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E-STOPS: STANDARDS, RECOMMENDATIONS AND OPTIONS

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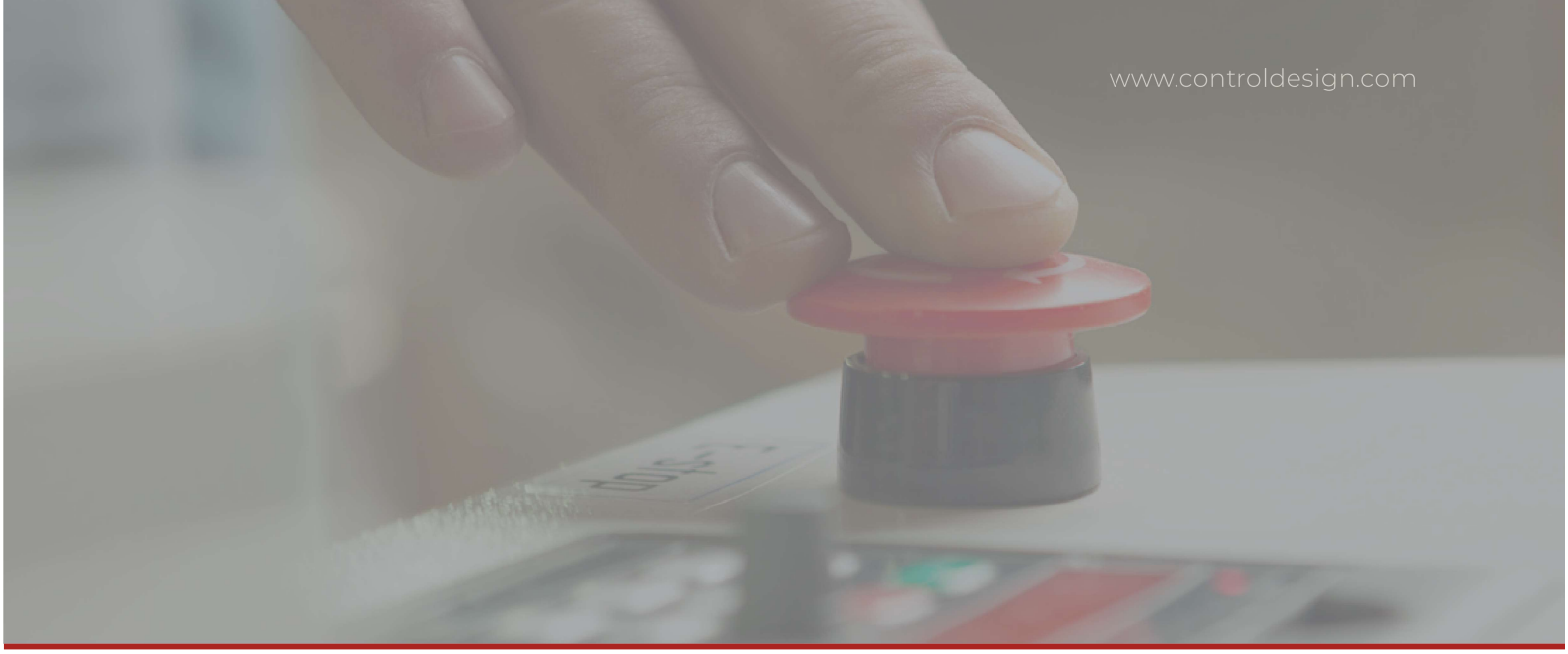
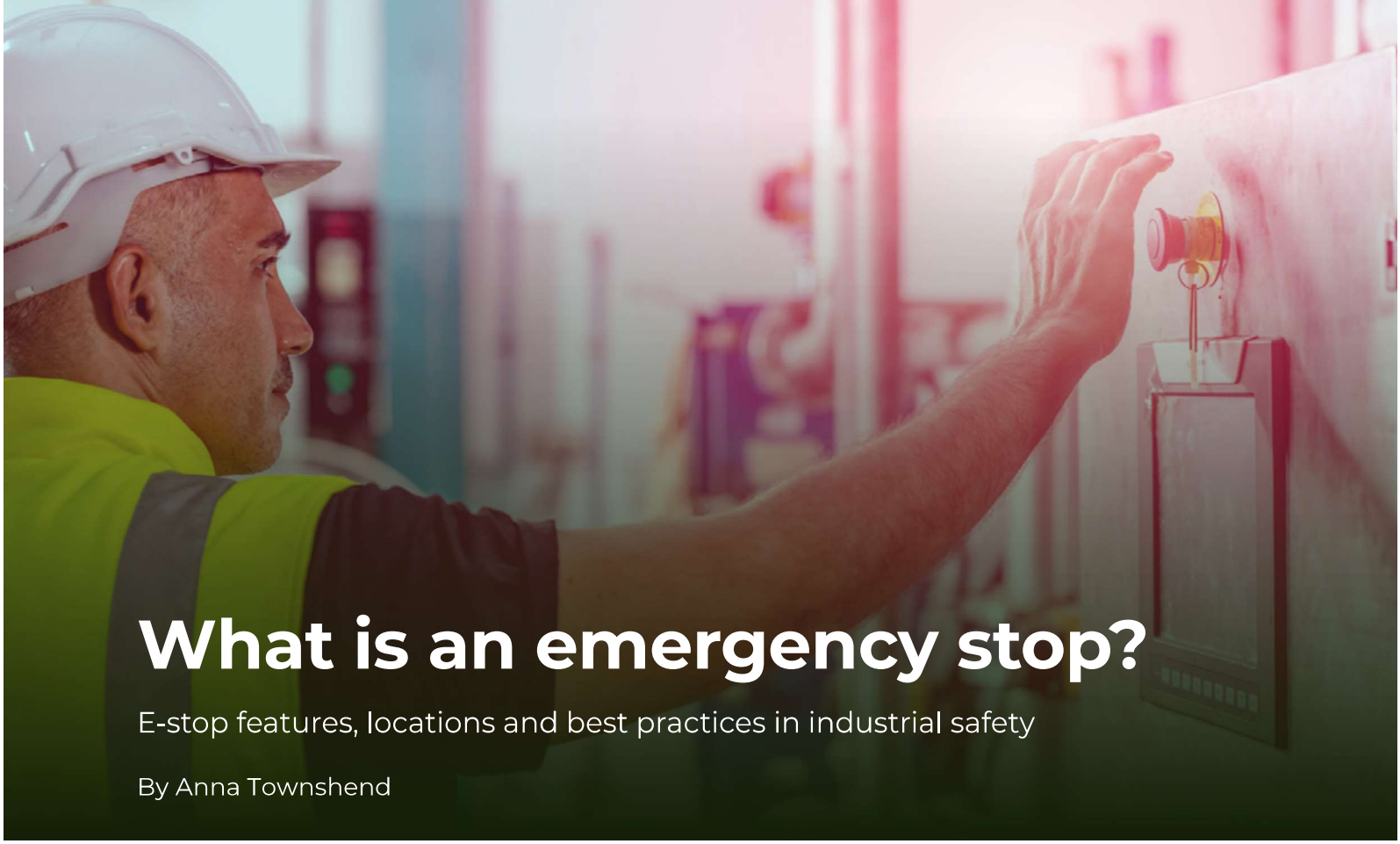


INTRODUCTION

An emergency stop (e-stop) is the last line of defense on a production line, used to stop any process quickly and safely to prevent, accidents, injuries or damage to equipment. E-stops are critical in industrial automation and machinery to protect workers and equipment. Many standards and guidelines dictate how e-stops should function, what they should look like and where they should be located. There are also many different types of e-stop buttons and forms of actuation, including some physical requirements, as well as practices that aren't allowed. Know your standards and your options. This guide has all the information you'll need to design a proper e-stop.



What is an emergency stop?

E-stop features, locations and best practices in industrial safety

By Anna Townshend

An emergency stop (e-stop) is a safety mechanism used in industrial machines and automation systems. It is an easily accessible button or switch that, when pressed or activated, immediately halts the operation of a machine or an entire industrial system.

The e-stop's primary purpose is to stop, as quickly and safely as possible, all potentially hazardous movements or processes in case of an emergency situation to prevent accidents, injuries or damage to equipment. When activated, most e-stops initiate a Cat. 1 stop in which the actuator/motor is brought to a controlled stop. "An emergency stop should be initiated by a single manual action," says Mark Eitzman, safety and product manager at Integrated Mills Systems in Willoughby, Ohio.

Emergency stops are a critical safety feature in industrial automation and machinery, ensuring the protection of both workers and equipment in emergency scenarios. E-stops should be color-coded red and yellow, and they often feature a distinctive mushroom-shaped button design to make them easy to identify and activate in high-stress situations.

Many standards guide the use and operations of e-stops, such as International Organization for Standardization (ISO) 13850 "Safety of machinery—Emergency stop function—Principles

for design," as well as NFPA 79, "Electrical Standard for Industrial Machinery," and IEC 60204-1, Safety of machinery – Electrical equipment of machines.

