Emergency Stops: What Designers Need to Know

Emergency stop switches, generally referred to as E-Stops, ensure the safety of persons and machinery and provide consistent, predictable, failsafe control response. A wide range of electrical machinery must have these specialized switch controls for emergency shutdown to meet workplace safety and established international and U.S. regulatory requirements. E-Stops – critical human machine interface (HMI) devices – differ from simple stop switches (that merely turn equipment off) in that they offer "foolproof" equipment shutdown. This is accomplished through advanced switch design that requires a twist, pull, or key to release electrical contacts to allow machinery restart.

E-Stops are generally designed for failsafe operation so the stop command has priority over the sustaining function. This has led to innovative switch designs that prevent "blocking" (wanton or accidental obstruction of the actuator with foreign objects) and "teasing" (which could result in premature or unreliable action). Switch companies also are developing new solutions to problems that arise when contact block and actuator are improperly installed or separated because of vibration or other malfunction.

E-Stops are critical to the human machine interface (HMI).

eao

An E-Stop must be initiated by a single human action using a manual control device.

Safe Emergency Stopping

According to international standards, the emergency stop function must be initiated by a single human action using a manually actuated control device. The E-Stop function must be operational at all times and designed to stop the machine without creating additional hazards.

Resetting the electrical system can only be done by first releasing the E-Stop that was originally activated. If E-Stops were activated at multiple locations, all must be released before machinery restart. It should be noted that resetting E-Stops does not in itself restart the machinery; it only *permits* restarting through normal procedures appropriate for the machinery involved.

Ergonomic, electrical, mechanical, and color requirements for E-Stops are quite specific. The E-Stop control, commonly a distinctive pushbutton switch or "mushroom type" pushbutton (although wires, ropes, bars, handles, or foot pedals are sometimes employed), must use direct mechanical action with mechanical latching. When the E-Stop is activated (pushed), it permanently opens the electrical contacts through a latching mechanism. To close the electrical contacts and allow machinery restart, the E-Stop actuator must be manually unlatched with a twist or a key release. Some E-Stop actuators can simply be pulled to close the electrical contacts. This approach may be less desirable from a safety standpoint than a twist or key release, which requires a more deliberate action by an operator.

Designers should be aware of international and U.S. standards and regulations that impact the design and use of E-Stops.

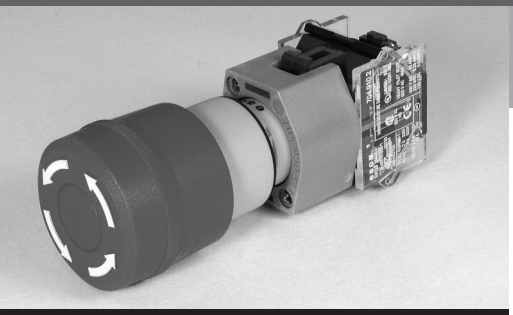
Selecting the Right E-Stop for Your Application

Because of the confusing array of E-Stops available, it is important to understand the design basics that contribute to high-quality, ergonomic switch design. EAO is a leader in HMI Components and Systems, including innovative, rugged, reliable, and affordable E-Stops that meet or exceed international and U.S. standards.

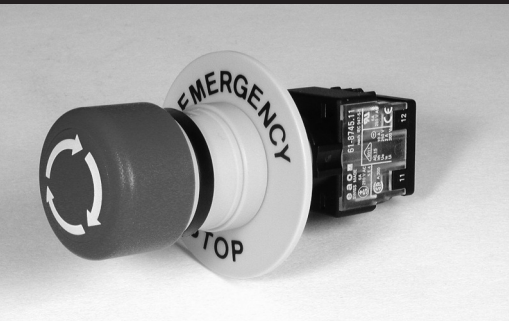
One of the first steps is determining where the E-Stop fits within your machine control system and whether your particular application requires Category 0 or Category 1 type emergency shutdown. The intended application often determines the placement, size, electrical specifications, mechanical characteristics, ergonomics, color/legends, and number of E-Stops required. So a thorough understanding of the machinery and associated control systems is key to making the right E-Stop choice.

A second, and equally important step, is determining what international and

eao



A 22.5 mm switch must be durable and rugged.



Today's applications often require a slimmer footprint for 16 mm mounting.

E-Stops may require shorter behind-panel depth.

Designed for rough duty

Robust, heavy-duty construction is the hallmark of the original 22.5 mm switches. Many, like the EAO Series 04 E-Stops, have stackable contact blocks, optional key release actuators, and mounting options for 22.5 mm panel openings. This EAO series is rated at up to 10 A, 600 VAC, has silver contacts with available gold over silver or silver over palladium contacts, and silver-plated screw terminals with available quick-connect terminals.

