Motion ICs Make Their Move

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Engineers that use motion control in their products are used to making decisions. Should step motors or servo motors be used? Will the system be direct drive or geared? These kinds of choices are what make motion control interesting as well as challenging. Motion controllers are the electronics associated with driving motion control actuators, and are no exception to this rule. In fact, the variety of choices available in the last several years for motion electronics has expanded at an impressive rate, resulting in cost savings and novel control architectures.

A direct comparison of motion controllers from past to present shows that costs are indeed dropping, but designers are finding that even larger savings are coming from changes in the architecture of the controller. This includes the much-discussed trend toward network-based (distributed) control, but perhaps equally important is the availability of new motion ICs which make it possible to integrate previously separate control functions more compactly and easily.

This article will discuss choices in motion control electronics with a focus on cost savings that can result in integrating functions that were previously separated. Emphasis will be placed on recent developments in motion ICs that have made these new architectures possible.

Rewriting the classics?

Figure 1 shows the classic bus-based motion board architecture that uses a controller card and separate amplifier modules. Cables connect the motion card to the amplifiers, the amplifiers to the motors, and the motors to the card. Because the popular standards for motion cards have evolved to support PCI, PC/104, compact-PCI and others, this architecture is still relevant today. But its weakness is the number of cables required to interconnect everything. The cost of this complexity is measured in dollar terms as well as reliability; since connectors are an important source of failures and signals on wires can degrade with distance.

The attendant costs of this approach represent a major dilemma in motion control, and solving this problem through the use of alternate architectures has been a major priority in the past ten years. Generally speaking, the goal is greater integration at the card level to eliminate connectors and cables.

Figure 2A shows an alternate control architecture which integrates the controller function and the amplifier function onto a single card. 2B shows a corollary version where the host software is also included on the control card, in the form of an on-card microprocessor. This second architecture is sometimes referred to as a machine controller, since it provides all control functions necessary to run the machine. Either of these approaches offer the advantage that the controller and the amplifier do not require cables to be interconnected, and the amplifier is much less expensive since it is integrated at the IC level rather than purchased as a standalone unit.

When is it appropriate to integrate the motion controller with the amplifier onto a single card? There are many aspects to this question, but the single most important factor is the power rating of the amplifier. Combining the motion controller with the amplifier tends to be most viable in lower power systems, such as those that drive NEMA 34-sized motors or smaller.

Another consideration is bus architecture. If other parts of the control system use a standard parallel bus, then it makes sense to locate the motion card on the bus, and separate the amplifier function. Although convenient in one respect, this represents a constraint to integrating the controller with the amplifier. By comparison, network/serial buses do not have this limitation, since there are no physical form factors to mate the control card to. This is one of the reasons that there has been so much excitement about distributed networks for motion control.

