Embedded systems extend automation

System 800xA incorporates numerous embedded applications

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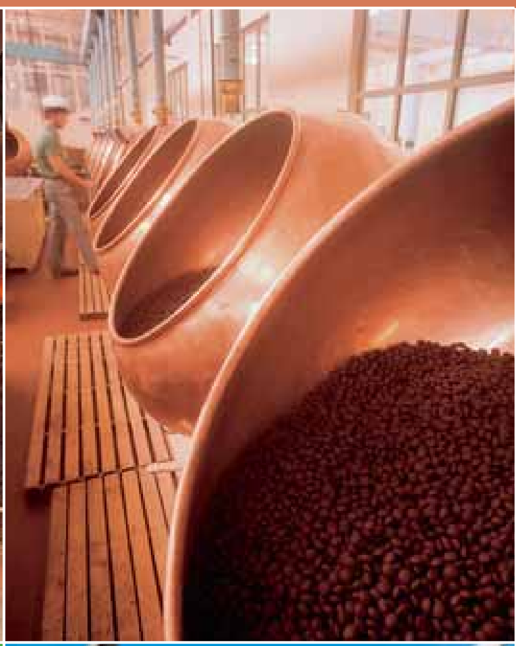
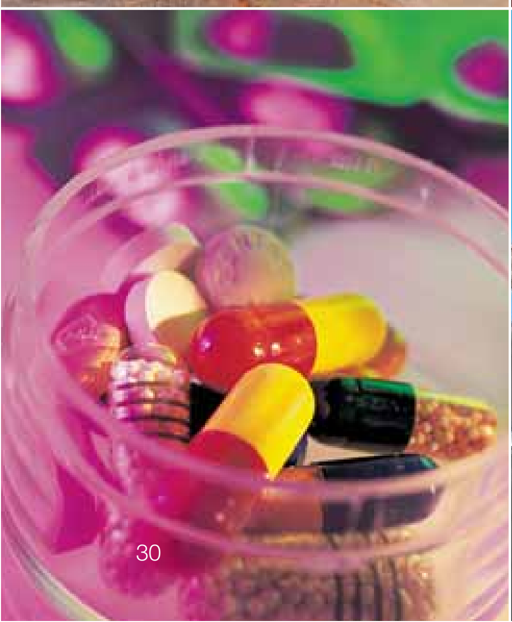




Users expect — and demand — more functionality from automation systems than ever before. Embedded system components that reside within a control system make much of this functionality possible. Advanced automation solutions, such as ABB's Extended Automation System 800xA, require the integration of numerous embedded technologies to perform the wide variety of productivity enhancing functions required by customers across the process industries. With plants that might be controlled remotely, and the very real need to keep production up and running around the clock for several years, process industry customers must have easy maintenance and reconfiguration options that do not interrupt production.

Embedded system technologies

Embedded systems are microprocessor-controlled computer systems that form an integral part of a larger system or piece of equipment. They are dedicated to specific tasks that contribute to the overall functionality of the system. Depending on the nature of the system and its function, the requirements of an embedded system can differ greatly.

Embedded components in System 800xA

The embedded components that are used with System 800xA allow it to deliver many different solutions for many different requirements. These requirements can include:

Real-time execution – It is often critical that a given task is finished at a predictable time, as well as being correctly computed. System 800xA can meet requirements ranging from "hard" real-time, where exact timing criteria must be met, to "soft" real-time, where response is less time-critical.

Flexibility – embedded components can be dedicated to a single predefined task, or to a number of fundamentally different assignments. Compare, for example, the difference in the flexibility of an I/O (input/output) module versus that of a normal desktop PC.

Availability – Because different processes have different back-up requirements, the redundancy level of a system must be flexible.

