Integrated HMI, Control and Communications Platform for Industrial Automation

The advance of integration and the standardization of system interfaces significantly increases the performance and efficiency of industrial control systems. The next step is the integration of control and interface functions onto a single die that unites CPU with FPGA.

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Modern automation systems need to integrate several distinct products: the PLC and I/Os, the Motion controller, the HMI for human machine interface, communication gateways and router for Internet access. However, technology has not yet allowed a better integration of these devices. The main issues for better integration are related to the physical dimensions of the electronic board's power consumption, the presence of several non-uniform connectivity standards and the low bandwidth of the bus systems.

It is still very common in industrial automation installation to find different communication gateway devices that reduce the overall performance and the system reliability but which are needed to create bridges for different fieldbuses. For the last decade the bottleneck of the traditional concept was in the low performance and high latency of the bus systems.

Recently, the use of industrial Ethernet and the strong diffusion of the standard for connecting different devices have made it possible to create greater integration and uniformity of the interfaces between the different devices.

The extremely high performance of modern real-time industrial Ethernet, such as the EtherCAT technology, enables control concepts that could not be realized with classic fieldbus systems. With EtherCAT, a communication technology is available that matches the superior computing capacity of modern Industrial PCs. The result is that the bus system is no longer the bottleneck of the control concept. Distributed I/Os are recorded faster than is possible with most local I/O interfaces.

Breaking the Bottlenecks

In modern systems, the master controller has now become the bottleneck of performance. We require a high capacity of calculation in order to process with cycle times of less than 1 millisecond for PLCs and motion cycle machines, and the controller should ensure a very precise network-wide time base with a low jitter.

If we add to the picture the need to send/receive several packets from other devices such as the operator interfaces, Internet gateway (CAN bus, legacy serial ports), devices that are connected though a different fieldbus, or remote clients, the problem becomes very complex and the architecture of single master CPU suffers (Figure 1).

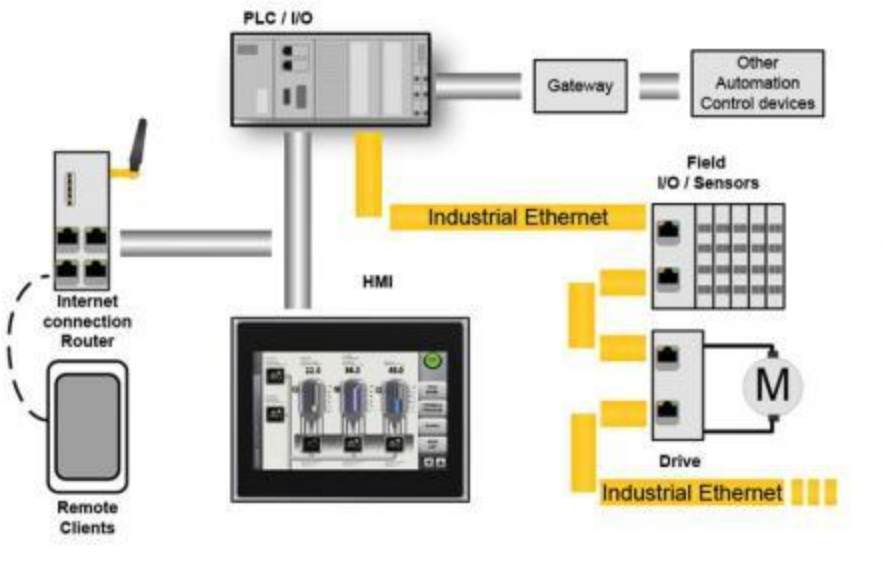

Figure 1
A typical industrial automation application with industrial real-time Ethernet connection and the most important components.

The remote client in the same figure must be able to access the real-time database of the main controller in order to locally or remotely view the different tags of the application, and to enable access in reading and writing to the system settings, PLC configuration (recipes), trends data upload/download, Web Interface, alarms and events management.

All these accesses to the application server and the PLC controller increase the number of interrupts from the different industrial controllers, creating latency problems for the real-time system. In these control applications that are based on industrial Ethernet, it is also necessary to completely decouple the real-time fieldbus Ethernet from the non-real-time Ethernet connection (Figure 2).

