input and another input, where the state of the first input determines the state of the output or of the second input.

Inputs Mapped to Outputs. The following devices can be mapped directly to the Safety Outputs:

- Emergency stop buttons
- Safety gate switches
- Optical sensors
- Two-hand control devices
- Safety mats
- Protective stop switches
- Rope pulls
- Enabling devices
- External device monitoring
- ON/OFF devices
- Manual reset devices
- Solenoid or press safety valves
- Cancel OFF-delay devices
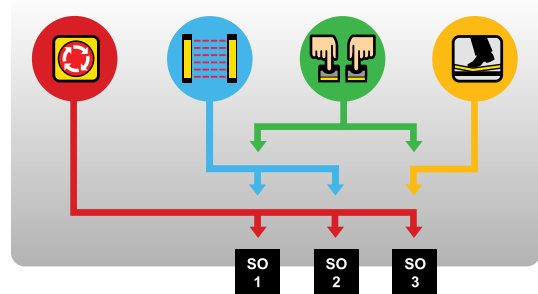
Figure 8. Input and Output mapping

Inputs Mapped to Inputs. Muting sensors and bypass switches work in conjunction with certain safety input devices to temporarily suspend the Stop signal of a safety input device. These sensors and switches are mapped directly to the safety inputs; they are then indirectly mapped to the Safety Output(s) that the muted safety inputs control (see section *4.6.4 Mute Function* on page 37).

2.7 System Settings

The Controller's system settings define parameters for both the configuration file and the Controller. These settings include:

- Configuration name
- Author's name
- Power-up mode
- Mute on power-up enable
- Monitored system reset

Configuration Name

The configuration name identifies the configuration that will be used in a Safety Controller application. The configuration name can be displayed on the Controller and will be useful to be sure that the configuration in a Controller is the correct one.

Author's Name

The author's name may also be helpful when questions arise about configuration settings.

Power-Up Mode (Operational Characteristics When Power Is Applied)

The Controller provides three power-up mode types to choose from, to determine how the Controller will behave just after power is supplied. These modes are: Normal, Automatic, and Manual.

- **Normal Power-Up Mode (default).** In normal power-up mode, after power is applied:

  - Only those Safety Outputs that have automatic reset inputs will turn ON.
  - Safety Outputs that have one or more manual reset inputs will turn ON only after a manual (latch) reset operation is performed.
  - *Exception:* Two-hand control inputs, bypass inputs, and enabling device inputs must be seen to be in the Stop state at power-up, regardless of the power-up mode selection. If these are seen to be in the Run state at power-up, the outputs will remain OFF.
- **Automatic Power-Up Mode.** In automatic power-up mode, after power is applied:

- All Safety Outputs will turn ON immediately if the inputs that are mapped to these outputs are all in the Run state.
  - *Exception:* Two-hand control inputs, bypass inputs, and enabling device inputs must be seen to be in the Stop state at power-up, regardless of the power-up mode selection. If these are seen to be in the Run state at power-up, the outputs will remain OFF.
- **Manual Power-up Mode.** In Manual Power-up Mode, after power is applied:
  - Safety Outputs will turn ON only after all inputs mapped to this output are in the Run state and a System Reset has been performed. (A manual latch reset is not required.)
  - *Exception:* Two-hand control inputs, bypass inputs, and enabling device inputs must be seen to be in the Stop state at power-up, regardless of the power-up mode selection. If these are seen to be in the Run state at power up, the outputs will remain OFF.

⚠️ **WARNING: . . . Automatic Power-Up**

When the Controller is configured for automatic system reset power-up mode, the Controller acts as if all input devices are configured for auto (trip) reset. **Each Safety Output will immediately turn on at power-up if the assigned input devices are all in the Run state, even if one or more of the input devices is configured for manual (latch) reset.** If the application requires that a manual (latch) reset operation be performed before the Safety Output turns ON, then either manual or normal power-up mode configuration must be used. **Failure to do so could cause a machine to operate in an unexpected way at power-up or after temporary power interruptions.**

⚠️ **WARNING: . . . Controller Operation on Power-Up**

It is the responsibility of the user of the Controller to assess what safeguarding devices and methods are appropriate for any given machine or application. **The Qualified Person who configures, installs, and/or maintains it must be aware of the power-up behavior of the Controller and instruct the machine operator on the operation of the Controller and its associated devices.**

Mute On Power-Up Enable

If configured, the Mute on Power-Up function will initiate a mute cycle after power is applied to the Safety Controller if the muted safety inputs are active (Run state or closed), and either M1-M2 or M3-M4 (but not all four) are signaling a muted condition (e.g., active or closed).

- For more information on the Mute On Power-Up function, see section

Monitored System Reset

Monitored System Reset is enabled by default and requires an OFF-ON-OFF signal at the reset input, where the ON-duration must be between 0.3 and 2 seconds (trailing edge reset), in order to reset the system.

If unchecked (Monitored System Reset disabled), the reset input requires only a signal from OFF to ON (leading edge reset), in order to reset the system.

2.8 Internal Logic

The Controller's internal logic is designed so that a Safety Output can turn ON only if all the controlling input device signals are in the Run state and the Controller's self-check signals are in the No-Fault state.

Safety Input 1	Safety Input 2	Safety Controller	Safety Output 1
Stop	Stop	Run (No Fault)	OFF
Stop	Run	Run (No Fault)	OFF
Run	Stop	Run (No Fault)	OFF
Run	Run	Run (No Fault)	ON

The table above illustrates the logic for two safety input devices mapped to control Safety Output 1. If any of the safety input devices are in the Stop state, then Safety Output 1 is OFF. When both safety inputs are in the Run state, then Safety Output 1 will turn ON.

2.8.1 Additional Logic Functions

Other logic functions are slight variations of the general AND logic rule set.

- **Two-Hand Control:** The machine initiation signal incorporating a 0.5 second actuator simultaneity limit and anti-tie-down logic, designed to prevent single-actuator machine cycle operation.
- **Safety Device Muting:** The automatic suspension of one or more safety input Stop signals during a portion of a machine operation when no hazard is present or when access to the hazard is otherwise safeguarded.
- **Safety Device Bypass:** The manually activated, temporary suspension of one or more safety input Stop signals when the hazard is otherwise safeguarded.
- **Enabling Device Control:** The actively controlled manual suspension of a Stop signal during a portion of a machine operation when a hazard could occur.
- **Cancel OFF-Delay:** The option to cancel a configured OFF-delay time by either keeping the Safety Output ON, or turning it OFF immediately.

The rules that apply to these special cases are explained in section *10 Input Device and Safety Category Reference* on page 90.

2.9 Password Overview

To provide security, the Safety Controller requires use of a password in some cases. For information about changing a Controller's password, refer to sections *5.1.4.6 Changing the Password Using the Personal Computer Interface (PCI)* on page 61 and *6.3.4 System Options* on page 66. If the password becomes lost, contact the Factory for assistance.

Creating a Configuration

- Via computer using the Safety Controller PC Interface (PCI) program (no password needed)
- Via the Controller Onboard Interface (OBI) (password needed)

Confirming a Configuration

- Via the PCI, using the PC connected to a powered Controller (password needed)
- Via the OBI, on a powered Controller (password needed)

Sending a Confirmed Configuration to the Controller

- Via a direct connection between the PC and the Controller, using the SC-USB1 cable and the PC Interface program (password needed)
- Via the PC, the XM card programming tool, and the XM card (password needed)

2.10 Confirming a Configuration

Although a Controller will accept an unconfirmed configuration, it will only activate it (adopt the configuration and function according to its parameters) after the configuration is confirmed, using the OBI or PCI.

IMPORTANT: If any modification is made to a confirmed configuration, or if a configuration is edited during the confirmation process, the PCI and the Controller will recognize this modified configuration as being new and will require it to be confirmed before it can be activated and used.

Once confirmed, a configuration can be stored and reused without reconfirmation. The configuration code will be validated automatically each time it is downloaded to a Controller and whenever the Controller powers up. Configurations, confirmed or not, can be sent via email. Sending (downloading) a new confirmed configuration to a Controller requires entry of the Controller password.

3 Components and Specifications

To order the Safety Controller ready for use, order it as part of a kit (see following table). It also can be ordered alone, without terminals, as a replacement part.

Kits include the Safety Controller, model **SC22-3** or **SC22-3E**, a set of plug-on terminal blocks (screw or cage-clamp type, depending on model), a USB A/B cable (for direct connection between a PC and the Safety Controller, included with some kits), external non-volatile memory card (XM card, with write-on label on reverse side), XM card programming tool (included with some models), a user CD (includes software interface, online manual, ethernet references and configuration tutorials), and quick start guide.
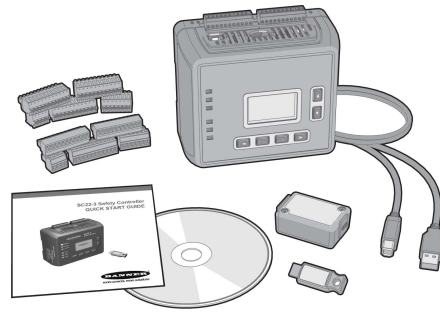
3.1 Safety Controller Starter Kit Models

Kit Model	Terminal Type	Safety Outputs	Status Outputs	Safety Output Rating	USB A/B Cable	XM Card	XM Card Programming Tool	Communication Protocol
SC22-3-S	Screw	6 PNP Terminals (3 pairs)	10 Status	0.75 amps each output	—	Yes	—	—
SC22-3-C	Clamp				—		—	
SC22-3-SU1	Screw				1.8 m		Yes	
SC22-3-CU1	Clamp				1.8 m		Yes	
SC22-3E-S	Screw		10 Status plus 32 Virtual Status	0.5 amps each output	—		—	EtherNet/IP & Modbus/TCP
SC22-3E-C	Clamp				—		—	
SC22-3E-SU1	Screw				1.8 m		Yes	
SC22-3E-CU1	Clamp				1.8 m		Yes	

3.2 Replacement Parts/Accessories

Model	Description
SC22-3	Replacement Controller (no terminals)
SC22-3E	Replacement Controller (no terminals), Ethernet compatible
SC-XM1	External memory card (XM card)
SC-XM1-5	Bulk pack of 5 XM cards
SC-XMP	USB programming tool for XM card
SC-TS1	Screw terminal replacement set
SC-TC1	Cage clamp terminal replacement set
SC-USB1	USB A/B cable, 1.8 m
134534	CD including PCI program and instruction manual

3.3 Ethernet Cordsets

Shielded Models	Cat5e Crossover Models	Length
STP07	STPX07	2.1 m
STP25	STPX25	7.6 m
STP50	STPX50	15.5 m
STP75	STPX75	23 m

3.4 Interface Modules

SC-IM9 series interface modules are for use only with the Safety Controller; dry contacts for use with higher ac/dc voltage and current. With 10A output, DIN-mount housing, removable (plug-in) terminal blocks for OSSD outputs (screw terminal block supplied). Measures approx. 72 mm H, 170 mm D, and 45 mm , 90 mm, or 140 mm W, (2.8" H, 6.7" D, and 1.8", 3.5", or 5.5" W) depending on model. See datasheet p/n 131845 for more information.

📝 **NOTE:** *External device monitoring (EDM) is required to be wired separately to the N.C. contacts to comply with ISO 13849-1 categories and ANSI/OSHA control reliability; see section 4.7.1 External Device Monitoring (EDM) on page 40.*

Model	Description	Supply Voltage	Inputs (Safety Controller Outputs)	Safety Outputs	Output Rating	EDM Contacts
SC-IM9A	For use with 1 Safety Controller Safety Output	24V dc (Controller supplied)	2 (SO1)	3 N.O.	10 amps	1 N.C. pair per output
SC-IM9B	For use with 2 Safety Controller Safety Outputs		4 (SO1 and SO2)	Total of 6 (3 N.O. per output)		
SC-IM9C	For use with 3 Safety Controller Safety Outputs		6 (SO1, SO2, and SO3)	Total of 9 (3 N.O. per output)		

IM-T-9 series interface modules have 6A output, 22.5 mm DIN-mount housing, removable (plug-in) terminal blocks. Low current rating of 1V ac/dc @ 5 mA, high current rating of 250V ac/dc @ 6A. See datasheet p/n 62822 for more information.

📝 **NOTE:** *External device monitoring (EDM) is required to be wired separately to the N.C. contacts to comply with ISO 13849-1 categories and ANSI/OSHA control reliability; see section 4.7.1 External Device Monitoring (EDM) on page 40.*

Model	Supply Voltage	Inputs	Safety Outputs	Output Rating	EDM Contacts	Aux. Outputs
IM-T-9A	24V dc	2 (dual-channel hookup)	3 N.O.	6 amps	2 N.C.	—
IM-T-11A			2 N.O.			1 N.C.

3.4.1 Mechanically Linked Contactors

Provides an additional 10 or 16 amp carrying capability to any safety system. If used, two contactors per Safety Output pair (e.g., 2 x SO1), are required. The N.C. contacts are to be used in an external device monitoring (EDM) circuit.

📝 **NOTE:** *External device monitoring (EDM) is required to be wired separately to the N.C. contacts to comply with ISO 13849-1 categories and ANSI/OSHA control reliability; see section 4.7.1 External Device Monitoring (EDM) on page 40.*

Model	Supply Voltage	Inputs	Outputs	Output Rating
11-BG00-31-D024	24V dc	2 (dual-channel hookup)	3 N.O. and 1 N.C.	10 amps
11-BF18C01-024				18 amps

3.5 Specifications

Power

24V dc, ± 20%

Model SC22-3: 0.4 A (Controller only), 5.9 A (all outputs ON @ full rated load)

Model SC22-3E: 0.4 A (Controller only), 4.9 A (all outputs ON @ full rated load)

The Controller should be connected only to a SELV (safety extra-low voltage, for circuits without earth ground) or a PELV (protected extra-low voltage, for circuits with earth ground) power supply.

Safety and Non-Safety Inputs (22 terminals)

Input ON threshold: > 15V dc (guaranteed on), 30V dc max.

Input OFF threshold: < 5V dc (guaranteed off with any 1 fault), –3V dc min.

Input ON current: 8 mA typical @ 24Vdc, > 2 mA (guaranteed with 1 fault)

50 mA peak contact cleaning current @ 24V dc

Sourcing current: 30 mA minimum continuous (3V dc max. drop)

Input lead resistance: 300 Ω max. (150 Ω per lead)

Input requirements for a 4-wire safety mat:

- **Max. capacity between plates:** 0.5 µF
- **Max. capacity between bottom plate and ground:** 0.5 µF
- **Max. resistance between the 2 input terminals of one plate:** 20 Ω

Safety Outputs (6 terminals, 3 redundant outputs)

Rated output current:

Model SC22-3: 0.75 A max. @ 24V dc (1.0V dc max. drop)
Model SC22-3E: 0.5 A max. @ 24V dc (1.0V dc max. drop)

Output OFF threshold: 0.6V dc typical (1.2V dc max. guaranteed with 1 fault)

Output leakage current: 50 µA max. with open 0V

Load: 0.1 µF max., 1 H max., 10 Ω max. per lead

Status Outputs (10 terminals)

Rated output current: 0.5A @ 24V dc (individual), 1.0 A @ 24V dc (total of all outputs)

O1 to O8 (General Purpose)—Output OFF voltage: < 0.5V dc (no load), 22 KΩ pull down to 0V

O9 and O10 (General Purpose or Monitored Mute Lamp)—

Output OFF voltage: Internal 94 KΩ pull up to 24V dc supply
Output ON/OFF threshold: 15V dc +/−4V dc @ 24V dc supply

NOTE: For O9 and O10 (when configured as a monitored mute lamp output), if a short circuit or other fault condition causes the output to drop below this threshold while the output is ON, a lockout will occur. If an open circuit or other fault condition causes the output to rise above this threshold while the output is OFF, a lockout will occur.

Response and Recovery Times

Response Time (ON to OFF): 10 ms max. (with standard 6 ms debounce; this can increase if debounce time increases. Refer to the configuration summary for actual response time.)

Recovery Time (OFF to ON): 400 ms max. (with manual reset option)

Recovery Time (OFF to ON): 400 ms max. plus input debounce time (auto reset)

Onboard LCD Information Display—Password Requirements

Password is not required:

Run mode (I/O status)

Fault (I/O fault detection and remedial steps)

Review configuration parameters (I/O properties and terminals)

Password is required:

Configuration mode (create/modify/confirm/download configurations)

Environmental Rating

NEMA 1 (IEC IP20), for use inside NEMA 3 (IEC IP54) or better enclosure

Operating Conditions

Temperature range: 0° to +55° C (+32° to 131° F)

Mechanical Stress

Shock: 15g for 11 milliseconds, half sine, 18 shocks total (per IEC 61131-2)

Bump: 10g for 16 milliseconds, 6000 cycles total (per IEC 61496-1)

Vibration: 3.5 mm occasional / 1.75 mm continuous @ 5Hz to 9Hz, 1.0g occasional and 0.5g continuous @ 9Hz to 150Hz: (per IEC 61131-2) and 0.35 mm single amplitude / 0.70 mm peak-to-peak @ 10 to 55Hz (per IEC 61496-1), all @ 10 sweep cycles per axis

EMC

Meets or exceeds all EMC requirements in IEC 61131-2, IEC 61496-1 (Type 4), and IEC 62061 Annex E, Table E.1 (increased immunity levels)

Removable Terminals

Screw terminals

Wire sizes: 16, 18, 20, 22 or 24 AWG (0.20 – 1.31 mm²)
Wire strip length: 5.00 mm (0.197")
Tightening torque: 0.23 Nm (2 in. lbs.) nominal; 0.34 Nm (3.0 in. lbs.) maximum

Clamp terminals

Important: Clamp terminals are designed for 1 wire only. If more than 1 wire is connected to a terminal, a wire could loosen or become completely disconnected from the terminal, causing a short.
Wire size: 16, 18, 20, 22, or 24 AWG (0.20 – 1.31 mm²)
Wire strip length: 9.00 mm (0.35")

Network Interface (Model SC22-3E only)

Ethernet 10/100 Base-T/TX, RJ45 modular connector

Selectable auto negotiate or manual rate and duplex

Auto MDI/MDIX (auto cross)

Protocols: EtherNet/IP (with PCCC), Modbus/TCP

Data: 32 configurable virtual Status Outputs; fault diagnostic codes and messages; access to fault log

Product Performance Standards

IEC 62061 Safety of Machinery – Functional Safety of Safety-Related Electrical, Electronic and Programmable Electronic Control Systems: SIL CL 3

IEC 61508 Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems: SIL 3

ISO 13849-1 (1999): Category 4

ISO 13849-1 (2006): Category 4 Performance Level (PL) e, complies with Machinery Directive 2006/42/EC

IEC 61131-2 Programmable Controllers, Part 2: Equipment Requirements and Tests

UL 508 Industrial Control Equipment

UL 1998 Software in Programmable Components

ANSI NFPA 79 Electrical Standards for Industrial Machinery

IEC 60204-1 Electrical Equipment of Machines: General Requirements

ISO 13851 (EN574) Safety of Machinery – Two-Hand Control Devices – Functional Aspects and Design Principles
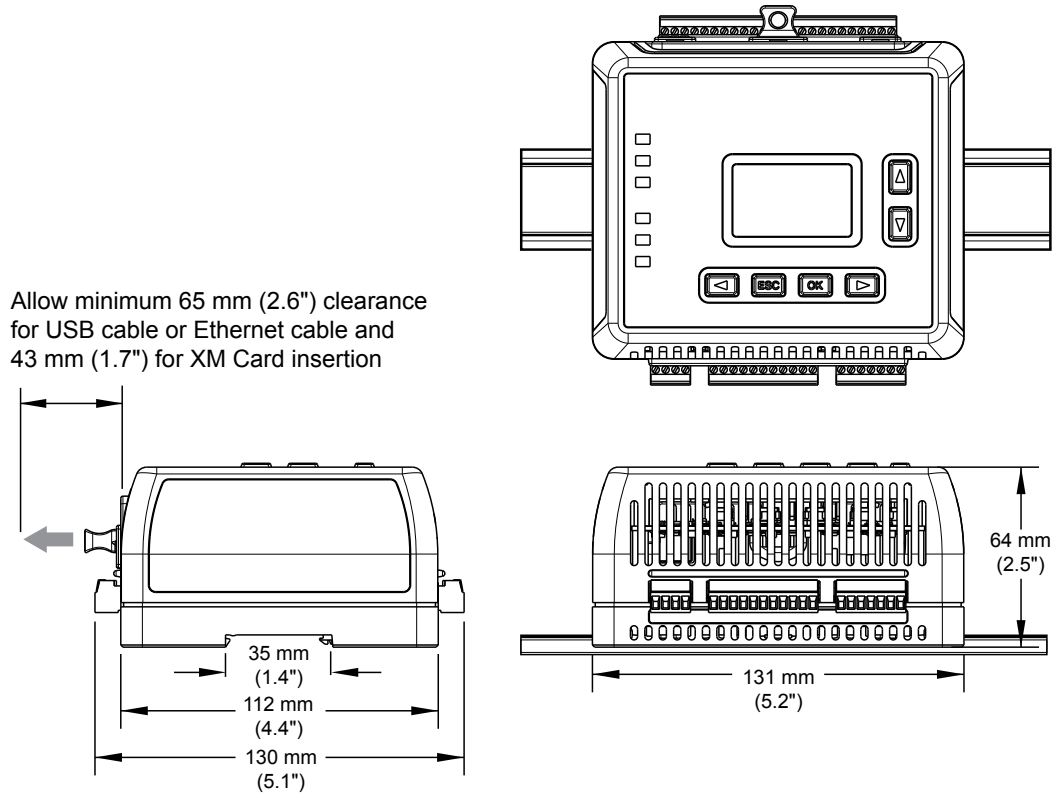
ISO 13850 (EN418) Emergency Stop Devices

Also see front section of this manual for a list of other applicable U.S. and international standards.

Agency Approvals

3.5.1 Dimensions

Allow minimum 65 mm (2.6") clearance for USB cable or Ethernet cable and 43 mm (1.7") for XM Card insertion

Figure 9. SC22-3 and SC22-3E dimensions

4 System Installation

4.1 Appropriate Application

The correct application of the Safety Controller is dependent on the type of machine and the safeguards that are to be interfaced with the Controller. The Controller is generally interfaced with safeguards that may be used only on machinery that is capable of stopping motion immediately upon receiving a stop signal and at any point in its machine cycle. It is the user's responsibility to verify whether the safeguarding is appropriate for the application and is installed as instructed by the appropriate installation manuals. **If there is any doubt about whether or not your machinery is compatible with this Controller, contact a Banner Applications Engineer.**

> **WARNING: . . . Not a Stand-Alone Device**
>
> **This Safety Controller is not a stand-alone point-of-operation guarding device, as defined by OSHA regulations.** It is necessary to install point-of-operation guarding devices, such as safety light screens and/or hard guards, to protect personnel from hazardous machinery. **Failure to install point-of-operation guards on hazardous machinery can result in a dangerous condition which could lead to serious injury or death.**

> **WARNING: . . . User Is Responsible for Safe Application of this Product**
>
> **The application examples described in this document depict generalized guarding situations.** Every guarding application has a unique set of requirements.
>
> **Extreme care is urged to ensure that all legal requirements are met and that all installation instructions are followed.** Direct any questions regarding safeguarding to a factory applications engineer at the number or addresses listed in the back of this document.

> **WARNING: . . . Shock Hazard and Hazardous Energy**
>
> **Always disconnect power from the safety system (e.g., device, module, interfacing, etc.) and the machine being controlled before making any connections or replacing any component.**
>
> Electrical installation and wiring must be made by Qualified Personnel and must comply with the relevant electrical standards and wiring codes, such as the NEC (National Electrical Code), ANSI NFPA79, or IEC 60204-1, and all applicable local standards and codes.
>
> **Lockout/tagout procedures may be required.** Refer to OSHA 29CFR1910.147, ANSI Z244-1, or the appropriate standard for controlling hazardous energy.

> **WARNING: . . . Read this Section Carefully Before Installing the System**
>
> The Banner Safety Controller is an accessory device that is typically used in conjunction with a machine safeguarding device. **Its ability to perform this function depends upon the appropriateness of the application and upon the Safety Controller's proper mechanical and electrical installation and interfacing to the machine to be guarded.**
>
> **If all mounting, installation, interfacing, and checkout procedures are not followed properly, the Safety Controller cannot provide the protection for which it was designed.** The user has the responsibility to ensure that all local, state, and national laws, rules, codes, or regulations relating to the installation and use of this control system in any particular application are satisfied. Extreme care should be taken to ensure that all legal requirements have been met and that all technical installation and maintenance instructions contained in this manual are followed. **Read Section 3 (and its subsections) of this manual carefully before installing the system. Failure to follow these instructions could result in serious bodily injury or death.**

The user has the sole responsibility to ensure that this Safety Controller is installed and interfaced to the guarded machine by Qualified Persons (see Glossary), in accordance with this manual and applicable safety regulations.

4.2 Installing the Safety Controller

The Safety Controller mounts to a standard 35 mm DIN-rail track. It must be installed inside an enclosure rated NEMA 3 (IEC IP54) or better. It can be mounted in any orientation. The user must comply with all instructions contained within product manuals and relevant regulations.

For reliable operation, the user must ensure that the operating specifications are not exceeded. The enclosure must provide adequate heat dissipation, so that the air closely surrounding the Controller does not exceed its maximum operating temperature. Methods to reduce heat build-up include venting, forced air flow (e.g., exhaust fans), adequate enclosure exterior surface area, and spacing between the Safety Controller and other sources of heat. (See *Specifications, "Operating Conditions"* on page 24.)

Mount the Safety Controller in a convenient location that is free from heavy impulse force and high-amplitude vibration.

Electrostatic Discharge (ESD) can cause damage to electronic equipment. To prevent this, follow proper ESD handling practices such as:

- Wear an approved wrist strap or other approved grounding products.
- Touch a grounded object before handling the Controller.

See ANSI/ESD S20.20 for further information about managing ESD.

4.3 Safety Input Devices

Safety input devices allow for the cessation of motion, or an otherwise hazardous situation, by controlling the Safety Outputs of the Safety Controller. A Safety Output in the OFF state results in a stop of motion and removal of power from the machine actuators (assuming this does not create additional hazards).

For a Safety Output to turn ON, all of its controlling safety input devices must be in their Run state. A few special safety input device functions can, under predefined circumstances, temporarily suspend the safety input "stop signal" to keep the Safety Output ON (e.g., muting and bypassing).

The Safety Controller input configurations, depending on the type, have means to detect failures and faults that would otherwise result in a loss of that control of the safety function. Once such a failure or fault is detected, the Safety Controller will lock out until the problem is fixed.

Other input configurations do not have this detection capability. It is recommended that in all circumstances the installation of the Safety Controller and its associated safety and safeguarding devices be installed to eliminate or minimize the possibility of failures and faults that could result in the loss of the safety function(s).

Methods to eliminate or minimize the possibility of these failures include, but are not limited to:

- Physically separating interconnecting control wires from each other and from secondary sources of power.
- Routing interconnecting control wires in separate conduit, runs, or channels.
- Locating all elements (modules, switches, and devices under control) within one control panel, adjacent to each other, and directly connected with short wires.
- Properly installing multi-conductor cabling and multiple wires through strain-relief fittings. (Over-tightening of a strain-relief can cause short circuits at that point.)
- Using positive-opening or direct-opening components, as described by IEC 60947-5-1 that are installed and mounted in a positive mode.
- Periodically checking the functional integrity / safety function and training the the operators, maintenance personnel, and others with the operation of the machine and the safeguarding, and to recognize and immediately correct all failures.

  Follow the device manufacturer's installation, operation, and maintenance instructions and all relevant regulations. If there is any question about the device(s) that are connected to the Safety Controller, contact a Banner Application Engineer for assistance.

Figure 10. Input and output terminal locations

⚠ **WARNING: . . . Sharing of Safety Inputs**

Multiple Safety Controllers must not share safety input devices; this includes solid-state outputs from light curtains, Safety Controllers, or other safety devices. A Safety Output from one Controller can be connected to a Safety Input of a second Controller. **However, the second Controller should be the only device to which the output from the first Controller is connected.**

If a third device is also connected to the same Safety Output (now used as the safety input of the second Controller): during a power transition of the second Controller, the input may be a source of current, momentarily causing a false ON (Run) signal at the input of the third device. **Failure to connect multiple Controllers correctly could create an unsafe condition that may lead to serious bodily injury or death.**

⚠ **WARNING: . . . Failures and Faults**

The Safety Controller Safety control can be interfaced with input devices at differing levels of integrity, as described in Appendix A. **The user must conduct a Risk Assessment** to determine the appropriate level of integration. **The user also must eliminate or minimize the possibility of failures and faults** that could result in the loss of the safety function(s).

4.3.1 Signals: Run and Stop States

Dual-channel safety input devices have two separate signal lines. Dual-channel signals for some devices are both positive (+24V dc) when the device is in the Run state. Others have a complementary circuit structure where one channel is at 24V dc and the other is at 0V dc when the device is in the Run state. For the sake of clarity, instead of referring to a safety input device as being "ON" (e.g., 24V dc) or "OFF" (e.g., 0V dc), this manual adopts the Run state/Stop state convention.

4.3.2 Safety Input Device Properties

The Controller can be configured to accommodate many types of safety input devices. However, a number of device properties must be established (using either the OBI or PCI interface) so that the Controller can properly monitor their signals. These configurable properties include:

- **Device name**—This is generated automatically by the Controller and can be changed by the user.
- **Circuit type**—The circuit and signal convention options that can be selected to define the input device.
- **Reset logic**—Automatic (Trip mode) or Manual (Latch mode).
- **Terminal number**—The assignment of input terminals for a device.
- **I/O mapping**—The logic control relationship between inputs and outputs or between inputs.
- **Signal change-of-state**—Simultaneous or Concurrent type, and signal convention (high or low)
- **Signal debounce time**—The signal state transition time.
- **Start-up test**—An optional precautionary safety input device test required after each power-up.
- **Function time limit**—The adjustable time limit within which a function is allowed to operate.
- **Muteable**—Whether or not the device can be muted.
- **Bypassable**—Whether or not the device can be bypassed.

Circuit Types: Contact and Solid State Circuits

The table below depicts many of the input devices and circuit types the Controller can monitor. It highlights which of these properties can be configured, and for which devices. More description of some of these topics is included in the following paragraphs.

Not all circuit types meet the Category 4 classification per ISO 13849-1; refer to section *10.1 Safety Circuit Integrity and ISO 13849-1 (EN954-1) Safety Circuit Principles* on page 90 for a discussion of safety circuit integrity levels.

	E-Stop	Safety Gate	Optical Sensor	Two-Hand Control	Rope Pull	Protect. Stop	Safety Mat	Enabling Device	Mute Sensors	Bypass Switch	EDM	AVM
Circuit Types	7	13	10	7	10	10	1	10	7	10	2	2
Reset Logic	Auto/ Manual	Auto/ Manual	Auto/ Manual	Auto	Auto/ Manual	Auto/ Manual	Auto/ Manual	Auto	Auto	Auto	—	—
I/O Mapping	I/O	I/O	I/O	I/O	I/O	I/O	I/O	I/O	I/I	I/I	I/O	I/O
Signal COS*	S/C	S/C	S/C	S	S/C	S/C	—	S/C	S	S/C	S	—
Debounce Times	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Start Up Test	—	Yes	Yes	—	—	—	—	—	—	—	—	—
Function Time Limit	—		—	—	—	—	—	Yes	Yes	Yes	—	Yes
Muteable	—	Yes	Yes	Yes	—	Yes	Yes	—	—	—	—	—
Bypassable	—	Yes	Yes	Yes	—	Yes	Yes	—	—	—	—	—

* Refer to change-of-state table.
  S = Simultaneous
  C = Concurrent

Reset Logic: Manual or Automatic Reset

Safety input devices can be configured to require a manual reset before the Safety Output(s) they control are permitted to turn back ON. This is sometimes referred to as "latch" mode because the Safety Output "latches" to the OFF state until a reset is performed. If a safety input device is configured for automatic reset or "trip" mode, the Safety Output(s) it controls will turn back ON when the input device changes to the Run state (provided that all other controlling inputs are also in the Run state).

Reset rules and types are discussed in section *4.5 Input Device Resets* on page 33.

Terminal Numbers: Connecting the Input Devices

The Controller needs to know what device signal lines are to be connected to which wiring terminals, so that it can apply the proper signal monitoring methods, Run and Stop convention, timing rules, and fault rules. Although terminals are assigned automatically during the configuration process, the terminal assignments can be changed manually, using either the Onboard Interface or the PC Interface.

Signal Change-of-State Types

Two change-of-state (COS) types can be used when monitoring dual-channel safety input device signals: Simultaneous or Concurrent. The rules for each circuit type are shown in the table below.

Input Circuit	Input Signal COS Timing Rules	
	Stop State—SO turns OFF when[1]:	Run State—SO turns ON when[2]:
Dual-Channel A and B Complementary 2 Terminals 3 Terminals 2 Terminals, PNP 24V ON OFF **Dual-Channel A and B** 2-Ch, 2 Terminals 2-Ch, 3 Terminals 2-Ch, 4 Terminals 2-Ch, 2 Terminal PNP 24V ON ON	At least 1 channel (A or B) input is in the Stop state.	**Simultaneous.** A and B are both in the Stop state and then both in the Run state within 3 seconds before outputs turn ON. **Concurrent.** A and B concurrently in the Stop state, then both in the Run state with no simultaneity, to turn outputs ON.
2X Complementary A and B 4 Terminals 5 Terminals 24V PNP ON OFF ON OFF	At least 1 channel (A or B) is within a pair of contacts in the Stop state.	**Simultaneous.** A and B concurrently in the Stop state, then contacts within a channel in the Run state within 400 ms (150 ms for 2-hand control), both channels in the Run state within 3 seconds (0.5 seconds for 2-hand control) **Concurrent.** A and B concurrently in the Stop state, then contacts within a channel in the Run state within 3 seconds. Both channels in the Run state with no simultaneity.
Dual-Channel Safety Mat 2-Ch, 2 Terminals	• Input channels are shorted together (normal operation), or • At least 1 of the wires is disconnected, or • One of the normally low channels is detected high, or • One of the normally high channels is detected low.	Each channel detects its own pulses.

[1] Safety Outputs turn OFF when one of the controlling inputs is in the Stop state.

[2] Safety Outputs turn ON only when all of the controlling inputs are in the Run state and after a manual reset is performed (if any safety inputs are configured for Manual reset and were in their Stop state).

Signal Debounce Times

Closed-to-Open Debounce Time (from 6 to 100 milliseconds in 1 ms intervals, except 6 to 1,500 ms for mute sensors). The closed-to-open debounce time is the time limit required for the input signal to transition from the high (24V dc) state to the steady low (0V dc) state. This time limit may need to be increased in cases where high-magnitude device vibration, impact shock, or switch noise conditions result in longer signal transition times. If the debounce time is set too short under these harsh conditions, the system may detect a signal disparity fault and lock out. (Default setting is 6 ms.)

⚠️ **CAUTION: . . . Debounce and Response**

Any changes in the closed-to-open debounce time will affect the Safety Output response (turn OFF) time. This value is computed and displayed for each Safety Output when a configuration is created. The values are also listed in the OBI and the PCI Configuration Summary documents. (Default setting is 6 ms.)

Open-to-Closed Debounce Time (from 10 to 500 milliseconds in 1 ms intervals, except 10 to 1,500 ms for mute sensors). The open-to-closed debounce time is the time limit required for the input signal to transition from the low (0V dc) state to the steady high (24V dc) state. This time limit may need to be increased in cases where high magnitude device vibration, impact shock, or switch noise conditions result in longer signal transition times. If the debounce time is set too short under these harsh conditions, the system may detect a signal disparity fault and lock out. (Default setting is 50 ms.)

When a safety mat is used, the response time calculation for the safety mat is dependent on the Stop (6 to 100 ms) debounce time.

⚠️ **CAUTION: . . . Response Times**

- **The response time for a complementary device is based on the closed contact(s) opening,** *not on the open contact(s) closing.* Both will lead to a stop signal, but only one determines the response time.
- **Any changes in the open-to-closed debounce time** will affect the Safety Output reaction (turn ON) time!
- The configurable debounce of an ON/OFF input and an enabling device input are not part of the calculated and confirmed response times.

4.4 Non-Safety Input Devices

The non-safety input devices include manual reset devices, ON/OFF switches, and mute enable devices.

Configurable Properties	Manual Reset	ON/OFF	Mute Enable	Cancel OFF-Delay
Circuit Types	3	3	3	3
Input and Output Mapping	I/O	I/O	I/I	I/O
Debounce Times	Fixed at 50 ms	Closed-to-open: 6-100 ms Open-to-closed: 10-500 ms	Fixed at 50 ms	Fixed at 50 ms
Monitored / Non-monitored	Yes	—	—	Yes

Manual Reset Devices. The manual reset is used to create a reset signal after a safety input device that has been configured to require a manual reset has been opened and closed. After the manual reset operation is performed, any of the Safety Outputs controlled by that safety input device can turn ON.

⚠️ **WARNING: . . . Non-Monitored Resets**

If a non-monitored reset (either latch or system reset) is configured and if all other conditions for a reset are in place, **a short from the Reset terminal to +24V will turn ON the Safety Output(s) immediately.**

ON/OFF Switch. The ON/OFF switch is used to provide a machine ON or OFF command. When all of the controlling safety inputs are in the Run state, this function permits the Safety Output to turn ON and OFF. This is a single-channel signal; the Run state is 24V dc and the Stop state is 0V dc. An ON/OFF input can be added without mapping to a Safety Output, which allows this input to control only a Status Output.

Mute Enable Switch. The mute enable switch is used to signal the Controller when the mute sensors are permitted to perform a mute function. When the mute enable function is configured, the mute sensors will not be enabled to perform a mute function until the mute enable signal is in the Run state. This is a single-channel signal; the enable (Run) state is 24V dc and the disable (Stop) state is 0V dc.

Cancel OFF-Delay Devices. This feature provides the option to cancel a configured OFF-delay time. It functions in one of two ways:

• Keeps the Safety Output ON, or
• Turns the Safety Output OFF immediately, after the Controller receives a Cancel OFF-Delay signal.

