Moving Beyond PLCs

When getting enough is too much

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Programmable Logic Controllers (PLCs) are widely used today in automated control applications that have one to several hundred I/O (Input/Output) requirements and can accept point-to-point wiring. The first PLC systems typically accommodated 20-256 I/O points. You can add I/O to a system by adding additional PLC modules: three or four PLC modules are usually adequate for machines with moderately increased I/O requirements.

But what do you do when the I/O count grows significantly and furthermore includes a requirement for safety interlocks that also may need to change over time to accommodate process changes? You can always add additional PLC modules but add in the safety interlock requirements and the point-to-point wiring quickly becomes an assembly nightmare. Imagine the added labor when interlock requirements change, and total system cost becomes magnified, costing altogether too much for a system that you end up working for, instead of the system working for you.

This paper will introduce a system alternative available today that is scalable from small (1) to high (2500) I/O count designs and offers up to 1,024 integrated configurable safety interlocks (no need for separate safety module – the safety interlocks are designed right in to the system) all at remarkably high speeds of communication.

A little history

PLCs were first conceived 1968 when Bedford Associates was selected to develop an electronic replacement for relay logic systems at GM (1). PLCs added more processing power as the need for more information from production processes grew. As the technology developed PLCs found a sweet spot in rugged factory environments where equipment had to tolerate dust, moisture and temperature variations. PLC systems were ideal for large factories where controllers were spread out, I/O density was low and their cost was a fraction of the overall investment.

During the latter part of the 20th century another industry was developing with far greater and more complex control requirements. The electronics industry became the microelectronics industry and computer chips gave birth to the semiconductor industry. Companies like Fairchild, Intel, AMD, Texas Instruments and Motorola, needed large, room size equipment (referred to as tools) that could work in fabrication factories (Fabs) with micron levels of cleanliness, making computer chips on silicon wafers with nanometer line widths. The semiconductor fabrication process requires the use of toxic chemicals and gases, so the machine controls have to be extensively interlocked to protect equipment and people from errors that could be physically and financially catastrophic.

Enter Stage Left – The Semiconductor Tool Industry

As the semiconductor industry grew, so too did the semiconductor manufacturing tool industry. Applied Materials, Lam Research, Samsung, Tokyo Electron, and ASML became giants. As the complexity and density of computer chips increased exponentially, so did the cost of Fab equipment. Given that each manufacturing company had its own secret sauce for running and controlling their equipment, it made integration of different manufacturers' tools in a fab difficult.

And Then Came EtherCAT

Beckhoff, in a brilliant marketing strategy, reached out to the end customers, the semiconductor manufacturers, and convinced them that one common controls communication protocol would make their lives much simpler. And the new Beckhoff industrial Ethernet communications protocol named "EtherCAT" was the right solution. And thus EtherCAT with its ring topology became, to quote Tolkien's ***Lord of the Rings***, the "One ring to rule them all". As a result, the semiconductor tool industry is going through a seismic shift in controls communication. All new tools being developed by the top 10 semiconductor tool manufacturers are EtherCAT based.

Growth of the Mountain

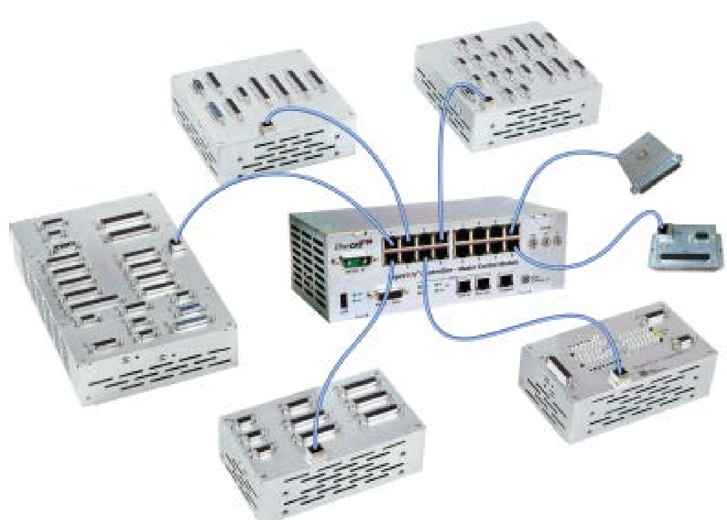
That is not to say that tools with current protocols will cease to exist. On the contrary, the market for semiconductor chips continues to expand by orders of magnitude. Some examples are AI chips, which gain efficiency and speed for AI applications through AI-optimized designs, and High Density NAND chips with <10nm line widths that may need the next generation of tools. Even as the mountain of demand for semiconductors continues to grow, the demand for current and older technology tools may also continue to expand. IOT has become a welcome force that is permeating our lives with home automation and security systems. In vehicles on the road today, electronics account for over 30% of their total value (1). According to Design News, "By 2030, as autonomous cars take their place in society, most experts expect electronics to account for 50% of a vehicle's value" (2). Our cars are quickly becoming computers on wheels.