Before operating a new e-stop application, be sure to consult the standards or a safety expert who understands the standards and the specific application.

WHAT ARE KEY FEATURES OF E-STOP ACTUATION?

E-stops are meant to operate as quickly as possible in an emergency situation, so visibility is key. The actuator of the emergency-stop device must be colored red, and the background area behind the actuator should be colored yellow. The actuation of an emergency-stop device must be from a single manual action, such as pressing a push button or pulling a cable. A mushroom-head actuator is a common device used for emergency-stop devices, but others are also acceptable.

The emergency stop of hazardous motion should not create new hazards, such as upsetting a load. This means using the proper stop category, Cat. 0 or Cat. 1.

- Category 0 is an uncontrolled stop which immediately removes power to the machine actuators.
- Category 1 is a controlled stop with power to the machine actuators available to achieve the stop. Power is removed when the stop is achieved.

  For example, for high-friction applications with unstable loads that could fall over, a Cat. 1 stop should be employed to extend the stop by ramping speed down to bring the machine to a stop. Conversely, a high-inertia load would include electrical or mechanical braking to bring the machine to a stop faster than it would if power were immediately removed from the actuator.

WHERE SHOULD EMERGENCY-STOP DEVICES BE LOCATED?

An emergency stop device should be located at each operator control station, and a risk assessment should determine other appropriate locations for the particular application. E-stops are commonly found at entrance and exit locations or where operators and machine work together.

Emergency-stop devices should be directly accessible to operators for easy actuation. The location should take into account the operator's line of sight and range of movement. Operators should not have to navigate obstacles to access e-stops. For larger machinery, multiple emergency-stop devices may be necessary. "Wireless, on-person e-stops should be considered for maintenance personnel that troubleshoot live equipment," Eitzman says.

The machines and application will determine an e-stop's span of control.

To determine that span through a layout analysis, Eitzman recommends the following considerations:

- the physical layout of the machine, based on the visible area of the machine
- the possibility to recognize hazardous situations—visibility, noise and odor
- any safety implications relating to the production process
- the foreseeable exposure to hazards
- the possible adjacent hazards.

"Each span of control can cover sections of a machine, an entire machine or a group of machines," Eitzman says. Task and hazard identification includes identifying the task zone, the physical area where people will do a task and the control zone for engineering controls, including interlock devices, presence-sensing devices, enabling devices, hold-to-run controls, resets and emergency stops. Spans of control may also overlap, Eitzman explains.

WHAT ARE THE RECOMMENDED PRACTICES FOR RESTARTING AFTER AN E-STOP?

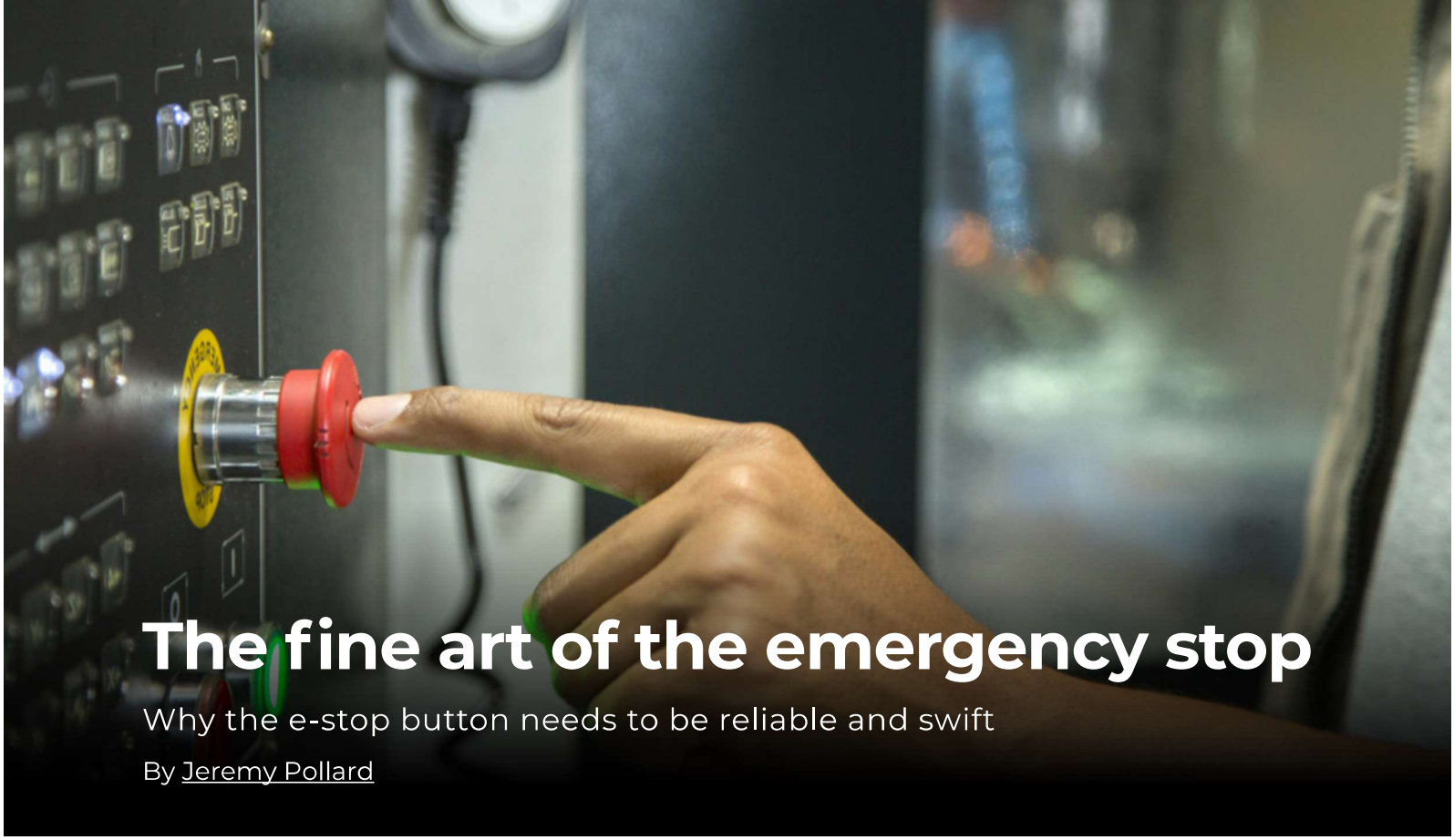
"An emergency-stop actuator shall be a maintained mechanism," Eitzman says. Once activated, the e-stop remains actuated until manually reset, so the machinery remains stopped until it is intentionally reset. "Once reset, the machine can be restarted with a separate, intentional, manual command," he explains.

Other control functions or systems should never override an emergency-stop command. Once activated, the stop condition should take precedence. Deactivation should require a manual reset, so operators must take a deliberate action to restart. "The twisting and/or pulling out the depressed actuator is a common feature used to reset the e-stop button," says Eitzman. "Other means include a separate reset button, typically blue and labeled as reset. Other devices, such as some cable pull switches have a blue reset button right on the main switch body."

WHAT ARE MAINTENANCE REQUIREMENTS FOR AN E-STOP?

Routine inspections should be part of the regular maintenance schedule for emergency-stop devices. Functional testing should periodically activate the e-stop function, according to the manufacturer's instructions, and verify that the machinery stops. Test any maintained mechanisms and confirm the e-stop control resets.

"The frequency of the testing needs to be balanced between the stresses that e-stop actuation causes the equipment—mechanically, electrically or fluid power—and ensuring that the e-stop functions properly," notes Eitzman. "Consider the level of risk that the e-stop measure is meant to reduce. In other words, if the risk is higher in severity and probability, then test more often."



The fine art of the emergency stop

Why the e-stop button needs to be reliable and swift

By Jeremy Pollard

Have you ever opened a door or stepped in front of a light curtain, and the whole production process shuts down with a loud groan? You know that feeling you get in your stomach that you probably did something wrong?

Well, you actually didn't. The safety system that has been put in place by the automation and control engineers is there to protect you against yourself.

Safety devices come in various shapes and flavors in order to protect the process from people mistakes. Of course, it is there to protect the people from the process whose inert personality cares not that you chose to stand in front of a moving wrapper gantry and get clobbered.

Safety sensors stand between the operator and a bad day. They have been strategically placed into the process to protect and provide safety on all fronts.

A good safety implementation provides a balance between protection of both the process and the people surrounding it and production requirements.

Safety devices have to work—full stop. If you hit an e-stop button, it's because it's an emergency. A mushroom head red pushbutton was used for the longest time.

However, it was a standard pushbutton with a standard contact block wired like a normal pushbutton. When the e-stop was hit, the contacts are supposed to open, cutting power to a master control relay (MCR) that controlled power given to the control circuit of the process.

Many points of failure exist in this line of protection. Contact blocks that have fallen off, loose wires, the MCR fails closed—these are just a few of the potential obstacles to saving someone's life when the e-stop needs to halt the process in its tracks.