A new Status Output (O.K. to Cancel Output's OFF-Delay Status) will indicate when a Cancel Delay Input can be activated, in order to keep the OFF-delayed Safety Output ON.
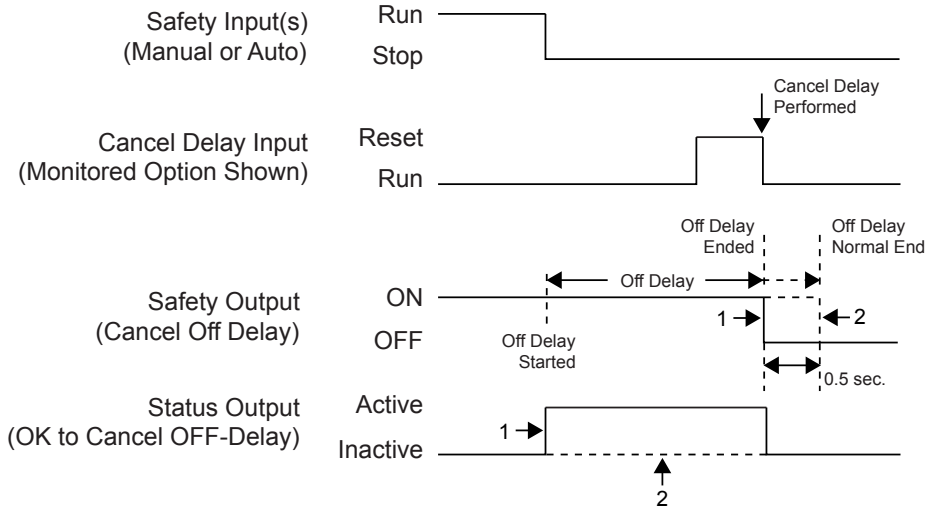
Note 1 - If "turn output off" function is selected

Note 2 - If "keep output on" function is selected

Figure 11. Cancel Delay Timing: Safety Input remains in Stop mode
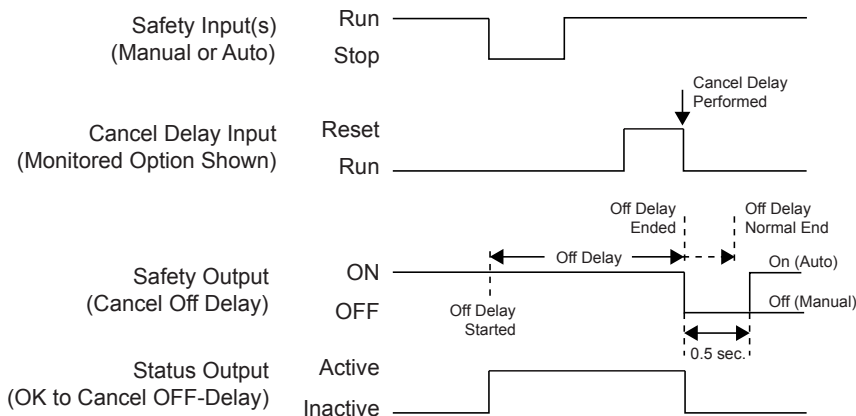
Figure 12. Cancel OFF-Delay Timing: "Turn Output OFF" function
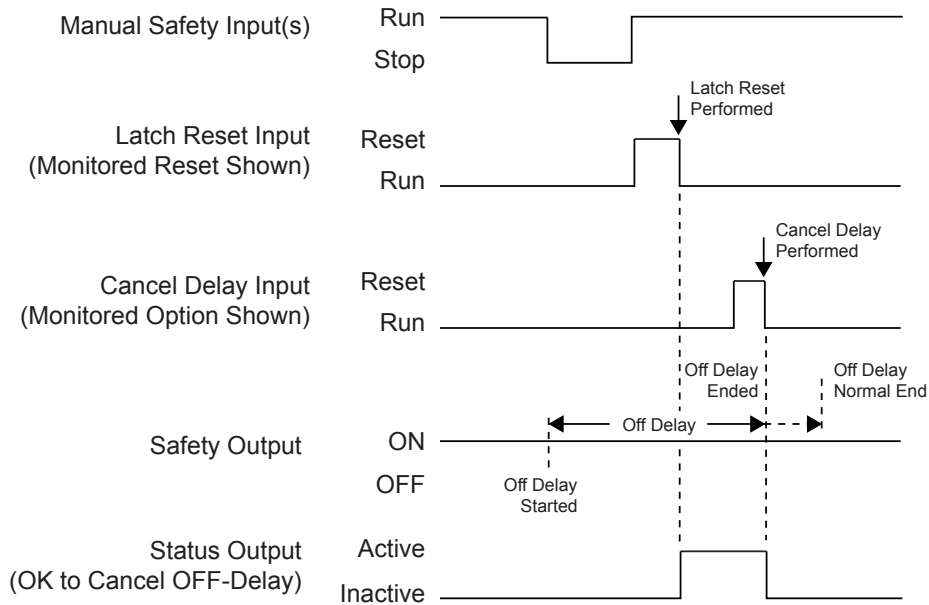
Figure 13. Cancel OFF-Delay Timing: "Keep Output ON" function, manual (latch) Safety Input
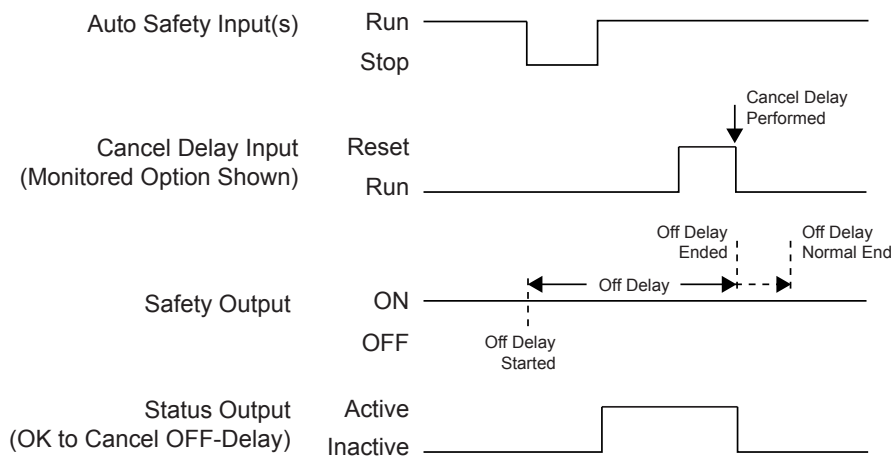
Figure 14. Cancel OFF-Delay Timing: "Keep Output ON" function, auto (trip) Safety Input

4.5 Input Device Resets

Three reset types are available:

- **Manual Reset:** used to manually reset a Safety Output that has turned OFF in response to a Stop signal from safety input device configured for manual ("Latch mode") reset. The reset signal type can be configured to be either monitored or non-monitored (the default setting is monitored).
- **System Reset:** used to recover from a fault condition or to restart the Controller after a new configuration has been altered. This reset device (a button or switch) connects to a dedicated input terminal on the Safety Controller, labeled SR. The reset signal type can be configured to be either monitored or non-monitored (the default setting is monitored).
- **Automatic Reset:** used to allow a Safety Output to return to an ON state without action by an individual once the input device changes to the RUN state (provided that all other controlling inputs are also in the Run state). Also known as "Trip mode," automatic reset is typically used in applications in which the individual continually is being sensed by the safety input device.

The reset switch must be mounted at a location that complies with the warning below. A key-actuated reset switch provides some operator or supervisory control, as the key can be removed from the switch and taken into the guarded area. However, this does not prevent unauthorized or inadvertent resets due to spare keys in the possession of others, or additional personnel entering the guarded

area unnoticed (a "pass-through hazard"). See section *4.5.3 Perimeter Guarding and Pass-Through Hazards* on page 35 for more information.

> ⚠️ **WARNING: . . . Reset Switch Location**
>
> **All reset switches must be accessible only from outside, and in full view of, the hazardous area. Reset switches must also be out of reach from within the safeguarded space, and must be protected against unauthorized or inadvertent operation** (e.g., through the use of rings or guards). If any areas are not visible from the reset switch(es), additional means of safeguarding must be provided. **Failure to do so could result in serious bodily injury or death.**

Resetting a safeguard must not initiate hazardous motion. Safe work procedures require a start-up procedure to be followed and the individual performing the reset to verify that the entire hazardous area is clear of all personnel, *before each reset of the safeguard is performed.* If any area can not be observed from the reset switch location, additional supplemental safeguarding must be used: at a minimum, visual and audible warnings of machine start-up.

4.5.1 Reset Signal Requirements

Both manual (latch) reset and system reset signals can be configured for monitored or non-monitored operation, as follows:

Monitored resets—Requires the reset signal to transition from low (0V dc) to high (24V dc) and then back to low. The high state duration must be 0.3 to 2 seconds. This is said to be a "trailing edge trip event."

Non-monitored resets—Requires only that the reset signal transitions from low (0V dc) to high (24V dc) and stays high for at least 0.3 seconds. After the reset, the reset signal can be either high or low. This is said to be a "leading-edge trip event."

4.5.2 Automatic and Manual Reset Inputs Mapped to the Same Safety Output

Safety input devices can be configured for either manual (Latch mode) or automatic (Trip mode) reset and both types can be mapped to the same Safety Output. In order for a Safety Output to turn ON, all associated safety input devices must be in their Run state. If one or more of these safety input devices is configured for manual reset and one or more of them change from the Stop state to the Run state, then the output will need a valid manual reset signal before it will turn ON.

If two safety inputs, each configured for manual reset, are mapped to the same Safety Output, then only one valid reset operation is required to reset the Safety Output. A manual reset operation is valid when all safety inputs mapped to the Safety Output are in the Run state and the manual reset is performed. If a manual reset is performed before a safety input is in the Run state, the manual reset signal is ignored (except in the case of a two-hand control and an ON/OFF input).

See sections *7.4 Manual Reset* on page 73 and *7.5 System Resets and Lockout Conditions* on page 74 for more information about resets.
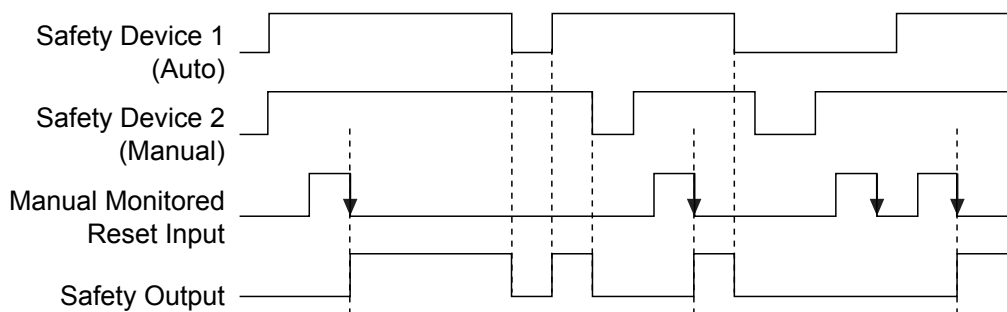

Figure 15. Timing logic: auto and manual monitored reset safety inputs mapped to the same Safety Output (no delay)
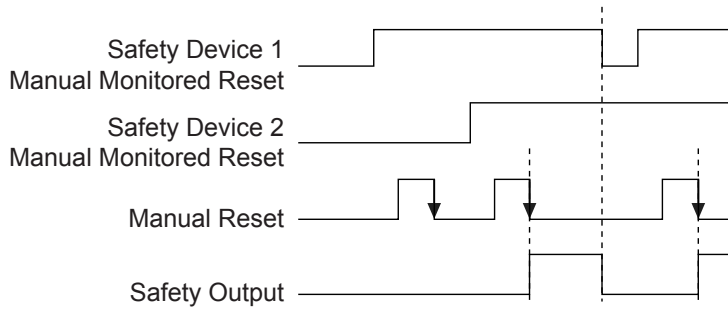
Figure 16. Timing logic: Safety Outputs with a common reset, mapped to the same Safety Output

4.5.3 Perimeter Guarding and Pass-Through Hazards

A "pass-through hazard" is associated with applications, such as perimeter guarding, where personnel may pass through a safeguard (which issues a stop command to remove the hazard), and then continue into the guarded area, where their presence is no longer detected. The related danger becomes the unexpected start or restart of the machine while personnel are within the guarded area.

Reducing or Eliminating Pass-Through Hazards

Eliminate or reduce pass-through hazards whenever possible. While it is recommended to eliminate the pass-through hazard altogether, this may not be possible due to machine layout, machine capabilities, or other application considerations.

- **One solution is to ensure that personnel are continually sensed** while within the hazardous area. This can be accomplished by using supplemental safeguarding, such as described by the ANSI B11 series of safety requirements or other appropriate standards.
- **An alternate method is to ensure that when the safeguarding device is tripped, it will latch** (manual reset), and will require a deliberate manual action to reset. This method of safeguarding relies upon the location of the reset switch as well as safe work practices and procedures to prevent an unexpected start or restart of the guarded machine.

⚠️ **WARNING: . . . Perimeter Guarding Applications**

If the application could result in a pass-through hazard (e.g., perimeter guarding), either the safeguarding device or the guarded machine's MSCs/MPCEs must cause a Latched response following a Stop command (e.g., interruption of the sensing field of a light curtain, or opening of an interlocked gate/guard). The reset of this Latched condition may only be achieved by actuating a reset switch that is separate from the normal means of machine cycle initiation. The switch must be positioned as described in this document.

Lockout/Tagout procedures per ANSI Z244.1 may be required, or additional safeguarding, as described by ANSI B11 safety requirements or other appropriate standards, must be used if a passthrough hazard can not be eliminated or reduced to an acceptable level of risk. **Failure to observe this warning could result in serious bodily injury or death.**

4.6 Safety Input Function

4.6.1 Internal Logic

The Controller's internal logic is designed so that a Safety Output can turn ON only if all the controlling safety input device signals and the Controller's self-check signals are in the Run state and report that there is no fault condition.

The table at right illustrates the logic for two safety input devices that are mapped to control Safety Output 1. If either safety input device is in the Stop state, the Safety Output will be OFF. When both safety inputs and the Controller are in the Run state, Safety Output 1 will be ON.

Safety Input 1	Safety Input 2	Safety Output 1
Stop	Stop	OFF
Stop	Run	OFF
Run	Stop	OFF
Run	Run	ON

4.6.2 Two-Hand Control (THC)

The two-hand control function requires that two hand actuators (e.g., hand/palm buttons) each be activated within 0.5 seconds of each other in order to produce a Run signal to start a machine cycle. THC devices are always the last input (in time) to turn the Safety Output ON. If one or more of the other controlling input devices are configured for manual reset and are used to stop the machine, a manual reset must be performed before the THC device can cycle the machine again.
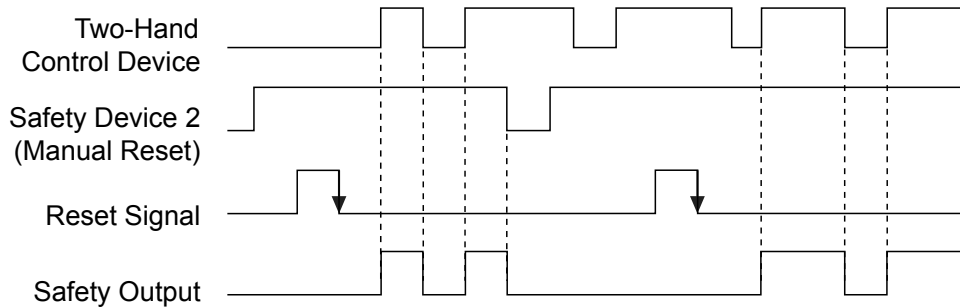
See section for more information.

Figure 17. Timing logic: two-hand control device and manual reset safety input device

Two-Hand Control Activation on Power-Up Protection. The Controller's two-hand control logic will not permit the assigned Safety Output to turn ON when power is initially supplied while the THC actuators are in their Run state. The THC actuators must change to their Stop state and return to the Run state before the Safety Output can turn ON.

A two-hand control device does not have a manual reset option.

4.6.3 Enabling Devices

The enabling device actively controls the suspension of a Stop signal during a portion of a machine operation where a hazard can occur. The enabling device permits a hazardous portion of the machine to run, but must not start it. A separate machine command signal from another device is needed to start hazardous motion. **This enabling device must have ultimate hazard turn OFF or Stop authority when being used.** The enabling device is sometimes referred to as the "live man pendant."

An enabling device can be mapped to one or more Safety Outputs. When the enable signal goes from the Stop state to the Run state, the Controller will go into Enable mode. In this mode, the associated Safety Outputs will turn ON if any of the assigned EDM inputs are closed (these may open after the outputs turn ON) and all of the controlling E-stop or rope pull devices are in their Run state. With the exception of the E-stop and rope pull devices, all other safety input signals (Run or Stop) will be ignored while the Controller is in Enable mode. Safety Output enabling control resides in the enabling device function when in Enable mode. Repetitive enable cycles are allowed.

In order to exit Enable mode, the enabling device must be in the OFF state, and a system reset must be performed.

Enabling Device Time Limit. The enabling device time limit can be adjusted between 1 second and 30 minutes and cannot be disabled. When the time limit expires, the associated Safety Outputs will turn OFF. In order to start a new Enable mode cycle with the time limit reset set to its original time limit value, the enabling device must switch from ON to OFF, and back to ON.

All ON- and OFF-delay times associated with the Safety Outputs that are controlled by the enabling device function will be honored during the Enable mode.
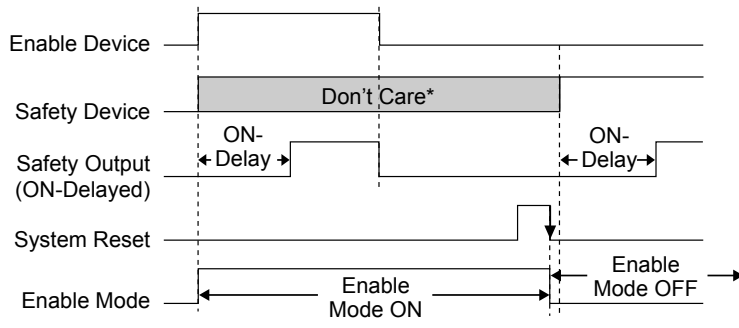
*Unless it's an E-Stop or a Rope-Pull

Figure 18. Timing logic: Enabling device and enable mode

See section *10.9 Enabling Device* on page 112 for more information.

4.6.4 Mute Function

Safety device muting is the automatically controlled suspension of one or more safety input stop signals during a portion of a machine operation when no immediate hazard is present or when access to the hazard is safeguarded. Muting sensors can be mapped to one or more of the following "mutable" safety input devices:

- Safety gate (interlocking) switches
- Optical sensors
- Two-hand controls
- Safety mats
- Protective stops

(E-stop buttons, rope pulls, enabling devices, external device monitoring, and bypass switches are said to be "non-mutable" devices or functions.)

At least two mute sensors are required for each muting operation (the mute occurs typically 100 ms after the second mute sensor input has been satisfied). One or two pairs of mute sensors can be mapped to one or more safety input devices so that their assigned Safety Outputs can remain ON to complete the operation; see section *10.11 Mute Sensor Pair* on page 116 for more information.

Mute Enable. The optional mute enable function can be configured to ensure that a mute function is permitted only at the appropriate time. If a mute enable input device has been mapped to a mutable safety input device, this safety input device can be muted only if the mute enable switch is in the Enable (24V dc) state at the time the mute cycle is started. After the mute cycle starts, the ME input can be turned OFF. A mute enable input device can be mapped to one or more mutable safety inputs.

NOTE: Mute enable is not a safeguarding function, but rather a machine logic function.
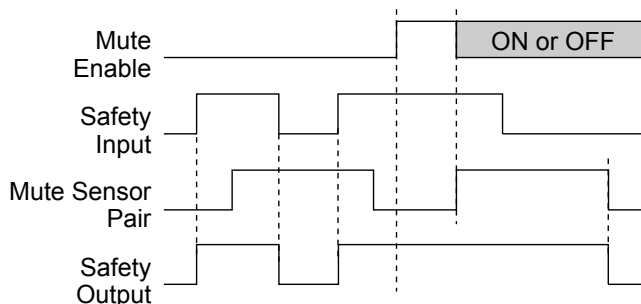
Figure 19. Timing logic: one mute sensor pair with mute enable

Mute Time Limit (Backdoor Timer). A time limit can be established to limit how long a mute cycle is permitted to be active. The time limit can be adjusted from 1 second to 30 minutes. A different time limit can be set for each mutable safety input device. Other input devices that are also muted are affected only by their own mute time limit setting. The mute time limit can be disabled. When disabled, the time limit for the mute function for that input device is infinite.

Directional Muting. As soon as two mute sensor pairs are configured and mapped to a muteable Safety Input, an advanced setting option appears in the PCI to provide the option of directional muting. Check the box "Enable Directional Muting," then select the muting sensor pair to be blocked first. The Controller requires sensor pair 1 to be blocked first, then the safeguard, then sensor pair 2 (all within the configured time limits) in order for the mute to take place.

Mute Sensor Debounce Time. The input debounce time, accessible under the "Advanced settings" in the Mute Sensor Pair properties window, can be used to extend a mute cycle after a mute sensor signal is removed. By configuring the "closed-to-open" debounce time, the mute cycle can be extended up to 1.5 seconds (1500 ms) to allow the Safety Input Device to re-energize its outputs (turn ON). The start of the mute cycle can also be delayed, by configuring the "open-to-closed" debounce time.

Mute on Power-Up Function. If configured, the Mute on Power-Up function will initiate a mute cycle after power is applied to the Safety Controller if the muted safety inputs are active (Run state or closed), and either M1-M2 or M3-M4 (but not all four) are signaling a muted condition (e.g., active or closed).

⚠️ **WARNING: . . . Mute on Power-Up**

The Mute on Power-Up function should be used _only_ in applications where:

- **Muting the System** (M1 and M2 closed) **when power is applied is required**, and
- **Using it does not, in any situation, expose personnel to any hazard.**

Mute on Power-Up Disabled. When the mute on power-up option is disabled, the Controller will not go into a mute cycle, even if the conditions for a valid mute cycle are fulfilled at power-up.

Mute on Power-Up Enabled. When the Mute on Power-Up option is enabled, the Controller will go into a mute cycle if the conditions for a valid mute cycle are fulfilled at power-up. Specific valid mute signal conditions must be present for a mute cycle to be initiated and maintained.

If Auto Power-Up is configured, the Controller allows approximately 2 seconds for the input devices to become active (closed) to accommodate systems that may not be immediately active at power-up. If Manual Power-Up is configured and all other conditions are satisfied, the first valid system reset after the muted safety inputs are active (Run state or closed) will result in a mute cycle. **The Mute On Power-up function should only be used if safety can be assured when the mute cycle is expected, and the use of this function is the result of a risk assessment and is required by that particular machine operation.**

⚠️ **WARNING: . . . Mute and Bypass**

Mute and Bypass operations must be done in a way that minimizes personnel risk. Implement the following when creating mute and bypass applications:

- **Guard against unintended stop signal suspension** by using one or more diverse-redundant mute sensor pairs or a dual channel key-secured bypass switch.
- **Set reasonable time limits** (no longer than needed) for the mute and bypass functions.

Failure to follow these rules could lead to an unsafe condition that could result in serious injury or death.

See section for more information.

4.6.5 Bypass Function

The safety device bypass is a manually activated and temporary suspension of one or more safety input stop signals when no immediate hazard is present. Bypass switches can be mapped to one or more of the following safety input devices:

- Safety gate (interlocking) switches
- Optical sensors
- Two-hand control devices
- Safety mats
- Protective stop

When the bypass switch signal changes to the Bypass (Run) state, it will turn ON or keep ON all the Safety Outputs that are controlled by the bypassed safety input devices only if all other non-bypassed safety devices that are mapped to these Safety Outputs are in the Run state.

Bypass Time Limit. A bypass function time limit can be established to limit how long the safety input device bypass is active. The time limit can be adjusted from 1 second to 12 hours and cannot be disabled. Only one time limit can be set, and this limit will apply to all safety devices that are bypassed. At the end of the time limit, Safety Output control authority is handed back to the bypassed safety input devices.

Two-Hand Control Bypassing. If a Two-Hand Control input is actuated while the input is being bypassed, the Safety Controller will lock out and issue a Stop signal. This ensures that the operator does not mistake that the Two-Hand Control is functional and is aware that the bypassed Two-Hand Control is no longer providing the safeguarding function.

Mute-Dependent Override. When this option is enabled, and a mute sensor is mapped to the safety input device, and the safety input device is in the STOP state, at least one of the Mute sensors must be in the Mute (Run) state in order to start a new bypass cycle. If the conditions are right for bypass, the mute Status Output indicator (if configured) will start flashing at 1 Hz. If this option is disabled, the Safety Input is not required to be in the Stop state and the mute sensors need not be blocked, in order to start a new bypass cycle.
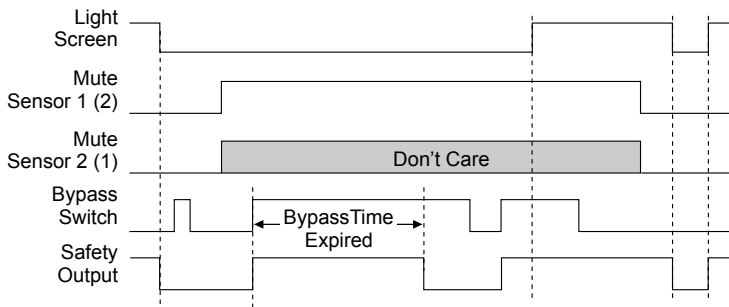

Figure 20. Timing logic: Light screen with mute sensors and bypass switch

4.6.6 Adjustable Valve Monitoring (AVM) Function

Adjustable Valve (Device) Monitoring function is similar in function to One-Channel External Device Monitoring (1-channel EDM, see section *4.7.1 External Device Monitoring (EDM)* on page 40). The function monitors the state of the device(s) that are controlled by the Safety Output to which the function is mapped. When the Safety Output turns OFF, the AVM input must be high/ON (+24V dc applied) before the AVM timer expires or a lockout will occur. The AVM input must also be high/ON when the Safety Output attempts to turn ON or a lockout will occur. See figure below; note that the 100 ms to 5 second time period is adjustable in 50 ms intervals (default is 100 ms).
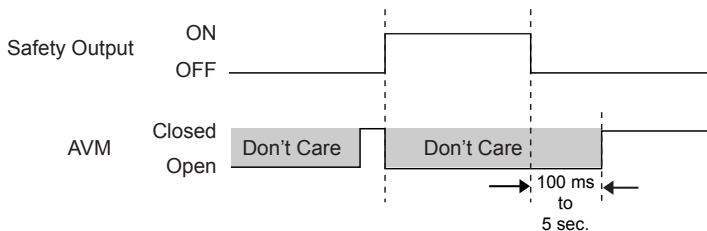
Figure 21. Timing logic: AVM function

The Adjustable Valve (Device) Monitoring function is useful for dynamically monitoring devices under control of the Safety Output that may become slow, "sticky," or fail in an energized state or position and whose operation needs to be verified after a Stop signal occurs. Example applications include single- or dual-solenoid valves controlling clutch/brake mechanisms, and position sensors that monitor the home ("safe") position of a linear actuator.

Synchronization or checking a maximum differential timing between two or more devices (e.g., dual valves) can be achieved by mapping multiple AVM functions to one Safety Output and configuring the AVM timer to the same values. Any number of AVM inputs can be mapped to one Safety Output. An input signal can be generated by a hard/relay contact or a solid-state PNP output.

⚠️ **CAUTION: . . . Adjustable Valve Monitoring (AVM) Operation**

When an input is configured with automatic reset logic and is quickly cycled (from Run to Stop to Run), the Safety Output(s) will not turn ON until the AVM input is satisfied. **This could result in an ON-delay up to the configured AVM monitoring time.**

It is the user's responsibility to ensure the AVM monitoring time is properly configured for the application and to instruct all individuals associated with the machine about the possibility of the ON-Delay effect, which may not be readily apparent to the machine operator or to other personnel.

4.7 EDM, OSSD (Safety Output), and FSD Hookup

4.7.1 External Device Monitoring (EDM)

The Controller's Safety Outputs can control external relays, contactors, or other devices that have a set of normally closed (N.C.) force-guided (mechanically linked) contacts that can be used for monitoring the state of the machine power contacts. The monitoring contacts are normally closed (N.C.) when the device is turned OFF. This capability permits the Controller to detect if the devices under load are responding to the Safety Output, or if the N.O. contacts are possibly welded closed or stuck ON.

The EDM function provides a method to monitor these types of faults and to ensure the functional integrity of a dual-channel system, including the MPCEs and the FSDs.

An EDM input can be mapped to only one Safety Output.

The EDM inputs can be configured in three ways: one-channel, two-channel, or no monitoring. One- and two-channel EDM are used when the OSSD outputs directly control the de-energizing of the MPCEs or external devices.

- **One-Channel Monitoring:** a series connection of closed monitor contacts that are forced-guided (mechanically linked) from each device controlled by the Controller. The monitor contacts must be closed before the Controller outputs can be reset (either manual or automatic). After a reset is executed and the Safety Outputs (OSSDs) turn ON, the status of the monitor contacts are no longer monitored and may change state. However, the monitor contacts must be closed within 250 milliseconds of the OSSD outputs going from ON to OFF.
- **Two-Channel Monitoring:** an independent connection of closed monitor contacts that are forced-guided (mechanically linked) from each device controlled by the Controller. Both EDM inputs must be closed before the Controller can be reset and the OSSDs can turn ON. While the OSSDs are ON, the inputs may change state (either both open, or both closed). If the inputs remain in opposite states for more than 250 milliseconds, a lockout will occur.
- **No Monitoring:** If no monitoring is desired, simply do not select either one-channel or the two-channel option. If the Controller does not use the EDM function in category 3 or category 4 applications, the user must ensure that any single failure or accumulation of failures of the external devices does not result in a hazardous condition and a successive machine cycle will be prevented.

⚠️ **CAUTION: . . . EDM Configuration**

If the application does not require the EDM function, **it is the user's responsibility to ensure that this does not create a hazardous situation.**

⚠️ **CAUTION: . . . External Device Monitoring Hookup**

It is strongly recommended that at least one normally closed, forced-guided monitoring contact of each MPCE or external device be wired in order to monitor the state of the MPCEs (as shown in the hookup figures). If this is done, proper operation of the MPCEs will be verified. **MPCE monitoring contacts must be used in order to maintain control reliability.**
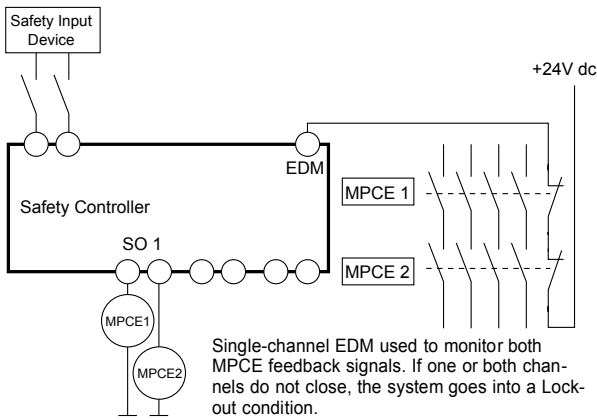
Figure 22. One-channel EDM hookup

Single-channel EDM used to monitor both MPCE feedback signals. If one or both channels do not close, the system goes into a Lockout condition.
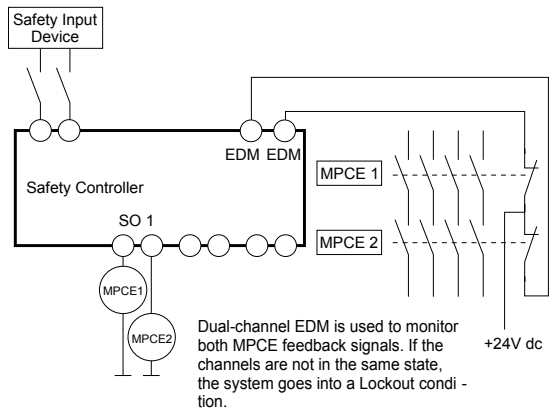
Figure 23. Two-channel EDM hookup

Dual-channel EDM is used to monitor both MPCE feedback signals. If the channels are not in the same state, the system goes into a Lockout condition.
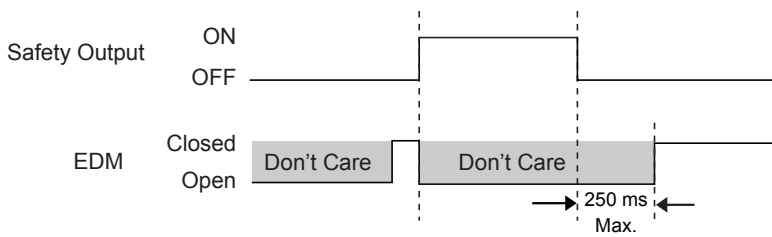
Figure 24. Timing logic: One-channel EDM status, with respect to Safety Output
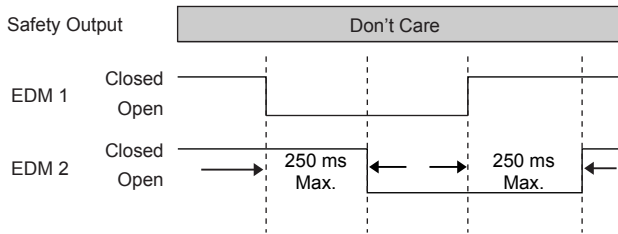
Figure 25. Timing logic: Two-channel EDM, timing between channels

For two-channel EDM, as shown below, both channels must be closed before the Safety Output(s) turn ON.
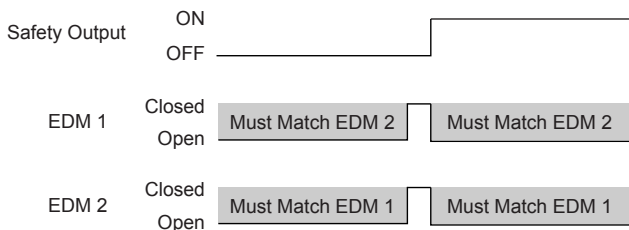
Figure 26. Timing logic: Two-channel EDM status, with respect to Safety Output

4.7.2 Safety Outputs

The Safety Controller has three pairs of solid-state Safety Outputs (SO1 a and b, SO2 a and b, and SO3 a and b). Each pair consists of two output signal switching devices (OSSDs). The solid-state Safety Outputs are actively monitored to detect short circuits to the supply voltage, to each other, and to other sources of electrical energy. If a failure is detected, the outputs will switch to an Off state. For circuits requiring the highest level of safety and reliability, either OSSD must be capable of stopping the motion of the guarded machine controlled by a Safety Output, in an emergency.

OSSD Output Connections

The output signal switching device (OSSD) outputs must be connected to the machine control such that the machine's safety related control system interrupts the circuit or power to the machine primary control element(s) (MPCE), resulting in a non-hazardous condition.

Final switching devices (FSDs) typically accomplish this when the Safety Outputs go to the OFF state.

Refer to the *output specifications* on page 23 and Warning below before making OSSD connections and interfacing the Controller to the machine.

ON-Delays and OFF-Delays

Each Safety Output can be configured to function with either an ON-delay or an OFF-delay (see Figure below), where the output turns ON or OFF only after the time limit has elapsed. An output cannot have both ON- and OFF-delays. The ON and OFF time delay limit options are from 100 milliseconds to 5 minutes, in 100 millisecond increments.

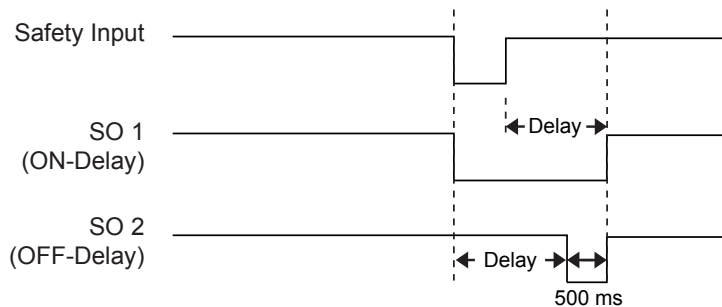Current operation is to honor the OFF-delay for internal and system faults, whenever possible.

Safety Input

SO 1
(ON-Delay) ← Delay →

SO 2
(OFF-Delay) ← Delay →

500 ms

Figure 27. Timing logic: Safety Output with OFF-delay

NOTICE: Safety Outputs are Dual-Channel.

An individual Safety Output is not, by itself, capable of meeting Category 4 applications (per ISO13849-1). When the risk assessment or relevant regulations require high levels of safety integrity (i.e., Category 4), both the output signal switching device (OSSD) outputs must be connected to the machine control so that the machine's safety related control system interrupts the circuit or power to the machine primary control element(s) (MPCEs), resulting in a non-hazardous condition.

Final switching devices (FSDs) typically accomplish this when the OSSDs go to an OFF state. See wiring diagrams.

WARNING: . . . OFF-Delays

A Safety Output OFF-delay time will be honored even if the safety input that caused the OFF-delay timer to start switches back to the Run state before the delay time expires. However, **in cases of a power interruption or a power loss, an OFF-delay time can end immediately. If such an immediate machine stop condition could cause a potential danger, then additional safeguarding measures must be taken to prevent injuries.**

WARNING: . . . Interfacing of Both OSSDs

Both of the OSSD (Output Signal Switching Device) outputs must be connected to the machine control so that the machine's safety-related control system interrupts the circuit to the machine primary control element(s), resulting in a non-hazardous condition.

Never wire an intermediate device(s) (e.g., PLC, PES, or PC) that can fail in such a manner that there is the loss of the safety stop command, OR in such a manner that the safety function can be suspended, overridden, or defeated, unless accomplished with the same or greater degree of safety.

⚠ **WARNING: . . . Safety Output Lead Resistance**

In order to ensure proper operation, the resistance in the Safety Output wires should not exceed 10 ohms. A higher resistance than 10 ohms may mask a short between the dual-channel Safety Outputs and could create an unsafe condition that may lead to serious bodily injury or death.

4.7.3 FSD Interfacing Connections

Final switching devices (FSDs) can take many forms, though the most common are forced-guided (mechanically linked) relays or Interfacing Modules. The mechanical linkage between the contacts allows the device to be monitored by the external device monitoring circuit for certain failures.

Dependent on the application, the use of FSDs can facilitate controlling voltage and current that differs from the OSSD outputs of the Controller. FSDs can also be used to control an additional number of hazards by creating multiple safety stop circuits.

Safety (Protective) Stop Circuits

A safety stop allows for an orderly cessation of motion or hazardous situation for safeguarding purposes, which results in a stop of motion and removal of power from the MPCEs (assuming this does not create additional hazards). A safety stop circuit typically comprises of a minimum of two normally open contacts from forced-guided (mechanically linked) relays, which are monitored to detect certain failures such that the loss of the safety function does not occur (i.e. external device monitoring). Such a circuit can be described as a "safe switching point."

Typically, safety stop circuits are a series connection of at least two N.O. contacts coming from two separate, positive-guided relays, each of them controlled by one separate Safety Output of the Controller. The safety function relies on the use of redundant contacts to control a single hazard, so that if one contact fails ON, the second contact will arrest the hazard and prevent the next cycle from occurring.

Interfacing safety stop circuits must be wired so that the safety function can not be suspended, overridden, or defeated, unless accomplished in a manner at the same or greater degree of safety as the machine's safety-related control system that includes the Controller.

The normally open outputs from an interfacing module are a series connection of redundant contacts that form safety stop circuits and can be used in either single-channel or dual-channel control methods. (See wiring diagrams.)

Dual-Channel Control. Dual-channel (or two-channel) control has the ability to electrically extend the safe switching point beyond the FSD contacts. With proper monitoring (i.e., EDM), this method of interfacing is capable of detecting certain failures in the control wiring between the safety stop circuit and the MPCEs. These failures include a short-circuit of one channel to a secondary source of energy or voltage, or the loss of the switching action of one of the FSD outputs. The result could lead to the loss of redundancy or a complete loss of safety if not detected and corrected.

The possibility of a wiring failure increases as the physical distance between the FSD safety stop circuits and the MPCEs increase, as the length or the routing of the interconnecting wires increases, or if the FSD safety stop circuits and the MPCEs are located in different enclosures. Thus, dual-channel control with EDM monitoring should be used in any installation where the FSDs are located remotely from the MPCEs.

Single-Channel Control. Single-channel (or one-channel) control, as mentioned, uses a series connection of FSD contacts to form a safe switching point. After this point in the machine's safety-related control system, failures can occur that would result in the loss of the safety function (e.g., a short-circuit to a secondary source of energy or voltage).

Thus, this method of interfacing should only be used in installations where FSD safety stop circuits and the MPCEs are physically located within the same control panel, adjacent to each other, and are directly connected to each other; or where the possibility of such a failure can be excluded. If this can not be achieved, then two-channel control should be used.

Methods to exclude the possibility of these failures include, but are not limited to:

- Physically separating interconnecting control wires from each other and from secondary sources of power.
- Routing interconnecting control wires in separate conduit, runs, or channels.
- Routing interconnecting control wires with low voltage or neutral that can not result in energizing the hazard.
- Locating all elements (modules, switches, devices under control, etc.) within the same control panel, adjacent to each other, and directly connected with short wires.

- Properly installing multi-conductor cabling and multiple wires that pass through strain-relief fittings. Over-tightening of a strain-relief can cause short circuits at that point.
- Using positive-opening or direct-drive components installed and mounted in a positive mode.

WARNING: . . . Use of Transient Suppressors

Transient suppressors are recommended. They MUST be installed across the coils of the FSDs. NEVER install suppressors directly across the contacts of the FSDs. It is possible for suppressors to fail as a short circuit. If installed directly across the contacts of the FSDs, a short-circuited suppressor will create an unsafe condition.

WARNING: . . . OSSD Interfacing

To ensure proper operation, the Safety Controller output parameters and machine input parameters must be considered when interfacing the solid-state Safety Outputs to the machine inputs. Machine control circuitry must be designed so that:

- The maximum cable resistance value between the Safety Controller solid-state Safety Outputs and the machine inputs is not exceeded,
- The Safety Controller's solid-state Safety Output maximum Off state voltage does not result in an ON condition, and
- The Safety Controller's solid-state Safety Output maximum leakage current, due to the loss of 0V, will not result in an ON condition.

