

# Tech Advances Impact Motion Control

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There are a number of technology trends that are profoundly changing how engineers are designing machines with motion control. Two among these stand out for their potential impact on cost, ease of assembly, and serviceability. These are the continual reduction of the size of the motion amplifier, and the advent of low cost, high-speed digital networks. In this article we will examine these trends with a particular eye on how they affect the design of machines that utilize state of the art motion control systems.

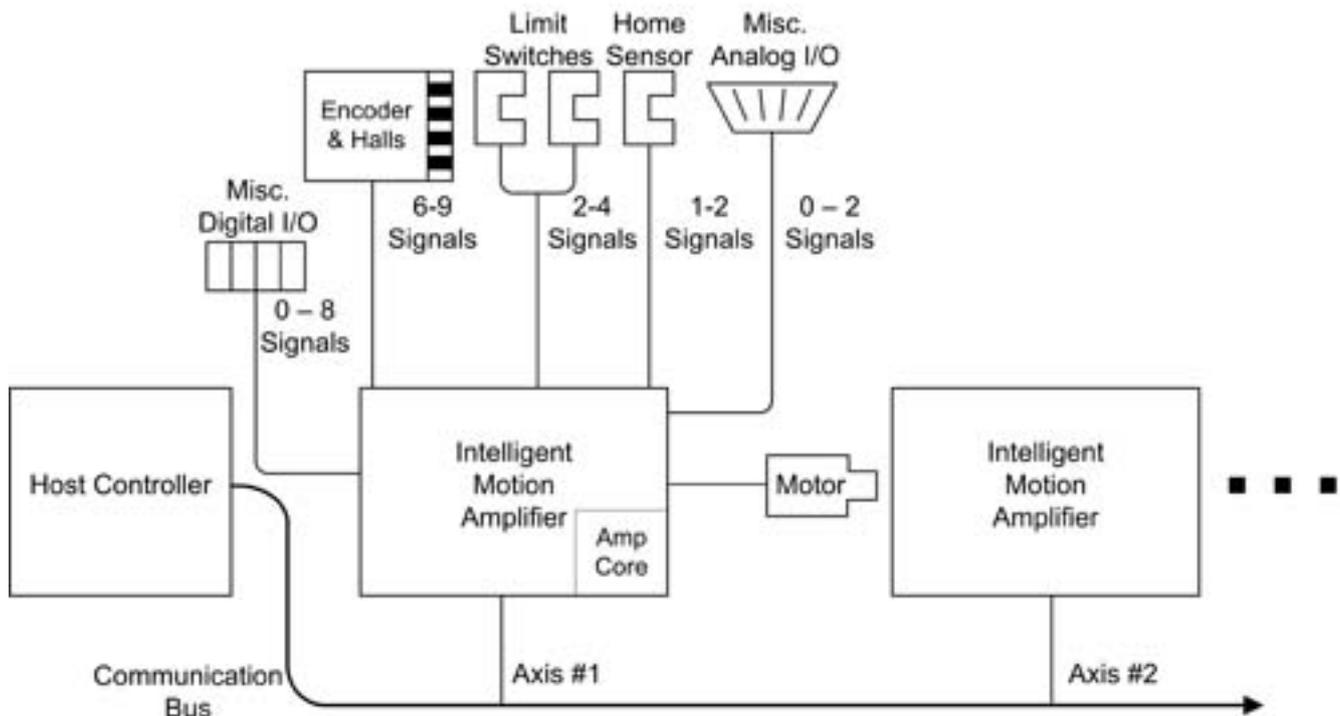
### **'Wire' we still having this conversation?**

Motion controllers span a broad range of size and power, but can roughly be broken down into two groups; small motor applications, where the controllers are often custom made single-card controllers that utilize IC-based amplifiers, and large motor applications, where the controllers are card or module-based motion modules interconnected by cables.

Small motor applications tend to be used in machines that are physically compact, and thus have short wire runs. This makes the control problem easier because shorter wires means reduced chance of lost position information over quadrature format encoders.

With larger, module oriented motion, position feedback signals can be connected to a control card which in turn drive an amplifier, or if 'intelligent' amplifiers are used, feedback signals can be directly connected to the amplifier.

Figure 1 shows a typical module-oriented motion system utilizing intelligent motion modules. In this system, the communications network provides overall synchronization for the motion trajectory, but signaling is routed into the amplifier using individual analog and digital wires.



**Figure 1. Typical module-oriented motion system utilizing intelligent motion modules.**

The problem with module-oriented motion? In a word, wires. Wires mean susceptibility to EMI (Electro magnetic interference), and lots of bulky and unreliable connectors. Typical intelligent motion amplifiers have as many 25 wires per axis to accommodate limit switches, encoder feedback, Hall sensors, and a plethora of other signals to and from the machine hardware.

