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Get the Edge

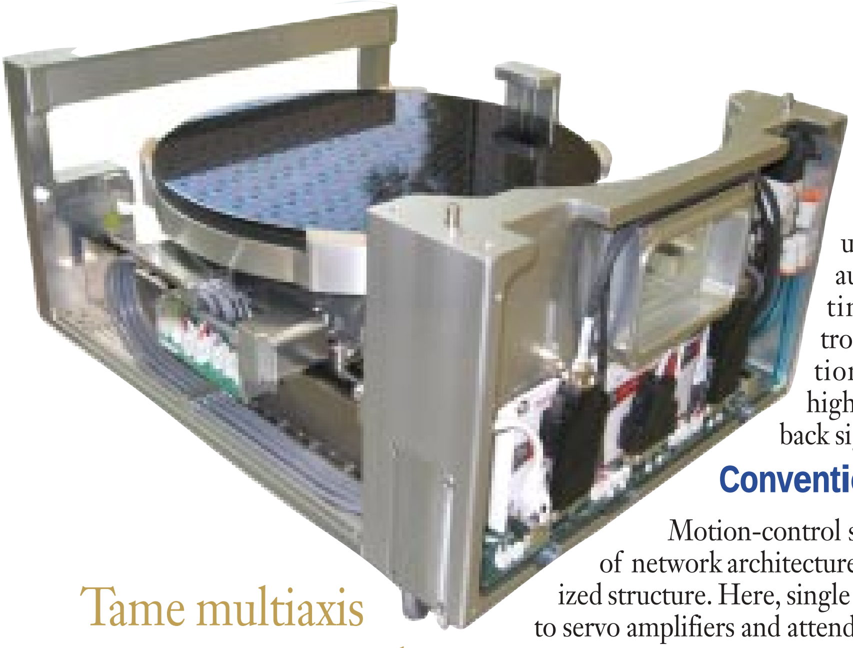
Sharpen your network IQ, page 22

A better way to drive, page 14

Supercharge servoloop tuning with software, page 36

Programmable Automation Special Section Inside

Winning with Teamwork



Tame multiaxis systems by distributing control tasks across peer-to-peer networks.

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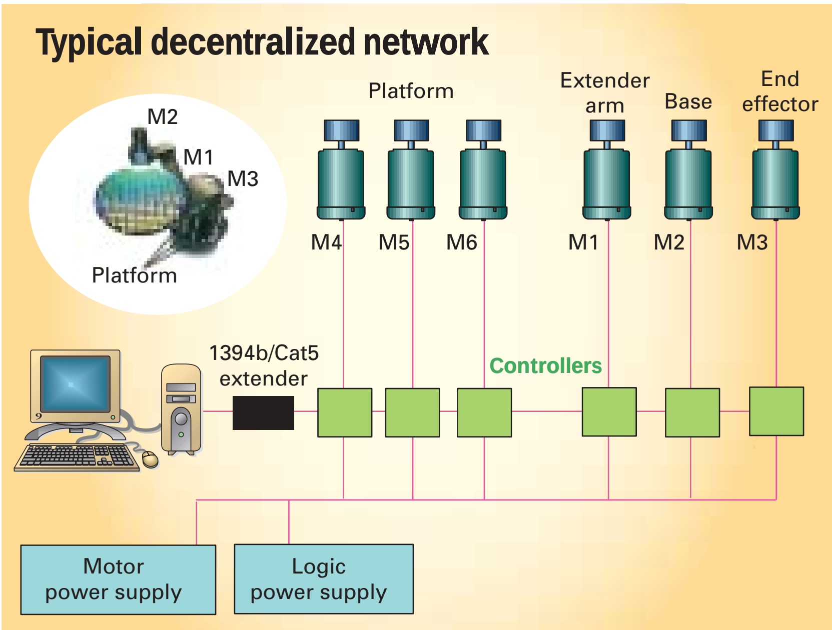
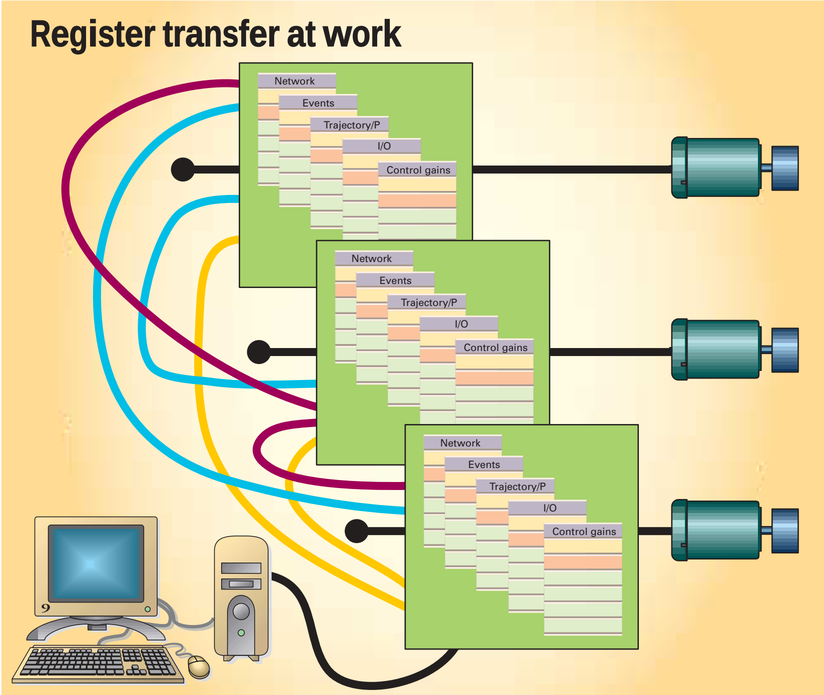
Growing throughput demand in high-tech equipment — machines used in semiconductor manufacturing, electronic assembly, and medical automation in particular — is a source of continual challenge for today's motion controllers. Not only does it require more integration flexibility at the system level, but also higher resolution and repeatability in the feedback signals shared among components.