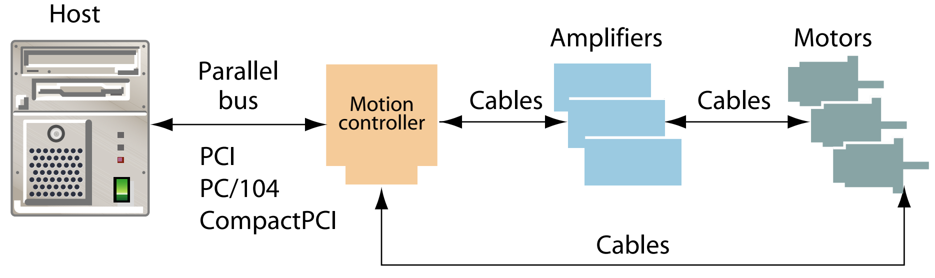

Figure 1. Bus-based motion card architecture

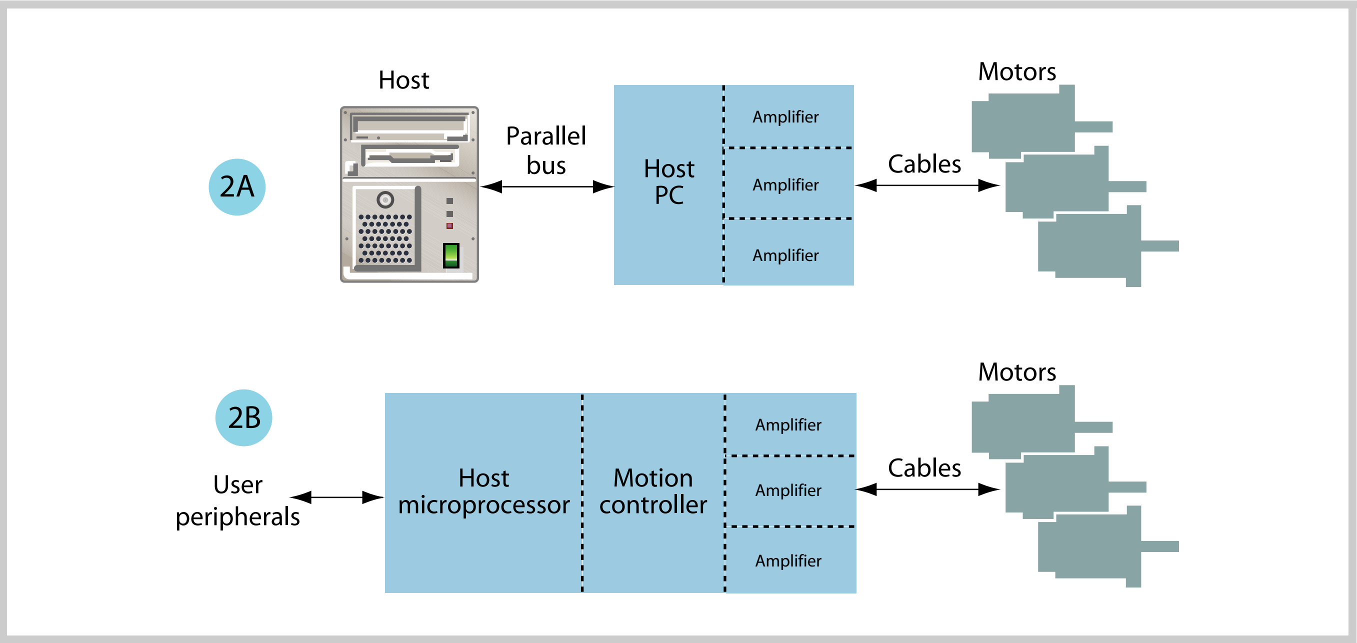

Figure 2. (2A) Integrated controller/amplifier; (2B) Machine controller (intergrated motion controller with host microprocessor)

The little engine that could

Whether the integrated control card pictured in figures 2A and 2B is built for a standalone configuration, or is located on a network, certain design considerations must be kept in mind. Figure 3 shows an internal block diagram of a typical integrated motion controller. The major elements are the motion processor, the signal conditioning circuitry and the amplifier. Note that there may be other major sections including a network interface chip and a host microprocessor, depending on the overall control and communications architecture.

The motion processor is the central IC that performs most of the motion control functions. These functions include quadrature signal decoding, trajectory generation, servo loop compensation (if servo motors are used), PWM (pulse width modulation), analog, or pulse & direction motor command output generation. Other functions may include commutation, digital I/O, analog I/O, breakpoints, servo trace and motion performance monitoring.

Since about 1985 it has been possible to purchase the motion processor off-the-shelf from a number of vendors. Varying in their degree of sophistication, the number of axes supported, and the motor types they work with, these handy products provide high-level motion commands and manage all low-level interface to motion peripherals.

Motion processors connect to the outside world through a parallel microprocessor-style interface, a serial interface such as RS232 or RS485, or more recently, via networks such as CANbus. Early-on, their motion features were not as powerful as those provided by off-the-shelf cards, but in the last five years that distinction has disappeared with the addition of S-curve profiling, dual biquad filtering, and on-board trace.

Hardware Trace Buffer aids in performance tuning

Here's the scenario: Your motor jogs in 16.8 mSec, but the spec calls for 15. You suspect that the servo parameters aren't optimized, but you're having trouble determining what's going on *inside* the motion controller. Solving this problem calls for a high performance data capture system, and many off-the-shelf motion solutions provide some form of this important capability.

The gold standard of data capture and display is known as a hardware trace buffer. Compared to older polled approaches, hardware trace guarantees synchronicity, and is limited only by the size of the on-card trace buffer. Here's how it works: before capture begins, the user selects which parameters are to be traced, usually as many as four at a time. Then the user specifies the capture event, much like a trigger on a traditional oscilloscope. Once trace starts, the motion processor loads the specified parameters (synchronized to its own cycle time) into a RAM buffer for later retrieval and analysis. Variations on this theme include rolling storage mode, where the user continuously reads as the motion hardware continually writes, and a programmable stop trigger.

