MACHINE DESIGN

Architectures for ECONOMICAL MOTION

Motion-control costs have more to do with what's needed to hook up components than with the motor and controller.

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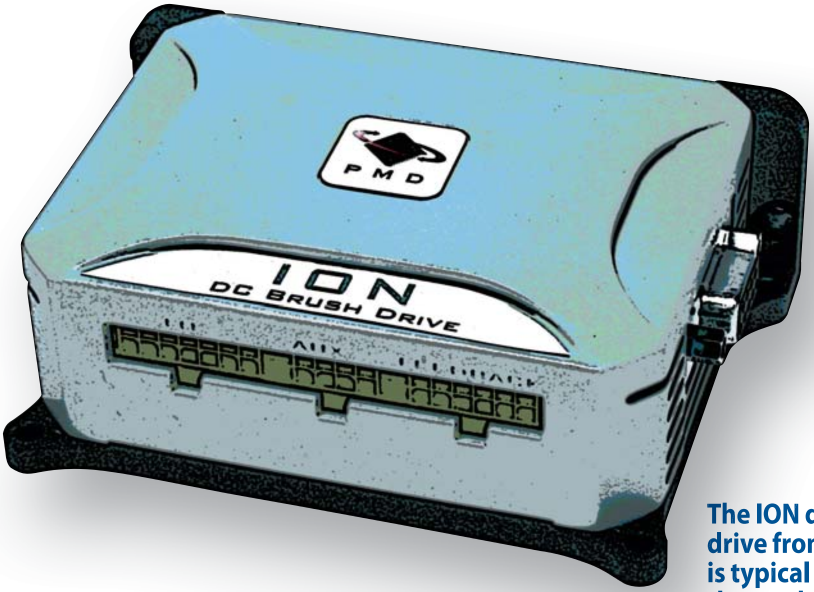

The ION digital drive from PMD is typical of the modular approach to motion control. Measuring just inches on a side, these controllers provide advanced motor control and central network connectivity.

Over the last 20 years advances in motion-control technology centered around more-powerful yet less-costly processors in the form of DSPs and CPUs. In addition, the development of inexpensive power electronics using ultraefficient MOSFETs made motion controllers more affordable and capable of handling powerful devices. However, many motion-related costs have not kept pace. For example, the price of connectors and cabling has risen over the years. And as expectations for reliability have gone up, expenses surrounding machine downtime have also grown.

It should be possible for engineers to take advantage of lower-cost components while minimizing exposure to rising costs. In some cases, a change in architecture that eliminates costly connectors and cabling pays big dividends at the bottom line.

Of course, one could run into reliability problems when trying to lower costs. But reliable architectures do not need expensive components.

The basic motor types used for the majority of machine motion-control projects haven't changed in the last 20 years. The usual suspects are still the dc servomotor, the brushless-dc motor, and the stepmotor.

But distinctly different from 20 years ago, and perhaps a little surprising, is that the choice of motor has little effect on the overall cost and architecture of the control system. What used to be the most-complicated and motor-specific part of the problem, trajectory calculation and servoloop control, is now just a software option on a high-speed DSP or microprocessor-based engine. And while the motion amplifier is still motor-specific, it, too, swaps easily with the motor.

Motion-control systems share similar core elements. They need control electronics to calculate the trajectory, power electronics to amplify a control signal and interface to the motor, and connections to hook everything together. Though servomotors need feedback from encoders and brushless-dc motors need Hall-sensor inputs, the overall configuration of the control system doesn't change much from one motor type to another.