In the late 1980s, a new form of safety devices started to emerge into the controls field. There was a recognized lack of fault tolerance in safety systems with the MCR mentality. It may have had something to do with the level of injuries created by the failures of the MCR systems.

The e-stop relay was born, which introduced a new way of protecting people and machines alike, and we have never looked back.

Safety systems are implemented in all walks of process but primarily in machine control. Continuous process being stopped by someone walking through a door would not be a good idea. That door would be locked shut while the process was going on, so as to not cause a disturbance to that process. Machine control is different though.

Press control, palletizing, wrapping, logistics are processes with moving parts that people need to be protected from. You should not be able to enter the product wrapper while it is in motion. By default, the process is protected by not damaging the product or the machinery.

However should the need arise to stop the wrapper, it needs to stop now.

A safety e-stop is not your standard push-button. It has two sets of redundant normally closed contacts. It is wired into a safety device such as a safety relay or safety programmable logic controller (PLC), which also sends a low-voltage signal through the wiring to detect a dropped wire or in fact a contact block that has fallen off the back of the pushbutton.

The purpose of a safety sensor is to operate as designed when it needs to. If it is unable to perform that function, such as a contact block falling off the e-stop switch, the control will stop the process in an uncontrolled fashion.

Remember that an e-stop is a safety stop, not a process stop function. There is no controlled stop function with an e-stop—shut it down now.

There are many options available for "safetyfying" a process and/or machine control. Guarding has become an art.

Robotic cells have fencing/guarding to protect from unintended entry while the robot is moving. Door safety gate switches prevent entry while the robot is moving. When the robot is stopped, the gate is available for entry, and the normal operation of the robot is no longer allowed until the gate is closed.

Can the robot operate while an operator is in the cell and the gate switch closed? Yes, it can, unless there are additional operator protection safety devices employed to detect the presence of a human.

Safety is a necessity. Safety systems are smart, programmable and functional. They report on which device was tripped since there is no longer a large string of serial safety devices controlling control power.

Did I mention that the control power relays are redundant, too? We are protected in every way.

Standards guide the use of e-stops

Wireless and remote e-stops are allowed but must follow strict guidelines for location and design

By Anna Townshend

A **Control Design reader writes**: I'm seeing new technologies available for wireless e-stops, remote e-stops and touchscreen e-stops. Are these allowable? Are there regulations governing the use of anything besides a physical red button? What machine applications would these be used for? What does the Occupational Safety and Health Administration (OSHA) say about them? And where is the reset to resume operation?

Answers

PUSHBUTTON STANDARDS SPECIFY PHYSICAL REQUIREMENTS

Yes, wireless e-stops and remote e-stops are allowable but must be compliant with the following:

- International Organization for Standardization (ISO) 13849—Safety of Machinery Package
- ISO 13850:2015 Safety of Machinery—Emergency Stop Function—Principles for Design
- American National Standards Institute (ANSI) B65.1-2005—Graphic Technology—Safety Standard—Printing Press
- International Electrotechnical Commission (IEC) 60204-1:2005 Safety of Machinery—Electrical Equipment of Machines—Part 1: general requirements
- IEC 62745 Safety of Machinery—Requirements for Cableless Control Systems of Machinery. This standard aims to define the guidelines of how wireless remote-control

systems must be designed to comply with the minimum requirements of machine design and safety.

For touchscreen e-stops, graphical representations of a button—an icon—on an HMI or flat panel display are not an option. The same standards do not permit flush or membrane-style switches or touchscreen buttons/icons.

Yes, regulations are governing the use of anything besides a physical red button. For emergency-stop pushbuttons to be compliant, they must be designed as follows:

- with direct opening operation
- as self-latching and must be reset manually
- with mushroom-head shape to make it easy to push
- to remain unguarded
- to be located at each operator control station and at any other location where an emergency stop would be required
- colored red and mounted on a bright yellow background. The yellow background must be a minimum of 3 mm beyond—surrounding—the mounting collar and visible beyond the control actuator—the button itself—according to ANSI B65.1-2005.

A common application where wireless e-stops are superior to wired e-stops is during crane operations. This allows greater operator freedom for their positioning to view crane movements, and lower costs for system implementation. The wiring alone, in a traditional wired e-stop system, can be a significant portion of the cost and complexity of an e-stop-based safety system implementation.

OSHA and relevant standards such as IEC 60204-1 state that an e-stop must be readily accessible to the operator. Additionally, it should be unobstructed—no collars or actuation restrictions—and easily accessible without having to reach over, under or around to actuate. Machine-building standards such as ANSI B11, B11-19 and National Fire Protection Agency (NFPA) 79 also address specifics in regard to safety devices such as an e-stop.

OSHA and relevant standards such as IEC 60204-1 further state that resetting of the e-stop alone shall not resume operation. A second deliberate action is needed, such as the pressing of a reset button. This could include twisting the mushroom button and allowing it to spring back up or pulling the button back up to reset. It cannot automatically reset.

Michael Warren / product manager—safety components and safety controllers / Omron

WIRELESS E-STOPS ENHANCE MAINTENANCE SAFETY

After looking through OSHA regulations and other global standards, I could not find anything that specifically says

wireless e-stops are not allowed. In fact, there is an offering for a wireless e-stop that actually meets ISO 13849 Category 3 specifications for functional safety systems. There isn't much in the way of where an e-stop button should be located and what it should look like other than "easily accessible and within arm's length," red button on a yellow background and requiring only a manual reset.

OSHA uses NFPA and other global standards, such as ISO, to form its standards. NFPA 79—Electrical Safety Standard for Industrial Machinery—sets out what is allowable for emergency-stop buttons. This includes pull-cord-operated, foot-operated, push-bar-operated and rod-operated switches. NFPA 79 does not allow emergency stops to be flat switches or a graphical/digital representation. So, while wireless e-stops would be allowable, touchscreen e-stops would not be.

Any machine or process could theoretically use a wireless e-stop. More specifically, imagine a scenario where a technician has to be physically inside a machine or is working on a section of the machine where the e-stop might be just out of reach. Having a wireless button that can stop the machine from anywhere would be a great benefit. Another scenario could be operators that keep wireless buttons on their person for potential need. They see someone who shouldn't be operating or performing maintenance on a machine. It takes time to get to the nearest button to e-stop the machine so being able to press one that's currently with them on hand could potentially save a life or limb.

The wireless button would need to have a manual reset, whether that be a twist-to-release or a pull-to-release function. Once that's done, assuming the safety system is a manual/manual, monitored setup, the resume operation would be as usual. Press the reset button. If the safety system is an automatic reset, manually releasing the e-stop button would reset the safety system to a ready state. Most likely, the machine itself will need to be rehomed and/or have the process reset/acknowledge button pressed to restart the production process.

Noah Greene / product specialist—safety / Phoenix Contact USA

E-STOP DIFFERS FROM AN EMERGENCY-OFF SWITCH

The short answer is yes. Wireless and remote e-stops are allowed with very strict regulations. The standards that dictate how an e-stop switch works are ISO 13850:2015, Safety of Machinery – Emergency Stop Function—Principles for Design; and IEC 60947-5-5, Low-Voltage Switchgear and Controlgear—Part 5.5: Control Circuit Devices and Switching Elements—Electrical Emergency Stop Device with Mechanical Latching Function.

These standards require a physical e-stop that opens a contact and, at the same time, latches. This means no latching without opening the contact and no opening without latching is allowed. ISO 13850 is the so-called machinery directive, which lists several other requirements for operating and resetting an e-stop.

It is important to note that there must be a physical e-stop, no matter what (Figure 1). A physical e-stop, which must open a physical contact, could be connected to a wireless or remote technology to activate it. It sends a signal, and the physical freeze of a machine is activated. It's also important to note the difference between an e-stop and an emergency-off switch. While an e-stop freezes the machine, an emergency-off shuts off the power, which is not necessarily the case for e-stops.

When it comes to resetting or resuming operation, there are safety regulations and protocols in place. For example, you are allowed to connect a normal-stop switch in a way that, if you push it, the machine stops or freezes. Once you release it, the machine runs again. That is for a normal-stop switch. However, with an e-stop, once you press it, the machine freezes and stops. If you release the emergency-stop switch, the machine must not run, it will stay stopped. For safety reasons, there must be another separate mechanism to restart the machine.

Reinhard Kalla / principal product manager / EAO

TOUCHSCREEN E-STOPS ARE NOT ALLOWED

E-stops shall be located at each operator control station. In addition, other locations can be considered according to a risk analysis, including entrance and exit location. See ISO 13850-4, Safety Requirements; 3, Terms and Definitions; and 2, Normative References. In case of e-stop activation, locally or remotely, the machinery shall be inspected in order to detect the reason for activation.

Wireless e-stops are allowed, but, according to the IEC 60204-1, the wireless e-stop shall not be the sole means to initiate an emergency stop. In addition, according to ISO 13850, a wireless e-stop shall comply with Subsection 4.3.8, Subsection 4.3.9, Subsection 4.6.2 and a minimum of safety level PLC, according to ISO 13849, and/or SIL 1, according to IEC 62061. The safety level shall be consistent with a risk analysis of the machine. IEC 62745 deals with wireless control systems for electrical equipment of machinery, and, since March 2021, it is now harmonized for machinery directive in Europe.

