Key Components Enhance the Human Machine Interface

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 specialised 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.

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”).

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...
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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.

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.

The ABCs of switch specification
Switches come in a wide variety of shapes, sizes, ratings, and functions. They...
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How contacts make or break can minimize arcing, welding, and bounce.

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 analysing 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 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 0.8 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)
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.

“With a maintained or alternate action switch, contacts move to a new position and remain there until the switch is activated a second time.”

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

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

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, 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
Industrial, transportation, indoor/outdoor public access, and lifting/moving environments are considerably more challenging, exposing switches to oil, solvents, chemicals, water, and dust. Rugged oil- and water-tight switches are needed.

“Switches come in ultra-miniature, sub-miniature, miniature, and standard sizes for various printed circuit board (PCB) and panel-mount applications.”

“Industrial, transportation, indoor/outdoor public access, and lifting/moving environments are considerably more challenging, exposing switches to oil, solvents, chemicals, water, and dust.”

Where switch controls will be used determines the degree of environmental protection required.

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, colour, and markings
3. Custom designs

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

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 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
Truly intuitive designs can be achieved by synthesizing or blending colours utilizing PWM (Pulse-width Modulation) techniques. This makes it possible to create any colour in the spectrum.

“A major change is the growing adoption of LEDs because of their high reliability and energy efficiency, low-temperature operation, and better control over colour and brightness.”

“Modular switch designs offer greater flexibility.”

Switches with multiple lenses or RGB LEDs can provide more information.

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 colours 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 colours, materials, and shapes; illumination types and colours; 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, ensuring the right switch for each application – whether it is a flush-mount design to avoid inadvertent actuation, or an emergen-
The lens is the touch surface for actuation so it must have good tactile and strength properties. Use a plastic surface that resists wear and environmental attack.

“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.”

“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.”

Figure 1 – Typical Switch Design
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. They are engineered like fine watches.

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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.

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 non-destructive keyboards and keypads are used indoor and outdoor for banking terminals, kiosks, parking meters, and access control. Special illumination completes the picture.

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.

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