Smaller mounting footprint

Modern applications often demand a slimmed down E-Stop with 16 mm mounting. Innovative products, like the EAO Series 61, are now available with an actuator shape that prevents blockage from foreign objects, a black indicator ring visible from long distances, and available key release actuators. This EAO series is rated at 5 A, 250 VAC, and has a choice of silver or gold contacts, screw or solder quick-connect terminals.

Short behind-panel depth

Newer electronic applications are requiring E-Stops with shorter behind-panel depth. EAO's Series 84 E-Stop, for example, features a very short behind-panel depth (18 mm maximum), single "mono-block" construction, 22.5 mm mounting, and available LED illumination that is visible from the side as well as front of the actuator. This series is rated at 3 A, 120 VAC and 1.5 A, 240 VAC, has gold contacts, quick-connect/solder printed circuit board terminals, and ribbon cable terminals.

U.S. standards, performance ratings, and codes apply for your application. Requirements vary by industry segment, so standards for E-Stops used on transportation vehicles may differ significantly from those used on process machinery or medical equipment and will be governed by different regulatory bodies specific to those segments. Regulatory bodies may also specify size, color, legend, contact terminals, etc.

It is then useful to construct or consult an existing E-Stop series selector chart (often supplied by vendors). For example, EAO provides a chart that allows easy comparison of key design factors for its multiple E-Stop series (see Figure 1). You can select panel opening size, type of actuator, type and number of contact blocks, connectors, colors, and maximum electrical rating to come up with one or more appropriate models.

Like many vendors, EAO provides special enclosures, switch guards, palm guards, custom labeling, and other accessories to complete virtually any E-Stop application. Some accessories may be specified by industry standards, such as the SEMI standards for semiconductor fabrication equipment that mandate the use of palm guards. EAO and other vendors also offer services to assist customers in the design, engineering, and production of HMI systems, integrating E-Stops.

1 EMERGENCY-STOP PUSHBUTTON ACTUATOR

Actuators should be precision molded from high quality polymeric materials to assure a mechanical life in excess of 6,050 operations as required by industry standards, including EN IEC 60947 5-5, paragraph 7.3.3. In real life, E-Stops generally exceed 250,000 operations. Actuators can be "tease-proof", twist-to-release, and foolproof in design. Actuators can also be pushbutton, mushroom, or key release.

2 SEALING

Many E-Stops are sealed to IP 65 oil and watertight standards.

3 FRONT PLATE

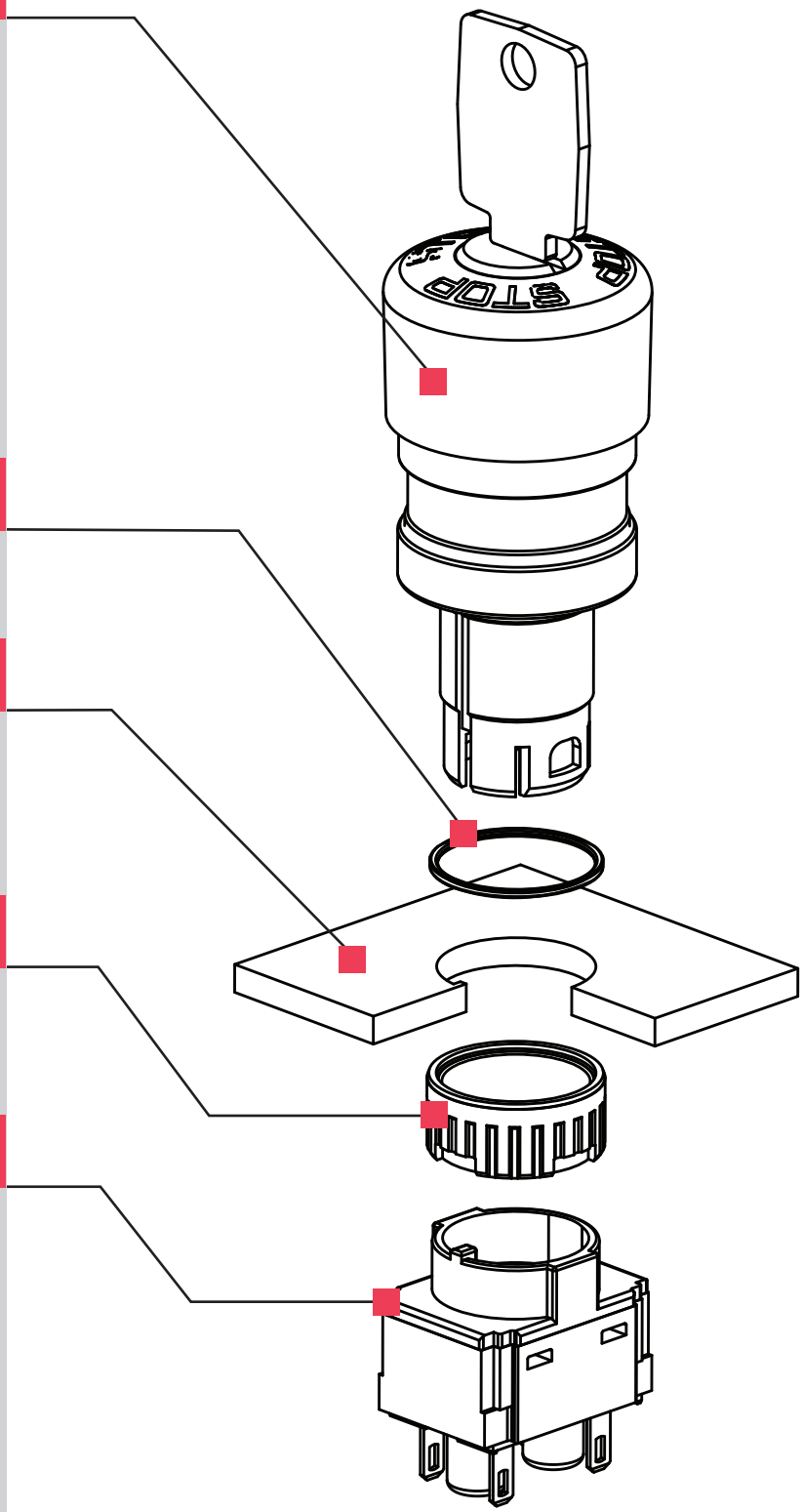
Front plates can be designed to conform to color and legend standards.