Although not at the ease-of-use level

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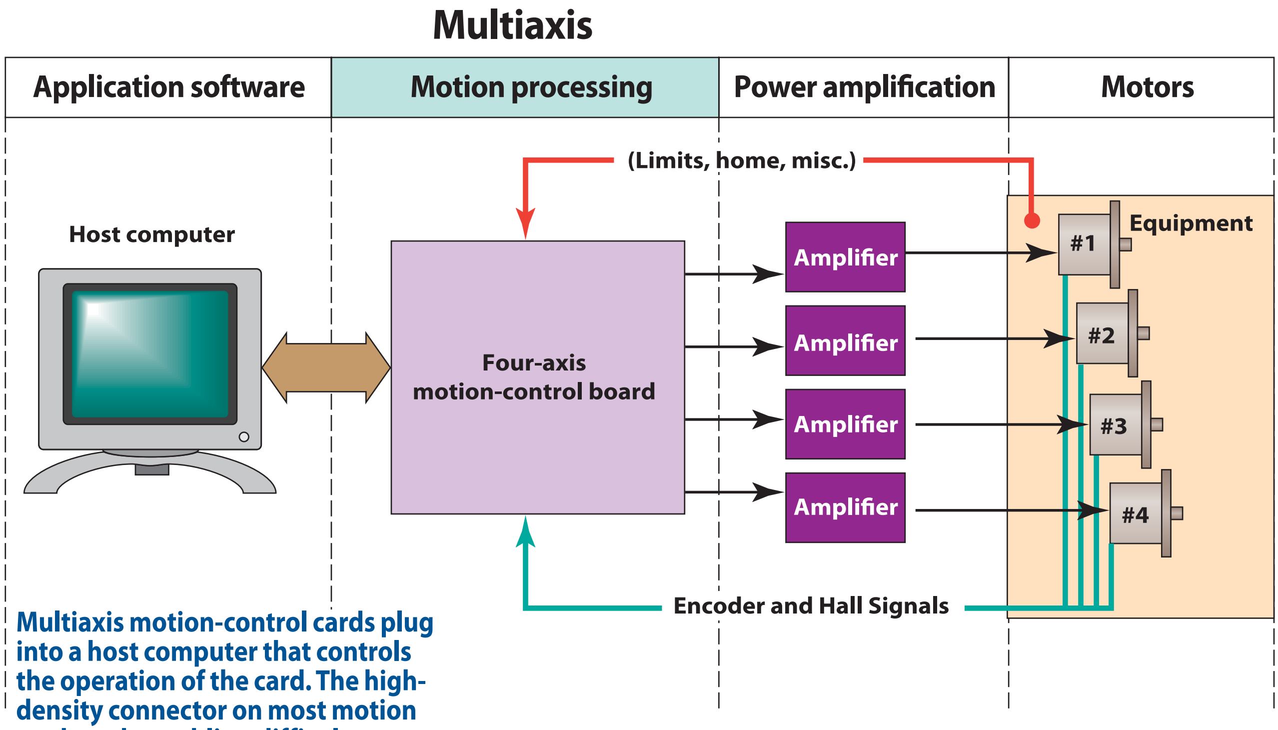


Multiaxis motion-control cards plug into a host computer that controls the operation of the card. The high-density connector on most motion cards makes cabling difficult.

many machine designers would like, autotuning routines make using servomotors almost as simple to use as stepmotors. Vice versa, microstep and other high-performance drive schemes for stepmotors make them behave more like servos. The reasons to choose one motor type over another become those of cost, lifetime, and speed/torque performance. The inner details of control operation are irrelevant to that choice.

So why does the choice of control architecture matter? The reason, in a word, is connectors. Too many connectors or the wrong style connector means more failures, higher manufacturing costs, and potential servicing headaches.

We can see why if we take a simple example from Motion Control 101. Let's imagine we purchase an off-the-shelf four-axis motion card that uses external amplifiers to drive the motors. In principle this is a simple system. In reality, most motion-control cards connect to the outside world through at least one high-density connector. To go from this connector directly to the amplifiers, motors, feedback devices, and perhaps throw in an emergency stop and some limit switches for good measure, necessitates a large and complex cabling harness that would be difficult to install and even harder to service.

An alternate approach to working with high-density connectors is to use "breakout boxes." The boxes turn the motion card's cramped connector into easily accessible jack screws. Typically one box is used per axis and they often mount on a DIN-rail system. Each machine tends to be hand wired when using this approach, with single cables or small bundles routed from the control rack to various parts of the machine. This approach works well for low-volume applications, but it is often unacceptable for cost-sensitive designs at high volumes.

Sometimes the use of a custom interconnect card creates a functional, easy-to-service, machine that has a lower build cost. The interconnect card provides direct hookups to the high density connector on the motion card. This is often done via ribbon cable. The card typically breaks the signals into more manageable groups, such as motor control, position feedback, and so forth.

