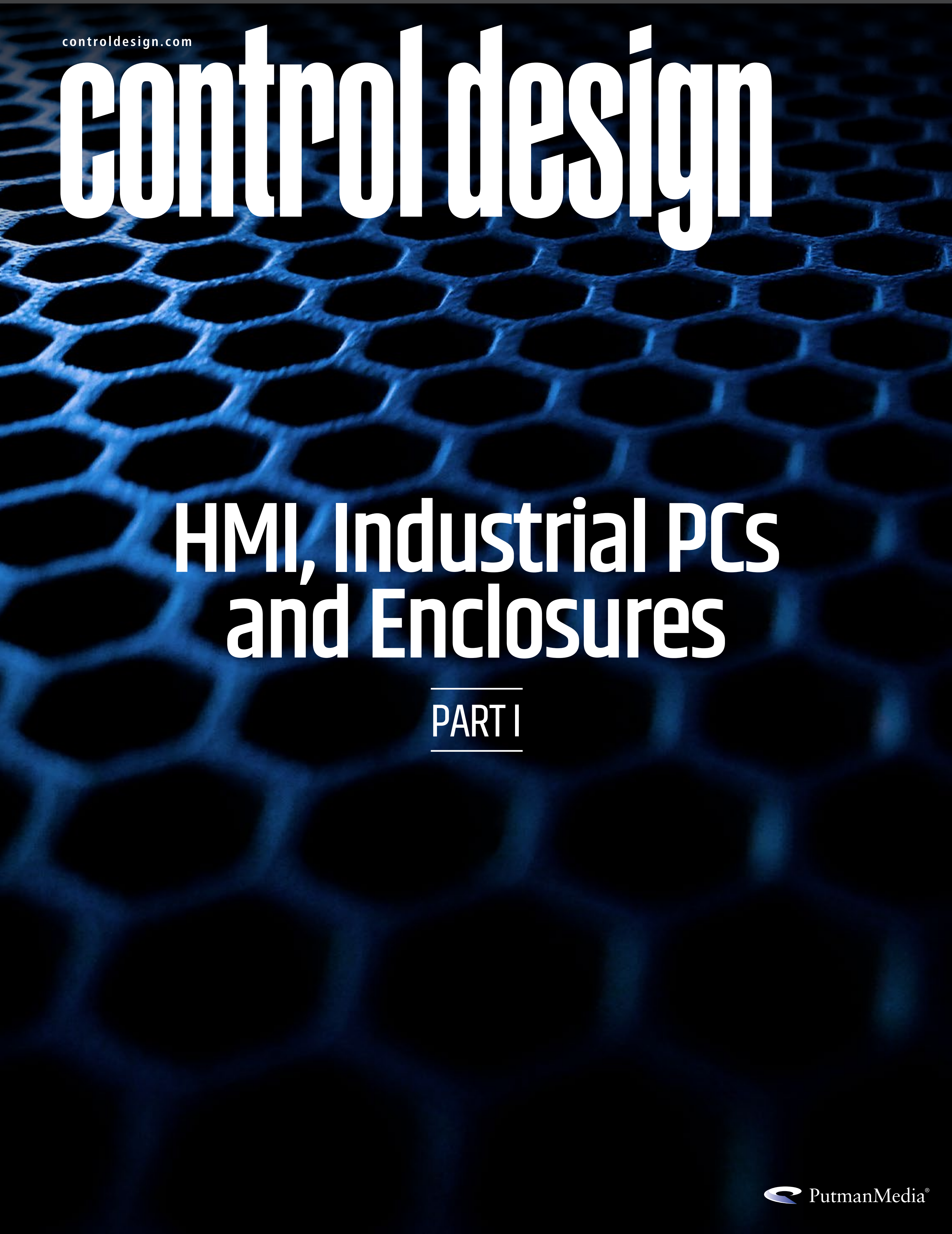
controldesign.com

control design



HMI, Industrial PCs and Enclosures

PART I

PutmanMedia®

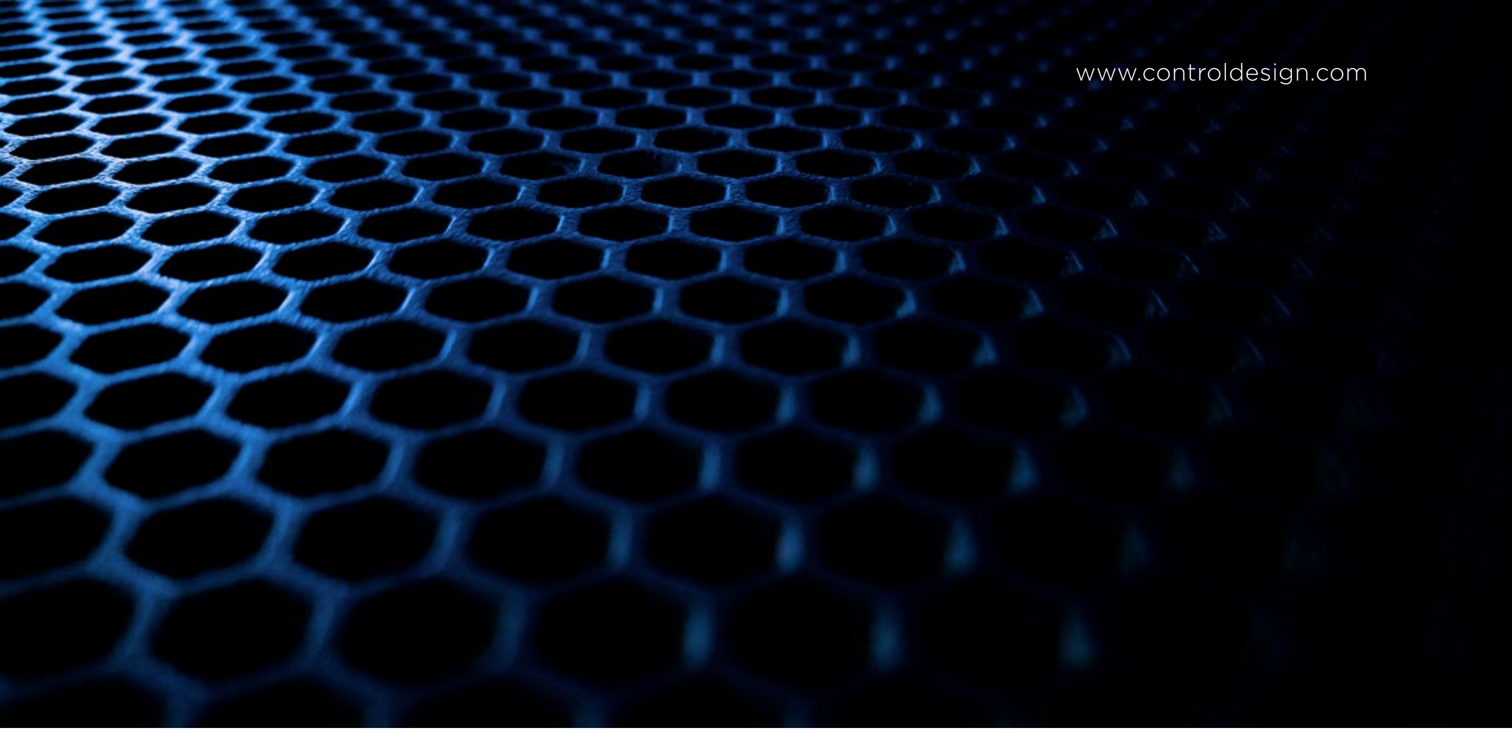


TABLE OF CONTENTS

AD INDEX

| PC11-50USA |

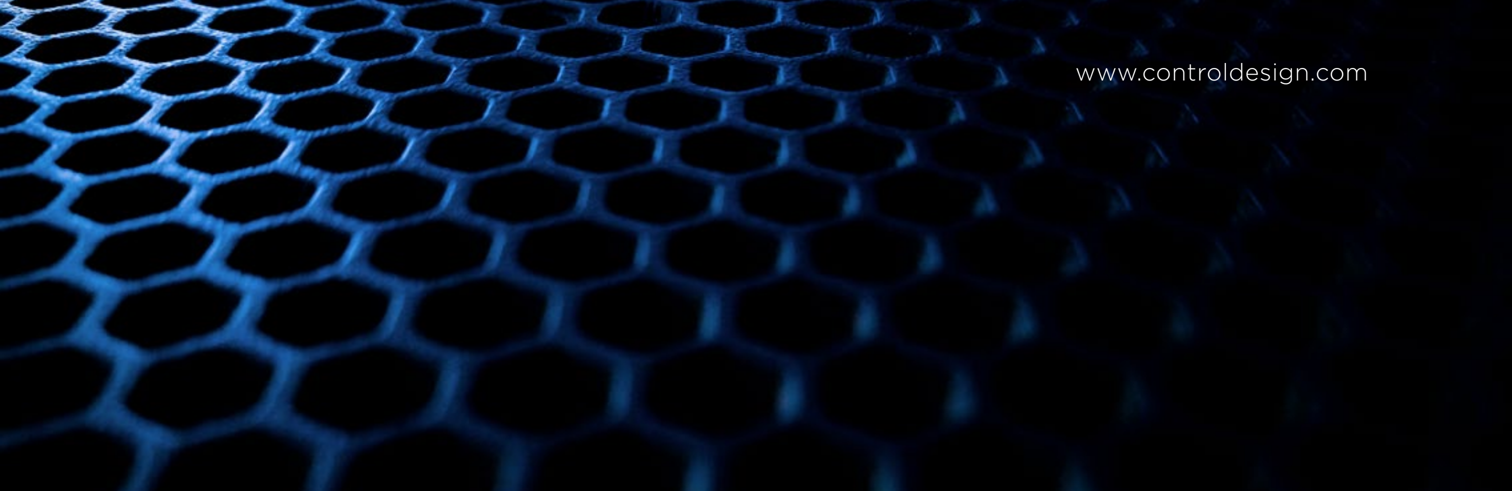
Ultra-compact Industrial PCs: huge performance in a small footprint

C6015 C6017 C6025 C6030 C6032

www.beckhoff.com/c60xx

Beckhoff raises the bar for PC Control with this generation of extremely compact and flexible Industrial PCs, from the C6015 entry-level model to the top of the line C6032 with extended interfaces. Even complex automation applications with the highest performance requirements can be implemented in ultra-compact form with high-end processing power. Find out which ultra-compact IPC model best fits your application!

New Automation Technology **BECKHOFF**



Keep Enclosures Cool and Safe

Air cooling methods for control panels in hazardous environments should rely on cabinet purge systems

By Rick Rice

In Illinois this year we have had the hottest summer on record. While this might have been great news for those of us who have a pool to cool off in, it's not great news for manufacturers who have control systems in warehouses where environmental controls are not in place. With outside temperatures approaching 100 °F, the temperature inside a building without the benefit of climate control can reach 130 °F or higher. The temperature inside a panel can climb exponentially when the main method of cooling—the surface of the electrical enclosure—is surrounded by air that is greater than the nominal energy—heat—generated within the enclosure.

Our control panels have components that, by their very nature, generate heat. Power supplies and variable-frequency drives are the main source of heat, but every single electronic device gives off some sort of heat as a result of performing their functions. Each one of these devices contributes to the ambient heat in the enclosure. As part of a control system design, we must take this factor into consideration when choosing the enclosure that our system will occupy.

When using a metallic enclosure and back panel, the property of thermal conduction can be used to transfer heat from the components into the backplane and then to the skin of the enclosure itself. This is not a perfect method of moving heat, but it does help. To further aid in the conduction of heat, the enclosure size can be increased to not only improve the surface area over which the heat can be exchanged but also increase the free air space inside the panel. Air currents are generated inside an enclosure, and this air passes over and through components to help aid in moving heat away from the components.

Not all enclosures are metallic, so, in addition to the consideration of free air space and thermal conduction, consideration of the movement of air inside a panel is an important part of panel design. Components that are more susceptible to higher temperatures should generally be located in the bottom of the enclosure because, as we all know, hot air rises, forcing cooler air down.