4 FIXING NUT

E-Stops have a variety of mounting options, for use in 22.5 mm or 16 mm panel openings.

5 SWITCHING ELEMENT

E-Stops typically offer a range of contact options including gold over silver or silver over palladium, and silver-plated screw terminals with available quick-connect terminals.



eao

Applications

Virtually all industry segments – from machinery, instrumentation, medical treatment and diagnostic, lifting/moving, and transportation – mandate E-Stops for safe operation. Designers need to have a thorough knowledge of E-Stop fundamentals, E-Stop switch characteristics and capabilities, and the international and U.S. standards and compliance requirements that apply to their application areas.

E-Stops are required on all machinery independent of the type of energy used to control the function except for machines in which an E-Stop function would not lessen the risk. An E-Stop switch is intended to be one part of a comprehensive safety system, so the equipment designer must also consider safety functions, such as reversal or limitation of motion, deflection, shielding, braking, or disconnecting, that are not specifically addressed in this paper. Primary application areas where electrical machinery is safeguarded with E-Stop technology include:

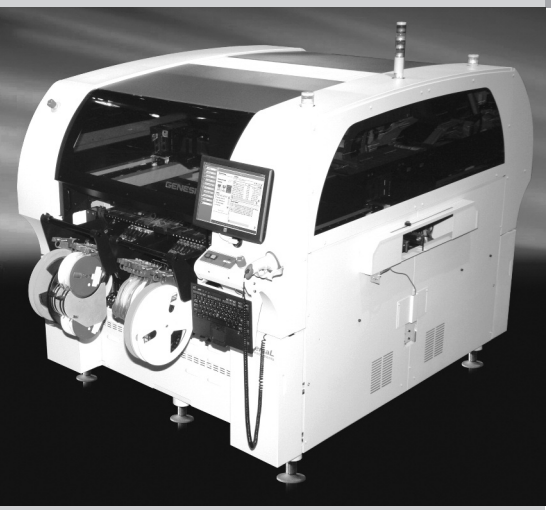
X-ray Equipment

Cabinet x-ray systems used for diagnostic and therapeutic medical applications, industrial non-destructive inspection and thickness gauging, security inspection of baggage, and other imaging are closely regulated for operational safety. E-Stops are covered by standards and regulations of the FDA Department of Health and Human Services. The key document is CFR Title 21, Part 1020 – *Performance Standards for Ionizing Radiation Emitting Products*, section 40, which requires accessible emergency stop switches and keyed lock-out switches to disable the system.