Worse than the sheer number of wires is that many of these signals are transmitted in analog format. For example the standard format to transmit a desired motor torque is a differential analog +/- 10V signal. Since modern motion controller components such as amplifiers and encoders tend to be digital, this brings up the head-scratching situation that peripheral devices convert digital signals into analog, transmit as analog along a wire, and reconverted back into digital at the receiving end for processing.

### **Veer going to... pump you up**

When motion control got its start, this architecture made sense because most of the peripherals were analog in design. Also, connectors were relatively cheap compared to expensive, bulky, and unreliable amplifiers. But that is true no longer. Today, the single most important factor that limits the ability to decrease size of a typical standalone motion amplifier is the space required for connectors.

For the typical motor, this means that the physical size taken up by the amplifier circuitry can be one third, one fifth, or even one tenth of the size of the motor itself.

Ultra capacitors, high efficiency MOSFETs, and minituration of other core components are allowing amplifiers to achieve densities of hundreds of Watts per cubic inch, soon to approach a thousand Watts per cubic inch.

But you wouldn't know it by looking at most motion amplifiers. Such products stay 'pumped up' because they bristle with connectors, because connectors are hard to miniaturize beyond a certain density and current carrying capacity.

### **A network in every pot**

Enter the high speed digital network. More accurately, this should be called the digital signaling backbone because digital networks such as Ethernet have been around for a long time, however they are not appropriate for transmitting high speed information from position sensors, limit switches, and other feedback devices for motion busses.

By the same token, earlier, dedicated signaling networks such as CANbus are too slow to accommodate the speed requirements of many motion applications. Compared to general factory floor control problems, the basic speed at which motion information needs to be updated to execute a position loop is at least 1,000 times per second, but ideally runs as high as 10,000 times per second.

Figure 2 shows a high speed digital backbone network used to control the same machine as in figure 1. Connections from encoders and limit switches tie directly in to the network, not into the amplifier module. Note also that the amplifier function has a single network connection, dramatically reducing the number of connections to the drive.

