Motion Control Has a Field Day

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Introduction

As technology progresses, the cost and performance of components goes down, and system-level products that utilize those components gain the benefit. Such is certainly the case for motion control products, where, thanks to dramatic reductions in computing cost, once-exotic features such as point-to-point S-curve profiling have become commonplace, even on lower-end systems.

But optimizations on older architectures can only go so far, no matter how much the cost of components goes down. This is because ancillary costs, such as for cabling, can outweigh the system cost. When this happens, elements need to be re-organized, so that the entire system cost can continue to drop with reduced component cost.

This is exactly what has happened in the field of motion control. Centralized rack and card-based systems are starting to give way to more distributed systems. And systems that once used cables to connect multiple modules are now being assembled on a single card.

This article will examine some of these trends, and detail the four major motion control architectures in use today, two of which can be traced back to earlier motion control approaches, and two of which are more recent additions. In all cases the cost of these systems have come down, but the newer architectures rearrange system cost in a way that may make them well-adapted for a growing number of applications.

If you've got the time, we’ve got the motion card.

Until about ten years ago, there were two primary motion controller types. The first is shown in Figure 1, and is called a *multi-axis motion card*. In this architecture, the motion card connects to external amplifiers, which accept +/- 10V analog signal input, and control torque or sometimes motor velocity. Today’s motion cards are available in a variety of interconnect formats including PCI, PC/104, compact PCI, and Ethernet.

Motion cards have a number of advantages, primary among them flexibility. Since the interface format to the amplifier is standardized, different motor sizes, and even different motor types, can easily be changed as the application evolves. This means that if the user changes the power of the motor, or the motor type, the motion card doesn't need to be changed, only

