Technical Article

Human Machine Interface Systems
for Marine Applications

The world's most prestigious boat builders, including builders of commercial vessels and megayachts, require Human Machine Interface (HMI) Components and System that provide superior styling and design, high reliability, high quality, and proven durability. From the engine room to the bridge, building the appropriate HMI Systems requires an understanding of the system's purpose and functionality, a clear identification of the operators and their needs, the selection of the appropriate technologies, an understanding of how the system will interface with the rest of the vessel, and the application of appropriate industry and international standards.

Human Machine Interface (HMI) Systems provide the controls by which a user operates a machine, system, or instrument. From the captain's bridge to the power distribution system in the engine room, or the multimedia entertainment system on a yacht, 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 the user. A well-designed HMI fits the user's image of the task he or she will perform. 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. In marine applications, the user might be engaged in navigation, communications, guidance, lighting, or passenger access and accommodation, or multiple simultaneous operations which make intuitive design a necessity.

Trends in HMI systems for marine application

An HMI System for a vessel could include alarm and status signals from a variety of the ship's subsystems, such as power, propulsion, stabilizers, surveillance, HVAC, and others. An HMI System might include communication and navigation functions, external and internal cockpits, engine room controls, power distribution, lighting and alarm systems, passenger access and egress, as well as peripheral systems like winches.

In many cases, the trend is toward controls with graphics that "mimic" the real function. For example, an engine room

Disabled passengers must not be overlooked.

ADA regulations require that controls be accessible for passengers with disabilities, utilizing the overall simple functionality and ease-of use criteria applicable to public access applications.

"An HMI System might include communication and navigation functions, external and internal cockpits, engine room controls, power distribution, lighting and alarm systems, passenger access and egress, as well as peripheral systems like winches."

"ADA regulations require that controls be accessible for passengers with disabilities."

From the captain's bridge to the power distribution system in the engine room, an HMI System is a critical component in marine applications.

control panel might include graphics that mimic the operation of the power plant, with a boiler graphic showing air, fuel, and oil feeds, pressure and temperature gauges, and other critical systems data. The graphic might contain access to historical data and trends as well as alarms that are triggered should the system deviate from specified operating parameters.

HMI Systems that offer reliable, intuitive, and ergonomic performance are important on both the operator and the passenger/ crew sides. ADA regulations require that controls be accessible for passengers with disabilities, utilizing the overall simple functionality and ease-of use criteria applicable to public access applications.

Passenger and crew applications often use audible feedback such as voice/sound indicators. Passenger and crew HMI controls can also include override systems, and emergency-call equipment prompted by audible, visual, and hidden indicators, and programmable acoustic warning signals.

Standard HMI components for marine use could include illuminated pushbutton switches, indicators, keylocks, selector switches, joysticks, membrane controls, emergency E-Stops, and more. These types of components would be suitable for virtually every type of application you might find on a vessel: navigation controls, bridge communication, lighting, passenger access, power distribution, even security. Components should be available in a variety of different materials including stainless steel and aluminium, in a range of shapes and mounting styles, in a choice of styles and colours to suit a particular usage.

Controls must also be durable and as "mistake-proof" as possible. In addition, control systems need to interface with other on-board equipment. Choosing the right communications interfaces is a key part of the design of the HMI System.

Marine Applications

There are a wide range of marine applications for HMI Components and Systems, including: bridge and helm controls, power distribution,communications and navigation, external cockpits, and peripheral systems.

Bridge and helm controls require:

- At-a-glance status indication using bright, illuminated switches and LED backlit engraved switches
- Dimmable switch lighting to control ambient conditions
- High quality tactile feedback Graphically expressive displays Flush Styling

Power distribution requires:

- High reliability switches for low to high current ratings
- Wide range of contact terminal types, such as solder, plug-in, PCB mount, screw-in terminals, ribbon cable, etc.
- Compliance with U.S. and International standards, including Coast Guard, National Fire Protection Association, Canadian

HMI devices are defined as an enclosure by the IEC. *The rating proves the device has been tested according to international standards, providing a more detailed measure than generic terms like waterproof.*

"HMI devices are defined as an enclosure by the IEC."

