Real-Time Ethernet Plays an Essential Role in Enabling A Soft-Control Architecture with Distributed Components

It is finally possible for machine and equipment builders to contain all their control logic in software – ending the long dependence on proprietary chipsets, boards, and networks. Today, a machine's control logic and Human Machine Interface can run on a single industrial PC and communicate using an open-standards communication and IO interface, to any remote device that is part of that equipment.

Importantly – with the arrival of Real-time Ethernet, sometimes referred to as Industrial Ethernet – solutions can be deterministic. The tight synchronization of control messages between the PC and remote devices (e.g. motion control, digital musical output) can be done in real-time, with tightly bounded cycle times and event response.

All real-time logic runs on commercial off-the-shelf PCs and network components. No proprietary communications boards; no proprietary control cards; no arrays of DSPs or FPGAs; no second PC with a stand-alone RTOS.

This breakthrough allows machine builders to capture their intellectual property and value in software components, while also dramatically reducing costs by eliminating proprietary hardware.

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Two important technology advances – multi-core chipsets and Real-time Ethernet – have enabled this long-desired Soft-Control Architecture. It is additional good news that machine equipment companies have a range of choices regarding how they take advantage of Soft-Control Architecture capabilities. Those choices are outlined in the charts below.

There are four key elements in a Soft-Control Architecture:

- Microsoft Windows OS
- A symmetric multiprocessing-enabled real-time extension to Windows, such as IntervalZero's RTX 2009 software
- Multi-core chipsets
- Real-time Ethernet capability.

(Note: A detailed Soft-Control Architecture white paper is available at www.IntervalZero.com)

While the enabling software has been available for years, multi-core chipsets and Real-time Ethernet have turned the vision of Soft-Control into a reality.

The multi-core x86 platform was the first enabling advancement.

Before multi-core, expensive, proprietary FPGA and DSP hardware solutions – typically running in a second PC – were necessary to satisfy a machine's deterministic needs. However, in a multi-core setting, Windows can run on one or more cores and the SMP-enabled real-time software extension can run on the remaining cores. This allows control logic to run in parallel on multiple cores and at a fraction of the cost, while also outperforming most FPGA or DSP applications.

An SMP-enabled Soft-Control Architecture contrasts sharply with virtualization approaches, which require additional costly infrastructure for their interprocess communication. Real-time Ethernet was the final, essential element that unleashed the immense power of a Soft-Control Architecture.

The road to Real-time Ethernet has taken many turns so a bit of background is helpful. Before the field bus concept was developed, machine builders did a lot of point-to-point hard wiring from inside the control panel to the machines and the actuators. The field bus provided a shared, yet deterministic, network so a machine designer could create a more modular, distributed and supportable solution rather than a monolithic, complex solution.

However, because conventional field buses did not benefit from the same massive volume of investment that Ethernet-based networks did, the costs and performance of conventional field bus components did not improve as quickly as Ethernet-based components.

As real-time logic became more distributed in order to solve more complex problems, conventional field buses became more prevalent and solved valuable architectural problems for machine builders. Still, conventional field buses themselves have significant cost, scalability and performance limitations.

Over the past five years, Real-time Ethernet solutions have displaced conventional field buses in next-generation machine designs, as newly developed standards overcame concerns about efficacy, performance and safety.

Because Ethernet-based TCP/IP had become the de facto standard for corporate networks, the hardware components used in those networks – copper and fiber, CAT5 cables, RJ45 jacks, NIC cards, Ethernet Switches – were seen as ideal for reducing the costs of a machine's bill of material if they could be used in a machine that demanded real-time control in a distributed setting. These components had become ubiquitous, high quality and most importantly because of the volume, extremely low cost.

Yet while Ethernet seemed like the obvious choice for cost reasons, machine builders had a major concern. The Ethernet protocol (CSMA/CD) was not deterministic, raising issues of scalability, performance and safety. The Collision Detection Model could not satisfy the real-time needs or tight time deadlines required by most industrial, test/measurement, music and medical equipment machines – particularly those relying on motion control. Without those capabilities, Soft-Control Architecture remained just an idea.

To address the shortcomings, companies such as Siemens, Beckhoff and others, sponsored efforts to define new protocols and topologies that avoid the collision detection mechanisms, assuring a bounded, deterministic response across the Ethernet-based field bus.

These sponsoring efforts have resulted in standards bodies such as PROFIBUS Nutzerorganisation e.V. (PNO) and EtherCAT Technology Group (ETG) that have gone on to define the innovative protocols Profinet and EtherCAT respectively.

Real Time Ethernet Solution	Organization	Principle
EtherCAT	ETG	Master/Slaves
Ethernet/IP with CIPSync	ODVA	Time Stamps
Powerlink	EPSG	Master/Slaves
Profinet/IRT	PNO	Internal Switches
SERCOS III	IGS	Master/Slaves

These protocols satisfy deterministic requirements while using off-the-shelf, high-quality, lowcost components. These new networks far outperform conventional buses and address safety concerns.

On the next page are examples of Real-time Ethernet-based protocols that have been in production for years. The table includes the principle technique for overcoming the non-deterministic CDMS/CD approach.

It should be mentioned that there are many other Real-time Ethernet protocols such as SynqNet, SynUTC, Precision Time Protocol, RTnet, JetSynC.

The Role of IntervalZero RTX in Capitalizing on Real-Time Ethernet for a Soft-Control Architecture

IntervalZero's RTX2009 SMP is an RTOS-like extension to Windows that can run on multiple cores.

Critical to satisfying performance and safety demands, RTX allows the control logic (e.g. motion control or digital music transformation) to run as a software component on a Commercial Off-the-Shelf (COTS) x86 system across one or more cores. RTX has drivers developed by Partners that enable real-time communication to support any of the protocols listed above, eliminating the need for proprietary communications boards and field buses.

Range Of RTX-Enabled Real-Time Ethernet (RTE) Solutions

Machine equipment companies have a range of choices regarding how they take advantage of Soft-Control Architecture capabilities.

At one end of the spectrum, machine builders may want only Real-time Ethernet access, and at the other end of the spectrum builders may want a completely pre-integrated solution.

On the next page are examples of scenarios deployed by IntervalZero customers. (See customer success stories and driver partners at www.intervalzero.com)

Each category has its strengths. For example, the time to market and the flexibility to make field fixes dramatically improves as the machine builder moves closer to an all-software model. And while the upfront costs increase with that approach, it is important to recognize that the ongoing costs are dramatically lower. These tradeoffs need to be evaluated in context of each machine design and market.

All Hardware	Mixed hardware and software	All Software components, integration required	All Software in a pre-integrated bundle
e.g. RTE Card	e.g. Soft RTE Protocol Stack Motion Card	e.g. Soft RTE Protocol Stack & Soft Motion Logic	e.g. Bundled RTE and Motion Logic
RTE card manufacturers provide the cards and drivers that allow RTX to access Real-Time Ethernet	Communications completed via NIC card but control logic still handled in DSPs or FPGA	All control logic executes on standard, open x86 and NIC card. Machine builder still integrates solution	All control logic and communications is pre-integrated and provided by vendor.

Summary

Real-time Ethernet is the final, missing link to a Soft-Control Architecture for machines and equipment with distributed deterministic requirements. Ethernet is familiar, universal and extremely cost-effective. Protocols like Profinet, SERCOSIII and EtherCAT have overcome the limitations that would prevent Ethernet from being deterministic. By adding Real-Time Ethernet to an RTX-enabled solution, customers can build breakthrough systems that outperform prior systems and do so at a fraction of the cost and complexity.

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