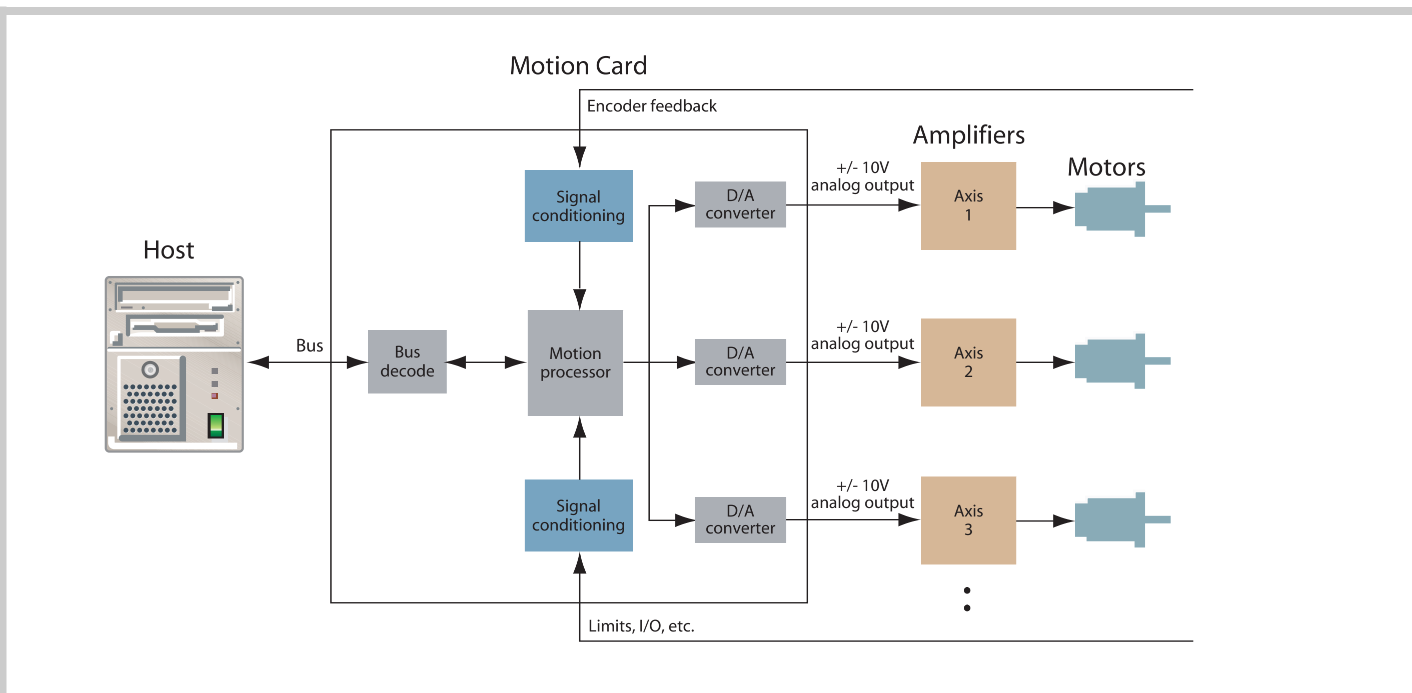

Figure 1. Multi-axis motion card

the amplifier. Another important advantage of motion cards, particularly multi-axis motion cards, is that synchronization is automatic. Control is usually all under one DSP or microprocessor "roof," so axes servo at exactly the same frequency.

A disadvantage of this architecture is wiring complexity and cost. Servo motors can have as many as twenty five wires per axis to carry signals such as encoder feedback, Hall-sensors, etc. If you are constructing a system with more than a few axes, this can quickly add up to thick cables, and a servicing nightmare.

Black Boxes

Another older approach, but still very-much used today, is the *standalone drive*. In this architecture the controller is a box, either rack-mounted, or standalone on the floor. It is often, but not always, a single axis device.

Figure 2 shows the configuration of this architectural approach. In this scheme programming tends to be PLC-oriented, with lots of digital inputs and outputs. Alternatively many boxes allow you to download a complete motion program, generally using some sort of vendor-specific language.

Stand-alone drives work well when the behavior of each axis is fairly simple, and more or less autonomous. For example it is easy to perform functions such as electronic gearing, or motion sequences such as "when PLC input 3 goes high, start profile number 7." It is difficult though, to synchronize multiple axis to perform coordinated actions.

Relative to motion cards, standalone drives have an advantage of simplified wiring, since the connections between the "motion computing" function and the amplifier function of the controller are internal to the drive. Another advantage is that drives can be located close to the motor or actuator. This reduces cable lengths and improves reliability.

A disadvantage of these devices, at least historically, is that their programming tends to be a bit clunky. They are designed to be externally controlled by PLC, or alternatively, using vendor-specific downloadable languages. It is rare to find a stand-alone drive that can be programmed in standard languages such as C, Java, or even Visual Basic.

Out of the rack...and into the fire

The third motion architectural approach, and one that has gained in importance in the last several years, is known as a *distributed drive*. This approach combines the synchronization ability of multi-axis motion cards with the reduced wiring of standalone drives. Such a drive uses a serial network to connect a central host, but still has all the standard drive features of profile generation, amplification, and internal AC or DC power management. This architecture is shown in Figure 3.

Two kinds of distributed drives are used. The first can be referred to as a *tightly coupled* drive. This type of drive uses high throughput, deterministic networks such as SERCOS, Firewire, EtherCat, or Ethernet/Powerlink. The second can be referred to as a *loosely coupled* drive, and uses slower or less deterministic networks such as CANbus, and standard Ethernet.

One difference between tightly and loosely coupled approaches is that loosely coupled drives are controlled directly from the host, by sending commands such as "move the axis to position

