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Human Machine Interfaces

White Paper

Key Components Enhance the Human Machine Interface

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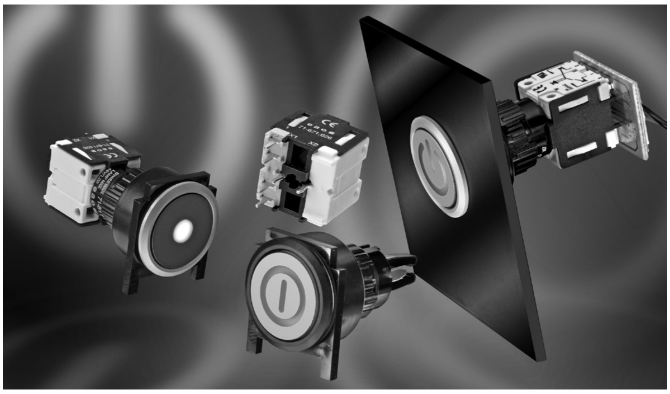
Electromechanical devices, including switches, keypads, keyboards, pointing devices and other elements such as indicators and alarms, are critical aspects of the human machine interface (HMI) for controlling equipment and systems. HMI Component technology has undergone major changes over the years to serve the increasingly specialized needs of industrial, transportation, telecommunications, audio/visual, public access/security, and lifting/moving applications. Designers today face a truly astonishing range of choices in electromechanical components that encompass not only the type of device, electrical specifications, environmental sealing, and mounting and termination styles, but also ergonomic considerations such as configuration, size, illumination, and tactile feel. Understanding how these electromechanical devices work and what is available to meet your requirements is an important first step to incorporating them in advanced HMI systems.

The Technology of Switch Design

Simply put, a switch makes or breaks an electrical connection or diverts current from one conductor to another through the motion of an actuating mechanism. A basic switch that makes and breaks a single circuit is said to have one pole. The number of poles a switch has represents the number of separate circuits that can be active through the switch. Switches are available with normally open (NO) contacts, normally closed (NC) contacts, or combinations of both. When a NO contact is activated the contact closes; when a NC contact is activated the contact opens. Moving switch contacts can interrupt one circuit before completing another (“break-before-make”) or complete one circuit before interrupting another (“make-before-break”).



Component ergonomic considerations such as configuration, size, illumination, and tactile feel enhance advanced HMI systems.

Making better contacts

Much early work leading to modern switch designs was concerned with perfecting durable contacts to reliably make and break the electrical connection. Chief requirements included corrosion resistance, electrical conductivity, resistance to abrasive wear, mechanical strength, affordability, and low toxicity. Gold and silver contacts are used in most switches. Gold contacts come in many forms: solid gold, gold over silver, gold-plated silver, and gold on nickel plating. Silver contacts are also available in a variety of forms: solid silver, hard silver, silver over silver, silver over palladium, and silver-nickel alloy. These options provide contacts suitable for various power levels and application requirements. But in search of a more perfect device, switch designers had to contend with three problems: contact arcing, welding, and bounce.