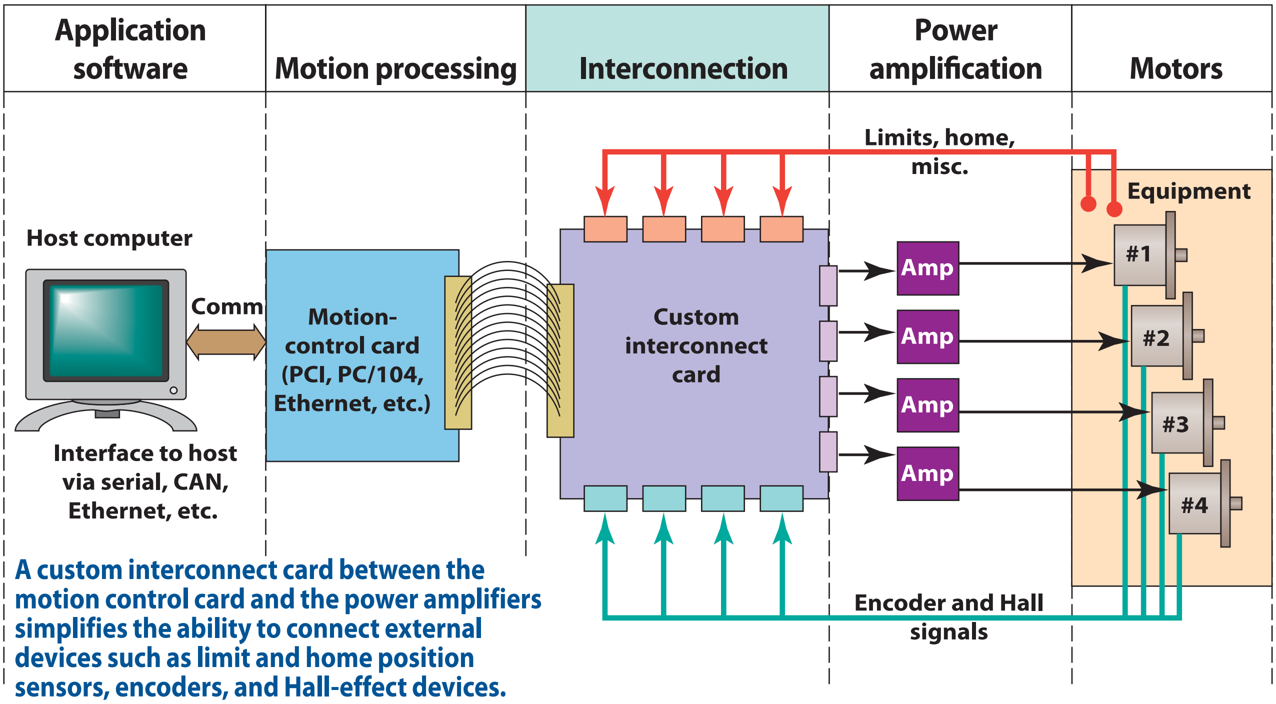
One disadvantage of the interconnect card is the upfront engineering cost. Another is that connecting amplifiers through these cards can be a bit messy from an electronic interference standpoint. The problem is aggravated when driving high-power motors.

A common variation of the interconnect card is to "piggyback" an amplifier card on it. This creates a hybrid system where low-power signals, such as motor feedback, run through the interconnect card while high-power signals wire through separate jack-screw connectors.

Bear in mind that many of the alternate configurations tend to have an application "sweet spot," affected by the goals for upfront engineering cost, cost per unit, serviceability, and production volume. Though there are often gray areas where several approaches might work, one still needs to determine which architecture best suits a specific application.

The all-in-one motion card combines the motion controller, the amplifiers, and the interconnect cables onto a single card. Custom-building these cards is

Custom interconnect



A custom interconnect card between the motion control card and the power amplifiers simplifies the ability to connect external devices such as limit and home position sensors, encoders, and Hall-effect devices.

not as difficult as it sounds. The most complicated part, the motion controller, can be purchased off the shelf in the form of a motion processor. Motion processors are IC-based devices that provide trajectory generation, servoloop closure, commutation, and other built-in functions.

An alternate course is to design this software from scratch and purchase DSPs or microprocessors to execute it. Obviously, this will add to the upfront engineering effort.

Dedicated motor-amplifier ICs purchased off the shelf aid the integration of the amplifiers onto the card. These handy devices accept a digital or analog input command signal from the motion processor and perform all amplifier functions needed to drive the motor. They are available for dc servo, brushless dc, and stepmotors.

