WHITE PAPER

Fiber Optic Emergency Stops Provide Crucial Safety Solutions for Harsh Environment Applications

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1. Abstract

Emergency stops are essential for keeping workers safe and machinery operational when a worst-case scenario arises, but traditional electromechanical e-stops have limitations to their abilities. Fiber optic emergency stops advance these safety capabilities in challenging and dynamic applications. This white paper will discuss how e-stops work, the standards that govern them and how fiber optic e-stops can provide increased safety in harsh and explosive environments.

2. Background

2.1. What is an Emergency Stop?

An emergency stop – often referred to as an e-stop, kill switch or emergency off – is a manually actuated device used to prevent harm or damage to persons and machinery. E-stops are meant to be used when machinery cannot be shut down in its usual manner, stopping all hazardous movement without shutting down the equipment itself. During this process, the e-stop is designed to initiate events that will terminate the operation immediately and bring the machinery to a fail-safe condition while preserving human safety and avoiding machine damage.

E-stops are designed with four main criteria that separate them from just a normal push button. First, standards dictate that they must be colored red with yellow backgrounds (if present). Second, e-stops are specifically built to avoid premature activation or being blocked when pressed. This can be accomplished by requiring full depression of the button before activation.

Next, e-stops must have a high reliability rating as the user will never know if the e-stop works until it is needed. This is fulfilled by using high quality components, wiring so as little as possible can go wrong and using a redundant design to avoid errors. Finally, e-stops are designed such that they must be manually reset before normal operation can resume to prevent accidently restarting operation while a hazard is still present. A common example is requiring a twist of the e-stop button to reset it to its unactuated position.

Figure 1. Emergency Stop Button

2.2. When to Use Emergency Stops

While all machinery has a traditional off switch, it is not always clear when an emergency stop is mandatory. In most cases, e-stops are mandated by established regulatory standards. For example, NFPA 79, a North American electrical standard for industrial machinery, requires that an e-stop be located at every operator control station. And, while following these standards is often sufficient, e-stops are crucial to workplace safety and should be implemented throughout the machine area and near operator stations when hazards are conceivable.

3. Fiber Optic E-Stop Benefits and Applications

3.1. Long Distance

One of the primary applications where a fiber optic emergency stop outperforms a traditional e-stop is in long distance implementations. While the relay contacts of an electromechanical e-stop are limited in range, fiber optic e-stops use a controller module that allows for signal transmission up to 10 kilometers.

The long-distance capability of fiber optics allows operators to monitor equipment via video from a remote location while still maintaining manual control of the local situation via an e-stop. This is exceptionally beneficial when the equipment is in a harsh or dangerous environment unsuitable for direct operator control.

3.2. Harsh/Explosive Environment

When monitoring machinery in harsh environments, emergency stops must be able to unilaterally withstand the conditions as e-stops are often the final safeguard. One typical harsh environment is an explosive atmosphere. Per IECEx, an Ex area refers to "areas where flammable liquids, vapors, gases or combustible dusts are likely to occur in quantities sufficient to cause a fire or explosion." In such an environment, safety is of the utmost importance and safety devices must be able to withstand the extreme conditions and maintain reliability for whenever they are required.

Fiber optic e-stop systems are typically rated inherently safe, simple mechanical devices because they cannot produce a spark, allowing the sensor to be safely deployed in all categories of harsh and explosive environments. And, since fiber optic sensors do not rely on electrical signals, they are able to withstand RFI, EMI, microwave, magnetic and high voltage fields as well.

3.3. Extending Remote Contacts to Multiple Locations

In certain cases, an emergency stop may be required to control and monitor equipment in multiple locations, especially in the case that an external threat requires a system-wide shut down. In the case of such an emergency, a single e-stop activation must shutoff all equipment without delay. And, while conventional e-stops can only turn off local equipment, fiber optics provide the ability to control multiple sets of contacts at locations up to 10 km apart. Triggering two controllers with a single e-stop is possible using an optical splitter and extension cables, as seen in *Figure 2*.

