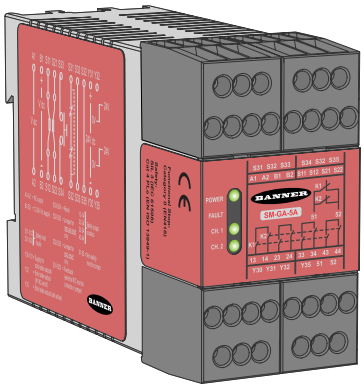
SM-xA-5A Safety Mat Monitoring Modules

Product Manual

SM-GA-5A (12 V DC to 24 V DC/ 115 V AC operation) and SM-HA-5A (12 V DC to 24 V DC/ 230 V AC operation)



- Monitors one 4-wire safety mat, or multiple mats in series
- Selectable Automatic (Auto) Reset or Monitored Manual Reset
- Input monitoring circuit incorporates redundant microprocessors
- Plug-in terminal blocks
- Four normally open output switching channels for connection to control-reliable power interrupt circuits and one normally closed auxiliary output channel for status monitoring
- Two auxiliary solid-state outputs indicate state of internal relays K1 and K2, and state of system (ON = normal operation)
- 6 amp safety output contacts; 5 amp aux. output contacts
- DIN-rail-mountable 45 mm-wide housing
- External device monitoring (one-channel EDM)
- Design complies with UL 991, ISO 13856-1, ISO 13849-1 Category 4: Internal Module, or Category 3 with 4-wire Safety Mat connected

WARNING:

- **Not a stand-alone safeguarding device**
- Failure to properly safeguard hazards according to a risk assessment, local regulations, and applicable standards might lead to serious injury or death.
- This Banner Engineering Corp. device is considered complementary equipment that is used to augment safeguarding that limits or eliminates an individual's exposure to a hazard without action by the individual or others.

Models

Model	Supply Voltage	Outputs	Output Rating
SM-GA-5A	12 V DC to 24 V DC or 115 V AC	4 Normally Open Safety	N.O. Safety Outputs: 6 A
SM-HA-5A	12 V DC to 24 V DC or 230 V AC	1 Normally Closed Aux.	N. C. Aux. Outputs: 5 A
		2 Solid-State Aux.	SS Aux Outputs: 100 mA

Important... Read This Before Proceeding

The user is responsible for satisfying all local, state, and national laws, rules, codes, and regulations relating to the use of this product and its application. Banner Engineering Corp. has made every effort to provide complete application, installation, operation, and maintenance instructions. Please contact a Banner Applications Engineer with any questions regarding this product.

The user is responsible for making sure that all machine operators, maintenance personnel, electricians, and supervisors are thoroughly familiar with and understand all instructions regarding the installation, maintenance, and use of this product, and with the machinery it controls. The user and any personnel involved with the installation and use of this product must be thoroughly familiar with all applicable standards, some of which are listed within the specifications. Banner Engineering Corp. makes no claim regarding a specific recommendation of any organization, the accuracy or effectiveness of any information provided, or the appropriateness of the provided information for a specific application.

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p/n: 122364 Rev. E

Overview

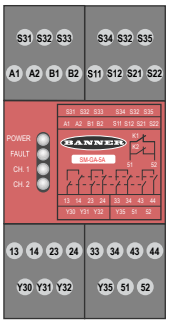
Safety Mat Monitor Modules SM-GA-5A and SM-HA-5A (the "Safety Module") are used to verify the proper operation of 4-wire presence-sensing switching mats (sensors).

Multiple mats may be switched in series to one Safety Module. The Safety Module provides the redundant safety outputs required for creating a control-reliable safety circuit. The Safety Module has two functions:

- To monitor the conductive elements (plates) and the wiring of one or more safety mat(s) for failures and prevent the machine from restarting if any mat or the Module fails
- To provide a reset routine after the operator steps off the safety mat. This prevents the controlled machinery from restarting automatically after the mat is cleared. This necessary reset/restart function is required by ANSI B11 and ANSI NFPA 79 machine safety standards. If the Module is used in auto-reset mode, the reset/restart function must be provided by the machine control system

NOTE: The Safety Module is not designed to monitor 2-wire mats, bumpers, or edges (with or without sensing resistors).

Indicator and Terminal Locations



In operation, the Safety Module monitors the conductive elements (plates) of the pressure-sensitive mat for shorting of those elements (that is, when the mat is stepped on) and certain faults, such as shorts to other sources of power or ground (0 V), or open connecting wires. With a +24 V dc supply, Channel 1 (S11-S12) supplies > 20 V dc that is pulsed low and Channel 2 (S21-S22) supplies < 2 V that is pulsed high; when these two channels are shorted together, the safety output contacts open (13-14, 23-24, 33-34, and 43-44).

If a fault is detected, the Module will lock out, open its safety outputs, and indicate the problem on its LED display, which can be diagnosed by using the troubleshooting table in this document. After repairing the fault, step on the mat and off it again to clear the lockout condition (or cycle power). If the fault has been cleared and no other faults exist, the Fault LED turns OFF and the Module can be reset (if configured for Auto Reset, the safety outputs will turn ON immediately).

The output relays energize automatically if the Module is wired for Auto Reset mode, all sensors are clear, all faults are removed or corrected, and power is applied. The Module requires a manual reset if it is wired for Manual Reset mode.

Application of Pressure-Sensitive Mats and Floors

Pressure-sensitive mats and pressure-sensitive floors must meet the requirements of the category and performance level for which they are specified and marked. These requirements are defined in ISO 13849-1.

The Safety Module is designed to monitor 4-wire safety mats; it is not recommended to use two-wire devices (mats, sensing edges, etc., with two wires and a "sensing" resistor). While the Module internally meets or exceeds ISO 13849-1 Category 4 requirements, the overall safety circuit performance is determined by the mat(s) or other sensor(s) connected to the Module.