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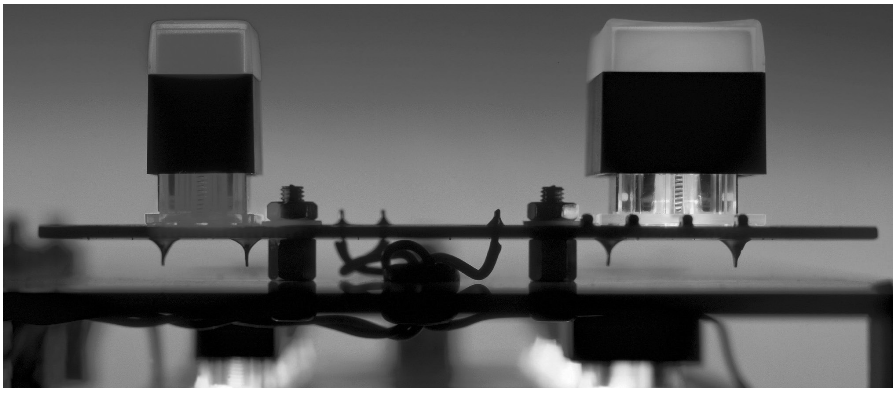
Arcing, welding, and bounce
Arcing is a discharge of electricity – a spark – that can occur when contacts make or break. Welding occurs when contact material melts and fuses, causing contacts to stick. Arcing and welding degrades or burns contacts, reducing useful life, and are more severe in DC than AC applications. Solid-gold contacts are more easily melted and eroded by arcing so they are limited to low-current switching where there is little or no arcing. As switched current increases, hotter arcs form and the potential for erosion and contact welding is greater. Arcing is also more severe when handling high inrush currents, i.e., inductive and capacitive loads that require high initial current. For example, lamps may draw 10 to 12 times their normal operating current when first activated. Relays, solenoids, and motors may show high inductive inrush currents when powering up. Switches for higher currents use gold-plated silver or all silver contacts that resist the effects of arcing. Minor periodic arcing with silver contacts is actually beneficial because it keeps contacts free from dirt and corrosion.

Another challenge in switch design is contact "bounce" or "chatter," a condition in which a contact rebounds for several milliseconds before it finally closes. This is not a concern for power circuits but causes problems in logic circuits that may interpret on-off bounces as data streams.

Mechanical solutions
How contacts make and break can minimize arcing, welding, and bounce. Switch designers minimize bounce by reducing the kinetic energy of the contact, incorporating buffer springs, air, or oil shock absorbers to dampen contact recoil, or employing wiping or sliding type contacts. Bifurcated, fork-shaped contacts minimize contact bounce while providing redundancy and higher reliability. Commercial switches generally limit contact bounce duration from <1 ms to <=100 ms.



How contacts make or break can minimize arcing, welding, and bounce.

The force holding movable and stationary contacts together is critical, ranging from 5 gm in miniature switches to more than 150 gm in heavy-duty, motor-load switches. Snap-action switching elements reduce arcing by rapidly moving contacts from one spring-loaded position to another independent of actuator speed. Self-cleaning contacts slide against each other when making or breaking a circuit, removing contamination to keep contact resistance low. On the other hand, slow make/break switching elements, usually used in emergency-stop switches and in high-power applications, employ rigid contact arms that force necessary contact separation to overcome contact welding.

Switches are available in a wide variety of shapes, sizes, ratings, and functions.

The ABCs of Switch Specification

Switches come in a wide variety of shapes, sizes, ratings, and functions. They are built for long life to minimize the need for replacement. High-quality switches are expected to have a mechanical life of 1 million to 10 million operations.

Many switches today are modular, comprised of quickly assembled components including actuators, switching elements, illumination blocks, lenses, marking plates, and mounting systems. Industrial water and oil tight switches are designed for front and back-of-panel environmental protection against intrusion of dust, dirt, water, solvents, and other foreign materials and certified to meet various levels of ingress protection as specified by NEMA and the international IP Code (see International Standards and Approvals).

Designers can simplify their search for the perfect switch by carefully analyzing their application requirements first, then, based on their needs, determine the following:

- Electrical ratings – determine the right specifications for the job;
- Actuation preferences – choose the most appropriate switch type;
- Physical configuration and mounting needs – decide on style and placement;
- Special requirements – select type of illumination, marking, and environmental sealing options.

Electrical ratings
Electronic switches are rated for current, voltage, voltage type (AC, DC), and load type (inductive, resistive). They are categorized into three power levels:

1. Signal level: typically up to 42 V, and 100 mA
2. General purpose: typically 42 – 250 V, and up to 5A
3. Power: typically >250 V and/or >5A

Level 1 is for low-power, logic-level applications while Levels 2-3 are for resistive and inductive power requirements. Continuous current capabilities range up to 100 mA to 10A or more over the three levels. Switches are supplied with appropriate contacts for their current-carrying capabilities. Contacts in modular switches are housed in a switching element that includes connection terminals and an attachment port for the actuator.