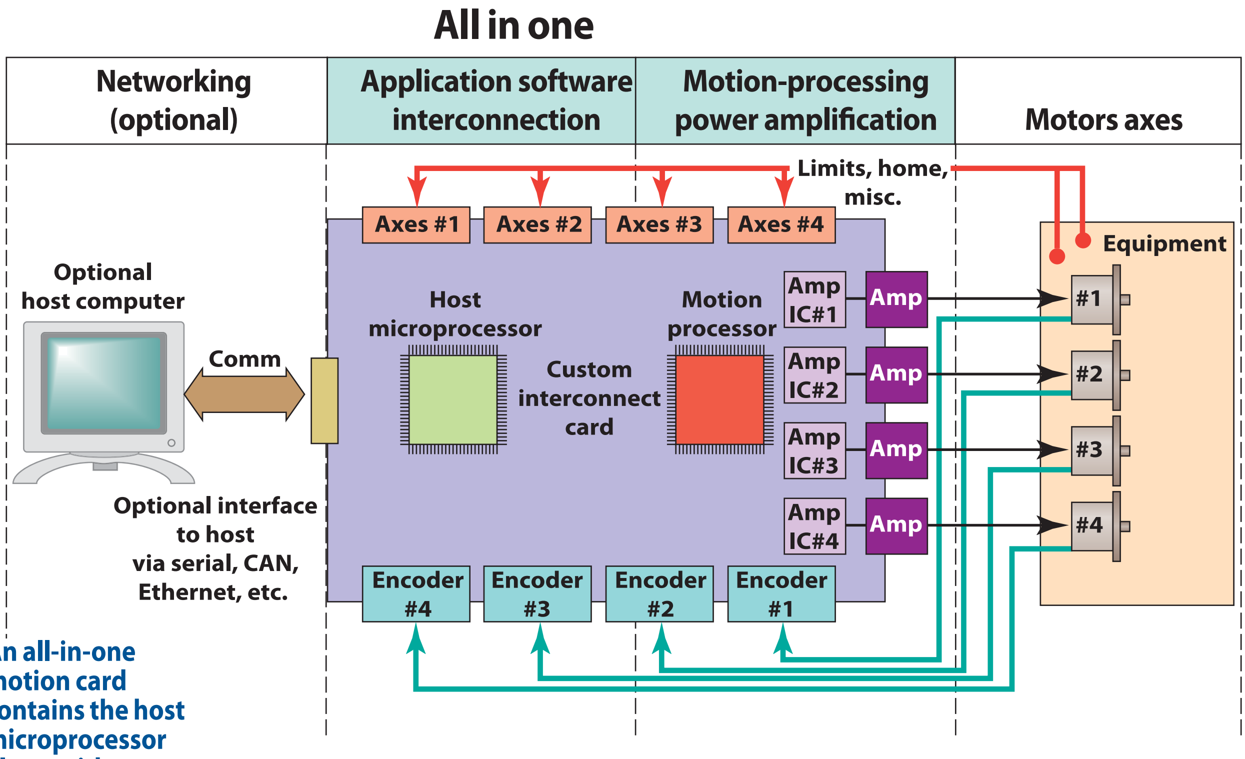
There are three advantages in the use of motor-amplifier ICs. First, the per-unit cost is low. There are no motion cards or boxes to purchase, and the amplifiers are purchased at the IC level. Second, the motion card is the interconnect card. This lets you tailor all connections to your application. Third, servicing is simple. Replacing the controller is a matter of replacing one card. There is no need to determine whether the problem is in the motion card, the amplifiers, or the elements connecting them.

One disadvantage of this approach is that the upfront engineering effort is greater than for more modular approaches. Another disadvantage is that onboard IC-based amplifiers tend to top out at about 48 V and 4 A. Although it is possible to design your own higher power amplifiers from scratch, doing so creates its own set of problems that include interference with digital circuitry and heat-management issues.

A common approach used to build motion systems is the stand-alone drive, also known as a smart amplifier. In this approach the motion-control card is replaced by a "box," often connected by serial networks. The drive either plugs into the wall or is fed with a dc-bus voltage. Stand-alone drives require less wiring than motion cards because the connections between the trajectory/calculation portion and the amplifier portion of the controller are inside the drive.