Conventional control

Motion-control systems are often differentiated on the basis of network architecture. The conventional approach uses a centralized structure. Here, single or multi-axis motion controls often connect to servo amplifiers and attendant servomotors through a 10-V analog ve-



In this example of a distributed-network-based control structure, the master is a central controller. It handles all interlocking and coordination tasks between the various axes, requiring a real-time operating system.



Multiple controllers on a peer-to-peer network are able to interact intelligently using a register transfer scheme. Register manipulation sequences for I/O-to-I/O, event-to-motion, position-to-gain, and so on can be defined in relatively simple data fields and executed transparently through the network.

locity command signal. The advantage of this conventional configuration is the excellent availability of many interoperable motion-control components from a relatively large number of vendors. The major disadvantage is an inherent susceptibility to electrical noise at the analog interface. To avoid noise-induced problems, wire runs must be kept short, making distributed control impractical based on this arrangement.

Over the years, industry has

evolved various network alternatives to analog interfaces. Of these, motion control systems that stream real-time *point-velocity-time* data (PVT) across the network seem to be the best approach. They achieve tighter, faster, and more accurate control using less network bandwidth than alternative systems that transmit velocity and torque set points instead.

Digital networks like these can be used to implement a decentralized control structure because they allow designers to mount servo amplifiers and other components in close proximity to driven devices. But the resulting networks are still plagued by the complexity of centralized control. The problem is especially evident in multi-axis systems because central controllers must commit considerable resources to monitor and direct each axis in addition to coordinating their moves, point by point, relative to one another as well as within the process in which they are employed.

Low-level foundation

Implementing a successful network, no matter what the architecture, depends on the complexity of the signal environment. In motion systems, a growing challenge can be traced to the increasing use of analog signals. Analog encoders, in particular, are becoming more common because of the universal demand for higher precision.

Analog encoders generate sinusoidal output signals that are only one volt (peak to peak) on both *A* and *B* channels. These small signals can be electronically interpolated, resolving position far more precisely than what's possible with conventional square-wave encoders that produce 5-V TTL logic signals.

Higher encoder resolution alone does not guarantee higher positioning accuracy. Current resolution also play a role.

In a typical servo system, a servo amplifier's output current determines torque. Shaft motion, a product of torque, is thus controlled by regulating motor current. In order to leverage higher encoder resolution, a servo system must be able to move the motor shaft in correspondingly fine increments. This requires higher current resolution than most systems can achieve.

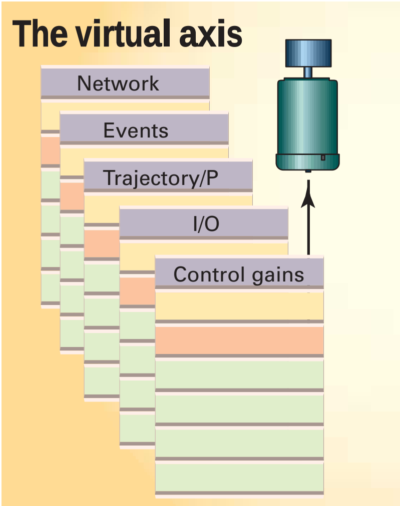
Higher current resolution is, of course, possible, and it starts with hardware that provides more bits of analog-to-digital conversion. It also requires effective filtering to separate the actual current signal from background noise. If these conditions are met, it's not unusual to achieve positioning resolutions of a few nanometers from a 14-bit microcontroller.