Failure to properly interface the Safety Outputs to the guarded machine could result in serious bodily injury or death.

WARNING: . . . Shock Hazard and Hazardous Energy

Always disconnect power from the safety system (e.g., device, module, interfacing, etc.) and the machine being controlled before making any connections or replacing any component.

Electrical installation and wiring must be made by Qualified Personnel and must comply with the relevant electrical standards and wiring codes, such as the NEC (National Electrical Code), ANSI NFPA79, or IEC 60204-1, and all applicable local standards and codes.

Lockout/tagout procedures may be required. Refer to OSHA 29CFR1910.147, ANSI Z244-1, or the appropriate standard for controlling hazardous energy.

WARNING: . . . Proper Wiring

The generalized wiring configurations shown are provided only to illustrate the importance of proper installation. The proper wiring of the Safety Controller to any particular machine is solely the responsibility of the installer and end user.

Generic Hookup: 1-channel, 2-channel, and No EDM Options

The following figure is generic in nature and represents all three EDM options:

- Safety Output SO1 is shown with NO EDM configured (typically used with self-monitored devices).
- Safety Output SO2 is shown with Two-Channel EDM configured.
- Safety Output SO3 is shown with One-Channel EDM configured.

Any particular Safety Controller configuration may use any combination of external device monitoring options, depending on the application.
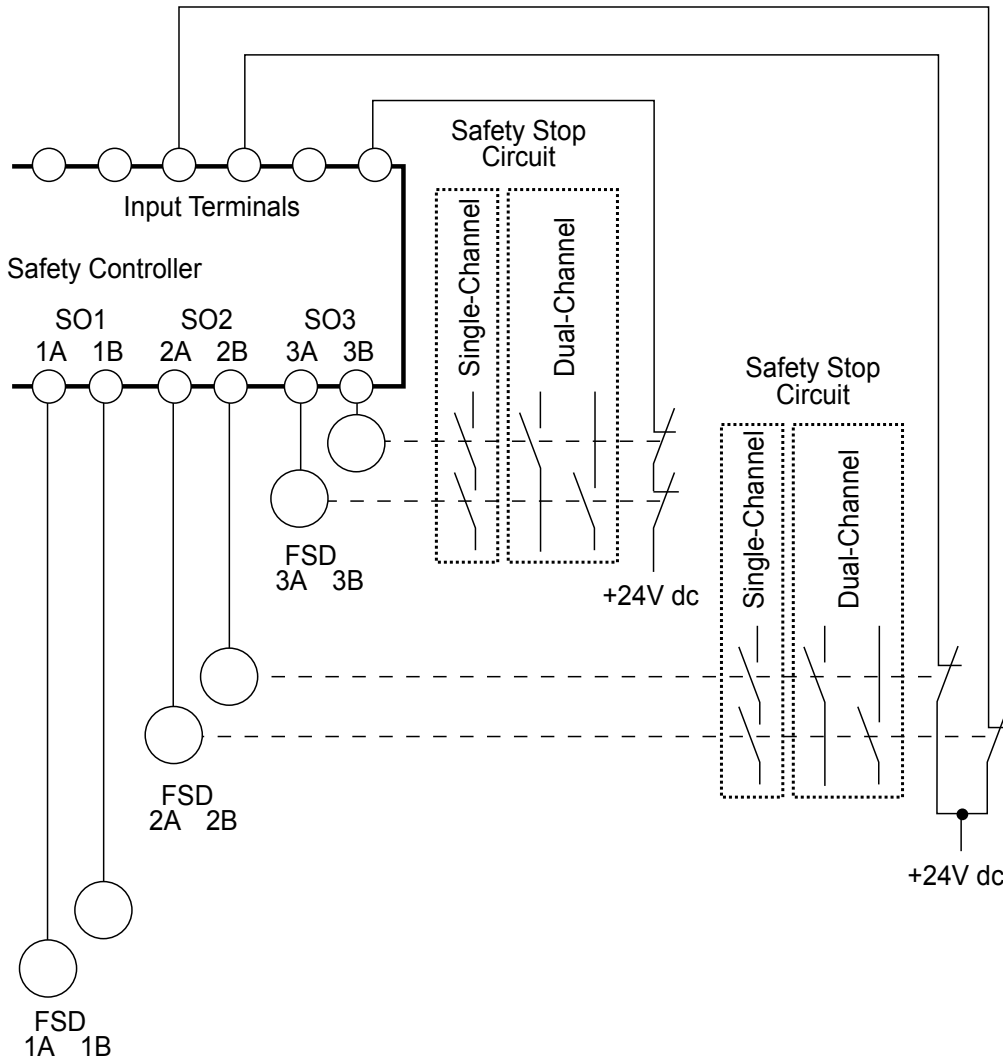
Figure 28. Generic hookup showing 1-channel, 2-channel, and no EDM options

One-Channel EDM Hookup to SC-IM9A Interface Module

The SC-IM9A interface module depicted in the following figure is shown in one-channel EDM hookup. The SC-IM9B and SC-IM9C modules are connected in the same manner, using individual one-channel EDM circuits (terminals 21/22 on each pair of contactors).
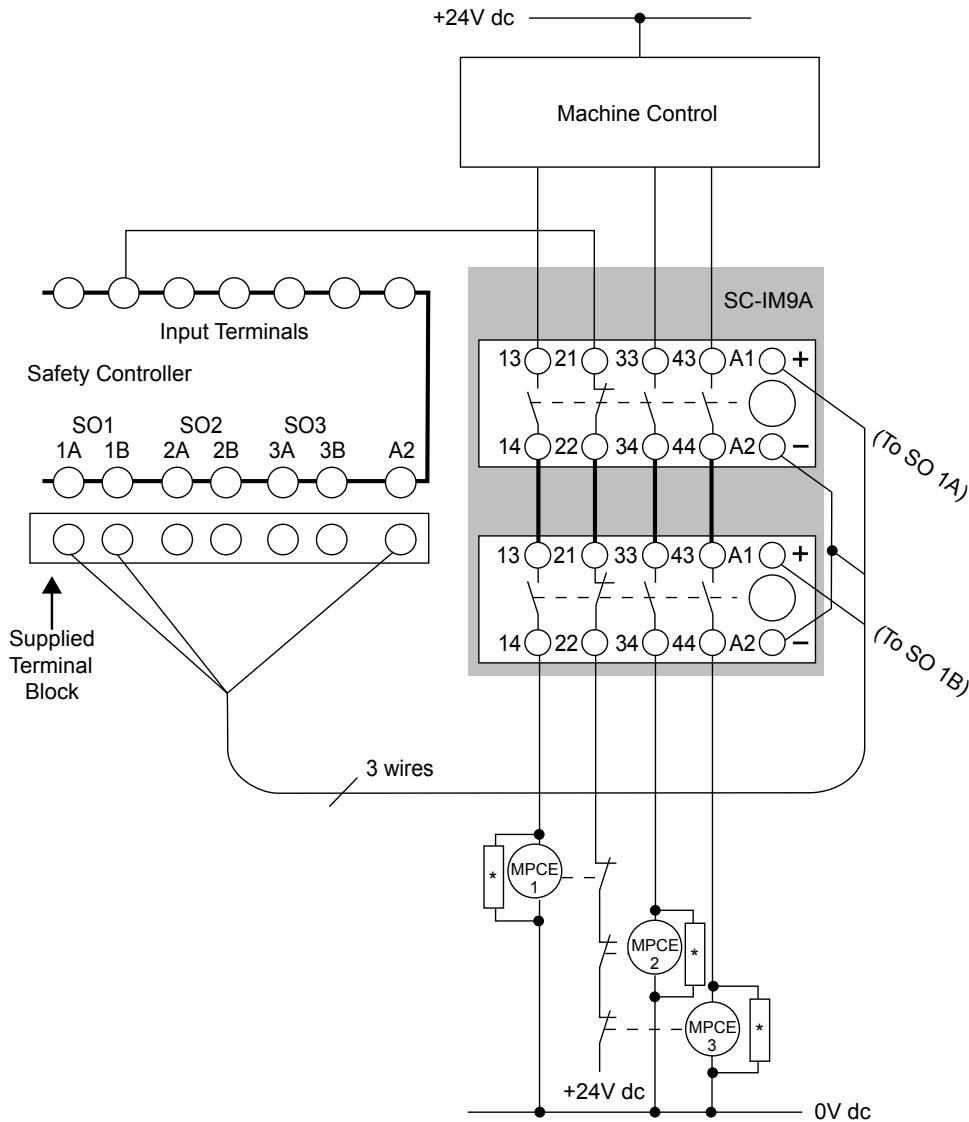
* Installation of transient (arc) suppressors across the coils of MPCE1, MPCE2, and MPCE3 is recommended (see Warning)

Figure 29. One-channel EDM hookup to SC-IM9A interface module

Two-Channel EDM Hookup to IM-T-9A Interface Module

The IM-T-9A interface module depicted in the following figure is shown in two-channel EDM hookup. The IM-T-11A module is connected in a similar manner. Depending on the application, each Safety Output requires a separate and individually wired IM-T-..A module.

* Installation of transient (arc) suppressors across the coils of MPCE1 and MPCE2 is recommended (see Warning)

Figure 30. Hookup: Two-channel EDM hookup to IM-T-9A interface module

One-Channel EDM Hookup to IM-T-9A Interface Module

The IM-T-9A interface module depicted in the following figure is shown in one-channel EDM hookup. The IM-T-11A module is connected in a similar manner.

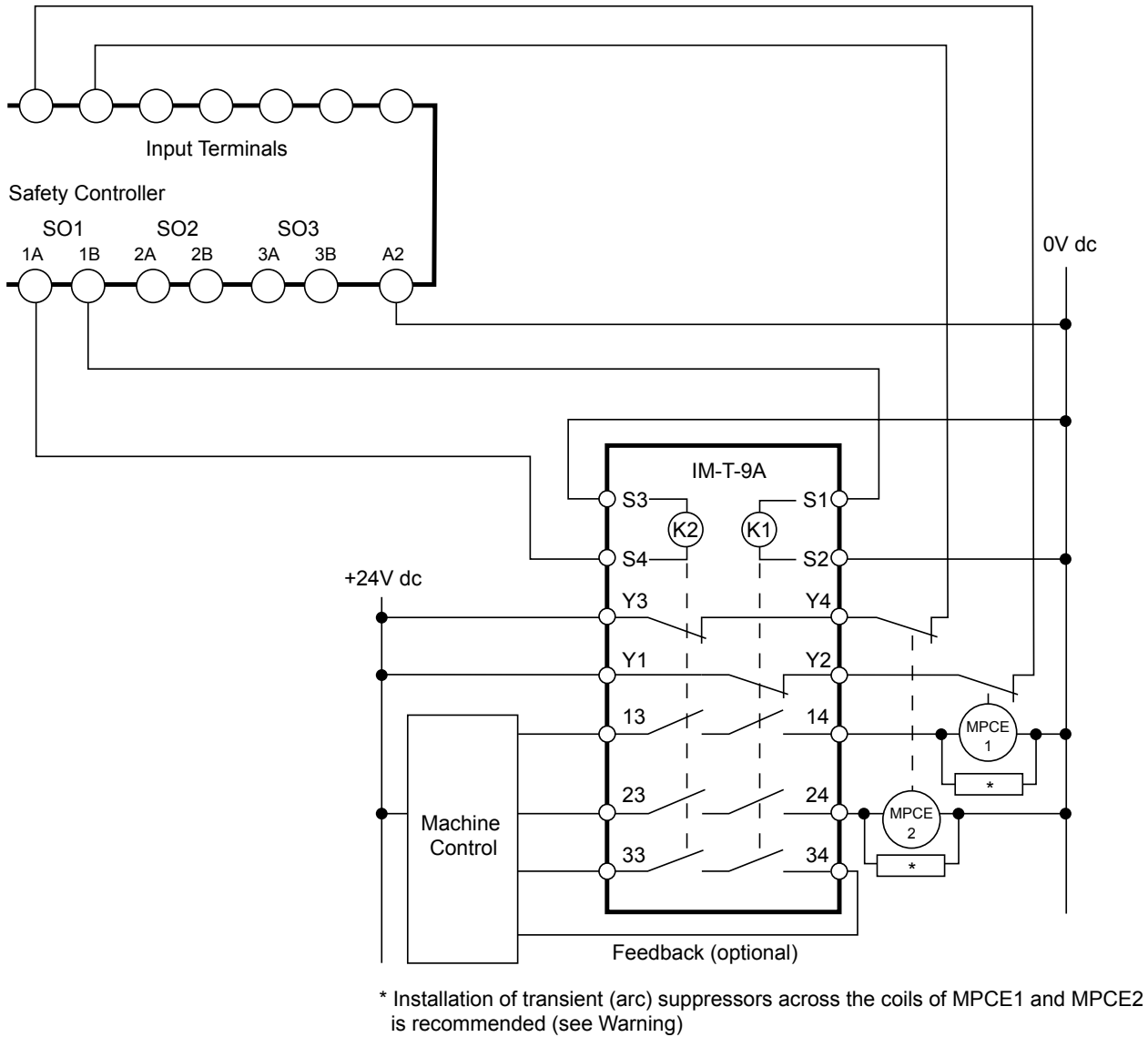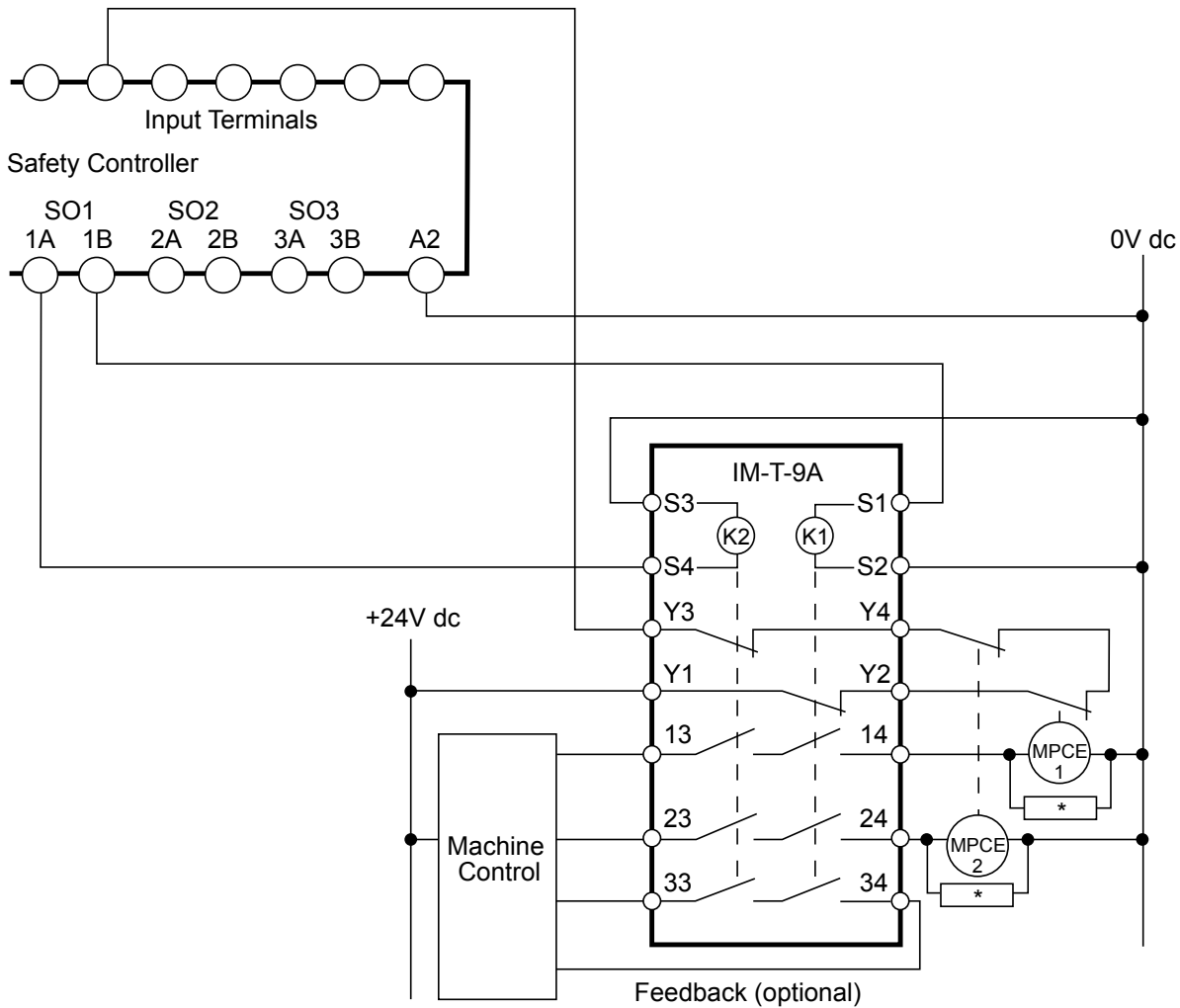Depending on the application, each Safety Output requires a separate and individually wired IM-T-..A module.

* Installation of transient (arc) suppressors across the coils of MPCE1 and MPCE2 is recommended (see Warning)

Figure 31. Hookup: One-channel EDM hookup to IM-T-9A interface module

4.7.4 Common Wire Installation

To avoid nuisance lockout codes 1.1, 1.2, or 1.5, give thoughtful consideration to the leadwire resistance of the 0V common wire and to the currents flowing in that wire. Notice the location of the block in the diagram below representing leadwire resistance (RL).
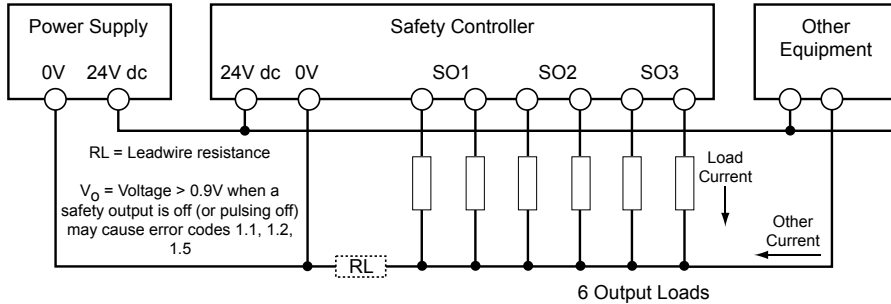
Figure 32. DC-common wire installation

When a safety output turns OFF, the voltage at the output terminal (V_O) must drop below 0.9V with respect to the 0V terminal of the Safety Controller. If the voltage is higher than this, the Controller may think that the output is still on and lock out.

This residual voltage can occur in several ways:

- a large current flowing in a shared 0V conductor by other safety outputs that are still on,
- a common mode current flowing from other equipment, or
- either of these, along with a 0V wire that is too small, or too long.

The solution is to increase the wire gauge of the 0V common wire and/or consider using the courtesy 0V terminals on the Safety Controller as shown in the following diagram. This eliminates the influence of common mode current from other equipment.
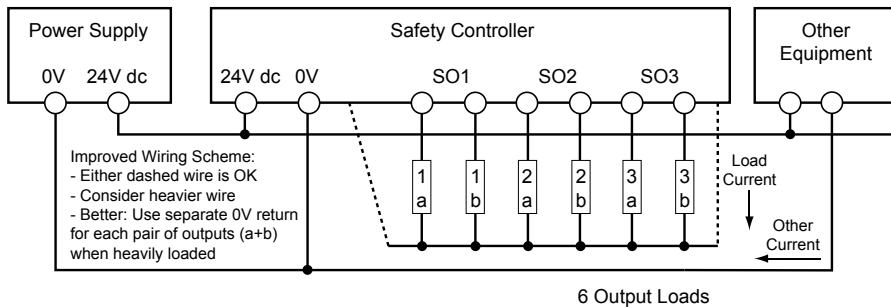
Figure 33. DC-common wire installation: eliminating the influence of common mode current from other equipment

4.8 Status Outputs

4.8.1 Status Output Signal Conventions

Two signal conventions are selectable for each Status Output. The default convention provides a 24V dc signal when the monitored input or output is active (closed, high or ON), when the system is in a Lockout, when there is an I/O-fault, when the system waits for a Reset, when the output waits for a reset or during an active mute cycle. If the above conditions are not true, the signal output would show 0V. Signal convention 2 is the reverse of convention 1, as shown in the following table.

Tracked Function	Mapped Status Output(s) State			
	Signal Convention 1 (default) 24V dc = Run		Signal Convention 2 0V dc = Run	
Track Input	Input Run	Input Stop	Input Run	Input Stop
	24V dc	0V dc	0V dc	24V dc
Track Output	Output ON	Output OFF	Output ON	Output OFF
	24V dc	0V dc	0V dc	24V dc
System Lockout Status	Lockout	Run Mode	Lockout	Run Mode
	24V dc	0V dc	0V dc	24V dc
I/O Fault	Fault	No Fault	Fault	No Fault
	24V dc	0V dc	0V dc	24V dc
System Waiting for Reset	Reset Required	Reset Not Required	Reset Required	Reset Not Required
	24V dc	0V dc	0V dc	24V dc
Mute Status	Muted	No Mute	Muted	No Mute
	24V dc	0V dc	0V dc	24V dc
Track Input Group	Input That Turned OFF First	Other Linked Inputs	Input That Turned OFF First	Other Linked Inputs
	24V dc	0V dc	0V dc	24V dc
Bypass Status	Input Bypassed	Not Bypassed	Input Bypassed	Not Bypassed
	24V dc	0V dc	0V dc	24V dc
Track Input Fault	Fault	No Fault	Fault	No Fault
	24V dc	0V dc	0V dc	24V dc
OK to Cancel OFF-Delay	OK	Not OK	OK	Not OK
	24V dc	0V dc	0V dc	24V dc

4.8.2 Status Output Functionality

Track Input

A Status Output configured for this function will indicate the current state of an input.

Track Output

A Status Output configured for this function will indicate the current physical state of a Safety Output, either ON or OFF.

Track Output's Logical State

When selecting the Status Output function 'Track output,' an option to track the logical state, rather than the physical state, of a Safety Output is provided. This option may be used to indicate a Safety Output has been commanded OFF, but is not OFF yet, such as during an OFF-delay.

System Lockout Status

A Status Output configured for this function will be active when a lockout that affects the entire Safety Controller has been detected, such as an internal memory fault.

I/O Fault Status

A Status Output configured for this function will be active when a lockout affecting a particular input or output has been detected, such as a failed input or an EDM fault.

System Waiting for Reset

A Status Output configured for this function will be active under the following conditions:

- A system fault has occurred and all Safety Outputs are OFF.
- An EDM fault has occurred.
- An AVM fault has occurred.
- A fault on a Safety Output has occurred.
- A fault for monitoring a mute lamp has occurred.
- The Safety Controller is configured for manual reset on power-up.
- A fault on a THC input has occurred.

The following conditions involve the use of the system reset but no indication is provided by a Status Output:

- Exiting Configuration Mode
- Exiting Enable Mode
- Re-enabling a Track Input Group function of a Status Output

Output Waiting for Reset

A Status Output configured for this function will be active when a Safety Output is ready to be turned ON (a manual reset must be performed).

Mute Status

A Status Output configured for this function will be active for a particular mutable Safety Input under the following conditions:

- ON during an active muting cycle.
- OFF during an inactive muting cycle.
- Flashing when all conditions for bypassing a mutable Safety Input (override) are present.
- ON when bypassing a mutable Safety Input.

Track Input Group

Status Outputs configured for this function will indicate which Safety Input of a defined group of Safety Inputs turned OFF first. Use a system reset to re-enable the function after all Safety Inputs of the group are ON.

Bypass Status

Status Outputs configured for this function will indicate when an input is truly bypassed. A Safety Input is required to be determined inactive at least once before a bypass can take place. The Status Output is active when the input is bypassed. A bypass cannot take place (the input must be open) on power-up.

Track Input Fault

Status Outputs configured for this function will indicate any fault on an input.

OK to Cancel OFF-Delay

Status Outputs configured for this function will indicate when an OFF-delay can be cancelled — that is, when the cancel delay input can be activated in order to keep the OFF-delayed Safety Output ON, or to immediately turn the Safety Output OFF.

4.9 Virtual Status Outputs

Using the PCI, the Safety Controller (model **SC22-3E** only) can configure up to 32 Virtual Status Outputs. These outputs can communicate the same information as the Status Outputs (see section *4.8.1 Status Output Signal Conventions* on page 50), but over a network. The Virtual Status Outputs appear and can be configured after the Enable Network Interface box is checked on the Network Settings menu in section *11 Ethernet Reference* on page 124.

One feature of the Virtual Status Outputs Properties window is the **Auto Configure** function. This function automatically configures the Virtual Status Outputs to a set of commonly used functions, based on the current configuration. This function is best used after the configuration has been determined. After Auto Configure has been used, Virtual Status Output configuration can be manually revised.

The information available over the network is consistent with the logical state of the inputs and outputs within 100 ms for the Virtual Status Output tables (viewable on the PCI) and within 1 second for the other tables (found on the included CD). The logical state of inputs and outputs is determined after all internal debounce and testing is complete. The PC Interface network functions are covered in more detail in the Ethernet Reference.

4.10 Commissioning Checkout

After power is connected to the Controller, the EDM has been properly configured, and the Safety Outputs have been connected to the machine to be guarded, the operation of the Controller with the guarded machine must be verified before the combined system may be put into service. To do this, a Qualified Person (see *Glossary*) must perform the commissioning checkout procedure; see section *8.2 Commissioning Checkout Procedure* on page 75.

5 PC Interface Configuration (PCI)

5.1 PC Interface (PCI) Overview

The PC Interface (PCI) is a computer program with real-time display and diagnostic tools that can be used to:

- Create, confirm, edit, store, send, and receive a configuration
- Display real-time Run mode information
- Record and display fault log data
- Record specific, user-defined information onto a "Notes" page.

The PCI program uses Input Device icons and circuit symbols to aid making appropriate device property selections. As the various device properties and I/O control relationships are established, the program automatically builds the corresponding wiring and ladder logic diagrams. These diagrams provide I/O device wiring detail for the installer and a symbolic representation of the Controller's safeguarding logic for the use of the machine designer or controls engineer. See the Safety Controller PCI tutorial for further instruction.

5.1.1 Configuration Tools

The PC Interface screen has a tool bar above the work area for creating and managing configuration files. Use the Live Display button to display real time Run mode data from a working Controller over a USB connection. The screen below shows the status after the Enable Network Interface button has been checked, enabling the Virtual Status Outputs and additional tabs above the documents section.
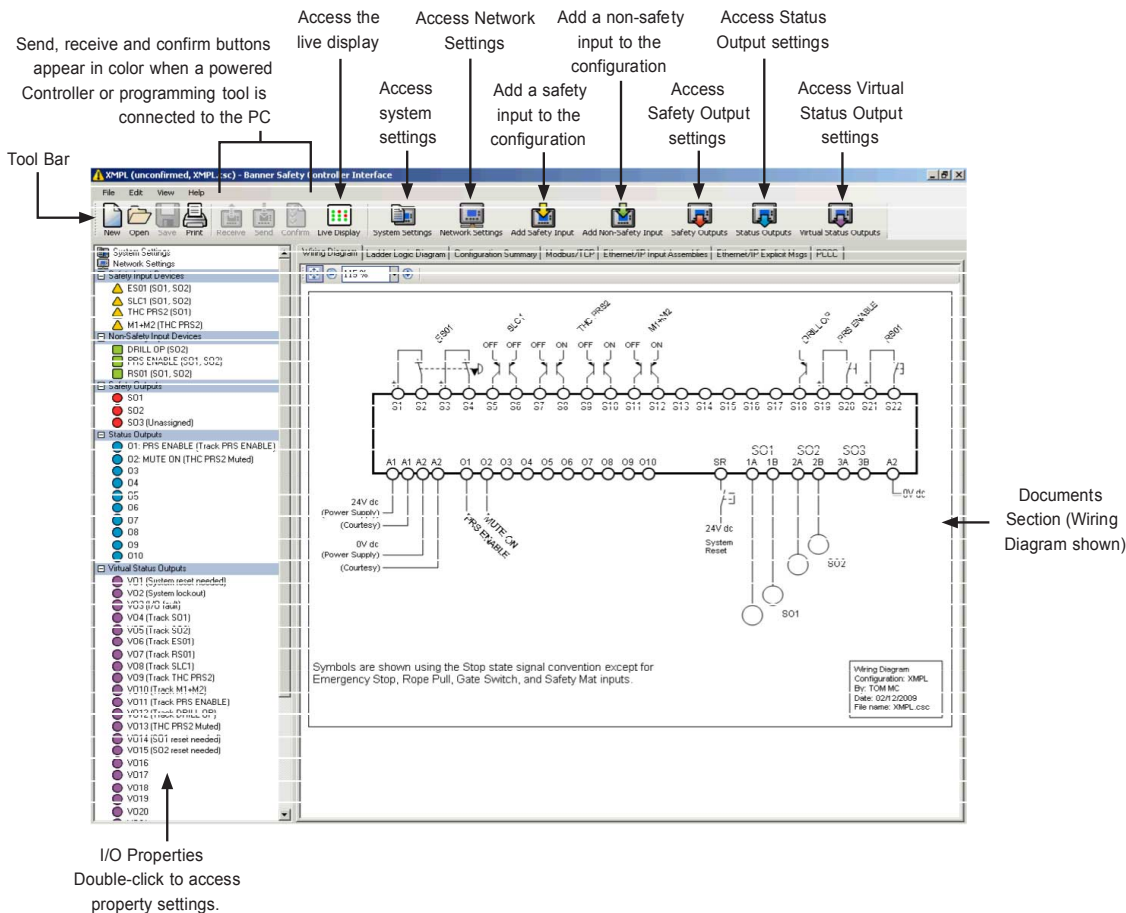

Figure 34. PCI Main screen components

5.1.2 Build a Configuration

To install the software on your computer, double-click on the Banner Safety Controller icon ⚠. Read and understand the warning on the Start-up page, and click **OK**. The main PCI screen should appear. The support documents, if opened at this point, show basic information, and auto-populate as the configuration develops; see following figure. Not shown is the Notes document, which remains blank until information is entered by the user, as desired.
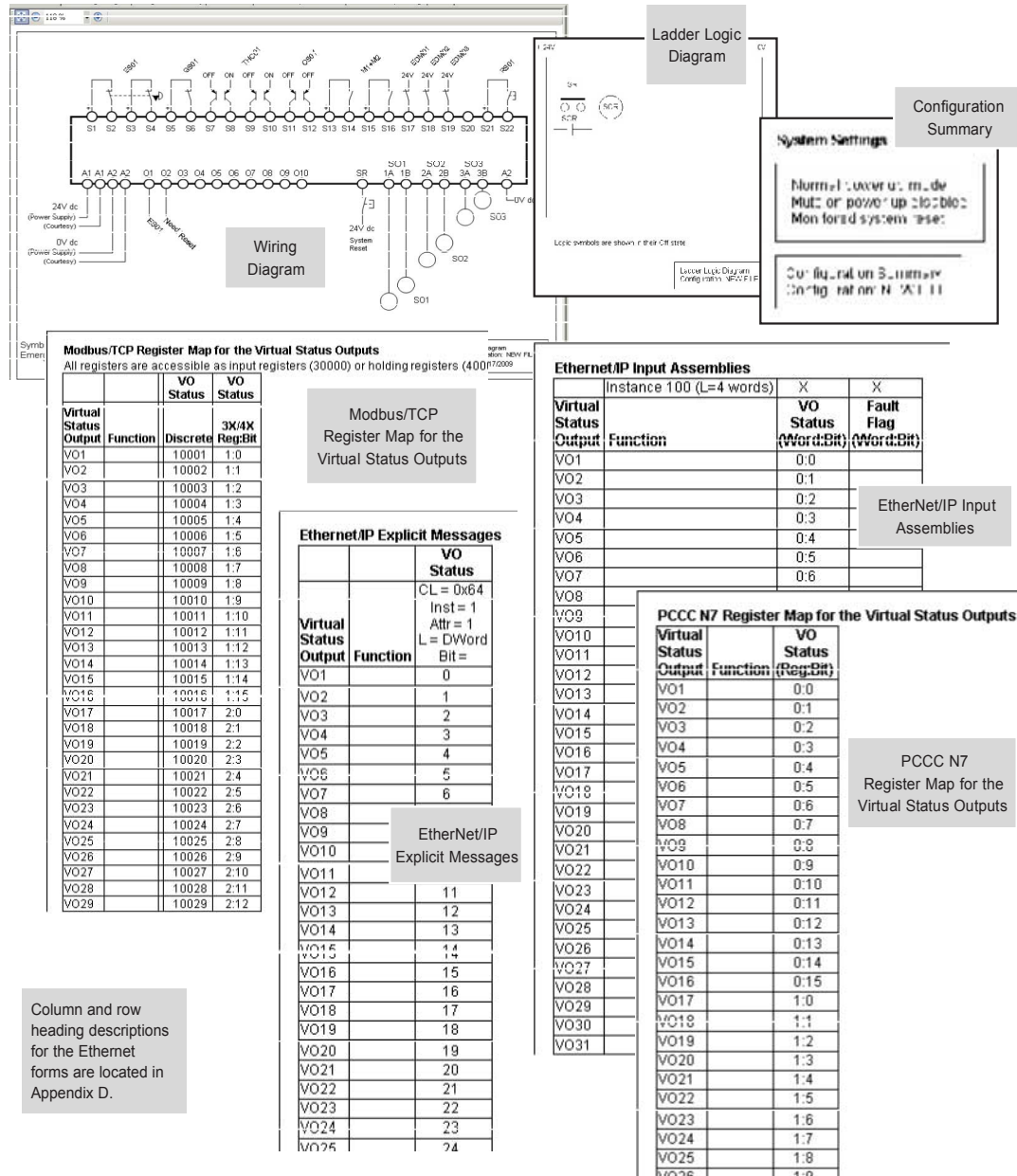
Ladder Logic Diagram

Configuration Summary

Wiring Diagram

Modbus/TCP Register Map for the Virtual Status Outputs
All registers are accessible as input registers (30000) or holding registers (400...

Virtual Status Output	Function	Discrete	3X/4X Reg:Bit
VO1		10001	1:0
VO2		10002	1:1
VO3		10003	1:2
VO4		10004	1:3
VO5		10005	1:4
VO6		10006	1:5
VO7		10007	1:6
VO8		10008	1:7
VO9		10009	1:8
VO10		10010	1:9
VO11		10011	1:10
VO12		10012	1:11
VO13		10013	1:12
VO14		10014	1:13
VO15		10015	1:14
VO16		10016	1:15
VO17		10017	2:0
VO18		10018	2:1
VO19		10019	2:2
VO20		10020	2:3
VO21		10021	2:4
VO22		10022	2:5
VO23		10023	2:6
VO24		10024	2:7
VO25		10025	2:8
VO26		10026	2:9
VO27		10027	2:10
VO28		10028	2:11
VO29		10029	2:12

Modbus/TCP Register Map for the Virtual Status Outputs

Ethernet/IP Explicit Messages

Virtual Status Output	Function	VO Status CL = 0x64 Inst = 1 Attr = 1 L = DWord Bit =
VO1		0
VO2		1
VO3		2
VO4		3
VO5		4
VO6		5
VO7		6
VO8		
VO9		
VO10		
VO11		
VO12		11
VO13		12
VO14		13
VO15		14
VO16		15
VO17		16
VO18		17
VO19		18
VO20		19
VO21		20
VO22		21
VO23		22
VO24		23
VO25		24

EtherNet/IP Explicit Messages

Ethernet/IP Input Assemblies

	Instance 100 (L=4 words)	X	X
Virtual Status Output	Function	VO Status (Word:Bit)	Fault Flag (Word:Bit)
VO1		0:0	
VO2		0:1	
VO3		0:2	
VO4		0:3	
VO5		0:4	
VO6		0:5	
VO7		0:6	
VO8			
VO9			
VO10			
VO11			
VO12			
VO13			
VO14			
VO15			
VO16			
VO17			
VO18			
VO19			
VO20			
VO21			
VO22			
VO23			
VO24			
VO25			
VO26			
VO27			
VO28			
VO29			
VO30			
VO31			

EtherNet/IP Input Assemblies

PCCC N7 Register Map for the Virtual Status Outputs

Virtual Status Output	Function	VO Status (Reg:Bit)
VO1		0:0
VO2		0:1
VO3		0:2
VO4		0:3
VO5		0:4
VO6		0:5
VO7		0:6
VO8		0:7
VO9		0:8
VO10		0:9
VO11		0:10
VO12		0:11
VO13		0:12
VO14		0:13
VO15		0:14
VO16		0:15
VO17		1:0
VO18		1:1
VO19		1:2
VO20		1:3
VO21		1:4
VO22		1:5
VO23		1:6
VO24		1:7
VO25		1:8
VO26		1:9

PCCC N7 Register Map for the Virtual Status Outputs

Column and row heading descriptions for the Ethernet forms are located in Appendix D.

Figure 35. Configuration support documentation (notes not shown)

Create a New Configuration

Open the software program, and a new un-named file is created. You may name the Configuration and the Author, and establish the system settings at this time.

Double-click the **System Settings** icon ![icon], on the right-hand side of the Tool Bar.

When the pop-up menu appears, name the configuration file, using up to 16 alphanumeric characters.

Add your name in the **Author's name** box (up to 10 characters; abbreviate as needed).

Keep or change the default system settings:

- Power up mode: Auto, Manual, or Normal (default), see section *2.7 System Settings* on page 18
- Mute on power up: ON or OFF (default), see section *2.7 System Settings* on page 18
- Monitored system reset: OFF or ON (default), see section *4.4 Non-Safety Input Devices* on page 31

When complete, click **OK**.

Add an Input Device

Refer to section *10 Input Device and Safety Category Reference* on page 90 for more information about each of the input device types. Click the **Add Safety Input** icon and the Safety Input Device selection menu appears. It displays the device types the Controller can accommodate.

Safety Input Devices

- Emergency stop button
- Rope pull
- Gate (interlock) switch
- Optical sensor (single-/multiple-beam sensors, safety light curtain, area scanner, etc.)
- Two-hand control device
- Safety mat
- Protective stop (miscellaneous devices)
- Enabling device
- Muting sensors
- Bypass switches
- External device monitoring (EDM or AVM) contacts

Figure 36. Safety Input Device Selection menu

Click the **Non-Safety Input** icon and the Non-Safety Input Device selection menu appears.