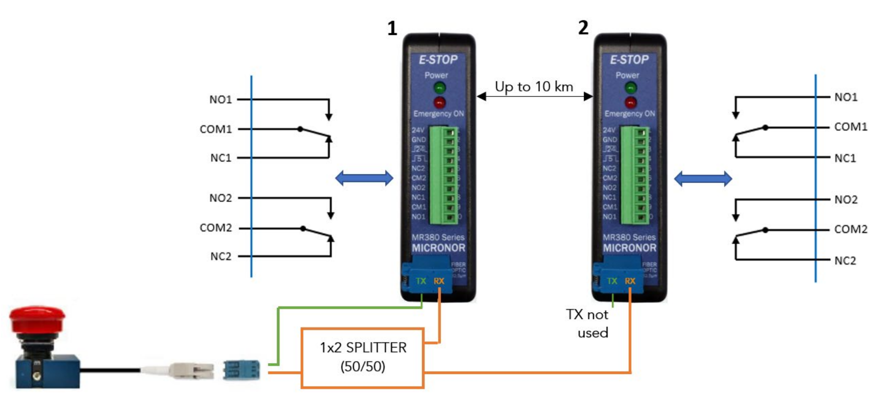


Figure 2. Managing Two Controllers with One E-Stop

3.4. Extending Electromechanical Emergency Stops

Although it is not an emergency case, fiber optic controllers are able to provide remote relay contacts when long-distance transmission is required and can even extend a conventional electromechanical emergency stop. This is extremely useful when a button or switch must be located in one area but is meant to control equipment in a secondary location. For example, stopping a long conveyer line can be made possible using fiber optics.

Using one fiber optic controller (local) as a transmitter and a second controller (remote) as a receiver provides remote relay contacts. Switching the power to the transmitting controller using an electromechanical e-stop determines whether it transmits light to the second controller. And, since the light is continuous, the second controller's relay contacts switch based on whether it receives light. *Figure 3* shows the power supply off and the NO contacts closed; turning the power supply on would then switch the NC contacts closed and the NO contacts open.

Power Supply to Controller 1	**Controller 1 (Transmitter)**	**Controller 2 (Receiver)**
ON	Transmits light	NC contacts closed
OFF	Does not transmit light	NO contacts closed

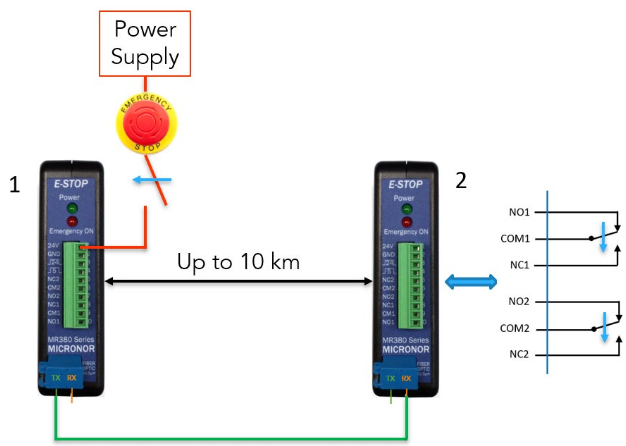


Figure 3. Using Two Fiber Optic Controllers to Provide Remote Contacts

3.5. Networking Multiple Emergency Stops

One crucial aspect of emergency stops is the ability to chain multiple switches together to increase the number of activation points available to operators. With fiber optics, several e-stops can be optically wired in series such that there remains an unbroken light path back to the controller. Then, the activation of any single e-stop in the chain will break the light path and switch the controller into its emergency state.