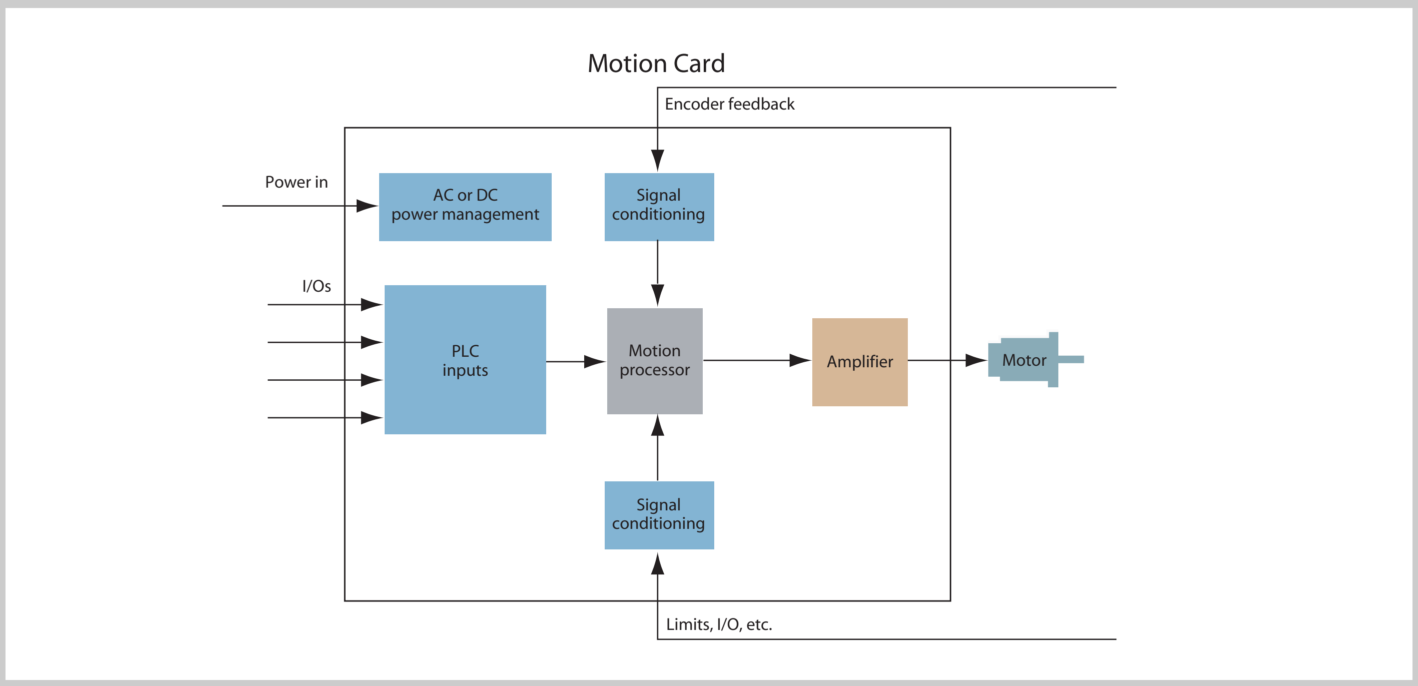

Figure 2. Standalone driver

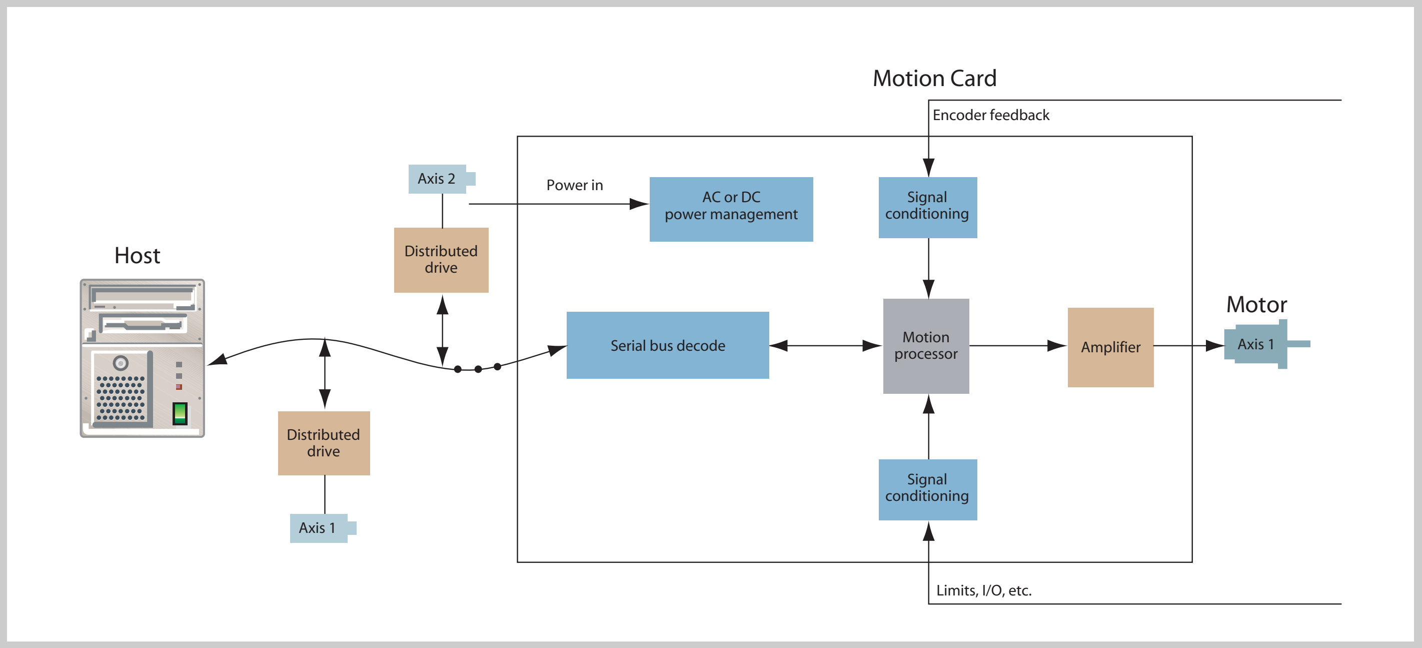

Figure 3. Distributed drive

x using a trapezoidal profile." Tightly coupled drives are different in that each drive receives rapid, synchronized, position and/or velocity updates. This occurs hundreds or even thousands of times per second.

Just like standalone drives, the advantage of distributed drives is reduced wiring and increased reliability. Another big advantage, particularly compared to a multi-axis motion card approach, is scalability, and motor interchangeability. Adding an axis in a distributed network is simple, since each drive tends to be a single axis module.

Towards an integrated society

The fourth major type of motion controller is the *integrated motion card*. In this approach, shown in figure 4, the amplifiers are integrated directly onto the card. This combines the easy synchronization capability of multi-axis motion cards with the reliability advantages of drives.