	04	44	61	84
22.5 mm panel opening	■	■		■
16 mm panel opening			■	
ISO 13850 (formerly EN418) "Tease-Proof" actuator	■	■	■	■
Stackable contact blocks/elements	■	■		
Short "behind-panel" depth (18 mm max)				■
Illumination				■
Cap color other than red	■	■	■	■
Screw terminals	■	■	■	
Quick-connect/solder terminals			■	■
Ribbon cable terminals				■
Sealed to IP 65 oil and watertight standards	■	■	■	■
Twist-to-release actuator	■	■	■	■
Key-release actuator	■	■	■	
Enclosure	■	■	■	■
Legend plates	■	■	■	■
Protective shroud	■		■	■
Max rating: 10 A/600 VAC	■			
Max rating: 10 A/660 VAC		■		
Max rating: 5 A/250 VAC			■	
Max rating: 3 A/250 VAC				■

Figure 1 – E-Stops selector chart by EAO Series

■ Standard feature ■ Available on request



In semiconductor manufacturing, there are strict guidelines set by the SEMI trade organization.

Markets and Applications

- Metalworking
- Wood production
- Textile production
- Food processing
- Printing
- Medical laser & x-ray equipment
- Packaging equipment
- Semi-fab equipment
- Pumping
- Lifting/moving equipment
- Plastics & rubber processing
- Materials handling
- Electronic production equipment
- Paper & cardboard production
- Inspection/testing equipment
- Compressors
- Laundry/dry cleaning facilities
- Transportation
- Construction/building materials

eao

Semiconductor Manufacturing

Semiconductor chips used in electrical and electronic devices are fabricated through a sequence of photographic and chemical processing steps. The process includes lithography, steppers, etching, and deposition equipment. The complex process is governed by specific operational and safety guidelines set down by SEMI, a trade organization of suppliers of equipment and materials used in the fabrication of semiconductor devices. SEMI S2-93 makes a clear distinction between emergency off (EMO) switches and E-Stops, requiring the latter to be clearly distinguishable from EMOs through the use of color (red), actuator shape (extended not mushroom), and labeling ("Emergency Stop"). It also specifies that E-Stops should stop all hazardous mechanical motion at the equipment interface, but not shut off associated equipment.

Overhead and Gantry Cranes

These large lifting and moving devices may have a gantry mounted cab which includes an E-Stop on the operator console. Smaller overhead cranes usually have a wired or wireless pendant control operated from ground level. The pendant includes an E-Stop. The chief regulating body for these massive devices is the Occupational Safety and Health Administration. OSHA 29 CFR 1910.179 (a)(59) defines "emergency stop switch" as a manually or automatically operated electric switch to cut off electric power independent of the regular operating controls. Another section, 9 CFR 1910.179(a)(61) defines "main switch" as a device controlling the entire power supply to the crane.

U.S. Standards for E-Stops

Occupational Safety and Health Administration (OSHA) – *Standards – 29 CFR* (Code of Federal Regulations); OSHA 1910

American National Standards Institute (ANSI) – B11, *Electrical and Mechanical Equipment Guidelines*

ANSI/NFPA (National Fire Protection Association) – 79, *Electrical Standards for Industrial Machinery*

Underwriters Laboratories Inc. (UL) – Category NISD, *Emergency Stop Device*

Food and Drug Administration, Department of Health and Human Services, Subchapter J – Radiological Health: CRF Title 21, Part 1020, *Performance Standards for Ionizing Radiation Emitting Products*

Other Compliance and Rating Bodies

Most quality E-Stop switches, including those made by EAO, are RoHS and REACH compliant, meet cUL (Canadian UL) requirements, and TÜV (Technischer Überwachungsverein, a German safety monitoring agency), SEV (a Swiss designation) and CE (European Union) approvals.

