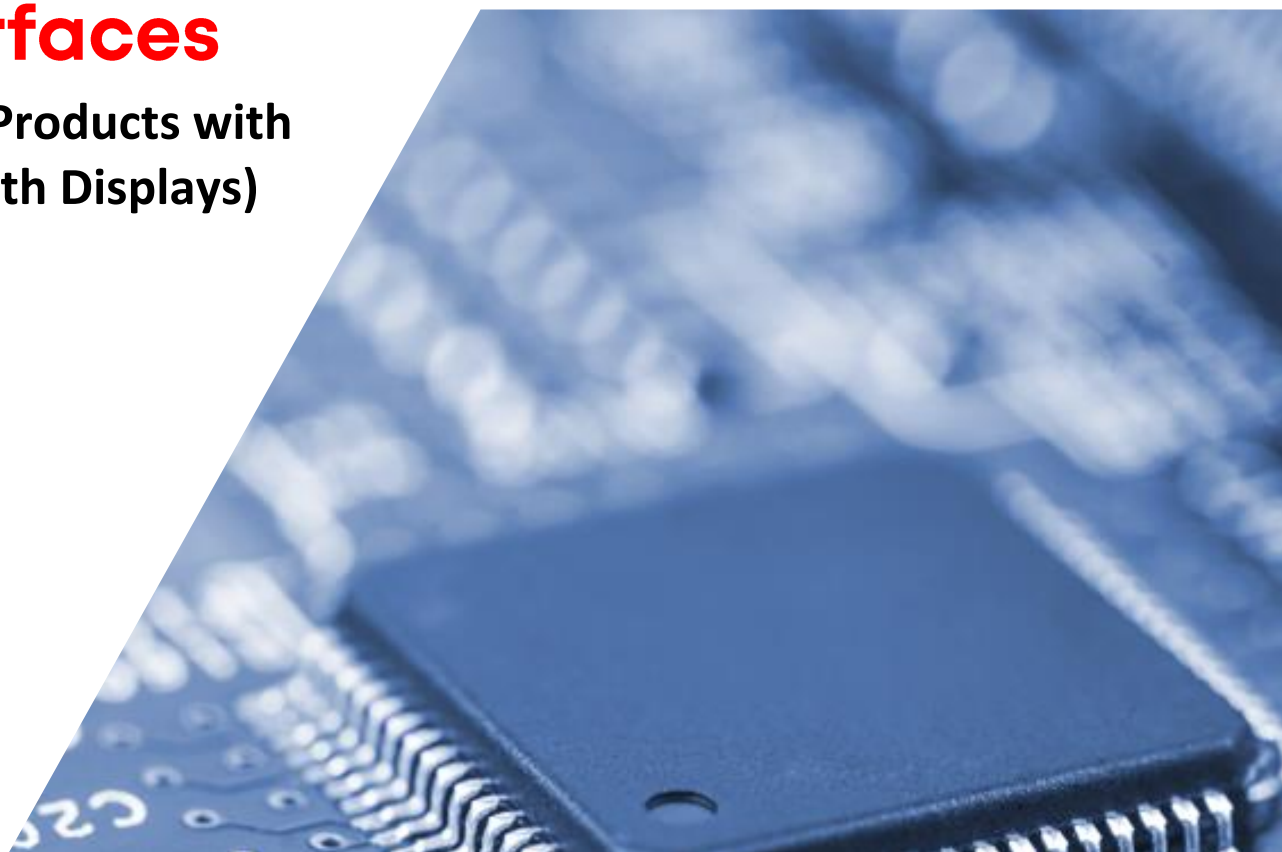
e2ip TECHNOLOGIES

Smart Touch Surfaces

Design Guidelines for OEM Products with Embedded HMI (Systems with Displays)

February 2024



Summary

Introduction

From gas pumps to bank machines, medical devices to industrial machinery, we encounter and interact with devices every day. Each of these devices has its own Human Machine Interface (HMI) that by purpose impacts how we engage with and use them. It displays system data and information, provides status indicators and feedback, and offers the user the ability to input the required information for the necessary controls and functionality to operate the product. The overall design of the HMI influences the other components of the embedded system, including the GUI, LCD display and the underlying board's functionality. As such, the OEM's decision regarding HMI components can significantly impact the end product. In some cases, a value-focused and streamlined HMI embedded solution becomes an ideal component of an OEM's product. Conversely, in complex environments like industrial or state-of-the-art food processing, a performance-based, full-featured HMI Embedded product offers increased power, processing capabilities, flexibility, and even full-motion video playback. When designing a new product that incorporates an HMI Embedded product , it is crucial to balance performance and cost, considering their impact on the overall user experience. In the following sections, we will explore six key steps crucial for designing, configuring, and selecting an embedded HMI product

1. User Experience (UX)

The overall User Experience (UX) is the key factor in the long-term success and performance of any product. UX refers to the overall experience a user has while interacting with a specific product. To ensure the long-term viability of the product, it is essential to consider the following factors:

- Consistency: A consistent design approach throughout the product enhances the user experience and makes it more straightforward to use.
- Continuity: The product should be designed to provide a cohesive experience, with a continuation from one element to the next.
- Context: The circumstances, background, or environment in which the product is integrated should be considered through the entire design process of the product.
- Complementary: The product components should be designed to complement each other as well as any other products that the user may use.