Touchscreen e-stop is not allowed, because ISO 13850 and IEC 60947-5-5 require that the emergency-stop device shall comply with IEC 60947-5-1, Annex K, a direct opening action of the electrical contact. A touchscreen is not compliant with this requirement.

According to NFPA 79 10.7.2.3, emergency-stop switches shall not be flat switches or graphic representations based on software applications.

In Europe, in compliance with Machinery Directive, in Annex 1, Subsection 1.2.4.3, emergency-stop machinery must be fitted with one or more emergency-stop devices to enable actual or impending danger to be averted.

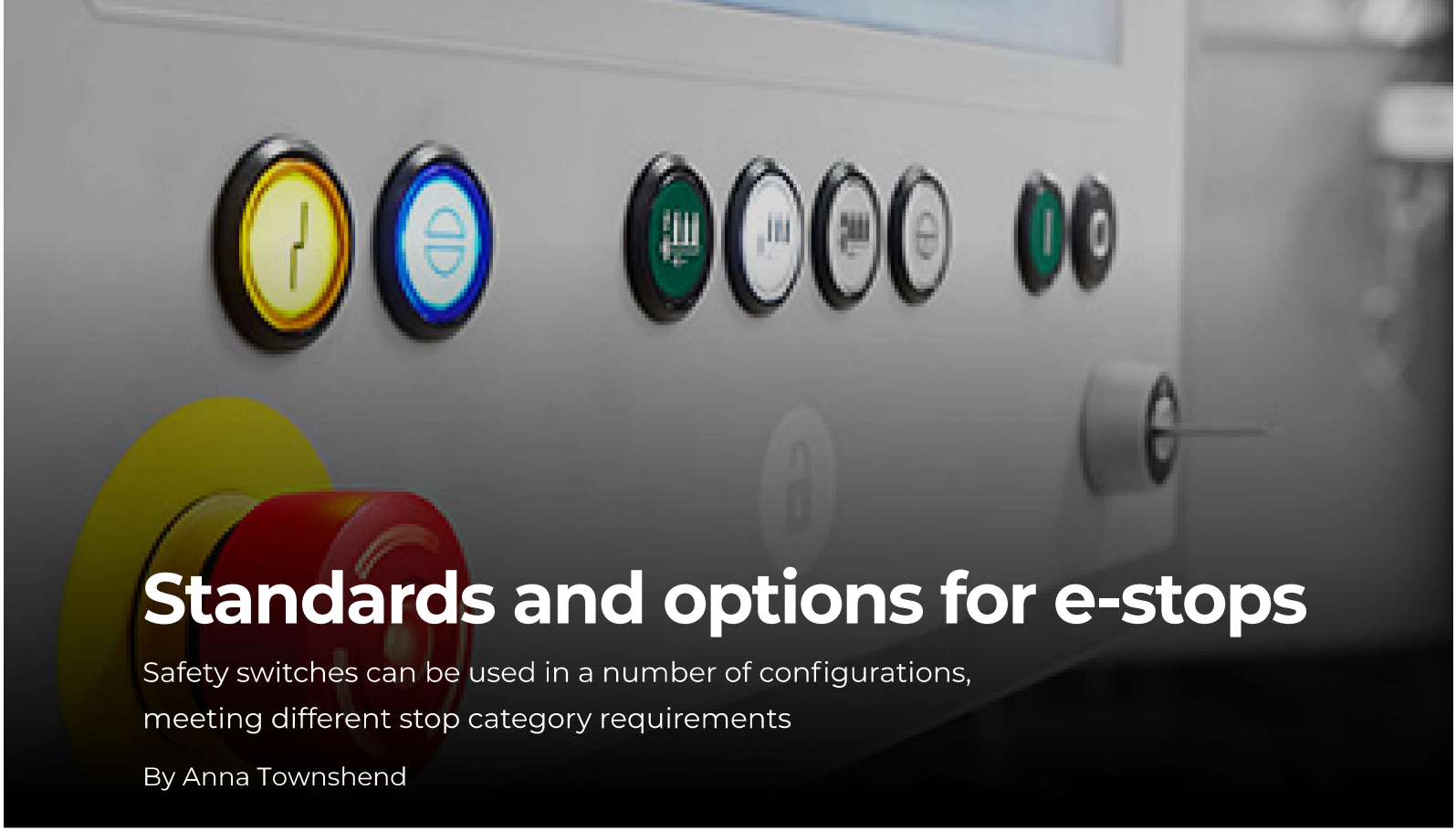
The following exceptions apply for:

- machinery in which an emergency-stop device would not lessen the risk, either because it would not reduce the stopping time or because it would not enable the special measures required to deal with the risk to be taken
- portable handheld and/or hand-guided machinery.

For the e-stop, the NFPA standard is more suitable than OSHA regulations. The main requirements of the e-stop are defined in NFPA 79 standard for machinery. The requirements from NFPA 79 are based on IEC 60204-1 with some few specificities for the e-stop.

In case of e-stop activation, locally or remotely, the reset button shall be located in general in the machine, because the machine shall be inspected to detect the reason for activation.

Eric Domont and Sébastien Chaigneau / standardization manager, e-stop expert and creation manager, safety expert / Schneider Electric



Standards and options for e-stops

Safety switches can be used in a number of configurations, meeting different stop category requirements

By Anna Townshend

Control Design reader writes: What is the standard method of using circuits for e-stop conditions and their categories? Are there cases in which an e-stop button can be software-based?

Answers

SAFETY AND RISK ASSESSMENT

From a machine designer perspective, the safety system that is being designed into the machine and the risk assessment for the machine will determine which components are needed in the safety system. E-stop switches are just one of the components of the safety system. There are many industry standards that need to be followed to accomplish this, below are a few examples:

- DIN ISO 13849-1, Safety of Machinery
- DIN ISO 13850, Safety of machinery—Emergency stop function—Principles for design
- IEC 60947-5-1, Low-voltage switchgear and control gear
- EN 60947-5-5, Control circuit devices.

In my experience, an e-stop has to be a physical switch versus an icon or software-based to meet the above specifications and industry standards (Figure 1).

JOE TORZILLO / vice president sales, HMI components / EAO / www.eao.com

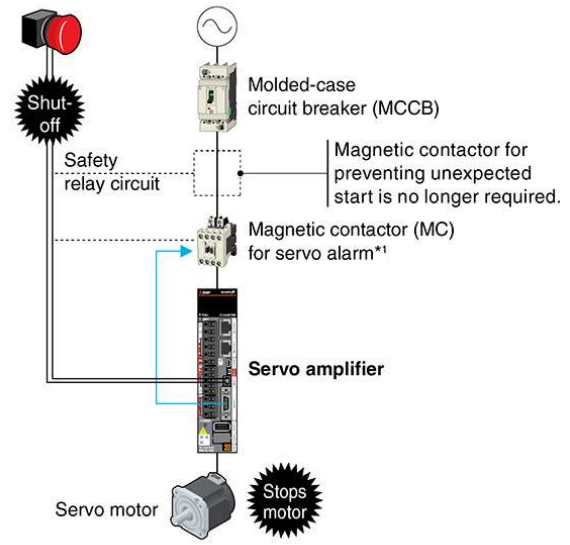


Figure 2: Possibilities exist by utilizing software-based safety, in this case, STO safety subfunction. (Source: Mitsubishi Electric)

SAFE TORQUE OFF

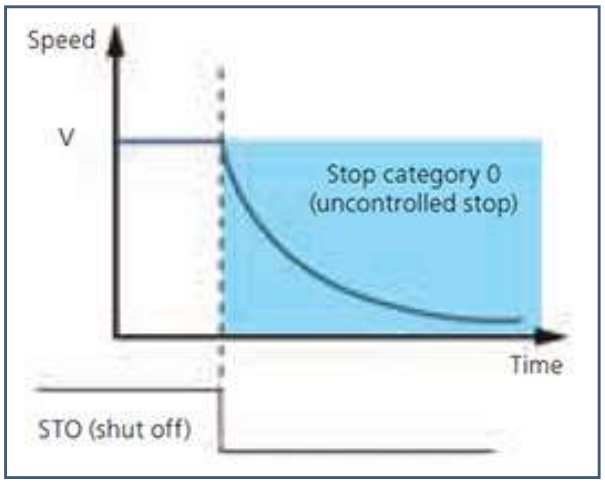
I'm not sure if there's a standard method of using circuits for e-stop conditions; however, there are a number of ways to configure an e-stop button in a servo drive system. Here is one example: the image in Figure 2 illustrates what's possible by utilizing software-based safety, in this case, STO safety subfunction.

E-stop buttons can be used in a number of configurations, but in their simplest form, they cut power to drive components when pressed to prevent damage to machine components or to prevent operator injury. In a hardware-based solution, power is cut to drive components via a series of magnetic contactors when the e-stop button is pressed. This serves the purpose of an e-stop by allowing motion to come to an uncontrolled stop, but the downside is that cutting power to the drives requires the drive to fully start up when the e-stop condition is removed.

