Technical Article

HMI System Design –
more than just a touch.

Designing intuitive and reliable HMI Systems requires in-depth specialist knowledge, particularly in display technology, electromechanical design, ergonomics and relevant industry standards. Good HMI design is all about the ideal combination of the application, environment, technology and perfect ergonomics. This article provides a gateway to better understanding the fundamentals of designing an innovative, intuitive and reliable HMI System.

HMI Systems take many forms, from a simple two-button instrument panel to an extensive software/hardware-based SCADA system at the heart of factory automation. Whatever their size and scale, it's critical to understand and appreciate the importance of an HMI as the link between user and machine.

Principal design considerations

- Industrial HMI design
  Industrial HMI design refers to the features of shape, configuration, pattern, and ergonomics for a device that is designed to meet the needs of a specific market segment and user – passenger entrance systems in public transportation, a main operator panel unit on a CNC machine, or driver's cabs in heavy-duty vehicles. A design should strive towards enabling intuitive, safe and reliable performance of user tasks.

- Operational requirements
  These are the core of every new design project and can include the user environment, the operating temperature and factors of influence such as humidity, dust or vibration.

There are many operational needs, all of which will guide a designer to the proper material and functional choices. Safety is always among the most important aspects.

When aligning HMI design so closely with safety, it’s critical to understand who will be operating.

Screens enhance the ability to control multiple system functions from a single point or location.

All touch screen interfaces have advantages and disadvantages, depending on their application.

‘Resistive’ technology remains the most common industrial touch technology, although the spread of capacitive technologies – especially projected capacitive touch displays – is seeing strong growth.

Human factors

With a focus on safety, it’s critical to understand who will be operating the machinery:

- Are they passive, intuitive, expert or novice users?
- What is their role?
- Are their movements restricted?
- Do they wear gloves?
- What feedback is required?
- What acoustic interference is the user exposed to?
- And more.

Selection of control elements

After a complete review of the application, functional requirements and operator needs, it’s time to put the knowledge gained into selecting the right control elements.

Displays

Displays are at the core of modern HMIs. They provide fast, easy-to-read graphical information.

Handheld control unit with a display and electromechanical devices.

LCD and LED non-touch displays

For simple numeric displays, LED displays remain competitive. For alphanumeric and graphic displays, LCD is the preferred technology. A bright LCD display with a high contrast factor works well in brightly lit conditions.

Touch displays

The selection of the type of touch screen plays a critical role in a properly functioning interface. All touch screen interfaces have advantages and disadvantages, depending on their application.

Common determining factors include operator and environmental characteristics such as an operator who uses gloves.

The following technologies are most frequently used for touch screens nowadays:

- Resistive
- Capacitive
- Surface acoustic wave (SAW)

Resistive touch screens

Resistive touch screens are generally used in industrial applications and can be activated with a variety of objects including a finger or stylus. Touch screens are resistant to moisture, dust, oil and cleaning agents. Although this technology is relatively inexpensive, touch screens are very vulnerable to damage from sharp objects that can scratch the display.

Capacitive technology

In industrial applications, capacitive technology is the second-most frequently used, and its market share is rising, because of its enormous popularity in the consumer segment. The robust glass surface makes this technology very resilient to scratches and chemicals.

Of the capacitive varieties, the two most common are surface capacitive and projected capacitive screens (PCTs). Initially, it was primarily surface capacitive technology that was used, but PCTs are becoming increasingly frequent, since this technology provides multi-touch functionality.

Surface acoustic wave technology (SAW)

In surface acoustic wave (SAW) ultrasonic waves are transmitted across the screen and picked up by sensors. Touching the screen causes the wave movements to change.

One of the biggest problems affecting industrial HMI Systems is false triggering.

Mixed technology solutions, the combination of touch displays and discrete tactile control elements, reduce the impact of the disadvantages of touch screens.

Dirt can affect sensitivity of touch screens or prevent a device from functioning at all.

Projected capacitive technology (PCT) screens operate within an electrostatic field and are the type used in consumer mobile devices. They support simultaneous inputs (multi-touch), allowing the simultaneous use of two or more fingers to pinch, expand, tap, click and rotate a screen.

Both surface and projective capacitive technologies offer improved image clarity over resistive screens as well as high resistance to surface contaminants and liquids and also to scratches and impacts.

Challenges in the use of touch screens

One of the biggest problems affecting safety and productivity of industrial HMI Systems is false triggering – the reporting of a touch where none actually occurred.

Unwanted reactions can be triggered by the following factors:

- Moisture: Water droplets can act like an object touching the screen
- Electrical interference from adjacent machinery, power supplies or other sources
- Dirt can affect sensitivity or prevent a device from functioning at all
- Oversensitivity: If the sensitivity of a screen is adjusted for gloved hands, a reaction may be triggered by merely hovering a finger over the screen without direct contact

For these and other reasons, touch displays are not suitable for all applications. Tactile control elements are also essential when the operator must concentrate on a work process and does not therefore have the HMI in his direct field of vision. For instance, when lifting and moving applications, but also when machinery is operated via remote controls.