Neglecting any of these factors can put the long-term viability of the product at risk. Therefore, it is crucial to consider all these factors while designing a product with an HMI Embedded Solution.

Medical Applications: Healthcare and medical environments operate within a complex, high-stress, and fast-paced framework where swift decisions are critical. In these clinical settings, both professionals and patients rely on high-performing and responsive OEM products with embedded HMI products. In these clinical settings, both professionals and patients rely on high-performing and responsive OEM products with embedded HMI products.

- High-Resolution Displays: Employing high-resolution, bright displays ensures precise presentation and interpretation of medical images and data, even in the brightest ambient environments.
- Symbol-Based Communication: Substituting text with universal iconography helps overcome language barriers, facilitating effective communication.
- Intuitive Dashboard Design: A clean and efficient dashboard design, with strategically placed buttons presented at the right time, ensures intuitive operation for users.
- Anti-Microbial and Anti-Glare Coatings: The addition of anti-microbial and anti-glare coatings improves infection control and optimizes screen visibility and legibility.
- Portability Considerations: In applications or settings where portability is required, power consumption and battery life become crucial factors.
- Usability and Compliance Testing: Medical devices undergo rigorous usability and performance testing to meet established Industry Standards, Regulatory, and Safety requirements, ultimately ensuring a positive

Industrial Applications: Industrial products should be designed to be rugged and robust, aligning with the demanding environments where they operate. In many plant-floor settings and applications, the embedded HMI component is expected to network, monitor, and control a large number of diverse machines or sub-systems. To meet these requirements, certain functionalities should be considered:

- Processing Power and Networking: The embedded HMI component must be equipped with ample processing power, networking capabilities, and communication ports to handle and process substantial amounts of data, often in real-time. Processing Power and Networking: The embedded HMI component must be equipped with ample processing power, networking capabilities, and communication ports to handle and process substantial amounts of data, often in real-time.
- Data Collection and Logging: Time-stamped event logging and data collection are essential. Therefore, the embedded HMI component should include features like battery backup and a real-time clock and calendar (RTCC). WE DON'T HAVE BATTERY BACKUP
- Intuitive Screen Layouts: Screens should be designed to be intuitive and informative aligning with the designed UX with dynamic graphics providing real-time feedback on the various systems and machines being monitored. Intuitive Screen Layouts: Screens should be designed to be intuitive and informative aligning with the designed UX with dynamic graphics providing real-time feedback on the various systems and machines being monitored.
- Portability Considerations: Some industrial applications may require portability. Hence, power conservation and battery life should be carefully considered.

- **Aerospace applications:** In commercial airplane cabins, embedded systems with displays play a crucial role in modern seatback entertainment systems, significantly impacting passenger comfort and satisfaction. Passengers expect innovative designs and intuitive interfaces that facilitate easy navigation and provide smooth, clear video displays for movies and in-flight information. Additionally, embedded systems control and monitor various navigation and environmental sub-systems, including flight navigation, climate controls, and galley equipment. These systems must effectively communicate and network with other critical onboard systems. Adherence to rigorous safety standards unique to aerospace applications is essential for these embedded systems.

2. Graphical User Interface (GUI)

User Experience (UX) encompasses the overall interaction between users and a product at every stage. Within UX, the Graphical User Interface (GUI) represents the visual graphics elements displayed on the display. This includes virtual buttons, sliders, icons, menus, windows, status indicators, videos, and more.

GUIs can take various forms and styles, implemented through different software applications. When designing an effective and intuitive GUI, the key lies in understanding the specific needs and tasks of the user. Engaging with one or more users during the GUI design process can ensure alignment with user requirements and preferences.

Once the products requirements are clear, consider how best to present them to the user for an optimal user experience: 'What functions should be displayed for effective and intuitive operation of the device, and how can we visually represent them in the GUI?'

- *Example of functions*: primary function of the piece of equipment as well as on/off function, navigation icons, settings, etc.

GUI content can be presented and displayed using words, symbols, static pictures, animations, and videos, ranging from simple to sophisticated artwork and graphics. When creating content, ensure that assets and artwork accurately and effectively represent and communicate the intended information, avoiding superfluous or redundant details while considering how it will be consumed and understood by the user. This will help ensure quick interpretation and comprehension by the user, leading to effective and quick decision-making.