Stand-alone drives connect to the machine in one of two ways. The first, perhaps counterintuitively, uses a custom-built interconnect card just like the one used with the motion-control card. The use of such a card again stems from cabling issues and serviceability. Even simple drives have a plethora of signals for each axis including emergency stop, enable, limits, home, and a handful of PLC-type general I/Os, not to mention power input, the motor-feedback signals, and the motor-drive output. To keep the stand-alone drive small, these signals tend to be bunched into one or a small number of high-density connectors just like the motion card. The complexity of building, installing, and servicing a cable harness that integrates all of these signals brings us back to the advantages of an interconnect card.

The second approach wires the drives directly to the motors. This brings the wiring advantages of the drive's higher integration level while still avoiding the engineering expense of designing an interconnect card. Whether or not this is



An all-in-one motion card contains the host microprocessor along with the motion processor. Any connection to an external computer is to provide setup and run-time data only, not direct operation.

possible, however, depends on the connector types provided by the drive and the application. An additional advantage of this approach, if practical, is that the drives can be distributed throughout the machine. This is attractive because it shortens cable lengths.

Other considerations may not be so obvious when comparing motion cards to networks of stand-alone drives. For example, unless the system uses a high-speed network, stand-alone drives are relatively difficult to synchronize for multidimensional moves. In this case it may be easier to use a multiaxis motion card.

Stand-alone drives do have an advantage in mixed-motor-type systems. For example, a single network can contain dc servodrives, brushless dc drives, and stepmotors. As long as each drive talks the same "language" on the network, the host software does not need to be aware of the motor type.

There is no easy or simple answer as to when one drive architecture should be used over another. Sometimes two architectures can be used with success for a given application.

In broad terms, the more cost sensitive the application, the more likely it is that you will design your own card and integrate onboard amplifiers, if possible. When designing your own card you can choose exactly the connectors you want and dimension the form factor of the card for the application.

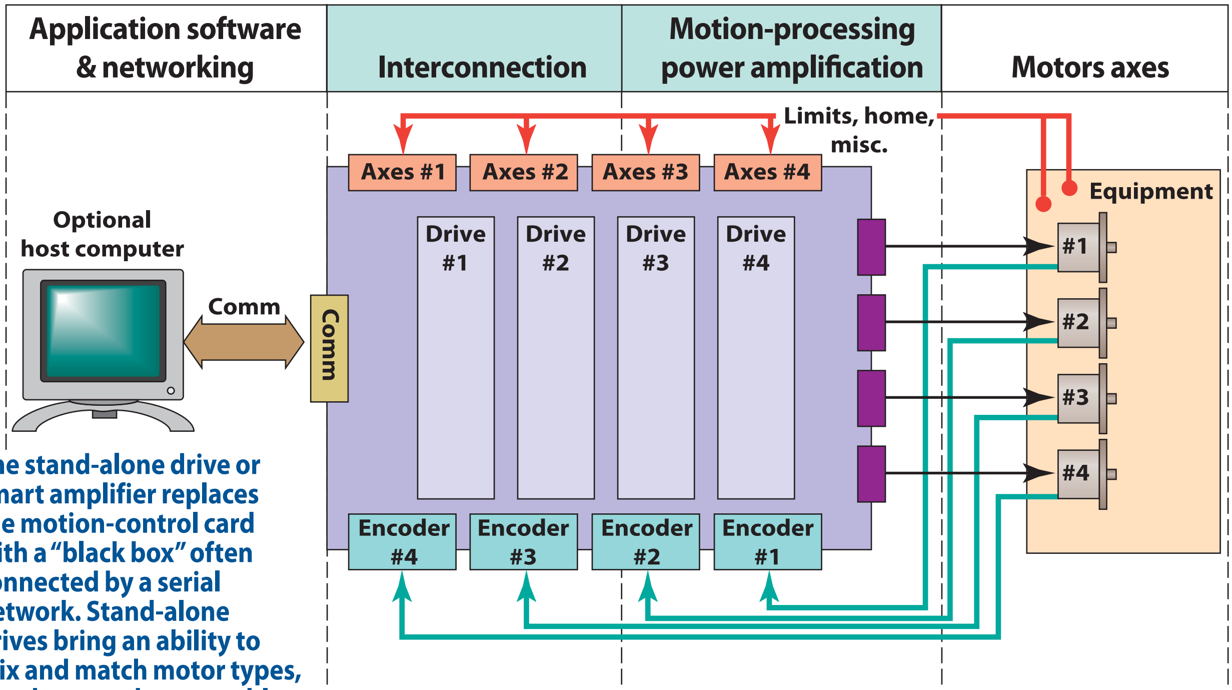
Motion cards and box-type drives can simplify the task of wiring, but you may well end up with a custom interconnect card. Again, volume and serviceability considerations sway the choices one way or the other.