The switching element also has contact terminals for connecting system electrical wiring. Several different terminal methods are used and many are offered as options when specifying a given switch. The most popular connectors include:

- Screw terminals
- Soldering terminals
- Quick-connect (QC) plug-in terminals (std. sizes: 2.85 x 0.5 mm [0.112 x 0.020”] 4.8 x 0.8 mm [0.189 x 0.031”], 6.3 x 0.8 mm [0.248 x 0.031”]); also available with two terminals per contact
- Soldering-/QC plug-in terminals (std. sizes: 2.0 x 0.5 mm [0.079 x 0.019”], 2.8 x 0.5 mm [0.110 x 0.019”], 2.8 x .8 mm [0.098 x 0.031”]); also available with two terminals per contact
- Push-in terminals
- PCB terminals (solder, wire wrap, straight, right angle, vertical, SMD)
- Ribbon cables

Production considerations may guide choices – using tool-less, snap-in panel mounting or wave soldering for PCB mounting, for example.

Actuation preferences
The actuator assembly, including the front lens touch surface, is the part of a switch that directly interacts with a user. Its form is closely related to its function.

The following is a sampling of electromechanical actuator types:

- Pushbuttons
- Emergency-stop pushbuttons (twist or key unlock)
- Keylocks (multiple position)
- Lever/selectors (multiple position)
- Joysticks
- Toggles
- Rockers
- Slides
- DIP (dual inline packaging)
- Membrane (metal dome and conductive rubber)

Pushbuttons, keylocks, and lever/ selector switch actuators provide one or a combination of switching actions. With a **momentary-action switch**, an activation force (push a pushbutton or twist a keylock) moves contacts to a new position. When the activation force is removed, the actuator and contacts return to the original position. With a **maintained or alternate action switch**, contacts move to a new position and remain there until the switch is activated a second time, which returns actuator and contacts to the original position. For safety applications,

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

E-Stops are a type of maintained-action switch that requires a pull, twist, or key to reset to the original position.

Actuators are designed to require a certain level of force to affect a switching action and that force varies considerably depending on switch type and the number of contacts. For example, a small, precision snap-acting pushbutton rated at 100 mA, 42 VAC/DC, needs only 140 g (1.4 N) of force to activate while a larger snap-action pushbutton rated at 230 VAC, 6A/24 VDC, 10A requires 2,000 g (20 N), and a slow-make E-Stop pushbutton rated at 250 VAC, 5A requires 5,000 g (50 N). Actuating force is part of the ergonomic design calculus that determines the tactile feel of a switch.

Tactile feel is another subtle feature that makes switches more than simple control devices. It provides an indication – sensed by human touch – that the point has been reached where slight additional pressure will activate the switch. A light touch is often desirable in large audio/video control consoles, for example, but a heavy-duty industrial E-Stop should require a determined effort to avoid inadvertent shutdown.

Touch-sensitive switches are totally electronic and use capacitive, high frequency, or Piezo technology rather than mechanical actuators to sense when they have been touched and initiate a response, such as turning on lights or opening passenger doors on mass transit vehicles. This same approach is used in touch-sensitive keyboards and keypads designed for use in harsh environments or where vandal protection is desired.

Physical configuration and mounting needs

Switches come in ultra-miniature, sub-miniature, miniature, and standard sizes for various printed circuit board (PCB) and panel-mount applications. Generally, as switch size decreases, so does the electrical rating. Common round hole diameters for panel mounting include 6 mm, 8 mm, 16 mm, 22.5 mm, and 30.5 mm. Switches are also made in a variety of rectangular and square shapes, many designed for quick snap-in panel mounting. Some panel-mount switches are designed to project above the panel surface, others for flush mounting or even sub-panel mounting. Where space behind a panel is limited, several switch styles are available with small behind-panel depth. PCB switches typically come in two mounting types: straight pin through-board mounting and surface mount devices (SMDs).