True distributed control

As digital networks become more common, distributed motion-control architectures are also increasing in use. The typical approach uses a master-slave signaling scheme, where the master is a central controller that handles all interlocking and coordination tasks. This requires a real-time operating system for virtually all high-performance applications. Even then, the compute power consumed by motion-control tasks leaves little bandwidth for process-related functions.

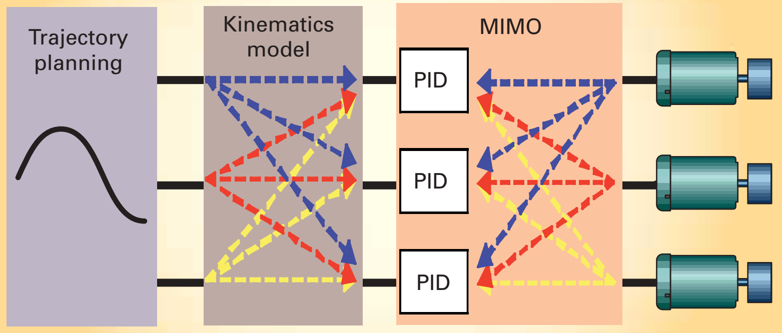
Another approach, peer-to-peer networking, eliminates such problems by removing motion management tasks from the main controller. In addition to making more resources available for process management, production scheduling, and even management information functions, this approach often eliminates the need for a real-time operating system.

To better understand the peer-to-peer concept, consider a regis-



A register model that captures all relevant information associated with a single motion axis makes it possible for all components in a peer-to-peer network to keep track of each other and work together.

Kinematics on controllers



Here, a kinematics model based on register transfer and trajectory planning is implemented entirely on single-axis motion controllers; no central machine controller is involved.

ter system that encapsulates the motion control functionality of one axis in a multi-axis system. Each register value corresponds to a defined control function. In the peer-to-peer network scheme, register values are exchanged between controllers in a synchronized fashion, ensuring that motion functions associated with each register value are executed at a defined point in time — synchronized across all axes in the system.

Register manipulation concepts for I/O-to-I/O, event-to-motion, position-to-gain, position-to-position, or trajectory-to-trajectory can be defined and executed transparently through the network.

The necessary ingredient is synchronization. Synchronization simply implies that the internal clock (or software time) of each controller is the same — specifically, exhibiting *zero drift* and *low jitter*. Zero drift means that two separate controllers would move two motors to the same position at the same time, whether it takes 20 msec or 20 hours.

Jitter, on the other hand, refers to the maximum error between axes that can occur during one register transfer cycle. It is easily minimized through the use of a synchronization signal propagated over the network or by simply using a high-speed synchronized network like Firewire.

Peer-to-peer networking paired with synchronized register transfer can accommodate even complex

Appropriate hardware can extend the flexibility gained with peer-to-peer control networks. On the backplane version of this motion controller, all data and power signals are accessible through two connectors.

kinematics models entirely over the network. What's more, trajectory planning and the kinematics model itself can be implemented entirely by single-axis controllers connected to the network, eliminating the need for a central machine controller.

Creating multi-axis motion control systems entirely from single-axis building blocks makes for flexibility: No matter how many variants of a machine there are, or optional motion axes each variant has, the motion control hardware and software that can handle all tasks is identical for each. As for simplicity, field installation of optional axes is reduced to the trivial task of plugging in additional control modules.

Peer-to-peer networking also reduces the bandwidth required in the connection between the motion system and machine controller. Any common fieldbus network will suffice.

Hardware upgrades

Appropriate hardware configuration can further boost the flexibility of peer-to-peer controller networking. For one thing, it can simplify wiring and connections.

Taking advantage of the networks residing within, all interface signals and power connections can be bought out of a machine, module, or subsystem on two compact connectors. The controller can be plugged directly into a printed circuit interconnect board — for a Lego-type building-block approach that reduces interconnect wiring, complexity, and cost.

Opening photo courtesy Micro Precision Automation. For additional information, e-mail the editor at eeitel@penton.com or visit agile-systems.com.

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