Once these concepts are employed, we need to look to other methods of reducing or controlling the temperature inside an enclosure. These considerations aren't really that different from cooling the living space in your home. For instance, for some immediate cooling of a particular object such as yourself, you might direct a fan to move air across your body. The movement of air promotes evaporation or thermal conduction by moving the hot air off your skin and replacing it with air that is a little cooler than the air that is immediately proximate to your skin. If that method isn't sufficient, you can create a circuit where hot air is evacuated out of the room you are in and outside air is brought back in. If further cooling is required, an air conditioner or air exchanger can be employed to remove moisture from

Pardon my absence

My apologies for my absence from Control Design's September 2020 issue. It was my first absence in the five years that I have been a contributing editor for Control Design. As you are all aware in early spring, the world was plunged into a global pandemic, in the name of COVID-19, and that cloud still hangs over us today. Despite my steadfast adherence to the guidelines for the prevention of spread, I managed to contract COVID-19 in early August. My official diagnosis was pneumonia due to COVID-19, but, whatever the definition, I struggled for 18 days to breathe on my own. I will never underestimate the function of the lungs again. Many people suffer from COPD (my parents died from the condition after a lifetime of smoking), but until you experience the panic of not being able to breathe on your own, you can't begin to imagine what it is like for those afflicted. I am well on the way to recovery and hope that you don't get sucked into the self-serving, politically motivated postings on social media. Observe social distancing, and wear a mask when you can't; and wash your hands if you have to touch something outside of your home. Remember that you are wearing the mask to protect others. My mask worked. I might have gotten COVID-19, but my family members, co-workers or friends didn't contract the virus from me. The mask worked.

the air inside the enclosed space. This method is based on the principle that moisture—humidity—retains heat in air. By reducing the humidity, we reduce the ability of the air to retain heat.

The equivalents of the home environment conditioning can be found in the automation realm in the guise of an enclosure air exchanger, air conditioner or a venturi-style air cooling system where compressed air is supplied to an enclosure. A thermostat controls a valve that passes the compressed air through a venturi and directs inside air back out of the enclosure through a one-way valve. This supplies clean, cool air to cool components in an enclosure.

This last principle leads us to cabinet purge systems. For control systems in hazardous environments, the choice of a cooling system becomes more important because the method employed must also make sure that the outside environmental conditions don't get inside the enclosure. Failure to do so could result in catastrophic failure of the panel components or, worse, an explosion or fire.

One could design everything using explosion-proof devices, but this can be very costly. The alternative, is to design the control cabinet in a NEMA 12 or 4 category and then add a purge system to effectively create a NEMA 7 or 9 category enclosure. The components outside the control enclosure must, of course, maintain the explosion-proof rating, but the cost reduction can be significant for the control enclosures. A NEMA 7 rating, you might recall, is designed to contain an internal explosion without causing an external hazard, while a NEMA 9 rating is designed to prevent the ignition of combustible dust by eliminating the means by which dust can get inside the enclosure.

A panel purge/pressurizing system is an addition to a control system that introduces a protective (inert) gas supply to an enclosure in such a manner that it positively pressurizes the enclosure. Gas or dust can't get in because the internal pressure of the enclosure is higher than the outside environment. For hazardous gas environments, the gas must be purged from the enclosure before pressurizing. For hazardous dust environments, the dust must be physically removed from the inside of the enclosure before closing and sealing the enclosure. At that point, the same procedures take place for both hazardous gas and hazardous dust situations. The main difference is that hazardous dust environments generally required a higher minimum pressure in the enclosure.

After purging the air present in the enclosure when the door is closed, the system applies the safe gas in such a way as to oppose any leaks caused by gaskets, doors, windows and cable glands. The pressure is monitored to ensure a minimal pressure is main-

> One could design everything using explosion-proof devices, but this can be very costly.

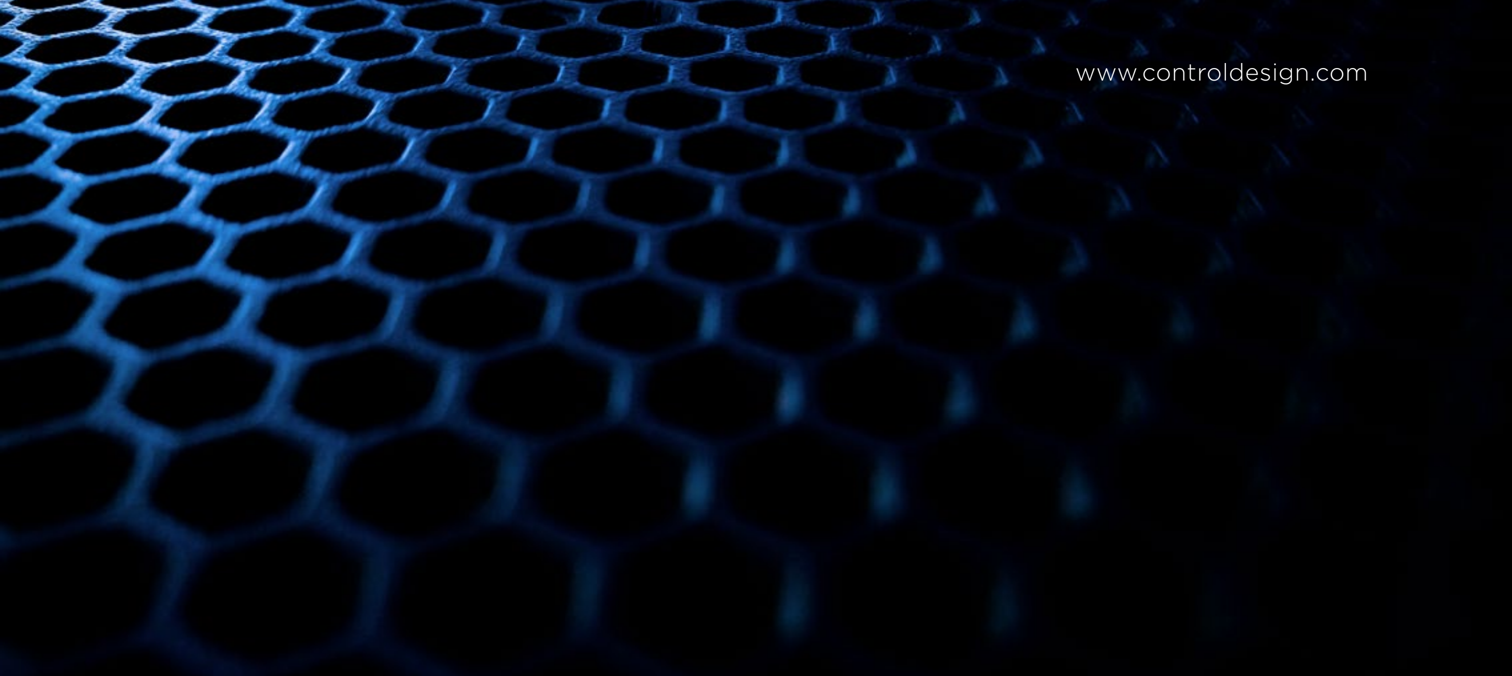
tained. NFPA 496 requires an exchange of four volumes—four times the volume of the enclosure—while IEC60079-2 requires an exchange of five volumes. In both situations, an external, one-way relief vent is employed to relieve any excess pressure in the enclosure. For a dust condition, a pressure-relief device is also required because a pressure regulator could fail and allow too much pressure to exhaust to outside, creating a situation where dust could enter the enclosure through the various leak points.