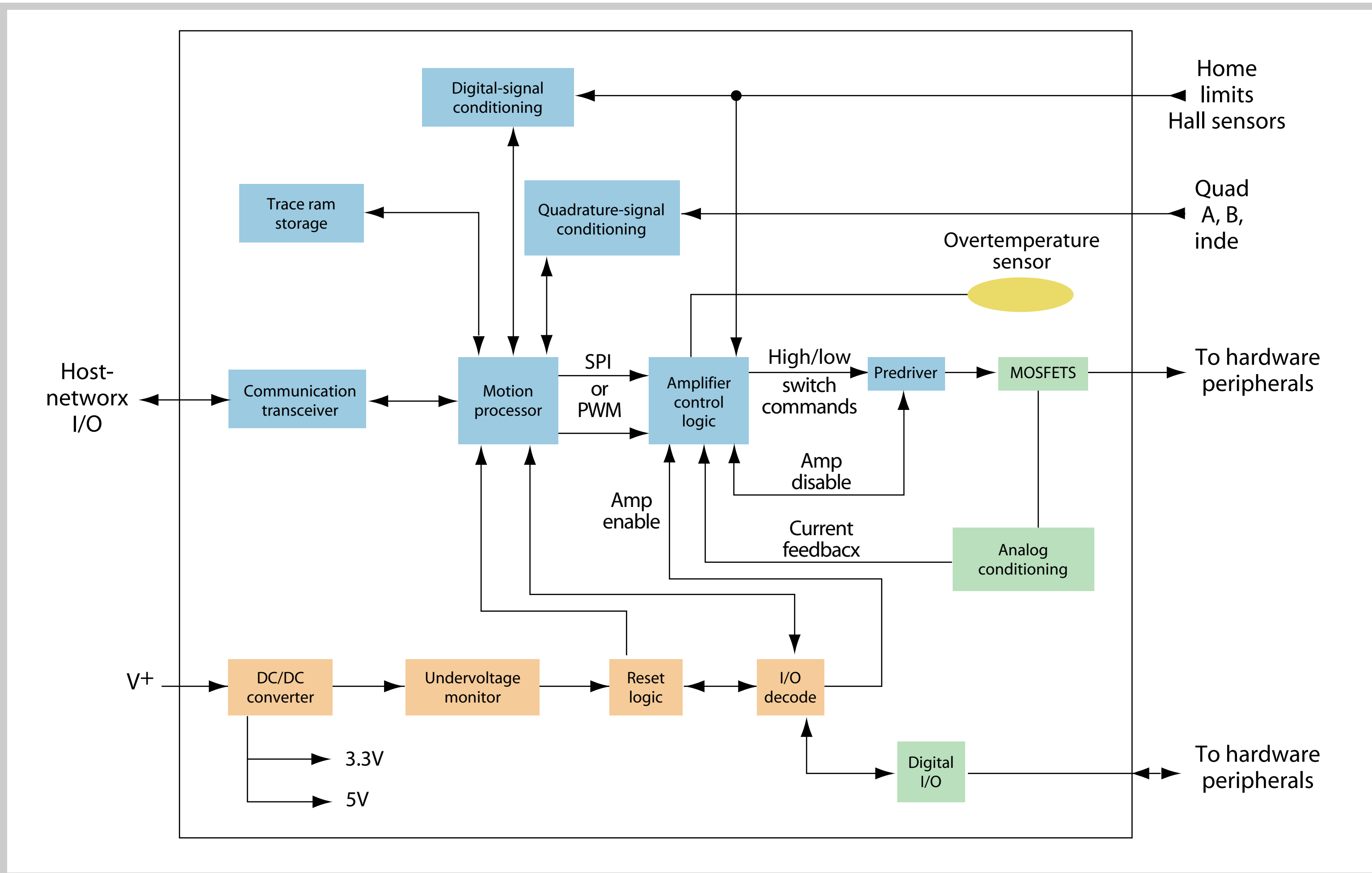

Figure 3. Integrated controller/amplifier internal block diagram

The other major choice for the motion processor is to purchase a DSP (digital signal processor) or microprocessor and program the motion functions directly. This approach has the advantage of lower cost, not only because most DSPs are less expensive then dedicated motion ICs, but because if the application is simple enough, it may be possible to eliminate the need for a separate microprocessor that contains the host code. Combining the host code (the code that controls the overall machine function) with the motion processor function has drawbacks. Motion processors generally require high speed, synchronous attention to motion peripherals, while the host code spends much of its time servicing communication requests or determining the next action. Combining the two functions does not always make for a reliable and responsive system.

