EAO – Your Expert Partner for
Human Machine Interfaces

Technical Article

Interface Technology Considerations for HMI Systems

John J. Pannone, VP Sales, HMI Systems

A well-organized, easy-to-use panel may be what the user sees first in an HMI System, but the choice of communications and connectivity technologies is just as critical to the system's successful use.

Human Machine Interface (HMI) Systems provide the controls by which a user operates a machine, system, or process such as high-speed trains, CNC machining centers, semiconductor production equipment, or medical diagnostic and laboratory equipment. An HMI encompasses all the elements a person will touch, see, hear, or use to perform control functions and receive feedback on those actions. A highly-functional HMI System makes the operation of the equipment or systems under control transparent to the user, enabling an efficient, harmonious alignment of operating equipment to task.

The effectiveness of the HMI — and consequent enhanced productivity of the user — depends upon an exacting design process that incorporates all technical, ergonomic, and commercial application requirements. Equally important, the choice of communications and connectivity technologies linking the HMI to the core application directly affects both operator and overall system performance.

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 machine. Hard wiring has limitations, including:

- Difficulty integrating changes or new features that require new wiring.

- Increased space and weight requirements, due to the number of wires and connectors, incurring higher fuel costs for transport vehicles.

In the rolling stock industry, many users continue to choose hard-wired HMI Systems because the prohibitive costs and inconvenience of changing operating controls across large working fleets outweighs the enhanced efficiency, performance, and revenues generated by newer connectivity technologies.

In the rolling stock rail transportation industry, many HMI Systems prefer direct hard-wired connectivity or use an intermediate connection to promote modularity.

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.

Industries such as semiconductor production, machinery, medical, process industries, and transportation use bus connections extensively because of the need for reliable, real-time operations and work-in-process feedback.

Advantages of serial bus connectivity

Bus systems provide a wide range of advantages over hard wired connections, including easy addition of new functionality — typically through software — without adding or replacing hardware. Wiring is much simpler and more flexible with smaller cables and connectors allowing for more compact design, and easier hardware updating and relocation. Buses reduce subsystem installation time and simplify fault identification with on-board diagnostic features. Bus systems also allow for any combination of information from multiple different sources to control output devices.

In order to facilitate faster data transmission rates, devices incorporated serial bus connections. Buses bring all the switching and illumination wires out as one data connection, reducing wiring, assembly, repair/maintenance time, and weight (which in transportation translates into lower fuel costs).

There are tradeoffs, however: systems are more complex when only a small number of inputs and outputs (I/O points) are required. Also, special tools and well-trained personnel are required to design and service a bus system. Bus connections incur slightly higher upfront costs, but these are outweighed by increased performance and long-term savings.

Selecting the appropriate bus technology

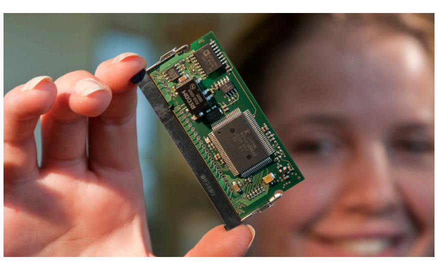
Differing market segment connectivity requirements have caused many different bus standards to be defined and deployed. Some systems offer faster reaction times, whereas others may allow for more devices to be connected or for larger amounts of data to be transferred.

Buses for specific applications include BACnet, LonTalk, Konnex, C-Bus and, others for building automation; and LIN, J1939, FlexRay, and others for automotive/transportation applications. There are also connection systems like the Actuator Sensor Interface (AS-i). Networks comprised of sensors, actuators, pushbuttons, and valves can use this system for a more intelligent method of cabling in control environments. It offers many of the benefits of more complex bus systems at a lower cost and provides a complementary and reliable way to connect binary and analog devices. It is suitable for interfacing to higher level networks and is especially useful in harsh environments.

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. CAN (controller–area network) is a message based protocol, designed specifically for automotive applications to interconnect and communicate without a host computer. Currently it is also used in a range of industrial automation, transportation, and medical equipment applications.

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. 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.

For other industrial applications, there are now additional protocol layers that format data to enable efficient data exchange across different networks, buses, and pieces of equipment.



CANOpen modules could be used in transportation, marine, medical, or machinery applications. An embedded version would be utilized for higher volume applications.

All bus technology is based on the Open System Interconnection (OSI) seven layer standard. This standard defines seven layers of interconnectivity from the physical layer (Layer 1) through data link, network, transport, session, presentation, to application. For example, technology defines the bottom two layers, the physical layer and the data link layer. The CAN protocol specifies how packets of data may be transported from one point to another using a shared communications medium. Higher level functions like flow control, node addresses, how to establish communications, and other capabilities are built in an HLP (higher layer protocol) like DeviceNet, to sit on top of the basic CAN technology.