Incorporating relevant images and real-world visuals helps users quickly interpret and understand product conditions or status at a quick and cursory glance. Color and animation can guide users through complex processes and provide awareness of critical alert and safety conditions. Ensuring situational awareness by displaying or emphasizing only pertinent information concerning the current state of the device or process further enhances user performance and decision-making. Creating or leveraging an existing theme and color scheme for GUI presentation ensures consistency and commonality across similar products or different product lines and devices. Familiarity helps user engagement and efficiency. Finally, minimizing the number of clicks required to navigate and access different screens, and optimizing the HMI layout streamlines user workflow and overall efficiency. Reducing complexity and providing clear navigation paths contribute to a smoother and more productive user experience.

Here are some types of GUI representations to consider:

- **GUI for flat design:** very simple with two dimensional shapes
- **Realistic GUI:** With design involving realistic elements such as shadows, textures, gradients etc
- **3D GUI:** using videos or 3D graphics mimicking real world objects

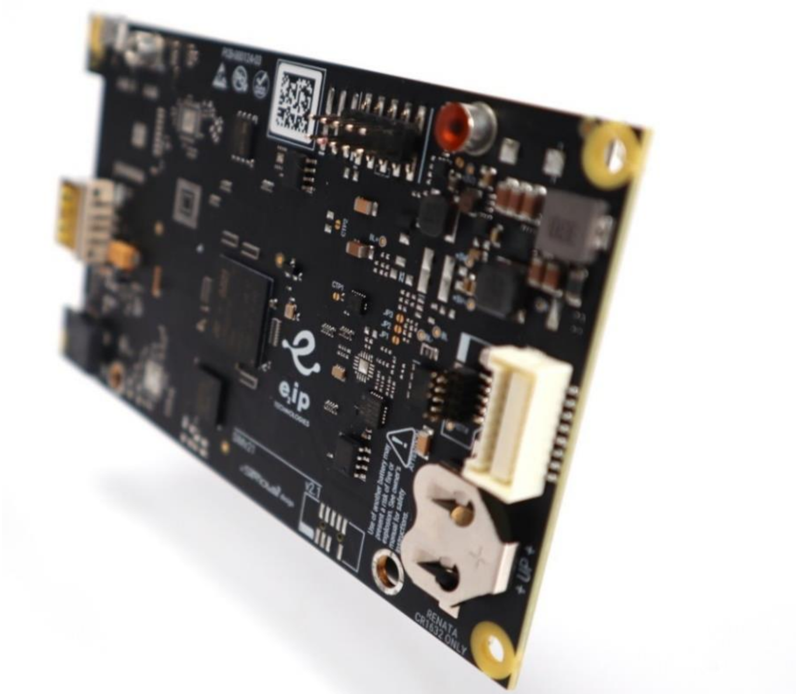
The more realistic & the more 3D visual elements that are displayed, the more expensive the underlying e embedded HMI system will be, as increased performance is required.

3. Embedded Systems

Keeping the user and (UX) at the forefront during the design process, we now move on to the next crucial step in developing the board and components of the Embedded HMI system.

Capabilities & Microcontroller/Microprocessor Selection

Properly assessing the expected computational demands and hardware requirements of the product is crucial to determine the level of processing power needed, which will directly impact the selection when choosing between an MCU (Microcontroller Unit) and an MPU (Microprocessor Unit) and associated operating systems. Although MCUs and MPUs are both sophisticated and capable chipset solutions, each has its own distinct purpose and strengths.



MCUs typically serve as straightforward and cost-effective processors, commonly used in low-level to mid-range applications with light to modest computing and processing requirements. They are simpler to implement, with programming typically required only for specific applications and configurations. They typically have faster start-up times and lower power consumption. From a chipset perspective, when compared to MPUs they are more budget-friendly.

MPUs, on the other hand, are more versatile and powerful processors. Because they can handle and process large amounts of data efficiently and quickly, they are typically used in larger applications with higher-level computing and processing power requirements. MPUs can offer multi-core capabilities with on-chip accelerators and advanced support for high-resolution video playback, advanced IIoT, and even EdgeAI, including high-speed connectivity and communications with high-speed peripherals. That said, an MPU will do everything an MCU can do and much more. However, with this added functionality and flexibility comes a higher cost, longer start-up period, and higher power consumption.

The Graphics Development Environment (GDE)

The Graphics Development Environment (GDE) is the software platform that provides the tools and resources necessary for designing and generating graphic assets and content of the GUI, including the associated interactions.