Non-Safety Input Devices

- Manual reset switch
- ON/OFF switch
- Mute enable switch
- Cancel OFF-delay switch

While their functions differ, the procedure to add and configure the two types of devices is virtually identical. Click on the appropriate icon to select the desired device and click **OK** (or double-click on the icon).
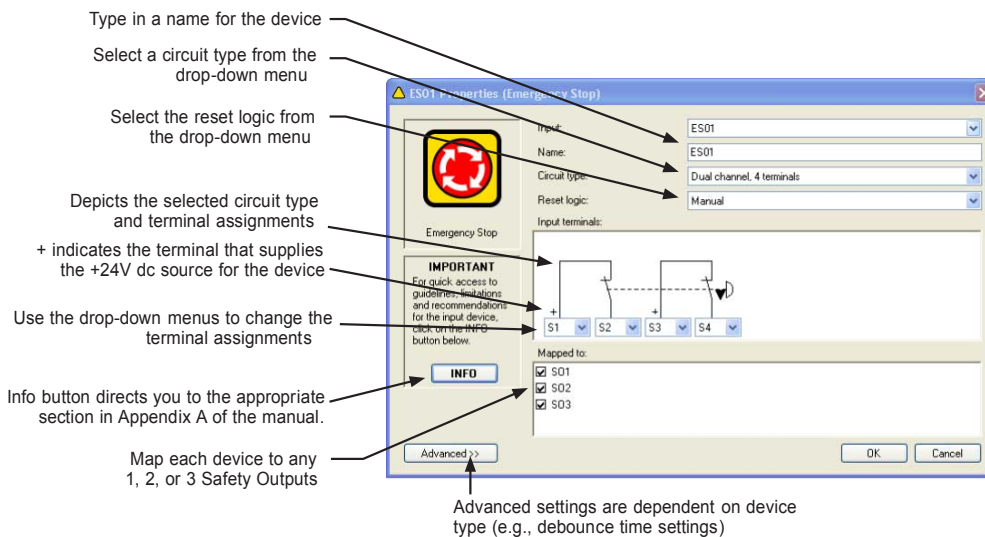

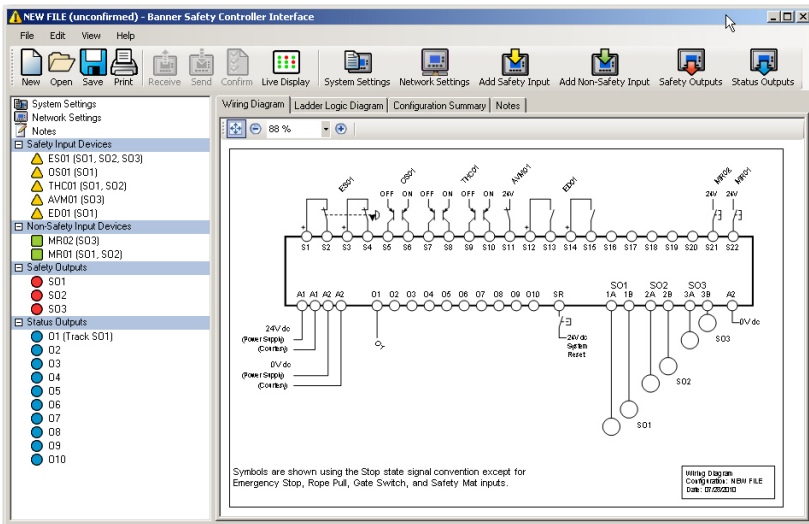**Figure 37. Non-Safety Input Device Selection menu**

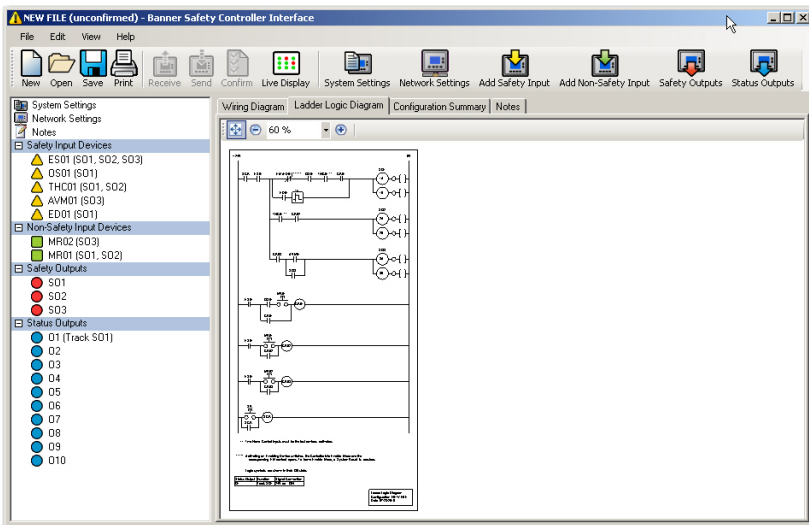**Figure 39. Wiring diagram populates with devices and output mapping**

Figure 40. Ladder logic diagram develops along with wiring diagram

Finish the Configuration

Repeat the steps in the previous section to include additional safety or non-safety input devices.

Select **Safety Outputs** or **Status Outputs** from the tool bar to configure properties for these outputs, using the same menu-driven process as that for the inputs.

Safety Output Properties — assigned individually for each Safety Output. Select the output to be configured from the drop-down menu in the top field of the screen, and type in or select:

  • Name
  • Delay type and duration

Status Output Properties — assigned individually for each Status Output. Select the output to be configured from the drop-down menu in the top field of the screen, and type in or select:

  • Name
  • Function
  • Source (depending on function selected)
  • Signal convention (depending on function selected)

Save and Confirm the Configuration

You will need to confirm this new configuration before it can be used in a safeguarding application. A 4-digit Controller password is required to save and confirm a configuration and to enable it to run on a Safety Controller. The confirmation process has two parts:

1. **Code validation:** The microcontrollers in the Safety Controller receive and check a copy of the configuration to be sure that all safety-critical settings are appropriate (all device settings, control relationships, logic functions and other parameters are valid).
2. Configuration verification: When the validation step is complete, the Controller saves the configuration to the internal non-volatile memory, reads it back from memory, and sends a copy of the stored file back to the PCI for a manual content verification that the user performs.

To confirm a configuration:

1. Save the configuration file to the PC:
   a. Go to **File > Save**
   b. Name the configuration file and select a file location on your computer.
   c. Click **Save**
2. Connect the Safety Controller to the PC using the USB cable (see section *2.4.2 USB Connections* on page 11).
3. Apply 24V dc power to the Controller. When the powered Controller is properly connected with the computer, the Receive, Send

   and Confirm buttons in the screen's tool bar become active and convert from gray scale to color.

4. Click the **Confirm** button in the tool bar. A message asking if you want to save a copy of the Controller's existing configuration will appear. The Controller used for the confirmation process may already have a user-defined configuration. Any configuration already loaded in the Controller will be overwritten during the confirmation process. **It is the user's responsibility to save the existing configuration, if needed**.

   • Select **Yes** to save the configuration and to proceed to overwrite the Controller's existing configuration.
   • Configure EDM, if desired.
   • Enter the password (the factory default is **0000**) on the Confirm Configuration pop-up menu.
   • Click **OK**.
   • A pop-up warning message will ask if you want to continue; select **Yes**.

   The configuration validation process takes a few seconds and when complete, the Verification screen appears.
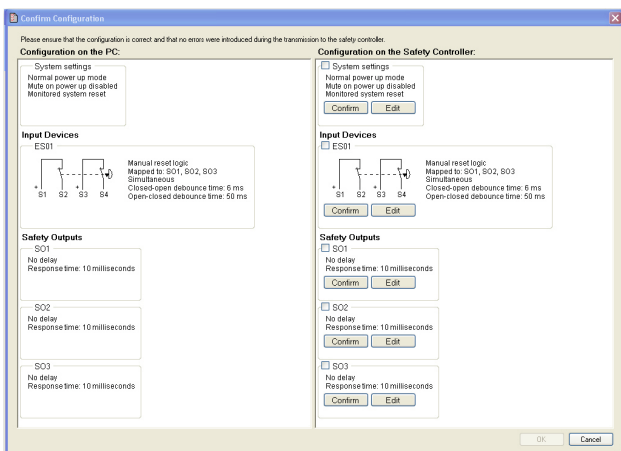

Figure 41. Verification screen, no devices yet confirmed by user

5. **If the columns match, and no changes need to be made:**
   • Verify that the properties in the right-hand column match those in the left-hand column. For each device, as you determine that its properties are correct, either click on **Confirm** or click in the corresponding checkbox. A check mark will appear in the box, and the section will compress to a list, as shown below.
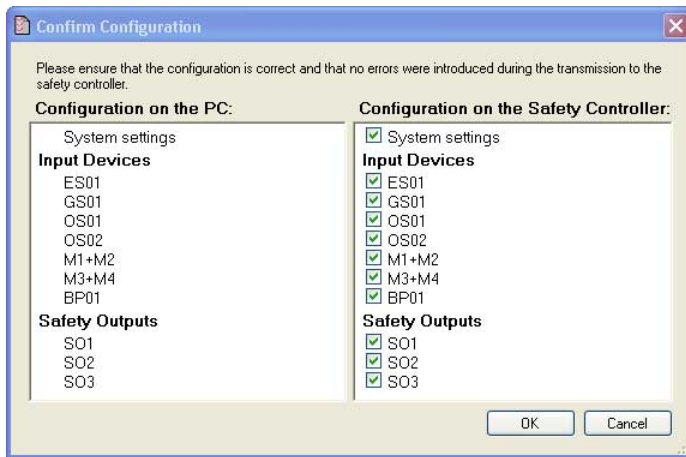
Figure 42. Confirm Configuration screen, all devices confirmed by user (checklist is compressed)

If the columns do not match, or if you wish to change any circuit:

- Select **Edit** for the device to be changed.
- The Properties menu for the device will open.
- Make the necessary change(s).
- Select **OK**.

A message will appear asking whether you want to edit any other devices or if you want to restart the confirmation process.**If any device properties are changed while in the manual verification stage of the confirmation, the Controller will proceed to re-validate the code.**

If the columns match, and no changes need to be made:

- Select **Confirm** for each device.
- The verification screen shows the summary that is created after each property has been verified.
- If you need to review a confirmed device property, un-check the checkbox and the Device Properties window will reappear. Edits may then be performed, as necessary.

6. When you are through with the manual verification, click **OK**.
7. When the verification process is complete, the Confirm Configuration summary screen is displayed. Select **Close** and perform a system reset; see section *5.1.2.5 System Reset* on page 59.
8. The Controller will activate the new configuration and will function according to the new parameters.

System Reset

The Controller requires a system reset under certain conditions:

- To place the Controller into Run mode after it has been configured.
- To recover from certain conditions (e.g., lockouts).

To perform a system reset, either provide a 24V dc signal on the System Reset input (located next to the Status Output O10 terminal), or cycle power.

When the configuration is successfully confirmed, the Controller will switch to Run mode.

5.1.3 Revise an Existing Configuration

When the software program opens, go to **File > Open** or click the icon to browse for the configuration to be changed. Make changes as described in section *5.1.2 Build a Configuration* on page 54.

5.1.4 Other Functions

Receive a Configuration from the Safety Controller

To receive a configuration from a Controller and display it in the PCI:

- Connect the Safety Controller to the PC using the USB cable.
- Apply 24V dc power to the Controller.
-
  Click on the **Receive** button in the tool bar.
- If the configuration is not already confirmed, you may choose to confirm it at this time.

Send a Configuration to the Safety Controller

To send a configuration from the PCI to a Controller:

- Connect the Safety Controller to the PC, using the USB cable.
- Apply 24V dc power to the Controller.
-
  Click on the **Send** button in the tool bar.

Open a Configuration from the XM Card

Both confirmed and unconfirmed configurations can be sent to or received from the XM card. To open a copy of a configuration from the XM card and display it in the PCI:

- Connect the SC-XMP programming tool to the PC using the USB cable.
- Insert the XM card into the programming tool.
- Go to **File > Open From XM Card** in the upper-left corner of the screen.

A message will appear when the operation is complete.

Send a Configuration to the XM Card

Both confirmed and unconfirmed configurations can be sent to or received from the XM card. To send a copy of a configuration from the PCI to the XM card (via the programming tool):

- Connect the SC-XMP programming tool to the PC using the USB cable.
- Insert the XM card into the programming tool.
-
  Select the **Open Folder** button in the tool bar and open the intended configuration file.
- Go to **File > Send To XM Card** in the upper-left corner of the screen.

A message will appear when the operation is complete.

Lock the XM Card

It is important to note that this operation cannot be undone. Once the card is locked, another configuration can never be stored on it. This operation is useful when the XM card and its configuration will be transported to another Controller, or for storing and archiving a configuration. To lock the XM card so that the stored configuration cannot be changed:

- Insert the XM card into the SC-XMP programming tool.
- Verify that the correct file is stored on the XM card.
- Go to **File > Lock XM Card** in the upper left of the tool bar.

A message will appear when the operation is complete.

Changing the Password Using the Personal Computer Interface (PCI)

For this procedure, the PC must be connected to the Controller via USB cable, and the Controller must be ON.

1. Go to **File > Change Safety Controller Password**. The Change Password screen will appear.
2. Fill in the boxes for Safety Controller password, new password, and new password again. Click **OK**.
3. The Entering Configuration Mode screen will appear, saying, "Are you sure you want to do this? All Safety Outputs will be turned off." (If you click **Yes**, all Safety Outputs will turn OFF, along with the machine or system the Safety Controller is monitoring.)
4. Click **Yes**. The Change Password screen will reappear.
5. Click **Close**. The password is now changed. Record the password for safekeeping.

Figure 43. Change Password screen

NOTE: If the password becomes lost, contact Banner Engineering for assistance.

Export Documents

Configuration notes can be exported in different formats. To export a configuration document:

1. Open the configuration file that you want to save.
2. Go to **File > Export** in the upper left of the tool bar.
3. Select the configuration document you want to export.
4. Verify that the File name is correct and pick the **Save as type** file option you need.
5. Select **Save**.
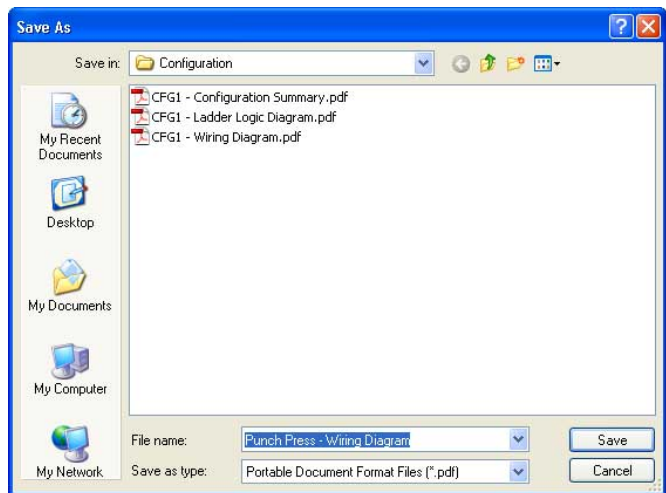
Figure 44. Save As screen

Print Options

To print a configuration file:

1. Open the configuration file that you want to print.
2. Go to **File > Print** in the upper left of the tool bar.
3. Select the configuration document you want to print.
4. A Page Setup menu will appear. Make the page and printer choices and click **OK**. (Hint: Wiring diagrams typically fit the page better when "landscape" is selected; the other documents fit better on "portrait.")

6 Onboard Interface Configuration (OBI)

6.1 Onboard Interface (OBI) Overview

The Safety Controller's onboard interface (OBI) consists of a display and six push buttons that are used to:
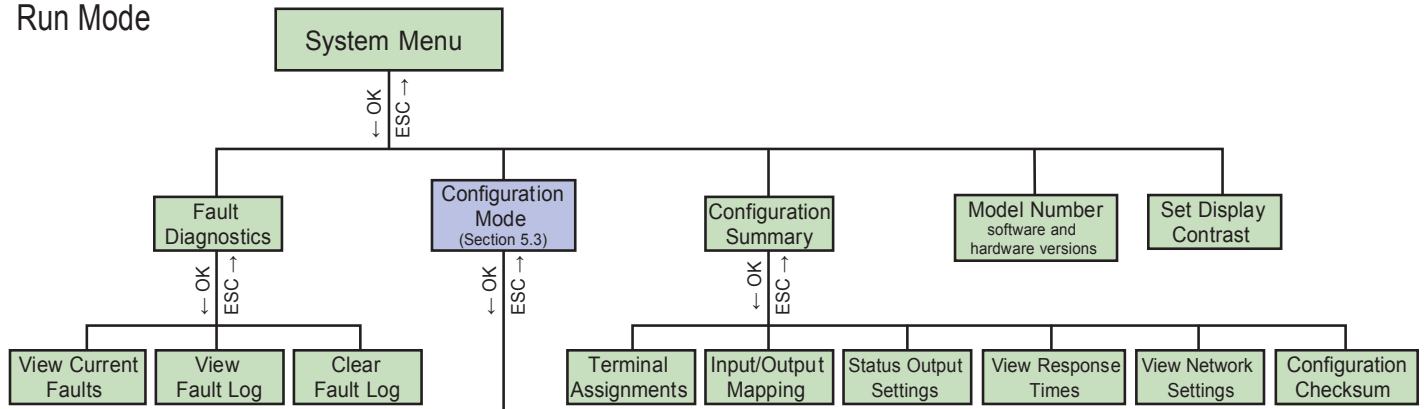
- Select a language
- Create, confirm, edit, erase, send, and receive a configuration
- Display real-time Run mode information
- Display current fault data, fault log data, and to clear the fault log
- Display the model number of the Safety Controller
- Set a password

The configuration is used to define the input devices that will be connected to the Safety Controller and to establish relationships between input devices, and between the input devices and the outputs.

This section provides a "map" and description of Run mode and Configuration mode options, using the OBI. See the following figure for an overview of all the Run mode and Configuration mode options available. For an example of a beginning-to-end configuration process using the OBI, refer to the OBI tutorial in the SC22-3/-3E Configuration Tutorial, to be found at *www.bannerengineering.com*.

To move through the menus, in most cases, press the **OK** push button to make a selection or move further into the menu tree; press the **ESC** push button to move up a step. When a vertical list of options appears on the screen, use the **up/down arrow** push buttons to highlight an option to select. Press **OK** to select the highlighted option. When a single option appears on the screen (for example, an input device) with an arrow running across the top of the screen, use the **left/right arrow** push buttons to step through the selections; press **OK** to select the option showing on the screen.

62   www.bannerengineering.com - tel: 763-544-3164   P/N 133487 rev. C

Run Mode

```
                              ┌─────────────────┐
                              │  System Menu    │
                              └─────────────────┘
                                    OK ↓  ESC ↑↑
```

- **Fault Diagnostics**
  - OK ↓ ESC ↑
    - View Current Faults
    - View Fault Log
    - Clear Fault Log
- **Configuration Mode** (Section 5.3)
  - OK ↓ ESC ↑
- **Configuration Summary**
  - OK ↓ ESC ↑
    - Terminal Assignments
    - Input/Output Mapping
    - Status Output Settings
    - View Response Times
    - View Network Settings
    - Configuration Checksum
- **Model Number** software and hardware versions
- **Set Display Contrast**

Enter Password (Section 5.3.1)

Configuration Mode

- **Configuration File** (Section 5.3.2)
  - OK ↓ ESC ↑
    - Edit Configuration (Section 5.4)
    - Erase Configuration
    - Send File to XM
    - Receive File from XM
- **Confirm Configuration** (Section 5.3.3)
  - OK ↓ ESC ↑
    - Confirm Inputs
    - Confirm Safety Outputs
    - Confirm System Settings
- **System Options** (Section 5.3.4)
  - OK ↓ ESC ↑
    - Edit Password
    - Set Language
- **Exit Configuration** (Section 5.3.4)

Edit Configuration (Section 5.4)
  - OK ↓ ESC ↑

Name Configuration (Section 5.4.1)

- **Inputs** (Section 5.4.2)
  - OK ↓ ESC ↑
    - Add Input (Section 5.5)
    - Delete Input
    - Edit Input
- **Outputs/System Settings** (Section 5.4.3)
  - OK ↓ ESC ↑
    - Status Outputs
    - Safety Outputs
    - System Settings
- **Configuration Summary** (Section 5.4.4)
  - OK ↓ ESC ↑
    - Terminal Assignments
    - Input/Output Mapping
    - Status Output Settings
    - View Response Times
- **Save Configuration** (Section 5.4.5)

Add Input (Section 5.5)
  - OK ↓ ESC ↑

- **Safety Input** (Section 5.5.1)
  - OK ↓ ESC ↑
    - E-Stop
    - Gate Switch
    - Optical Sensor
    - Two-Hand Control
    - Safety Mat
    - Protective Stop
    - EDM
    - Rope Pull
    - Enabling Device
    - Mute Sensor
    - Bypass Switch
    - AVM
- **Non-Safety Input** (Section 5.5.2)
  - OK ↓ ESC ↑
    - Reset
    - ON/OFF
    - Mute Enable
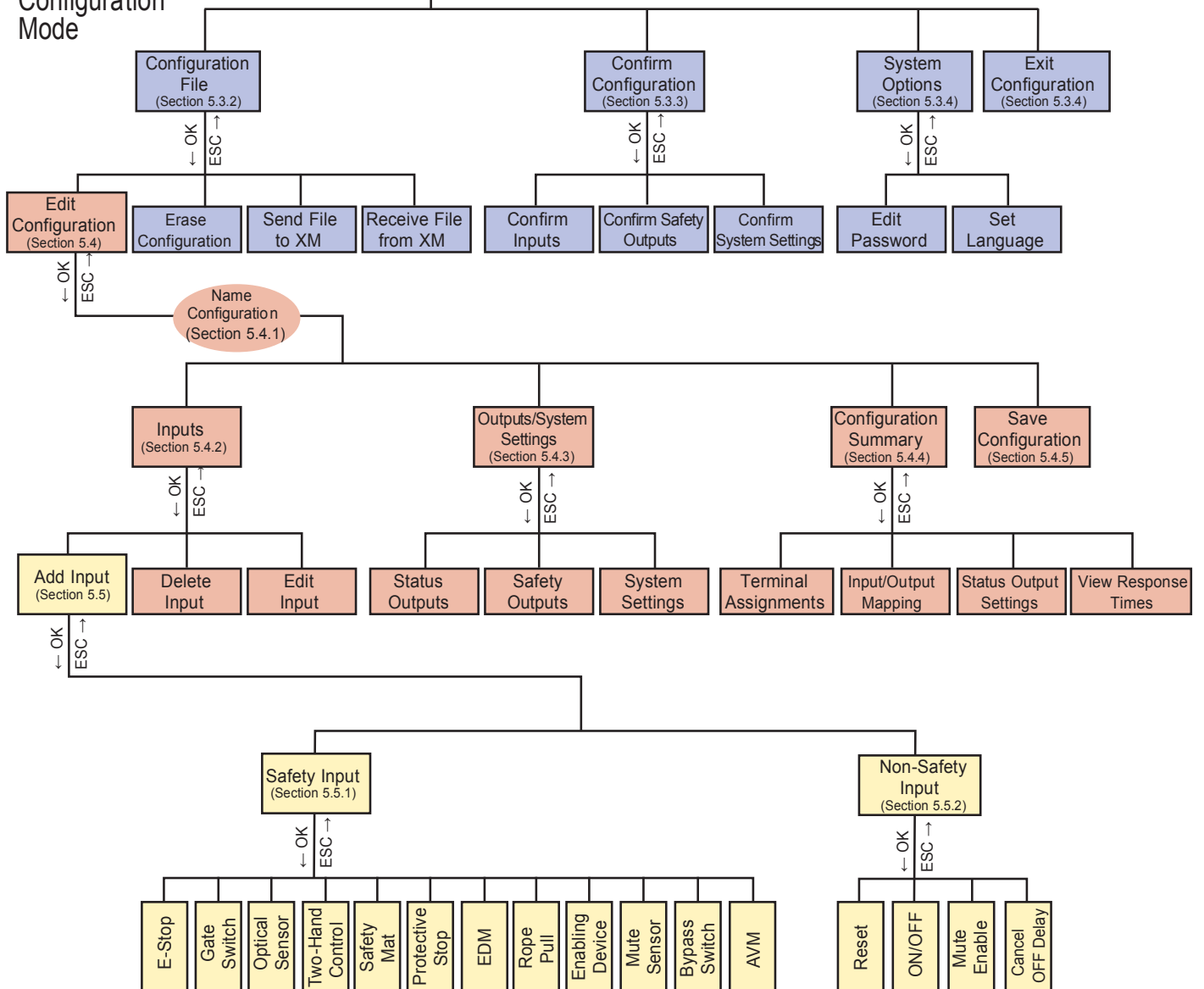   - Cancel OFF Delay

Figure 45. OBI Configuration mode options

6.2 Run Mode

From Run mode, press **OK** to view the System menu. This menu provides the ability to read fault diagnostic information, enter Configuration mode to create or edit a configuration, read the configuration summary, read the Safety Controller Model number, and adjust the contrast of the display itself.

Use the **up/down arrows** to highlight your selection, then press **OK** to select.

Fault Diagnostics—Use this screen to view current faults, view the fault log, or clear the fault log. Refer to section *9.3 Troubleshooting— Finding and Fixing Faults* on page 82 for more information.

Configuration Mode—Use this selection to enter Configuration mode and create or edit a configuration; refer to section *6.3 Configuration Mode* on page 64 for more information.

Configuration Summary—This selection provides read-only screens to review:

- Input device terminal assignments for each device in the current configuration,
- The mapping relationships between input devices, and between input devices and Safety Outputs,
- The current settings of the Status Outputs (to change the settings, see section *6.4.1 Name Configuration* on page 66),
- Safety Output response times (used to calculate safety distance) for each input mapped to the output,
- The current network settings configured for network communication, and
- The configuration checksum: a unique identifier for any configuration that is programmed into a Safety Controller. It becomes available after a configuration is confirmed and is provided for the user to track configuration revisions.

Use the **up/down arrows** to highlight your selection, then press **OK** to select.

Model Number—Select this screen to see the Controller model number, and software and hardware versions. This can be useful when an Applications help call is needed.

Set Display Contrast—Select this screen to adjust the brightness of the Controller display screen background and images for ambient conditions. Use the **left/right arrows** to adjust contrast level (left for lighter, right for more saturated); when contrast is correct, press **OK**.

6.3 Configuration Mode

The first step in creating a configuration using the OBI is entering Configuration mode. To enter Configuration mode from the main Run mode screen, press the **OK** button to display the System menu. At the System menu, press the **down arrow** push button until *Configuration Mode* is highlighted. Then press **OK**.

6.3.1 Enter Controller Password

Before any configuration can take place, the password must be entered. The default password is 0000. For instructions on changing the password, refer to section *6.3.4 System Options* on page 66.

- Use the **left/right arrows** to select the password digit position.
- Use the **up/down arrows** to select the digit (value) for each position (choices 0-9).
- When the password is entered, press **OK** to enter Configuration mode.
- Read the caution that the Safety Outputs will turn OFF when Configuration mode is entered and press **OK**.

```
Enter Password:
    0000

Then Press "OK"
```

6.3.2 Configuration File

Edit Configuration—To edit the configuration from the Configuration Mode menu, select Configuration File and press **OK**. See section *6.4.1 Name Configuration* on page 66 for more instructions. To begin editing the configuration, select **Edit Configuration** from the Configuration File menu and press **OK**.

Erase Configuration—This selection is used to remove the current configuration from the Controller, so a new configuration can be created (the Controller can hold only one configuration at a time). To keep the current file, send it to the XM card before erasing it from the Controller.

To perform an Erase, use the **up/down arrows** to select the option from the menu and press **OK**. When prompted whether you want to do this, highlight **Yes** and press **OK**.

Send File to XM—This selection is used to send a configuration file to the XM card plugged into the Controller's XM port. The file can then be stored and/or transported to another Controller. Insert the XM card into the Controller's XM port, highlight the selection and press **OK**.

Receive File from XM—This selection is used to receive a configuration from the XM card. Highlight the selection and press **OK**. The Controller will ask if you want to overwrite the current configuration (if not, send the existing configuration to an empty XM card first). Answer Yes, then if one is not already in the port, insert an XM card and press **OK**. If the new configuration is unconfirmed, the Controller provides the option to confirm it at this time.

6.3.3 Confirm Configuration

If any changes are made to a configuration, it must be confirmed again before it can be used in a safeguarding application. Select **Confirm Configuration** and press **OK**.

The Confirm Configuration menu will appear. To confirm, you will review the safety-critical configurations for the inputs, the Safety Outputs, and the system settings. An unchecked box in the Confirm Configuration menu indicates the safety-critical settings have not yet been confirmed.

```
Confirm Configuration
☐ Inputs
☐ Safety Outputs
☐ System Settings
< Done >
```
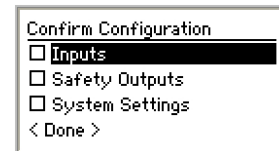
Confirm Configurations of Inputs—Select **Confirm Inputs** and press **OK**. The next menu lists all of the safety inputs in the configuration. Use the **up/down arrows** to select an input and press **OK**.
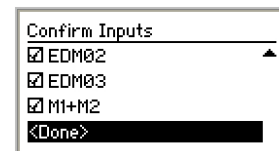
The next series of menus lists the safety-critical configurations for this input, including some or all of the following (depending on the device):

- Circuit type
- Safety Output mapping or input mapping
- Reset logic (manual or automatic)
- Simultaneity (simultaneous or concurrent)
- Startup test
- Mute time limit
- Enabling device time limit
- Bypass time limit
- Debounce times (if not equal to default)
- Directional muting (enabled or disabled)
- Mute-dependent override (enabled or disabled)
- AVM monitoring time limit

Press **OK** after reviewing each setting.

Repeat the confirmation process for each input. When all inputs have been confirmed, each input in the display will have a check mark.

To continue confirming the configuration, select **<Done>** and press **OK**.

```
Confirm Inputs
☑ EDM02                ▲
☑ EDM03
☑ M1+M2
<Done>
```

Confirm Configuration of Safety Outputs—Select **Safety Outputs** and press **OK**. Use the **up/down arrows** to select a Safety Output and press **OK**. The next series of menus displays the safety-critical configurations for the selected Safety Output. Review each setting and press **OK**.

When the Safety Output is confirmed, a checked box should appear in front of it, on the Confirm Outputs screen. Repeat the confirmation process for each Safety Output. When all Safety Outputs have been confirmed, each output in the display will have a check mark.

```
Confirm Outputs
☑ SO1
☑ SO2
☑ SO3
<Done>
```

After each output is confirmed, select **<Done>** and press **OK**.
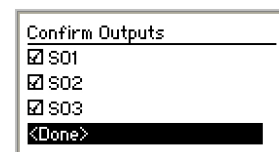
The Confirm Configuration menu reappears, indicating whether the inputs and Safety Outputs are confirmed. If any boxes do not have a check mark, repeat the confirmation of those components.

Confirm System Settings—The last step is to confirm the system settings. Select **System Settings** and press **OK**. The next series of menus lists the safety-critical system settings. Review each setting and press **OK** to confirm.

Final Confirmation Step—After all of the safety-critical configuration settings are confirmed, the configuration can be used in a safeguarding application. If any changes are made to the configuration, the confirmation process must be repeated.

Select **<Done>** and press **OK** to exit the Confirm Configuration menu. Press **ESC** or go to **Exit Configuration** to return to Run mode.

```
Confirm Configuration
☑ Inputs
☑ Safety Outputs
☑ System Settings
< Done >
```
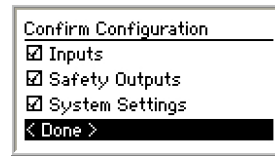
6.3.4 System Options

Edit Password—This is the screen that can change the password to something other than the default. The password may be unique to each Controller. The procedure is similar to that used to enter the default password initially:

1. Use the left/right arrows to select the password digit position.
2. Use the **up/down arrows** to select the digit (value) for each position (choices 0-9).
3. When the password is entered, press **OK** and record the new password in a file for safekeeping and later reference.

Set Language—This screen is used to determine what language will appear on the display. Choices are English, German, Spanish, French, Italian, Portuguese, and Japanese. Highlight the correct language to select it, then press **OK**.

NOTE: Language can also be changed immediately following power-up. A screen appears automatically, and the language selection can be changed at that time. If nothing is changed, the screen times out after 5 seconds and continues to Run mode in the language that was selected before the Controller was last powered down.

6.3.5 Exit Configuration

Use this screen to return to Run mode. Select **Exit Configuration Mode** and press **OK** to exit Configuration mode and return to the System menu.

6.4 Edit Configuration

6.4.1 Name Configuration

The first property of the configuration that can be changed is the name.

1. Use the **left/right arrows** to select the character position. Up to 16 characters are possible.
2. Use the **up/down arrows** to select the character for each position (choices A-Z, 0-9, -, +, or space).
3. When the configuration name is entered, press **OK**.

```
Enter Configuration Name:

C F G 1 _ _ _ _ _ _ _ _ _ _ _ _

Then Press "OK"
```
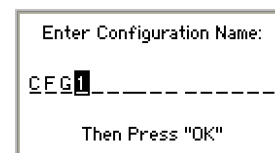
6.4.2 Inputs

Add Input—Select this option to add either a safety or non-safety input device. See section *6.5 Add an Input* on page 68 for the procedure.

Delete Input—This option is used to remove a previously added input device from the configuration. A screen will appear with all of the previously configured inputs; use the **left/right arrows** to select a device and press **OK**. A screen will ask whether you really intend to delete this input; select **Yes** and press **OK**. If you select **No**, the screen will return to select a different input to delete. To return to the Inputs menu, press **ESC**. If you select **Yes**, you are asked whether you want to delete another input.

Edit Input—This option is used to edit a previously configured input device in the configuration. A screen will appear with all of the previously configured inputs; use the **left/right arrows** to select a device and press **OK**. A series of screens will appear, with the device's

properties; select each property (in the same way used to define the input initially; see section *6.5 Add an Input* on page 68), and press **OK**.

The Inputs screen also reappears when **ESC** is pressed after all of the required inputs have been added. Press **ESC** when the Inputs menu reappears, to return to the Edit Configuration menu.

6.4.3 Outputs/System Settings

Safety Outputs

This option is used to configure the Safety Outputs. Use the **up/down arrows** to select **Safety Outputs** and press **OK**. Select the output to configure in the resulting menu and press **OK**. You will be given the opportunity to change the output's name, and give it an ON- or OFF-delay.

Status Outputs

This option is used to configure the Status Outputs. Status Outputs are configured individually. Use the **up/down arrows** to select **Status Outputs** and press **OK**.

1. Use the **left/right arrows** to select the Status Output to configure (O1 to O10), and press **OK**.
2. The Status Output Properties menu appears. This menu is used to configure the Status Output to indicate:

    - The status of an input device
    - The status of a Safety Output
    - A system lockout
    - An I/O fault
    - The need to perform a system reset
    - The need to perform a reset operation on a Safety Output
    - When an input is being muted
    - The logical status (ON or ON-delay) of a Safety Output

Name the Status Output—Use the **up/down arrows** to select **Change Name** and press **OK**.

1. Use the **left/right arrows** to select the character to be changed (up to 10 characters).
2. Use the up/down arrows to change the character (choices A-Z, 0-9, -, +, or space).
3. Press **OK** when done.
4. When the display returns to the Status Output Properties menu, the top line of the display will display the new name.


```
Enter Name:
ES01_____

Then Press "OK"
```
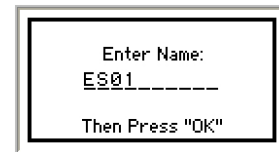
Select the function of the Status Output—Use the **up/down arrows** to select **Select Function** and press **OK**.

1. Use the **left/right arrows** to select a function, then press **OK**.
2. The display returns to the Status Output Properties menu.


```
Select Function:
◄   Track Input   ►
Then Press "OK"
```
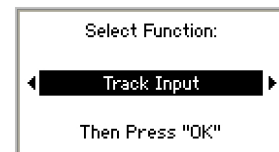
Select the source for the Status Output function—Select **Select Source** and press **OK**.

1. Use the **left/right arrows** to select a device and press **OK**.
2. The display returns to the Status Output Properties menu.


```
Select Source:
ES01   ►
Then Press "OK"
```
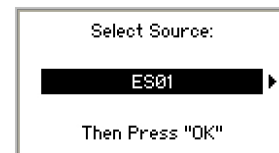
Select the signal convention—The options are:

- **24V = Input Active** and
- **24V = Input Inactive** (e.g., if tracking an input; see section *4.7.1 External Device Monitoring (EDM)* on page 40 for more information).

1. Use the left/right arrows to toggle between the selections and press **OK**.

2. To save the settings for this output, select **<Done>** and press **OK**. The display returns to the Outputs/System Settings menu. To configure additional Status Outputs, select **Status Outputs**, select another Status Output and repeat the steps above. When the last Status Output is configured, press **ESC** to return to the Edit Configuration menu.

System Settings

Select the output's reset mode, power up mode and whether mute will be active on power-up.

System Reset—Use the **left/right arrows** to toggle between **Monitored** or **Non-Monitored**, and press **OK**.

Power Up Option—Use the **left/right arrows** to select among **Normal**, **Auto**, or **Manual**, and press **OK**.

Mute on Power-Up—Use the **left/right arrows** to toggle between **Off** or **On**, and press **OK**.

6.4.4 Configuration Summary

This section is similar to that in section *6.2 Run Mode* on page 64, and is included for convenient reviewing of the current settings while in Configuration mode. It provides read-only screens to review:

- Input device terminal assignments for each device in the current configuration,
- The mapping relationships between input devices, and between input devices and Safety Outputs,
- The current settings of the Status Outputs (to change the settings, see section *6.4.3 Outputs/System Settings* on page 67), and
- Safety Output response times for each input mapped to the output. Response times can be used to calculate safety distance (separation distance).

Use the **up/down arrows** to highlight your selection, then press **OK** to select.

6.5 Add an Input

Input devices are categorized as either safety inputs or non-safety inputs. While the devices differ, the process for adding either is virtually identical. Use the **up/down arrow** buttons to select **Safety** or **Non-Safety** and press **OK**.

6.5.1 Add a Safety Input

Safety input device options include:

- E-stop buttons
- Gate (interlock) switches
- Optical sensors (including safety light curtains, single-/multiple-beam sensors, and area scanners)
- Two-hand control devices
- Safety mats
- Protective stop devices
- External device monitoring (EDM and AVM) contacts
- Rope pulls
- Enabling devices
- Mute sensors
- Bypass switches

See section *10 Input Device and Safety Category Reference* on page 90 for more information about each of the input device types.

6.5.2 Add a Non-Safety Input

Non-safety input device options include:

- Manual reset switches
- ON/OFF switches
- Mute Enable switches

• Cancel OFF-delay switch

Select an Input Device (Either Safety or Non-Safety)—Use the **left/right arrows** to select the proper device, then press **OK**. The arrows at the top of the screen indicate whether more options are available to the left or to the right. After the device is selected, a new screen appears with the appropriate properties to select for that device.

6.5.3 Configure Input Device Properties

For each input device, the following parameters must be configured:

• Name (or use the auto-generated default name)
• Circuit type
• Terminal assignments (or use the auto-generated terminal assignments)
• Reset logic (for some devices)
• Output mapping or input mapping (depending on device)

Enter Input Device Name—The Enter Name menu is displayed. A default name automatically appears, but the device may be renamed (up to 10 characters).

1. Use the **left/right arrows** to select the character position.
2. Use the **up/down arrows** to select the character for each position (choices A-Z, 0-9, -, +, or space).
3. When the screen (as shown below) shows the correct device name, press **OK**.
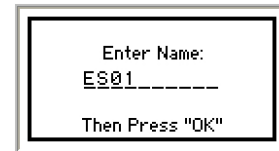
Input Properties Menu—The Input Properties menu is used to:

• Select the input device's circuit type
• Edit the terminal assignments, if needed
• Select the output(s) (or input), the input will control
• Select between automatic and manual reset logic (depending on device)

Select the Circuit Type of the Input—Use the **up/down arrows** to select **Select Circuit Type**, and press **OK**.

See section *10 Input Device and Safety Category Reference* on page 90 for more information about safety circuit integrity levels and the capabilities of each circuit type.

1. The Select Circuit Type menu appears.
2. Use the left/right arrows to select the desired circuit type (a dual-channel, 4-terminal circuit type is shown below) for the input device and press **OK**.
3. After the circuit type is selected, the display returns to the Input Properties menu.
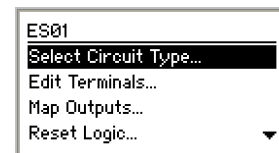
Edit the Terminal Assignments—When the input circuit type is selected, the Safety Controller automatically assigns the next available terminals for the input device. Only unassigned terminals can be assigned. (Exception: Terminals used for a specific input device can be assigned twice during the edit process, if the same terminals will be used, in a different order, for this specific device.) To view and change these terminal assignments, select **Edit Terminals**, and press **OK**.

1. Use the left/right arrow buttons to select the terminal assignment to be changed.
2. Use the up/down arrows to change the terminal assignment.
3. When the terminal assignments are as desired, press **OK**.
4. After the terminal assignments are approved, the display returns to the Input Properties menu.
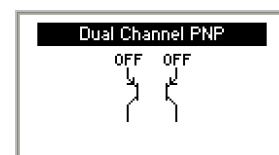
Map Outputs—This option is used to select which of the Safety Output(s) the input controls. Any combination of 1, 2, or all 3 outputs may be selected, but *at least one must be selected.* All safety devices, plus reset and ON/OFF non-safety devices must be mapped to one or more Safety Outputs. Map mute enable devices, mute sensors, and bypass sensors to a safety input device.

1. Select **Map Outputs** in the Input Properties menu, and press **OK**.
2. To map the input to an output, use the **up/down arrows** to select the output, then press **OK**.
3. A filled-in circle on the display indicates the input is mapped to the corresponding output; an empty circle indicates the input is not mapped to that output.
4. To add or remove the input mapping, select the output and press **OK**. When the input is mapped to the Safety Outputs as desired, select **Save** and press **OK**.
5. After the input is mapped to the Safety Outputs, the display returns to the Input Properties menu.
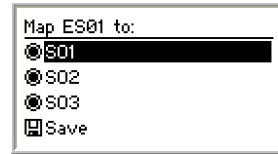
The screen shows device ES01 mapped to all three Safety Outputs.