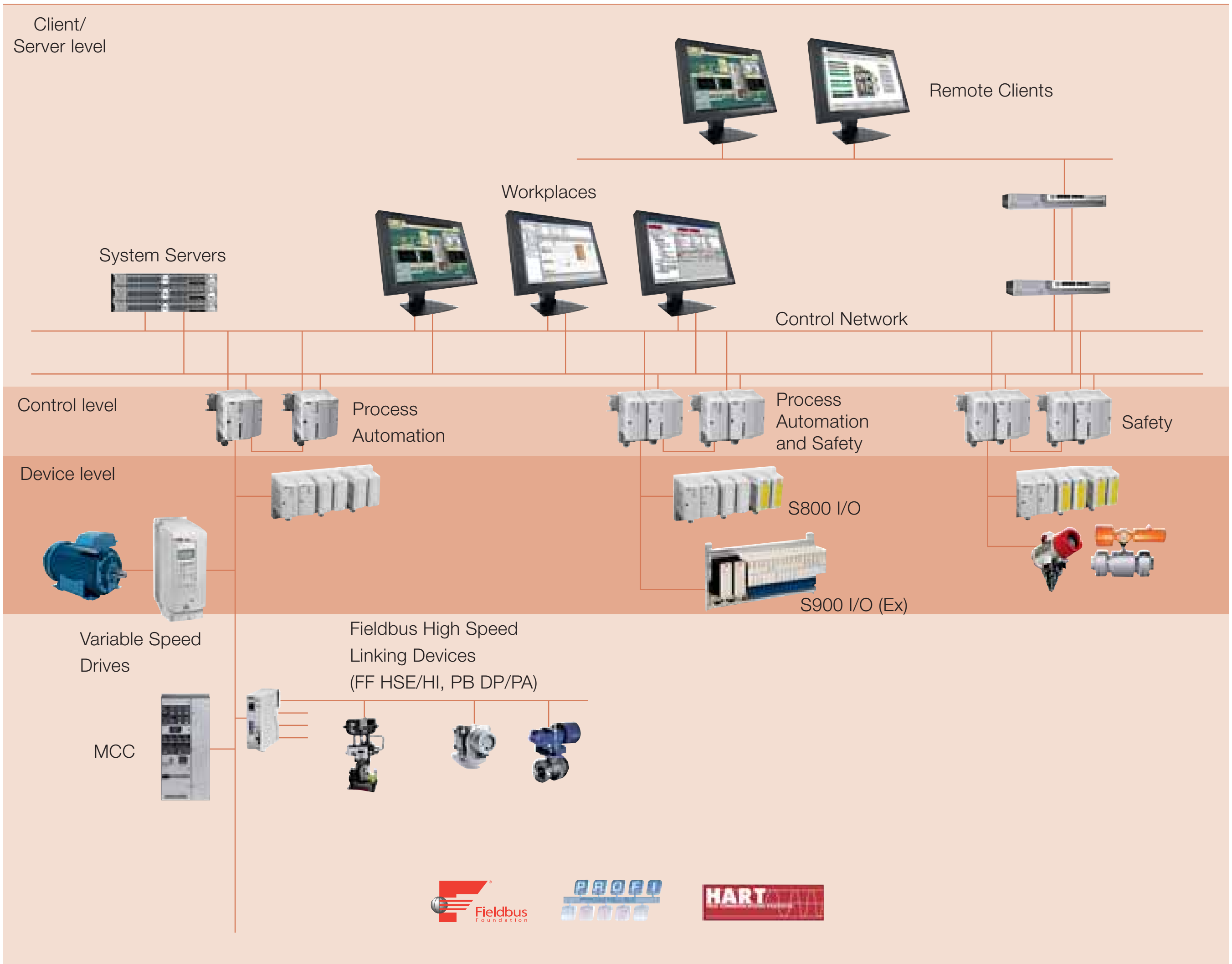
Cost – The acceptable unit cost for a component is often tightly linked to its required quantity. It is important to consider whether the component will be used thousands of times in an installation, or in just a single instance.

Environmental hardening – In industrial environments, the components, if subjected to heat, vibration and dust, must be environmentally hardened.

Distributing embedded intelligence

As an extended automation system, the 800xA distributes intelligence and computing power to where it is most appropriate 1. Such distribution can take the form of different types of servers, providing services to clients, and one another. On the control side, control logic can be distributed across several controllers, exchanging measurement and calculation values. Preprocessing can range from I/O modules filtering and time-stamping data

1 A simplified overview of a process plant built around System 800xA



Embedded system technologies

packets, to sensors and actuators performing advanced pre-processing and diagnostic functions. Input and output data from I/O buses are scanned by dedicated communication modules.