WARNING:

- **Application of Safety Mats**
- Failure to follow these instructions could result in serious injury or death.
- Safety Mat application requirements vary for the level of control reliability or category and performance level as described by ISO 13849-1 and ISO 13856. Although Banner Engineering Corp. always recommends the highest level of safety in any application, the user is responsible 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), because of 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 (for example, at a control station). This type of application uses reverse/negative logic and certain failures (for example, loss of power to the Module) can result in a false enable signal.

Safety Circuit Integrity and ISO 13849-1 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 integrity (performance) must be incorporated into its design. Standards that detail safety performance levels include ANSI B11.19 Performance Criteria for Safeguarding and ISO 13849-1 Safety-Related Parts of a Control System.

Safety Circuit Integrity Levels

Safety circuits in International and European standards have been segmented into Categories and Performance Levels, depending on their ability to maintain their integrity in the event of a failure and the statistical likelihood of that failure. ISO 13849-1 details safety circuit integrity by describing circuit architecture/structure (Categories) and the required performance level (PL) of safety functions under foreseeable conditions.

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 Category 3 or 4 and/or Performance Level “d” or “e” (see ANSI B11.19).

Perform a risk assessment to ensure appropriate application, interfacing/hookup, and risk reduction (see ANSI B11.0 or ISO 12100). The risk assessment must be performed to determine the appropriate safety circuit integrity in order to ensure that the expected risk reduction is achieved. This risk assessment must take into account all local regulations and relevant standards, such as U.S. Control Reliability or European "C" level standards.

Fault Exclusion

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

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 requirements of ISO 13849-1/-2.

Requirements vary widely for the level of safety circuit integrity in safety applications (that is, Control Reliability or Category/Performance Level) per ISO 13849-1. Although Banner Engineering Corp. always recommends the highest level of safety in any application, the user is responsible to safely install, operate, and maintain each safety system and comply with all relevant laws and regulations.

WARNING:
- **Determine the safety category**
- The design and installation of the safety devices and the means of interfacing of those devices could greatly affect the level of safety circuit integrity.
- Perform a risk assessment to determine the appropriate safety circuit integrity level or safety category, as described by ISO 13849-1, to ensure that the expected risk reduction is achieved and that all applicable regulations and standards are met.

Safety Mat Requirements

WARNING:
- **Ensure the safety circuit integrity**
- The safety circuit integrity level is affected by the design and installation of the safety devices and the means of interfacing with those devices.
- Perform a risk assessment to determine the appropriate safety circuit integrity level or category to ensure the expected risk reduction is achieved and all applicable regulations and standards are in compliance (see ANSI B11.0 and ANSI B11.19, ISO 12100 and ISO13849-1 or the applicable standards).

The following are minimum requirements for the design, construction, and installation of four-wire safety mat sensor(s) to be interfaced with the Safety Mat Monitoring Module. These requirements are a summary of standards ISO 13856-1 and ANSI/B11.19. Review all relevant applicable regulations and standards and apply the Module and any sensors in full compliance.

Design and Constructions

The safety mat system [Safety Module, sensor(s), and any additional devices] must have a response time that is fast enough (less than 100 to 200 ms, depending on the relevant standard) to reduce the possibility of an individual stepping lightly and quickly over the mat's sensing surface, without being detected.

For a safety mat system, the minimum object sensitivity of the sensor must detect, at a minimum, a 30 kg (66 lb.) weight on an 80 mm (3.125 in) diameter circular disk test piece, anywhere on the mat's sensing surface, including at 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 (for example, oxidation of the contact elements) which could cause a loss in sensitivity.

The sensor must meet a minimum environmental rating of IP54. When the sensor is specified for immersion in water, the sensor's minimum environmental rating must be IP67. Special attention may be required to the interconnect cabling; 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 Module interconnect cables and the sensor must withstand dragging or carrying the sensor by its cable without failing in an unsafe manner (for example, 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.

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. Avoid the collection of fluids under or around the sensor. Prevent the risk of failure due to build-up of dirt, turning-chips, or other material under the sensor(s) or the associated hardware. Give special consideration to joints between sensors to ensure that foreign material does not migrate under or into the sensor.

Immediately repair or replace any damage (for example, 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. 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.

Routinely inspect and test the sensor(s) per the manufacturer's recommendations. Care must be taken not to exceed operational specifications (for example, the maximum number of switching operations).

Securely mount the sensor(s) 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.

Install the sensor(s) to minimize tripping hazards (particularly towards the hazard). A tripping hazard may exist when the difference in height of an adjacent horizontal surface is 4 mm (1/8 in) or more. Minimize tripping hazards at joints, junctions, 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.

Size and position the safety mat system 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.

Take into account the possibility of easily stepping over the sensing surface without 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 between 750 mm to 1200 mm (30 in to 48 in), depending on the application and the relevant standard. Prevent the possibility of stepping on machine supports or other physical objects to bypass or climb over the sensor.

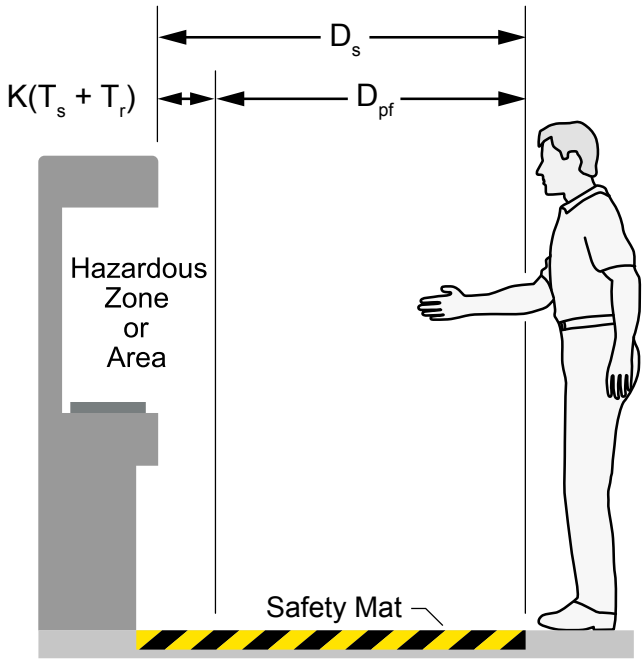
Safety Distance (Minimum Distance)

As a stand-alone safeguard, the safety mat must be installed at a safety distance (minimum distance) so that the exterior edge of the sensing surface is at or beyond that distance, unless it is solely used to prevent start/restart, or solely used for clearance safeguarding (see ANSI B11.19, ANSI/RIA R15.06, and ISO 13855).