Control units with mixed technology solutions.

Mixed technology solutions

By designing HMI Systems using a combination of both touch screens and tactile control elements, it is possible to overcome these disadvantages.

Electromechanical actuators and indicators in mixed technology solutions offer the following benefits:

- Intuitive operation of critical functions
- Discrete pushbuttons enable independent control of various functions
- Illumination allows clear, easily visible status displays (e.g. illuminated pushbuttons)
- Softkeys are a perfect complement for touch displays [1)]

[1)] Softkeys are keys outside of the touch display that perform different functions depending on what is displayed on-screen.

As experts in mixed technology HMI solutions, we can provide our customers with our comprehensive expertise – from the initial idea right through to the manufacturing stage – and generate real added value on their behalf.

Electromechanical devices remain unsurpassed – intuitive to operate and tactile.

Modern actuators and indicators are quick to mount, offer serial bus connectivity, and consume little power.

Control devices should be modular and configurable to suit a variety of front panel designs and budgets.

Modern mounting systems feature a tight seal into which the actuator holder can be pushed or 'snapped in' using one hand.

Electromechanical devices
Electromechanical devices such as pushbuttons, emergency stops, selector switches, potentiometers, keylock switches and optical and acoustic signaling devices remain an important part of most control systems and will continue to be used far into the future for their convenience, safety, intuitive use, robustness and reliability.

EAO's new Series 45.

Pushbuttons in particular remain unsurpassed, being intuitive to operate, providing distinctive tactile feedback, and with a very robust design (up to IP69K).

When selecting these devices, it's important to consider the following attributes:

- Modern construction
  Modern actuators and indicators are easy to install, provide flexible communications options, consume less power and deliver a long service life of up to 10 million switching cycles.

  They typically come in three sizes: 16, 22.5 and 30.5 mm, although 22.5 mm devices remain the de facto industrial standard and are easy to operate – even with gloved hands. Modern HMIs are fitted with actuators and indicators today that are almost perfectly flush with the front panel – often in combination with a 30.5 mm mounting cut-out.

- Materials
  Stainless steel and special-purpose plastics are important providing HMIs with resistance to chemicals and UV radiation.

- Modularity and configurability
  Electromechanical devices should be modular and configurable to suit a variety of specific requirements. Modular surface elements include the actuator, such as for a pushbutton, combined with a front ring of metal or plastic. These two components define the look of the HMI design, because they are visible to the user.

  Switching elements should be stackable and provide high contact stability, even with small voltages and currents. Connection options should be appropriately selected and can include funnel-shaped cable entries and screwdriver guides to prevent screw loss. Depending on the mounting process, solder connections or time-saving spring-loaded push-in terminals (PITs) may be a superior option.

- Mounting
  The device mounting mechanism is critically important to provide secure attachment – for instance, under vibration. Proper consideration can also reduce mounting and maintenance costs. Modern mounting systems feature a tight seal into which the actuator holder can be pushed or 'snapped' in using only one hand. These newer designs also eliminate the need for an anti-rotation slot or groove, potentially saving even more time in the mounting process.

Series 45 toggle stick.

Food and beverage applications may involve high-pressure/temperature wash-downs.

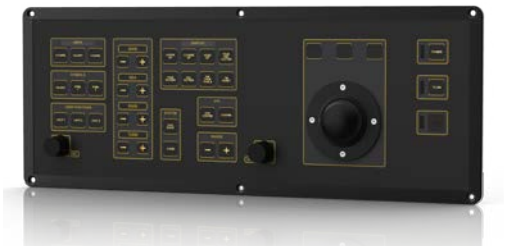
Short travel technologies are becoming more widespread due to their design flexibility, excellent haptic feedback and lower overall costs.

Of the motion control devices, joysticks have become the most widely used.

Environmental conditions
Dust, water, oils, caustic solutions and extreme environmental conditions must not affect the reliability of HMI functions, which is why IP65 front protection is usually selected in harsh environments.

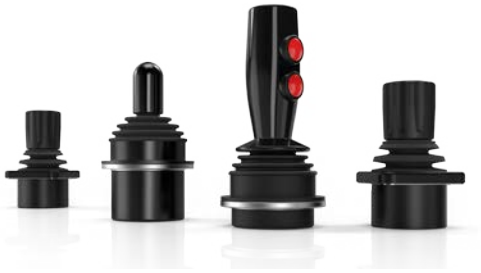
However, food and beverage applications may involve high-pressure/temperature wash-downs and therefore the highest protection, IP69K, should be specified. This standard exceeds the NEMA 4 standard by withstanding close range, high-pressure water up to 100 bar, tested from a variety of angles, as well as high temperatures up to 80 °C.