First, the GDE must be compatible with the hardware and software constraints of the embedded HMI system. Therefore, the choice of GDE platform will be a deciding factor. For example, if TouchGFX is preferred for GUI development, an MCU-based embedded HMI may be required. Conversely, if QT is required , an MPU-based embedded HMI is often the better fit.
Second, all graphic elements and assets must be created and optimized for compatibility with the constraints and available resources . Resource-intensive graphic elements and assets (e.g., hi-res videos, complex animations, etc.) will require more processing power and resources, thus, in general, an MPU is recommended. Conversely, simple graphics and static displays can efficiently be processed on an MCU-based system.

MPU or MCU - How to choose?

When choosing between MPU or MCU, balancing the aforementioned factors helps ensure a cost-effective GUI design that aligns with the capabilities of the given hardware and processor. If the intended application involves limited peripheral devices, and the GUI does not require high-performance graphics or video playback, consider an MCU-based embedded system with an RTOS operating system. They are more efficient for simpler tasks and will conserve power.

Conversely, when dealing with large data collection and processing requirements, the need for extensive network or peripheral connectivity, the ability for future scalability, or high-resolution video playback, then an MPU-based embedded HMI product with a Linux operating system is the better choice. MPUs offer robust performance, advanced features, and flexibility, but with a higher price tag.

4. Display

The LCD display (and touch screen components) make up the display and are essential and integral elements of an effective OEM product integrating and embedded HMI. The display is integral the embedded HMI product which can significantly affect the overall UX.

When designing a product with an embedded HMI system, the choice of display will impact both performance and cost. For this reason, the different technologies available for each should be carefully considered for the intended application.

Touch Technologies & Options

The LCD screen renders & displays the visual content, responsible for everything visible on the screen. It conveys and communicates all critical information necessary for effective device operation at any given moment. However, users cannot interact directly with the LCD screen alone. This is accomplished via the touchscreen panel component. The touchscreen panel acts as the intermediary input device that allows the user to interact directly with the graphics and content on display on the LCD screen. The HMI and LCD displays are available to be configured with various touch technologies and options:

- No touch: Inexpensive and effective when the LCD display is used only for informational purposes and does not require interaction with a user.
- Resistive touch: Inexpensive, robust, and suitable for most conditions, including gloved hand and wet environments. Capable of simple and limited multi-touch selections.
- Capacitive: For higher-end applications with bare finger and dry conditions. Newer capacitive touch technologies are more resilient to small amounts of water or even food service or medical gloves. Capable of complex multi-touch selections.

These options provide a range of choices to suit different applications and requirements.

Glass Cover Lens:

Capacitive Touch Panel (CTP) displays typically include a protective glass cover-lens mounted on the front face of the LCD display. This cover-lens is typically larger than the LCD display and the underlying Embedded System (ES) module mounted underneath. The glass cover-lens acts as a bezel and provides a surrounding perimeter frame that is typically silkscreened black. The glass cover-lens allows the HMI display to be panel-mounted either from the front or the back of the panel. In contrast, Resistive Touch Panel (RTP) displays typically do not include a protective glass cover lens and require the inclusion & use of mating bracket(s) to install & secure the display & embedded system to the respective panel. These display are typically finished afterwards with cosmetic trim or bezel.

LCD & Options:

LCDs are far from being a simple screen or display panel. LCDs encompass a diverse array of technologies and display options, each designed to meet the specific needs and requirements of various applications and help ensure a positive User Experience (UX).

When selecting the LCD display for a product with embedded HMI system, consider the following determining factors:

Resolution: Consideration of an LCD's resolution is crucial, as it directly affects the visual quality and clarity of displayed images and graphic assets. Higher-resolution displays offer denser arrangement of pixels, resulting in visually appealing interfaces. They ensure sharp and clean rendering of graphics and video content, with vibrant and rich colors. In medical and scientific settings where precision matters, higher-resolution displays improve data visualization and interpretation. Additionally, applications requiring high-precision touchscreen navigation and selection of on-screen elements benefit from higher-resolution screens. However, it's essential to weigh the trade-offs:

- Costs: Achieving higher resolutions often involves additional expenses.
- Processing Demands: More pixels require greater processing power.
- Power Consumption: High-resolution displays consume more energy.

In many scenarios, lower-resolution displays offer practical advantages, especially when simple graphics need to convey limited information and content. These displays are:

- Cost-effective: Budget-friendly without compromising functionality.
- Swift: Faster rendering due to fewer pixels.
- Efficient: Lower power consumption and reduced processing requirements.

Higher-resolution displays aren't always necessary, so the LCD's resolution should at least meet the functional requirements of the GUI and the intended goals of the product or application.

Backlight Brightness: the brightness of the LCD screen significantly impacts the User Experience (UX). Brighter displays ensure clear and vibrant GUI content, images, and videos. Conversely, dim displays can lead to difficulty in interpreting and interacting with GUI content, potentially causing frustration.

Typically, the brighter the display, the better, but this comes with increased power consumption and considerations for battery life.