A Product for Today and Tomorrow

If your new tool needs to support the EtherCAT standard, where do you find a controls company that can design and build a system to meet your needs? It's a jungle out there and you need a controls partner who knows the territory. Digital Dynamics, Inc. (DDI), based in Scotts Valley, CA has designed and built over 80,000 I/O Controllers that support old and new protocols and are running on tools in most Semiconductor Fabs around the world.

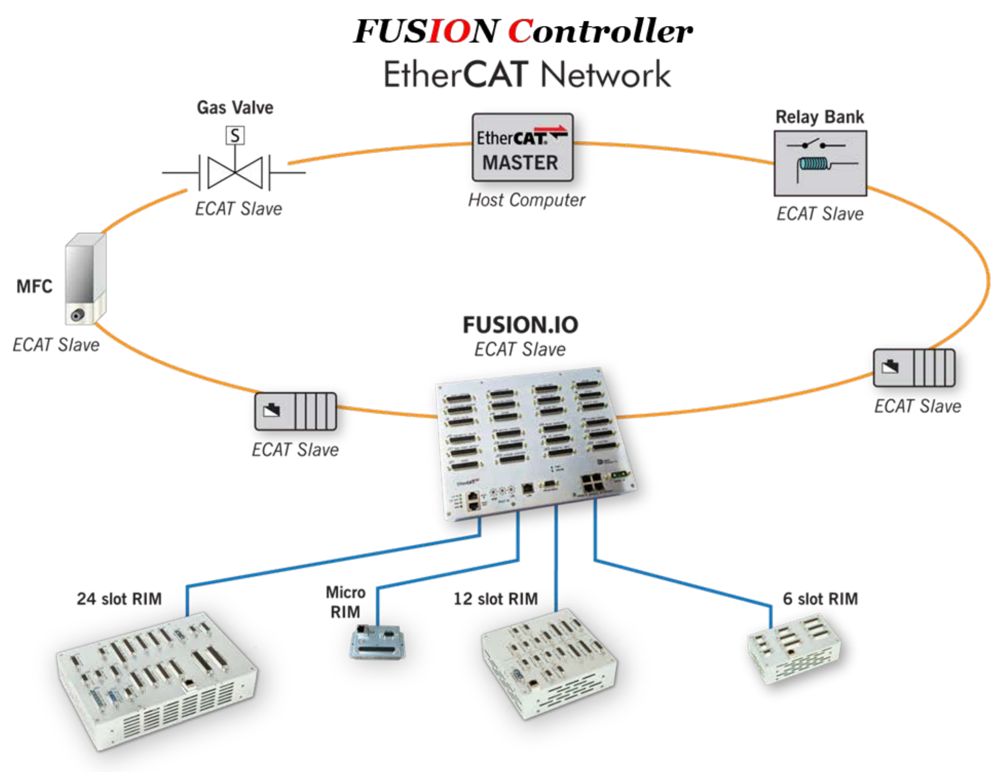
Our newest controllers, the ***SuperIOr® Controller*** family is configurable, scalable and customizable to match a tool designer's specific needs (see figure 1). It is available with multiple Control Modules (CMs) to match with multiple Remote I/O Modules (RIMs) that can each have multiple combinations of I/O.

Figure-1: 16 Port CM connected to 7 RIMs



The ***FUSION Controller*** is the newest member of the SuperIOr family that is a 4 port CM "fused" with a 24 slot RIM into a single unit. FUSION units can also connect with up to 4 additional RIMs. An example network diagram with FUSION design is shown in Figure 2.

Figure-2: FUSION EtherCAT Diagram



RIMs can be customized with a variety and number of Input/Output (I/O) cards as shown in figure 3.