Most of the system's components are implemented as embedded systems with a design optimized for specific needs:

I/O modules, with simple signal processing, can be implemented entirely by hardware components, with some of the logic executed in an FPGA (field-programmable gate array). More complex I/O modules, intelligent sensors and actuators are based on embedded microcontrollers that provide greater functional flexibility. Many of these use some kind of real-time operating system.

Communication modules may implement a protocol stack, partly in hardware and partly in firmware, running on the embedded central processing unit (CPU). One way of splitting the job may be to process acyclic messages with the CPU and handle cyclic messages with a direct memory access (DMA) unit, sometimes with an application-specific integrated circuit (ASIC) dedicated the task.

The Processor Module in the AC 800M uses a commercial real-time operating system and runs one of the most complex and flexible embedded applications. Most of its functions are completely defined by the user 2.

It is often critical that a given task is finished at a predictable time, as well as being correctly computed.

Client/Server level

On the Client/Server level, a number of software systems combine to comprise operational functionality, eg, presenting measured values and process status to operators. They also support engineering, commissioning and maintenance of the whole system. At this level, standard servers and PCs are built on Windows technology rather than embedded systems, but even here, special solutions are available, eg, redundancy of servers and network to ensure high system availability.

Controller level

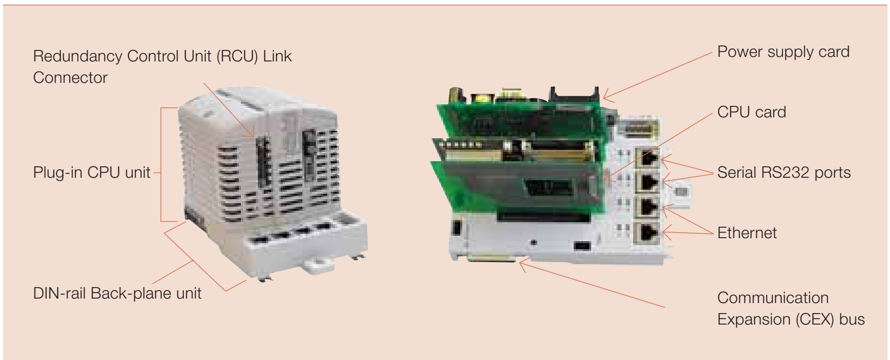
The most advanced embedded systems are found at the controller level. Here, the components must be able to sustain harsh conditions such as vibration and heat. A controller should also have high flexibility, supporting simple functions, ranging from binary control to advanced proportional, integral and derivative (PID) control. ABB has a family of controller units, the most advanced of which is the AC 800M processor module 3.

To achieve the desired flexibility of communication options, the AC 800M's processor module has a number of different communication interfaces 4:

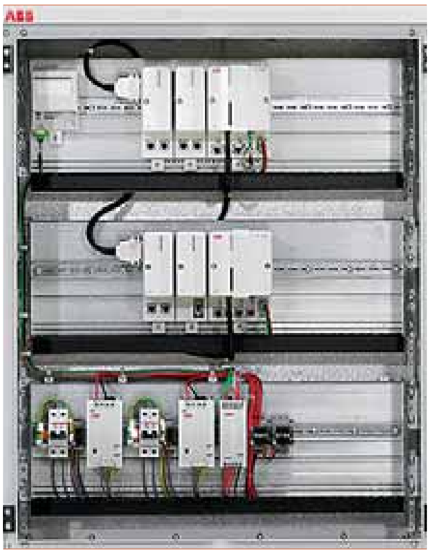
- Two Ethernet ports allow communication with the Client/Server level and other Controllers.
- The ModuleBus accommodates directly-connected S800 I/O modules.
- The communication expansion (CEX) bus allows additional communication modules to be connected.

2 Extended 800xA workplace

3 The AC 800M processor module, the central unit in the controller



4 The AC 800M controller mounted in a rack cabinet



- Two RS232 ports are available for serial protocols.
- A redundancy control unit (RCU) link is also available.

Eliminating moving parts, such as hard-disks and fans, ensures control unit reliability under tough conditions. In the AC 800M processor module, program and data are stored in Flash PROM (programmable read-only memory) and RAM (random access memory), and, thanks to the energy-efficiency of the CPU, the unit is cooled by natural air-flow alone. Maintenance problems prohibit the use of mechanical fans.