"Most marine applications demand a minimum IP 67 for external HMI components due to the risk of immersion."

HMI Systems provide flexibility for configuring power distribution panels.

standards for small craft, ISO standards for electrical systems, CFR regulations, IP Ratings, and more.

Communication and navigation controls require:
- Pushbuttons, indicators, levers, buzzers, and keylocks.
- Engraved symbols or legends.
- Intuitive and ergonomic control panels.

External cockpits require:
- Water resistance to IP 68.
- Shock and vibration protection Reliable operation in temperature extremes.
- Immediately recognizable status indication.

Peripheral systems might require:
- Easy recognition in day or night use.
- High-quality tactile feedback.
- Water resistance to IP 68.

The International/Ingress Protection, or IP rating system, is widely used and describes the degree of protection as defined by the International Electrical Commission (IEC) standard 60529. The degree of protection as defined by the IEC is used to describe:
- Protection offered to people against hazardous parts inside and enclosure;
- Protection of equipment inside the enclosure against the intrusion of solids;
- Protection of equipment inside the enclosure against the ingress of liquids.

HMI devices are defined as an enclosure by the IEC. The rating proves the device has been tested according to international standards, providing a more detailed measure than generic terms like "waterproof."

In an IP number, for example IP 68, the first number is a measure of how well the enclosure can prevent an invasion by solids — 6 is dust tight. The second number represents the measurement of protection against liquids at various pressures — the 8 indicates protection against immersion beyond one meter. Most marine applications demand a minimum IP 67 for external HMI components due to the risk of immersion. Consideration of the choice of material and its resistance to salt water corrosion is very important; and additional rubber seal might be desirable.

The importance of aesthetic appeal

In marine applications, aesthetic considerations are a powerful factor, especially in megayacht and cruise ship design. The style of an HMI System and its components provide an instantly recognizable level of luxury and investment to the operator and owner. Sleek design that is also highly functional can be a significant part of the selling appeal and confirmation of quality. In many ways, both visually and functionally, megayachts are on the leading edge of HMI Component and System design.

Meeting industry best practices is important in the placement of components, surface area, size and colour, emergency stop consideration, protective switch guards and shields, plus other ergonomic factors. *The goal is optimal usability, efficiency, and safety.*

"The key to an effective HMI System for marine applications is consistent and predictable performance with time-proven controls that are familiar and intuitive to multiple operators."

"Feedback can be visual, auditory, tactile, or any combination necessary for the application."

An HMI System provides alarm, status, and performance information for a variety of vessel systems.

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 system's functional requirements.

Applications in marine systems often have operator terminals. They may consist of touchscreen displays that are essentially flat-screen computers of various sizes interfaced to various other systems, such as a power distribution panel or the engine room. The environment can range from the spotless engine room of a megayacht to the working environment of a super tanker.

The key to an effective HMI System for marine applications is consistent and predictable performance with time-proven controls that are familiar and intuitive to multiple operators. As marine applications grow more complex and control more functions, operator controls need to become easier to understand and use in order to reduce the risk of human error.

An HMI System provides alarm, status, and performance information for a variety of vessel systems.

General functionality
How many functions will be controlled by this interface? Typically, marine 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?

Degree of input complexity
Input can be as simple as an on/off switch or a touchscreen display. Touchscreen HMI Systems are popular in marine applications due to the complexity and interaction of several processes. Input is really defined by the needs of the user. A novice user will have simpler requirements while an expert user will have added layers of capabilities. Users responsible for supervision and maintenance will have their own specific levels of complexity.

Operator feedback
Feedback is critical to operator effectiveness and efficiency. Feedback can be visual, auditory, tactile, or any combination necessary for the application. In some cases feedback provides confirmation of an action, while in others it adds to the functionality.

Meeting industry best practices is important in the placement of components, the component's surface area, legend size and colour, emergency stop consideration, protective switch guards and shields, plus other ergonomic factors. The goal is optimal usability, efficiency, and safety.