In a software-based solution, the system configuration uses software-based safety subfunctions, in this case safe torque off (STO). Safe torque off cuts torque producing current to the servo motor when the e-stop button is pressed bringing motion again to an uncontrolled stop. The benefits of using safety subfunctions such as STO is that the magnetic contactors are no longer required, which reduces system costs and the power to the drive is not cut, which reduces start-up time.

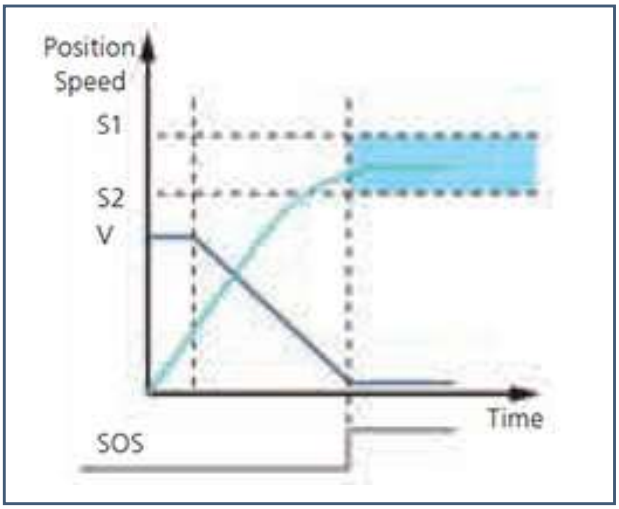
We have a full range of safety subfunctions, in addition to STO, offered with safety over network that allow for more advanced safety features. Table 1 includes a full list of the range of offerings, including a brief definition for each.

DAN ZACHACKI / senior product marketing engineer / Mitsubishi Electric Automation / *us.mitsubishielectric.com/fa/en/*



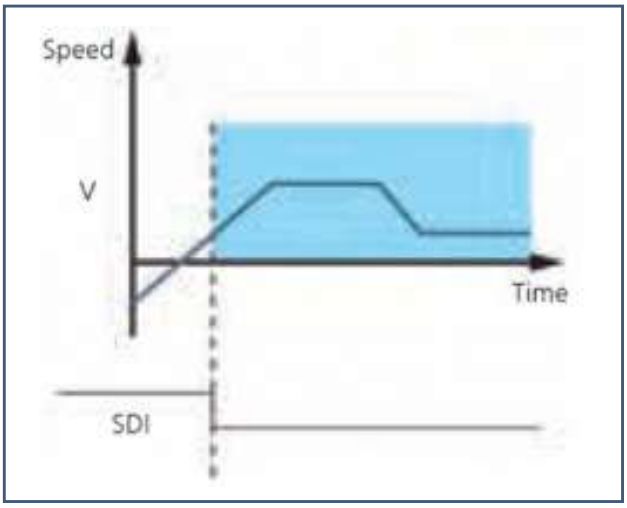
SAFE TORQUE OFF (STO)

Responding to the input signal from external equipment, the STO function shuts off power to the servo motor electronically using the internal circuit (shuts off through secondary-side output). This function corresponds to the Stop category 0 of IEC/EN 60204-1.



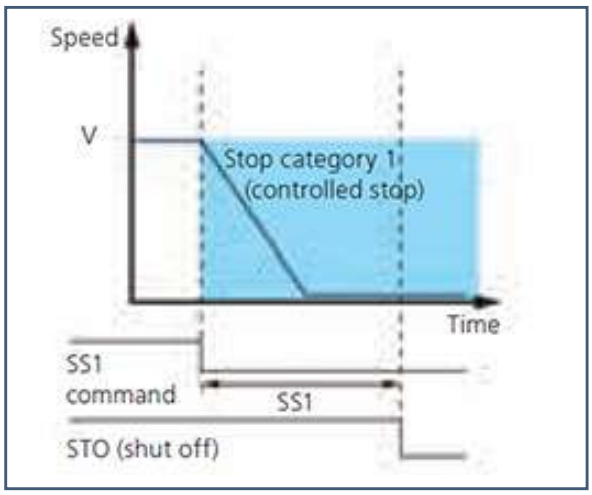
SAFE OPERATING STOP (SOS)

This function monitors the position of the servo motor not to deviate from the specified range. Power is still supplied to the servo motor during the SOS function.



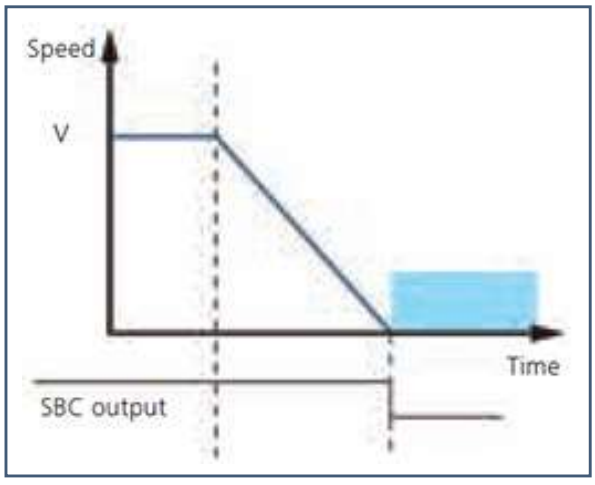
SAFE DIRECTION (SDI)

This function monitors whether the servo motor moves in the command direction. If the servo motor moves in a different direction from the command direction, the STO function is executed.



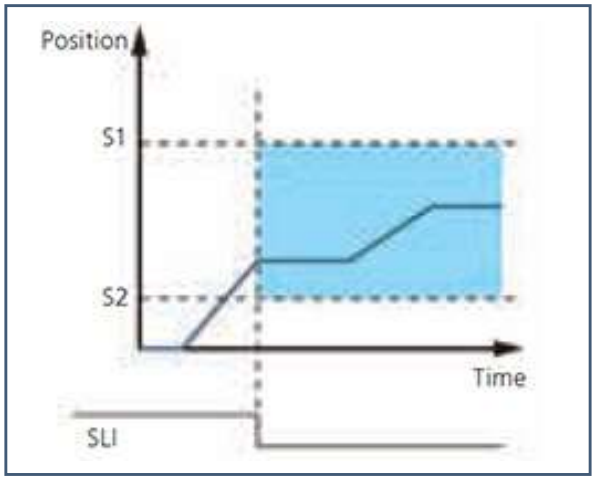
SAFE STOP 1 (SS1)

Responding to the input signal from external equipment, the servo motor starts to decelerate. After the set delay time for the motor stop is passed, the STO function starts. Monitoring the servo motor deceleration based on the motor deceleration rate is also supported. This function corresponds to the Stop category 1 of IEC/EN 60204-1.



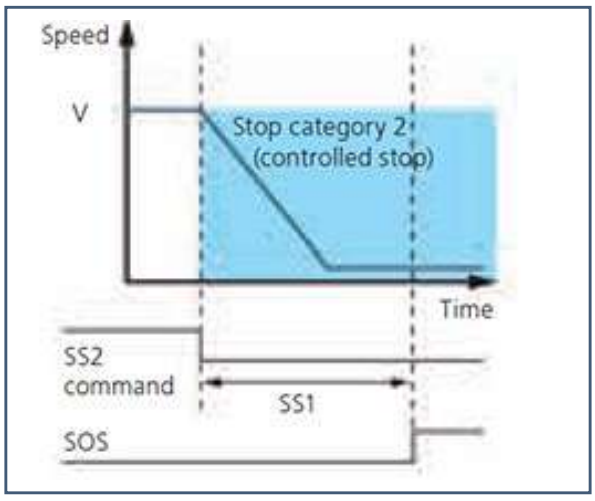
SAFE BRAKE CONTROL (SBC)

The SBC signals are outputted for external brake control.



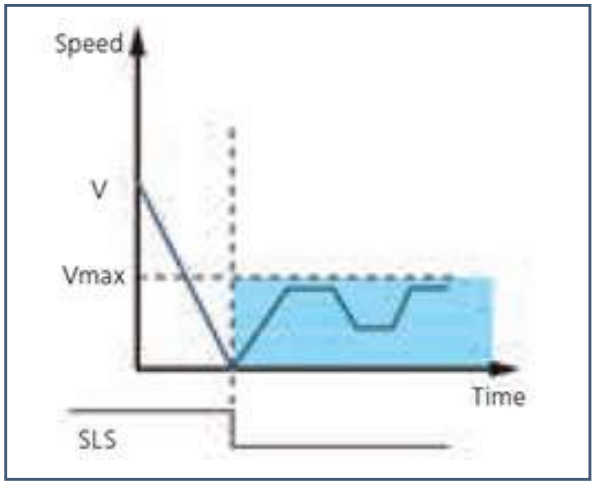
SAFELY LIMITED INCREMENT (SLI)

This function monitors the travel distance of the servo motor not to deviate from the specified range. If the travel distance exceeds the range, the STO function is executed.