In all situations, the pressure in the panel is monitored. If the pressure falls below the minimum, an action is required to remedy. The response to low pressure might be to immediately de-energize all equipment and require manual intervention to correct this issue. The response might be, instead, a visual and audible alarm prompting action from the operator. The severity of the hazard will dictate the type of prompt to this issue.

The type of protective gas, in most applications, is clean, compressed air. For some situations, an inert gas light nitrogen is used. In either situation, the supply is regulated and filtered to maintain the quality of the supply. The incoming supply must exceed the desired, maintained pressure flow rate of the system. The pressure in the system, however, should not be so high that it distorts windows, doors, gaskets or wiring glands. Care should be taken to make sure the size of the lines providing the purge/pressure system are sufficient to maintain the pressure during the most consuming part of the process, usually the purge cycle.

Most electrical enclosure manufacturers also offer purge/pressurization systems. Each vendor has worksheets that help with the correct sizing of a system. Some large-volume systems can be used for up to two separate enclosures, while low- or medium-volume systems are sized for individual enclosures only.

Ultimately, the choice to use a purge/pressurization system should consider the steady state environment of the application. If the dust or gas in the environment is highly combustible or explosive when exposed to the potential of heat or an arc, then the use of a NEMA 7 or NEMA 9 enclosure should be considered first, over the potential savings of a NEMA 12 or NEMA 4 enclosure and components. Always err on the side of caution when dealing with such environments. Keep it cool, but always keep it safe.



Which panel design standards are relevant?

A Control Design reader writes: Having spent many years writing PLC programs, I am familiar with electrical and pneumatic schematics and am creating these design documents. However, lately, I'm drawing these schematics and panel layouts myself, and I am constantly thinking about what are the best practices in control panel design. I'm in need of a mentor.

I'm creating many designs for industrial control systems small to large, most with small to midsize PLCs that control machines and equipment. Can you point me to national and international standards that I should be using and other resources to get the design right. I want to ensure I get the wiring, panel layouts and integration done in an industry standard way.

ANSWERS

HMI INDUSTRY STANDARDS

The interactive impact of the human/machine interface (HMI) is much more significant than its basic functionality. HMI systems are the principle point of contact between the user and a machine or process. A good HMI system makes this interaction seem intuitive. A poor HMI system can alienate users or potential customers, encourage users to circumnavigate the system, or result in poor or unsafe system performance. As the direct link to the user, HMIs directly represent the core system's quality and value. A sophisticated mix of design and layout considerations, such as contemporary style, color and tactile response coupled with ergonomic and intuitive operation, create an optimal user experience that determines a customer's satisfaction with the core product.

A highly-reliable HMI system that delivers safe, cost-effective, consistent and intuitive performance relies on the application of engineering best practices throughout design and panel layout, production, testing and quality assurance processes. Just as critical, in-depth knowledge of and compliance with all relevant ergonomic, safety and industry standards must inform each step of the design and manufacturing cycle. Clear definitions of the functional requirements, the operator's level of expertise, and any communications/interactions with other systems provide the starting point in the knowledge-intensive design process.

The tools needed for effective operator control of the equipment, as well as the requirements of the overall application, determine the selection of interface functions. There are many factors to consider in the initial design phase that are critical to both the HMI and the core system to which it is interfaced. Besides industry and functional requirements, selection priorities also depend upon the experience level of the operator and environment, among many other factors. The driving priority might tilt toward ergonomics, for example, as is the case for applications subject to ADA (Americans with Disabilities Act) guidelines.

On the other hand, production floor applications are typically robust and strictly functional, driven by the need to withstand a harsh environment. In the transportation industry, for example, consistency with a previous design – to provide a consistent operator environment – is very often the ruling priority.

A thorough knowledge of technical ergonomic, design and manufacturing standards is fundamental to proper and effective HMI system design whether working independently or with a sanctioned design partner. These include engineering standards, such as MIL-STD-1472F, which establishes human engineering design criteria for military systems, subsystems, equipment and facilities; federal standards set by the Americans With Disabilities Act; and industry guidelines such as those from SEMI S2-93, the global semiconductor industry association, covering HMI for semiconductor manufacturing equipment. Additional HMI specifications are defined by the American National Standards Institute (ANSI), the Institute of Electrical and Electronics Engineers (IEEE), the International Organization for Standardization (ISO), and others.