The safety distance (minimum distance) required for an application depends on 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. Refer to the relevant standard to determine the appropriate distance or means to ensure that individuals cannot be exposed to the hazard(s).

If an individual can cross completely over the sensor and be no longer detected, supplemental safeguarding or other means should be used to prevent unexpected startup and exposure to a hazard. At a minimum, the safety mat system (or the machine control) must be manually reset and require re-initiation of the normal actuating means prior to the start or re-start of the machine cycle.

Determining safety distance for the safety mat



U.S. Applications

The Safety Distance formula, as provided in ANSI B11.19:

$$D_s = K \times (T_s + T_r) + D_{pf}$$

D_s

the Safety Distance (in inches)

K

the OSHA/ANSI recommended hand-speed constant (in inches per second), in most cases is calculated at 63 in/s, but may vary between 63 in/s to 100 in/s based on the application circumstances;

not a conclusive determination; consider all factors, including the physical ability of the operator, when determining the value of K to be used.

T_s

the overall stop time of the machine (in seconds) from the initial stop signal to the final ceasing of all motion, including stop times of all relevant control elements and measured at maximum machine velocity.

T_s 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.

T_r

the response time of the safety mat system: Module response time plus the response time of the sensor(s), as stated by the manufacturer.

D_{pf}

the added distance due to the penetration depth factor

equals 48 in, per ANSI B11.19

European Applications

The Minimum Distance Formula, as provided in EN 13855:

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

S

the Minimum Distance (in millimeters)

K

the EN 13855 recommended hand-speed constant (in millimeters per second), in most cases is calculated at 1600 mm/s, but may vary between 1600 mm/s to 2500 mm/s based on the application circumstances;

not a conclusive determination; consider all factors, including the physical ability of the operator, when determining the value of K to be used.

T

the overall machine stopping response time (in seconds), from the physical initiation of the safety device to the final ceasing of all motion.

C

the added distance due to the depth penetration factor equals 1200 mm, per EN 13855.

Mechanical Installation

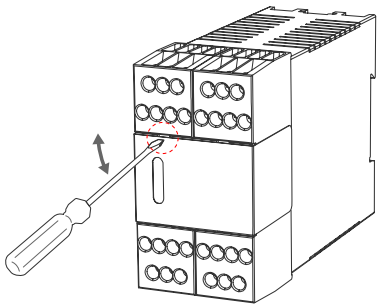
The SM-xA-5A Modules must be installed inside an enclosure.

It is not designed for exposed wiring. It is the user's responsibility to house the SM-xA-5A Modules in an enclosure with NEMA 3 (IEC IP54) rating, or better. The SM-xA-5A Modules mounts directly to standard 35 mm DIN rail.

Heat Dissipation Considerations: For reliable operation, ensure that the operating specifications are not exceeded. The enclosure must provide adequate heat dissipation so that the air closely surrounding the SM-xA-5A Modules does not exceed the maximum operating temperature stated in the Specifications. Methods to reduce heat build-up include venting, forced airflow (for example, exhaust fans), adequate enclosure exterior surface area, and spacing between modules and other heat sources.

Remove or Install a Terminal Block

Remove the Terminal Block



To remove a terminal block:

1. Insert a small screwdriver into the slot between the cover label and the terminal block.
2. Using the screwdriver, pry to loosen the terminal block.
3. Slide the terminal block out from the face of the module.

To reinsert the terminal block:

1. Carefully slide the dovetail on the terminal block into the slot on the housing.
2. Press on the terminal block until it is fully seated. A "click" should be heard when the terminal block is properly installed.

Electrical Installation

WARNING:

- **Risk of electric shock**
- Use extreme caution to avoid electrical shock. Serious injury or death could result.
- Always disconnect power from the safety system (for example, device, module, interfacing, etc.), guarded machine, and/or the machine being controlled before making any connections or replacing any component. Lockout/tagout procedures might be required. Refer to OSHA 29CFR1910.147, ANSI Z244-1, or the applicable standard for controlling hazardous energy.
- Make no more connections to the device or system than are described in this manual. Electrical installation and wiring must be made by a Qualified Person[1] and must comply with the applicable electrical standards and wiring codes, such as the NEC (National Electrical Code), NFPA 79, or IEC 60204-1, and all applicable local standards and codes.

Electrical installation must be made by qualified personnel and must comply with NEC (National Electrical Code), ANSI/NFPA 79 or IEC/EN 60204-1, and all applicable local standards. It is not possible to give exact wiring instructions for a device that interfaces to a multitude of machine control configurations. The following guidelines are general in nature. Perform a risk assessment to ensure appropriate application, interfacing/hookup, and risk reduction (see ANSI B11.0 or ISO 12100).

The Safety Module is powered by either a 12 V DC to 24 V DC supply at 4 W or an ac supply (115 V AC, model SM-GA-5A, or 230 V AC, model SM-HA-5A) at 7 VA. The sensor circuit, which monitors the conductive elements (plates) of the safety mat, consists of two channels (A and B) that issue a stop command (that is, open the safety outputs) when an individual steps onto the safety mat, shorting the two channels together.

Since the Safety Module functions by detecting the short circuit between the channels, resistance to electrical current flow in the contact monitoring circuit impacts the operation and the safety of the system. Total resistance includes contact resistance of the internal mat contacts, the number of mats in the circuit, and the wire resistance of the interconnect cables and connections.