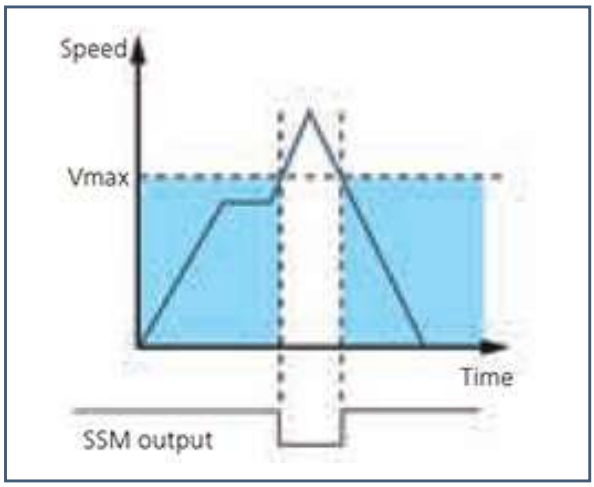
SAFE STOP 2 (SS2)

Responding to the input signal from external equipment, the servo motor starts to decelerate. After the set delay time for the motor stop is passed, the SOS function starts. Monitoring the servo motor deceleration based on the motor deceleration rate is also supported. This function corresponds to the Stop category 2 of IEC/EN 60204-1.



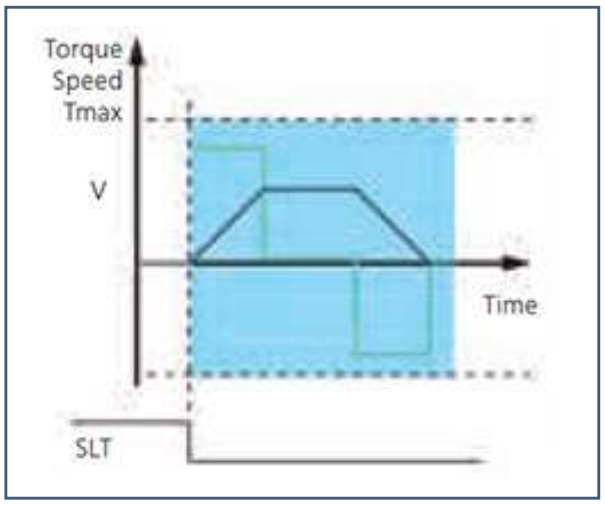
SAFELY LIMITED SPEED (SLS)

This function monitors the speed of the servo motor not to exceed the specified speed limit. If the speed exceeds the limit, the motor power is shut off by the STO.



SAFE SPEED MONITOR (SSM)

The SSM signals are outputted when the speed of the servo motor is below the specified speed limit.



SAFELY LIMITED TORQUE (SLT)

This function monitors the torque (or the thrust) of the servo motor not to deviate from the specified range. If the torque (or the thrust) exceeds the range, the STO function is executed.

Table 1: A full range of safety subfunctions, in addition to STO, are offered with safety over network that allow for more advanced safety features. (Source: Mitsubishi Electric)

EMERGENCY STOP VS. STOP CATEGORIES

The idea that the terms "e-stop," "emergency-stop" and "stop categories" are equivalents is a common misconception. An emergency-stop function, which is normally linked to an emergency-stop pushbutton, or e-stop, in a machine, refers to a safety function that must be initiated by a single human action and is intended to minimize hazards to people, as well as damage to machinery or works in progress. Since this safety function does not prevent people from being exposed, it is considered a complementary protective measure, according to ISO 12100:2010 and ISO 13850:2015.

Stop categories, on the other hand, refer to the way in which a machine will stop. These categories, which are based on IEC 60204-1 and NFPA 79, can be defined as follows:

- **Category 0** is a means of stopping the machine through the immediate removal of power to its actuators and is considered an uncontrolled stop. An example of Category 0 is to pull a plug and wait until the machine has completely stopped.
- **Category 1** is a controlled stop with power to the machine actuators available to achieve the stop condition. This category allows powered brakes, so the power has to be available until the machine stops. For example, in a machine that uses drives, the stop is generated with a controlled deceleration ramp before disabling the drive's output to the motor. In this case, the drive works as an actuator to bring the motor into a non-torque state after the deceleration. Once the machine motion has ceased completely, the power will be removed.
- **Category 2** is a controlled stop with power left available to the machine actuators. An example of this category is a normal production stop in which the machine is brought to a stop and power is available to start at any point.

According to IEC 60204-1, an emergency stop must operate as either a Category 0 or Category 1 stop as determined by a risk assessment. Both of these categories require that the emergency stop function override all other operations and functions, so a restart is possible only after a manual reset. Category 2 is not suitable for an emergency stop function because power is still available after the machine stops, and no additional measures are required to restart the machine.

Also read: ***How to improve the safety of an operating machine beyond just an e-stop button***

To provide an example of an emergency-stop function that performs a Category 0 stop, we can consider a safety circuit in which an emergency stop pushbutton (e-stop) is identified as S1, a reset button as S2, a motor as M, and contactors as KM1 and KM2 (Figure 3). All of these devices are connected to a status-monitoring relay, which ensures the switching action and provides contactor monitoring through T31 and T32. When the e-stop is activated, it will cause the contactors to isolate the power from M. The power to M is kept removed until e-stop S1 is released and reset switch S2 is pressed.

This will exemplify a scenario where an emergency stop in a piece of equipment has been pressed and power has been removed completely, preventing the machine from starting. At this point, the machine won't be permitted to start until the emergency-stop pushbutton is manually released and the reset switch is pressed. After all safety conditions are acknowledged by the safety circuit, then the machine is permitted to restart.

In terms of emergency-stop devices, graphical representations of a button on an HMI or flat panel display are not an option. The standards do not permit flush or membrane-style switches or touchscreen buttons. The specific requirements for an emergency-stop pushbutton to be compliant are as follows:

- It must have a direct opening operation.
- It must be self-latching, meaning that it can only be reset manually.
- It must be colored red and mounted upon a bright yellow background. The yellow background must be a minimum of 3 mm beyond the mounting collar and visible beyond the control actuator, according to ANSI B65.1-2005.
- It must have a mushroom-head shape to make it easy to push.
- It must remain unguarded.
- It must be located at each operator control station and at any other location where an emergency stop would be required.

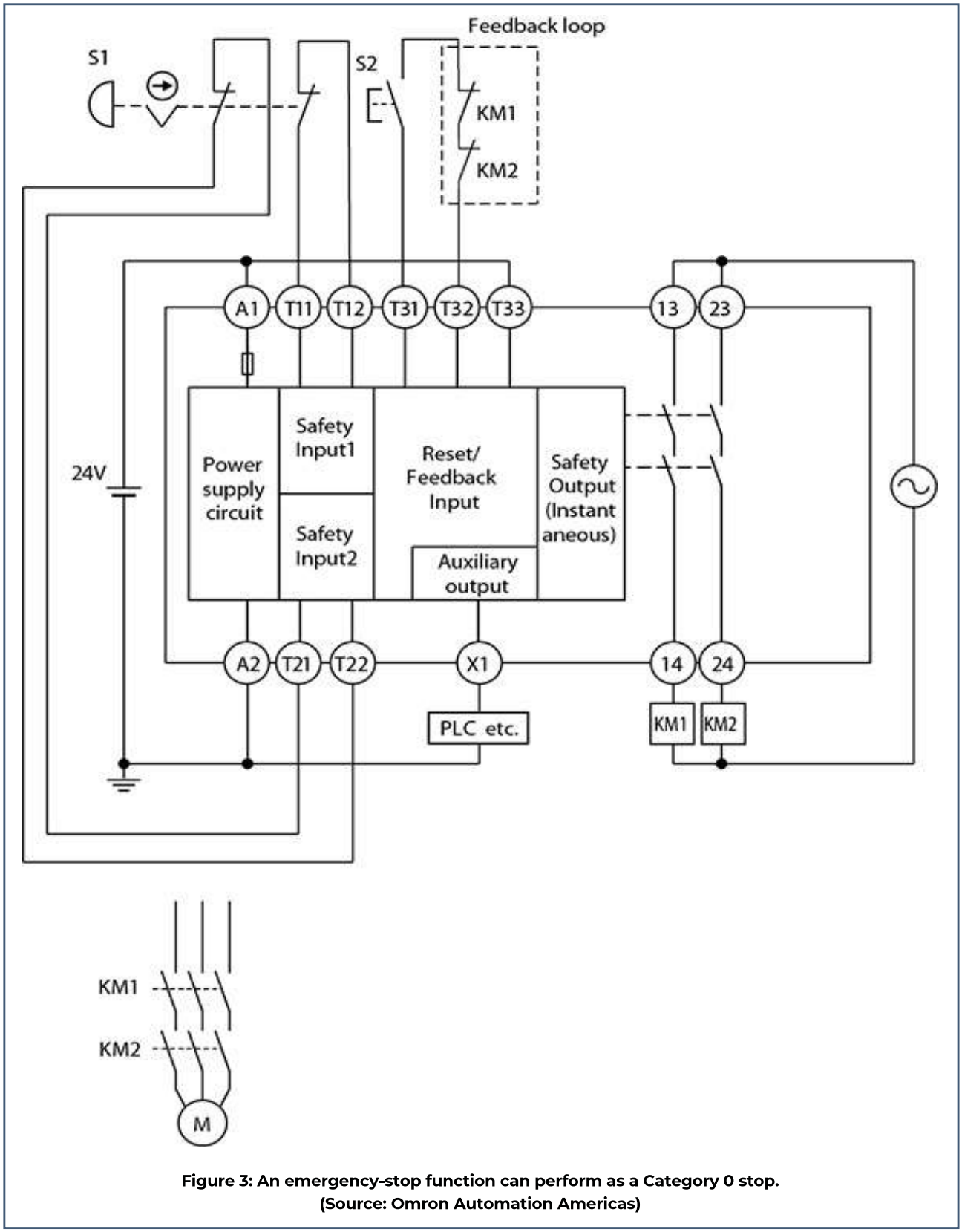


Figure 3: An emergency-stop function can perform as a Category 0 stop. (Source: Omron Automation Americas)