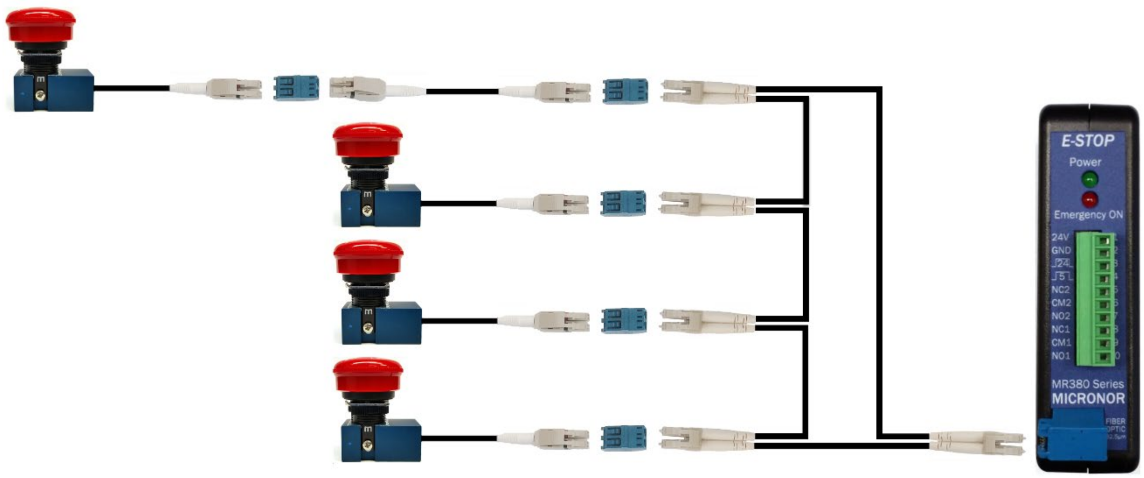


Figure 4. Fiber Optic E-Stops in Series

3.6. Industries Where Used

Industry	Long Distance	Explosive Atmosphere	EMI/RFI	Magnetic Fields	High Voltage
Medical			✓	✓	
Military	✓	✓	✓	✓	✓
Oil & Gas	✓	✓	✓		
Civil Infrastructure	✓				
Industrial	✓	✓	✓	✓	✓
Power	✓		✓		✓
Chemical Plants	✓	✓	✓		

4. Fiber Optic E-Stops

4.1. Design

Micronor's MR387 series fiber optic emergency stops employ a photo interrupt scheme operating over a duplex fiber link – multimode OM1 62.5/125 µm or OM2 50/125 µm fiber, single mode OS1 9/125 µm fiber or 1 mm POF. The controller transmits light through one fiber to the e-stop where it is reflected off a mirror and returned to the controller through the second fiber. When this light path goes uninterrupted and the controller receives light, the controller remains in its unactuated, standard position (see *Figure 5*, left). Then, when the e-stop is pressed, the light path is blocked and the photodiode within the controller no longer receives light. It then switches into its actuated, emergency state (see *Figure 5*, right).

One key aspect about a fiber optic e-stop that separates it from a traditional e-stop is that the fiber optic design also indicates if there is a broken or disconnected fiber connection or if the controller loses power. Since the controller diverts into an emergency state when it no longer receives light, fiber optics provide increased safety margin and alert users that the emergency stop will fail before it is too late.

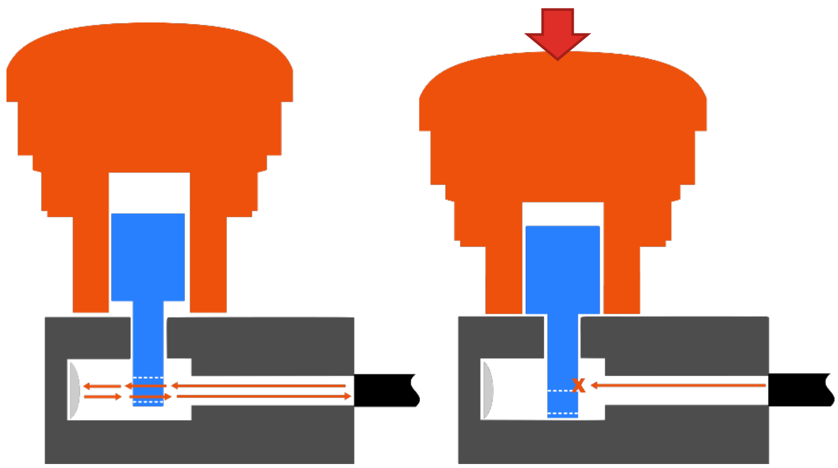


Figure 5. Fiber Optic E-Stop Design, Unactuated (left) and Actuated (right)

