Human Machine Interface Systems
for Electronics Production Applications

Electronics production is an industry undergoing constant change. As the industry continues to climb, its mantra for success is smaller, better, faster, cheaper. As electronics production manufacturers strive to meet these demands, they are looking for equipment that will help them by providing more effective and more intuitive control of their processes.

Human Machine Interface (HMI) Systems provide the controls by which a user operates a machine, system, or instrument. From pick-and-place assembly systems to automated semiconductor etch and deposition systems in fabrication facilities, HMI Systems encompass all the elements an operator will touch, see, hear, or use to perform control functions and receive feedback on those actions.

The task of an HMI System is to make the function of a technology self-evident to a range of potential users. A well-designed HMI fits the individual user’s image of the task he or she will perform, and provides easily discernible operator feedback. The HMI System is judged by its usability, which includes how easy it is for an operator to learn, operate, maintain, and productively utilize the related electronics production equipment. In electronics manufacturing, productivity and yield enhancement translate directly into the bottom line.

HMI trends for electronics production
There are several important trends in the development of HMI systems for electronics production equipment. New approaches to HMI are focusing on providing a clear and intuitive user experience that is an integral part of the process under control. A well-designed HMI is expected to provide a high level of functionality and interactivity for the user so that it becomes the front-end of the process, not just a graphical add-on. The goal is to increase ease-of-use, improve productivity, reduce the time it takes to complete a task, and increase operator satisfaction.
HMI Systems should provide a consistent operating environment from machine to machine. As manufacturers decentralise, operators from diverse language and training experience must feel comfortable.

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And process efficiency by providing a seamless user experience.

In addition, an HMI System should provide a consistent operating environment from machine to machine. As many manufacturers decentralize manufacturing operations around the globe, it is essential for operators from diverse language and training experience to feel comfortable with how information is presented and how they can complete their assigned tasks.

HMI Systems are also expected to take an open systems approach in terms of software development and integration to allow for the use of a broad array of potential tools and systems. Unlike traditional control systems that depended on “closed” or proprietary approaches, today’s HMI Systems are designed to allow for timely updates and enhancements to software and capabilities.

Finally, this open architecture needs to provide for flexible interconnection and communication with other systems and controllers in the manufacturing environment. Flexibility in communication is essential to the efficient operability of all the equipment in an electronics production environment.

Defining the operational/functional requirements
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. Applications in electronics production and semiconductor tend to have many operator terminals. They consist of touchscreen displays that are essentially flat-screen computers of various sizes interfaced to production machines. The environment is generally clean.

General functionality
How many functions will be controlled by this interface? Typically, electronics production equipment includes multiple functions that 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?

Typical operations require real-time indicators often with multiple data-entry points. Emergency stop and safety also need to be considered. Industry standards will also have an effect on functionality.

Degree of input complexity
Input can be as simple as an on/off switch or a touchscreen display. Touchscreen HMI Systems are popular in electronics production due to the complexity of the process. The key to a successful HMI System implementation requires a well-grounded definition and understanding of the operators.

Operator feedback
Feedback is critical to operator effectiveness and efficiency. Feedback can be visual, auditory, tactile, or any combination necessary for the...
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The HMI System should be rugged and durable to last through the equipment lifecycle.

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/Interconnection with other systems
HMI Systems must be able to interface/interconnect with the system under control as well as other related systems. For semiconductor applications, interconnection might be through an industry specific bus like EtherCAT.

Environmental considerations
The application environment — encompassing both physical location and vertical industry environment — determines HMI System durability requirements. In electronics production, environmental considerations might need to include clean room safety, corrosive gas protection, and resistance to acids and other caustic agents.

Lifecycle durability
Not only should the HMI System be rugged enough to withstand the elements and heavy use, but it should also last for the duration of the equipment lifecycle.

Regulatory/standards considerations
A thorough knowledge of technical ergonomic, design, and manufacturing standards is fundamental to HMI System design.