	Emergency Stop	Stop Switch
General		
Color of actuator	Actuators of emergency switching off devices shall be colored RED. • EN IEC 60947-5-5 § 4.2.1 • EN 60204-1 § 10.8.3 • DIN EN ISO 13850 § 4.4.5	Not defined
Actuator/Background	When a background exists behind the actuator, and as far as it is practicable, it shall be colored yellow. • EN IEC 60947-5-5, 4.2.1 • EN 60204-1, 10.8.3 • DIN EN ISO 13850 § 4.4.5	Not defined
Inscription of actuator	The direction of unlatching shall be clearly identified when resetting is achieved by rotation of the button. • EN IEC 60947-5-5 § 4.2.1	Not defined
Electrical requirements		
Utilization categories	The utilization categories shall be AC-15 and/or DC-13 and/or DC-14 in accordance with EN 60947-5-1. • EN IEC 60947-5-5 § 5.1	Not defined
Direct opening action	All normally closed contact elements of an emergency stop device shall have a direct opening action (positive opening action). • EN IEC 60947-5-5 § 5.2	Not necessary
Latching	It shall not be possible for the emergency stop device to latch-in without generating the emergency stop signal. • EN IEC 60947-5-5 § 6.2.1	Not defined
Resetting	Resetting of the emergency stop shall only be possible as the result of a manual action at the location where the emergency stop was initiated. • EN ISO 13850, 4.4.4	Not defined
Resetting	The resetting of the latching means shall be by turning a key, by rotation of the button in the designated direction, or by a pulling motion. • EN IEC 60947-5-5 § 6.3.1	Not defined, but usually realized by turning a key, by rotation of the button in the designated direction, or by a pulling motion.
Testing		
Robustness of a button actuator	A button actuator shall withstand a torque as specified below, in both directions of latched and unlatched positions, where the resetting action requires rotation of the push-button. • EN IEC 60947-5-5 § 7.3.2 Ø Force Torque 16 mm 80 N 1.6 Nm 22 mm 110 N 2.2 Nm 30 mm 150 N 3.0 Nm	Not defined
Durability test	The test shall consist of 6,050 cycles in which latching and resetting of the actuator occurs during each cycle. The movement and actuating forces shall be consistent throughout the test. Monitoring of these parameters shall be carried out to ensure consistency. • EN IEC 60947-5-5 § 7.3.3	Not defined
Norms		
Mandatory standards	• EN IEC60947-5-5 (International Standard) • EN ISO 13850 (Safety of Machinery) • EN 60204-1 (Safety of Machinery)	Not defined

Figure 2 – International standards that apply to Emergency Stops vs. Stop Switches

Depending on design and application requirements, many E-Stops are listed as UL category NISD emergency stop devices. This rating covers two categories of E-Stop function as defined in ANSI/NFPA 79, *Electrical Standards for Industrial Machinery* (ANSI is the American National Standards Institute and NFPA is the National Fire Protection Association):

1. Stop Category 0 – Immediate removal of power to the machine or mechanical disconnection (de-clutching) of hazardous elements.

2. Stop Category 1 – Controlled stop with power available to stop the machine followed by removal of power when the stop is achieved.

The emergency stop actuator provided in these devices must be a self-latching type. E-Stops with this rating have been reviewed for their functionality in addition to fire and electric shock safety.

Future of the Technology

Once you understand the E-Stop function and relevant standards, codes, and compliances you can determine the appropriate device.

The pace of change in E-Stop technology is steady, not revolutionary. By their nature, these devices must be recognizable, reliable, and rugged. They have a straightforward function: instantly shut down equipment with a simple push of a (usually) bright red actuator. For safety, reactivation of the switch requires twisting or pulling the actuator by hand or, for even more security, unlocking it with a key before machinery can be restarted. Established standards, function, and familiarity dictate a certain beneficial inertia in new E-Stop developments.

Many advances are driven by norm changes for E-Stops, such as DIN EN ISO 13850: 2008 that now requires mechanical latching and manual resetting of E-Stops. Most research and development is aimed at improving the safety and reliability of the switches themselves and expanding their roles as lockout devices in some worker safety applications.

One area of current interest is making sure that the E-Stop itself will "failsafe" should the actuator and contact block be separated. The contact block has normally closed contacts that allow power to flow to the machinery. Pushing an E-Stop separates the spring-loaded contacts, and mechanical latching keeps them open, stopping the machinery. But what happens if the actuator separates from the contact block or the latching mechanism fails?

Separation of the contact block from the actuator renders an E-Stop ineffective. Current solutions include mono-block or unibody switches with a one-piece actuator/contact block, as well as switches with failsafe contact blocks that automatically cause machinery shutdown if the actuator and contact block are separated.

Other advances are application-driven. EAO's Series 84 E-Stops, for example, were developed for hand-held enclosures with slim behind-panel depth for robotics applications. These versatile E-Stops also are used in pendant controls for lifting and moving machinery. Application requirements have also created a wide variety of available optional features and accessories for most E-Stop products – illumination, protective rings, enclosures, guards, legend plates, etc. – that add to the functionality and safety of E-Stop installations.

E-Stops will continue to evolve to meet new standards and new applications. For designers, the most important considerations in making the right design decisions are a thorough understanding of E-Stop function; a grounding in the standards, codes, and compliances involved; proper selection of devices that meet or exceed the application requirements.

EAO Switch Corporation
98 Washington Street
Milford CT 06460
T: (203) 877 4577
F: (203) 877 3694
E-mail: sales@eaoswitch.com
www.eao.com

Member of the EAO Group