Short travel technologies
Short travel technology can include cost-effective, conductive rubber keys in a typical keyboard, dome keys under an overlay, or a multilayer membrane. Ever more popular, they offer HMI design flexibility, excellent haptic feedback, and are a low-cost solution.



HMI System with Series 70 switches.

The look and feel of these devices is easily customised. A wide variety of illumination techniques, custom graphics, surface textures and materials can be easily tailored to the specific application requirements. Where regular cleaning or disinfecting is mandatory, like operating theatres or food laboratories, short-travel membranes facilitate strict hygiene procedures.



Series 09 joysticks.

Motion control devices
Trackballs, touchpads and joysticks may be required where precise and intuitive movement and control is required. Of these, joysticks have become the most widely used control technology due to the high density of control functions in a single unit.

Selecting an appropriate joystick depends on:

- Functionality
  - Number of axes of operation
  - Analogue or digital signal processing
  - Number of required outputs
- Ergonomics
  - Actuating force
  - Handle design
  - Tactile feedback
  - Pushbutton form
- Environment
  - Required IP rating
  - Required impact resistance
  - Selection of materials

Modern actuators and indicators are increasingly connected via serial bus communication.

Emergency stops must always be actuated mechanically – not by solid-state mechanisms.

Keylock switches are typically used to prevent unauthorised access.

„Mixed Technology“ HMI System.

EAO Series 45 E-Stop switch.

EAO Series 45 keylock switch.

Safety and security devices
Among the most common safety products are the emergency stop button and mushroom-head stop button.

Emergency stop switches
Emergency stop switches are regulated worldwide by strict safety regulations. According to current standards, the actuation of the emergency stop function to the off position must be performed by a mechanical action.

The actuated state must be clearly visible and the release must be done manually. Due to these reasons, the emergency stop function must not be operated using a touch-based system – at least at present.

Mostly, the state of the emergency stop signal is detected by opening the switched current circuit. Currently so-called ‘safety bus protocols’ (e.g. CAN-Safety/AS-i Safety) allow this state to be transmitted directly to the corresponding controls.

Keylock switches
Key-operated switches prevent accidental or unauthorised access. Different keys have different coding, providing authentication of employee groups or individual employees. If necessary, operator access and time can even be recorded.

Communication and interfaces
HMI Systems were traditionally connected using hard-wired, point-to-point connections. Modern pushbuttons and signaling devices on the other hand are increasingly connected via serial bus communication cables to control systems.

AS-i, CAN, IO-Link, Profibus and Profinet are common interfaces. These pluggable communication links reduce initial wiring time and make expansion/fault detection much easier. AS-i is an open, international standard according to EN 50295 and IEC 62026-2 for process and field communication.

Selection of the types for use is often market-specific:
- Transportation and Heavy Duty & Special Vehicles: CAN/J1939 protocol.
- Machinery, process control and building automation: PROFIBUS and DeviceNet.
- Medical devices: CAN/CAN Open.

Therefore, it is important for the HMI provider to understand the requirements and accepted technologies of the market before selecting the appropriate HMI interface.

Using an experienced HMI System designer is worthwhile in many respects.

Standards are of the highest level of importance within HMI System and Component design.

HMI application in a hygiene area.

EAO headquarters in Olten (Switzerland).

Standards and regulations
Standards are of the highest level of importance within HMI System design. The criteria specified within general and industry-specific requirements dictate features, functional attributes, and design elements. Even the placement of components, markings and component colours can be affected or specified by standards.

EU Machinery Directive
EU specifications for any equipment in domestic, commercial or industrial applications that have parts actuated by an electrical power source. Meeting this directive earns the equipment a CE mark.

UIC 612
European passenger rail market guidelines that focus on the standardisation, modernisation, and modularity of operator controls.

SEMI S2-93
The global semiconductor industry association, covering HMIs for semiconductor manufacturing equipment.

Additional specifications of HMI Systems and components are defined by ANSI, IEEE and the International Organisation for Standardisation (ISO).

EMC regulations (electromagnetic compatibility) define testing for immunity, radiation, electrical field and discharges.

EAO – Your Expert Partner for Human Machine Interfaces

EAO AG, a Swiss, family-owned company founded in 1947, has developed into one of the world's leading manufacturers of high-quality switches, keyboards, sophisticated control elements, and complete HMI control units and HMI Systems.

With over 600 dedicated employees, EAO has a global production and distribution network at its disposal. And with production sites in Switzerland, Germany, North America and China, as well as our 11 country sales companies and distributors in over 50 countries, we can guarantee global availability.

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