These include industry guidelines such as those from Semiconductor Equipment and Materials International (SEMI®), including S2-93: Safety Guidelines for Semiconductor Manufacturing Equipment, S8-95: Safety Guidelines for Ergonomics/Human Factors Engineering of Semiconductor Manufacturing Equipment, SECS (SEMI Equipment Communications Standard), GEM (General Equipment Model), and related industry standards covering HMI for semiconductor manufacturing equipment.

The SEMI guidelines recommend that an independent third party evaluate each production tool using an Ergonomic Success Criteria (SESC) checklist to ensure that the design meets the following criteria:

- Accommodates a diverse user base (e.g. 90% of the world’s working population)
- Allows users to work in a comfortable, neutral posture
- Accommodates user visual limits
- Facilitates maintainability
- Avoids overexertion due to manual handling tasks
- Provides user-friendly interfaces

Define the operator
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...
Panel layout should be designed to provide the operator functional groups of related information in a predictable and consistent way. The operator should be clearly prompted in advance when the next action is required.

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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 action is required.

HMI component selection
HMI designers can simplify their search for the appropriate switch or HMI Component by carefully analysing 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.
- Industry standard requirements, for example protective shroud requirements for E-Stops in semiconductor applications.

Operators
The primary concern is providing the operator with intuitive access to the subset of controls necessary for daily production tasks on the equipment. In general, the idea is to minimize unnecessary data while keeping detailed data available upon request. Changing parameters is typically restricted to prevent potential errors or experimentation. The controls should allow an operator to make intelligent decisions but limit the potential for error or improper control settings.

Supervisors
A higher level of control is generally granted to supervisors and access may be controlled by a password/log-in procedure. This may include separate screens of detailed information and offer more data entry options.

Maintenance
Maintenance personnel can be given full access to machine control and data displays. These capabilities are often inaccessible by operators and supervisors.

It is critical that an HMI System meet industry and regulatory standards, including SEMI S2-93 for the semiconductor industry.
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Feedback is critical to an HMI System — determine if it is visual, auditory, tactile, or a combination.

Colour scheme
The key to effective use of colour is simplicity. Avoid too many colours 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

Keep colours bold and bright and use a neutral background if necessary to make them stand out. Use colours conservatively, conventionally, and consistently. Colour should never be the sole source of information.

HMI illumination technology can integrate the use of multiple indication colours using widely available RGB LEDs. The LEDs can generate each primary colour but also blend colours to create an unlimited number of indication choices. This colour generation capability provides an HMI designer with the ability for multiple uses of a single discrete switch for multiple functions via a combination of software sequence and colour creation.

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The military in MIL-STD-1472F recommends the following use of colours:
- Flashing red to denote emergency conditions
- Red to alert an operator that any portion of the system is inoperative
- Yellow to indicate a condition exists which is marginal
- Green to indicate that a monitored condition is within tolerance
- White to indicate conditions that do not have a “right” or “wrong” connotation

Blue to be used as an advisory light

In all cases and standards the overriding factor is consistency throughout the HMI design so that what a colour “means” remains the same no matter where it appears in the HMI.

Information presentation
Once again, simplicity is the key. Don’t crowd a screen – avoid cluttering it with irrelevant data. Forcing an operator to search for the required information increases response time and potential errors. Have a consistent set of menu buttons and functions from screen to screen.

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.

How do you choose the best control technologies?
Once you have defined HMI functionality, you are ready to investigate control technologies. Each technology has advantages and
Pushbutton switches allow the option of illumination to indicate open/close switch status when a quick visual indication is desired. In electronics production, they allow for easier manipulation when gloves are worn.

“Rotary-switch and keylock technologies serve best when the application requires position indicators.”

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Modular products can be fitted with different actuators.

Emergency Stops (E-Stops) are always a discrete function in this environment.

Display technologies (LCD, Active Matrix, OLED, FED, Plasma)
The basic function of displays in HMI applications is to provide an information source – operators interact to obtain information or to prompt for the next screen. Display technology choices are dictated by the HMI System environment and its degree of ambient illumination, as well as by colour requirements. Active matrix LCD technologies are commonly used for colour functionality, while legacy LCD technology is used in applications where monochromatic feedback is sufficient. OLEDs, organic (carbon-based) light-emitting diodes can currently support smaller displays.