Figure-3: Configuration Cards

I/O Slot Card	Description
D-Out - 16 ch (sourcing); +24V*	Digital Output Card (sourcing)
D-Out - 16 ch (sinking)	Digital Output Card (sinking)
D-In - 16 ch (24V)*	Digital Input Card has 16 inputs, with a 12 Volt on/off threshold
D-In - 16 ch (5V)*	Digital Input Card has 16 inputs, with a 2.5 Volt on/off threshold
D-In - 16 ch (Inverted 24V)*	Digital Input Card with 16 inverting inputs, and a 12 Volt on/off threshold
D-Out - 8 ch Optocoupler	8-channel Opto-Isolator Output, dual-sided outputs
D-Out - 16 ch Optocoupler	16-channel Opto-Isolator Output, common return
Relay - 8-ch (Dry Contact)	8-channel SPST Relay
A-In - 8 ch, 16 bit	8-channel, 16-bit, analog input, differential inputs, input range -10V to +10V
A-In 16 ch, 16 bit	16-channel, 16-bit, analog input, single-ended, input range -10V to +10V
A-Out - 8 ch, 16 bit	8-channel, 16-bit, analog output, 0 to 10V, ground-offset cancellation
A-Out - 8 ch, 16 bit Bipolar	8-channel, 16-bit, analog output, -10V to +10V, ground-offset cancellation
A-Out - 16 ch, 16 bit	16-channel, 16-bit, analog output, 0 to 10V, common return
A-Out - 16 ch, 16 bit Bipolar	16-channel, 16-bit, analog output, -10V to +10V, common return
Serial Interface (RS-232) - 4 Ch	4-channel, RS-232 UARTs
Temperature Card - 8 ch T/C	8-channel thermocouple interface (All TC types)
Temperature Card - 4 ch RTD	4-channel RTD input. 2, 3, 4-wire RTDs supported

* SIL 3 Performance Level e (PL e) per IEC 61508 by TÜV

Following are some of the key features and benefits of the family:

1. Designed and built to meet the SIL 3 level safety requirements of IEC 61508 certified by TÜV Rheinland.
2. The system can simultaneously manage up to 1024 Digital Inputs and Outputs, and 960 Analog Inputs and Outputs at an 8 kHz scan rate.
3. A CM provides precise coordination of as many as 16 configurable RIMs that can be distributed throughout a tool.
4. A very large number of digital I/O points can be interlocked in any combination of RIMs.
5. Up to 128 reprogrammable interlocks are electrically configurable in dual PROMs to comply with IEC-61508 safety standards.
6. 6, 12, and 24 slot RIMs are configurable with over a dozen different factory installed I/O cards.
7. MicroRIMs with fixed I/O are as small as a deck of cards,making them incredibly useful for tight application situations, are also available.
8. The type and size of connectors on the RIMs are customer specified to exactly match the tool designer's requirements.
9. RIMs are connected to the CM with low cost CAT6 cables that provide dual paths for communication verification.
10. RIMs can be installed up to 250 cable feet (76 meters) from the CM, in close proximity to the devices/sensors that they interface with (eg. vacuum pumps, valves, MFCs, facility boxes, etc.) vastly reducing cable costs.

So coming back to a comparison of PLCs to the ***SuperIOr*** family, which of these systems makes the most sense to use today in a given manufacturing system? Let's consider a number of important factors in such a decision:

Scalability and Cost

- As mentioned earlier, PLCs work fine in applications that have a small number of I/O. You can get more I/O by adding additional PLC modules but the total system cost gets pretty steep and the point-to-point wiring becomes an assembly nightmare.
- ***SuperIOr*** systems can accommodate designs anywhere from a few dozen I/O points up to several thousand with interconnects specific to each design for about half the cost of a comparable PLC design.

Safety Interlocking

Safety is an expensive challenge for PLCs especially if the design requires fault-tolerant I/O or power.

SuperIOr Controllers complement an EtherCAT network by providing fail-safe, reconfigurable hardware-based interlocks and high-speed embedded control. The system double checks DOs to be sure that all data is clean and correct. The product is so safe, in fact, that TÜV Rheinland has certified the product at SIL3.

In summary, probably the best way to think about the ***SuperIOr Control*** system is as a single I/O controller with all the I/O and interlocks directly available to the CPU in the CM. In fact, all the I/O exists within the CPU's address space. The dual FPGA hardware takes care of updating the CPU registers at an 8 KHz rate independent of the number of RIMs or their size and all I/O across all RIMs is updated simultaneously on the tick of the 8 KHz clock. We even go so far as to compensate for speed of light delays in different lengths of CAT6 cables to be sure that all digital outputs everywhere switch together.

So which system stands out as the best choice for your industrial control needs?

PLCs work fine in smaller simpler applications.

SuperIOr Controllers provide the flexibility, scalability and cost savings tool designers need to compete in an EtherCAT world.

The choice is clear: The ***SuperIOr Controller*** is the system to provide unmatched industrial control.

Bibliography

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