4.2. Installation

A fiber optic emergency stop system is easy to install and can even be less expensive to install than an electromechanical e-stop. When it comes to hazardous environments, the fiber optic system is inherently safe and does not require the expense and regulatory oversight that traditional e-stops demand.

Furthermore, a fiber optic e-stop is especially easy to install if a fiber optic circuit is already in place. As mentioned above, the fiber optic system is compatible with multimode fiber, single mode fiber and plastic optical fiber (POF) which makes it easy for the user to choose an e-stop that best integrates into their system without increasing losses.

4.3. Interfacing

Electrical (or dry) contacts are the primary signaling output for emergency stops, both electromechanical and fiber optic. However, fiber optic e-stops use a controller with an integrated relay to provide these contacts whereas electromechanical e-stops have integrated contacts. External relays or solenoids use a low power signal to manage circuits requiring control of higher power electrical loads or to manage several circuits with a single signal. Depending on the application there are several different relay configurations available, but a fiber optic controller provides double pole, double throw (DPDT) relay contacts as seen in *Figure 6*. Additionally, the fiber optic controller has 5 V and 24 V normally high digital outputs that switch simultaneously with the relay contacts.

Finally, with regards to the fiber optic connection, Micronor's MR380-1-3 is a universal controller that uses an OS1 9/125 µm transmit fiber paired with an OM1 62.5/125 µm receive fiber. By using a small diameter transmit fiber and a larger diameter receive fiber, the controller can be paired with any standard fiber for both multimode and single mode e-stop installations.

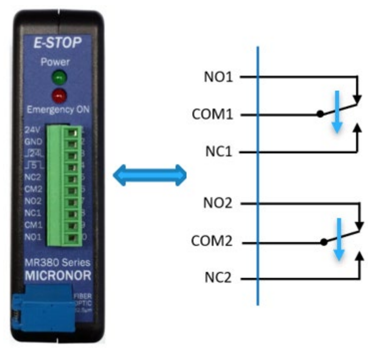


Figure 6. Fiber Optic E-Stop Controller with DPDT Relay Contacts

4.4. Standards and Functional Safety

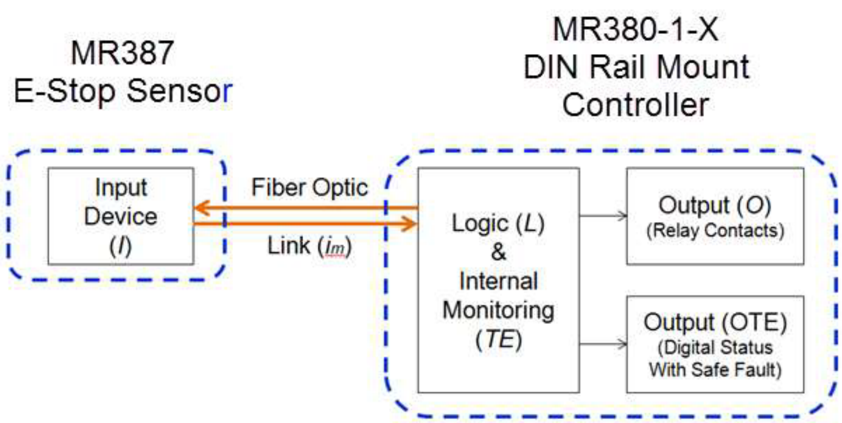
ISO 13850 defines the functional requirements and design principles for the emergency stop function and emergency stop device on machinery. In operation, an emergency stop function is initiated by a single human action to trigger the event(s) required to bring the machinery to a fail-safe condition.