Key to the entire HMI system design cycle is a thorough knowledge of federal, industry, ergonomic, safety and design standards. These include human engineering standards, such as MILSTD- 1472F, which establishes human engineering design criteria for military systems, subsystems, equipment and facilities; federal standards like those set by the Americans with Disabilities Act; and industry guidelines, such as those from SEMI, the global semiconductor industry association, covering HMI for semiconductor manufacturing equipment. Additional HMI specifications are furnished by ANSI, IEEE, ISO, and others. The EU provides specifications in its EU Machinery Directive for any equipment for domestic, commercial or industrial applications that have parts actuated by a power source other than manual effort. Meeting this directive earns the equipment a CE mark. There are also standards for public access HMI systems, including security and cryptography standards for systems that handle payment cards; specific flammability standards and test procedures for transportation systems; and medical device and equipment standards.

Depending on the ultimate product application, observing appropriate standards ensures that a product will meet industry criteria. This includes the placement of components, legend size and color, emergency stop switch configuration and guards, and other ergonomic factors that improve usability, efficiency and safety.

U.S. and industry standards by application
Manufacturing and Process Industries (shop floor applications) International standards

- EU Current Machinery Directive, from Dec. 2009
- MIL-STD-1472F, addresses human engineering design criteria for military systems, subsystems, equipment, and facilities
- IP (International Ingress Protection) codes
- ISO 9001 and ISO 14001
- CE Mark – Meets European Union (EU) requirements and guidelines for safety, health, or environmental requirements
- CSA International – Canadian Standards Association provides product testing and certification
- UL, C-UL – Underwriters Laboratories, U.S./Canadian rating organization
- VDE – Electrical, Electronic & Information Technologies, a German testing organization
- DIN EN ISO 13850: 2008 (Safety of machinery – Emergency stop – Principles of design) The first edition of ISO 13850 (published in 1996) replaced the EN 418 “Emergency Stop” directive in March 2008. Significant changes in this second draft mandate the manual resetting of E-Stops; require E-Stops to use mechanical latching; and state that the revision will remain unchanged until 2010.

U.S. Federal

- ADA Standards for Accessible Design, 28 CFR Part 36
- NEMA (National Electrical Manufacturers Association) similar to the international IP standard, e.g., the NEMA 4 standard is similar to IP 65
- ANSI

Industry standards

- IEC Safety Integrity level (SIL)

Transportation Industry

- ISO: 9000, specifically for railway
- EN 5155 develops standards for electronics on railway passenger vehicles
- The Federal Railroad Administration (FRA, under the U.S. Department of Transportation) is responsible for defining standards covering safety issues
- ASTM (under ANSI) specifies testing procedures in transportation; A range of ASTM standards provide methodology and performance specifications for testing FRA regulations flammability testing
- 49 CFR Appendix B to Part 238 – Test Methods and Performance Criteria for the Flammability and Smoke Emission Characteristics of Materials Used in Passenger

Cars and Locomotive Cabs

- ADA
- ANSI
- IEEE
- IRIS (International Railway Industry Standard) Rev. 02; ensures products meet globally recognized quality levels

Semiconductor Industry

- Semiconductor Equipment and Materials International
- Safety Guidelines for Semiconductor Manufacturing Equipment SEMI S2-93
- Safety Guidelines for Ergonomics/Human Factors Engineering of Semiconductor Manufacturing Equipment SEMI S8-95

Medical Industry

- ISO Standards for medical devices – ICS 11.1100.20 and ICS 11.040.01 [5], [6]
- Quality and risk management – ISO 13485 and ISO 14971
- IEC 60601-1 and IEC 62304 for medical software
- U.S. FDA 21 CFR Subchapter H – Medical Devices [7]
- Food, Drug, and Cosmetic Act – Section 510(k) – for pre-market notifications Americans with

JOHN PANNONE

VP Sales, HMI systems, key customer management, North America, EAO Corporation

ART AND COMMON SENSE IN DESIGN

If you are designing control panels for the North American market, one of the best standards to be familiar with is UL508A. UL508A is a standard for the construction of electrical control panels. Additionally, the National Fire Protection Agency (NFPA) 79A (Electrical Standard for Industrial Machinery) and the National Electrical Code (NFPA 70) are great resources.

Europe has its own standards, mainly IEC (International Electrotechnical Commission). I would start with a study of the various IEC standards. For example, IEC 60204-1 is a basic safety standard "Electrical equipment of machinery – Part 1: General requirements for the electrical equipment of machines." There are many IEC standards, and individual countries have their own versions of the IEC standards.

There are two things to keep in mind: 1. Always follow the codes for the country/region that the control panel is going to and; 2. use good, common sense. Simply following codes is only part of the art of designing control panels. A neat, nicely laid-out control panel is very important. The Internet has a plethora of resources for you; definitely research articles and look at other designs.

In my opinion, providing a great panel design is a mixture of engineering, art and common sense.

JIM DAVIS

Automation engineer / Motion Industries

COMPONENT CONSIDERATIONS AND CODES

Control panel design requires knowledge in several interrelated areas:

Codes

- Hazardous area considerations: This may define the type of protection required of the enclosure and/or the components.
- If the panel must be UL approved, the pertinent UL standards must be followed. This may dictate the components that may be allowed.

Electrical considerations

- Follow the applicable codes (the National Fire Protection Agency (NFPA) handbook), and UL standard when required
- Wire size, type and color or insulation
- Fuses, circuit breaker

Thermal considerations

- Consider the temperature rating of the items in the enclosure, the heat output of those items, and the ambient conditions where the assembly will be installed.
- Various methods for controlling the internal temperature can be utilized if necessary: selection of the exterior color, insulation, air purging, insulation, heater/thermostat, compressed air cooler, air conditioning.

Familiarity of various components (see list below): This comes with experience and involves knowing what types of components are acceptable for the sector you are selling to. Having knowledgeable vendors and distributors can be a big help.

- Enclosure
- Wire ducts or guides.
- Wire markers
- Terminal blocks
- Fuses, circuit breakers

Client's requirements

- Where it will be located?
- How will the client access it?

- Does it need a convenience outlet or internal lighting?
- From what direction(s) will the client run his cabling or conduit?

Practical sense (if not defined elsewhere)
- Space needed between components
- Space between component wiring terminals and wire ducts
- Size of wire duct
- Space to allow between cable entry and ducts or components
- Space around the edge of the panel
- Location of some components relative to others for ease of access, considerations for inter-wiring or other factors.