Interactive displays, touchscreen
Touchscreen technologies offer a range of functionalities and characteristics that govern HMI Systems choice according to application and environment. It is important to determine which touch technology will be used in the early stages of the design cycle as the different options offer quite unique electrical and mechanical requirements.

Capacitive touchscreens transmit 75% of the monitor light (compared to 50% by Resistive touchscreens), resulting in a clearer picture. They use only conductive input, usually a finger, in order
The purpose of the E-Stop shroud is to protect against random operation. An E-Stop that is mistakenly hit during operation could result in significant impact on process quality as well as process yield.

Infrared touchscreen technology projects horizontal and vertical beams of infrared light over the surface of the screen. When a finger or other object breaks those beams, the X/Y coordinates are calculated and processed. These cost-effective touchscreens can also be used by workers with gloves and are relatively impervious to damage.

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Connecting/communicating with an HMI System

Typically, communication can be achieved through several approaches: hard-wired connection, serial bus connection, or wireless connection. Each approach has pros and cons — selection will depend on how your HMI needs to fit within your applications. Selecting the appropriate communications technologies may include combining some or all of these approaches.

Emergency stop requirements

Emergency stops are always a discrete function in this environment. The SEMI S2 Guidelines identifies them as EMO stops, distinguished from E-stop configurations used in other industries. The primary difference is SEMI’s requirement of a guard over the switch, which allows operation with the palm of the hand only, in order to guard against accidental shutdown and the loss of work-in-process.

The protective shroud requirement includes the use of an unbreakable material, for example Lexan plastic. The free actuation angle to release the E-Stop should be approximately 210° with an anti-rotation pin and protection to IP 65. The purpose of the E-Stop shroud is to protect against random operation. An E-Stop that is mistakenly hit during operation could result in significant impact on process quality as well as process yield. The shroud helps to prevent unacceptable production downtime due to inadvertent operator error.

Pendant control systems

Other specific characteristics of control systems in electronics production include some use of tethered pendants with operations brought to a tethered box — both wired and wireless boxes. This allows the operator to move away from the main control panel to perform tasks such as setting parameters, for example. Most other functions are similar to other manufacturing environments.

Hard-wired connections

Hard-wired systems require no special tools and are simple, visible, and easy to understand, especially where the HMI interface controls a
As equipment and control systems became more complex and data hungry, transmission of data became a critical issue. *Serial bus connections provide reliable, real-time operations and work-in-process feedback.*

“Electronics production uses bus connections extensively because of the need for reliable, real-time operations and work-in-process feedback.”

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Higher level networks connect with field bus protocols primarily across variations of Ethernet. These include:
- PROFINET,
- Ethernet/IP, EtherCAT,
- Ethernet Powerlink,
- Modbus-TCP, and SERCOS III.

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The EtherCAT industrial Ethernet protocol (a specific version of Ethernet) was developed for the semiconductor production environment and is now used in a wide variety of semiconductor and flat panel display manufacturing operations. EtherCAT provides superior performance, bandwidth, and topology flexibility to cover the entire range of communications requirements in semiconductor manufacturing equipment with a single technology: from process control via control computer integration to high-end motion control applications.

Another standard that applies to semiconductor equipment communication is the Generic Model for Communications and Control of Manufacturing Equipment or GEM standard. SECS/GEM defines messages, state machines, and scenarios.
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Wireless connections/communications
Industrial applications have employed wireless technologies over the last 20 years to take advantage of real-time data transmission, application mobility, and remote management capabilities. WWANs (wireless wide-area networks) utilize mobile communication networks such as cellular, UMTS, GPRS, CDMA2000, GSM, CDPD, Mobitex, HSDPA, 3G, and WiMax. All of these networks offer wide service coverage and are normally used for citywide, nationwide, or even global digital data exchange.