Basing a control system's processor module on an embedded microcontroller reduces the number of components needed, lowering costs and power consumption. An FPGA is used for most of the additional onboard logic needed. Ethernet ports and the serial ports are implemented in the microcontroller. In addition, a number of special functions that could have been implemented in discrete hardware units, eg, the ModuleBus interface, the CEX bus and the redundancy control unit, are instead implemented as building blocks in the FPGA.

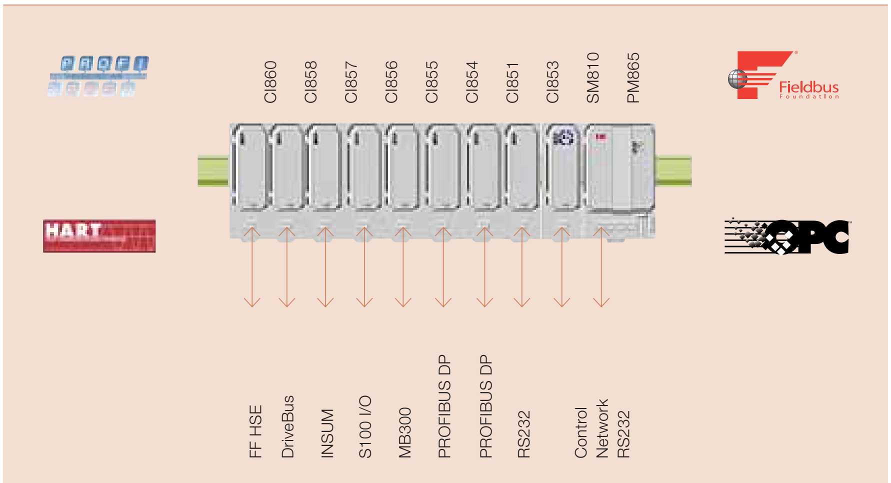
The combined abilities of the processor and the real-time operating system allow the software to perform various tasks for real-time response of control loops, and timely communication with the plant operator.

The main task for the Processor Module, and therefore one with a very high priority, is the execution of the process control logic. This is a set of calculations that defines when valves open and close, when motors start, how fast they run, etc., plus all the other actions that directly control the process. Since the calculation is based on input and output data, the process control logic is entirely dependent on the accuracy with which these data are read. The embedded system software must handle the process control logic and the I/O scanning in a way that is flexible enough to allow logic changes without losing control of the on-going production process.

Most of the system's components are implemented as embedded systems with a design optimized for specific needs.

The high availability of the AC 800M is assured via redundant units for the controller CPU. The incorporation of redundancy in embedded systems is a complicated business as it requires a detailed understanding of all the different ways in which a system could fail and a corresponding knowledge of the redundancy solutions that can handle each type of failure. Additional complications arise because some processes are more important than others, but in the AC 800M, critical failures can be detected and a back-up CPU implemented in less than 10 ms.

5 Communication interfaces used with AC 800M



Communication

System 800xA includes many different units that communicate via a bus or a network 5.

The Process Automation industry employs several standards for communicating between process controllers and peripheral units such as I/O systems, intelligent sensors and actuators, and other field devices. The AC 800M controller supports a wide range of these protocols, including internationally standardized fieldbuses, eg, PROFIBUS, Foundation Fieldbus and HART, which facilitate communication with various system components, such as I/O systems, intelligent sensors and actuators.

Serial protocols, such as Modbus, and protocols that can be implemented by the user in the control logic, comprise another group of communications protocols that are supported by the AC 800M.

A third group of communications protocols supported by the AC 800M provides connectivity to other specific products, such as ABB's motor control system INSUM, ABB's advanced drive systems and different I/O systems using dedicated communication protocols.

Most of these options are implemented as dedicated communication modules that are connected on the CEX bus to the processor module. The communication modules implement the protocols, and the exchange of process data and status, with the Processor Module through a standardized software interface. Data are exchanged via dual-port memory on the communication module that the processor module accesses via the CEX bus.