CAN (Controller Area Network)

CAN was developed as a network for distributed real-time systems. CAN is a multimaster, asynchronous serial bus. Its low guaranteed maximum latency makes it ideal for real-time applications. It also delivers a high level of safety, making it well-suited for harsh environments. While developed for automotive use, with its low cost, ease of implementation, and fast communication, short reaction time, timely error detection, and quick error recovery and repair, CAN is now used for industrial applications, medical equipment, and other real-time control systems.

The CAN standard includes a physical layer and a data link layer that defines a different message types, arbitration rules for bus access, and methods for fault determination and fault confinement. CAN uses CSAM/CD with non-destructive bitwise arbitration to ensure low latency and maximal bus utilization. In contrast to Ethernet, CAN communication is data-oriented and not destination oriented. A CAN network has a maximum of 64 nodes.

CANOpen

CANOpen is a standard defined and widely used in Europe and North America. It builds on CAN and adds Higher Layer Protocols (HLP). It is designed for a maximum of 110 nodes with a maximum wire length to 500 m at 125 kBaud with twisted pair cable available for higher rates. CANOpen supports flow control, device addressing, and transporting of data blocks larger than one message. An example of device addressing can be seen in setting the brightness of LEDs through a CANOpen slave module. The slave module can control the brightness of up to 128 outputs. In addition, an individual setpoint can be transferred to every bus participant via the CANOpen master.

CANOpen is typically used as a slave device to collect data from switches and send information to digital outputs. It is used in the automotive industry, public transportation including railway and buses, marine applications, medical, and machining.

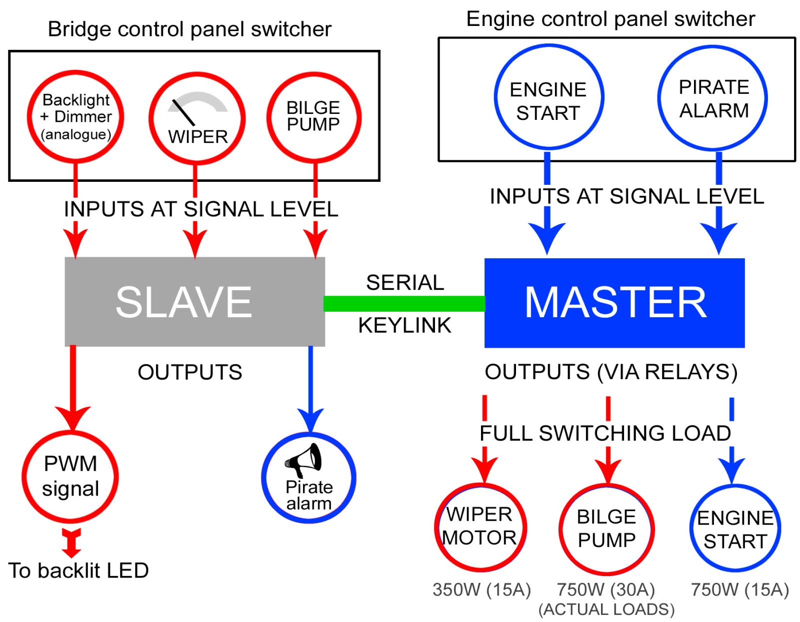
CAN J1939

J1939 is designed for a maximum of 30 nodes with a maximum length of 40 m and a fixed Baud rate of 250 kBaud. There is no galvanic isolation required between the controller and the bus section. J1939 is widely used in commercial vehicles.

KeyLink

KeyLink is a simple communications protocol which allows for fast and easy integration into an existing bus system such as CANOpen or Profibus. KeyLink features a simple point-to-point connection without setting an address for each connection. Inputs and outputs are connected using a serial half- or full-duplex interface. There can be up to 128 I/O points. KeyLink allows for separation of the power and control units. The switching load is defined by the relay in the master power unit instead of the KeyLink switch. The basic configuration of the master and slave is done automatically. Two analog signals can be captured for each direction and re-sent as PWM signals. The analog signals can be used to control brightness or analog outputs. Keylink also has two selectable transmission speeds. Extended systems capabilities include input for more complex applications, and configuration storage on the switching source.

Example of 24 volt control system



KeyLink is a simple communications protocol for fast and easy integration into an existing bus system.

DeviceNet

DeviceNet is a low level network designed to connect industrial devices like sensors and actuators with high-level devices, like controllers. The strength of DeviceNet is the interchangeability of very low-cost devices, typically used in manufacturing applications. Devices might include switches, sensors, motor starters, bar code readers, etc.