A fiber optic e-stop sensor system functions similar to a standard electromechanical, mushroom-style e-stop. The passive optical sensor integrates a conventional e-stop actuator which controls an optical circuit or light path – similar to the way an electrical e-stop switch directly controls an electrical circuit. As required by ISO 13850, a fiber optic e-stop should incorporate the same mechanical latching and rest mechanism as a conventional e-stop. The optical transmit and receive paths comprise a duplex fiber link which is completed by connection to a controller module. This module contains the system's optoelectronics as well as the electrical interface and relay contacts which connect to the machinery's control system.

Next, ISO 13849-1 details the principles, guidelines and safety requirements for the design and integration of safety-related control systems. It also outlines the parameters that dictate the functional safety of a control system and how to calculate them. Functional safety is an important method to characterize the overall safety of a system and is particularly important for e-stops since they are typically implemented independently from the rest of the operating system.

When calculating or identifying the functional safety of a system, the primary parameters that must be identified include the category used to describe the required behavior of the control system, the mean time to dangerous failure ($MTTF_d$), the performance level (PL), safety integrity level (SIL) and diagnostic cobverage (DC). These parameters are provided in the following table.

Functional Safety Characteristics	Fiber Optic Emergency Stop System consisting of MR387-1-3 DIN Universal Controller Module and MR387 E-Stop Sensor Switch
ISO 13849	Category 2
MTTF (for System)	236.5 years, 2.07 E+06 hrs
MTTFd (for System)	473.1 years, 4.14 E+06 hrs
Safety Integrity Level (SIL)	SIL=1
Performance Level (PL)	PL=c
Safe Failure Fraction (SFF)	SFF=87.84%
Diagnostic Coverage (DC)	DC=0%
Optical Loss Margin	23dB min.
Maximum Distance	Distance is the function of the user's system loss budget which is the total round-trip loss of all optical link components – sensors, connectors, splices and cable segments. Based on a single singlemode E-Stop connected to the Controller, the maximum distance is 17km. Consult application note AN118 for more detailed information about connecting multiple E-Stop sensors and calculating/verifying System Loss Budget.



5. Technology Comparison

5.1. Emergency Stop Technologies – Electromechanical vs. Fiber Optic

In benign applications, the dry contacts of electromechanical emergency stops are the traditional solution for emergency signaling or system shutdown when the control equipment is nearby. When the e-stop and control equipment are widely separated (>50-100m), the low loss over distance of optical fiber and ease of installation provides key benefits, even in benign environments.

In harsh environments and explosive atmospheres, fiber optic e-stops can provide cost savings through their ease of deployment and inherent safety. Some examples where fiber optic e-stops provide value over electromechanical e-stops can be seen in *Section 5.3*.

5.2. Comparing Performance Specifications

Typical Characteristics	**Electromechanical E-Stop**	**Fiber Optic E-Stop**
Maximum Distance	100 m*	10 km
IP Protection	IP65	IP65
Operating Temperature	-40°C to +65°C	-40°C to +65°C
Lifetime	100,000 cycles min.	100,000 cycles min.

*There is no specific limit to the range of an electromechanical e-stop, but in practice, extending the range of high-power signals is not practical and can become a safety hazard.

5.3. Comparing Operating Environments

For a system to operate safely, the activation of an emergency stop must guarantee the system goes into an emergency state. The table below compares the compatibility of electromechanical and fiber optic e-stops in various types of operating environments.

Environment	**Electromechanical E-Stop**	**Fiber Optic E-Stop**
Benign, Short Distance	✓	✓
Benign, Long Distance	✘	✓
EMI/RFI	✘	✓
Magnetic Fields	✘	✓
High Voltage/Lightning	✘	✓
Explosive Atmospheres	✘	✓
Cost to Install in Hazardous Locations	$$	$

6. Product Overview

6.1. MR387 Emergency Stops

Micronor offers two fiber optic emergency stop configurations that can be deployed in hazardous environments and operate over long distances. The first option is a standard e-stop that can be mounted within a user's panel while the second option is a ruggedized e-stop in IP housing for harsh environments. Specifications for the e-stops can be found at https://micronor.com/product/mr387/.