Special requirements

Switches are available with many options to satisfy environmental considerations, ergonomic requirements, and stylistic interpretations. Special requirements fall into three areas:

1. Environmental sealing
2. Illumination, color, and markings
3. Custom designs

Environmental sealing

Where switch controls will be used determines the degree of environmental protection required. Clean, indoor environments not subject to rigorous cleaning, such as recording studios and telecommunications control rooms, generally don't need protected switchgear. Industrial, transportation, indoor/outdoor public access, and lifting/moving environments are considerably more challenging, exposing switches to oil, solvents, chemicals, water, and dust. For these conditions, rugged oil- and water-tight switches are needed, and under certain hazardous conditions, explosion-proof enclosures as well.

Where switch controls are used determines the degree of environmental protection necessary.

Where water, fuel, cleaning solutions, fine dust, and other materials may come in contact with control panels it is important to select switch controls that have appropriate environmental sealing. Many switches conform to the following international ingress protection (IP) codes:

- IP 40 – granular material (dia <1 mm) tight but not protected from water;
- IP 60 – dust tight but not protected from water;
- IP 65 – dust tight and protected against water and liquid jets;
- IP 67 – dust tight and protected against temporary water and liquid immersion.

Industry standards developed by NEMA (National Electrical Manufacturers Association) in the U.S. are similar to the international IP standards. For example, the NEMA 4 standard is similar to IP 65. Switch manufacturers design to these standards for front and back panel levels of protection.

LEDs are being adopted for illuminated switches.

Illumination, color, and markings

Illumination visually shows the state of a switch. Illuminated switches use incandescent, neon, or light emitting diode (LED) light sources. A major recent change is the growing adoption of LEDs because of their high reliability and energy efficiency, low-temperature operation, and better control over color and brightness compared to incandescent and neon bulbs. While LEDs cost more, they can last ten times longer and consume half the power of incandescents, and excel in applications requiring frequent on-off cycling that may cause incandescent bulbs to fail faster. They are perfectly suited to new switch styling trends such as halo lighting and multicolor effects.

Colored illumination is provided in two ways: the lens on a pushbutton switch can be specified in a variety of colors, or LEDs of various colors can be used. A combination of both will often produce even better results. Switches with multiple lenses or RGB LEDs can provide more information by using different colors to indicate specific switch states, i.e., green = “on,” red = “stopped,” yellow = “standby,” etc. Truly intuitive designs can be achieved by synthesizing or blending colors utilizing PWM (Pulse-width Modulation) techniques which give the ability to create any color in the spectrum.

Legends or graphics to identify a switch or its function are placed on the lens or marking plate behind the lens using engraving, hot stamping, pad printing, and other techniques. Contrasting colors of inks can be used to highlight these legends. Other techniques include the addition of Braille and blind dots which often comply to ADA and other disability requirements.

Because of the great flexibility of modular switch designs, customization is easily achieved through the specification of lens colors, materials, and shapes; illumination types and colors; bezel materials and finishes; actuator functions; switching element specifications, and the use of multiple switching elements for a range of switching configurations.

Use Advanced HMI Components in Demanding Applications

Today’s advanced HMI Components are precisely crafted devices, made to exacting design specifications and very close tolerances from high-grade plastics, metals, and carefully calibrated springs. To achieve reliable, long service lives, they are engineered like fine watches with the performance, feel, and look required in modern HMI systems. Ergonomics play a key role in modern switch design, assuring the right switch for each application – whether it is a flush-mount design to avoid inadvertent actuation, or an emergency-stop switch with a mushroom actuator for fast palm-slap shutdown and safe twist or key release to enable re-power of a circuit.

When designing an HMI System for demanding applications, design engineers should carefully select the appropriate HMI Components to ensure safety, anticipated product life, and ergonomic appeal of their equipment.

Following are several HMI challenges in industrial, transportation, audio/visual, public access/security, and lifting/moving applications that have been solved through the creative use of advanced switching technology.

Industrial
With today's focus on space saving solutions, HMI systems incorporate sophisticated human interface design and space utilization. User-friendly panel design using advanced switch technology combine to deliver greater industrial system uptime and productivity.