Don't forget that other aspects of the motion problem can greatly impact architecture choice. Highly synchronized applications, such as machine tools, gravitate toward multiaxis motion cards or distributed drives interconnected by a high-speed network. Networked drives such as Sercos allow flexibility, but they may still need a motion-control card for overall path generation to correctly split up and send out the motion segments to each individual drive axis.

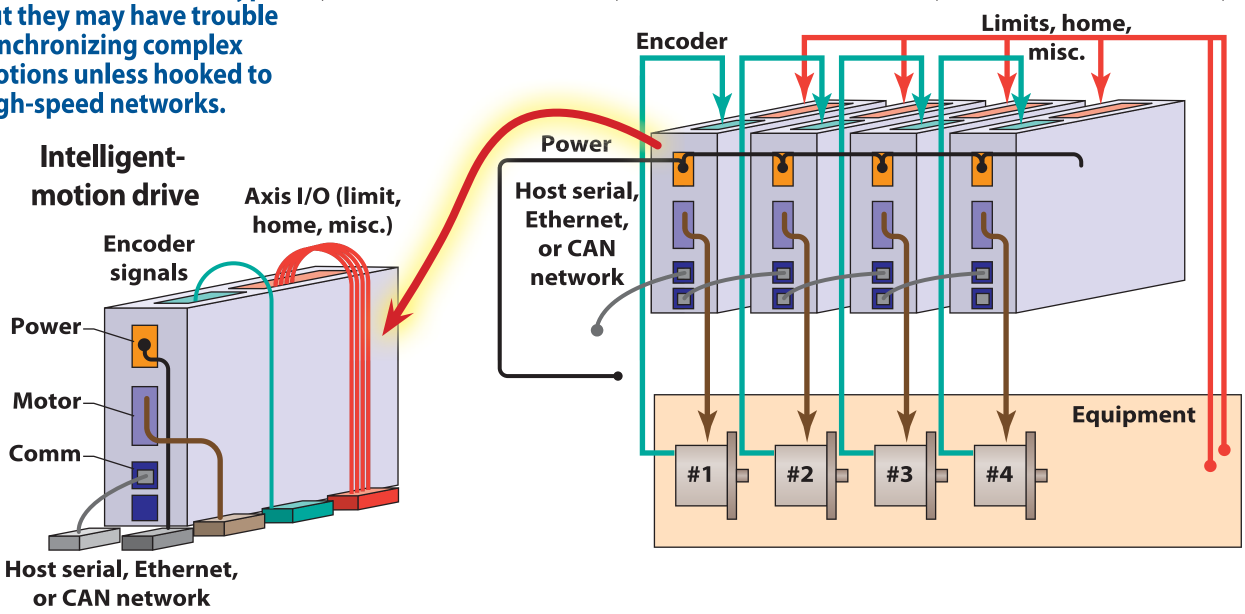
Many applications such as medical automation, semiconductor automation, scientific instrumentation, and low-power general automation, are well served by stand-alone drives on slower networks such as RS-485 or CANbus, or by multiaxis motion cards. Other factors that tilt the approach toward stand-alone drives include a larger number of axes and the use of two or more different motor types. Factors which tilt toward multiaxis cards include the need for synchronization, smaller number of axes, or use of a single motor type.

OEMs designing cost-sensitive machines have typically steered clear of "big iron" solutions such as PLCs and stand-alone

Stand-alone drive



The stand-alone drive or smart amplifier replaces the motion-control card with a "black box" often connected by a serial network. Stand-alone drives bring an ability to mix and match motor types, but they may have trouble synchronizing complex motions unless hooked to high-speed networks.



drives. Large and bulky, they often force users to learn special motion languages and are expensive.

However, the latest generation of motion modules is changing that perception. Measuring just inches on a side, these intelligent controllers provide advanced motor-control techniques and connect via high-speed networks to a central controller that holds the user's control program. In most cases the central controller is nothing more than a standard PC.

These modular drives are exemplified by the Ion digital drive from PMD. The compact drives offer serial or CANbus connectivity and can control all three motor types. Some of its features, like field-oriented control S-curve profiling, and PID position loop with biquad filtering, are typically found only in much larger drives. **MD**

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