Figure 7. MR387 with Duplex LC Pigtail (left) and in IP Housing (right)

6.2. MR380 Controllers

The MR380 series Controller provides DPDT relay and digital signal outputs based on the return signal of the MR387 e-stop. The standard unit for most applications is the MR380-1-3 Universal DIN rail mountable unit (see *Figure 8*, left). "Universal" designates that the controller can be used for both single mode and multimode e-stop links and networks. Additionally, Micronor offers the MR380-0-UNI Universal OEM Controller Board for users to embed the fiber optic emergency stop system into their OEM design (see *Figure 8*, right). When using the OEM board, it is important to note that the PCB has no functional safety value so this must be calculated for the entire OEM system and the PCB only has an open collector output that can drive a relay, it does not have any dry contacts. Specifications for the controllers can be found at https://micronor.com/product/mr380-1/ and https://micronor.com/product/mr380-0/.

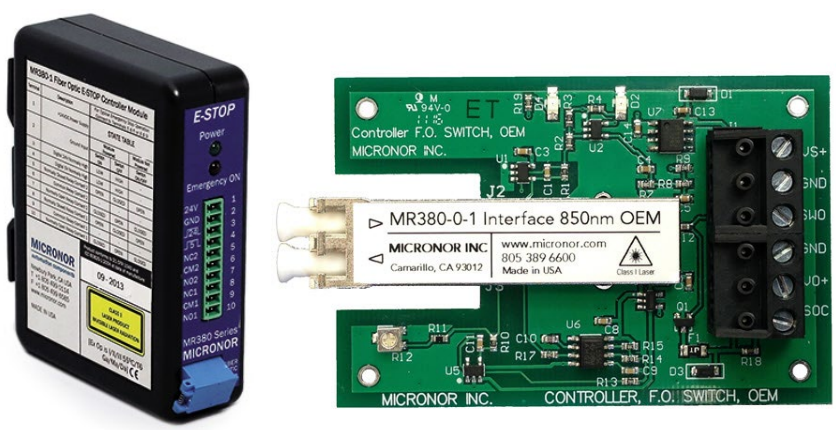


Figure 8. MR380-1-3 DIN Rail Mountable Controller (left) and MR380-0-1E OEM Controller Board (right)

7. Conclusion

Fiber optic emergency stops are designed to be used as an alternative to conventional electromechanical e-stops. The passive optical e-stop provides immunity to EMI/RFI/lightning, can be safely used in hazardous locations, provides increased safety margin and can operate over extremely long distances, places where an electromechanical e-stop is inadequate or marginal.

References

IECEx. "About the IECEx." *IECEx*, 2021, www.iecex.com/information/about-iecex.

ISO 13849-1, *Safety of machinery – Safety-related parts of control systems*

ISO 13850, *Safety of machinery – Emergency stop function*

NFPA 79, *Electrical Standard for Industrial Machinery*

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Micronor Sensors, Inc.

Micronor Inc. was founded 2003 in Newbury Park, California. The founders accurately predicted the need for fiber optic sensors which provide immunity from lightning, EMI/RFI, radiation and magnetic fields. Based on an innovative and patented technology, using wavelength as the information carrier, the first products introduced to the market were incremental encoders. These products are used in the transportation, mining, oil & gas industries for position sensing and controlling the speed of VFD drives.

Fast forward to 2021, the FO Encoder and E-Stop product lines were acquired by Micronor AG and moved to Switzerland. Dennis Horwitz, one of the original founders, established Micronor Sensors, Inc. (MSI) to oversee North American Sales and Support (US, Canada, Mexico, and US Territories) as well as Special Worldwide EAF (Electric Arc Furnace) Applications. MSI is a reknown specialist in both Fiber Optic and Electromechanical sensors and controls.