The only limitation on the number of mats that can be connected in series is the amount of resistance. The total resistance within each channel can not exceed 250 ohms when the Module is supplied by 24 V DC or an AC power supply, and no more than 25 ohms when the Module is supplied by 12 V DC.

The resistance between the channels when shorted together (that is, when an individual steps on the mat) can not exceed 150 ohms (24 V DC or an AC supply) or 10 ohms (12 V DC supply).

WARNING:

- **Connect two or more devices to the same safety module (controller) in series**
- Connecting devices in parallel defeats the switch contact monitoring ability of the module and creates an unsafe condition that could result in serious injury or death.
- Failure to test each device individually in this manner could result in undetected faults and create an unsafe condition that could result in serious injury or death.
- Connect the contacts of the corresponding pole of each switch in series. Never connect the contacts of multiple switches in parallel. Individually actuate (engage) each device, then release (or re-arm) and reset the safety module. This allows the module to check each switch and its wiring to detect faults. Perform this check during the prescribed checkouts.

NOTE: The minimum amount of time for the Module to detect a STOP condition is 15 milliseconds. This "recovery time" (OFF state) is required for the internal integrity tests to complete, allowing a reliable reset to occur. A lockout may occur if the Module is cycled too quickly. To clear the lockout, the inputs must be re-cycled, meeting the minimum recovery time requirements.

Safety Mat Device Checkout - Prior to Module Connection

Before connecting the safety mat to the Module, verify the installation does not exceed the maximum resistance specification. Check the mat with an ohmmeter to verify that none of the following values are exceeded.

1. Check the leadwire resistance.
   a. Keeping track of which wire goes to which terminal, disconnect all 4 wires from the terminal blocks.
   b. Measure and record the resistance between the wires going to terminals S11 and S12: _____ (=Ra)
   c. Measure and record the resistance between the wires going to terminals S21 and S22: _____ (=Rb)
   d. Review the values for Ra and Rb.

If both Ra and Rb are	Then
Less than 50 ohms	The lead resistance is acceptable for all supply voltages; check the mat resistance next. If it is 50 ohms or more for either, continue below.
Less than 500 ohms	The lead resistance is acceptable for an AC supply and for a DC supply >20 V. If resistance is acceptable for your supply, check the mat resistance next. If

Continued on page 6

[1] 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.

Continued from page 5

If both Ra and Rb are	Then
	resistance is not acceptable, lower the lead resistance by shortening the leadwires or by increasing the wire diameter. Recheck Ra and Rb.

2. Check the mat resistance.
    a. Step on the mat in various locations while taking the measurements listed below.
    b. Measure and record the highest observed resistance between S11 and S12: _____ (=Rc)
    c. Measure and record the highest observed resistance between S21 and S22: _____ (=Rd)
    d. Review the values for Rc and Rd.

If both Rc and Rd are	Then
Less than 10 ohms	The mat and leadwire resistance is acceptable for all supply voltages and the safety mat checkout is complete.
Less than 150 ohms AND you are using an AC supply or DC supply greater than 20 V DC	The mat and leadwire resistance is acceptable and the safety mat checkout is complete.
Any other value	If resistance is not acceptable, proceed to the next step.

3. Connect the ohmmeter to the wires to be connected to S11-S12 (Channel A), and note the resistance.
4. Connect the ohmmeter to the wires to be connected to S21-S22 (Channel B), and note the resistance.
5. Perform the following calculation: Rm = (Rc + Rd - Ra - Rb)/2.

If Rm is:	Then
Less than 10 ohms	The mat resistance is acceptable for all supply voltages; the safety mat checkout is complete.
Less than 150 ohms AND you are using an AC supply or DC supply greater than 20 V DC	The mat resistance is acceptable and the safety mat checkout is complete.
Any other value	The resistance in the mat is too high for safe operation. Replace the safety mat. Repeat the mat resistance checkout for the new mat.

WARNING:
- **Do not exceed the maximum resistance between the monitoring channels.**
- Decreased performance of the safety mat could occur when the maximum resistance between the monitoring channels (usually due to degradation of the mat) is exceeded. Failure to verify the quality and specifications of the mat could result in serious injury or death.
- Verify the quality and specifications of the mat being connected to this Module, and perform periodic checks of the safety mat's resistance, as described in the Safety Mat Initial Checkout.

Connection of Reset Switch

The reset circuit switch can be any mechanical switch, such as a normally open momentary switch, or a two-position key switch. The reset switch must be capable of reliably switching 12-30 V DC at 20-50 mA. As shown in the wiring diagrams, the reset switch connects between Safety Module terminals S33 and S34.

The reset switch must be located outside of – and not be accessible from – the area of dangerous motion, and must be positioned so that any area of dangerous motion may be observed by the switch operator during the reset procedure. See warning below.

A switch with a PNP (sourcing) can be used to reset the module. The PNP output would supply 24 V to S34.

WARNING:
- **Install reset switches properly**
- Failure to properly install reset switches could result in serious injury or death.
- Install reset switches so that they are accessible only from outside, and in full view of, the safeguarded space. Reset switches cannot be accessible from within the safeguarded space. Protect reset switches against unauthorized or inadvertent operation (for example, through the use of rings or guards). If there are any hazardous areas that are not visible from the reset switches, provide additional safeguarding.

Automatic Reset Mode

The Safety Module may be configured (via wiring) for automatic reset. If no MSC contacts are monitored, install a jumper between terminals S32 and S35 (see wiring diagrams). The Safety Module will reset (and its outputs energize) as soon as the switch returns to its armed (closed-contact) position.

Automatic reset is useful for some automated processes. **However, if automatic reset is used, it is necessary to provide a means of preventing resumption of hazardous machine motion, until an alternate reset procedure is performed.** The alternate procedure must include a reset/restart switch, located outside the area of dangerous motion and positioned so that any area of dangerous motion may be observed by the switch operator during the reset procedure. See warning.