In cellular communication, GSM (Global System for Mobile Communication) is the leader with over 80% market share, followed by CDMA (Code Division Multiple Access). The biggest issues regarding data exchange over a WWAN are the associated costs, bandwidth, and IP management. However, as technologies improve and costs drop, WWAN is predicted to replace traditional microwave, RF (radio frequency), and satellite communication due to lower infrastructure costs.

Popular wireless communication technologies that are being applied to electronic production applications are WiFi, Bluetooth, ZigBee, and UWB. All are based on IEEE 802 standards: WiFi 802.11a/b/g; Bluetooth 802.15.1; ZigBee 802.15.4; UWB 802.15.3.

WiFi
WiFi was developed for data-intensive communications — accessing the Internet, streaming video — typical web browser behaviour. WiFi devices communicate via radio signals that must penetrate solid objects to reach other wireless network nodes. Transmitter power output and antenna type are important considerations. In an electronics production environment, other machinery often produces a large amount of electrical noise. WiFi for these applications typically is more robust in order to provide the performance levels industrial users require.

Bluetooth
Like WiFi, Bluetooth uses higher transmission power and requires higher battery power. Typically, batteries life can be measured in weeks. It is designed to connect short range, inexpensive devices and replace cable connection to computer peripherals like printers. Bluetooth is part of a group of technologies considered as a wireless personal network (WPAN).

ZigBee
ZigBee is specified as a low-rate WPAN for supporting simple devices that consume minimal power and typically operate in the personal operating space (POS) of 10 m. It is considered a viable solution for electronics production applications with low rate, low power, and short range needs. ZigBee is popular for its low power requirements, network scalability, and reliability. It is often used to drive a diverse set of sensor network applications. ZigBee uses mesh networking. Networks can scale to hundreds and thousands of devices and all communicate using the best available path for reliable message delivery. If one path fails, a new one is automatically discovered without affecting system operation. This provides long-term reliability.

UWB
UWB is gaining attention as an indoor, short-range, high-speed wireless communication. With a bandwidth over 110 Mbps, it can satisfy most multimedia applications such as audio and video delivery and can act as a wireless cable replacement of a high speed serial bus such as USB 2.0 and IEEE 1394.
The impact of the human/machine interface is much more significant than its basic functionality. HMI Systems are the principal point of contact between the user and a machine or process.

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

International standards:
http://www.conformance.co.uk/directives/ce_new_machinery.php

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

U.S. Federal:
ADA (Americans with Disabilities Act) Standards for Accessible Design, 28 CFR Part 36
http://www.ada.gov/stdspdf.htm

NEMA (National Electrical Manufacturers Association) similar to the international IP standard, e.g., the NEMA 4 standard is similar to IP 65

ANSI (American National Standards Institute)
OSHA regulation 1910.147 The control of hazardous energy (lockout/tagout).

Industry standards:
IEC Safety Integrity level (SIL) http://www.iec.ch

Semiconductor industry

SEMAPTECH Application Guide 2.0 for:
Safety Guidelines for Semiconductor Manufacturing Equipment SEMI S2-93
Safety Guidelines for Ergonomics/Human Factors Engineering of Semiconductor Manufacturing Equipment SEMI S8-95

Manufacturing Equipment SEMI S20-0697

Summary
The effectiveness of an HMI System can affect the acceptance of the entire system; in fact in many applications it can impact the overall success or failure of a product. The HMI System is judged by its usability, which includes how easy it is to learn as well as how productive the user can be with it. A well-designed HMI System does more than just present control functions and information; it provides an operator with active functions to perform, feedback on the results of those actions, and information on the system’s performance.

The impact of the human/machine interface is much more significant than its basic functionality. HMI Systems are the principal 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, colour, and tactile response coupled with ergonomic and intuitive operation, create an optimal user experience that determines a customer’s satisfaction with the core product.

In electronics production applications, a well designed HMI System that meets user requirements, industry standards, and government regulations is a key component in the overall sound design of the equipment itself. Creating the right HMI System requires working with an HMI expert who can help to navigate all the functional and regulatory requirements, and satisfy the unique demands of an electronics production environment.