LCD backlight longevity is typically measured in thousands of hours. If the backlight operates at 100% full power from the initial LCD power-up (fresh from E2IP), the typical brightness after that many hours will be approximately 50% of its initial luminance. Dimming or flickering LCD panels due to aging or premature failure can negatively impact the User Experience (UX) and potentially affect productivity and safety. Optimizing backlight lifetime is essential to align with the product's needs and lifecycle requirements.

A well-maintained backlight ensures reliable performance and enhances the overall user experience. Here are some common backlight longevity specifications:

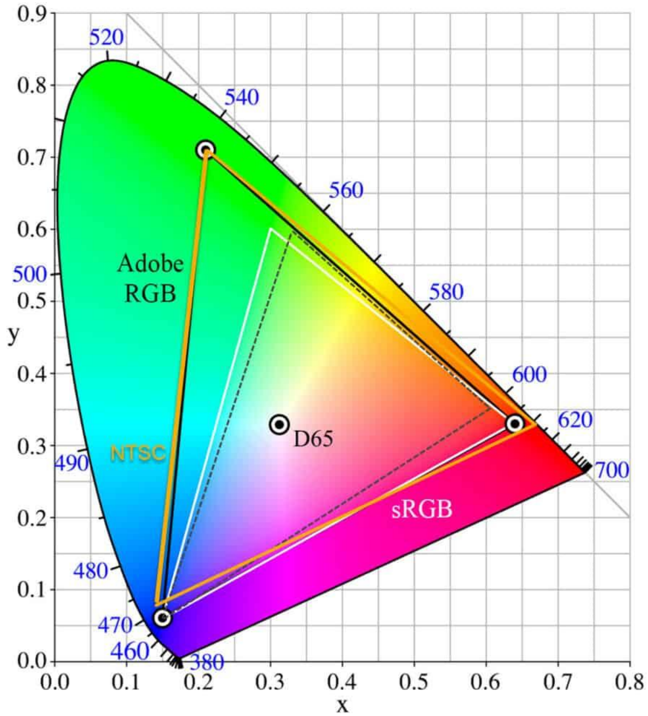
- 20K+ (20,000+): Normal longevity, cost-effective.
- 30,000+: Enhanced longevity, less commonly available.
- 40,000+: Enhanced longevity, uncommon.
- 50,000+: Long life, nearly the longest, with a price premium

Operating Temperature Range: The operating environment of the intended HMI+ES application can significantly impact the LCD display and the overall User Experience (UX). At elevated and hot temperatures, the contrast of the LCD display can be adversely affected, and the display may appear washed out. When operated at colder temperatures, LCDs tend to darken, and screen display and response will be sluggish. At the extreme limits of Operating Temperatures, the LCD may not function at all. The LCD temperature range is the MIN and MAX temperature range the LCD is expected to perform acceptably:

- 20°C to +70°C: The most common, cost-effective range.
- -30°C to +70°C or 80°C: Harder to obtain, premium product with a slightly wider operational range.
- -40°C or beyond: Rare and challenging to find; often requires a heater module that adds costs and requires additional power.

Note: The temperature range limits of the LCD do not mean the embedded HMI system will cease to function at temperature extremes. Most embedded HMI systemare rated at -40 to +80°C, so it is possible they will continue to function even if the LCD itself is not visible to the user.

Color Appearance & Depth: Color depth is the number of bits used by an LCD to represent one pixel. The goal of color appearance of an LCD is to ensure that colors are perceived by the human eye as accurately as possible. Unless the GUI has complex assets requiring large-shading gradients, 16-bit is almost always adequate for most applications. Going above 16 bits often incurs a GUI performance penalty because it impacts memory and performance (or, alternatively, the power of the MCU required to deliver equivalent performance)