WARNING:
- **Reset routine required**
- Failure to prevent the machine from restarting without actuating the normal start command/device can create an unsafe condition that could result in serious injury or death.
- Do not allow the machine to restart without actuating the normal start command/device. Perform the reset routine after clearing the cause of a stop condition, as required by U.S. and international standards.

Connection to the Machine to be Controlled

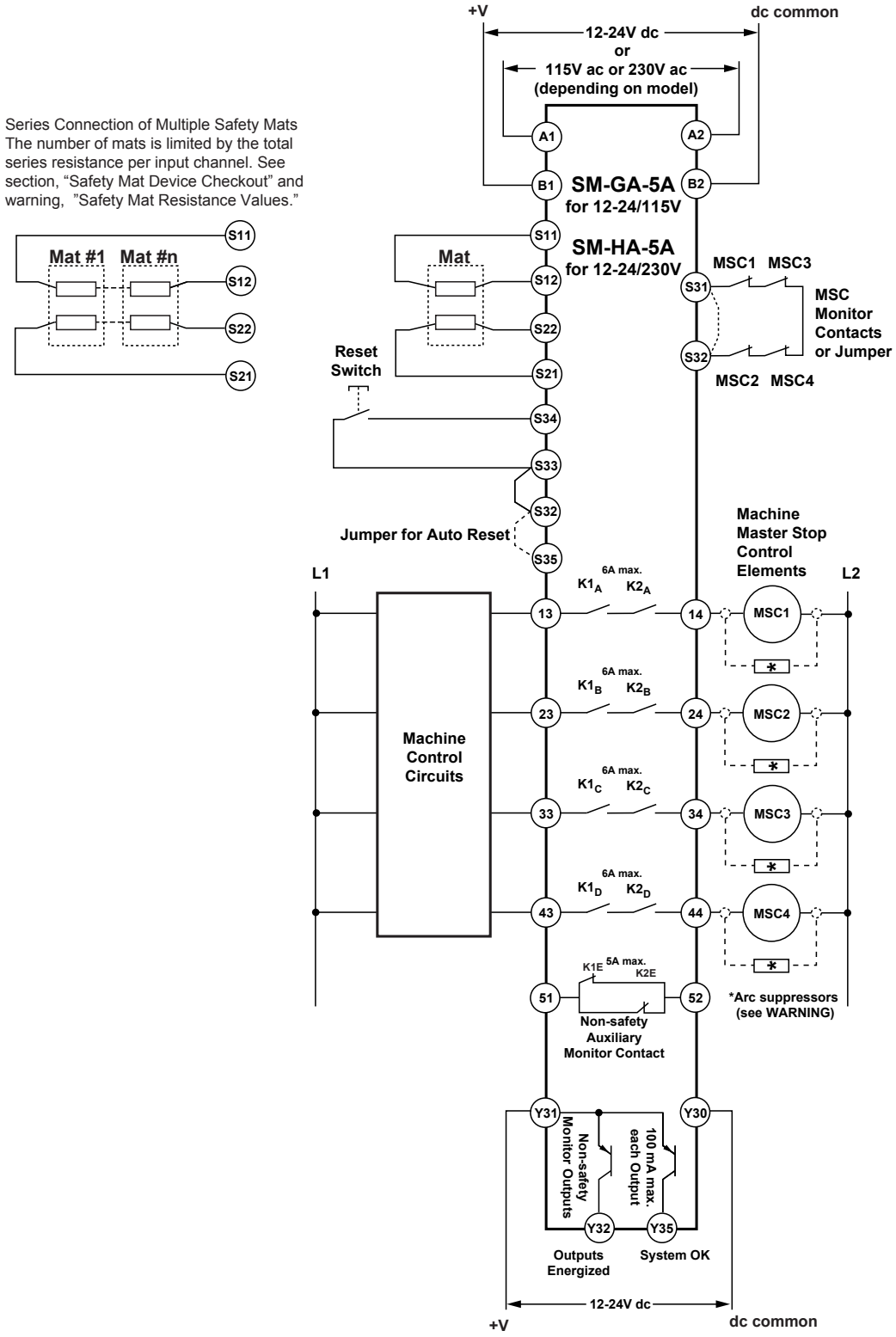
The machine hookup diagram shows a generic connection of the Safety Module's redundant output circuits to the master stop control elements (MSCs). An MSC is defined as an electrically powered device, external to the Safety Module, which stops the machinery being controlled by immediately removing electrical power to the machine and (when necessary) by applying braking to dangerous motion. This stopping action is accomplished by removing power to the actuator of either MSC.

External Device Monitoring

To satisfy the requirements of Control Reliability (OSHA and ANSI), Category 3 and 4 of ISO 13849-1, the Master Stop Control Elements (MSCs) must each offer a normally closed, forced-guided (mechanically linked) monitor contact. Connect one normally closed monitor contact from each master stop control element in series to S31 and S32.

In operation, if one of the switching contacts of either MSC fails in the energized condition, the associated monitor contact will remain open. Therefore, it will not be possible to reset the Safety Module. If no MSC-monitor contacts are monitored, a jumper must be installed between terminals S31-S32, as shown in the hookup drawings. It is the user's responsibility to ensure that any single failure will not result in a hazardous condition and will prevent a successive machine cycle.

Wiring to a Four-Wire Safety Mat



WARNING:
- **Properly install arc or transient suppressors**
- Failure to follow these instructions could result in serious injury or death.
- Install any suppressors as shown across the coils of the machine primary control elements. Do not install suppressors directly across the output contacts of the safety or interface module. In such a configuration, it is possible for suppressors to fail as a short circuit.