Select Reset Logic—To select automatic or manual reset logic, select **Reset Logic** and press **OK**.

1. Use the **left/right arrows** to select the desired reset logic parameter and press **OK**.
2. The display returns to the Input Properties menu.

Save the Input Device Parameters—When all of the device's parameters have been set as desired, select **< Done >** and press **OK** to save the parameters.

1. The display indicates the input parameters were saved. Press **OK** to continue.
2. The display returns to the Edit Inputs menu.
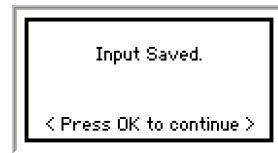
7 Operating Instructions

7.1 Monitoring Controller Operation

The Safety Controller can be operated using either the OBI or the PCI interfaces to monitor ongoing status.

7.2 Display Controller Information — PC Interface (PCI)

To display real-time Run mode information on a PC, the computer must be connected to the Controller, via a USB cable (see Section 1.3 for connection instructions). Open the Banner Safety Controller program and click on the Live Display button in the PCI screen to launch the Live Display screen. This feature continually updates Run mode data and displays it in a pop-up screen.

The Live Display screen provides the same information that can be viewed on the Controller's LCD. It shows the status of each Safety Output and reports on any input device or system event that can cause a Safety Output to turn OFF.

Figure 46. Live Display screen — PCI

7.3 Display Controller Information — Onboard Interface (OBI)

To display current information on the Controller's Onboard Interface screen (OBI), use the Controller's arrow buttons to step through the Run mode menu, as shown below.
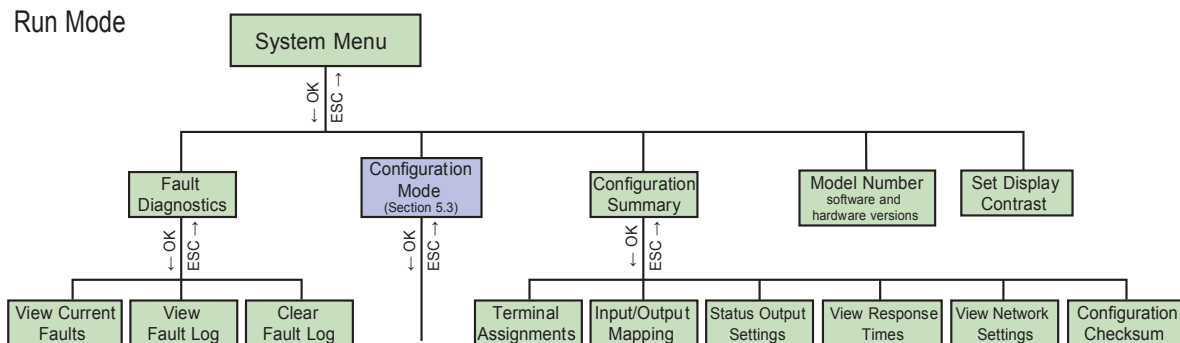
Figure 47. Run mode menu selections — OBI

7.3.1 Run Mode Screen—OBI

The OBI Run mode screen displays current information about the Safety Controller, including:

- The configuration name
- Safety Output status
- Input status
- System status
- XM card status
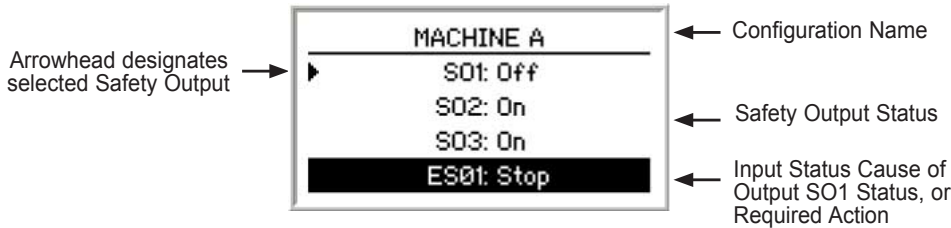
Figure 48. Run mode screen—OBI

Configuration Name: The top line of the display reads either the name of the configuration stored in the Safety Controller, if it has been confirmed, or *Configuration not confirmed*, if it has not.

Safety Output Status: Lines 2, 3, and 4 of the screen display the status of the three Safety Outputs. The selected output will have a small arrowhead to its left, on the screen. (The arrowhead scrolls through the Safety Outputs that are OFF, at 2-second intervals.) Line 5 of the display states the reason for the status of the selected Safety Output.

NOTE: Output faults are recoverable via a system reset (see section *7.5 System Resets and Lockout Conditions* on page 74).

Safety Output Status Message	Cause and/or Required Action
ON	The Safety Output is ON.
ON-Delay	The Safety Output will turn ON when the ON-delay time expires.
OFF	The Safety Output is OFF. Line 5 of the display indicates the reason the Safety Output is OFF.
OFF-Delay	The Safety Output will turn OFF when the OFF-delay expires. Line 5 of the display indicates the reason the Safety Output is in an OFF-delay.
Reset Needed	A manual reset operation needs to be performed. Line 5 of the display indicates the name of the manual reset input to press.
Fault	A problem has been detected with the Safety Output. See section *9.3.1 Troubleshooting Fault Co-deTable* on page 83 to find additional information regarding the fault. If the fault is due to an external device monitor (EDM) fault, line 5 of the display indicates the name of the EDM.
Enable Mode	Line 5 of the display indicates Enable Mode if a Safety Output is in Enable mode.

Input Status: If a Safety Output is OFF or turning OFF, line 5 of the display indicates information about the input that is keeping the output OFF.

Line 5 also indicates when a manual reset operation needs to be performed.

NOTES:

- Line 5 changes to indicate each input when the status of more than one input must be displayed.
- Press the **Up arrow** button to pause the screen on the current input.
- Press the **Down arrow** button to change the last line to the next input. (Press the **Down arrow** button repeatedly to quickly cycle through the inputs.)

• If more than one output is OFF, a small arrowhead indicates the Safety Output to which the input messages correspond, as shown in the preceding figure.

Input Device Status Message	Cause and/or Required Action
Stop	The safety input is in a state that causes the Safety Output to turn OFF.
Test	A start-up test needs to be completed on the safety input. To perform the test, cycle the input (Run-Stop-Run) to turn the Safety Output ON.
Deactivate	A two-hand control input or an enabling device needs to be cycled (Run-Stop-Run) before the Safety Output will turn ON.
Fault	A problem has been detected with an input that controls the output.
Timed Out	The Safety Output is in enable mode and the enabling device active time limit has expired. Cycle the enabling device to turn the output back ON, or turn the enabling device OFF and perform a system reset to exit Enable mode.
Test Active	An AVM test is running. The output will turn ON when the test is complete.

When a Safety Output is ON, no input information is displayed unless a mapped input is muted, bypassed, or in a fault condition.

Status Output: Line 5 of the screen displays Mute Lamp Fault when a mute lamp fault exists.

System Status: Line 5 of the screen displays System Reset Needed whenever a system reset is needed to turn the Safety Outputs ON. However, when a fault condition exists, the fault must be corrected before the system reset operation will turn the Safety Outputs ON.

External Memory Card (XM Card) Status: The status of the XM card is temporarily displayed when it is inserted while the Run mode screen is active. Remove and replace the correct XM card as necessary.

| XM Card Message	Cause
XM matches the active configuration	The configuration stored on the card is the same as the Safety Controller's configuration.
XM does not match the active configuration	The configuration stored on the XM card is different from the Safety Controller's configuration.
XM has no configuration	The XM card does not have a configuration stored in it.
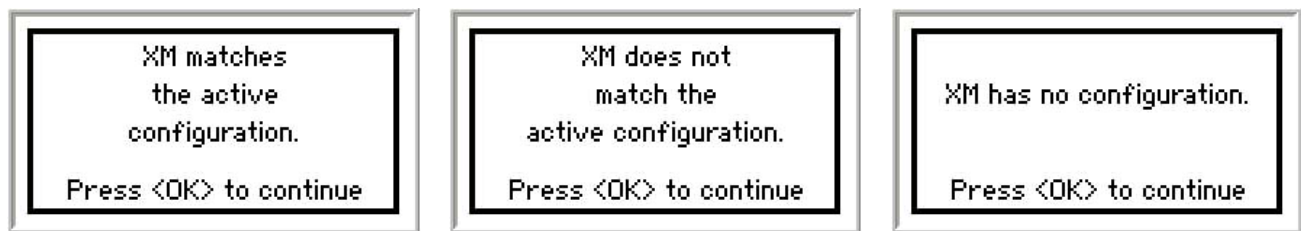
Figure 49. XM Card status message screens—OBI

7.4 Manual Reset

A manual reset operation is valid when all safety inputs mapped to the Safety Output are in the Run state when the manual reset is performed; see section *4.5.1 Reset Signal Requirements* on page 34.

When a single manual reset device is mapped to two or more Safety Outputs, one of which has an OFF-delay, then the manual reset will not be able to turn ON either Safety Output until the OFF-delay time has expired.

If a safety input device configured for manual reset changes from the Run state to Stop and back to Run, then any Safety Outputs to which that device is mapped will turn OFF and remain OFF until a valid manual reset is performed.

7.5 System Resets and Lockout Conditions

A system reset is necessary under the following conditions:

- Recovering from a lockout condition
- Starting the Controller after a new configuration has been downloaded
- Recovering from an output fault
- Entering Run mode after power-up, when configured for manual power-up
- Exiting Enable mode
- Recovering from an AVM fault
- Recovering from a two-hand control input fault

A system reset is used to clear lockout conditions not related to safety inputs. A lockout condition is a response where the Controller will turn OFF all affected Safety Outputs when a safety-critical fault is detected. Recovery from this condition requires all faults to be remedied and a system reset to be performed. A lockout will recur after a system reset unless the fault that caused the lockout has been corrected.

The reset device (a button or switch) connects to a dedicated input terminal on the Safety Controller, labeled **SR**. The reset signal type can be configured to be either monitored or non-monitored (the default setting is monitored); see section *4.5.1 Reset Signal Requirements* on page 34.

> **WARNING: . . . Non-Monitored Resets**
>
> **If a non-monitored reset (either latch or system reset) is configured** and if all other conditions for a reset are in place, **a short from the Reset terminal to +24V will turn ON the Safety Output(s) immediately.**

> **WARNING: . . . Check Before Reset**
>
> When performing the system reset operation, **it is the user's responsibility to make sure that all potential hazards are clear and free of people** and unwanted materials (such as tools) that could be exposed to the hazard. **Failure to do so could result in serious bodily injury or death.**

7.6 Reset Signal Requirements

Both manual (latch) reset and system reset signals can be configured for monitored or non-monitored operation, as follows:

Monitored resets—Requires the reset signal to transition from low (0V dc) to high (24V dc) and then back to low. The high state duration must be 0.3 to 2 seconds. This is said to be a "trailing edge trip event."

Non-monitored resets—Requires only that the reset signal transitions from low (0V dc) to high (24V dc) and stays high for at least 0.3 seconds. After the reset, the reset signal can be either high or low. This is said to be a "leading-edge trip event."

8 System Checkout

8.1 Schedule of Required Checkouts

Verifying the configuration and proper functioning of the Safety Controller includes the verification of each safety and non-safety input device, along with each output device. As the inputs are individually switched from the Run state to the Stop state, the Safety Outputs must be checked to verify that they turn ON and OFF as expected.

A comprehensive test must be used to verify the operation of the Safety Controller and the functionality of the intended configuration. Section *8.3 Initial Setup, Commissioning and Periodic Checkout* on page 76 is generic and is intended to assist in developing a customized (configuration-specific) checklist for each application. This customized checklist must be made available to maintenance personnel for commissioning and periodic checkouts. A similar, simplified daily checkout checklist should be made for the operator (or Designated Person). It is highly recommended to have copies of the wiring and logic diagrams and the configuration summary available to assist in the checkout procedures.

Commissioning Checkout: A Qualified Person* must perform a safety system commissioning procedure before the safeguarded machine application is placed into service and after each Safety Controller configuration is created or modified.

Periodic (Semi-Annual) Checkout: A Qualified Person* must also perform a safety system re-commissioning semi-annually (every 6 months) or at periodic intervals based on the appropriate local or national regulations.

Daily Operational Checks: A Designated Person* must also check the effectiveness of the protective devices per the device manufacturers' recommendation each day that the safeguarded machine is in service.

*See section *12 Glossary* on page 128 for definitions.

⚠️ **WARNING: . . . Periodic Checkouts**

The commissioning, periodic and daily safety system checks must be performed by appropriate personnel at the appropriate times (as described above) in order to ensure that the safety system is operating as intended. **Failure to perform these checks may create a potentially dangerous situation which could lead to serious injury or death.**

⚠️ **WARNING: . . . Do Not Use Machine Until System Is Working Properly**

If all of these checks cannot be verified, do not attempt to use the safety system that includes the Safety Controller and the guarded machine until the defect or problem has been corrected (see Troubleshooting). **Attempts to use the guarded machine under such conditions could result in serious bodily injury or death.**

⚠️ **WARNING: . . . Before Applying Power to the Machine**

Verify that the guarded area is clear of personnel and unwanted materials (such as tools) before applying power to the guarded machine. Failure to do so could result in serious bodily injury or death.

8.2 Commissioning Checkout Procedure

Before proceeding, verify that:

- *The Safety Output terminal strip is NOT connected* to the Safety Controller; unplug the 7-pin connector so that the Safety Outputs SO1 (A and B), SO2 (A and B) and SO3 (A and B) are not connected to the machine), and
- *Power has been removed from the machine,* and no power is available to the machine controls or actuators.

Permanent connections will be made at a later point in this checkout.

8.2.1 Verifying System Operation

The commissioning checkout procedure must be performed by a Qualified Person, as defined in the glossary of this manual. **It must be performed only after configuring the Controller and after properly installing and configuring** the safety systems and safeguarding devices connected to its inputs (per section *10 Input Device and Safety Category Reference* on page 90 and the appropriate standards).

The commissioning checkout procedure is performed on two occasions:

1. When the Controller is first installed, to ensure proper installation, and
2. Whenever any maintenance or modification is performed on the System or on the machinery being guarded by the System, to ensure continued proper Controller function. (See section *8.1 Schedule of Required Checkouts* on page 75.)

For the initial part of the commissioning checkout, the Controller and associated safety systems must be checked <u>without power being available to the guarded machine.</u> Final interface connections to the guarded machine cannot take place until these systems have been checked out.

Verify that:

- **The Safety Output leads are isolated** — not shorted together, and not shorted to power or ground;
- If used, external device monitoring (EDM) connections have been connected to +24V dc via the N.C. monitoring contacts of the device(s) connected to the Safety Outputs, as described in section *4.7.1 External Device Monitoring (EDM)* on page 40 and the wiring diagrams.
- The proper Controller configuration file for your application has been installed into the Safety Controller; and
- All connections have been made according to the appropriate sections and comply with NEC and local wiring codes.

Figure 50. Safety Output terminal block

This procedure will allow the Controller and the associated safety systems to be checked out, by themselves, before permanent connections are made to the guarded machine.

8.3 Initial Setup, Commissioning and Periodic Checkout

📝 **NOTE: If any of the Status Outputs are mapped to functions within the configuration, monitor the function of each Status Output as the associated operation is tested.**

1. Configure the machine so that the indicators for the Safety Outputs (SO1, SO2, and SO3) of the Safety Controller and for the associated output devices can be observed and verified to operate correctly and without risk of injury. ***Do not apply power to the Safety Controller or to the guarded machine now.***
2. **Safety System and Safeguarding Device Checkout**

   a. Verify that the guarded machine is of a type and design compatible with this safeguarding system, as described on page 1.
   b. Verify the installation and perform the checkout procedures for the external safety/safeguarding systems and devices connected to the Safety Controller inputs as described by the appropriate manuals. Do not proceed until all checkout procedures are completed successfully and all problems have been corrected.
   c. Verify that:

      - Access to any dangerous parts of the guarded machine is not possible from any direction not protected by the safeguarding system, hard guarding, or supplemental safeguarding, and that
      - Supplemental safeguarding and hard guarding, as described by the appropriate safety standards, are in place and functioning properly.
   d. Verify that all Reset switches are mounted outside and in full view of the guarded area, out of reach of anyone inside the guarded area, and that means of preventing inadvertent use is in place.

    e. Examine the electrical wiring connections between the Safety Controller's OSSD outputs and the guarded machine's control elements to verify that the wiring meets the requirements stated in section *4.7.1 External Device Monitoring (EDM)* on page 40.

3. Verify that all two-hand control devices, enabling devices, muting sensors, and bypass switches are in the inactive (Stop) state.NOTE: In all cases, outputs associated with a two-hand control device should not turn ON at power-up. Also, bypass or enabling devices in the active (Run) state at power-up will not function until they are seen as OFF first.

4. Ensure that all other input devices are in the active (Run) state.

Power-Up and Reset Functions:

5. Ensure that no individual is exposed to the hazardous motion/situation of the guarded machine during the checkout procedure.Observe the SO status indicators or the messages on the front panel display to verify whether a Safety Output is ON or OFF. Apply power to the Safety Controller and all input devices that require power, but not to the guarded machine.

6. Verify that the configuration file (e.g., revision level) is appropriate for the application. At a minimum, have a copy of the Configuration Summary from the PC Interface software available for reference during the checkout procedure.

7. Verify that Status Outputs configured for a monitored mute lamp (if used) turn ON briefly (i.e., flash) after power-up.

8. **Power-Up Configuration (see "System Settings" in the Configuration Summary)** *[In all cases, Safety Outputs associated with a two-hand control will not turn ON at power-up. Enabling devices and bypass functions are not available at power-up — they must begin in a Stop state (OFF).]*

    • **If configured for Normal Power-Up (default):** Verify that Safety Outputs associated only with device inputs configured for automatic reset turn ON.

    • **If configured for Automatic Power-Up:** Verify that all Safety Outputs turn ON within 5 seconds (outputs with a configured ON-delay may extend this time).

    • **If configured for Manual Power-Up:**

        1. Verify that all Safety Outputs remain OFF.

        2. Wait at least 10 seconds after power-up, then apply a system reset.

        3. Verify that Safety Outputs turn ON, even if an associated non-safety input is configured for a manual reset.

9. **Reset Configuration**

    • **If configured for Automatic Reset:** Verify that the corresponding Safety Output indicator is ON Green, indicating that the Safety Output(s) is ON (assuming that other inputs configured for manual reset are not associated with the Safety Output; see Manual Reset). If the Red status indicator begins to flash at any time, refer to Troubleshooting for more information.

    • **If configured for Manual Reset:** Verify that the Green status LED is flashing to indicate that a reset is being requested, and that the message "Reset Needed" appears on the Diagnostic Display. If the Red status indicator begins to flash at any time, refer to Troubleshooting for more information.

    NOTE: If a "monitored manual reset" has been configured, perform a reset by closing the Reset input for at least ¼ second, but not longer than 2 seconds, and then reopening the contact. Verify that the Green status indicator comes ON steady.

    a. Verify that all reset switches are mounted in full view of the guarded area, but outside it and out of reach of anyone inside the guarded area, and that means of preventing inadvertent use is in place.

    b. Actuate each (non-safety input) manual reset device to turn ON remaining outputs not associated with a two-hand control device.

    c. Verify that all Safety Outputs not associated with two-hand control devices are now ON. (Exception: An output associated only with an enabling device will remain OFF.)

If a particular function or device is not part of the application, skip that step and proceed to the next check or to the final step.

Two-Hand Control Functions

10. Ensure all inputs are in the ON-state associated with Safety Outputs and activate each two-hand control device to turn ON the remaining outputs.

    a. Verify that the associated Safety Output remains OFF unless both hand controls are activated within 0.5 seconds of each other.

    b. Verify that when one hand is removed and replaced, the Safety Output turns OFF and remains OFF.

Emergency Stop and Rope-Pull Functions

11. While the outputs are ON, individually actuate and re-arm each E-stop and/or rope-pull device, one device at a time.

    Verify that each associated Safety Output turns OFF with the proper OFF-delay, where applicable.

12. As the E-stop or rope-pull device is returned to the Run state (armed):

    If configured for Manual Reset or if associated with a two-hand control device: Verify that the Safety Output remains OFF.

    If configured for Automatic Reset (assuming that another device is not holding it OFF): Verify that the Safety Output turns ON.

13. Apply a manual reset and/or activate the two-hand control device as necessary to turn the output(s) back ON.

    Verify that each associated Safety Output turns ON with the proper ON-delay, where applicable.

    Other Stopping Device Functions

14. Repeat the preceding three steps for each device type below, as applicable:

    a. Verify operation of all gate switches.
    b. Verify operation of all optical sensors.
    c. Verify operation of all protective stops (i.e., other safety/safeguarding devices otherwise not listed).
    d. Verify operation of all ON/OFF inputs.

    If Mute, Bypass and/or Enabling Device functions are not used, proceed to the final step in this procedure.

15. **Mute Functions**

    a. While the outputs are ON, initiate a mute cycle by activating the mute enable input (if used) and then activate each mute sensor of a pair within 3 seconds.

       Verify that the mute lamp, if used, turns ON.

    b. Generate a stop command from the safeguarding device that has been muted.

        a. Verify that the associated Safety Outputs remain ON (Green status indicator remains ON).
        b. If a time limit (backdoor timer) is associated with the mute, verify that the associated Safety Outputs turn OFF when the mute timer expires.

    c. Repeat above steps for each muting sensor pair.

       Verify proper operation with each associated muted device

    d. Generate a stop command from the non-muted safeguarding device(s), one at a time.

       Verify that the associated Safety Outputs turn OFF while the muted input is muted.

    📓 **NOTE:** The mute function will end when an associated output turns OFF for any reason. In order to complete this test with the other non-muted safeguarding devices, a new mute cycle must be initiated for each one.

16. **Directional Muting Option**

    a. If 2 Mute Sensor pairs have been configured and mapped to a mutable Safety Input (i.e., a light screen), a setting of the mutable Safety Input in the PC GUI provides the option for **Directional Muting.**

       Check the "Enable directional muting" box in the PC GUI. Select sensor pair 1.

    b. Verify that all mute sensors and the light screen are clear, and the Safety Outputs are ON.
    c. Block sensor pair 1 (the one selected in the PC GUI), followed by the light screen, and sensor pair 2.
    d. Verify, that the mute lamp, if used, turns ON.
    e. If a time limit (backdoor timer) is associated with the mute, verify that the associated safety outputs turn OFF when the mute timer expires.
    f. Repeat the test in the *wrong direction* (mute sensor pair 2, then the light screen, then mute sensor pair 1), and verify that the mute **does _not_ take place:** the Safety Output(s) turn(s) OFF as soon as the light screen is blocked.
    g. *Repeat the steps above for all devices with directional muting.*
    h. Mute an input device that is configured for directional muting. While the Safety Output(s) are ON, generate a Stop command from a non-muted safeguarding device(s) mapped to the same Safety Output(s). Verify that the associated Safety Output(s) turns OFF, even though an input is muted.

17. **Mute on Power-Up Option**

SC22-3/-3E Safety Controller Instruction Manual

a. Turn the Safety Controller power OFF.

    a. Activate the mute enable inputs (if used).

    b. Activate an appropriate muting sensor pair for starting a mute cycle.

    c. Ensure all input devices are in their Run (active) state (not including two-hand control devices).

    d. Verify that all enabling devices and bypass switches are in the Stop (inactive) state.

b. Verify proper operation at power-up. *NOTE: In all cases, Safety Outputs associated with a two-hand control device will not turn ON at power-up. The Mute on Power-Up feature does not apply to mutable two-hand control devices.*

  • **If configured for Auto Power-Up:**

    1. Verify that all Safety Outputs turn ON.
    2. Verify that the mute Status Output (if used) turns ON.

  • **If configured for Normal Power-Up:**

    1. Verify that all Safety Outputs associated with only auto-reset devices or mutable manual-reset devices turn ON.
    2. Verify that the mute Status Output (if used) turns ON.

  • **If configured for Manual Power-Up:**

    1. Verify that all Safety Outputs remain OFF.
    2. Wait at least 10 seconds after power-up and apply a system reset.
    3. Verify that all Safety Outputs turn ON.
    4. Verify that the mute Status Output (if used) turns ON.

c. Generate a stop command from the safeguarding device that has been muted.

  Verify that the associated Safety Outputs remain ON (i.e., the input is muted); the Green status indicator should remain ON.

18. **Mute-Dependent Override Option**

a. Select **"Enable Mute-Dependent Override Function"** (default) for a bypass input.
b. Clear all mute sensors and the light screen; verify that the Safety Output(s) are ON.
c. Block the light screen.
d. Verify that the Safety Output(s) turn OFF.
e. Block one of the mute sensors.
f. Start the bypass by closing the bypass input.
g. Verify that the Safety Output(s) turn ON.
h. Clear the light screen and all mute sensors.
i. Verify that the Safety Output(s) remain ON.
j. Open the bypass input.
k. Verify that the Safety Output(s) remain ON.

19. **Bypass Function (with Mute)**

a. Verify that each safety input, if it is both mutable and can be bypassed, is in the Stop state.

  If the Safety Controller is still muting, the associated Safety Outputs should remain ON. Even if the timer expires and the outputs turn OFF, go to the next step.

b. Activate one or both mute sensors in a mute sensor pair. If there are two mute sensor pairs, at least one sensor in one of the pairs must be activated.

  Verify that the mute lamp, if used, is flashing.

c. Verify that when the bypass switch is in the Run state:

  • The associated Safety Outputs turn ON.
  • The mute lamp, if used, is now steady ON.
  • The associated Safety Outputs turn OFF when the bypass timer expires.

d. Verify that when the bypass switch is in Stop state and goes back into Run state: The associated Safety Outputs turn ON.

e. Verify that when all other non-bypassed inputs associated with the same output are in a Stop state, one at a time: The associated Safety Outputs turn OFF while the input is bypassed.

20. **Safety Mat Device Checkout**

Before connecting the mat to the Safety Controller, verify that the mat and the wiring to the mat does not exceed the maximum resistance specification using the following procedure.

1. Measure the resistance between wires connected to the same surface of the mat (see diagram):

    W1 and W2:_____A_____ ohms

    W3 and W4:_____B_____ ohms
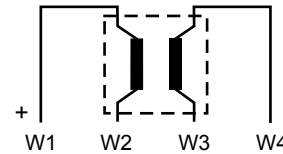
2. While stepping on the mat, measure the resistance between W1 and W3. Repeat the measurement while stepping in various locations around the mat. Choose the location with the highest reading and record the following measurements.

    W1 and W3:_____C_____ ohms

    W2 and W4:_____D_____ ohms

    W2 and W3:_____E_____ ohms

    W1 and W4:_____F_____ ohms

3. If all measurements (A through F) are less than 20 ohms, the mat and leadwire resistance is acceptable and no further calculations are needed.

4. If A and B are both less than 300 ohms, the leadwire resistance is acceptable.

5. Calculate the mat resistance: **R = E + F - (A + B + C + D) / 2**

6. If **R < 20 ohms**, the mat resistance is acceptable.

21. **Bypass Function (without Mute)**

    a. Verify that when the safety input to be bypassed is in the Stop state: The associated Safety Outputs are OFF.

    b. Verify that when the bypass input is in the Run state:

        • The associated Safety Outputs turn ON.
        • The associated Safety Outputs turn OFF when the bypass timer (backdoor timer) expires.

    c. Verify that when the bypass switch is in the Stop state and goes back into the Run state: The associated Safety Outputs turn ON.

    d. Generate a stop command from the non-bypassed safeguarding device(s), one at a time. Verify that the associated Safety Output(s) turns OFF while the input is bypassed.

22. **Cancel OFF-delay Function**

    a. Configure a delayed output and check the box *"Allow output to remain ON when off delay is cancelled"* in the Advanced Setting menu. Turn the delayed output ON. Start the delay time by generating a stop command from a safety input, mapped to the delayed safety output.

        • If the Safety Input is a **latch input**, perform the following steps:

            1. Close the Safety Input.
            2. Push the Reset button.
            3. Activate the Cancel Delay Input.

        • If the Safety Input is a **trip input**, perform the following steps:

            1. Close the Safety Input.
            2. Activate the Cancel Delay Input.

    b. Verify that the delayed safety output stays closed, after the delay time has expired.

    c. Configure a delayed output and **_do not_** check the box *"Allow output to remain ON when off delay is cancelled"* (turn the output OFF immediately after a Cancel OFF-Delay" signal) in the Advanced Setting menu. Turn the delayed output ON. Start the delay time by generating a stop command from a safety input, mapped to the delayed safety output.

    d. Close the Safety Input again during the OFF-delay time.

        • If the Safety Input is configured for **manual reset:** Verify that the delayed output turns OFF immediately and remains OFF (a reset signal during the delay time is ignored).

  • If the Safety Input is configured for **auto reset:** Verify that the delayed safety output turns OFF immediately for 500 ms, then turns back ON.

23. **Enabling Device Function**

 a. Verify that all inputs associated with the same output as the enabling device are in the Run state to turn the output(s) ON. The enabling device is to remain in the Stop state. Verify that the associated Safety Outputs are ON.

 b. Verify that when the enabling device is in the Run state: The associated Safety Outputs remain ON and the LCD displays *ENABLE MODE*.

 c. Verify that when the enabling device is in the Stop state: The associated Safety Outputs turn OFF.

 d. Verify that when the enabling device is in the Run state:

  a. The associated Safety Outputs turn ON.

  b. The associated Safety Outputs turn OFF when the enabling device timer expires.

 e. Verify that when the enabling device is in the Stop state and goes back into the Run state: The associated Safety Outputs turn ON.

 f. Verify that when all E-stop and rope-pull inputs associated with the same outputs are in the Stop state, one at a time (repeat step for each device, as needed): The associated Safety Outputs turn OFF while in Enable mode.

 g. Verify that the enabling device is in the Stop state and then apply a system reset.

  a. Verify that the LCD no longer displays *ENABLE MODE*.

  b. Verify that the Safety Controller is back to normal operation.

24. **System (Final) Checkout**

  📝 **NOTE:** *DO NOT continue checkout until all problems are corrected.*

The operation of the Safety Controller with the guarded machine must now be verified before the combined system may be put into service. To do this, a Qualified Person must perform the following checks.

Remove power from the Safety Controller.

Reinstall the **Safety Output terminal strip** to the Safety Controller to connect the machine control circuit to the Safety Outputs SO1 (A and B), SO2 (A and B), and SO3 (A and B). **This is a permanent connection.**

 a. Verify that all wiring complies with NEC and local wiring codes.

 b. Apply power to the guarded machine and verify that the machine does not start up.

 c. Apply power to the Safety Controller and apply resets as needed to turn the Safety Outputs ON.

 d. Generate a stop command from each of the safety devices or safeguards connected to the input terminals of the Safety Controller and verify for each input device that:

  a. The Safety Outputs and Status Outputs operate as expected (e.g., ON-delays, OFF-delays, etc.). Use the configuration summary to verify operation.

  b. It is not possible for the guarded machine to be put into motion.

 e. Initiate machine motion of the guarded machine and, while it is moving, generate a stop command from each of the safety devices or safeguards. Do not attempt to insert anything into the dangerous parts of the machine. Upon issuing the stop command, verify that the dangerous parts of the machine come to a stop.

 f. Upon reset of the safety device or safeguard and/or the Controller, verify that the machine does not automatically restart, and that the initiation devices must be engaged to restart the machine.

 g. Test the machine stopping response time, using an instrument designed for that purpose, to verify that it is the same or less than the overall system response time specified by the machine manufacturer. (A Banner Applications Engineer may be able to recommend a suitable instrument.)

If any of these checks fail, do not attempt to use the system until the reason for the failure(s) is identified and corrected.

9 Troubleshooting

9.1 Cleaning

Disconnect power to the Controller and wring out excessive moisture from the cloth before cleaning. If cleaning of the polycarbonate enclosure and display is required, wipe it down with a soft cloth that has been dampened with a mild detergent and warm water solution.

9.2 Repairs and Warranty Service

The Controller is designed and tested to be highly resistant to a wide variety of electrical noise sources that are found in industrial settings. However, intense electrical noise sources that produce EMI or RFI beyond these limits may cause a random trip or lockout condition. If random trips or lockouts occur, check that:

- The supply voltage is within 24V dc +/- 20%.
- The Safety Controller's plug-on terminal blocks are fully inserted.
- Wire connections to each individual terminal are secure.
- No high-voltage or high-frequency noise sources or any high-voltage power lines are not routed near the Controller or alongside wires that are connected to the Controller.
- Proper transient suppression is applied across the output loads.

The Safety Controller has no internal field-replaceable parts. If the Controller is not operating properly please contact the factory. **In case of a non-recoverable fault, do not open the housing of the Controller and do not attempt to repair the Controller yourself.** Contact a Banner factory applications engineer at a number listed in the beginning of this document. The applications engineer will attempt to troubleshoot the Controller from your description of the problem. If he or she concludes that the Controller or a component is defective, they will issue an RMA (Return Merchandise Authorization) number for your paperwork, and give you the proper shipping address. Package the Controller carefully; damage which occurs during return shipping is not covered by warranty.

9.3 Troubleshooting—Finding and Fixing Faults

Depending on the configuration, the Safety Controller is able to detect a number of input, output and system faults, including:

- A stuck contact
- An open contact
- A short betweeen channels
- A short to ground
- A short to a voltage source
- A short to another input
- A loose or open connection
- An exceeded operational time limit
- A power drop

When a fault is detected, a message describing the fault is displayed in the fault diagnostics menu. An additional message may also be displayed to help remedy the fault. The following troubleshooting table summarizes the faults and suggests additional checks to find the cause of the problem. The following sections describe how to recover from a lockout and how to access fault information, using either the PCI or the OBI.

If a problem with network communications occurs, a network user's guide, available on *www.bannerengineering.com*, may be helpful.

9.3.1 Troubleshooting Fault CodeTable

Fault Code	Displayed Message	Additional Message	Further Steps and Checks
0.0	Input Fault	Cycle Input	• Check for unstable input signal. • Turn input OFF to clear the fault indication.
1.1	Output Fault	Check for Shorts	A Safety Output appears ON when it should be OFF. • Check for short to external voltage source. • Check DC common wire size connected to the Safety Output loads. The wire must be heavy-gauge wire or as short as possible to minimize resistance and voltage drop. If necessary, use a separate DC common wire for each pair of outputs and/or avoid sharing this DC common return path with other devices (see section *4.7.4 Common Wire Installation* on page 49).
1.2	Output Fault	Check for Shorts	A Safety Output is sensing a fault to another voltage source while the output is ON. • Check for short between Safety Outputs. • Check for short to external voltage source. • Check load device compatibility (too much capacitance?). • Check DC common wire size connected to the Safety Output loads. The wire must be heavy-gauge wire or as short as possible to minimize resistance and voltage drop. If necessary, use a separate DC common wire for each pair of outputs and/or avoid sharing this DC common return path with other devices (see section *4.7.4 Common Wire Installation* on page 49).
1.3 – 1.4	Internal Fault		Internal failure – Contact Banner Factory (see section *9.2 Repairs and Warranty Service* on page 82).
1.5	Output Fault	Check Output Wiring	A Safety Output appears ON prematurely. • Check DC common wire size connected to the Safety Output loads. The wire must be heavy-gauge wire or as short as possible to minimize resistance and voltage drop. If necessary, use a separate DC common wire for each pair of outputs and/or avoid sharing this DC common return path with other devices (see section *4.7.4 Common Wire Installation* on page 49).
1.6	Internal Fault		Internal failure – Contact Banner Factory (see section *9.2 Repairs and Warranty Service* on page 82).
1.7	Output Fault	Check for Shorts	An overload is detected on the Safety Outputs. • Check each output terminal for a short to ground or overload condition (a fault on only one output may cause other outputs to indicate a fault). • Verify system power supply rating with system load requirements.
1.8	Internal Fault		Internal failure – Contact Banner Factory (see section *9.2 Repairs and Warranty Service* on page 82).
1.9	AVM Input Fault	Perform System Reset	After this Safety Output turned OFF, an AVM input associated with this output did not close before its AVM monitoring time expired. • The AVM may be disconnected or its response to the Safety Output turning OFF may be too slow. • Check the AVM input and then perform a System Reset to clear the fault.
1.10	AVM Input Fault	Perform System Reset	An AVM input associated with this Safety Output was not closed when the Safety Output was commanded to turn ON.

Fault Code	Displayed Message	Additional Message	Further Steps and Checks
			• The AVM may be disconnected; check the wiring. • Perform a System Reset to clear the fault and cause another test to occur.
2.1	Concurrency Fault	Cycle Input	On a dual-channel input with both inputs in the Run state, one input went to the Stop state then back to Run. • Check wiring. • Check input signals. • Consider adjusting debounce times.
2.2	Simultaneity Fault	Cycle Input	On a dual-channel input, one input went into the Run state but the other input did not follow within 3 seconds. • Check wiring. • Check input signal timing.
2.3 or 2.5	Concurrency Fault	Cycle Input	On a complementary pair with both inputs in the Run state, one of the inputs changed to Stop then back to Run. • Check wiring. • Check input signals. • Check power supply providing input signals. • Consider adjusting debounce times.
2.4 or 2.6	Simultaneity Fault	Cycle Input	On a complementary pair, one input went into the Run state but the other input did not follow within the time limit. • Check wiring. • Check input signal timing.
2.7	Internal Fault	Check Terminal xx	Internal failure – Contact Banner Factory (see section *9.2 Repairs and Warranty Service* on page 82).
2.8 – 2.9	Input Fault	Check Terminal xx	Input stuck high. • Check for shorts to other inputs or other voltage source. • Check input device compatibility.
2.10	Input Fault	Check Terminal xx	• Check for short between inputs.
2.11 - 2.12	Input Fault	Check Terminal xx	• Check for short to ground.
2.13	Input Fault	Check Terminal xx	Input stuck low. • Check for short to ground.
2.14	Input Fault	Check Terminal xx	Missing test pulses. • Check for short to other inputs or other voltage source.
2.15	Open Lead	Check Terminal xx	• Check for open lead.
2.16 – 2.18	Input Fault	Check Terminal xx	Missing test pulses. • Check for short to other inputs or other voltage source.

Fault Code	Displayed Message	Additional Message	Further Steps and Checks
2.19	Open Lead	Check Terminal xx	• Check for open lead.
2.20	Input Fault	Check Terminal xx	Missing test pulses. • Check for short to ground.
2.21	Open Lead	Check Terminal xx	• Check for open lead.
2.22 – 2.23	Input Fault	Check Terminal xx	• Check for unstable signal on the input.
2.24	Input Activated While Bypassed	Perform System Reset	A two-hand control input was activated (turned ON) while it was bypassed.
2.25	Input Fault	Monitoring Timer Expired Before AVM Closed	After the associated Safety Output turned OFF, the AVM input did not close before its AVM monitoring time expired. • Either the AVM is disconnected, or its response to the Safety Output turning OFF is too slow. • Check the wiring to the AVM. • Check the timing setting; increase the setting if necessary. • Contact the factory.
2.26	Input Fault	AVM Not Closed When Output Turned ON	The AVM input was open, but should have been closed, when the associated Safety Output was commanded ON. • The AVM may be disconnected; check the wiring to the AVM.
3.1	EDMxx Fault	Check Terminal xx	EDM contact open prior to turning ON the Safety Outputs. • Check for a stuck-ON contactor or relay. • Check for open wire.
3.2	EDMxx Fault	Check Terminal xx	EDM contact(s) failed to close within 250 ms after the Safety Outputs turned OFF. • Check for slow or stuck-ON contactor or relay. • Check for open wire.
3.3	EDMxx Fault	Check Terminal xx	EDM contact(s) open prior to turning ON the Safety Outputs. • Check for stuck-ON contactor or relay. • Check for open wire.
3.4	EDMxx Fault	Check Terminal xx	EDM contact pair mismatched for longer than 250 ms. • Check for slow or stuck-ON contactor or relay. • Check for open wire.
3.5	EDMxx Fault	Check Terminal xx	• Check for unstable signal on the input.
3.6	EDMxx Fault	Check Terminal xx	• Check for short to ground.
3.7	EDMxx Fault	Check Terminal xx	• Check for short between inputs.