For additional references on emergency-stop functions and their requirements, please review *ISO 13850:2015, Safety of Machinery—Emergency Stop Function—Principles for Design and IEC 60204-1:2005, Safety of machinery—Electrical*

equipment of machines—
Part 1: General requirements.

PAM HORBACOVSKY KLANCEWICZ / product manager—safety / Omron Automation Americas / automation.omron.com/en/us/

NFPA 79 STANDARDS

The best standard method for using an e-stop would be just that, starting with a standard. Using standards such as the latest revision of National Fire Protection Association (NFPA) 79—the 2021 revision was just released—to understand the requirements of an emergency stop and how it should function in your system. NFPA 79 requires the use of a "self-latching" type contact for push-button emergency stops. It is important to also differentiate the categories of an e-stop function versus the categories of safety system design. The stop function has three categories:

- **Category 0** is instantaneous removal of power to the machine actuators.
- **Category 1** is a delayed removal of power, where a breaking mechanism or a controlled and powered stop is achieved, and then power is removed.
- **Category 2** is a controlled stop under power where power is never removed from the machine actuators.

According to NFPA 79, an emergency stop should be stop category 0 or 1. It is important to select the correct stop function for your application. For example, you may think that an instantaneous removal of power would be best for every application, but if you have a large spinning drum or a fast-moving flywheel, removing power immediately could leave them moving and hazardous for a long time. A better solution would be to stop them under power and then to remove power (Category 1). Categories are also used when describing safety system design. Without going into too much detail, essentially design categories B, 1 and 2 are single-channel type designs, and categories 3 and 4 are redundancy designs. For more information on safety categories, reference EN ISO 13849-1 or ANSI B11.19.

There could be applications in which a software e-stop could be used, but it would need to be on a safety visualization package, on a safety network, as part of a fail-safe PLC. I'm not aware of any safety-related visualization software that would allow this type of setup, but with the continued advances in control technology, there may be some available.

ZACHARY STANK / product marketing manager—I/O and networks / Phoenix Contact / www.phoenixcontact.com

What are the different acceptable types of e-stop devices?

Guidelines inform requirements for design, and the application-specific environment plays a role

By Anna Townshend

A **Control Design reader writes**: What are the acceptable forms of an e-stop button? We typically see the mushroom-head push button, but are other manual actuators acceptable under the appropriate standards? What about color—red and yellow? Are remote or touchscreen e-stops feasible and compliant?

ANSWERS

WORK WITH OPERATORS

Emergency stop (e-stop) buttons are significant safety devices used as part of the human-machine interface (HMI) to quickly shut down equipment in emergency situations. The acceptable forms can vary depending on the specific standards and regulations applicable to the industry or location, so it is critical to review American National Standards Institute (ANSI)/ Robotics Industries Association (RIA) R15.06, International Organization for Standardization (ISO) 13850, to ensure compliance with applicable requirements and alignment with best practices.

It's equally important to work with the operators who will be interfacing with the equipment to understand access points and types of actuators that will provide quick and efficient use in emergency situations.

From my experience, there are some general principles and common practices:

1. The mushroom-head push button is the most common form of e-stop button. They are easily identifiable and can be operated quickly in an emergency.
2. Other manual actuators may include pull switches or other types of push buttons with distinctive shapes or features that make them suitable for emergency-stop applications.
3. Red is the most widely accepted color for e-stop buttons because it is highly visible and universally recognized as a signal for stopping or indicating an emergency. Red means stop; yellow means caution. In the event of an emergency, we want to stop the equipment, not take caution or slow it down.
4. Touchscreen e-stops may be technically feasible, but their compliance with safety standards may vary depending on factors such as reliability, visibility and ease of operation. Prior to implementing, failure rates and false activations must be considered, as well as ensuring that operators can quickly and easily access the emergency-stop function when needed.
5. Routine testing of any type of e-stop must be conducted to ensure functionality. It's important to consider the type of e-stop you are using to determine the frequency of testing.
6. Similar to personal protective equipment (PPE), e-stops are the last line of defense to prevent an injury. Other safeguards and controls, such as guarding and light curtains, must work in conjunction with the e-stop to provide safe and reliable equipment function.
7. It's crucial to consider the specific application, environment and operational requirements to choose the most suitable type of e-stop button for the situation. It's not a one-size-fits-all approach.

Rebecca Stephenson/ director of risk / Gray Solutions

RED SIGNALS STOP

According to ISO 13850:2015 and ANSI B11.19-2019, emergency-stop devices (e-stops) are used to reduce risk, but they do not serve as a substitute for safeguarding measures. As stated in ANSI B11.19, "Since an individual must manually actuate an emergency-stop device to initiate the stop command, usually in reaction to an event or hazardous situation, it neither detects nor prevents exposure to a hazard." E-stops are intended to avert arising or existing hazards to persons or damage to machinery or work in progress.

Emergency-stop devices shall be designed to be easily identified and actuated by a single human action.

However, identification of the actuator or the background cannot be labelled with text or symbols. The actuator of the e-stop device shall be colored red, and, if a background exists behind the actuator, the background shall be colored yellow when possible.

An emergency-stop device may exist in one of several forms, according to ANSI B11.19-2019, CSA Z432:23 and National Fire Protection Association (NFPA) 79-2024:

- Pushbutton-operated devices or mushroom-head type that are easily activated by the palm of a hand. Actuator/button must be red and the background must be yellow.
- Rope or cable pull-operated devices where the actuator is not run through conduit or other tubing, and the device will detect a slack condition or a break of the rope or cable. Actuator/cable must be red; if flags or markers are used along the rope, they must be red and yellow.
- Foot-operated devices without a protective cover, are applicable where other solutions are not. Actuator/pedal must be red; background should be yellow where feasible. These devices should be mounted in a fixed position directly at access level.
- Rod-operated devices are designed to be actuated by the hand of an individual. Actuator/rod must be red; background should be yellow where feasible.
- Push-bar-operated devices are designed to be actuated by the body of an individual. Actuator/bar must be red; background should be yellow where feasible.

E-stops shall be in the following areas:

- at each operator control station, unless a risk assessment deems this not necessary
- at other locations such as entrance and exit locations, as determined by the risk assessment
- at locations where intervention to the machinery is expected—loading/unloading.

An interface on a touchscreen or human-machine interface (HMI) is not permitted to be used as an e-stop device. International Electrical Commission (IEC) 60947-5-1 states e-stops require a direct opening action of an electrical contact. This cannot be provided through a touchscreen. In addition, an e-stop must always be accessible and active during all modes of operation, and a touchscreen interface cannot fulfill this requirement if it loses power or is reprogrammed.

When considering implementation of wireless e-stops, several aspects must be considered within IEC 60204-1:2016.

The cableless control system (CCS) shall have functionality and response time suitable for the application based on the risk assessment.

The CCS shall be designed as follows:

- It shall be automatically monitored, either continuously or at suitable intervals and the status of this ability shall be clearly indicated—through an indication light/visual display indication.
- If the communication signal is degraded, a warning to the operator shall be provided before the ability of the CCS to control a machine is lost.
- An automatic stop of the machine shall be initiated when the ability of the CCS to a machine is lost for a time interval determined by the risk assessment.
- Wireless e-stops should have published performance ratings.

It is important to note that ISO 13850 now requires Performance Level c (PLc) at minimum for e-stop circuits. This is only applicable to new equipment after the date of publication.

Sarah Starsiak/ market product manager, industrial safety / Sick

Chris Soranno, FS Exp, CFSAE-T/ manager of international safety standards / Sick

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PALM OF YOUR HAND

For many years, the standard associated with emergency stops was ISO 13850:2006, which specified that one form of an emergency-stop device may be a "mushroom-type push button." However, a more recent revision of this standard, ISO 13850:2015, has an expanded definition, which now specifies "push buttons easily activated by the palm of a hand." Therefore, other forms for e-stop buttons are permissible, so long as they are easily activated by the palm of the hand. The standard has also allowed wires, ropes, bars, handles and foot pedals without a protective cover.