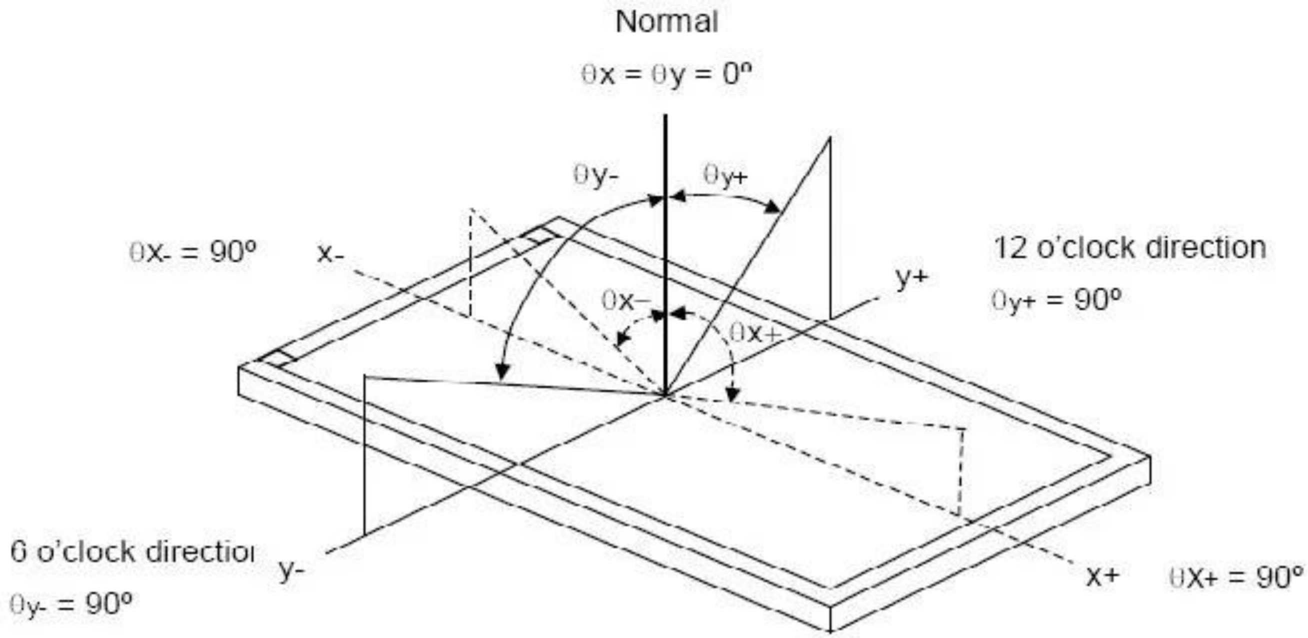


This diagram shows the "standard" color spaces

Viewing Angle & Size

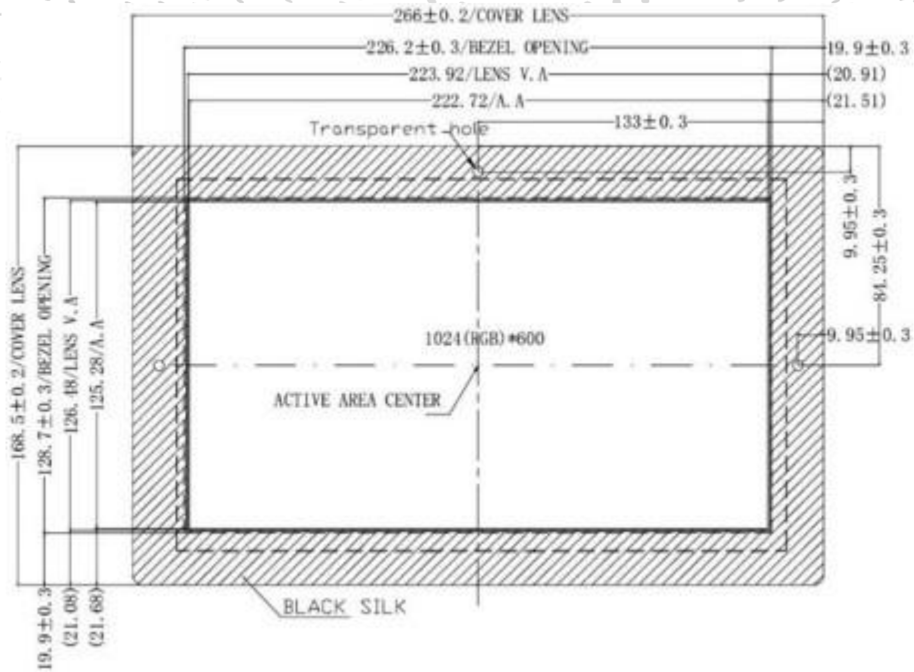
The viewing angle of the LCD display refers to the range of angles perpendicular to the straight-on vector of the screen from which the displayed image and content remain visible and suitable to the user, without too much distortion. It ensures optimal visibility of screen content, including contrast and readability. That said, the larger the viewing angle of an LCD display, the better.

The viewing direction of the LCD display corresponds to the best angle from which to view the display. Analogously, think of it like the hands of a clock: 12:00 corresponds to the top view, 6:00 to the bottom view, and 3:00 and 9:00 to the left and right views, respectively.



The goal of an LCD display is to provide the sharpest contrast and readability for viewers. Achieving this requires considering the widest viewing angle for the optimal viewing direction. As users move away from this ideal position (left, right, up, or down), the displayed image may degrade. Generally speaking, the optimal position for the LCD display is when the center of the LCD is somewhere between eye level and thirty degrees below the line of sight. Anything outside this could lead to eye strain. A well-designed HMI solution with an LCD display will consider both the optimal viewing direction and a wide viewing angle to enhance user experience and readability.