Fault Code	Displayed Message	Additional Message	Further Steps and Checks
4.1	Supply Voltage Low	Check Power Supply	The supply voltage dropped below the rated voltage for longer than 6 ms. • Check the power supply voltage and current rating. • Check for an overload on the outputs that might cause the power supply to limit the current.
4.2	Internal Fault		A configuration parameter has become corrupt.To fix the configuration: • Replace the configuration by sending a backup copy of the configuration using the PC Interface or an XM card. • Or, erase and recreate the configuration using the on-board user interface.
4.3 – 4.11	Internal Fault		Internal failure – Contact Banner Factory (see section *9.2 Repairs and Warranty Service* on page 82).
4.12	Configuration Timeout	Check Configuration	Safety Controller was left in Configuration mode for more than one hour without pressing any keys.
4.13	Configuration Timeout	Check Configuration	Safety Controller was left in Configuration mode for more than one hour without receiving any commands from the PC Interface.
4.14	Configuration Unconfirmed	Confirm Configuration	Configuration was not confirmed after being edited. • Confirm configuration using the Onboard Interface or the PC Interface.
4.15 – 4.19	Internal Fault		Internal failure – Contact Banner Factory (see section *9.2 Repairs and Warranty Service* on page 82).
4.20	Unassigned Terminal in Use	Check Terminal xx	This terminal is not mapped to any device in the present configuration and should not be active. • Check wiring.
4.21 – 4.33	Internal Fault		Internal failure – Contact Banner Factory (see section *9.2 Repairs and Warranty Service* on page 82).
5.1	Mute Lamp Fault	Check Lamp and Wiring	The monitored Status Output voltage should be low when the lamp is OFF and is sensing a high, indicating an open in the mute lamp circuit.
5.2	Mute Lamp Fault	Check for Shorts	The monitored Status Output voltage should be high when the lamp is ON and is sensing a low, indicating a short in the mute lamp circuit.
5.3	Internal Fault		Internal failure – Contact Banner Factory (see section *9.2 Repairs and Warranty Service* on page 82).
6.xx	Internal Fault		Invalid configuration data. Possible internal failure. • Try to load a new configuration using the PC Interface, Onboard Interface, or XM card.

9.4 Recovering from a Lockout

To recover from a lockout condition:

1. Follow the recommendation in the fault display (for example, Cycle Input).
2. Follow the recommended steps and checks listed under Further Steps and Checks in the troubleshooting table.
3. Perform a system reset.
4. Cycle the power and perform a system reset if needed.

If these steps do not remedy the lockout condition, contact the factory (see section *9.2 Repairs and Warranty Service* on page 82).

9.5 Fault Diagnostics—PCI

The first step in diagnosing faults via the PCI is to bring up the Live Display screen (see section *7.2 Display Controller Information — PC Interface (PCI)* on page 71).

The Live Display screen (if the PC is connected to the Controller) shows in real time, the status of each Safety Output, which device caused an output to turn OFF, if any, and basic information about the Controller model and the configuration.

9.5.1 Fault Log—PCI

While the Controller is powered up and connected to the PC, every fault that occurs is stored in the fault log. The PCI displays real-time fault information via the Fault Log screen shown in the following figure. The fault information includes the following information about each fault; expand the size of the window as needed to see all the faults.

- Date and time of the fault
- Device name
- General description of the fault, and
- Fault code (for lookup table reference).

Additional code information can be displayed, should factory applications assistance be required.
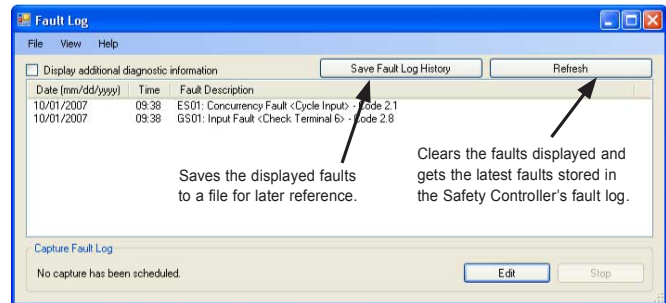
Figure 51.   Fault Log screen—PCI

9.5.2 Fault Log Recording—PCI

To determine the cause of a persistent fault, compile an extended record of the faults and save it to a file. Select the Edit button in the Fault Log screen to establish the times at which the fault data record starts and stops. The Schedule Fault Log Capture menu will then appear.

The menu settings at right show that any fault that occurs from Friday, June 29, 2007 at 11:00 pm until Saturday, June 30, 2007 at 6:00 am will be recorded to a user-designated file for future reference.

Figure 52. Schedule Fault Log Capture menu

NOTE: The selected start and stop times must be later than the time at which this selection is made; the fault log capture will not capture past faults.

9.6 Fault Diagnostics—OBI

Troubleshooting the Controller and connected I/O devices is easy using the Onboard Interface. Any event that causes a Safety Output to turn OFF or stay OFF (either for fault or input stop events) will be immediately detected and displayed on the Controller's display. Further information about current and past faults can be accessed using the Fault Diagnostics menu. To get to the Fault Diagnostics menu, press **OK** from the Run mode menu. Select **Fault Diagnostics** and press **OK**.

The Diagnostics menu provides three choices:

1. View fault conditions that currently exist,
2. View faults that have been stored in the fault log, and
3. Clear the fault log.
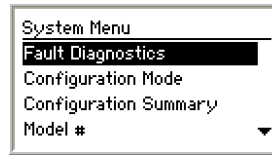
Figure 53. Select Fault Diagnostics—OBI

9.6.1 View Current Faults—OBI

To view current fault conditions, select **View Current Faults** using the up/down arrow buttons and press **OK**.

The screen shows the fault conditions that currently exist, one at a time. Use the left/right arrow keys to view all the faults. (Shortcut: To view current faults when the Run mode screen is displayed, simply press **OK** three times.)
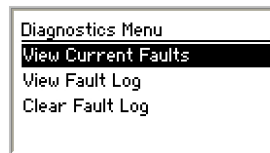
Figure 54. View current faults—OBI

• The top line of the Current Fault menu indicates which device has the fault.
• The second and third lines provide a brief description of the fault.
• The fourth line provides a suggestion for correcting the fault.
• The fifth line provides the fault code. Use the fault code and information in section *9.3.1 Troubleshooting Fault CodeTable* on page 83 to obtain more information about the fault and additional suggestions for correcting it.

Use the left/right arrow (**<** and **>**) buttons to access fault information for all faulty devices.
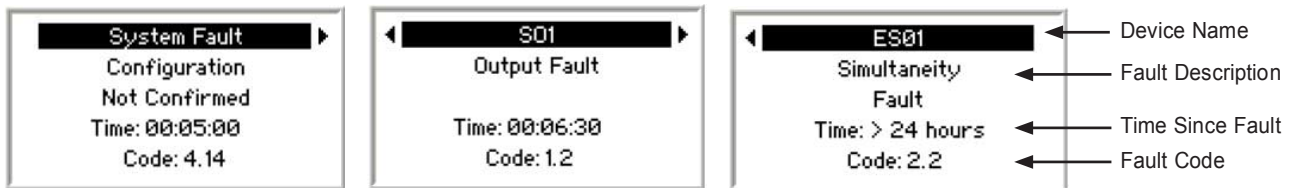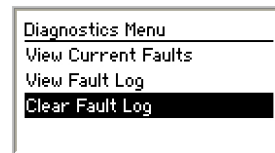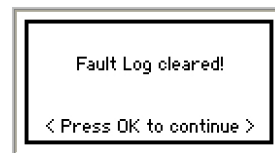
Figure 55. Current Fault screens—OBI

10 Input Device and Safety Category Reference

For ease in finding information about them, the specific device types discussed are presented in the following order.

Follow the device manufacturer's installation, operation, and maintenance instructions and all relevant regulations. If there is any question about the device(s) that are to be connected to the Safety Controller, contact a Banner Applications Engineer for assistance.

10.1 Safety Circuit Integrity and ISO 13849-1 (EN954-1) Safety Circuit Principles

Safety circuits involve the safety-related functions of a machine that minimize the level of risk of harm. These safety-related functions can prevent initiation, or they can stop or remove a hazard. The failure of a safety-related function or its associated safety circuit usually results in an increased risk of harm.

The integrity of a safety circuit depends on several factors, including fault tolerance, risk reduction, reliable and well-tried components, well-tried safety principles, and other design considerations.

Depending on the level of risk associated with the machine or its operation, an appropriate level of safety circuit performance (i.e., integrity) must be incorporated into its design. Standards that detail safety performance levels include ANSI/RIA R15.06 Industrial Robots, ANSI B11 Machine Tools, OSHA 29CFR1910.217 Mechanical Power Presses, and ISO 13849-1 (EN954-1) Safety-Related Parts of a Control System.
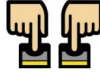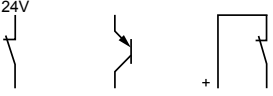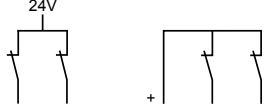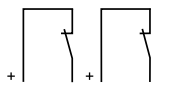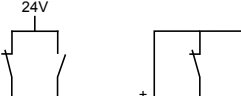
10.1.1 Safety Circuit Integrity Levels

Safety circuits in International and European standards have been segmented into categories, depending on their ability to maintain their integrity in the event of a failure. The most recognized standard that details safety circuit integrity levels is ISO 13849-1 (EN954-1), which establishes five levels: Categories B, 1, 2, 3, and the most stringent, Category 4.
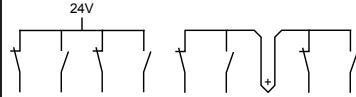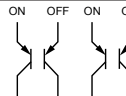
In the United States, the typical level of safety circuit integrity has been called "control reliability." Control reliability typically incorporates redundant control and self-checking circuitry and has been loosely equated to ISO 13849-1 Categories 3 and 4 (see CSA Z432 and ANSI B11.19).

If the requirements described by ISO 13849-1 are to be implemented, a risk assessment must first be performed to determine the appropriate category, in order to ensure that the expected risk reduction is achieved. This risk assessment must also take into account national regulations, such as U.S. control reliability or European "C" level standards, to ensure that the minimum level of performance that has been mandated is complied with.

The following sections deal only with Category 2, Category 3, and Category 4 applications, as described by ISO 13849-1 (1999). The following figure provides a snapshot of the possible safety categories that can be achieved for each device type, depending on the selected circuit option. Refer to the text sections following, as well as the appropriate standards, for further information.

Circuit Symbol	E-Stop	Safety Gate	Optical Sensor	Two-Hand Control	Rope Pull	Protect. Stop	Safety Mat	Enabling Device
(24V, single channel)	Cat. 2	Cat. 2	Cat. 2	—	Cat. 2	Cat. 2	—	—
(24V, dual channel)	Cat. 3	Cat. 2 Cat. 3	Cat. 2 Cat. 3	Type IIIa Cat. 1 Type IIIb Cat. 3	Cat. 3	Cat. 2 Cat. 3	—	Cat. 2 Cat. 3
(ON ON)	Cat. 2 Cat. 3 Cat. 4	Cat. 2 Cat. 3 Cat. 4	Cat. 2 Cat. 3 Cat. 4	Type IIIa Cat. 1	Cat. 2 Cat. 3 Cat. 4	Cat. 2 Cat. 3 Cat. 4	—	Cat. 2 Cat. 3 Cat. 4
(dual channel +)	Cat. 4	Cat. 2 Cat. 3 Cat. 4	Cat. 2 Cat. 3 Cat. 4	Type IIIa Cat. 1 Type IIIb Cat. 3	Cat. 4	Cat. 2 Cat. 3 Cat. 4	—	Cat. 2 Cat. 3 Cat. 4
(24V)	—	Cat. 2 Cat. 3 Cat. 4	Cat. 2 Cat. 3 Cat. 4	—	Cat. 2 Cat. 3 Cat. 4	Cat. 2 Cat. 3 Cat. 4	—	Cat. 2 Cat. 3 Cat. 4
(ON OFF)	—	Cat. 2 Cat. 3 Cat. 4	Cat. 2 Cat. 3 Cat. 4	—	Cat. 2 Cat. 3 Cat. 4	Cat. 2 Cat. 3 Cat. 4	—	Cat. 2 Cat. 3 Cat. 4
(24V, 4 contact)	—	Cat. 3 Cat. 4	—	Type IIIc Cat. 4	—	—	—	Cat. 3 Cat. 4
(ON OFF ON OFF)	—	Cat. 3 Cat. 4	—	Type IIIc Cat. 4	—	—	—	Cat. 3 Cat. 4
(safety mat)	—	—	—	—	—	—	Cat. 2 Cat. 3	—

NOTES
• Cat. B or 1 is assumed when not using safety-rated devices.
• All safety input device contacts are shown in the ON/active state (e.g., E-stop in the armed state, safety gate in the closed state, light screen in the clear state, etc.)
• Cat. B/1, 2, 3 and 4 are per ISO 13849-1 (EN 954-1), except for two-hand control.
• Two-hand categories are per ISO 13851.

Figure 59. Input devices, circuit options, and their potential safety categories

⚠ WARNING: . . . Safety Categories

The level of safety circuit integrity can be greatly impacted by the design and installation of the safety devices and the means of interfacing of those devices. **A risk assessment must be performed to determine the appropriate safety circuit integrity level or safety category as described by ISO 13849-1 (EN 954-1) to ensure that the expected risk reduction is achieved and that all relevant regulations and standards are complied with.**

> ⚠️ **WARNING: . . . Input Devices with Solid State Outputs**
>
> **The Safety Controller will not detect shorts between inputs or from an input to +24V,** if the input signals on these terminals are coming from input devices with Solid State Outputs.
>
> **It is the user's responsibility to use a device that can detect these shorts** (e.g., the Banner EZ-SCREEN® Light Screen can detect a short between its two solid-state outputs or from each output to +24V).

> ⚠️ **WARNING: . . . Category 2 or 3 Input Shorts**
>
> **Detection of a short between two input channels** (contact inputs, but not complementary contacts), if they are supplied through the same source (e.g., the same terminal from the Controller in a dual-channel, 3-terminal hookup, or from an external 24V supply) is not possible, if the two contacts are closed.
>
> **Such a short can be detected only when both of the contacts are open and the short is present for at least 2 seconds.**

10.1.2 Fault Exclusion

An important concept within the category requirements of ISO 13849-1 is the "probability of the occurrence of the failure," which can be decreased using a technique termed "fault exclusion." The rationale assumes that the possibility of certain well-defined failure(s) can be reduced to a point where the resulting fault(s) can be, for the most part, disregarded—that is, "excluded."

Fault exclusion is a tool a designer can use during the development of the safety-related part of the control system and the risk assessment process. Fault exclusion allows the designer to design out the possibility of various failures and justify it through the risk assessment process to meet the intent requirements of Category 2, 3 or 4. See ISO 13849-1/-2 for further information.

10.2 Protective (Safety) Stop

🛑 A Protective (Safety) Stop is designed for the connection of miscellaneous devices (not otherwise listed on the "Add Safety Device" screen) that could include safeguarding (protective) devices and complementary equipment. This stop function is a type of interruption of operation that allows an orderly cessation of motion for safeguarding purposes. The function can be either automatically or manually activated and reset either manually or automatically.
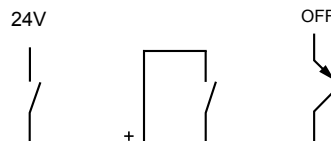
10.2.1 Protective (Safety) Stop Requirements

The required safety circuit integrity level is determined by a risk assessment and will indicate the level of control performance that is acceptable (e.g., Category 4, Control Reliability), see section *10.1 Safety Circuit Integrity and ISO 13849-1 (EN954-1) Safety Circuit Principles* on page 90. The protective stop circuit must control the safeguarded hazard by causing a stop of the hazardous situation(s), and removing power from the machine actuators. This is typically functional stop category 0 or 1 as described by ANSI NFPA 79 and IEC60204-1.

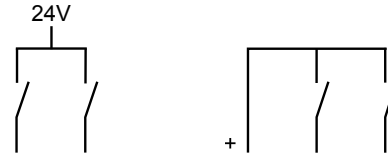## 10.2.2 Protective (Safety) Stop Hookup Options

All figures show the input device in the OFF (Stop) state.

Single-Channel (1 terminal, 2 terminals or PNP device): These circuits can typically meet ISO 13849-1 Category 2 requirements, depending on the safety rating of the device(s). At a minimum, a safety-rated device must be used to achieve a Category 2. The 1-terminal and the PNP device circuits can not detect a short circuit to another source of power. Two-terminal hookup uses pulse monitoring and can detect a short circuit to another source of power.
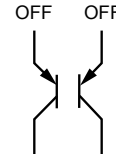
Fault Exclusion must be used to achieve a higher level of safety circuit integrity.
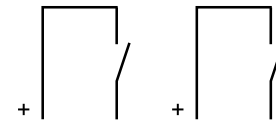
Dual-Channel (2 or 3 terminals): This circuit typically can meet ISO 13849-1 Category 2 or Category 3 requirements, depending on the safety rating and installation of the device(s). Dual Channel 3-terminal hookup uses pulse monitoring and can detect a short circuit to another source of power. Both 2- and 3-terminal hookup can detect a short between channels when the contacts are open longer than 2 seconds.
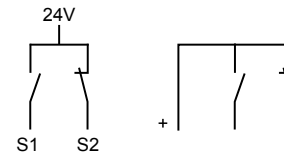
Dual-Channel (PNP device): This circuit can meet ISO 13849-1 Category 2, 3, or 4 requirements depending on the safety rating, installation, and the fault detection (e.g., short circuit) capabilities of the device. The Safety Controller does not provide short circuit detection in this configuration.
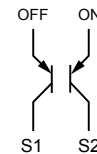
Dual-Channel (4 terminals): This circuit can meet ISO 13849-1 Category 2, 3, or 4 requirements, depending on the safety rating and the installation of the device. This circuit can detect a short circuit between channels or to another source of power.

Complementary (2 or 3 terminals): This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the safety rating and the installation of the device. This circuit can detect a short circuit between channels. In the actuated condition (e.g., S1 open/S2 closed below), a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

Complementary (PNP device): This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the safety rating and the installation of the device. This circuit can detect a short circuit between channels. In the actuated condition (e.g., S1 OFF/S2 ON as shown), a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

10.3 Interlocked Guard or Gate

The Safety Controller safety inputs may be used to monitor electrically interlocked guards or gates.

10.3.1 Safety Circuit Integrity Levels

Requirements vary widely for the level of control reliability or safety category per ISO 13849-1 (EN954-1) in the application of interlocked guards. While Banner Engineering always recommends the highest level of safety in any application, it is the responsibility of the user to safely install, operate and maintain each safety system and comply with all relevant laws and regulations.

The safety performance (integrity) must reduce the risk from identified hazards as determined by the machine's risk assessment. See section *10.1 Safety Circuit Integrity and ISO 13849-1 (EN954-1) Safety Circuit Principles* on page 90 for guidance if the requirements as described by ISO 13849-1 are to be implemented.

In addition to the requirements stated in this section, the design and installation of the interlocking device should comply with ANSI B11.19 or ISO14119.

10.3.2 Safety Interlock Switch Requirements

The following general requirements and considerations apply to the installation of interlocked guards and gates for the purpose of safeguarding. In addition, the user must refer to the relevant regulations to be sure to comply with all necessary requirements.

Hazards guarded by the interlocked guard must be prevented from operating until the guard is closed; a stop command must be issued to the guarded machine if the guard opens while the hazard is present. Closing the guard must not, by itself, initiate hazardous motion; a separate procedure must be required to initiate the motion. The safety switches must not be used as a mechanical or end-of-travel stop.

The guard must be located an adequate distance from the danger zone (so that the hazard has time to stop before the guard is opened sufficiently to provide access to the hazard), and it must open either laterally or away from the hazard, not into the safeguarded area. The guard also should not be able to close by itself and activate the interlocking circuitry. In addition, the installation must prevent personnel from reaching over, under, around or through the guard to the hazard. Any openings in the guard must not allow access to the hazard (see OSHA 29CFR1910.217 Table O-10, ANSI B11.19, ISO 13857, ISO14120/EN953 or the appropriate standard). The guard must be strong enough to contain hazards within the guarded area, which may be ejected, dropped or emitted by the machine.

The safety interlocking switches and actuators must be designed and installed so that they cannot be easily defeated. They must be mounted securely, so that their physical position can not shift, using reliable fasteners that require a tool to remove them.

⚠️ **WARNING: . . . Perimeter Guarding Applications**

If the application could result in a pass-through hazard (e.g., perimeter guarding), either the safeguarding device or the guarded machine's MSCs/MPCEs must cause a Latched response following a Stop command (e.g., interruption of the sensing field of a light curtain, or opening of an interlocked gate/guard). The reset of this Latched condition may only be achieved by actuating a reset switch that is separate from the normal means of machine cycle initiation. The switch must be positioned as described in this document.

Lockout/Tagout procedures per ANSI Z244.1 may be required, or additional safeguarding, as described by ANSI B11 safety requirements or other appropriate standards, must be used if a passthrough hazard can not be eliminated or reduced to an acceptable level of risk. **Failure to observe this warning could result in serious bodily injury or death.**

Positive-Opening Safety Interlocking Switches

Safety interlock switches must satisfy several requirements. Each switch must provide electrically isolated contacts: at minimum, one normally closed (N.C.) contact from each individually mounted switch. The contacts must be of "positive-opening" (direct-opening) design, as described by IEC 60947-5-1, with one or more normally closed contacts rated for safety. Positive-opening operation causes the switch to be forced open, without the use of springs, when the switch actuator is disengaged or moved from its home position (visit *www.banner-engineering.com* for examples).

In addition, the switches must be mounted in a "positive mode," to move/disengage the actuator from its home position and open the normally closed contact when the guard opens.

Magnetically Operated Safety Interlocking Switches

In higher levels of safety performance, the design of a dual-channel magnetic switch typically uses complementary switching, in which one channel is open and one channel is closed at all times. This provides redundancy (two contacts) and diversity (different principles of operation) to minimize the possibility of the loss of the switching function due to common mode failures (e.g., secondary magnetic fields). The circuitry or the Safety Controller that is monitoring the magnetic switch will detect and respond to a failure that results in the loss of the complementary state (e.g., a short circuit between the channels, or a short circuit to other sources of power).

Coded and non-coded magnetic switches affect the ability of the switch to be defeated and to withstand common mode failures. Non-coded switches are easily defeated by the presence of a simple magnetic field and should be mounted in a concealed position. A coded magnetic switch that uses alternating magnetic poles should be used in applications that require higher levels of safety performance.

The switch and its magnet must be mounted a minimum distance from any magnetized or ferrous materials for proper operation. If either the switch or magnet is mounted on a material that can be magnetized (a ferrous metal, such as iron), the switching distance will be affected. This distance will be stated by the manufacturer.

Monitoring Series-Connected Safety Interlock Switches

When monitoring two individually mounted safety switches (as shown in the Category 2 circuit figure), a faulty switch will be detected if it fails to switch as the guard opens. In this case, the Controller will de-energize its Safety Outputs (OSSDs) and disable its reset function until the input requirements are met (i.e., the faulty switch is replaced). However, when multiple safety interlock switches are series-connected, the failure of one switch in the system may be masked or not be detected at all (refer to Category 3 and 4 circuit figures).

Series-connected interlock switch circuits may not meet OSHA Control Reliability or ISO 13849 (EN954-1) Safety Category 4 requirements because of the potential of an inappropriate reset or a potential loss of the safety stop signal. This is due to the typical inability to fault exclude the failure of the safety interlock switch. **A multiple connection of this type should not be used in applications where loss of the safety stop signal or an inappropriate reset can lead to serious injury or death.** The following two scenarios assume two positive-opening safety switches on each guard, both connected in series to switches of a second guard:

1. **Masking of a failure.** If a guard is opened but a switch fails to open, the redundant safety switch will open and cause the Controller to de-energize its outputs. If the faulty guard is then closed, both Controller input channels also close, but because one channel did not open, the Controller will not reset. However, if the faulty switch is not replaced and a second "good" guard is cycled (opening and then closing both of the Controller's input channels), the Controller considers the failure to be corrected. With the input requirements apparently satisfied, the Controller allows a reset. This system is no longer redundant and, if the second switch fails, may result in an unsafe condition (i.e., the accumulation of faults resulting in loss of the safety function).
2. **Non-detection of a failure.** If a good guard is opened, the Safety Controller de-energizes its outputs (a normal response). But if a faulty guard is then opened and closed before the good guard is re-closed, the faulty guard is not detected. This system also is no longer redundant and may result in a loss of safety if the second safety switch fails to switch when needed.

The systems in either scenario do not inherently comply with the safety standard requirements of detecting single faults and preventing the next cycle. In multiple-guard systems using series-connected safety switches, it is important to periodically check the functional integrity of each interlocked guard individually. **Operators, maintenance personnel, and others associated with the operation of the machine must be trained to recognize such failures and be instructed to correct them immediately.**

Open and close each safeguard separately while verifying that the Controller outputs operate correctly throughout the check procedure. Follow each safeguard closure with a manual reset, if needed. If a contact set fails, the Controller will not enable its reset function. If the Controller does not reset, a switch may have failed; that switch must be immediately replaced.

This check must be performed and all faults must be cleared, at a minimum, during periodic checkouts. **If the application can not exclude these types of failures and such a failure could result in serious injury or death, then the series connection of safety switches must not be used.**

Series Connection and Safety Circuit Integrity Considerations

Category 2 Interlocked Guard Circuit

A single-channel interlocked guard application typically provides a Category 2 level of circuit performance, because a short circuit could cause loss of safety function. The principle of fault exclusion must be incorporated into the design and installation to either eliminate, or reduce to an acceptable (minimal) level of risk, the possibility of faults that can result in loss of the safety function.
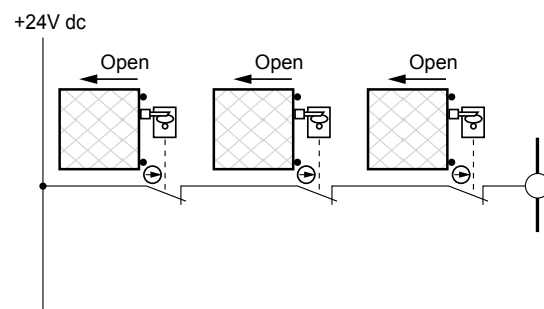

Figure 60. Category 2 Interlocked Guard Circuit

Category 3 Interlocked Guard Circuit

A dual-channel hookup switching +24V dc is typically a Category 3 application, because a single failure does not result in a loss of safety. Loss of the switching action in one channel is detected by the actuation of opening and closing the guard, allowing the monitoring function of the safety inputs to detect the discrepancy between the channels. However, a short circuit between input channels or Safety Outputs may not be detected. It should be noted that an accumulation of faults may cause loss of the safety function. The principle of fault exclusion must be incorporated into the design and installation to either eliminate, or reduce to an acceptable (minimal) level of risk, the possibility of undetected faults or catastrophic/common mode failures that could result in the loss of safety function.
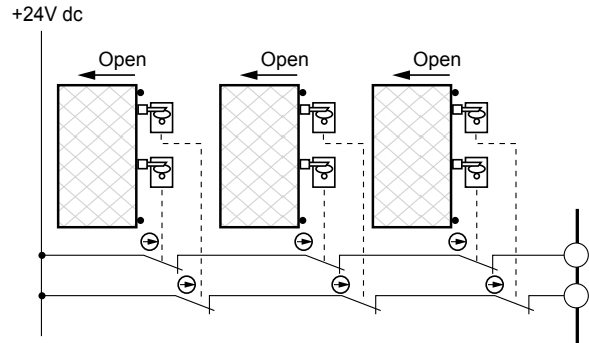

Figure 61. Category 3 Interlocked Guard Circuit

Category 4 Interlocked Guard Circuit

The self-monitoring safety inputs can be interfaced to achieve a Category 4 level of safety. The principle of fault exclusion must be incorporated into the design and installation to either eliminate, or reduce to an acceptable (minimal) level of risk, the possibility of catastrophic/common mode failures that could result in loss of the safety function.
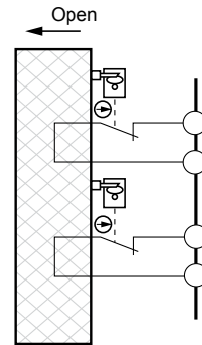

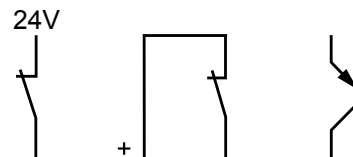**Figure 62. Category 4 Interlocked Guard Circuit**

Interlock Switch Hookup Options

All figures are shown with the gate (guard) in the closed (Run) state.

The safety contact is considered to be the normally closed contact that is of a positive-opening design (unless otherwise noted), normally marked with the ⊖ symbol.

Single-Channel (1 terminal, 2 terminals or PNP device): These circuits can typically meet ISO 13849-1 Category 2 requirements, depending on the safety rating of the device(s). At a minimum, a safety-rated device must be used to achieve a Category 2. The 1-terminal and the PNP device circuits can not detect a short circuit to another source of power. Two-terminal hookup uses pulse monitoring and can detect a short circuit to another source of power. Fault Exclusion must be used to achieve a higher level of safety circuit integrity.
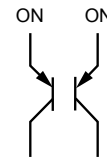
Dual-Channel (2 or 3 terminals): This circuit typically can meet ISO 13849-1 Category 2 or Category 3 requirements, depending on the safety rating and installation of the switch(es). Dual Channel 3-terminal hookup uses pulse monitoring and can detect a short circuit to another source of power. Both 2- and 3-terminal hookup can detect a short between channels when the contacts are open if the short is present longer than 2 seconds.
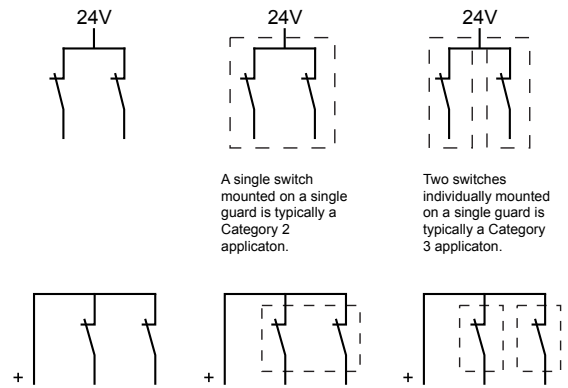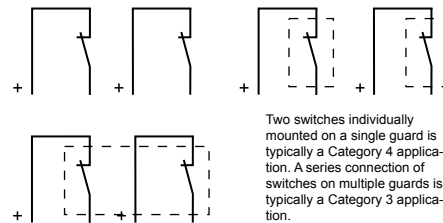

A single switch mounted on a single guard is typically a Category 2 applicaton.

Two switches individually mounted on a single guard is typically a Category 3 applicaton.

Dual-Channel (PNP device): This circuit can meet ISO 13849-1 Category 2, 3, or 4 requirements depending on the safety rating, installation, and the fault detection (e.g., short circuit) capabilities of the device. The Safety Controller does not provide short circuit detection in this configuration.
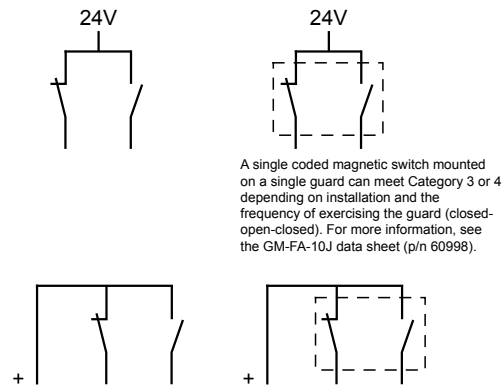

Dual-Channel (4 terminals): This circuit can meet ISO 13849-1 Category 2, 3, or 4 requirements, depending on the safety rating and the installation of the switch(es). This circuit can detect a short circuit between channels or to another source of power.

Two switches individually mounted on a single guard is typically a Category 4 application. A series connection of switches on multiple guards is typically a Category 3 application.
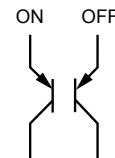
One switch mounted on a single guard is typically a Category 2 application.

Complementary (2 or 3 terminals): This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the safety rating and the installation of the switch(es). This circuit can detect a short circuit between channels. A coded magnetic switch would typically use this style. In the guard-closed condition (as shown), a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

A single coded magnetic switch mounted on a single guard can meet Category 3 or 4 depending on installation and the frequency of exercising the guard (closed-open-closed). For more information, see the GM-FA-10J data sheet (p/n 60998).

Complementary (PNP device): This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the safety rating and the installation of the switch(es). This circuit can detect a short circuit between channels. In the guard-closed condition (as shown), a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

2x Complementary (4 or 5 terminals): This circuit can meet ISO 13849-1 category 4 requirements, depending on the safety rating and the installation of the switches. This circuit can detect a short circuit between channels. A coded magnetic switch would typically use this style. In the guard-closed condition (as shown), a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.
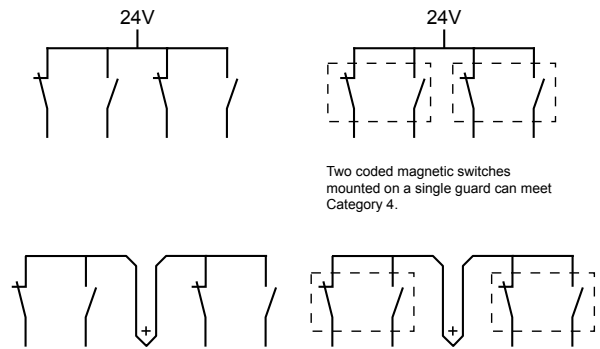
24V   24V

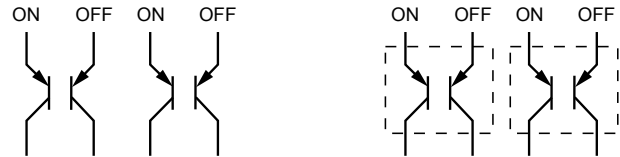Two coded magnetic switches mounted on a single guard can meet Category 4.

2x Complementary (PNP device): This circuit can meet ISO 13849-1 category 4 requirements depending on the safety rating and the installation of the switches. This circuit can detect a short circuit between channels. In the guard-closed condition (as shown), a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

ON OFF ON OFF   ON OFF ON OFF

10.4 Optical Sensor

The Safety Controller safety inputs may be used to monitor optical-based devices that use light as a means of detection.

10.4.1 Safety Circuit Integrity Levels

Requirements vary widely for the level of control reliability or safety category per ISO 13849-1 (EN954-1) in the application of optical safeguarding. While Banner Engineering always recommends the highest level of safety in any application, it is the responsibility of the user to safely install, operate and maintain each safety system and comply with all manufacturer instructions and all relevant laws and regulations.

The safety performance (integrity) must reduce the risk from identified hazards as determined by the machine's risk assessment. See section *10.1 Safety Circuit Integrity and ISO 13849-1 (EN954-1) Safety Circuit Principles* on page 90 for guidance if the requirements as described by ISO 13849-1 (EN954-1) are to be implemented.

In addition to the requirements stated in this section, the design and installation of the optical safeguarding device should comply with ANSI B11.19 or IEC61496 (all parts).

10.4.2 Optical Sensor Requirements

When used as safeguarding, these devices are described by IEC61496-1/-2/-3 as "active Opto-electronic protective device" (AOPD) and "active opto-electronic protective device responsive to diffuse reflection" (AOPDDR).

AOPDs include safety light screens (curtains) and safety grids and points (multiple-/single-beam devices). These devices are described as meeting Type 2 or Type 4 design requirements; a Type 2 device is allowed to be used in a Category 2 application, per ISO 13849-1, and a Type 4 device can be used in a Category 4 application.

AOPDDRs can also be area or laser scanners. The primary designation for these devices is a Type 3, for use in up to Category 3 applications.

> ⚠ **WARNING: . . . Incomplete Information**
>
> Many installation considerations necessary to properly applying these devices are not covered by this document. **Refer to the appropriate device installation instructions to ensure the safe application of the device.**
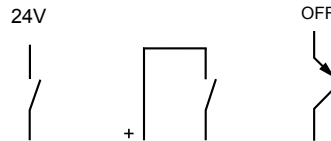
Optical safety devices also must be placed at an appropriate safety distance (separation distance), according to applicable standards. Because these devices vary, it is not practical to list specific calculations here. Refer to the applicable standards and to manufacturer documentation specific to your device for the appropriate calculations; for the purpose of the calculation, Safety Controller default response is 0.010 seconds, plus any additional closed-to-open debounce time. If the debounce time is adjusted, the time in excess of 6 ms (default closed-to-open debounce time) must be added to the stated response; refer to *Specifications* on page 23. Also see sections *6.2 Run Mode* on page 64, Configuration Summary and the OBI flowchart (see *Figure 45. OBI Configuration mode options* on page 63) for instructions on gaining quick access to a specific Controller's response time.

If the application includes a pass-through hazard (a person could pass through the optical device beams and stand undetected on the hazard side), other safeguarding may be required, and manual reset should be selected; see section *4.5 Input Device Resets* on page 33.
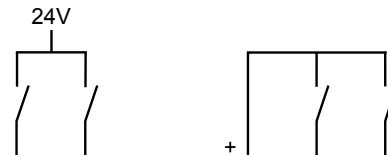
10.4.3 Optical Sensor Generic Hookup

All figures show the optical sensor actuated, in the Normally Open (OFF) state.
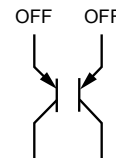
Single-Channel (1 terminal, 2 terminals or PNP device): These circuits can typically meet ISO 13849-1 Category 2 requirements, depending on the safety rating of the device(s). At a minimum, a safety-rated device must be used to achieve a Category 2. The 1-terminal and the PNP device circuits can not detect a short circuit to another source of power. Two-terminal hookup uses pulse monitoring and can detect a short circuit to another source of power. Fault Exclusion must be used to achieve a higher level of safety circuit integrity.
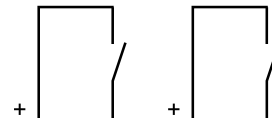

Dual-Channel (2 or 3 terminals): This circuit typically can meet ISO 13849-1 Category 2 or Category 3 requirements, depending on the safety rating and installation of the device(s). Dual Channel 3-terminal hookup uses pulse monitoring and can detect a short circuit to another source of power. Both 2- and 3-terminal hookup can detect a short between channels when the contacts are open longer than 2 seconds.

Dual-Channel (PNP device): This circuit can meet ISO 13849-1 Category 2, 3, or 4 requirements depending on the safety rating, installation, and the fault detection (e.g., short circuit) capabilities of the device. The Safety Controller does not provide short circuit detection in this configuration.

Dual-Channel (4 terminals): This circuit can meet ISO 13849-1 Category 2, 3, or 4 requirements, depending on the safety rating and the installation of the device. This circuit can detect a short circuit between channels or to another source of power.

Complementary (2 or 3 terminals): This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the safety rating and the installation of the device. This circuit can detect a short circuit between channels. In the actuated condition (e.g., S1 open/S2 closed below), a short across the closed contact can

cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.
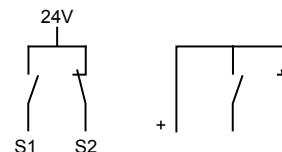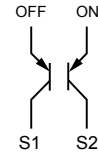
Complementary (PNP device): This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the safety rating and the installation of the device. This circuit can detect a short circuit between channels. In the actuated condition (e.g., S1 OFF/S2 ON as shown), a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

OFF   ON

S1   S2

10.5 Two-Hand Control

The Safety Controller may be used as an initiation device for most powered machinery when machine cycling is controlled by a machine operator.

Using a two-hand control system makes the operator, in effect, a "hostage" while the hazard is present, thus limiting or preventing exposure to the hazard. The two-hand control actuators must be located so that hazardous motion is completed or stopped before the operator can release one or both of the buttons and reach the hazard (see section *10.5.1 Two-Hand Control Separation (Safety) Distance* on page 101).