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 marine applications, interconnection might be

Know your operator. *The key to a successful HMI System implementation requires a well-grounded definition and understanding of the operators.*

"In marine use, environmental consideration might include potential exposure to salt water and the elements."

"For an expert user, where more sophisticated control is desirable, there may be multiple layers or levels for interfacing with equipment in many areas of the ship."

Panel layout should provide the operator with functional groups of related information.

through hard wiring or a bus system such as CANbus or ProfiBus. Use of serial bus systems is developing slowly due to increased complexity and limited serviceability away from the OEM builder location.

Environmental considerations

The application environment— encompassing both physical location and vertical industry environment—determines HMI System durability requirements. In marine use, environmental consideration might include potential exposure to salt water and the elements.

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. Durability and reliability are also key for vessels that embark on extended trips where servicing or replacing components can be difficult.

Regulatory/standards considerations

A thorough knowledge of technical ergonomic, design, and manufacturing standards is fundamental to HMI system design. This includes industry guidelines such as ISO 9001 and ISO 14001, as well as the following marine specific standards:

- U.S. Coast Guard, Boat builder Handbook, Compliance Guidelines for Electrical Systems
- American Boat and Yacht Council (ABYC) Electrical Systems Standards
- National Marine Manufacturers Association (NMMA) Engineering Standards Programs
- National Fire Protection Association (NFPA) NFPA 302: Fire Protection Standard for Pleasure and Commercial Motor Craft
- TP 1332: Construction Standards for Small vessels (Canadian standards) ISO Standards 10133 and 13297 – electrical systems for small craft
- USA Commercial Standards for small passenger vessels
- USA Recreational Boat Electrical Regulations

Define the operator

Know your operator — 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 in many areas of the ship.

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

Avoid too many colours or flashing alarms.

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.

"A pushbutton on a deck might be fitted with a stainless steel housing and silicone lens cap for extra resistance to saline erosion."

"Have a consistent set of menu buttons and functions from screen to screen."

Illuminated switches make the status of operations easier to see.

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.

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 components might include IP ratings, ISO standards for electrical systems, CFR regulations, Coast Guard regulations for electrical systems, fire protection standards, and more.
- Environmental considerations, for example, a pushbutton on a deck might be fitted with a stainless steel housing and silicone lens cap for extra resistance to saline erosion.

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

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 disadvantages related to the HMI system, equipment, and application.

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. Rotary-switch and keylock technologies serve best when the application requires position indicators. Keylocks provide an additional layer of security to the application. Rotary switches also can be

Applications operating in aggressive environments require a rugged, completely sealed surface. *Piezo, capacitive, and high frequency technologies all offer rugged switch technology with long life cycles and low maintenance costs.*

"Pushbutton switches allow the option of illumination to indicate open/close switch status when a quick visual indication is desired."

"Applications operating in aggressive environments require a rugged, completely sealed surface."

Short travel technology can include cost effective, conductive rubber keys in a typical keyboard, dome keys under an overlay, or a multi-layer membrane.

used for an application requiring multiple positions.

Slide switches are the technology of choice when ease-of-use and low-cost switching is desirable—commonly found on notebook cases and handheld on/off functionality.

Short travel technologies (Conductive rubber, membrane, keyboards)
Short travel technology can include cost effective, conductive rubber keys in a typical keyboard, dome keys under an overlay, or a multi-layer membrane.

Touch and switching technologies (Capacitive, Piezo, high frequency, etc.)
Applications operating in aggressive environments require a rugged, completely sealed surface. Piezo, capacitive, and high frequency technologies all offer rugged switch technology with long life cycles and low maintenance costs.

Display technologies (LCD, Active Matrix, OLED, FED, Plasma, etc.)
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 touchscreen 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 to register a touch.

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.

Motion control
Motion control most often employs joystick technology for applications requiring macro control, such as controlling a winch, or directional control for materials handling equipment, or pull mechanisms.