WARNING:
- **Interfacing master stop controls**
- Failure to follow these instructions could result in serious injury or death.
- Unless the same degree of safety is maintained, never wire an intermediate device(s) (PLC, PES, PC) between the safety module outputs and the master stop control element it switches such that a failure causes a loss of the safety stop command or the failure allows the safety function to be suspended, overridden, or defeated.
- When forced-guided, mechanically linked relays are added as intermediate switching devices, a normally closed (N.C.) forced-guided monitor contact from each relay must be added to the series feedback loop or properly wired external device monitoring channel.

Overvoltage Category II and III Installations (EN 50178 and IEC 60664-1)

The SM-xA-5A Modules is rated for Overvoltage Category III when voltages of 1 V to 150 V AC/DC are applied to the output relay contacts. It is rated for Overvoltage Category II when voltages of 151 V to 250 V AC/DC are applied to the output relay contacts and no additional precautions are taken to attenuate possible overvoltage situations in the supply voltage. The SM-xA-5A Modules can be used in an Overvoltage Category III environment (with voltages of 151 V to 250 V AC/DC) if care is taken either to reduce the level of electrical disturbances seen by the SM-xA-5A Modules to Overvoltage Category II levels by installing surge suppressor devices (for example, arc suppressors), or to install extra external insulation in order to isolate both the SM-xA-5A Modules and the user from the higher voltage levels of a Category III environment.

For Overvoltage Category III installations with applied voltages from 151 V to 250 V AC/DC applied to the output contact(s): the SM-xA-5A Modules may be used under the conditions of a higher overvoltage category where appropriate overvoltage reduction is provided. Appropriate methods include:
- An overvoltage protective device
- A transformer with isolated windings
- A distribution system with multiple branch circuits (capable of diverting energy of surges)
- A capacitance capable of absorbing energy of surges
- A resistance or similar damping device capable of dissipating the energy of surges

When switching inductive AC loads, it is good practice to protect the SM-xA-5A Modules outputs by installing appropriately-sized arc suppressors. However, if arc suppressors are used, they must be installed across the load being switched (for example, across the coils of external safety relays), and never across the SM-xA-5A Modules's output contacts.

Auxiliary Monitor Contact/Solid-State Monitor Outputs Connection

The action of the auxiliary monitor contact, terminals 51-52, inversely "follows" the action of the safety outputs. Two additional solid-state monitor outputs (at terminals Y32 and Y35) each are capable of switching up to 100 mA at 12- 24 V dc. The output at terminal Y32 follows the action of the output circuits (K1 and K2); the output at terminal Y35 opens (low signal) when there is a loss of power or a fault is detected. **These outputs are to be used only for nonsafety functions** (typically, to communicate the status of the Safety Module to a programmable logic controller). See the appropriate figure for wiring information.

Safety Mat Module Initial Checkout Procedure

WARNING: Checkouts for Multiple Safety Devices. If more than one safety mat is series-connected to one Safety Mat Monitor Module, run this checkout procedure individually for each mat.

CAUTION:
- **Disconnect power prior to checkout**
- Dangerous voltages might be present along the module wiring barriers whenever power to the machine control elements is on.
- Before performing the initial checkout procedure, disconnect all power from the machine to be controlled. Exercise extreme caution whenever machine control power is or might be present. Always disconnect power to the machine control elements before opening the enclosure housing of the module.

1. Remove power to the machine control elements, if it is already connected.
2. Apply force to the mat's sensing area, using a test piece as outlined in the mat manufacturer's literature, or the appropriate standard.
3. Apply input power to the Safety Mat Monitor Module at terminals A1 and A2 or B1 and B2. Verify that only the Power indicator LED is ON.
4. Remove the test piece from the safety mat (clear the mat sensing area).
5. **Manual Reset mode**: Ch1 and Ch2 indicators should be flashing. Close and reopen the Reset switch.
6. Verify that the Ch1 and Ch2 indicators both come ON. If only one indicator comes ON or if any indicator is flashing, refer to the Troubleshooting section for more information. Return to step 2 after correcting the problem.
7. Apply force in several locations (using a test piece) to the mat's sensing area, per the mat manufacturer's recommendations. Verify that the Ch1 and Ch2 indicators turn OFF simultaneously. If either indicator does not go OFF, disconnect the input power and check all wiring. Return to step 2 after correcting the problem.
8. Repeat for each safety mat individually.
9. Close and secure the enclosure. Apply power to the machine control elements and perform the following Periodic Checkout Procedure.

Safety Mat System Periodic Checkout Procedure

Verify the functioning of the safety mat monitoring system periodically to ensure proper operation (see also the machine manufacturer's recommendations).

WARNING:
Checkouts for Multiple Safety Devices. If more than one safety mat is series-connected to one Safety Mat Monitor Module, run this checkout procedure individually for each mat.

1. With the machine running, apply force to the mat's sensing area, using a test piece as described in the mat manufacturer's literature, or the appropriate standard. Verify that the machine stops within the expected time period.
2. Remove the test piece from the safety mat. Verify that the machine does not restart.
3. Close and then open the Reset switch (if using Manual Reset mode). Verify that the machine cycle can be restarted by normal initiation.
4. Repeat for each safety mat individually.

Specifications

Supply Voltage and Current	A1-A2: 115 V AC (model SM-GA-5A) or 230 V AC (model SM-HA-5A)	±15%, 50/60 Hz

BI-B2: 11 V DC to 27.6 V DC

Connect the Safety Module 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, according to EN IEC 60950, NEC Class 2.

Power Consumption

Approx. 4 W / 7 VA

Supply Protection Circuitry

Protected against transient voltages and reverse polarity

Overvoltage Category

Output relay contact voltage of 1 V to 150 V AC/DC: category III

Output relay contact voltage of 151 V to 250 V AC/DC: category III, if appropriate overvoltage reduction is provided, as described earlier.

Pollution Degree

2

Solid-State Outputs

Two non-safety solid-state DC outputs

Output circuits require application of +12 to 24 V DC ± 15% at terminal Y31; DC common at Y30.

Max. switching current: 100 mA at 12 to 24 V DC

Both outputs are protected against short circuits.