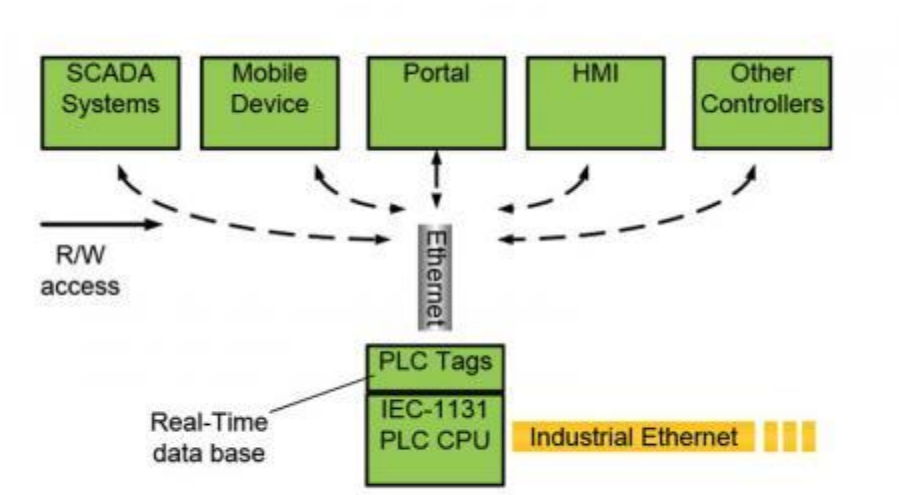

Figure 2
The non-real-time Ethernet connections to HMI, mobile device, etc., are separated from the real-time industrial Ethernet.

One possible solution to this problem is to use powerful Industrial PCs with Core i5 and i7 CPUs and up to four cores combined. While the PC architecture is a very high-performance platform, it is currently not flexible enough to integrate the different communication standards used in industrial automation. In addition, the PC with an i7 CPU core is not a platform with low enough power consumption, and its reliability for industrial control is not optimal.

Another interesting solution would be to integrate the various components that are installed inside the cabinet into an industrial single platform (all-in-one solution) in order to reduce the wiring and increase the performance of the bus system interfaces (Figure 3). This also improves the interfacing of the various hardware and software modules that are necessary for the automation of the process.

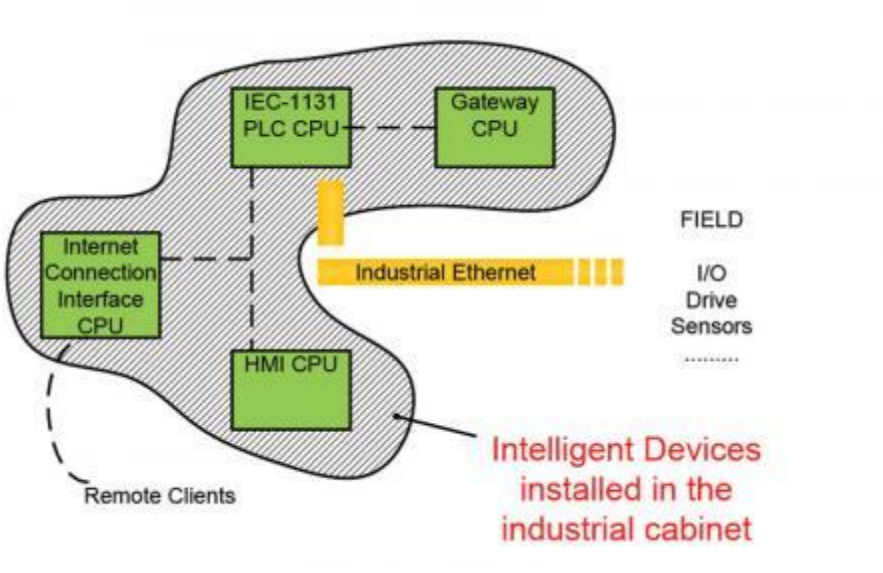

Figure 3
Integration and efficiency are further enhanced by integrating multiple intelligent components inside the same cabinet.