MICHAEL CORWIN, manager, customer support
Motion Industries International

PLC DEFINITIONS AND REQUIREMENTS

IEC 61131 is an IEC standard for programmable logic controllers (PLCs). The purposes of this standard are:
- To establish the definitions and identify the principal characteristics relevant to the selection and application of PLCs and their associated peripherals;
- To specify the minimum requirements for functional, electrical, mechanical, environmental and construction characteristics, service conditions, safety, EMC, user programming and tests applicable to PLCs and the associated peripherals.

IEC 61499 proposes applications hosted and running in several devices.

IEC 61499 proposes applications hosted and running in several devices. Function blocks running in different devices, within a distributed application, have to be strongly coupled, so it is required to have more sophisticated synchronization methods than IEC 61131-3 defines. For example, in contrast with the Send/Receive functions or Networked Variables, the IEC 61499 offers Publisher/Subscriber and Client/Server services.

NEMA GFCI P1-2019 GFCI covers products intended primarily to protect human beings from the harmful effects of electric shock by sensing ground fault(s) and/or leakage current(s) on grounded and/or ungrounded systems rated 1,000 volts AC or DC and below.

NEMA IA 2.2-2005 Programmable Controllers (PLC), Part 2 Equipment Requirements and Test specifies requirements and related tests for PLC and their associated peripherals, such as programming and debugging tools and human machine interfaces, which are intended to be used for the control and command of machines and industrial processes.

NEMA IA 2.3-2005 Programmable Controllers (PLC), Part 3 Programming Languages specifies syntax and semantics of programming languages for PLC as defined in Part 1 of IEC 61131.

NEMA IA 2.5-2005 Programmable Controllers (PLC), Part 5 communications specifies communication aspects of a PLC. This standard is a NEMA Adoptive Standard based on Part 5 of IEC 61131.

The control panel needs to be UL Standard 60947-4-1 or NEC Compliant. Article 409 [Industrial Control Panels] of the National Electrical Code (NEC) has been a part of the code since the 2005 edition. Industrial control panels are defined in Art. 100. Basically, these panels can be any assembly of relays, pushbuttons, motor controllers, etc.

DANIEL WEISS

senior product manager / Newark

FINAL SOLUTION: UL508A CERTIFIED

My answer is relatively simple: get certified for UL508a. There are as many wrong ways to design as there are control panels, and one correct way - designing it to UL508a Standards and building it out to those standards so it can pass certification. It is very important to understand that there is a big difference between building a control panel using UL508a certified components, and designing and building a UL508a certified control panel. Just because the pieces are UL508a, that does not mean the final solution is.

UL training:
https://ultraining.myabsorb.com/#/search?term=Industrial%20Control%20Panel

Intertek training for UL 508a certification and panel builder program:
https://www.intertek.com/industrial-equipment/panel-builder/

Take the classes, get certified, design and build your control panels.
It's not hard, but it's not simple.

TED WODOSLAWSKY, director of commercial marketing

c3controls

COMPONENTS THAT MEET GLOBAL STANDARDS

Figuring out what standards are required for industrial control panel design in different areas around the world can be a daunting task, since the standards change constantly in relation to technological innovation and new safety requirements. Although there is a movement to harmonize some of these standards, there are still many differences that must be addressed. It is possible to cover most requirements by following a few standards like UL508A, NFPA79 and CSA C22.2 No. 286-17 in North America, and the EU Directive in Europe as well as the international IEC standards such as IEC 60204-1.

When designing a control panel to meet industry standards, it's a good idea to choose a component supplier that has both a global presence and a large product portfolio. Suppliers with a presence around the world have more knowledge about standards compliance across all markets, while those with large product portfolios are more likely to offer products that are suitable for a wide range of industrial control systems. The first step in engineering a panel that meets industry standards is to select components that have been tested and that comply with global standards. This significantly reduces engineering time and cost by unifying the panel design for different markets.

Companies are also developing new component technologies to help panel builders more easily comply with control panel standards while improving design efficiency. Components that feature a slim profile, consistent heights, and a means of making wiring more simple and secure provide advantages that help meet spacing requirements, optimize heat dissipation, and simplify the panel layout. It's also important to follow manufacturing instructions when installing components, including those related to mounting, wiring, and device protection, to ensure that the panel is built to comply with industry standards.

DAVE LUNDQUIST / automation engineer / Omron Automation Americas

CUSTOMER DRIVEN DESIGN

Control panel design is driven by your customer, what are their expectations? Where is the machine located? Europe? Canada? USA? What are the safety requirements?

You must understand the environment where the equipment will be located, NFPA 79 guidelines will ensure worker safety and the machine will perform without any electrical hazards.

The UL 508 and UL 508A standard covers control panel devices used for most industrial machines.

Special consideration is necessary for machinery that will be located in an explosive environment or need to be intrinsically safe. If the machinery will be shipped to Europe, CE mark is necessary. If the machinery is going to Canada, it must be inspected by CSA inspector for electrical safety.
You can always contact a certified control panel builder to work with you to guarantee conformance. Sometimes working with the experts pays in the long run!

WERNER LAMBERGER

Technical Support Engineer / Automation24 Inc.

5 BEST PRACTICES FOR WIRING

In terms of laying out industrial control panels, wiring plays an absolutely critical role in effective design and construction. Here are five best practices I'd suggest in that area:

1. Separate power and control wiring

To reduce the possibility of electrical noise affecting the control signals, it is best to separate the power and control wiring. Lay out the panel so that the power and control are in separate sections. Group all power fuses, motor starters and variable frequency drives on the same side of the panel as the incoming power (typically the right side, when facing the front of the panel). Then locate all low-voltage control components on the opposite side. Contactors and variable frequency drives will require some control wiring. Consider how you can route the control wires over to the power side while trying to keep them separated.

2. Separate field wiring from internal wiring
Think about how field wiring going to the machine will route into the panel. Will you use conduit, cables or wireway? Will the wiring enter from the bottom, the top, or side? Referring back to our first best practice, consider how best to keep the power and control wiring separated. Lay out terminal strips so that there are separate wire ducts for the internal and field wiring. This simplifies the field wiring and also helps if you have to disconnect the wiring when shipping the machine.

