How to best design an HMI system

A proper interface between a machine and its human operator greatly impacts efficiency and ease of use and should promote a harmonized connection between the two. Learn how to best build that connection though a human machine interface.

Key concepts

- Efficiency and ease of use rely on the design of the human-machine interface.
- Application, best practices, standards, and operator skill setsl influence HMI designs.
- Guidelines and experience help with HMI designs.

Human-machine interface (HMI) systems provide the controls by which a user operates a machine, system, or instrument. Sophisticated HMI systems enable reliable operations of technology in every application, including high-speed trains, CNC machining centers, semiconductor production equipment, as well as medical diagnostic and laboratory equipment. HMI systems encompass all the elements a person will touch, see, hear, or use to perform control functions and receive feedback on those actions.

How to design an HMI system?

A highly reliable HMI system that delivers safe, cost-effective, consistent, and intuitive performance relies on the application of engineering best practices throughout design, 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.

***EAO emergency stop switches** with forced-opening contacts (compliant with DIN EN ISO 13850 and EN 60204-1) are used to enhance personal safety and to prevent damage when vehicles, machinery, equipment, and control systems break down. All graphics courtesy: EAO*

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.

How many functions will be controlled by this interface? Where one function might be served by pushbutton, key-lock, and rotary switches, multiple functions could require several screen displays to cover operator functions and options. What kind of visual, auditory, or tactile feedback will best serve the operator in performing the defined functions?

Input can be as simple as an on/off switch or a touchscreen display. Touchscreen HMI systems are increasingly popular in public transaction applications, because they can simplify complex operations and tolerate a moderate degree of rough use. Defining input requirements will help decide which control technology is best suited for a specific application.

Feedback is critical to operator effectiveness and efficiency. Feedback can be visual, auditory, tactile, or any combination of these that is necessary for the application. Feedback is essential in systems that have no mechanical travel, such as a touchscreen or a capacitive device that when triggered has no moving parts. In some cases feedback provides confirmation of an action, while in others it adds to the functionality.

Interface and interconnections

HMI systems must be able to interface or interconnect with the system under control as well as other related systems. For example, in an industrial setting the HMI might connect via hardwire or a serial bus to input/output (I/O) points that provide machine status. Additionally, it might be networked into a manufacturing execution system and a supply logistics/inventory system.

The application environment—encompassing both physical location and vertical industry environment—determines HMI system durability requirements. Environmental stresses include exposure to moisture and the elements, temperature extremes, wear and tear, vandalism, and general rough use characteristic of harsh environments, such as an industrial production floor.

The HMI system should be rugged enough to withstand the elements and heavy use, but it also should last for the duration of the equipment lifecycle. For example, a magnetic resonance imaging (MRI) HMI system interface should last at least 10 years.

A thorough knowledge of technical ergonom-

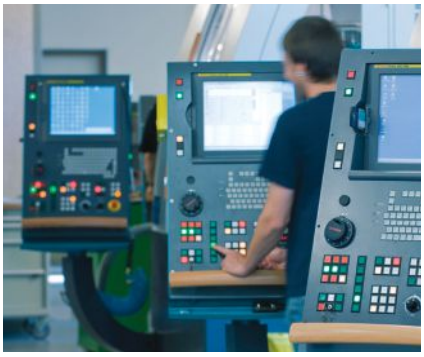
ic, design, and manufacturing standards is fundamental to HMI system design. These include engineering standards, such as MIL-STD-1472F, which establishes human engineering design criteria for military systems, sub-systems, equipment, and facilities; Federal standards set by the Americans with Disabilities 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 ANSI, IEEE, International Organization for Standardization (ISO), and others.

The key to a successful HMI system implementation requires a well-grounded definition and understanding of the operators. Will the operator be a passive/intuitive user? If so, commands/functions should be simple with an easy-to-comprehend interface. For this type of user, repeatability is also important–information and actions should appear consistently from use to use. For an expert user, where more sophisticated control is desirable, there may be multiple layers or levels for interfacing with equipment.

For any user along the range from intuitive to expert, interface ergonomic considerations should include: panel layout, HMI component selection, information presentation, feedback, and safety considerations.

Panel layout: The panel layout should be designed to provide the operator functional groups of related information in a predictable and consistent manner. In addition, the system must require an operator to initiate action and keep the operator informed by providing timely feedback on those actions. The layout should be organized so that the operator is clearly prompted in advance when the next operator action is required.

A circular HMI, *the Siemens Simatic Mobile Panel, designed for local operation and monitoring tasks, is said to be easy to hold for a long time. The portable wireless panel provides maximum mobility for wireless HMI.*



How many functions *will be controlled by an interface? One function might be served by pushbutton, keylock, and rotary switches; multiple functions could require several screen displays to cover operator functions and options. What kind of visual, auditory, or tactile feedback will best serve the operator?*

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HMI component selection: HMI designers can simplify their search for the appropriate switch or HMI component by carefully analyzing their application requirements then determining the following:

- Electrical ratings
- Actuation preferences (momentary, maintained, rotary, etc.)
- Physical configuration and mounting needs
- Special requirements such as illumination, marking, environmental sealing, etc.

Color scheme: The key to effective use of color is simplicity. Avoid too many colors or flashing alarms. Stick with the "traffic light" model for key actions:

- Red for stop/failure/fault
- Yellow for warning
- Green for OK/start/go/pass.

User feedback: Feedback is critical to ergonomic industrial design. Make sure the results of pressing a control button, toggling a switch, or entering a command are absolutely clear. Determine if operator feedback is visual, auditory, tactile, or a combination of multiple techniques.

Cursor control (Trackball, joystick, keypad, touchpad, etc.): The selection between different control technologies is primarily determined by the resolution of control that is required by the application. A trackball or joystick enables granular, pixel-by-pixel control, a far higher resolution than possible with a typical PC point-and-click controller.

Switches (Pushbutton, rocker, slide, keylock, rotary, etc.): Pushbutton switches allow the option of illumination to indicate open/close switch status when a quick visual indication is desired. **ce**

- John J. Pannone is vice president for HMI systems sales; edited by Eric R. Eissler, editor-in-chief, Oil & Gas Engineering, *eeissler@cfemedia.com.*

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