Audio/visual
Switches for audio/visual, light, and stage production equipment must be silent and 100% reliable. User fatigue is a big challenge in this industry so components need to be ergonomically correct.

Lifting/moving
Elevators, forklift trucks, cranes, conveyors, robotics, and special ground support equipment require durable, reliable control systems that function in all environments and resist shock, vibration, and heavy wear.

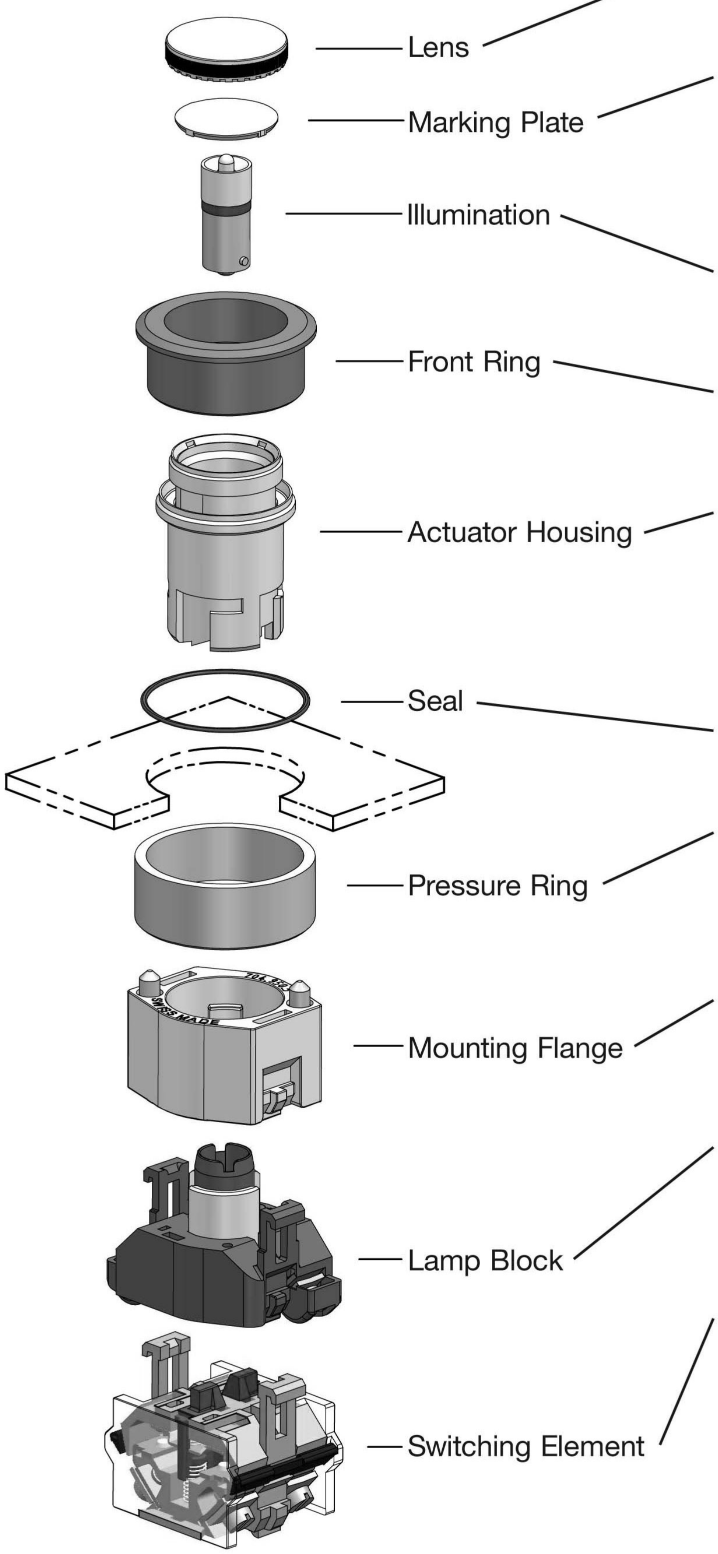
Transportation
Switches and control panels are used in driver compartments, for passenger doors, emergency controls, operating panels, and passenger communication systems.