Bringing It to a Single Die

The ideal industrial automation platform should have a high-performance multiprocessor architecture that solves the problem at the architectural level of connection between different CPU boards/modules and integrates into a single component. A key attribute of convergence is integration of and access to a broad range of control, connectivity and HMI functionalities, made practical by Moore's Law and from embedded technology.

Today, Moore's Law has proven an all-important influence on advanced automation technologies for legacy PLC, HMI, I/O, CNC safety and motion technologies. This has resulted in the ability to integrate several CPU cores, powerful peripherals and FPGA technology in the same high-performance component.

For example, Altera's Cyclone V FPGAs provide the industry's lowest system cost and power, along with performance levels that make the device suitable for differentiating an industrial control master device with integrated all-in-one PLC controller, HMI controller, communication gateway and remote Web Internet or mobile clients. The solution is optimal for industrial automation and lower power consumption compared with the industrial PC platform. It provides efficient logic integration capabilities in an innovative SoC platform with integrated Dual Core 925 MHz ARM Cortex-A9 and FPGA.

Exor International has created a platform for this type of architecture with a JMobile SoC (JMSoC) solution PLC+HMI architecture (Figure 4). This architecture combines performance and flexibility in an all-in-one embedded solution-based dual core ARM Cortex-A9 CPU and FPGA technology. This serves to increase the flexibility to add customized peripherals that are needed to extend connectivity and to drive different display types.

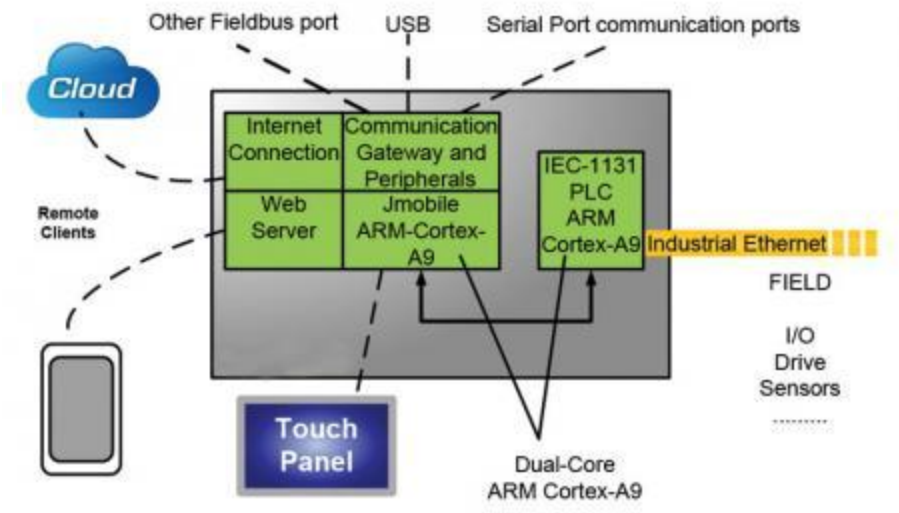

Figure 4
Integrated HMI and control solution.

The high-bandwidth on-chip backbone connecting the Altera Cyclone V SoC CPU and FPGA fabric provides over 100 Gbit/s peak bandwidth and is suitable for sharing data between the ARM processors and devices that are implemented in FPGA software.

JMSoC it is an industrial automation platform comprised of hardware and software components that provide a complete solution for control, connecting equipment and visualizing data. The runtime is designed to optimize the performance and the size of memory (e.g., 512 Mbyte DDR + 1 Gbyte Flash disk) running on an Embedded Linux Real-Time Altera Cyclone V SoC platform. The result is a single device that integrates everything in an all-in-one SoC component. Using JMobile Studio' object-oriented programming, a GUI application can be developed in a few weeks without writing a single line of code in C language.

JMobile Studio is used to program the JMSoC for GUI design as well as to program the communication interface with CoDeSys 3.x for Motion / SoftPLC Control application provide by the German firm 3S. The functionality of the control such as I/O and drive is guaranteed by the EtherCAT Master integrated in CoDeSys 3.x runtime for Linux.