DeviceNet builds on the CAN technology and adds the media and application layers. DeviceNet allows for hot insertion of devices without powering down the network. It also provides for up to 64 node addresses on a single network.

Foundation Fieldbus

Distributed process control applications are addressed by Foundation Fieldbus. This bus has the ability to integrate functions that are part of the field device itself, thereby distributing control throughout an implementation, as opposed to a centralized control architecture. Foundation Fieldbus is a popular selection when the application calls for the use of smart devices. The key to success is using devices “certified” by the Fieldbus Foundation and creating device descriptions for each device. By defining a device’s capabilities, an attached controller is quickly able to “learn” the device’s functionality.

PROFIBUS

PROFIBUS is popular in manufacturing, process automation, and building automation. It can be used where high-speed data transmission between controllers and I/O points is critical or for complex communications between programmable logic controllers (PLCs). PROFIBUS can be used at both the field/ device level or manufacturing cell level.

HART

HART, Highway Addressable Remote Transducer, is accepted as an industry-standard for digitally enhanced 4-20 mA communication with smart field instruments. The HART protocol was designed specifically for use with intelligent measurement and control instruments which traditionally communicate using 4-20 mA analog signals. The HART protocol permits the process variable to continue to be transmitted by the analog signal, while additional information pertaining to other variables, parameters, and device configuration, calibration and diagnostics are transmitted digitally at the same time.

Ethernet

Ethernet is used as the basis for a higher level network. The difference between Ethernet and bus protocols of any kind, is Ethernet's use of the TCP/IP protocol. TCP/IP allows Ethernet to connect to a LAN/WAN as well as the Internet. This can deliver physically larger networks with greater data carrying capacity than a bus architecture like CAN. Where real-time response through the network is critical, CAN provides a better choice. Where remote access is important, Ethernet wins.

There are now available Ethernet-based bus protocols such as PROFINet, Ethernet/IP and Ethernet Powerlink that are hoping to capture some of the capabilities of bus protocols while keeping the advantages of TCP/IP. Open access technology is critical for acceptance of Ethernet-based protocols in many markets.

USB

In addition to the above-mentioned technologies, there are also connections between industrial networks and USB connections. USB hubs and ports can connect industrial wired and wireless system to this PC- based communication system. For hot swap of devices, and plug-and-play among PCs and a variety of peripherals. Using USB 2.0 hubs, typically housed in rugged enclosures, industrial USB communications support noise reduction for harsh environments, low power requirements, and good data speed at 480 Mbits/second. However, USB was not really designed for industrial use — any single bus segment can't exceed 5 m, and there's no provision for signal isolation. USB 2.0 finds its most common use in converters for serial-to-USB or Ethernet-to-USB.

PROFIBUS is popular in manufacturing, process automation, and building automation.

The right bus for the application

HMI control panel assemblies have embedded interfaces that link them with the core system through serial communications connection, usually on the same transmission medium. The presence of multiple devices requires resources to regulate the exchange of data and ensure that it's transferred and identified correctly — each device must be identifiable so that the source or the content of the data can be assigned appropriately.

Assignments are made according to either:

- The specific response of an individual device — which must have a unique address in order for the system to regulate contact with the bus.
- The content of the data. In this case, the data set supplies the identification.

This issue illustrates the necessity of choosing the right bus for a specific application. The technical framework of bus-connected systems becomes more sophisticated than hard-wired systems in terms of controlling data flow. The more ways a system supports assignment, the greater the effort required to get the right configuration and, in the event of disruption, to identify the reasons for the failure. Software and on-board microcontrollers provides a versatile and efficient way to configure and control HMI subsystems, as well as encryption technology for PIN-protected secure access and other high-level data management capabilities.

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. 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 industrial 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.

Wireless communications can deliver real-time data transmission, application mobility, and remote management capabilities.

WiFi

WiFi was developed for data-intensive communications — accessing the Internet, streaming video — typical web browser behavior. 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 industrial environment, other machinery often produces a large amount of electrical noise. WiFi for industrial applications typically is more robust.

Bluetooth

Bluetooth is primarily a cable replacement for point-to-point connections, and is typically used more in consumer environments. 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 industrial 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.

Summary

The effectiveness of the HMI System — and consequent enhanced productivity of the user — depends upon an exacting design process that incorporates all technical, ergonomic, and communication requirements. Connectivity technologies linking the HMI to the core application directly affects both operator and overall system performance. This key interconnection is critical to overall successful use of the system. Selecting the appropriate communications strategy from hard-wired, serial bus, wireless, and other options demands a careful evaluation of the application and, in most cases, a blend of available technologies.

EAO Switch Corporation
98 Washington Street
Milford CT 06460
T: (203) 877 4577
F: (203) 877 3694
E-mail: sales@eaoswitch.com
www.eao.com