Another factor is motor type. Programming a servo loop is complicated, and relatively few designers attempt this themselves. Getting the micro to generate pulses through a digital I/O port is simpler, so if the application uses a step motor, a home-built motion controller may be a good option.

On top of these product design considerations however, it is important to consider overall project costs as well. Off-the-shelf motion chips result in a shorter development cycle because the design effort focuses on the application itself, rather than the low-level motion routines. In addition to this, motion IC vendors provide developer's kits for their products. These products contain PC-based cards along with programs and software tools which save time, because they allow members of the design team to start working earlier. The software engineer can start writing motion sequences early on, while the mechanical engineer can prototype different motors and linkages before the application motion card is available. Once the application motion card is ready, the code can be hosted on the actual user-developed card for final integration and testing.

Pump up the volume

The other major part of the integrated control card is the amplifier. The amplifier takes relatively weak signals from the motion processor, phases them for the given motor and application, and amplifies them. The motor command from the motion processor is either a PWM signal, a +/- 10V analog signal, or a pulse and direction signal. Servo motors generally use the first two methods, while step motors use the latter.

A newer variation for analog motor output is SPI (Serial Peripheral Interface) format. In this scheme the motion processor outputs a 16 bit signed motor command on a digital serial line. This method is useful because a number of D/A (digital to analog) converter ICs and other amplifier controllers directly accept it. Compared to the traditional +/- 10V analog scheme, this method is an improvement because it avoids conversion to analog on both ends, a noise and cost-inducing process.

Depending on the architecture of the motion processor, commutation may be done in the amplifier, or it may be done by the motion processor. It should be noted that only brushless DC motors require commutation. If the amplifier is to perform the commutation, then the motion processor sends a single phase signal for each motor, and the amplifier uses Hall sensors to distribute the power to the correct motor coil. If the motion processor performs the commutation, then it sends multiple motor signals per motor (one for each motor phase) and the amplifier does not have to perform any commutation. Using the motion processor to perform commutation has the advantage that it can perform more advanced motor control techniques such as sinusoidal commutation and field oriented control because the motion processor "sees" all the signals from the motor, including the encoder data stream, while the amplifier only "sees" the motor currents.

Another important consideration for amplifier design is whether or not current control, also called torque control, will be used. Current control means that there is an additional control layer between the motion processor and the motor which measures the actual current through each phase of the motor and adjusts the drive voltage to match the desired current (from the motion processor) to the actual current measured in the motor. Current control generally increases the bandwidth of the motor, which means it can react more quickly to outside disturbances, and thus is a must for high end applications such as machine tools. Lower power and/or lower performance applications may consider not using a current loop as long as some type of over current protection is included to protect against short circuits at the motor.

Ready, set, amplify

Once some of these decisions have been made, there are two major design approaches for motion amplifiers. The first utilizes all-in-one low power amplifier ICs, while the other utilizes discrete components such as pre-drivers, MOSFETs or IGBTs and other circuitry. All-in-one amplifier ICs integrate PWM signal input, current control, a charge pump and switched output voltage drive into a single IC unit. Although incredibly convenient, they top out at about 36 volts and 4 amps of output, often less — depending on the application. If your application exceeds that, or if you are looking for higher performance and more control over the design, you will likely be using the discrete approach to assemble the amplifier.

Until recently, designing a discrete component amplifier from scratch, particularly one with current control and high efficiency MOSFET switchers, was a complex undertaking. But in the last year a new type of motion control IC has been developed by several companies — including International Rectifier and Performance Motion Devices, Inc. (PMD). Known as intelligent motor controllers (IMC), these devices are designed to interface with external switchers such as MOSFETs or IGBTs, while internalizing functions such as current control, PWM generation, shoot-through protection, and more.

Figure 4 shows a block diagram of a typical intelligent amplifier IC. It can be programmed to perform commutation, torque control and velocity control. It can communicate via a serial port to a microprocessor, or can accept a direct SPI data stream for autonomous operation.

Future improvements for intelligent amplifier ICs may include more power efficient commutation techniques and other features designed to work with high power, high efficiency motor applications. Power efficiency in traditional positioning motion control is not usually a primary concern, but for ancillary markets such as white goods, electric vehicles, and industrial applications (such as pumps, compressors and A/C units) it is rapidly becoming very important.