Public access/security
Vandal resistant and virtually nondestructive keyboards and keypads are used indoor and outdoor for banking terminals, kiosks, parking meters, and access control. Special illumination completes the picture.

Figure 1 – Typical Switch Design

Flush-mounting, illuminated pushbutton switch used as an example

Exploded View



Use a plastic surface that resists wear and environmental attack. The lens is the touch surface for activation so it must have good tactile and strength properties. Make it smooth, concave, or convex; clear or colored; a serrated edge to facilitate assembly is helpful.

Design to diffuse light with a refracting surface facing the bulb that creates pleasing, equal distribution of illumination. The smooth outer surface must accept markings using hot stamping, engraving, or pad printing. Edge-key the plate to fit alignment guides in the actuator housing so the legend is oriented correctly during assembly. Plastic used must resist the heat of the illuminating element.

Light-emitting diodes (LEDs) are recommended, but incandescent and neon lamps are also used. LEDs are more energy efficient, last 10-12 times longer, come in a variety of colors, are less fragile than incandescent bulbs, and are relatively maintenance free.

Use strong, resistant, anodized metal or plastic to secure the outer actuator housing to the panel. An elastomeric ring is needed to seal the front ring and panel face. Styling of this visible element is important: provide colors in addition to silver and black finishes.

A core switch element, the actuator housing seals the movable cylinder, and is mated to the mounting flange with a twist. It translates the user's physical push to the switching element to initiate contact make and/or break. The type of actuator specified determines if the switch action is momentary or maintained (shown here). Special actuator configurations are used for emergency-stop switches. Precise, complex molding of high-strength plastics is a requirement for repeatability, reliability, and long operating life.

Seal the front ring and the front of the panel to meet IP and/or NEMA requirements using high-quality, environmentally resistant and long-lasting elastomeric materials.

Make the switch assembly tight and vibration-resistant with a strong pressure ring.

Carefully design this key interconnect module for strong, fast switch assembly. It must accurately mate the actuator with the lamp block and the switching element.

For quick assembly, design the lamp block to snap into the mounting flange. It should accept standard bayonet-type LED and incandescent bulbs. Snap locks should be easy to release when bulb replacement is needed. Electrical connections should be automatically made when switching element is attached.

This is the heart of the switch. Contact materials and configurations determe switch rating for current, voltage (AC or DC), and type of load (resistive or inductive). Precision design and assembly are needed for the snap-action, self-cleaning contacts (shown here). Bifurcated, fork-shaped contacts are useful in low-current applications to provide redundancy, higher reliability, and low contact bounce. Slow-make/slow-break contacts must be designed to force contact separation in high-power switching and E-Stop applications. Provide various types of connectors -- screw, solder, quick connect, push-in, or ribbon cables -- to accomodate a range of user wiring assembly needs.

International Standards and Approvals

Many HMI Components are recognized or certified as meeting safety, electrical, environmental standards, and approvals of a variety of international organizations. Among the most important:

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 61058 T.1 (VDE 0630 T.1)** – specifies electric shock protection in switchgear;

IEC – International Electrotechnical Commission, publishes international standards for all electrical, electronic, and related technologies;

IP Code – International Protection Rating or Ingress Protection Rating are European specifications for rating environmental sealing as defined in international standard IEC 60529;

NEMA – National Electrical Manufacturers Association, a U.S. trade association sets ratings for environmental sealing; NEMA 4 and NEMA 13 standards are similar to IP 64 and IP 65 ratings but include additional tests for salt spray, icing, and oil exclusion.

To assure that HMI Components meet all required international and U.S. standards, the important certifications and approvals to meet and conform to include CE, CSA, UL, C-UL, and VDE as well as suitable IP and NEMA ratings.

* German Institute for Standardization
** Standards maintained by the European Committee for Standardization

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