3. Determine the right size wiring duct
Wire duct can consume a lot of space in a panel, especially if you run extra ducts to separate power and control. The proper size duct for each section is one that's neither under-filled nor over-filled and one that has space for easy access when wiring. It is sometimes helpful to draw a cross-section of the duct profile in CAD and then fill it with circles that represent the wire sizes and quantities. This quick visual can help evaluate the loading for different size ducts. This is especially useful for when working with large diameter wire and cables.

4. Provide adequate space for wire routing
When designing panel layouts in CAD, it's tempting to reduce the working space around components in order to shrink the overall size of the panel. However, you also need to provide adequate room to get your hands and tools into spaces. After building a panel, go evaluate the space you put around different devices and take some notes. This will help you improve future design. When working with larger wire, be sure to allow enough room to route & bend those wires.

5. Properly ground the panel & devices
Include a row of ground terminals in the panel and connect all ground wires here (including grounds from components, doors, the subplate, etc.) Consider mounting a ground terminal adjacent to the disconnect and running a large ground wire between it and the ground terminals. This makes it obvious where to terminate the ground for the incoming power.

Three useful national and international standards:

- NFPA79: Electrical Standard for Industrial Machinery – The official standard description is: "NFPA 79 provides safeguards for industrial machinery to protect operators, equipment, facilities, and work-in-progress from fire and electrical hazards," but it contains a wealth of helpful information and is an essential tool for anyone designing industrial controls and equipment.

- UL508A: the UL standard for the construction of Industrial Control Panels
- CE specifications for Europe – The CE specifications contain a mix of directives & standards, including 2006/42/EC Machinery Directive, 2014/35/EU Low Voltage Directive, 2014/30/EU Electromagnetic Compatibility Directive and a long list of other standards for machine safety systems, risk assessments, guarding, ergonomics, etc.

There are also separate standards for specific types of equipment. The best way to get started is to consult with a notified body. A notified body is an organization authorized by the EU to assess the conformity of products. They can help you determine which directives and standards are applicable to your equipment and also discuss methods for certifying your equipment.

Some of the machinery directive elements should be incorporated into your standard designs. They're good practice and will help you create a more universal design. For example, use green/yellow wire for grounds and use touch-safe components throughout the panel.

And finally, for panel design and build resources, we have a section of Allied's Expert Advice content dedicated to industrial control panels, and we've partnered with both Schneider Electric and Eaton on industrial panel builder digital resource hubs.

JIM DAVIS

Director of advanced solutions and technical support / Allied Electronics & Automation


PLC
+
HMI

Standards and options for e-stops

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

By Anna Townshend, managing editor

A 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

PHYSICAL SWITCH

Figure 1: E-stop switches are just one of the components of the safety system.

(Source: EAO)

- 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

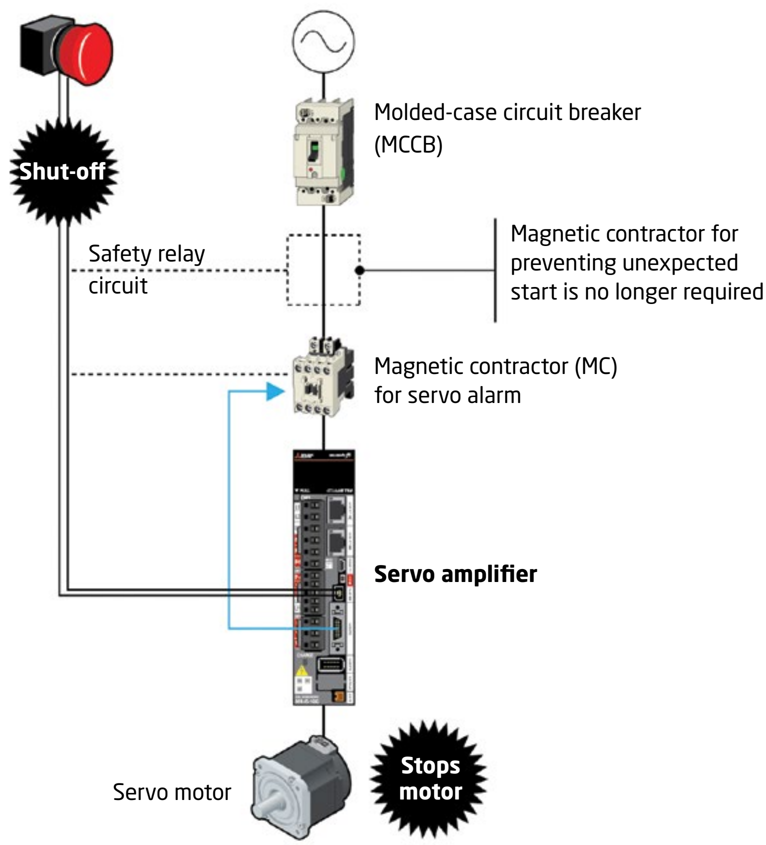
vice president sales, HMI components / EAO / www.eao.com

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.

[SHUT-OFF BY STO]



SAFETY SUB-FUNCTION

Figure 2: Possibilities exist by utilizing software-based safety, in this case, STO safety subfunction.

(Source: Mitsubishi Electric)

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/

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.