Output at Y32 monitors state of outputs – conducts (output high) when both K1 and K2 are energized.

Output at Y35 conducts (output high) when in normal operation (no lockout).

Output Response Time

35 ms max. (25 ms typical)

Input Requirements

Safety mat normally open contact must be capable of switching 20 to 100 mA at 12 to 30 V DC; and must be closed > 25 ms for a valid stop command.

V AC or 24 V DC Supply: Max. lead resistance 250 ohms; max. contact resistance: 150 ohms.

12 V DC Supply: Max. lead resistance 25 ohms; max. contact resistance: 10 ohms.

Reset switch: must have one normally open contact capable of switching 20 to 50 mA at 12 to 30 V DC.

OFF-State Recovery Time

350 ms maximum

Indicators

3 green LED indicators: Power ON, Channel 1 (high side), Channel 2 (low side)

1 red LED indicator: indicates a fault condition (see Troubleshooting)

Construction

Polycarbonate housing. Rated NEMA 1, IEC IP20

Mounting

Mounts to standard 35 mm DIN rail track. Safety Module must be installed inside an enclosure rated NEMA 3 (IEC IP54), or better.

Vibration Resistance

10 to 60 Hz at 0.35 mm peak displacement per UL 991

60 to 150 Hz at 5 g max.

Operating Conditions

Temperature: 0 °C to +50 °C (+32 °F to +122 °F), (surrounding air)

90% at +50 °C maximum relative humidity (non-condensing)

Safety Ratings

Category 4 PI e per EN ISO 13849-1

SIL3 per IEC 61508

PFHd 5.8 × 10^{-8}

Proof Test Interval: 20 years

Certifications

EMERGENCY STOP DEVICE 29YL LISTED

IND. CONT. EQ. 447Y LISTED

Relay Outputs

4 normally open (N.O.) output channels and 1 normally closed (N.C.) output

Each normally open output channel is a series connection of contacts from two forced-guided (mechanically linked) relays, K1-K2. The normally closed Aux. output channel is a parallel connection of contacts from two forced-guided relays, K1-K2.

Contacts: AgNi, 5 µm gold-plated

Low Current Rating: The 5 µm gold-plated contacts allow the switching of low current/low voltage. In these low-power applications, multiple contacts can also be switched in series (for example, “dry switching”). To preserve the gold plating on the contacts, do not exceed the following max. values at any time:

Minimum voltage: 1 V AC/DC	Maximum voltage: 60 V
Minimum current: 5 mA AC/DC	Maximum current: 300 mA
Minimum power: 5 mW (5 mVA)	Maximum power: 7 W (7 VA)

High Current Rating: If higher loads must be switched through one or more of the contacts, the minimum and maximum values of the contact(s) changes to:

Certification	Minimum	Maximum
EMERGENCY STOP DEVICE 29YL LISTED IND. CONT. EQ. 447Y LISTED	Voltage: 15 V AC/DC	N.O. Safety Contacts (13-14, 23-24, 33-34, 43-44): 250 V AC / 24 V DC, 6 A resistive B300, Q300 (UL508)
	Current: 250 mA AC/DC	N.C. Auxiliary Contact (51-52): 250 V AC / 24 V DC, 5 A resistive B300, Q300 (UL508)
	Power: 5 W (5 VA)	
Certification	**Minimum**	**Maximum — IEC60947-5-1**
CE	Voltage: 15 V AC/DC	N.O. Safety Contacts: AC-1: 250 V AC, 6 A; DC-1: 24 V DC, 6 A AC-15: 230 V AC, 3 A; DC-13: 24 V DC, 4 A
	Current: 250 mA AC/DC	N.C. Auxiliary Contact: AC-1: 250 V AC, 5 A; DC-1: 24 V DC, 5 A AC-15: 230 V AC, 2 A; DC-13: 24 V DC, 4 A
	Power: 5 W (5 VA)	

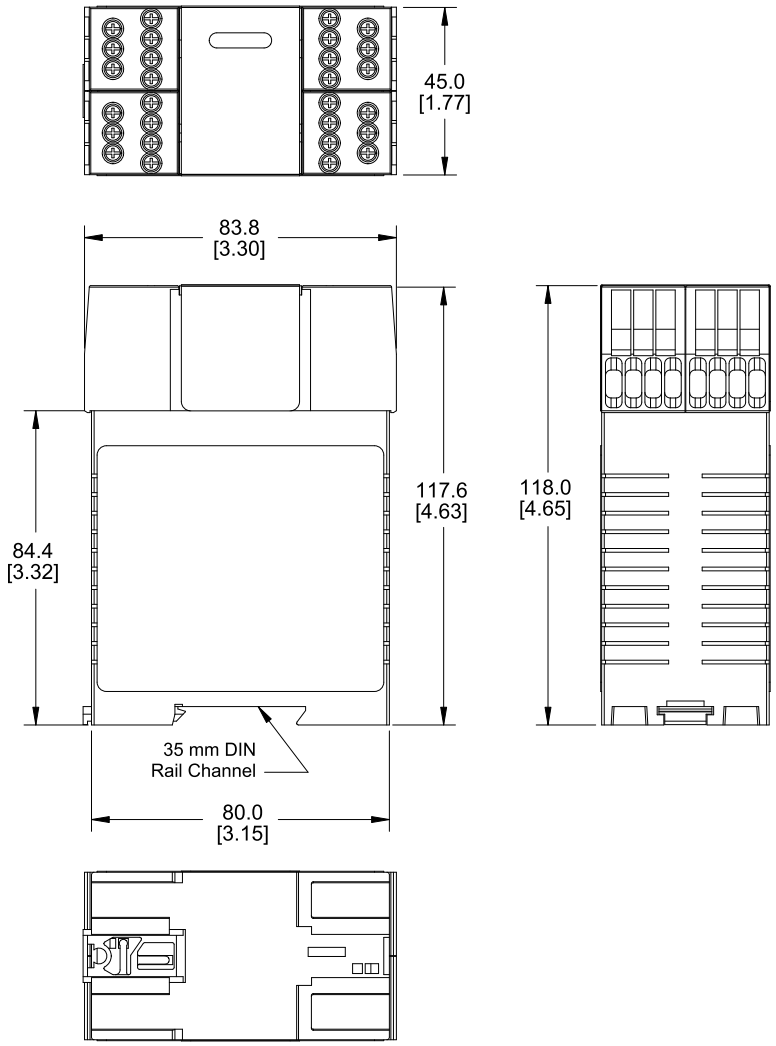
Mechanical life: > 50,000,000 operations