Size is a crucial factor to consider when designing GUI. Standard sizes can vary based on the complexity of the interface and the dimensions of the equipment. Typically, screens range from 3.4 inches to 10 inches. A typical capacitive touch LCD is dimensioned similar to this drawing:



5. Treatments, Films & Overlays

The next step in the design process of the product with embedded HMI is to consider and select any treatments or films for the LCD touchscreen display. Various options are available, and each should be carefully considered to see if the benefits and costs of each can further enhance the overall User Experience (UX).

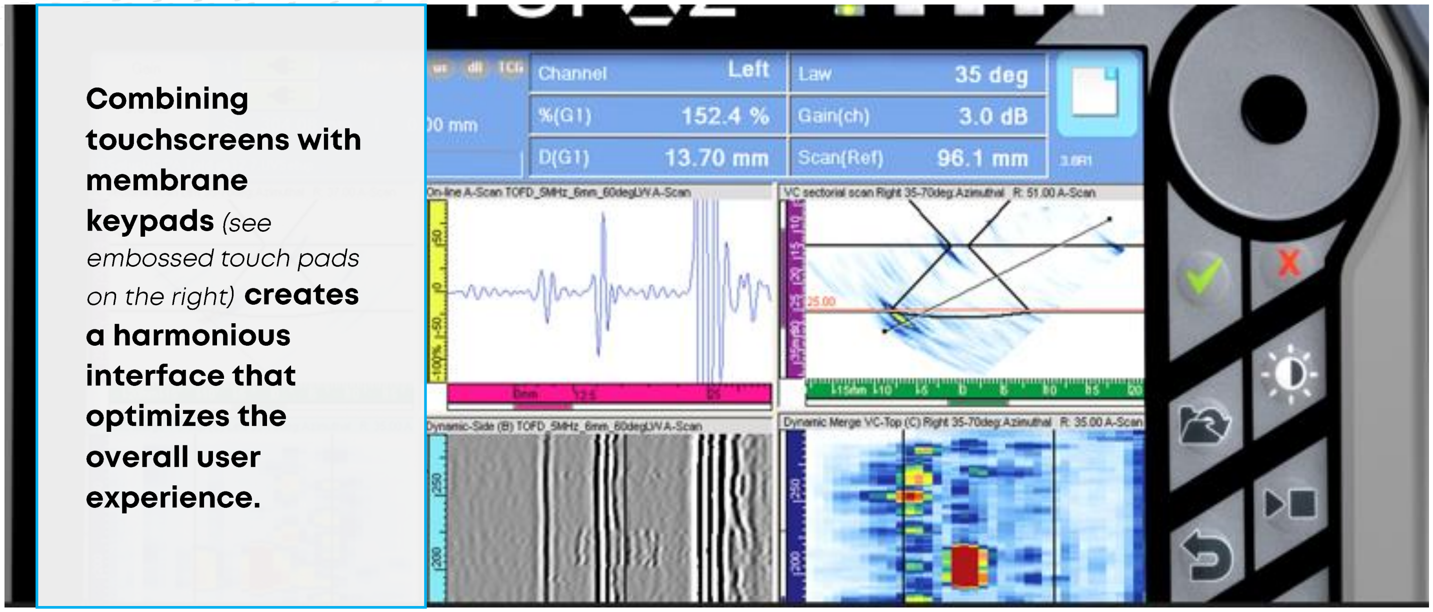
- Anti-Reflection (AR) Treatments or Films: This treatment involves the application of a thin film or coating to the front surface of the glass lens of the LCD display. This film will improve the optical clarity of the screen by filtering or canceling out reflections.
- Anti-Glare (AG) Treatments: This treatment is an etching process that makes the front surface of the glass lens a matte finish. This helps reduce and mitigate the adverse effect of any reflected images or light source on the lens surfaces
- Anti-Fingerprint (AF) and/or Anti-Smudge (AS) Treatments and Coatings: These treatments and coatings can be applied to the glass lens to create an ultra-smooth surface. This reduces the ability for fingerprints or other oily residues to stick and remain on the surface of the screen. It also makes the screen much easier to clean. Additionally, the smooth surface helps reduce stiction and traction of the finger on the screen, thereby improving screen navigation and the overall User Experience (UX).