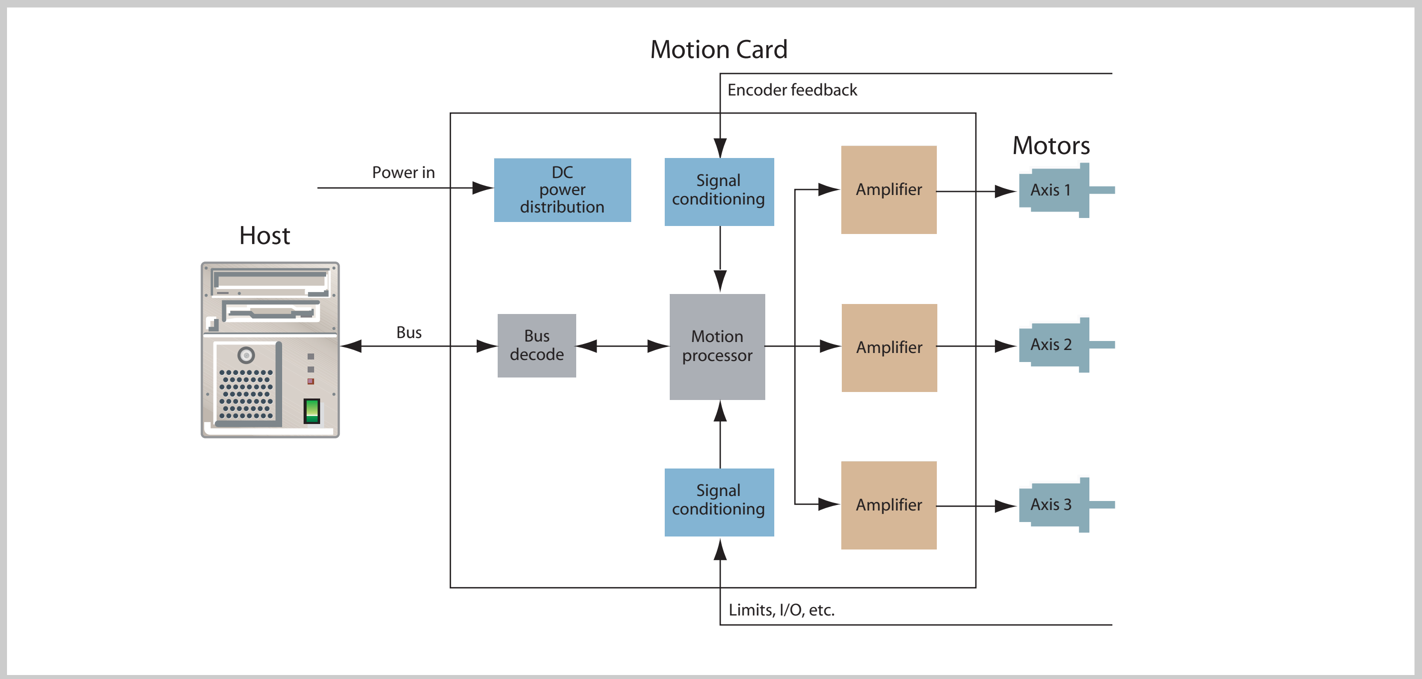

Figure 4. Integrated motion card

A big advantage of this approach is easy servicing and very low cost, since there are no separate amplifiers to purchase. The main disadvantage is that the motor drive power levels tend to be low, since high switching voltages and heat are difficult to combine reliably with sensitive digital logic circuitry.

Another important consideration is that the total number of possible combinations of motion computing platforms, amplifier power levels, and motor types, is extensive. Because of this, integrated motion cards tend to be designed for a specific application, rather than purchased off-the-shelf.

Such a custom card design can be a major undertaking, because algorithms for profiling and servo loop closure can be complex. The availability of off-the-shelf motion processor ICs greatly simplifies the task however. These ICs, available from a number of vendors, provide built-in functions such as trajectory generation, servo loop closure, commutation, and other functions.

Choose one and call me in the morning

When should a particular architectural approach be used over another? There are no automatic answers, and sometimes two architectures can be used with success for a given application.

In general terms, the more cost-sensitive the application, the more likely it is that designing a card will make sense, and if possible, integrating on-board amplifiers. Using this approach you can choose exactly the connectors you want, and size the card's form factor for your own application.

Highly synchronized systems involving higher power motors, such as machine tools, will gravitate toward either multi-axis motion cards, or increasingly, toward tightly-coupled distributed drives. While not cheap, these drives allow a lot of flexibility in motor type and power range. Since this is a tightly-coupled approach, you will still need to purchase a motion control card for overall path generation, and to coordinate the tiny move segments executed by each drive.

A large number of applications such as medical automation, semiconductor automation, scientific instrumentation, and low-power general automation, are well-served by loosely-coupled distributed drives, or by multi-axis motion cards. Considerations that push the solution toward distributed drives include larger number of axes, and use of two or more different motor types. Considerations that tilt the solution toward multi-axis cards are the need for synchronization.

Intelligent Motion Modules

OEMs designing high performance, cost-sensitive machines have typically steered clear of “big iron” solutions such as standalone drives. Large and bulky, they often require the user to learn special motion languages, and are expensive.

But the latest generation of motion modules is entirely 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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About Performance Motion Devices

Performance Motion Devices (PMD) is the recognized world leader in motion control ICs, cards, and modules. Dedicated to providing cost-effective, high performance motion systems to OEM customers, PMD utilizes extensive in-house expertise to minimize time-to-market and maximize customer satisfaction.