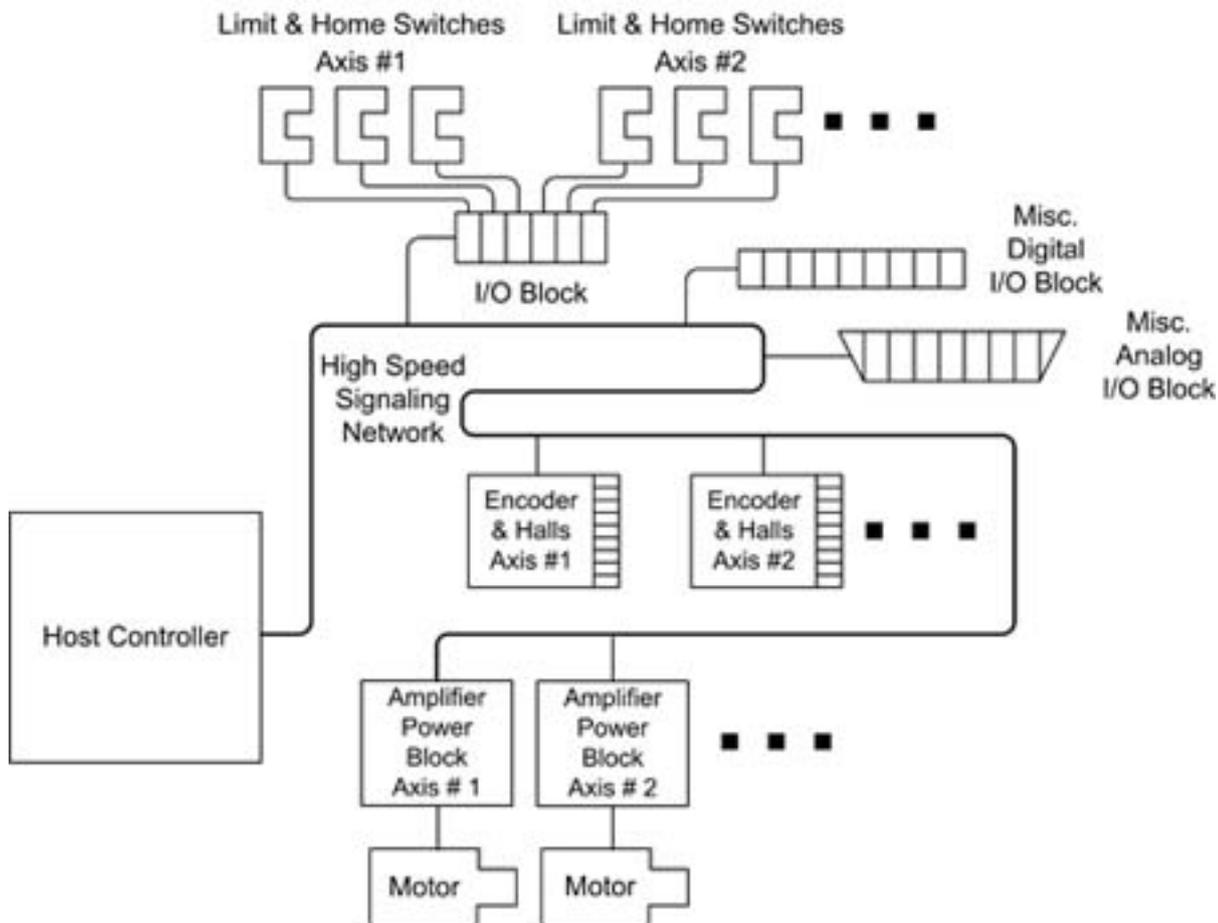


Figure 2. A high-speed digital backbone network.

In this configuration the amplifier is used as a 'power block'. Decoupling the amplifier function from the signal processing function has a number of advantages, first among them separation of high voltage, high power circuitry from more delicate digital signals. Another advantage is that heat sinking is much simpler, because the now size-reduced amplifiers can be clustered together, and mounted wherever they are easiest to service.

### Putting it all together

Now that we have a vision for a digital motion world with compact 'block' amplifier modules and a single backbone connection for the whole machine, we need to do a sanity check to determine whether the real world is catching on!

Happily, the answer is yes, but in fits and starts. The most important development to move this vision along is the development of the 'Ether' backbones, EtherCAT and Ethernet/Powerlink. These are both high speed deterministic versions of the popular and ubiquitous Ethernet network used by PCs.

Standard motion protocols such as CoE (CANopen over EtherCAT) provide much of the protocol background we need, but the full vision requires amplifiers, encoders,

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Hall sensors, and other signals to easily be input directly to the network. Luckily, this is starting to happen. In the case of encoders, which are probably the most important piece of the puzzle because of their high wire count, so far only high-end devices provide direct connection to networks. But as time goes on, that will change, and eventually digital networks may become the standard approach for connecting motor encoders.

It would also be nice to have direct network-connect limit switches, and a variety of options for terminal blocks that plug into the network. Here again, some products are available, but they are still expensive compared to their non-network cousins.

Amplifiers are further ahead, with a number of products being available that offer EtherCAT connectivity, and some that offer Ethernet/Powerlink connectivity. However these amplifiers still have arrays of connection inputs for encoders and other miscellaneous signals. So they use a traditional metaphor for signal connection, while adopting high-speed networks mainly for synchronization among axes.

Another important development that will help the cause is the adoption of physically smaller network connectors, and connectors that include a low voltage power feed for sensor electronics. EtherCAT and Ethernet/Powerlink still rely on relatively bulky RJ45 connectors, to see a glimpse of the future, look no further than your own cell phone! Power feeds are available through some Ethernet connector flavors such as Power Over Ethernet (PoE), but this hefty system is overkill for the low power, 1-10 milliamp sensors and connector blocks that will typically be attached to a machine signaling backbone.

### Summary

Underlying the drive toward digital signaling backbones is the desire to eliminate wires and shrink components. Amplifiers, due to their own technological progress, will be most affected by the adoption of digital signaling backbones, but the entire motion system will benefit from lower cost and higher reliability.

Digital networks have an enormous advantage over discrete wires in that once connected to the network, information is traceable and verifiable. Even a single signal, wired through a connector that has an intermittent failure, can threaten the reliability of the entire machine. These problems are very difficult to trace in a world where wire bundles predominate. But they become both rare, and easier to trace, when the wire bundle is replaced with a digital network.

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OEMs designing high performance, cost-sensitive machines have typically steered clear of standalone drives because they tended to be large, box-like units.

But the latest generation of motion modules is different. Measuring just inches on a side, these intelligent, distributed drives provide advanced motion control and can be programmed using C, Visual Basic, or other standard languages.

The ION digital drive from PMD is an example of such a product. Measuring just 4" x 3" x 1.5" this product offers serial or CANBus connectivity and can control DC Brush, Brushless DC, or Step Motors. It has features typically found in much larger drives including field oriented control, S-curve profiling, PID position loop with bi-quad filtering, and MOSFET drivers.

The most eye-opening aspect of these products is their price. At \$200 - \$500 per axis, they are very cost effective compared to motion cards or PLCs connected to off-the-shelf amplifiers.

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