Electrical life: 150,000 cycles @ 1500 VA; 1,000,000 cycles @ 450 VA; 2,000,000 cycles @ 250 VA; 5,000,000 cycles @ 125 VA

NOTE: Transient suppression is recommended when switching inductive loads. Install suppressors across load. Never install suppressors across output contacts (see Warning, Wiring of Arc Suppressors).

Dimensions

All measurements are listed in millimeters [inches], unless noted otherwise. The measurements provided are subject to change.



Certifications and Standards

EU Declaration of Conformity (DoC)

Banner Engineering Corp. herewith declares that these products are in conformity with the provisions of the listed directives and all essential health and safety requirements have been met. For the complete DoC, please go to www.bannerengineering.com.

Product	Directive
SM-GA-5A and SM-HA-5A Safety Mat Monitoring Modules	EU: Machinery Directive 2006/42/EC

Representative in EU: Spiros Lachandidis, Managing Director, **Banner Engineering BV** Park Lane | Culliganlaan 2F bus 3 | 1831 Diegem, BELGIUM

Standards and Regulations

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

U.S. Application Standards

ANSI B11.0 Safety of Machinery

ANSI B11.19 Performance Requirements for Risk Reduction Measures: Safeguarding and Other Means of Reducing Risk

NFPA 79 Electrical Standard for Industrial Machinery

International/European Standards

ISO 12100 Safety of Machinery – General Principles for Design – Risk Assessment and Risk Reduction

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

ISO 13856-1 (EN1760-1), Safety of Machinery – Pressure-Sensitive Protective Devices

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

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

IEC 62061 Safety of Machinery – Functional Safety of Safety-Related Control Systems

ISO 13849-1 Safety of Machinery – Safety-Related Parts of Control Systems – Part 1: General Principles for Design

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

IEC 60529 Degrees of Protection Provided by Enclosures

Product Support

Troubleshooting

Use the LED display to help diagnose the problem. After fixing the fault:

- Manual Reset configured — step ON and OFF the mat to clear the lockout.
- Auto Reset configured — the outputs turn ON immediately.

The Fault LED turns OFF if the proper repair has been made.

Condition	Indicator Status	Possible Causes or Solution
Module will not reset	Power LED ON Fault LED OFF Ch1 LED Flashing Ch2 LED Flashing	Waiting for manual reset: • EDM monitoring contacts are not closed. Check MSCs. • Check jumper at S32-S35 (auto reset) or S32-S33 (manual reset). • Check reset button connection.
No fault indicated	Power LED ON Fault LED OFF Ch1 LED OFF Ch2 LED OFF	Safety mat appears actuated: • Check mat for damage or heavy debris. • Check for proper wiring. • Check for a short in the wiring.
No fault indicated	Power LED ON Fault LED ON* Ch1 LED OFF Ch2 LED ON	Channel 1 open: • Check wiring to S11-S12. • Check connectors are properly seated.
No fault indicated	Power LED ON Fault LED ON* Ch1 LED ON Ch2 LED OFF	Channel 2 open: • Check wiring to S21-S22. • Check connectors are properly seated.
Fault	Power LED ON Fault LED ON* Ch1 LED ON Ch2 LED ON	Possible temporary fault: • Check for loose wiring. • Actuate the mat to clear the fault. Possible internal fault: • Return to factory for repair or replacement.
	All LEDs OFF	Possible fault in the machine control or wiring to the Module: • Check input power connections or external fuses. • Check connectors are properly seated.
	Dim LEDs	Power LED dim: • Check power supply capacity and load. Other LEDs dim: • May glow during power-up (normal). • Check power supply load and capacity.
	*Fault LED Flickers	This is normal while the Fault LED is ON.
MSCs do not energize	Power LED ON Fault LED OFF Ch1 LED ON Ch2 LED ON	Possible fault in machine control or an open circuit between machine control and MSCs: • Check continuity of safety outputs (for example, between terminals 13 and 14). • Check control wires and connectors. • Check MSCs

Repairs

Contact Banner Engineering for troubleshooting of this device. **Do not attempt any repairs to this Banner device; it contains no field-replaceable parts or components.** If the device, device part, or device component is determined to be defective by a Banner Applications Engineer, they will advise you of Banner's RMA (Return Merchandise Authorization) procedure.

Obtain assistance with product repairs by contacting your local Banner Engineering Corp distributor or by calling Banner directly at (763) 544-3164. Access literature translated into your native language on the Banner website at www.bannerengineering.com or contact Banner directly at (763) 544-3164.

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IMPORTANT: If instructed to return the device, pack it with care. Damage that occurs in return shipping is not covered by warranty.

WARNING:

- **Do not abuse the module after failure**—If an internal fault has occurred and the module will not reset, do not tap, strike, or otherwise attempt to correct the fault with a physical impact to the housing.
- Failure to follow these instructions could result in serious injury or death.
- An internal relay might have failed in such a manner that its replacement is required. If the module is not immediately replaced or repaired, multiple simultaneous failures might accumulate such that the safety function cannot be guaranteed.

Contact Us

Banner Engineering Corp. headquarters is located at: 9714 Tenth Avenue North | Plymouth, MN 55441, USA | Phone: + 1 888 373 6767

For worldwide locations and local representatives, visit www.bannerengineering.com.

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