Summary

Newly developed motion ICs have made it easier to integrate amplifiers with motion controllers, thereby lowering cost and improving reliability. Knowing the tradeoffs in the build versus buy decision for motion control applications is important, and when making this decision, the overall cost of the system including maintainability and time to market should be considered.

A new type of controller IC, known as an Intelligent Motor Controller has been developed which is designed to dramatically simplify the design of motion control amplifiers. By integrating the functions of profile generation, current control, commutation, and switch signal timing generation, these ICs promise to increase the ease with which designers can integrate the control function and the amplification function, thereby reducing cabling and improving reliability.

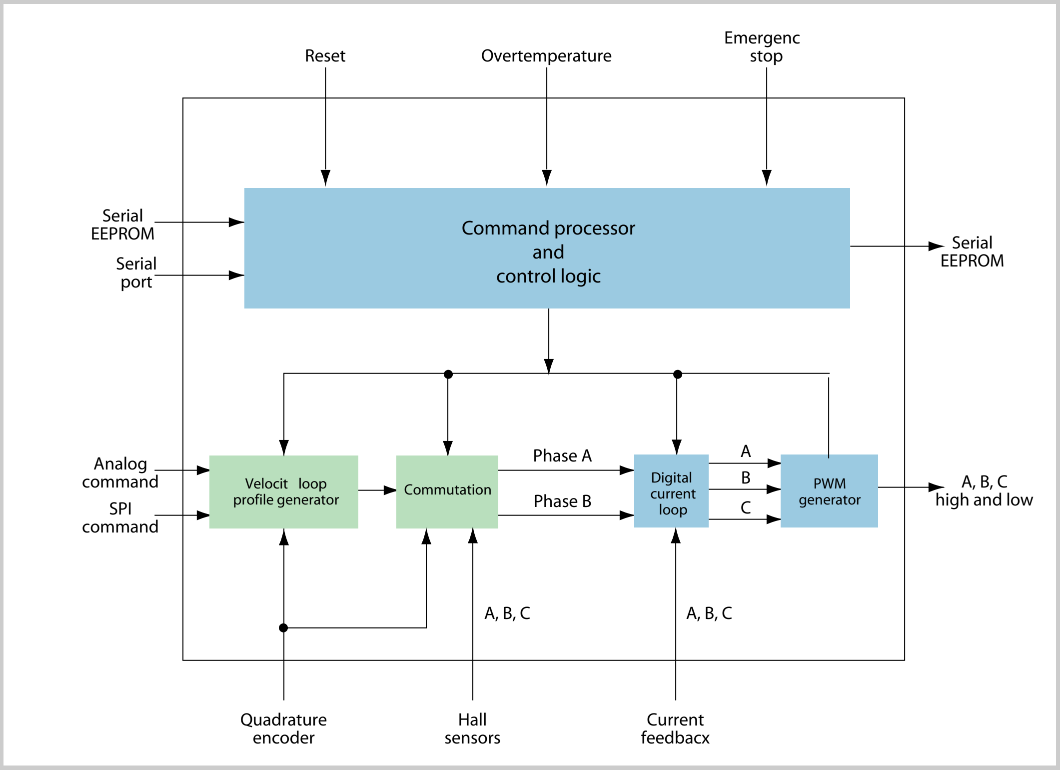

Figure 4. Intelligent motor controller internal block diagram

Brushless Motor Control IC

Thanks to new developments in MOSFETs, IGBTs, and DSP-based control, motor amplifiers have never been more compact and reliable. But even with all these innovations, engineers are still left with a difficult choice of purchasing an expensive off-the-shelf amplifier, and designing an amplifier from scratch using discrete components. Now, a new type of motor control IC has been developed known as an *Intelligent Motion Controller* (IMC) which provides a third option.

The MC73110 from PMD is an example of such a product. It accepts a desired torque or desired velocity command, and performs all functions required to output 6 synchronized digital signals which control the high and low sides of a triple-half bridge. Internally it integrates analog current input, quadrature encoder input, commutation, digital torque control, shoot-through compensation, and over temperature management.

IMCs usually come with a developer's kit which includes Windows software and a complete amplifier card. The card can be used as a test bed for development, or as a template for your own design. Either way building a high performance brushless DC motor amplifier is now easier and faster then ever before.

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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.