E-Stop requirements for marine applications
Measures to assure safety and usability offer a delicate balance between the ability to

Typically, communication can be achieved through several approaches: hard-wired, serial bus or wireless connection. *Each approach has pros and cons—selection will depend on how your HMI needs to fit within your applications.*

"In addition to operator E-Stops, there are also passenger and crew related systems that need to be considered for emergency stops."

"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."

Illuminated E-stops are more visible in difficult and changeable light conditions.

instantly stop a system in an emergency and protecting against accidental stoppage that might cause an emergency. In addition to operator E-Stops, there are also passenger and crew related systems that need to be considered for emergency stops.

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.

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 single operation, for example, power distribution. Hard wiring has limitations, however, including difficulty integrating changes or new features that require new wiring.

Serial communication bus systems

As equipment and control systems became more complex and data hungry, transmission of data became a critical issue. Data transmission depends on distance and speed. The longer the cable length, the lower the transmission speed to keep bit-error rates acceptable. Marine applications are starting to use serial buses more frequently as systems become more complex.

Maintenance, serviceability and repair must be considered to have seamless uptime operation.

Selecting the appropriate bus technology

Differing market segment connectivity requirements have caused many different bus standards to be defined and deployed. Some systems offer faster reaction times, whereas others may allow for more devices to be connected or for larger amounts of data to be transferred.

Field bus protocols evolved for interconnecting industrial drives, motors, actuators, and controllers. Field buses include: PROFIBUS, DeviceNet, ControlNet, CAN/CANOpen, KeyLink, InterBus, Foundation Field Bus, and HART. For example, a CANBus module can connect switch controls, potentiometers, pilot lights, and other components as part of an integrated HMI System interface, configured to enable plug-and-play capability.

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

While bus systems introduce great advantages to countless marine application, hard wiring and direct current switching is still the preferred method in many marine applications due

A poor HMI System can alienate users or potential customers, encourage users to circumnavigate the system, or result in poor or unsafe system performance. *HMIs directly represent the core system's quality and value.*

Contact

EAO AG
Tannwaldstrasse 88
CH-4601 Olten, Switzerland
Tel. +41 62 286 91 11
Fax +41 62 296 21 62
info@eao.com

More information
www.eao.com/downloads

to cost, reduced complexity, and serviceability.

U.S. and Industry Standards by Application

Marine Industry
Compliance Guidelines for: Subpart I — Electrical Systems Revised November, 2003 Title 33 CFR Sections 183.401 —183.460 http://www.uscgboating.org/regulations/boatbuilder_s_handbook/electrical_ systems.aspx

ABYC Electrical Systems E-11—Electrical Systems is E.11 AC & DC ELECTRICAL SYSTEMS ON BOATS

National Marine Manufacturers Association http://www.nmma.org/certification/default. aspx

NFPA 302: Fire Protection Standard for Pleasure and Commercial Motor Craft http://www.nfpa.org/aboutthecodes/ AboutTheCodes.asp?DocNum=302 -

Canada Standards for small craft.
TP 1332: CONSTRUCTION STANDARDS FOR SMALL VESSELS Section 8 Electrical Systems International Standard For small craft ISO Standard 10133: Small craft — Electrical systems — Extra-low-voltage d.c. installations International Standard For small craft ISO Standard 13297: Small craft— Electrical systems—Alternating current installations

USA Standards for Commercial Small Passenger Vessels
46 CFR Subchapter T Part 183 Electrical Installations: Passenger Vessels under 100 Gross Tons.

USA Recreational Boat Electrical Regulations 33 CFR Subpart I: Electrical Systems Americans with Disabilities Act (ADA) American National Standards Institute (ANSI)

Reference sites:
The following sites offer more information on regulations and standards:
http://www.abycinc.org/ — ABYC
http://www.uscgboating.org/regulations/boat_builders_handbook_and_regulations.aspx—US Coast Guard

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. 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 marine applications a sound and well designed HMI System that meets user requirements, industry standards, and government regulations is a key component in the overall sound design of the vessel itself. Creating the right HMI System in a marine application requires working with an HMI expert who can help navigate all the functional and regulatory requirements and satisfy the customer.