The requirements for real-time performance on a communication module are sometimes very complex, partly because of the large amounts of data that must be processed, and partly because the timing constraints of the protocol may be very strict. Both of these challenges justify the use of a dedicated communication module with a local, embedded CPU, instead of just adding more hardware components onto the processor module.

Embedded system technologies

Rather than using an additional, dedicated module on the CEX bus, some communication options are implemented using the ModuleBus. Certain Motor Drives can be connected directly on this bus as they use the same protocol as the S800 I/O.

HART communication for intelligent sensors and actuators is implemented by special I/O modules that, as well as handling normal process signals, handle the digital FSK (frequency shift keying) signal that is superimposed on the process signal.

Hot swap

To achieve high availability, communication modules can be exchanged while the controller is running. Thus, if one communication module breaks down, it can be replaced with a spare without having to restart the controller and thereby interrupting the production process. This strategy also makes it easy to reconfigure the controller and thus change the communication options without halting the controller. Control logic and communication links that are not changed operate continuously during this reconfiguration. The only part of the control application affected is that that uses data from the swapped communication module.

To support this, the embedded system software that accesses the Communication Modules is capable of dealing with units that suddenly fail to respond by configuring and restarting a healthy module.

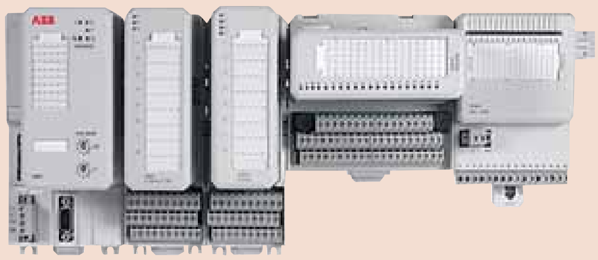
Redundant communication

Some communication modules support redundancy. Communication with units on PROFIBUS and Foundation Fieldbus HSE (High-Speed Ethernet), for example, use dual communication modules to eliminate single points of failure between the controller and the external unit.

I/O and instruments

The device level, which contains I/O devices and instrumentation, is found one step further down towards the process. The number of I/O units (eg, Digital Input unit) in a plant is much larger than the number of controllers. Component cost is therefore a factor to consider, and the reason why less advanced embedded processors are more often used here than in the controllers. A simple scheduling of tasks, rather than a complete real-time operating system might also be preferable. However, real-time response is as important at this level as it is at the controller level.

6 S800 I/O



Parts of the I/O system may need to be "intrinsically safe" ie, be suitable for use in hazardous environments. This can be achieved by encasing the equipment in an expensive housing, or, preferably, by using I/O units with very low power consumption such that potentially hazardous electrical sparks will not be generated. ABB provides a large range of I/O units for different needs, the S800 I/O system, for example 6.

The S800 I/O comprises a substantial number of different modules of hardware and software solutions, each having their own specific features. For example, the hardware of the S880 safety I/O is based on an embedded microcontroller and an FPGA module. As a safety I/O module, it employs a dual solution where both the microcontroller and the FPGA execute the ModuleBus slave protocol, as well as the logic for the data input, output and diagnostics. Real-time demands on this unit are very strict. When a message is received from the controller, the reply must be given within 330 ms. Missing this 'deadline' results in the controller assuming that the I/O unit is not functioning, and continuing with the next unit. The I/O module must also handle configuration data and all possible error states.

Power supply

Another important consideration for all embedded devices in a system with high availability is the power supply. Units must have over- and under-voltage detection. Redundant power supplies must be carefully designed, so that they will not constitute a single point of failure.

Embedded system modules provide a high degree of flexibility

The enormous number of embedded systems found in a typical process plant provides a wide range of different hardware and software solutions. It is quite a challenge to organize these components into a single unified system, but the results are well worth the effort. As this very simplified discussion shows, different demands on different parts of a system create heterogeneous elements within a unified system. With System 800xA, ABB has brought together optimal embedded hardware and software components and integrated them to deliver a dependable system with the wide range of advanced functionality that is needed in today's process industries.

Top-of-the-line equipment and systems, designed in consultation with end-users, will continue to improve production automation and enhance efficiency. As one of the foremost process automation companies in the world, ABB can be relied upon to provide two elements needed by every successful industry – power and productivity.

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