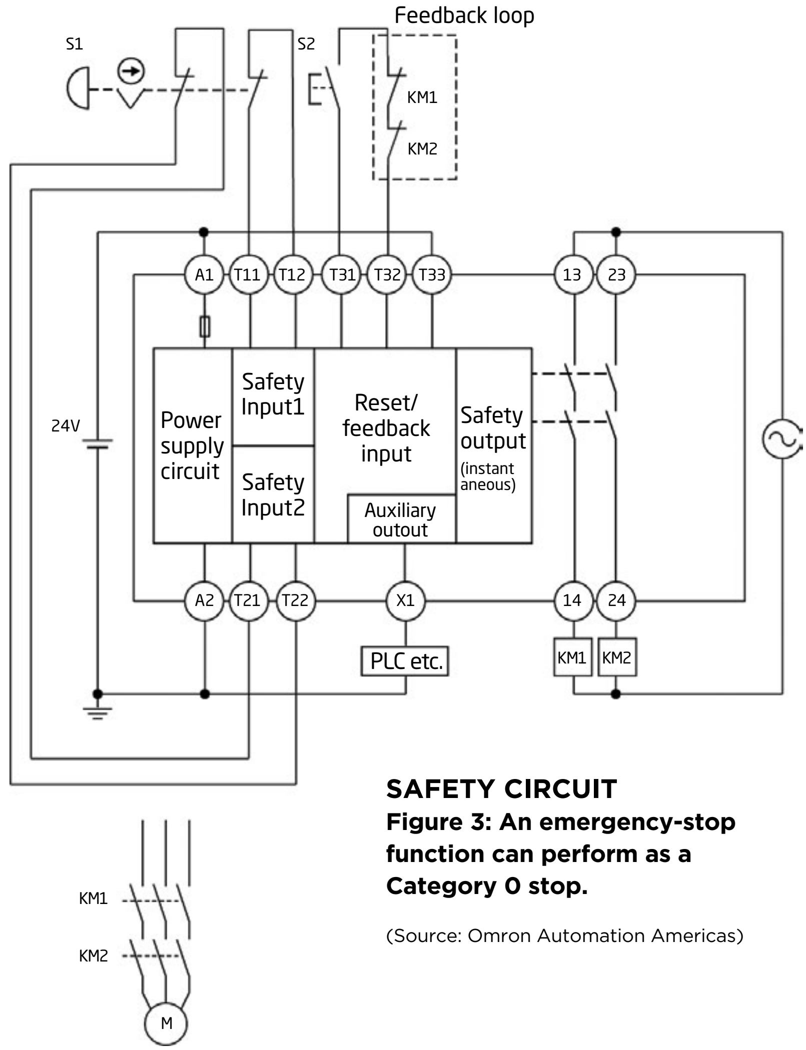
Stop categories, on the other hand, refer to the way in which a machine will stop. These categories, which are based on IEC 60204-1 and NFPA 79, can be defined as follows:

- 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.

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.



SAFETY CIRCUIT

Figure 3: An emergency-stop function can perform as a Category 0 stop.

(Source: Omron Automation Americas)

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.

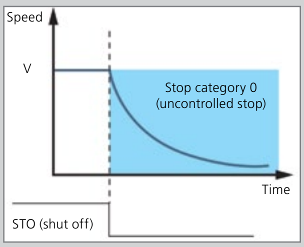
SAFETY SUBFUNCTIONS COMPLIANT WITH IEC/EN 61800-5-2

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)

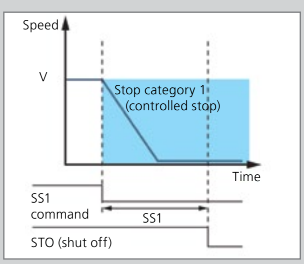
Safe torque off (STO)

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.



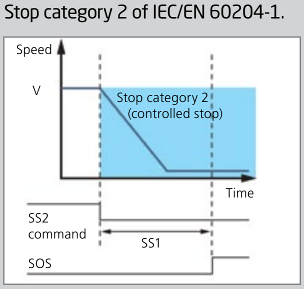
Safe stop 1 (SS1)

Responding to the input signal from external equipment, the servo motor starts to decelerate. After the set delay time for 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.



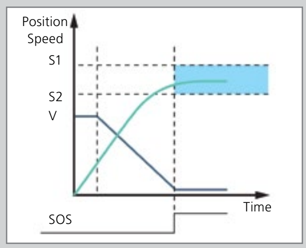
Safe stop 2 (SS2)

Responding to the input signal from external equipment, the servo motor starts to decelerate. After the set delay time for 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.



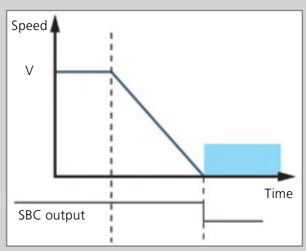
Safe operating stop (SOS)

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.



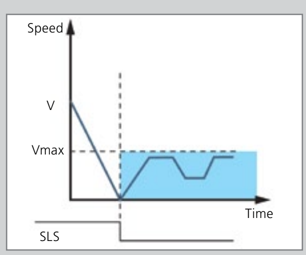
Safe brake control (SBC)

The SBC signals are outputted for external brake control.



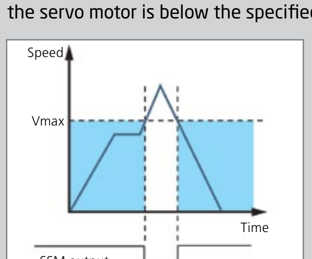
Safely limited speed (SLS)

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



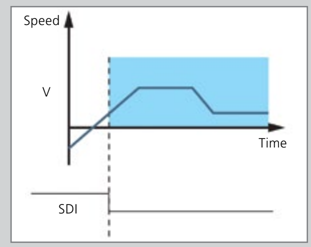
Safe speed monitor (SSM)

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



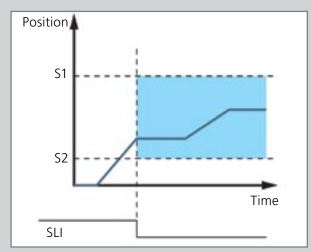
Safe direction (SDI)

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.



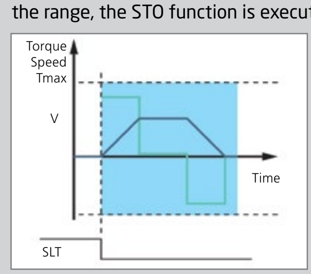
Safely limited increment (SLI)

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.



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.



Function activation area

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)

- 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.

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 instanta-

neous 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.phoenix-contact.com


Thrives in rugged environments.
Lives to test limits.
Yes, this is a tardigrade. And it's also every product Sealevel designs and manufactures.
• Resilient
• Rugged
• Up for the challenge