- Anti-Shatter (AS) Film: This film coating prevents the dislodging and spread of glass fragments because of a broken or damaged glass lens or LCD screen. This is especially important in medical settings, food and pharmaceutical processing settings, or in portable device applications.
- Anti-Microbial (AM) Treatments or Films: For HMI embedded systems and LCDs to be used in a medical environment, a custom antimicrobial overlay layer can be added to help destroy certain bacterial strains on contact. The antimicrobial agents on the overlay film disrupt bacterial reproduction without compromising the mechanical performance and chemical resistance.
- Optical Viewing Angle (OVA) Films: OVA films can be applied to the surface of a traditional TN panel and deliver typically 75%+ viewing angles in all four directions, similar to true Multi-domain-Vertical Alignment (MVA) panels. Often, OVA and MVA panels are categorized together as Multi Viewing Angle (MVA) panels, providing a way to mimic the benefits of an IPS panel.
- ESD & EMI Shielding: Electrostatic discharge (ESD) and Electro-Magnetic Interference (EMI) are critical variables to consider. The human body can accumulate and discharge enough electrostatic energy to cause damage to vital electronic components of the HMI or further down the line. Similarly, external electromagnetic interference (EMI) from AC power sources or other electrical devices can adversely affect the operation and performance of electronic displays, HMIs, and LCD displays. In EMI/ESD-sensitive applications such as military, medical, and aerospace, micromesh films or transparent conductive coatings are available. These can be applied over the entire display to mitigate EMI noise and ESD while still allowing the necessary light transmission for LCD display and optical clarity.

LCD and Traditional Keypads: A Harmonious Duo for Enhanced User Experience

LCD indeed offer remarkable versatility and intuitive user interfaces, allowing for extensive customization and adaptability. However, it’s essential to recognize that traditional membrane switch keypads continue to provide add on advantages , even in the era of touchscreen dominance. Traditional membrane switch keypads are carving out new areas of application and reaffirming their value as an effective & complimentary technology to modern HMI’s with LCD touchscreen displays.

Redundancy: Integrating membrane switch keypads alongside LCD touchscreen displays in the Human-Machine Interface (HMI) solution can provide valuable redundancy. In critical patient-care applications or settings where user control must be assured at any given time, membrane keypads can serve as the primary controller interface or a reliable backup to ensure unencumbered access to clinical or emergency functions. In other applications or settings, it might be preferred to keep crucial functions and controls completely independent from the LCD touchscreen display, both geographically and electrically. This approach helps mitigate single-point failure conditions.



Combining touchscreens with membrane keypads *(see embossed touch pads on the right)* **creates a harmonious interface that optimizes the overall user experience.**

Improved Navigation and Input:
While touchscreen displays offer versatility and intuitive navigation, integrating membrane keypads alongside touchscreens enhances usability. By moving and locating critical or commonly used commands and controls to a dedicated membrane keypad, a more efficient user experience can be achieved. Users won't need to navigate or switch across multiple touchscreen menus, streamlining their interactions. Additionally, membrane switch keypad controls and buttons remain fully accessible regardless of the state or status of the touchscreen display. Whether the touchscreen is active or not, users can rely on the tactile feedback of the membrane keypad. This approach also leaves more screen real estate for graphics, visuals, and data presentation.

6. Testing - Iterating

Now that the initial design or configuration of the has been completed, it is crucial to validate the design through prototyping and thorough, rigorous testing. This critical phase serves several important purposes:

- Assessing User Experience:
  – Prototyping and testing allow us to evaluate how the ultimate user experience is received. By interacting with the prototype, users can provide valuable feedback, helping us refine and enhance the design.

– We assess whether the chosen components and underlying architecture align with the goals of the intended and expected user experience. Any discrepancies can be addressed during this phase.

- Iterative Design and Development:

– Iterations are essential in reaching a robust, reliable, and secure solution. As we identify areas for improvement, we can iterate on the design and development process.

– By refining the solution iteratively, we enhance its overall performance and usability.

- Comprehensive Testing:

– Testing should be all-encompassing and comprehensive. It involves functional testing, usability testing, performance testing, and security testing.

– We ensure compliance with all applicable industry standards, regulatory guidelines, and safety requirements. This step is critical for delivering a solution that meets quality and safety standards.

Remember that this validation phase is an integral part of the development lifecycle, contributing to the success of the HMI+ES Platform Solution.

Conclusion

When crafting or choosing the Human-Machine Interface (HMI) solution for the product, it is paramount to begin with the User Experience (UX) at the forefront. The UX acts as the guiding compass, delineating the lanes and boundary lines throughout the development journey. It not only illuminates the path but also allows to steer toward effective design decisions. Remember, a well-considered UX not only enhances usability but also fosters meaningful interactions between users and the product.

Ready to Illuminate Your Project?

This product design guideline serves as the foundational step in your design planning process. At E2IP Technologies, we wholeheartedly embrace the power of collaboration during the ideation and conceptualization phases. By placing early collaboration at the core of our process, we forge HMI solutions that transcend expectations and illuminate diverse applications. Our team of seasoned engineers brings extensive experience in assisting companies across automotive, avionics, medical, industrial, and consumer electronics domains. Whether you're a customer or an end-user, our commitment remains unwavering: to deliver HMIs that shine brilliantly. Reach out to us today! We're here to address your inquiries and guide you toward the perfectly aligned solution for your distinctive needs!

TECHNOLOGIES

e2ip.com
info@e2ip.com