Through Link layer optimizations, the solution is capable of handling cycle times well below the millisecond. The solution adopted was EtherCAT Master, based on Open Source Automation Development Labs (OSADL) Linux real-time operating system, which allows for easy and fast deployment of EtherCAT customized applications as well as porting of existing applications on the compact and powerful master controller.

The first problem solved by the architecture in Figure 5 is the separation of the real-time control (I/O, Motors) in the domain of one millisecond from the other tasks related to the HMI, and the communication with the different devices in the time domain of 50 milliseconds or more.

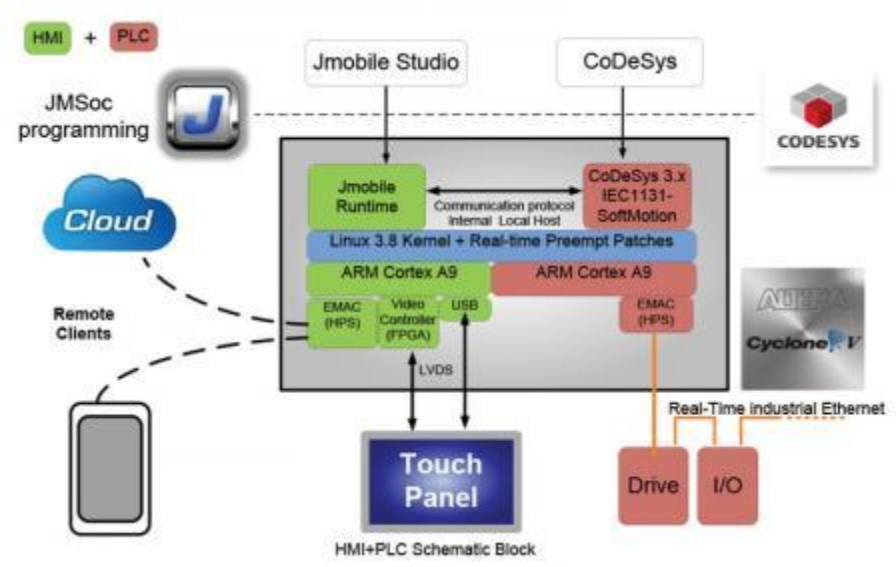

Figure 5
HMI+PLC schematic block.

In order to ensure the highest performance, the architecture of the PLC is created using two different processors to decouple the applications of the video control and HMI from the connection with other real-time devices. Both CPUs run different threads and interrupt the operating system on different processors. All interrupts that come from communication with external clients go to one CPU so that they do not create interference with the real-time PLC program execution on the other, ensuring the execution of the program with very low jitter.

The ARM Cortex A9, with its integrated Neon media processing engine for media and signal processing acceleration, is an architecture that can meet the real-time requirements and have very low probability of not servicing interrupts in a timely manner. JMSoC suite provides multiple communication interfaces associated in the FPGA.

Because of the internal FPGA, beyond the USB, Ethernet, Serial and CAN ports, it is also possible to make further customizations in the FPGA with the addition of other connections, such as digital I/O, analog interfaces, DVI ports and more. The JMSoC solution ensures a high degree of flexibility and reliability thanks to the combination of mixed solutions of ARM cores and FPGA, and numerous other useful interfaces.

JMobile is an innovative software solution for the design of HMI applications in a simple and intuitive way. It is a powerful and versatile tool designed for the rapid creation of new applications, and for easy updating of existing projects, in order to provide a solution for the end customer that is tailored to their needs. JMobile includes among its main features: simplicity and immediacy of use, programming efficiency, and graphics based on SVG technology with full object-oriented design properties.

This new platform provides users with advanced control options and remote supervision with a client-server architecture based on Web technologies, therefore making it compatible with smartphone and tablet devices. In addition, the ability to capture, store and share data in higher-level structures makes it an effective tool for integration across the enterprise. The developer can program an HMI within a single development environment (JMobile Studio) and choose to download it on operator panels or on industrial PCs.

HMI +PLC integrated architecture has just followed Moore's Law from the consumer and IT markets into industrial controls. The innovative architecture, "all-in-one" JMSoC-based Altera Cyclone V SoC ARM-FPGA legacy control platform has proven that an optimized and cost-effective platform that reduces energy consumption is able to match the requirements of a complex industrial control automation application.

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