The latest standard also has direction regarding e-stop device colors, stating that the "actuator of the emergency stop device shall be colored red. As far as a background exists, behind the actuator and as far as it is practicable, the background shall be colored yellow." Furthermore, there is direction that the e-stop actuator and background should not be labelled with text or symbols to simplify usage so users do not expend time figuring out the markings in an emergency, although there are allowances for some types of markings when necessary.

Whether remote or touchscreen e-stops are feasible and compliant is an interesting question. ISO 13850 states that the e-stop device shall be designed to be operated

by the operator or another person, but it doesn't say anything regarding whether this action must be a direct operation. It is not proper to replace a required e-stop device with a remote operation device or touch panel function; however, a remote function could be used as a supplementary way to trigger the e-stop device. This opens up possibilities for designers to incorporate compliant e-stop devices, which provide required functionality while also enabling additional ways to operate the device, such as using a remote wireless system to operate an e-stop from a distance, providing improved user safety.

Luiz Shida/ marketing specialist / IDEC

RECOMMENDED TYPES

Emergency-stop devices or buttons are safety control devices designed to enable workers to swiftly stop machinery or equipment operation during critical situations or an emergency, designed to prevent accidents, injuries or damage to machinery by providing a fast and easily accessible means of shutting down equipment.

E-stops serve as fail-safe control switches. They are used when the machinery's master switch cannot be accessed in time. The emergency-stop pushbuttons are engineered for rapid response and are wired along the control circuit of the machinery.

E-stop buttons are designed for easy handling and can be operated by hand or by a footswitch on the ground level. The recommended types of e-stop buttons are:

- Mushroom-head pushbutton: This is the most common and widely accepted form. It features a large, mushroom-shaped button that is easy to identify and press during emergencies. Its distinctive shape and size make it a widely recognized standard for emergency-stop controls.
- Palm button: Palm buttons are also acceptable forms of e-stop buttons. These buttons require the operator to press them with their palm, ensuring deliberate and immediate action.
- Push-pull: The push-pull emergency button is pushed to lock into position to cut off the power to the machinery and pulled back to reset to its original position.
- Twist to release: This can be pushed to cut off electrical power to the connected industrial machinery. However, it requires twisting the button to reset after activation. This helps prevent accidental reactivation.
- Key release: These buttons are pushed in and locked to cut off the electrical contact. It can be unlocked using a removable key provided with the e-stop.
- Pull cord: Pull-cord e-stop switches are used where the operator may need to stop the machinery from a distance or where hands-free operation is necessary. The emergency-stop command is

triggered by pulling on the tensioned pull-wire. Additionally, all these switches incorporate cord-breakage monitoring. If the cord is pulled or breaks, the normally closed (NC) contacts are forcefully opened while the normally open (NO) contacts close. Restoring the pull-cord emergency stop switch requires deliberate resetting action.

- Foot-operated switch: These e-stop switches work as permissive switches in machines and plants where operators need to maintain balance or control over the equipment. Operators can press down on the foot pedal to stop the machinery, allowing them to maintain control while keeping their hands free for other tasks.
- Wireless e-stop systems: Wireless and remote emergency stop switches provide convenience in operation without physical tethering to the switch. These switches typically feature wireless communication capabilities for remote activation. In emergencies, they can swiftly halt machinery or processes from a distance, enhancing safety and responsiveness in industrial settings.

Regardless of the form, all e-stop buttons should be easily identifiable, readily accessible and marked with universally recognized symbols. They should also prevent accidental activation while enabling quick and decisive action in emergencies. Additionally, they must comply with relevant standards such as American National Standards Institute (ANSI), International Organization for Standardization (ISO) and Occupational Safety and Health Administration (OSHA) regulations.

Emergency-stop categories refer to different levels of safety and functionality associated with e-stop systems in industrial settings. The e-stop categories are broken down into three general groups to ensure proper design and implementation of safety measures and are defined by ISO 13850 and International Electrical Commission (IEC) 60204-1 standards:

- **Category 0**: This category involves immediately removing power to the machinery or equipment without safety monitoring functions. It's the most basic emergency stop, used only when immediate shutdown is necessary. In this case, the machine may continue to run mechanically, posing a potential danger or risk of damage and injury even after actuation.
- **Category 1**: In this category, the emergency-stop function is initiated by a single action. The machine is stopped in a controlled way, followed by cutting off the energy supply to the drive elements. For example, heavy loads under high acceleration or deceleration rates require a controlled stop to prevent hazards.
- **Category 2**: It is a powered stop category that does not remove power from the machine. This category must

not be used to switch off in dangerous situations, but it is still a helpful feature.

A risk assessment of the machine must be carried out to determine the correct stop category for an emergency stop. It is also used to determine whether an emergency stop is necessary.

The mushroom-head pushbutton is the most commonly observed form of e-stop button. However, other manual actuators are acceptable under the appropriate compliance and standards, such as ANSI B11.19-2010, ISO 13850:2015 and OSHA 29 CFR 1910.212. These include palm buttons, pull cords, foot pedals and paddle buttons, among others listed.

According to ANSI Z535.1-2017 and OSHA 1910.144, an emergency-stop button must be colored red to ensure quick identification in emergency situations. Red signifies danger and is universally recognized as indicating the need for immediate action.

The area surrounding the red mushroom button, background or housing, should be yellow, as per ANSI Z535.4-2011 and OSHA 1910.144 for improved visibility. National Fire Protection Association (NFPA) 79 reinforces such yellow enclosures, incorporating a prominent yellow emergency-stop label or adding yellow coloring to the stem of the button. The standard specifies that the red/yellow color combination should be reserved exclusively for emergency-stop applications.

Wireless e-stops and remote e-stops are feasible and comply with ISO 13849, ISO 13850:2015, ANSI B65.1-2005, IEC 60204-1:2005, and IEC 62745 standards.

In a scenario where an operator performing maintenance cannot reach the machine's hardwired emergency stop, the wireless e-stop can be invaluable. The wireless e-stop system allows safer access closer to operational activities. In addition to the safety function, it has a handheld transmitter featuring a button and switch that can be freely configured for user-specific control tasks for convenient operation. Secure operation is ensured regardless of the user's location, and the system allows facilities to be switched off in dangerous situations. It promotes universal usability for maximum mobility and safety.

A touchscreen e-stop is not allowed. Graphical representations of emergency-stop buttons—icons—on a human-machine interface (HMI) or flat panel display are not permissible for e-stops operation.

Ankur Tomar/ solutions marketing manager / Newark

RED/YELLOW EXCLUSIVELY

Emergency-stop buttons are critical devices to ensure safety. Numerous established standards guarantee their effectiveness and visibility. According to IEC 60204, it is imperative for e-stops to be readily identifiable and easily accessible, should an operator detect a machine hazard.

The most common type of e-stop buttons, as specified by ISO 13850, IEC 60204, IEC 60947, and NFPA 79, feature an easy-to-operate mushroom-head, with a red button against a yellow background for enhanced visibility.

NFPA 79 does include other types of actuations such as pull cords and foot-operated controls. It does specify "emergency stop devices shall be colored red. The background immediately around push buttons and disconnect switch actuators used as emergency stop devices shall be colored yellow. The red/yellow color combination shall be reserved exclusively for emergency stop applications."

Along with the form and color requirements, there are additional regulations for e-stops. These include:

- directly opening an electrical contact
- self-latching in the open state
- requiring manual reset to resume operation.

While a touchscreen e-stop cannot meet these requirements and thus would not be compliant, a remote e-stop that fulfills all the discussed criteria would not only comply but also offer potential advantages. This is particularly relevant in scenarios where mobility around the machinery is necessary, and the observer may not have an e-stop easily accessible.

Mike Davis/ product manager industrial electronics / Misumi USA

NFPA 79

In the United States, we can refer to NFPA 79 for what an e-stop device must do and look like. As stated in Chapter 10.7.1, e-stop devices do not have to be buttons; they can also be pull cords, foot-operated switches and push bars, just to name a few examples. NFPA 79—10.7.3 says that the actuators, the part that is interacted with, of e-stop devices, shall be red with an immediate background yellow. In the same section, the shape of e-stop buttons specifically shall be palm or mushroom-head type. Lastly, section 10.7.2 says that e-stop devices shall not be flat switches or graphical representations, meaning that software e-stop, such as from an HMI screen, are not allowed.

As for remote e-stop devices, these are certainly allowed, provided that they adhere to the requirements outlined in NFPA 79. I won't go through all of the requirements, but I will list a few important ones:

- The e-stop function shall override all other functions regardless of operation mode.
- Power to the machine actuators—motors, presses—shall be removed as quickly as possible without introducing other hazards.
- Reset of the e-stop device shall not cause the machine/process to reset.
- More details on emergency stop functions can be found in NFPA 79, chapters 9 and 10.

Noah Greene/ product specialist—safety / Phoenix Contact USA