The Safety Controller safety inputs used to monitor the actuation of the hand controls for two-hand control comply with the functionality of Type III requirements of IEC60204-1 and ISO 13851 (EN 574) and the requirements of ANSI NFPA79 and ANSI B11.19 for two-hand control, which include:

- Synchronous (simultaneous) actuation by both hands within a 500 ms time frame
- Where this time limit is exceeded, both hand controls must be released before operation is initiated
- Continuous actuation during hazardous condition
- Cessation of hazardous condition if either hand control was released
- Release and re-actuation of both hand controls to re-initiate the hazardous motion or condition (i.e., "anti-tie down")
- The appropriate performance level of the safety-related function (e.g., Control Reliability, Category/Performance level, or appropriate regulation and standard, or SIL) as determined by a risk assessment

See section *4.6.2 Two-Hand Control (THC)* on page 36 for more information.

> ⚠️ **WARNING: . . . Point-of-Operation Guarding**
>
> When properly installed, a two-hand control device provides protection only for the hands of the machine operator. **It may be necessary to install additional safeguarding,** such as safety light screens, additional two-hand controls, and/or hard guards, **to protect all individuals from hazardous machinery.**
>
> **Failure to properly guard hazardous machinery can result in a dangerous condition which could lead to serious injury or death.**

> ⚠️ **CAUTION: . . . Hand Controls**
>
> **The environment in which hand controls are installed must not adversely affect the means of actuation.** Severe contamination or other environmental influences may cause slow response or false ON conditions of mechanical or ergonomic buttons. **This may result in exposure to a hazard.**

The level of safety achieved (e.g., ISO 13849-1 Category) depend in part on the circuit type selected. See section *10.5.2 Two-Hand Control Hookup Options* on page 102.

The installation of the hand controls must consider:

- Failure modes that would result in a short circuit, a broken spring(s), mechanical seizure, etc. that would result in not detecting the release of a hand control
- Severe contamination or other environmental influences that may cause slow response when released or false ON condition of the hand control(s), e.g., sticking of a mechanical linkage
- Protection from accidental or unintended operation (e.g., mounting position, rings, guards or shields)
- Minimizing the possibility of defeat (e.g., hand controls must be far enough apart so that they cannot be operated by the use of one arm — typically, not less than 550 mm (21.7") in a straight line, per ISO 13851
- The functional reliability and installation of external logic devices
- Proper electrical installation per NEC and NFPA79 or IEC 60204

When used in single-cycle or single-stroke mode, the machine control must provide an anti-repeat feature so that the operator must release the two-hand control actuators after each machine cycle, before a new cycle can be initiated. In addition to the anti-repeat of the machine control, the Safety Controller input(s) can also be used to halt a machine cycle and help in providing Anti-Repeat Control (see Caution below).

⚠️ **CAUTION: . . . Install Hand Controls to Prevent Accidental Actuation**

Total protection for the two-hand control system from "defeat" is not possible. However, **the user is required by OSHA regulations to arrange and protect hand controls to minimize possibility of defeat or accidental actuation.**

⚠️ **CAUTION: . . . Machine Control Must Provide Anti-Repeat Control**

Appropriate anti-repeat control must be provided by the machine control and is required by U.S. and International standards for single-stroke or single-cycle machines.

10.5.1 Two-Hand Control Separation (Safety) Distance

Both hand controls must be located far enough away from the nearest hazard point that the operator cannot reach the hazard with a hand or other body part before the hazardous motion ceases. This is the "separation distance" ("safety distance"), and may be calculated as follows.

⚠️ **WARNING: . . . Location of Touch Button Controls**

Hand controls must be mounted a safe distance from moving machine parts, as determined by the appropriate standard. It must not be possible for the operator or other non-qualified persons to relocate them. **Failure to establish and maintain the required safety distance could result in serious injury or death. so that the machine's safety-related control system interrupts the circuit to the machine primary control element(s), resulting in a non-hazardous condition.**

Formulas for U.S. Installations	Formula for EU-Certified Installations
For Part-Revolution Clutch Machinery where the machine and its controls allow the machine to stop motion during the hazardous portion of the machine cycle, use the following formula: **Ds = K x (Ts + Tr + Th)**	The formula used to calculate the minimum safety distance (**S**) from the nearest actuator to the danger zone is: **S = (K x T) + C**
For Full-Revolution Clutch Machinery where the machine and its controls are designed to complete a full machine cycle, once activated, use the following formula: **Ds = K x (Tm + Tr + Th)**	

In all cases, where:

Ds = the separation (safety) distance in inches

S = the minimum safety distance in millimeters

K = OSHA/ANSI and ISO 13855 hand speed constant of 1600mm/s (63" per second) (NOTE 1 below)

T = the overall stop time of the machine, measured from the actuation of the sensing function to the final ceasing of all motion.

Ts = the stop time (in seconds) of the machine, measured from the application of the "stop" signal to the final ceasing of all motion, including stop times of all relevant control elements, and measured at maximum machine velocity (see NOTE 2)

Tr = the response time of the Safety Controller as measured from the time a stop is signalled by either hand control. (Controller default response is 0.010 seconds, plus any additional closed-to-open debounce time. If the debounce time is adjusted, the time in excess of 6 ms (=default closed-to-open debounce time) must be added to the stated response; refer to Specifications, Section 2.2.)

Th = the response time of the slowest hand control (from the time when a hand disengages that control until the switch opens; see NOTE 3)

Tm = the maximum time (in seconds) the machine takes to cease all motion after it has been tripped. For full-revolution clutch presses with only one engaging point, **Tm** is equal to the time necessary for one and one-half revolutions of the crankshaft. For full-revolution clutch presses with more than one engaging point, **Tm** is calculated as follows:

Tm = (1/2 + 1/N) x Tcy

where:

N = number of clutch engaging points per revolution

Tcy = time (in seconds) necessary to complete one revolution of the crankshaft

C = the added distance due to depth penetration factor: 250 mm, per ISO 13855. The ISO 13855 "**C**" factor can be reduced to 0 if the risk of encroachment is eliminated, but the safety distance must always be 100 mm or greater.

NOTES:

1. The hand-speed constant (**K**) has been determined by various studies, and although these studies indicate speeds of 1600mm/s (63"/second), 2000 mm/s (79"/second), to more than 2540 mm/s (100"/second), they are not conclusive determinations. The employer should consider all factors, including the physical ability of the operator, when determining the value of K to be used.
2. **Ts** is usually measured by a stop-time measuring device. If the specified machine stop time is used, add at least 20% as a safety factor to account for brake system deterioration. If the stop-time of the two redundant machine control elements is unequal, the slower of the two times must be used for calculating the separation distance.
3. **Th** is usually insignificant for purely mechanical switches. However, Th should be considered for safety distance calculation when using electronic or electromechanical (i.e. powered) hand controls. For Banner Self-checking Touch Buttons (STBs) response time = 0.02 seconds.

10.5.2 Two-Hand Control Hookup Options

The device is shown not actuated or in the Off state. See ISO 13851 for a complete explanation of "Type" designations and ISO 13849-1 Category requirements.

Dual-Channel (2, 3, or 4 terminals): The drawings show a Type IIIa Two-Hand Control circuit as described by ISO 13851, and typically can meet ISO 13849-1 (EN 954-1) Category 1 requirements. A Type IIIb and Category 3 can be achieved if redundant contacts from each hand control are used in each channel, i.e., two each in series, as shown in image D, or with a 3-terminal hookup that uses pulse monitoring and can detect a short circuit to another source of power. Both 2- and 3-terminal hookups can detect a short between channels when the contacts are open if the short is present longer than 2 seconds. The 4-terminal circuit can detect a short circuit between channels or to another source of power (image C).
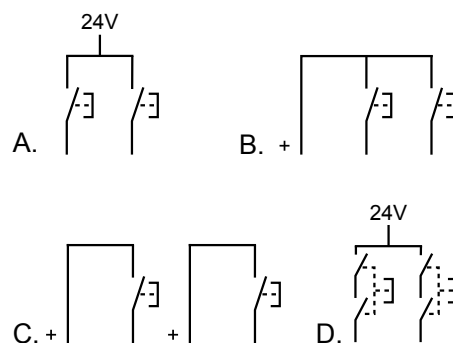
Dual-Channel (PNP device): This circuit is a Type IIIa Two-Hand Control circuit as described by ISO 13851, and typically can meet ISO 13849-1 (EN 954-1) category 1 requirements. The Safety Controller does not provide short circuit detection between channels in this configuration.
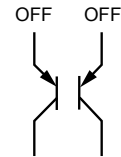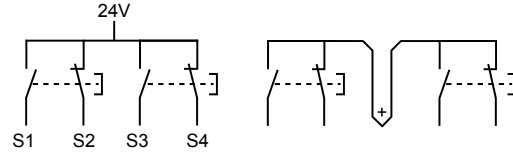
2x Complementary (4 or 5 terminals): These circuits show is a Type IIIc Two-Hand Control circuit as described by ISO 13851, and typically can meet ISO 13849-1 (EN 954-1) Category 4 requirements. In the actuated condition (e.g., S1 open/S2 closed) a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer as specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

Select this option if using Banner Self-checking Touch Button models **STBVR81…**

2x Complementary (PNP device): This image shows a Type IIIc Two-Hand Control circuit as described by ISO 13851, and typically can meet ISO 13849-1 (EN 954-1) Category 4 requirements. In the actuated condition (e.g., S1 open/S2 closed as shown), a short across the closed contact can cause the response time to increase, based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.
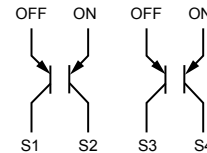
Select this option if using Banner Self-checking Touch Buttons models **STBVP6…**

10.6 Safety Mats

The Safety Controller may be used to monitor pressure-sensitive safety mats and safety edges (sensors).

The purpose of the safety mat input of the Safety Controller is to verify the proper operation of 4-wire presence-sensing safety mats (sensors). Multiple mats may be switched in series to one Controller; 150 ohms maximum per input (see section *10.6.2 Safety Mat Hook-up Options* on page 104). **The Controller is not designed to monitor 2-wire mats, bumpers, or edges (with or without sensing resistors).**

The function is to monitor the contacts (contact plates) and the wiring of one or more safety mat(s) for failures and prevent the machine from restarting if a failure is detected. A reset routine after the operator steps off the safety mat can be provided by the Safety Controller, or, if the Controller is used in auto-reset mode, the reset/restart function must be provided by the machine control system. This prevents the controlled machinery from restarting automatically after the mat is cleared.

> **WARNING: . . . Application of Safety Mats**
>
> Requirements vary widely for the level of control reliability or category as described by ISO 13849-1 (EN 954-1) in the application of safety mats. While Banner Engineering always recommends the highest level of safety in any application, **it is the responsibility of the user to safely install, operate, and maintain each safety system per the manufacturer's recommendations and comply with all relevant laws and regulations.**

Do not use safety mats as a tripping device to initiate machine motion (such as in a presence-sensing device initiation application), due to the possibility of unexpected start or re-start of the machine cycle resulting from failure(s) within the mat and the interconnect cabling.

Do not use a safety mat to enable or provide the means to allow the machine control to start hazardous motion by simply standing on the safety mat (e.g., at a control station). This type of application uses reverse/negative logic and certain failures (e.g., loss of power to the Module) can result in a "false" enable signal.

10.6.1 Safety Mat Requirements

The following are minimum requirements for the design, construction, and installation of four-wire safety mat sensor(s) to be interfaced with the Safety Controller. These requirements are a summary of standards ISO 13856-1, ANSI/RIA R15.06 and ANSI B11.19. The user must review all relevant applicable regulations and standards and apply the Controller and any sensors in full compliance.

Safety Mat System Design and Construction

The safety mat system sensor, Safety Controller, and any additional devices must have a response time that is fast enough to reduce the possibility of an individual stepping lightly and quickly over the mat's sensing surface (less than 100 to 200 ms, depending on the relevant standard).

For a safety mat system, the minimum object sensitivity of the sensor must detect, at minimum, a 30 kg (66 lb.) weight on an 80 mm (3.125") diameter circular disk test piece, anywhere on the mat's sensing surface, including joints and junctions. The effective sensing surface or area must be identifiable and can comprise one or more sensors. The safety mat supplier should state this minimum weight and diameter as the minimum object sensitivity of the sensor.

User adjustments to actuating force and response time are not allowed (ISO 13856-1). The sensor should be manufactured to prevent any reasonably foreseeable failures (e.g., oxidation of the contact elements) which could cause a loss in sensitivity.

The environmental rating of the sensor must meet a minimum of IP54. When the sensor is specified for immersion in water, the sensor's minimum enclosure level must be IP67. The interconnect cabling may require special attention. A wicking action may result in the ingress of liquid into the mat, possibly causing loss of sensor sensitivity. The termination of the interconnect cabling may need to be located in an enclosure that has an appropriate environmental rating.

The sensor must not be adversely affected by the environmental conditions for which the system is intended. The effects on the sensor of liquids and other substances which can be expected must be taken into account. For example, long-term exposure to some liquids can cause degradation or swelling of the sensor's housing material, resulting in an unsafe condition.

The sensor's top surface should be a lifetime non-slip design, or otherwise minimize the possibility of slipping under the expected operating conditions.

The four-wire connection between the interconnect cables and the sensor must withstand dragging or carrying the sensor by its cable without failing in an unsafe manner (e.g., broken connections due to sharp pulls, steady pulls, or continuous flexing). If not, an alternate means must be employed to avoid such a failure, for example, a cable which disconnects without damage and results in a safe situation.

10.6.2 Safety Mat Hookup Options

Pressure-sensitive mats and pressure-sensitive floors must meet the requirements of the category for which they are specified and marked. These categories are defined in ISO 13849-1 (EN 954-1).

The safety mat, its Safety Controller and any output signal switching devices must meet the requirements of safety Category 1 as a minimum. To meet these requirements, the system must at minimum meet the requirements of ISO 13856-1 (EN 1760-1) and the relevant requirements of ISO 13849-1 (EN 954-1).

The Safety Controller is designed to monitor 4-wire safety mats; the Safety Controller is not compatible with two-wire devices (mats, sensing edges, etc., with two wires and a "sensing" resistor).

This circuit typically can meet ISO 13849-1 category 2 or category 3 requirements depending on the safety rating and installation of the mat(s) or other sensor(s). This circuit can detect a short circuit between channels or to another source of power.
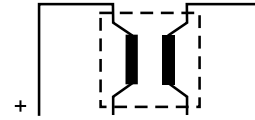
10.6.3 Safety Mat Installation

The mounting surface quality and preparation for the sensor must meet the requirements stated by the sensor's manufacturer. Irregularities in the floor (or other mounting surfaces) may impair the function of the sensor and therefore should be reduced to an acceptable minimum.

The mounting surface should be level and clean. The collection of fluids under or around the sensor should be avoided. The risk of failure due to build-up of dirt, turning-chips, or other material under the sensor(s) or the associated hardware must be prevented. Special consideration should be given to joints between sensors to ensure that foreign material does not migrate under or into the sensor.

Any damage (e.g., cuts, tears, wear, or punctures) to the outer insulating jacket of the interconnect cable (in the presence of fluids) or to any part of the exterior of the sensor must be immediately repaired or replaced. Ingress of material (including dirt particles, insects, fluid, moisture, or turning-chips) which may be present near the mat can cause the sensor to corrode or to lose its sensitivity.

Each sensor must be routinely inspected and tested per the manufacturer's recommendations. Care must be taken not to exceed operational specifications (e.g., the maximum number of switching operations).

Each sensor must be securely mounted to prevent inadvertent movement (creeping) or unauthorized removal. Methods include, but are not limited to, secured edging or trim, tamper-resistant or one-way fasteners, and recessed flooring or mounting surface, in addition to the size and weight of large mats.

Each sensor must be installed to minimize tripping hazards (particularly towards the machine hazard). A tripping hazard may exist when the difference in height of an adjacent horizontal surface is 4 mm (1/8") or more. Tripping hazards must be minimized at joints, junctions, and edges, and when additional coverings are used. Methods include a ground-flush installation of the sensor, or a ramp that does not exceed 20° from horizontal. Use contrasting colors or markings to identify ramps and edges.

The safety mat system must be sized and positioned so that persons cannot enter the hazardous area without being detected, and can not reach the hazard before the hazardous conditions have ceased. Additional guards or safeguarding devices may be required to ensure that exposure to the hazard(s) is not possible by reaching over, under or around the device's sensing surface.

A safety mat installation must take into account the possibility of easily stepping over the sensing surface and not being detected. ANSI and international standards require a minimum depth of field of the sensor surface (the smallest distance between the edge of the mat and hazard) to be from 750 to 1200 mm (30" to 48"), depending on the application and the relevant standard. The possibility of stepping on machine supports or other physical objects to bypass or climb over the sensor also must be prevented.

Safety Mat Separation (Safety) Distance

As a stand-alone safeguard, the sensor must be installed at a separation (safety) distance so that the exterior edge of the sensing surface is at or beyond the separation (safety) distance, unless solely used to prevent start/restart or solely used for clearance safeguarding (see ANSI B11.19, ANSI/RIA R15.06, and ISO 13855).

The separation (safety) distance required for an application depends upon several factors, including the speed of the hand (or individual), the total system stopping time (which includes several response time components), and the depth penetration factor. The user must refer to the relevant standard to determine the appropriate distance or means to ensure that individuals can not be exposed to the hazard(s).
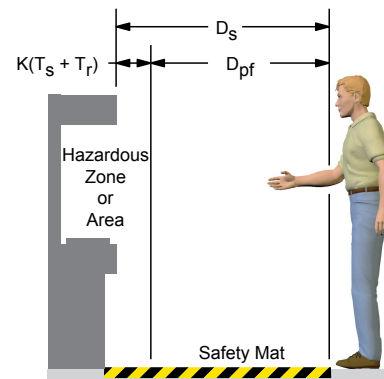

Figure 63. Determining safety distance for the safety mat

Formula for U.S. Installations	Formula for EU-Certified Installations
The formula used to calculate separation (safety) distance (**Ds**) is: **Ds = K x (Ts + Tr) + Dpf**	The formula used to calculate minimum safety distance (**S**) is: **S = (K x T) + C**

in both cases, where:

Ds = the separation (safety) distance in inches.

S = the minimum safety distance in millimeters.

K = the OSHA/ANSI and ISO 13855 hand speed constant of 1600 mm/second (63" per second) (see NOTE 1 below).

T = the overall stop time of the machine, measured from the actuation of the sensing function to the final ceasing of all motion (in essence, **T = Ts + Tr**).

Ts = the overall stop time of the machine, measured from the application of the "stop" signal to the final ceasing of all motion (including stop times of all relevant control elements, and measured at maximum machine velocity) (see NOTE 2 below).

Tr = the response time of the safety mat system: the response time of the sensor(s), as stated by the manufacturer, plus the response time of the Safety Controller as measured from the time a stop is signalled by the safety mat, after it was stepped on. (Controller default response is 0.010 seconds, plus any additional closed-to-open debounce time.) If the debounce time is adjusted, the time in excess of 6 ms (default closed-to-open debounce time) must be added to the stated response; refer to Specifications, Section 2.2.)

Dpf = the added distance due to depth penetration factor: 1200 mm (48"), per ANSI B11.19.

C = the added distance due to depth penetration factor: 1200 mm (48"), per ISO 13855.

NOTES:

1. The hand-speed constant (**K**) has been determined by various studies, and although these studies indicate speeds of 1600mm/s (63"/second), 2000 mm/s (79"/second), to more than 2540 mm/s (100"/second), they are not conclusive determinations. The employer should consider all factors, including the physical ability of the operator, when determining the value of K to be used.
2. **Ts** is usually measured by a stop-time measuring device. If the specified machine stop time is used, add at least 20% as a safety factor to account for brake system deterioration. If the stop-time of the two redundant machine control elements is unequal, the slower of the two times must be used for calculating the separation distance.

10.7 Emergency Stop Push Buttons

 The Safety Controller safety inputs may be used to monitor emergency stop push buttons.

10.7.1 Safety Circuit Integrity Levels

Requirements vary widely for the level of control reliability or safety category per ISO 13849-1 (EN954-1) in the application of emergency stops. While Banner Engineering always recommends the highest level of safety in any application, it is the responsibility of the user to safely install, operate and maintain each safety system and comply with all relevant laws and regulations.

The safety performance (integrity) must reduce the risk from identified hazards as determined by the machine's risk assessment. See section *10.1 Safety Circuit Integrity and ISO 13849-1 (EN954-1) Safety Circuit Principles* on page 90 for guidance if the requirements as described by ISO 13849-1 (EN954-1) are to be implemented.

In addition to the requirements stated in this section, the design and installation of the Emergency Stop device should comply with ANSI NFPA79 or ISO 13850.

WARNING: . . . Emergency Stop Functions

Do not mute or bypass any Emergency Stop device. ANSI NFPA79 and IEC/EN 60204-1 require that the Emergency Stop function remain active at all times. **Muting or bypassing the Safety Outputs will render the emergency stop function ineffective.**

The Safety Controller Emergency Stop configuration prevents muting or bypassing of the E-Stop input(s). However, the user still must ensure that the E-Stop device remains active at all times.

⚠️ **WARNING: . . . Reset Routine Required**

U.S. and international standards require that a reset routine be performed after clearing the cause of a stop condition (e.g., arming an E-stop button, closing an interlocked guard, etc.). **Allowing the machine to restart without actuating the normal start command/device can create an unsafe condition which could result in serious injury or death.**

10.7.2 Emergency Stop Push Button Requirements

As shown in the following figures, the E-stop switch must provide one or two contacts for safety which are closed when the switch is armed. Once activated, the E-stop switch must open all its safety-rated contacts, and must require a deliberate action (such as twisting, pulling, or unlocking) to return to the closed-contact, armed position. The switch must be a "positive-opening" (or direct-opening) type, as described by IEC 60947-5-1. A mechanical force applied to such a button (or switch) is transmitted directly to the contacts, forcing them open. This ensures that the switch contacts will open whenever the switch is activated.

Standards ANSI NFPA 79, ANSI B11.19, IEC/EN 60204-1, and ISO 13850 specify additional emergency stop switch device requirements, including the following:

- Emergency stop push buttons shall be located at each operator control station and at other operating stations where emergency shutdown is required.
- Stop and Emergency stop push buttons shall be continuously operable and readily accessible from all control and operating stations where located. **Do not mute or bypass any E-stop button.**
- Actuators of emergency stop devices shall be colored red. The background immediately around the device actuator shall be colored yellow. The actuator of a push-button-operated device shall be of the palm or mushroom-head type.
- The Emergency stop actuator shall be a self-latching type.

NOTE: Some applications may have additional requirements; comply with all relevant regulations.

Safety Circuit Integrity Levels and Multiple E-Stop Buttons

As part of the required risk assessment for the machine, ANSI NFPA 79 and IEC/EN 60204-1 state that the safety performance (integrity) must reduce the risk from identified hazards as determined by the risk assessment. See section *10.1 Safety Circuit Integrity and ISO 13849-1 (EN954-1) Safety Circuit Principles* on page 90 for guidance if the requirements as described by ISO 13849-1 (EN954-1) are to be implemented.

In addition to the requirements stated above, the design and the installation of the emergency stop device (e.g., switch, button, or rope-pull) must be such that the possibility of a catastrophic failure of the device resulting in the loss of the safety function must be excluded (designed out). The device must comply with ISO 13850 requirements such that the fault exclusions of ISO 13849-2 are applicable. Electromechanical devices that have contacts designed in accordance to IEC 60947-5-1 Annex K and that are installed per manufacturer's instructions are expected to open when the emergency stop device is actuated.

⚠️ **WARNING: . . . Multiple Switching Devices**

Whenever two or more devices are connected to the same safety module (controller):

- **Contacts of the corresponding pole of each switch must be connected together in series. *Never connect the contacts of multiple switches in parallel.*** Such a parallel connection defeats the switch contact monitoring ability of the Module and creates an unsafe condition which could result in serious injury or death.
- **Each device must be individually actuated (engaged), then released (or re-armed) and the safety module reset.** This allows the module to check each switch and its wiring to detect faults.

This check must be performed during the prescribed checkouts. **Failure to test each device individually in this manner could result in undetected faults and create an unsafe condition which could result in serious injury or death.**

Category 2 E-Stop Circuit

A single-channel emergency stop application typically provides a Category 2 level of circuit performance, because a short circuit could cause the loss of the safety function. The principle of fault exclusion must be incorporated into the design and installation to either eliminate, or reduce to an acceptable (minimal) level of risk, the possibility of undetected faults or failures that can result in the loss of the safety function.
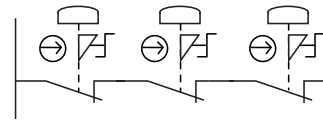

Figure 64. Category 2 E-stop circuit

Category 3 E-Stop Circuit

A dual-channel hookup switching +24V dc is typically a Category 3 application, because a single failure does not result in a loss of safety. Loss of the switching action in one channel is detected by the actuation of the E-stop button, the opening of the second channel, and the monitoring function of the safety inputs. However, a short circuit between input channels or Safety Outputs may not be detected. It should be noted that an accumulation of faults may cause the loss of the safety function.
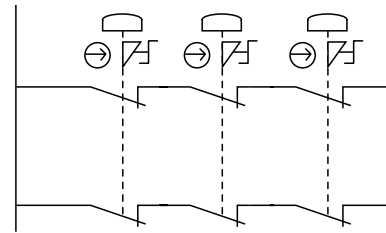
The principle of fault exclusion must be incorporated into the design and installation to either eliminate, or reduce to an acceptable (minimal) level of risk, the possibility of undetected faults or catastrophic failures that could result in the loss of the safety function.

Figure 65. Category 3 E-stop circuit

Category 4 E-Stop Circuit

The self-monitoring safety inputs can be interfaced to achieve a Category 4 application. The principle of fault exclusion must be incorporated into the design and installation to either eliminate, or reduce to an acceptable (minimal) level of risk, the possibility of catastrophic failures or faults that could result in the loss of the safety function.
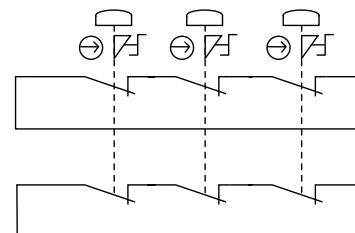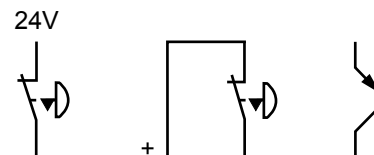

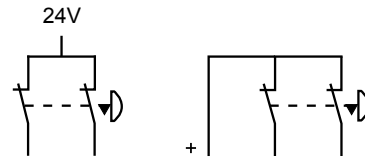**Figure 66. Category 4 E-stop circuit**

Emergency Stop Hookup Options

The device is shown in the armed, or Run, state.

Single-Channel (1 terminal, 2 terminals or PNP device): These circuits can typically meet ISO 13849-1 Category 2 requirements, depending on the design and installation of the switch. At a minimum, the switch must be a safety-rated device in order to achieve Category 2. The 1-terminal and the PNP device can not detect a short circuit to another source of power. Two-terminal hookup uses pulse monitoring and can detect a short circuit to another source of power. Fault Exclusion must be used to achieve higher level of safety circuit integrity.

24V

Dual-Channel (2 or 3 terminals): This circuit typically can meet ISO 13849-1 Category 3 requirements, depending on the design and installation of the switch. Dual-channel 3-terminal hookup uses pulse monitoring and can detect a short circuit to another source of power. Both 2- and 3-terminal hookup can detect a short between channels when the contacts are open if the short is present longer than 2 seconds.

Dual-Channel (PNP device): This circuit can meet ISO 13849-1 Category 2, 3, or 4 requirements depending on the safety rating, installation, and the fault detection (e.g., short circuit) capabilities of the switch. The Safety Controller does not provide short circuit detection in this configuration.
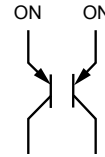
Dual-Channel (4 terminals): This circuit can meet ISO 13849-1 Category 4 requirements, depending on the safety rating and the installation of the switch. This circuit can detect a short circuit between channels or to another source of power.
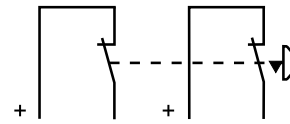
10.8 Rope/Cable Pull

Rope pull (cable pull) emergency stop switches use steel wire "rope"; they provide emergency stop actuation continuously over a distance, such as along a conveyor.

Rope pull emergency stop switches have many of the same requirements as emergency stop push buttons, such as "positive opening" (or direct-opening) operation, as described by IEC 60947-5-1. **See section *10.7 Emergency Stop Push Buttons* on page 106 for additional applicable information.**

It is recommended to use rope pull emergency stop switches that have the capability not only to react to a pull in any direction, but also to slack or a break of the rope. Typically, this is accomplished by separate contacts within the switch. When the rope is properly tensioned, both contacts of the switch are closed. When the rope is pulled, the positive-break contacts open. If the rope breaks or goes slack, the second set of contacts opens; see section *10.8.2 Rope Pull Hookup Options* on page 111.

Some rope pull emergency stop switches provide a latching function that requires a manual reset after actuation. If using a switch that does not provide a latching function after the rope is released, a separate latching circuit is required, which can be provided by the Safety Controller.
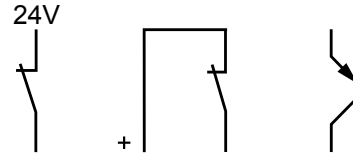
10.8.1 Rope/Cable Pull Installation Guidelines

- The wire rope should be easily accessible and visible along its entire length. Markers or flags may be fixed on the rope to increase its visibility.
- Mounting points, including support points, must be rigid.
- The rope should be free of friction at all supports. Pulleys are recommended.
- Use pulleys when routing the rope around a corner, or whenever direction is changed, even slightly.
- Never run rope through conduit or other tubing.
- Never attach weights to the rope.
- Temperature affects rope tension. The rope expands (lengthens) when temperature increases, and contracts (shrinks) when temperature decreases. Significant temperature variations require frequent checks of the tension adjustment.
- Do not exceed the manufacturer's recommended maximum rope length.
- Mount the switch securely on a solid, stationary surface.
- The anchor point for rope must be solid and stationary, and be able to withstand the constant tension of the rope.
- Each rope pull emergency stop installation should be tested and inspected for proper operation at suitable intervals as determined by the user's risk assessment, based upon severity of the operating environment and the frequency of switch actuations.
- Pulleys and other moving parts associated with the rope should be periodically lubricated.
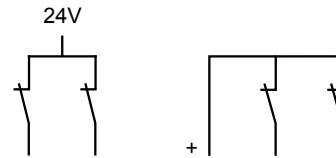
10.8.2 Rope Pull Hookup Options

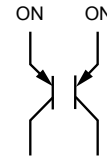The device is shown in the armed (Run) state.

Single-Channel (1 terminal, 2 terminals or PNP device): These circuits can typically meet ISO 13849-1 Category 2 requirements, depending on the design and installation of the switch. At a minimum, to achieve a Category 2, the switch must be a safety-rated device. The 1-terminal and the PNP device can not detect a short circuit to another source of power. Two-terminal hookup uses pulse monitoring and can detect a short circuit to another source of power. Fault Exclusion must be used to achieve higher level of safety circuit integrity.
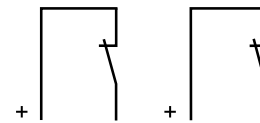
Dual-Channel (2 or 3 terminals): This circuit typically can meet ISO 13849-1 Category 3 requirements, depending on the safety rating and installation of the switch. Dual-channel 3-terminal hook-up uses pulse monitoring and can detect a short circuit to another source of power. Both 2- and 3-terminal hook up can detect a short between channels when the contacts are open if the short is present longer than 2 seconds.
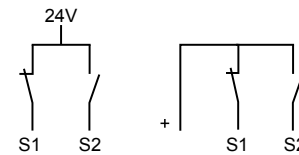
Dual-Channel (PNP device): This circuit can meet ISO 13849-1 Category 2, 3, or 4 requirements depending on the safety rating, installation, and the fault detection (e.g., short circuit) capabilities of the device. The Safety Controller does not provide short circuit detection in this configuration.

Dual-Channel (4 terminals): This circuit can meet ISO 13849-1 Category 2, 3, or 4 requirements, depending on the safety rating and the installation of the device. This circuit can detect a short circuit between channels or to another source of power.

Complementary (2 or 3 terminals): This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the safety rating and the installation of the switch. This circuit can detect a short circuit between channels. In the actuated condition (e.g., S1 closed/S2 open as shown), a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

Complementary (PNP device): This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the safety rating and the installation of the switch. This circuit can detect a short circuit between channels. In the actuated condition (e.g., S1 ON/S2 OFF as shown), a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.
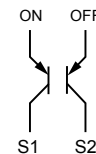
10.9 Enabling Device

An enabling device is a manually operated control that, when continuously actuated, will allow a machine cycle to be initiated in conjunction with a start control. Standards that cover the design and application of enabling devices include:

ISO 12100-1/-2
IEC 60204-1
ANSI/NFPA 79
ANSI/RIA R15.06
ANSI B11.19

See section for more information.

10.9.1 Enabling Device Guidelines

Depending on the application, the use of the enabling device may require supervision and allow only limited machine operation when the individual actuating the device is exposed to a hazardous situation. When the enabling device is in use, the control of machine motion must be prevented from other sources that would override the function of the enabling device. Simply actuating the enabling device should not create a hazard.

An enabling device allows a hazardous situation when continuously actuated in one position only. In any other position, the hazard must be eliminated and the start function be inhibited.

Since an individual's reaction to an emergency situation may be either to release or to tighten the grip, many standards require the use of three-position devices:

- **Position #1:** the OFF function of the switch (actuator is not operated).
- **Position #2:** the enabling function (actuator is operated in its midpoint).
- **Position #3:** the OFF function of the switch (actuator is operated past its midpoint).

Release of, or compression past, the midpoint-enabled position (#2) of the device must initiate an immediate stopping of hazardous motion or situations. It is required that the enabling device be released and re-actuated before machine motion can be reinitiated.

If allowed, for two-position types, the positions are as follows:

- **Position #1:** the OFF function of the switch (actuator is not operated).
- **Position #2:** the enabling function (actuator is operated).

The stop function must be either a functional stop Category 0 or a Category 1 (see ANSI NFPA79 Section 9). The design and installation of the enabling device must consider the ergonomic issues (force, posture, etc.) of sustained activation. A visual means of indicating that the device is active may be required.

Only trained and qualified individuals are allowed to operate the enabling device if it is bypassing other safeguards. Safe work procedures must include, but are not limited to, the use of the device, the associated hazards, and the task requiring the use of the device.

If more than one individual is to be safeguarded by the use of enabling devices, each individual must have their own device. Each enabling device must be concurrently operated before machine motion can be initiated.

The means to return the machine to production mode must be located outside the hazardous area, where it can not be reached from within that area and is guarded against unintended operation. In addition, the reset switch operator must have full view of the entire guarded area and verify that the area is clear of individuals during the reset procedure.

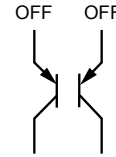## 10.9.2 Enabling Device Hookup Options

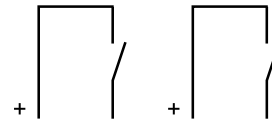The device is shown in the actuated position (Stop) state.

Dual-Channel (2 or 3 terminals): This circuit typically can meet ISO 13849-1 Category 2 or Category 3 requirements, depending on the safety rating and installation of the device(s). Dual Channel 3-terminal hookup uses pulse monitoring and can detect a short circuit to another source of power. Both 2- and 3-terminal hookup can detect a short between channels when the contacts are open longer than 2 seconds.
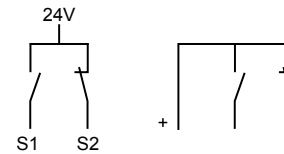
Dual-Channel (PNP device): This circuit can meet ISO 13849-1 Category 2, 3, or 4 requirements depending on the safety rating, installation, and the fault detection (e.g., short circuit) capabilities of the device. The Safety Controller does not provide short circuit detection in this configuration.
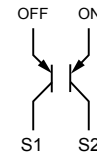
Dual-Channel (4 terminals): This circuit can meet ISO 13849-1 Category 2, 3, or 4 requirements, depending on the safety rating and the installation of the device. This circuit can detect a short circuit between channels or to another source of power.
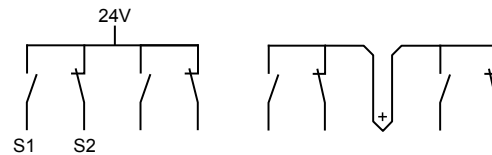
Complementary (2 or 3 terminals): This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the safety rating and the installation of the device. This circuit can detect a short circuit between channels. In the actuated condition (e.g., S1 open/S2 closed below), a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

Complementary (PNP device): This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the safety rating and the installation of the device. This circuit can detect a short circuit between channels. In the actuated condition (e.g., S1 OFF/S2 ON as shown), a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

2x Complementary (4 or 5 terminals): This circuit can meet ISO 13849-1 category 3 or category 4 requirements depending on the design and installation of the enabling device. This circuit can detect a short circuit between channels. In the guard closed condition (e.g., S1 open/S2 closed) a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

2x Complementary (PNP device): This circuit can meet ISO 13849-1 category3 or category 4 requirements depending on the design and installation of the enabling device. This circuit can detect a short circuit between channels. In the actuated condition (e.g., S1 OFF/S2 ON) a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.
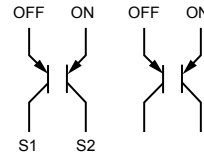
10.10 Bypass Switches (Bypassing Safeguards)

The Safety Controller may be used to monitor switches that initiate the bypassing of a safeguarding device.

"Bypassing" or "overriding" a safeguarding device is the manual interruption or suspension of the normal function of a safeguard under supervisory control. It is typically accomplished by selecting a bypass mode of operation using a key switch to facilitate machine setup, web alignment/adjustments, robot teach, and process troubleshooting.

See section *4.6.5 Bypass Function* on page 38 for more information.

10.10.1 Requirements of Bypassing Safeguards

Requirements to bypass a safeguarding device include*:

- The bypass function must be temporary.
- The means of selecting or enabling the bypass must be capable of being supervised.
- Automatic machine operation must be prevented by limiting range of motion, speed, or power (e.g., only used in inch, jog, or slow-speed modes). Bypass mode must not be used for production.
- Supplemental safeguarding must be provided. Personnel must not be exposed to hazards.
- The means of bypassing must be within full view of the safeguard to be bypassed.
- Initiation of motion should only be through a hold-to-run type of control.
- All emergency stops must remain active.
- The means of bypassing must be employed at the same level of reliability as the safeguard.
- Visual indication that the safeguarding device has been bypassed must be provided and be readily observable from the location of the safeguard.
- Personnel must be trained in the use of the safeguard and in the use of the bypass.
- Risk assessment and risk reduction (per the relevant standard) must be accomplished.
- The reset, actuation, clearing, or enabling of the safeguarding device must not initiate hazardous motion or create a hazardous situation.

* This summary was derived from the following and other sources: ANSI NFPA79, ANSI/RIA R15.06, ISO 13849-1 (EN954-1), IEC60204-1, ANSI B11.19

Bypassing a safeguarding device should not be confused with "muting," which is the temporary, automatic suspension of the safeguarding function of a safeguarding device during a non-hazardous portion of the machine cycle. Muting allows for material to be manually or automatically fed into a machine or process without issuing a stop command. Another term commonly confused with bypassing is "blanking," which desensitizes a portion of the sensing field of an optical safeguarding device (e.g., disabling one or more beams of a safety light curtain so that a specific beam break is ignored).

Safe Working Procedures and Training

The user must also address the possibility that an individual could bypass the safeguarding device and then either fail to reinstate the safeguarding or fail to notify other personnel of the bypassed condition of the safeguarding device; both cases could result in an unsafe condition. One possible method to prevent this is to develop a safe work procedure and ensure personnel are trained and correctly follow the procedure.

Safe work procedures provide a means for individuals to control exposure to hazards through the use of written procedures for specific tasks and the associated hazards. Such procedures also provide base documentation for a training program. Once again, personnel must be trained in the use of the safeguard and the use of the bypass.

Lockout/Tagout

In machine maintenance and servicing situations in which the unexpected energization, start up, or release of stored energy could cause injury, OSHA 29CFR1910.147 "The control of hazardous energy (lockout/tagout)" or ANSI 2244.1 "Lockout/Tagout of Energy Sources" must be adhered to. The user must refer to these standards to ensure that bypassing a safeguarding device does not conflict with the requirements that are contained within that standard.
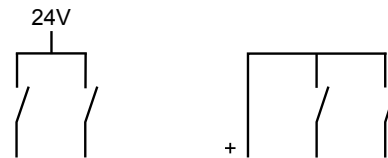
> ⚠ **WARNING: . . . Limit Use of Bypass Function**
>
> **The Bypass function is not intended for production purposes; it is to be used only for temporary or intermittent actions, such as to clear the defined area of a safety light screen if material becomes "stuck".** When Bypass is used, it is the user's responsibility to install and use it according to relevant standards (such as ANSI NFPA79 or IEC/EN60204-1). It must not be possible for the operator or other non-qualified persons to relocate them.
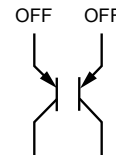
10.10.2 Bypass Switch Hookup Options

The device(s) is shown not actuated (OFF) state.

Dual-Channel (2 or 3 terminals): This circuit typically can meet ISO 13849-1 Category 2 or Category 3 requirements, depending on the safety rating and installation of the device(s). Dual Channel 3-terminal hookup uses pulse monitoring and can detect a short circuit to another source of power. Both 2- and 3-terminal hookup can detect a short between channels when the contacts are open longer than 2 seconds.

Dual-Channel (PNP device): This circuit can meet ISO 13849-1 Category 2, 3, or 4 requirements depending on the safety rating, installation, and the fault detection (e.g., short circuit) capabilities of the device. The Safety Controller does not provide short circuit detection in this configuration.

Dual-Channel (4 terminals): This circuit can meet ISO 13849-1 Category 2, 3, or 4 requirements, depending on the safety rating and the installation of the device. This circuit can detect a short circuit between channels or to another source of power.

Complementary (2 or 3 terminals): This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the safety rating and the installation of the device. This circuit can detect a short circuit between channels. In the actuated condition (e.g., S1 open/S2 closed below), a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

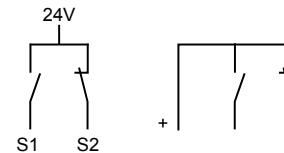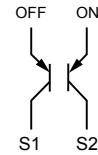**Complementary (PNP device):** This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the safety rating and the installation of the device. This ci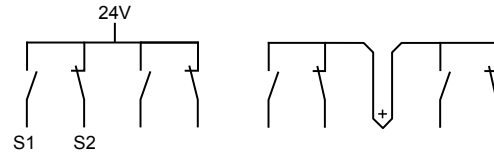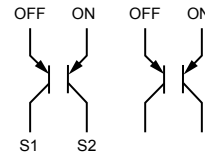rcuit can detect a short circuit between channels. In the actuated condition (e.g., S1 OFF/S2 ON as shown), a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

2x Complementary (4 or 5 terminals): This circuit can meet ISO 13849-1 category 4 requirements depending on the design and installation of the device(s). This circuit can detect a short circuit between channels. In the guard closed condition (e.g., S1 open/S2 closed) a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

2x Complementary (PNP device): This circuit can meet ISO 13849-1 category 4 requirements depending on the design and installation of the device(s). This circuit can detect a short circuit between channels. In the actuated condition (e.g., S1 OFF/S2 ON) a short across the closed contact can cause the response time to increase based on the debounce time. In this situation, the response time could be longer than specified, based on the (selected) debounce time, see section *4.3.2 Safety Input Device Properties* on page 28.

10.11 Mute Sensor Pair

10.11.1 The Muting Function

— The user is required by OSHA and ANSI to arrange, install, and operate the safety system so as to protect personnel and minimize the possibility of defeating the safeguard.

To mute the primary safeguard appropriately, the design of a muting system must:

1. Identify the non-hazardous portion of the machine cycle,
2. Involve the selection of the proper muting devices, and
3. Include proper mounting and installation of those devices.

The Controller can monitor and respond to redundant signals that initiate the mute. The mute then suspends the safeguarding function by ignoring the state of the Input Device that the muting function has been assigned to; e.g., this allows an object or person to pass through the defined area of a safety light screen without generating a stop command. (This should not be confused with blanking, which disables one or more beams in a safety light screen, resulting in larger resolution.)

The mute may be triggered by a variety of external devices. This feature provides a variety of options (see the following sections) to tailor the System to the requirements of a specific application.

A pair of muting devices must be triggered simultaneously (within 3 seconds of one another). This reduces the chance of common mode failures or defeat. Directional muting, in which sensor pair 1 is required to be blocked first, also can reduce the possibility of defeat.

See section *4.6.4 Mute Function* on page 37 for more information.

⚠️ **WARNING: . . . Muting Limitations**

Muting is allowed only during the non-hazardous portion of the machine cycle.

A muting application must be designed so that no single component failure can prevent the stop command or allow subsequent machine cycles until the failure is corrected (per OSHA 1910.217(c)(3)(iii)(d), and ANSI B11.19).

⚠️ **WARNING: . . . Mute Inputs Must Be Redundant**

It is not acceptable to use a single switch, device, or relay with two N.O. contacts for the mute inputs. This single device, with multiple outputs, may fail so that the System is muted at an inappropriate time. **This may result in a hazardous situation.**

10.11.2 Muting Function Requirements

The beginning and end of a mute cycle must be triggered by outputs from either pair of muting devices, depending on the application. The mute device pairs both must have normally open contacts, or have PNP outputs, both of which fulfill the Muting Device Requirements, described below. These contacts must close (conduct) when the switch is actuated to initiate the mute, and must open (non-conducting) when the switch is not actuated and in a power-OFF condition.

The Controller monitors the mute devices to verify that their outputs turn ON within 3 seconds of each other. If the inputs do not meet this simultaneity requirement, a mute condition can not occur.

Several types and combinations of mute devices can be used, including, but not limited to: limit switches, photoelectric sensors, positive-driven safety switches, inductive proximity sensors, and "whisker" switches.

Mute Device Requirements

The muting devices (typically sensors or switches) must, at a minimum, comply with the following requirements:

1. There must be a minimum of two independent hard-wired muting devices.
2. The muting devices must either both have normally open contacts, PNP outputs (both of which must fulfill the input requirements listed in the Specifications), or complementary switching action. At least one of these contacts must close when the switch is actuated, and must open (or not conduct) when the switch is not actuated or in a power OFF condition.
3. The activation of the inputs to the muting function must be from separate sources. These sources must be mounted separately in order to prevent an unsafe muting condition resulting from misadjustment, misalignment, or a single common mode failure. (For example, physical damage to the mounting surface could cause both muting devices to be knocked out of alignment, resulting in false muting input signals.) Only one of these sources may pass through, or be affected by, a programmable logic controller or similar device.
4. The muting devices must be installed so that they can not be easily defeated or bypassed.
5. The muting devices must be mounted so that their physical position and alignment can not be easily changed.
6. It must not be possible for environmental conditions to initiate a mute condition (e.g., extreme airborne contamination).
7. The muting devices must not be set to use any delay or other timing functions (unless such functions are accomplished so that no single component failure prevents the removal of the hazard, subsequent machine cycles are prevented until the failure is corrected, and no hazard is created by extending the muted period).

Examples of Muting Sensors and Switches

⚠️ **WARNING: . . . Avoid Hazardous Installations**

Two or four independent position switches (at M1–M2 or M3–M4) must be properly adjusted or positioned so that they close only after the hazard no longer exists, and open again when the cycle is complete or the hazard is again present. If improperly adjusted or positioned, injury or death could result.

The user has the responsibility to satisfy all local, state, and national laws, rules, codes, and regulations relating to the use of safety equipment in any particular application. It is extremely important to be sure that all appropriate agency requirements have been met and that all installation and maintenance instructions contained in the appropriate manuals are followed.

Photoelectric Sensors (Opposed Mode):

Opposed-mode sensors, which initiate the muted condition when the beam path is blocked, should be configured for dark operate (DO) and have open (non-conducting) output contacts in a power OFF condition. Both the emitter and receiver from each pair should be powered from the same source to reduce the possibility of common mode failures.

Photoelectric Sensors (Polarized Retroreflective Mode):

The user must ensure that false "proxing" (activation due to shiny or reflective surfaces) is not possible. Banner "LP" sensors with linear polarization can greatly reduce or eliminate this effect.

Use a sensor configured for Light Operate (LO or N.O.) if initiating a mute when the retroreflective target or tape is detected (e.g., home position). Use a sensor configured for Dark Operate (DO or N.C.) when a blocked beam path initiates the muted condition (e.g., entry/exit). Both situations must have open (non-conducting) output contacts in a power OFF condition.

Positive-Opening Safety Switches:

Two (or four) independent switches, each with a minimum of one closed safety contact to initiate the mute cycle, are typically used. An application using a single switch with a single actuator and two closed contacts could result in an unsafe situation.

Inductive Proximity Sensors:

Typically, inductive proximity sensors are used to initiate a muted cycle when a metal surface is detected. Due to excessive leakage current causing false ON conditions, two-wire sensors are not to be used. Only three- or four-wire sensors that have discrete PNP or hard-contact outputs that are separate from the input power should be used.

10.11.3 Muting Device Hookup Options

The Controller provides configuration options for the muting devices. One or two pairs of muting devices (typically sensors or switches) must be used; these pairs are designated M1-M2 and M3-M4. In the circuit diagrams below, **it is assumed that each contact or output is being generated by an individual device for category 3 and category 4.**

To meet category 4 requirements for the category 3 hookups shown, "design out" or otherwise eliminate the possibility of a short circuit between muting sensors (input channels); see section *10.1.2 Fault Exclusion* on page 92.

Dual-Channel (2 or 3 terminals): This circuit typically can meet ISO 13849-1 category 2 or category 3 requirements depending on the installation of the mute device(s). Dual-channel 3-terminal hookups use pulse monitoring and can detect a short circuit to another source of power. Both 2- and 3-terminal hookup can detect a short between channels when the contacts are open if the short is present longer than 2 seconds.
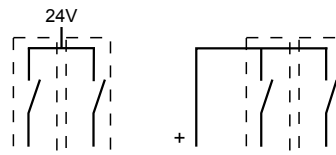
Dual-Channel (PNP device): This circuit can meet ISO 13849-1 category 2 or category 3 requirements depending on the installation and the fault detection (e.g., short circuit) capabilities of the mute device. The Safety Controller does not provide short circuit detection in this configuration.
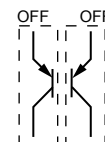
Dual-Channel (4 terminals): This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the installation of the mute device(s). This circuit can detect a short circuit between channels or to another source of power.

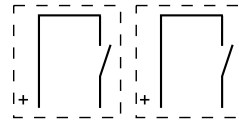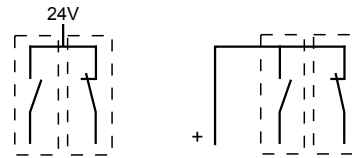**Complementary (2 or 3 terminals):** This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the safety rating and the installation of the output device. This circuit can detect a short circuit between channels. The 3-terminal hookup can detect a short circuit to another source of power, when the contact is closed.

Complementary (PNP device): This circuit can meet ISO 13849-1 category 2, 3, or 4 requirements depending on the safety rating and the installation of the output device. This circuit can detect a short circuit between channels.
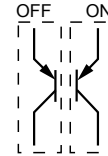
10.11.4 Mute Enable (ME)

The Mute Enable input is a non-safety-rated input. When the input is closed, the Controller will allow a mute condition to occur; opening this input while the System is muted will have no effect.

Typical uses for Mute Enable include:

- To allow the machine control logic to create a "window" for muting to begin;
- To inhibit muting from occurring; or
- To reduce the chance of unauthorized or unintended bypassing or defeat of the safety system.

Simultaneity Timer Reset Function

The Mute Enable input can also be used to reset the simultaneity timer of the mute inputs. If one input is active for longer than three seconds before the second input becomes active, the simultaneity timer will prevent a mute cycle from occurring. This could be due to a normal stoppage of an assembly line that may result in blocking one mute device and the simultaneity time running out.

If the ME input is cycled (closed-open-closed) while one mute input is active, the simultaneity timer is reset, and if the second mute input becomes active within three seconds, a normal mute cycle begins. The timing requirement for the closed-open-closed is similar to the manual reset function. Initially, the input needs to be active (closed) for longer than 1/4 second, then open for longer than 1/4 second, but not longer than 2 seconds, and then must reclose to reset the simultaneity timer. The function can reset the timer only once per mute cycle (i.e., all mute inputs M1–M4 must open before another reset can occur).

10.11.5 Mute Lamp Output (ML)

Some applications require that a lamp (or other means) be used to indicate when the safety device (e.g., light screen) is muted; the Controller provides for this through the Status Outputs. If a monitored output signal is required (see Caution below), Status Outputs O9 and O10 can be configured for a monitored output. The monitored output will prevent the initiation of a mute after an indicator failure is detected. If the application requires compliance with UL 61496, Lamp Monitoring must be selected and the lamp used must meet applicable requirements.

⚠️ **WARNING: . . . Mute Status Must Be Readily Observed**

Indication that the safety device is muted should be provided and be readily observable.

Failure of this indication should be detectable and prevent the next mute, or operation of the indicator should be verified at suitable intervals.

Lamp monitoring must be selected if the application requires compliance with UL 61496.

10.11.6 Muting Time Limit (Backdoor Timer)

The muting time limit (backdoor timer) allows the user to select a maximum period of time that muting is allowed to occur. This feature hinders the intentional defeat of the muting devices to initiate an inappropriate mute. It is also useful for detecting a common mode failure that would affect all mute devices in the application.

The timer begins when the second muting device makes the simultaneity requirement (within 3 seconds of the first device), and will allow a mute to continue for the predetermined time. After the timer expires, the mute ends – no matter what the signals from the mute devices indicate. If the input device being muted is in an OFF state, the mapped OSSD outputs will turn OFF and must be manually reset (if the input device is configured for manual reset).

WARNING: . . . Muting Time Limit

An infinite time for the backdoor timer (i.e., disabling) should be selected only if the possibility of an inappropriate or unintended mute cycle is minimized, as determined and allowed by the machine's risk assessment. It is the user's responsibility to ensure that this does not create a hazardous situation.

10.11.7 Mute on Power-Up

If selected (see section *4.6.4 Mute Function* on page 37), the Mute on Power-Up function will initiate a mute when:

  • Power is applied,
  • The Mute Enable input is closed (if configured),
  • The safety device inputs are active (closed), and
  • Either M1-M2 or M3-M4 (but not all four) are closed.

If Normal or Automatic Power Up mode is configured and all other mute conditions are satisfied, a mute event will start immediately.

If Manual Power Up mode is configured and all other mute conditions are satisfied, the first valid System Reset will result in a mute event.

WARNING: . . . Mute on Power-Up

The Mute on Power-Up function should be used _only_ in applications where:

  • **Muting the System** (M1 and M2 closed) **when power is applied is required**, and
  • **Using it does not, in any situation, expose personnel to any hazard.**

10.11.8 Corner Mirrors, Optical Safety Systems, and Muting

Mirrors are typically used with safety light screens and single-/multiple-beam safety systems to guard multiple sides of a hazardous area. If the safety light screen is muted, the safeguarding function is suspended on all sides. It must not be possible for an individual to enter the guarded area without being detected and a stop command issued to the machine control. This supplemental safeguarding is normally provided by an additional device(s) that remains active while the Primary Safeguard is muted. Therefore, mirrors are typically not allowed for muting applications.

10.11.9 Multiple Presence-Sensing Safety Devices

Muting multiple presence-sensing safety devices (PSSDs) or a PSSD with multiple sensing fields is not recommended unless it is not possible for an individual to enter the guarded area without being detected and a stop command issued to the machine control. As with the use of corner mirrors (see section *10.11.8 Corner Mirrors, Optical Safety Systems, and Muting* on page 120), if multiple sensing fields are muted, the possibility exists that personnel could move through a muted area or access point to enter the safeguarded area without being detected.

For example, in an entry/exit application where a pallet initiates the mute cycle by entering a cell, if both the entry and the exit PSSDs are muted, it may be possible for an individual to access the guarded area through the "exit" of the cell. An appropriate solution would be to mute the entry and the exit with separate safeguarding devices.

 WARNING: . . . Guarding Multiple Areas

DO NOT safeguard multiple areas, with mirrors or multiple sensing fields, if personnel can enter the hazardous area while the System is muted, and not be detected by supplemental safeguarding that will issue a stop command to the machine.

10.11.10 Mute Timing Sequences
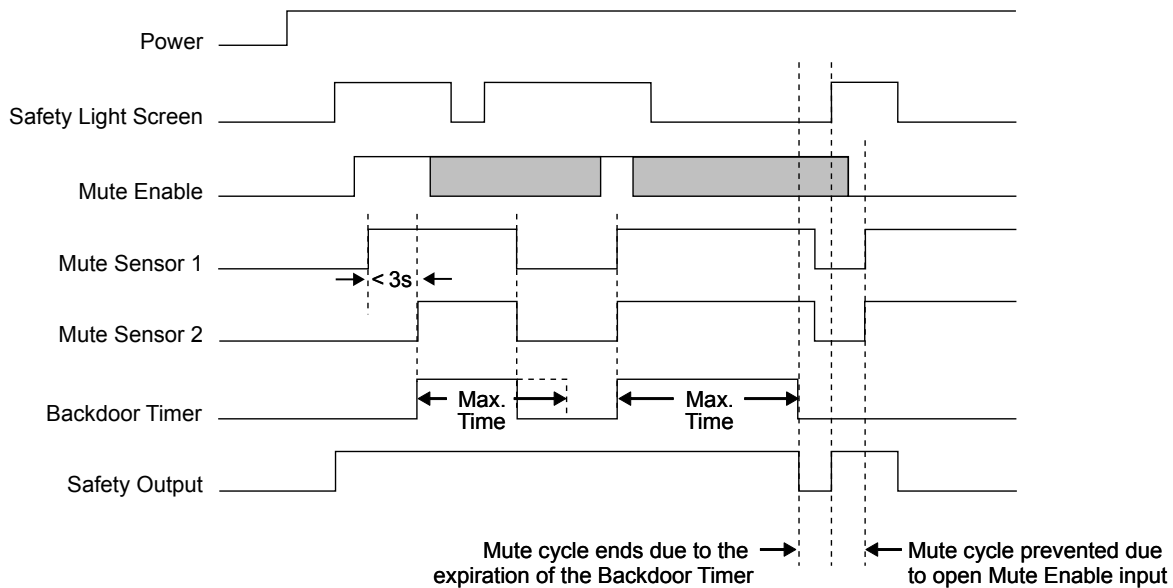
Figure 67. Timing logic: two mute sensors, mute enable, safety light screen and limited mute time. Mutable safety device configured for Auto Reset.
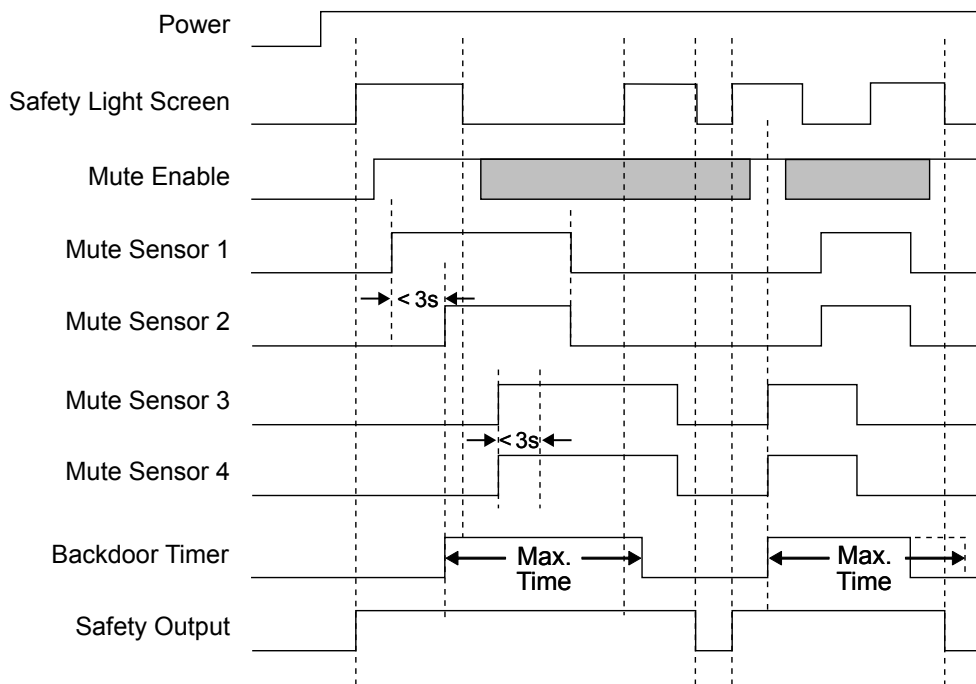
Figure 68. Timing logic: four mute sensors, mute enable, safety light screen and limited mute time. Safety light screen configured for Auto Reset.

When a two-hand control is muted: Once muted, the outputs will remain ON until one of the mute sensors opens, another safety input device causes a stop, the mute time limit (backdoor timer) expires, a lockout occurs, or the Module loses power. Both hand control actuators must be released in order to start another cycle.

Power

2-Hand Inputs

Mute Enable

Mute Sensor 1

< 3s   < 3s

Mute Sensor 2

Backdoor Timer   Max. Time   Max. Time

Safety Output

Mute cycle prevented due to open Mute Enable input

Output remains OFF when mute cycle expires, even though THC is ON

Output remains OFF until THC is cycled

Figure 69. Timing logic: two mute sensors, mute enable, two-hand control and limited mute time
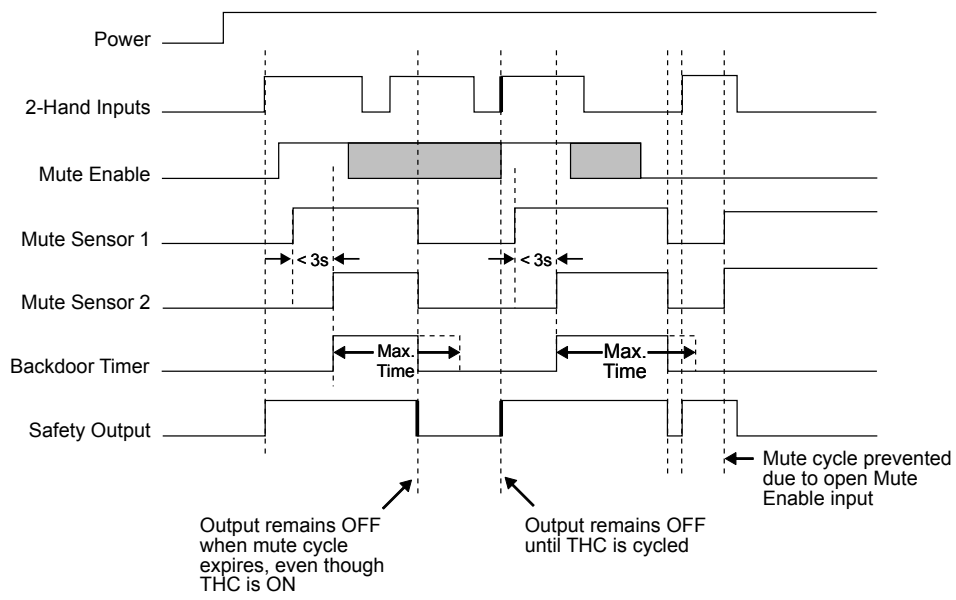
11 Ethernet Reference

Information on Ethernet functionality can also be found in the following sections of this manual:

2.1 Ethernet-Compatible Model on page 9: Description of supported Ethernet protocols

2.5.2 Personal Computer Interface (PCI) on page 14: Accessing Ethernet functionality

2.6.4 Virtual Status Outputs on page 17: See Warning

3.1 Safety Controller Starter Kit Models on page 21: **SC22-3E** model options and accessory Ethernet cordsets

Specifications on page 24: Network Interface specifications

4.9 Virtual Status Outputs on page 52: Detailed description, including the Auto Configure function

Figure 34. PCI Main screen components on page 53: Descriptions of PCI icons and fields

Figure 35. Configuration support documentation (notes not shown) on page 54: Examples of the Ethernet support documents

11.1 Ethernet Setting Access

To access the Ethernet settings, click on the Network Settings icon of the PCI and check the Enable Network Interface box (see figure below). By default, the Safety Controller communicates using Modbus/TCP and EtherNet/IP.

IP Address. The factory default IP address for the Safety Controller is: **192.168.0.254**

Subnet Mask. The factory default Subnet Mask for the Safety Controller is: **255.255.255.0**

Gateway Address. By default, the Safety Controller Gateway Address is **disabled**.

Link Speed and Duplex Mode Options. The following speed and duplex options are available. The factory default setting is **Auto Negotiate**; other options, available by drop-down list, are:

> **100 Mbps / Full Duplex**
> **100 Mbps / Half Duplex**
> **10 Mbps / Full Duplex**
> **10 Mbps / Half Duplex**

Reset Advanced Network Settings. This will cause the advanced network settings to revert back to the factory default settings.

Ethernet TCP. Default port: **502** (TCP502); Device ID: **1**

Figure 70. Ethernet Settings Menu (advanced view shown)

11.2 EtherNet/IP Assembly Objects

Input (T->O) Assembly Objects

The following Instance IDs are supported:
- Instance ID 100 (0x64) with a size (data length) of four 16-bit words. Instance ID 100 is used to access basic information about the Virtual Status Outputs.
- Instance ID 101 (0x65) with a size (data length) of forty-two 16-bit words. Instance ID 101 is used to access advanced information (inclusive of the basic information) about the Virtual Status Outputs.
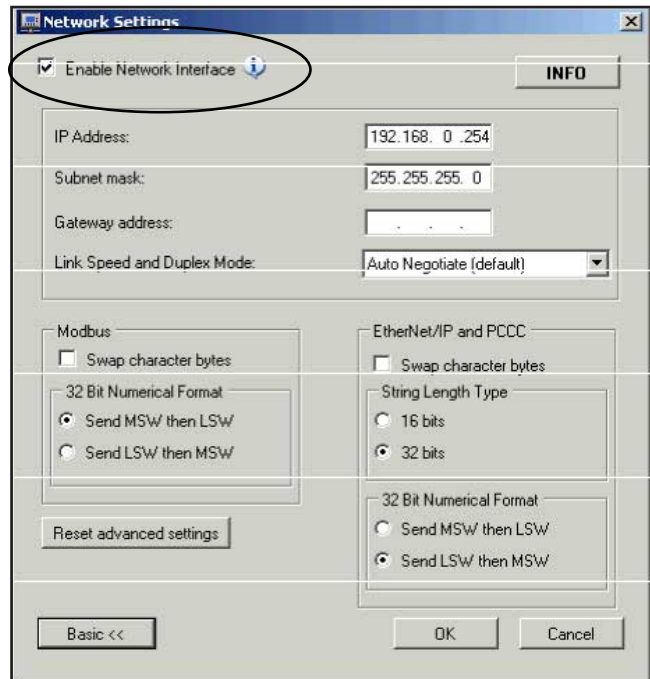
- Instance ID 102 (0x66) with a size (data length) of one hundred forty 16-bit words. Instance ID 102 is used to access fault log information (it provides no Virtual Status Output information). The format of the fault log information starts with a time stamp and may be found in the appropriate Fault Log Support file (see section *11.3 Support Files* on page 125).

Output (O->T) Assembly Object

The Output Assembly Object is not implemented. However, some EtherNet/IP clients require one. If this is the case, use Instance ID 112 (0x70) with a data length of two 16-bit words.

Configuration Assembly Object

The Configuration Assembly Object is not implemented. However, some EtherNet/IP clients require one. If this is the case, use Instance ID 128 (0x80) with a data length of 0.

11.3 Support Files

During installation of the PCI, the following support files are copied to the computer's Program Files directory (C:\Program Files\Banner Engineering\Banner SC\Network Tables), in both .csv and .pdf formats. These files contain network communication information and fault diagnostic information. To access the files, use your computer's navigation tools (e.g., "My Computer" or Windows Explorer).

Any references in this section to files are referring to these support files. All of these files are also available on *www.bannerengineering.com*.

- Fault Index Table (applies to all protocols)
- MB Fault Log
- MB System Info
- EIP Fault Log
- EIP Fault Log Explicit Messages
- EIP System Info Explicit Messages
- PCCC Fault Log
- PCCC System Info

An additional file is included with a .eds format. This file is a simple text file used by network configuration tools to help identify products and easily commission them on a network.

11.3.1 Retrieving Current Fault Information

To retrieve information via network communications about a fault that currently exists, the following procedure may be used:

1. Read the *Fault Flag* location. If this location is set, then a fault exists.
2. Read the *Fault Index* location. The number in this location provides an index value used with a *Fault Index* Table file that contains fault diagnostic information.
3. Access the data in the *Fault Index Table* file using the *Fault Index* number. The data in the file provides a specific fault number, a short fault description, a longer fault description, and a remedy.

11.3.2 Retrieving Fault Log Information

To retrieve information via network communications about faults contained in the fault log, the following procedure may be used:

1. Read the number in the *Seconds Since Power-up* location in the appropriate System Info file. The number indicates, in seconds, how long the Safety Controller has been ON.
2. Compute the real time that the Safety Controller powered up (e.g., hour, minute, second) by using the *Seconds Since Power-up* number with a real time reference.
3. Read the number in the *Time Stamp* location in the *Fault Log* file. The number indicates, in seconds, when the fault happened, relative to a power-up.
4. Compute the real time when the fault occurred by using the *Time Stamp* number with the power-up time of the Safety Controller, computed in Step 2.
5. Read the *Fault Index* location in the *Fault Log* file. The number provides an index value used with a *Fault Index Table* file that contains fault diagnostic information.

6. Access the data in the *Fault Index Table* file using the *Fault Index* number. The data in the file provides a specific fault number, a short fault description, a longer fault description, and a remedy.

11.4 Table Row and Column Descriptions

The following are table row and column descriptions (listed in alphanumeric order) for the register maps found on the PCI, the computer, and the Banner website.

3X/4X (Modbus/TCP)

This column lists the offset for a 30000 Input register or a 40000 Holding register.

Corresponds to Virtual Output # (Fault Log File)

In the Fault Log file, this provides another way to link the fault to an input, output, or system via a Virtual Status Output (if assigned). If, for example, VSO7 is assigned to track a gate switch which has a fault in the wiring, this number will be 7. If Virtual Status Outputs are not assigned, this number will be 0.

Data Type

UINT	unsigned integer - 16 bits
UDINT	unsigned double integer - 32 bits
Word	bit string - 16 bits
Dword	bit string - 32 bits
String	Two ASCII characters per Word (see String Format below)
Octet	reads as each byte translated to decimal separated by a dot
Hex	reads as each nibble translated to hex, paired, and then separated by a space

Date Code Format (System Info File)

YYWWL - Two ASCII characters for the year, followed by two characters for the week indicating the date of manufacture. This is followed by a letter code for the manufacturing location. See "String Format" below for more details.

Fault Flag (Advanced View)

If the particular input or output being tracked causes a lockout, a flag associated with that virtual output will be set to **1**. In Modbus/TCP, this can be read as a Discrete input, Input register, or Holding register.

Fault Index (Advanced View)

If the Fault Flag bit is set for this virtual output, this index number provides a pointer to a particular fault code and message in the Fault Index Table which is provided in a .csv or .pdf file on the CD that came with the Safety Controller.

Function

The function that determines the state of that virtual output. This function is assigned during configuration of the virtual outputs using the PCI software.

Name of I/O/system (Fault Log File)

If the fault is system related, the name "System" or "Internal" will be used. Otherwise, the name of the input or output associated with the fault will be given. Refer to "String Format" below for more details.

Operating Mode (System Info File)

0	Reserved
1	Reserved
2	Manual Power-up Mode — waiting for System Reset

3	Normal Operating Mode (including if I/O faults are present)
4	Configuration Mode
5	Waiting for System Reset (exiting Configuration Mode)
6	System Lockout

REG:BIT

Indicates the offset from 30000 or 40000 followed by the specific bit in the register.

Reserved

Banner has reserved these registers for internal use.

Seconds Since Power-up (System Info File)

The time in seconds since power was applied to the Safety Controller. May be used in conjunction with the time stamp in the Fault Log and a real time clock reference to establish a time that a fault occurred.

SO1/2/3 is OFF Due to… (Advanced View)

A bit will be set high if the input device associated with this virtual output is a reason why the output is off.

String Format (Ethernet/IP and PCCC Protocol)

The default format Ethernet/IP string format has a 32 bit length preceding the string (suitable for ControlLogix). When configuring the network settings using the PCI, you may click on the "Advanced" button to change this setting to a 16 bit length which corresponds to the standard CIP "String". Note, however, that when reading an Input Assembly that includes a string with a 16 bit length, the string length will be preceded by an extra 16 bit word (0x0000).

The string itself is packed ASCII (2 characters per word). In some systems, the character order may appear reversed or out of order. For example, the word "System" may read out as "yStsme". The advanced network settings option in the PCI also allows you to "Swap" characters so that it reads correctly.

String Format (Modbus/TCP Protocol)

The string format is packed ASCII (2 characters per word). In some systems, the character order may appear reversed or out of order. For example, the word "System" may read out as "yStsme". The advanced settings option in the PCI allows you to "Swap" characters so that it reads correctly.

While the string length is provided, it is usually not required for Modbus/TCP systems. Note that if you use string length for Modbus/TCP, the length format corresponds to the settings used for Ethernet/IP.

Time Stamp (Fault Log File)

This is the time since power up, in seconds, when the fault occurred. To use this information, such as for fault analysis, refer to section

Virtual Status Output

The reference designator associated with a particular Virtual Status Output (e.g., VO10 is Virtual Status Output ten).

VO Status

This identifies the location of a bit indicating the status of a Virtual Status Output. In the case of Modbus/TCP, the state of the Virtual Status Output can be read as a discrete input, as part of an input register or holding register. The register given is the offset from 30000 or 40000 followed by the bit location within the register.

12 Glossary

The following terms are used in this manual. Where possible, definitions are from the U.S. and international product performance standards that govern the design of the Safety Controller. For more definitions, visit the online learning segment under Support and Training at *www.bannerengineering.com*.

Automatic reset:

The safety input device control operation setting where the assigned Safety Output will automatically turn on when all of its associated input devices are in the Run state. No manual reset operation is required for the Safety Output to turn on when controlled only by safety input devices configured for Automatic Reset. When Automatic Reset is selected, the input device may be said to be configured to run in Trip mode.

Change of state (COS):

The change of an input signal when it switches from Run-to-Stop or Stop-to-Run state. Dual-channel input signals, have two possible configurable COS settings describe the signal disparity limits that can exist between channels before a fault condition is registered: simultaneous and concurrent. If simultaneity is a requirement or a concern for the application, the user has to ensure that he made the right selection during configuration.

Closed-Open debounce time:

Time to bridge a jittery input signal or bouncing of input contacts to prevent nuisance tripping of the Controller. Adjustable from 6 ms to 100 ms. Default is 50 ms for mute sensors, 6 ms for other devices. A longer closed-open debounce time will also affect and increase the response time of the system and/or the machine response time.

Code validation:

The configuration code file inspection process automatically performed by the Controller to verify that the configuration code has not been corrupted or altered in any way.

Commissioning:

The process of operationally checking a Safety Controller installation on a working machine, in order to verify that the control system is working properly.

Complementary Contacts:

Two sets of contacts which are always in opposite states.

Concurrent:

The setting that permits an indefinite signal disparity between channels, without going into a fault condition. A fault condition is created if the Stop signal changes back to a Run signal before its allied signal changes to the Stop state. Both signals must change from the STOP state to the RUN state before the dual-channel device is considered to be in the RUN state.

Configurable:

Describes a control device that has pre-defined and pre-tested operational parameters that can be selected or enabled, in order to accommodate a variety of control application requirements.

Configuration:

A selected set of pre-defined and pre-tested input and output device properties and logic relationships that define the operating algorithm that the Safety Controller uses to control hazardous machine motion.

Confirmation:

The two-step process where a new or modified configuration is sent to a Controller for code validation, and a copy of the validated code is sent back from the Controller to the PCI for manual parameter (I/O and System settings) verification.

Designated Person:

A person or persons identified and designated in writing, by the employer, as being appropriately trained and qualified to perform a specified checkout procedure.

Diverse-redundancy:

The practice of using components, circuitry or operation of different designs, architectures or functions to achieve redundancy and to reduce the possibility of common mode failures.

Dual-channel:

Having redundant signal lines for each safety input or Safety Output.

Enable a mute time limit:

As soon as a mute sensor is mapped to a safety input device, a default time limit of 30s will show up in the properties window. This time limit can be disabled by unchecking the 'Enable Time Limit' box. This extends the time for the mutable safety device to be muted to infinite.

IEC:

International Electrotechnical Commission

Input/output mapping:

The configurable logic association, created during the configuration process, between the state of the input signals and the corresponding state of the output signals. After an Input is assigned to control one or more outputs, it is said to have been mapped to these outputs and that the outputs have been mapped to this input.

ISO:

International Organization for Standardization

Machine response time:

The time between the activation of a machine stopping device and the instant when the dangerous parts of the machine reach a safe state by being brought to rest.

Manual reset:

The safety input device control operation setting where the assigned Safety Output will turn ON only after a manual reset is performed and if the other associated input devices are in their Run state. When Manual Reset is selected, the input device may be said to be configured to run in Latch mode; meaning that the controlled output has latched to the OFF state and requires a manual reset to turn back ON. This reset is sometimes called a manual latch reset.

OFF signal:

The Safety Output signal that results when at least one of its associated input device signals changes to the Stop state. In this manual, the Safety Output is said to be OFF or in the OFF state when the signal is 0V dc nominally.

ON signal:

The Safety Output signal that results when all of its associated input device signals change to the Run state. In this manual, the Safety Output is said to be ON or in the ON state when the signal is 24V dc nominally.

Open-Closed debounce time:

Time to bridge a jittery input signal or bouncing of input contacts to prevent unwanted start of the machine. Adjustable from 10 ms to 500 ms. Default is 50 ms. A longer open-closed debounce time will also affect the recovery time of the Controller.

Pass-through hazard

A "pass-through hazard" is associated with applications where personnel may pass through a safeguard (which issues a stop command to remove the hazard), and then continues into the guarded area, such as in perimeter guarding. Subsequently, their presence is no longer detected, and the related danger becomes the unexpected start or restart of the machine while personnel are within the guarded area.

PELV:

Protected extra-low voltage power supply, for circuits with earth ground. Per IEC 61140: "A PELV system is an electrical system in which the voltage cannot exceed ELV (25 V ac rms or 60 V ripple free dc) under normal conditions, and under single- fault conditions, except earth faults in other circuits."

Qualified Person:

A person who, by possession of a recognized degree or certificate of professional training, or who, by extensive knowledge, training and experience, has successfully demonstrated the ability to solve problems relating to the subject matter and work.

Run Signal:

The input signal monitored by the Controller that, when detected, causes one or more Safety Outputs to turn ON, if their other associated input signals are also in the Run state. In this manual, either the input device or the device signal is said to be in the Run state.

Safety-rated device:

A device that is designed to an applicable safety standard and when properly applied, reduces the level of risk.

SELV:

Separated or safety extra-low voltage power supply, for circuits without earth ground. Per IEC 61140: "A SELV system is an electrical system in which the voltage cannot exceed ELV (25 V ac rms or 60 V ripple free dc) under normal conditions, and under single-fault conditions, including earth faults in other circuits."

Simultaneous:

The setting that permits a signal disparity between channels within the input device for a limited time, without going into a fault condition. If a signal disparity exists for more than 3 seconds, then a fault condition occurs.

Single-channel:

Having only one signal line for a safety input or Safety Output.

Start up test:

For certain safety devices, like safety light screens or safety gates, it can be an advantage to test the device on power up at least one time for proper function. If 'Start up Test' has been selected for a safety light screen and the light screen is clear at power up, it would be necessary to cycle the light screen one time (from ON to OFF and back to ON), even if the Controller has been configured for auto power up.

Stop Signal:

The input signal monitored by the Controller that, when detected, causes one or more Safety Outputs to turn OFF. In this manual, either the input device or device signal is said to be in the Stop state.

System Reset:

The term used to describe a manual system reset operation required for one or more Safety Outputs to turn ON after Controller power-up, when configured for manual power-up, and lockout (fault detection) situations.

UL:

Underwriter's Laboratory