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PC-Based Motion Control

In conjunction with PC processing power increases over recent years, powerful motion controller plugin PC cards have become available. The combination of the two is fueling the use of hybrid, PC-based industrial motion control solutions for automation applications.

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For many applications such as light manufacturing, laboratory machines and instrumentation, a popular way to implement motion control requirements is to integrate plugin motion control cards into personal computer (PC) platforms. These embedded motion control systems combine digital signal processor (DSP) and field programmable gate arrays (FPGAs), and have become a mainstream method for the design of open architecture systems based on the x86 PC platform.

These form factors, which have mainly been driven by the specific computer platforms they work on, enable typical PC hardware to be extended with powerful motion control capabilities. Making this solution even more attractive, PC computational performance has increased exponentially while the cost has been dropping rapidly.

With the proliferation of powerful and economical PC platforms, end users have been looking for ways to simplify and consolidate motion control platforms to realize improved performance at lower cost.

Today, most industrial automation tasks use PCs to some extent or another, and both engineers and plant floor personnel alike are extremely comfortable with this economical yet powerful solution. But even a modern PC and multi-tasking operating system (like Microsoft Windows) does not offer the required feature set to properly achieve motion control. This means PC platforms must be supplemented to effectively provide motion control.

A motion control card can be installed into an industrial PC to achieve the best of both worlds: high-performance motion control combined with a user-friendly PC-based supervisory system. These motion control cards incorporate dedicated microcontrollers with a localized real-time operating system to ensure responsive operation.

In addition, these cards include native support of industry-standard Ethernet protocols optimized for motion control. Furthermore, standardizing on a motion control card allows engineers to reuse this critical component for many different applications, while the supervisory PC can be configured with a variety of software packages to meet user interface and other needs.

Hybrid architectures combining a PC with one or more integrated motion control cards offer a number of technical and commercial advantages for system designers as compared to traditional solutions implemented with separate motion controllers. This white paper discusses the basic requirements of motion control systems, and the benefits of integrating PCs with motion controller cards.

Real-Time Basics

In the most basic sense, motion control applications are all about speed. For purposes of this white paper, we are considering not so much the speed of the resulting motion devices, but instead the required processing speed of the motion controller system. A controller system with enough speed can evaluate the position, velocity and acceleration of motion devices; execute supervisory control logic; and command the available output signals—all fast enough so the system motion always remains within required parameters. If any of these actions happens too slowly, the result will be a system veering out of control.

The PC system is performing numerous fundamental administrative tasks (such as checking the keyboard and mouse), orchestrating some demanding activities (such as updating the user displays), executing many user programs and constantly coordinating so none of these tasks conflict. Along the way, calculations will always be correct, but it is less important exactly when they occur.

A CPU is “context switching” very quickly among these tasks, and while it is really only doing one thing at a time, it does each task so fast that the end result appears to humans like all necessary tasks are occurring concurrently. All of this switching coordination actually introduces an additional computational overhead load, which exacerbates the issue of added delays. Yet the resultant reality, from a human perspective and timescale, makes it unimportant if any of these tasks happens a millisecond earlier or later than planned.

On the other hand, motion control applications can definitely be impacted by even by such minute timing variations. The efficiency and stability of data processing in motion control processes play a crucial role in achieving the desired system characteristics of high speed and exacting precision. In these cases, not only must the computations be correct, but they must be supplied with fresh data, and produce results in a timely manner. If any timing constraints are not met, then system failure may occur.

Time sensitive systems as described here are said to be “deterministic”, which implies not only will functionality be achieved quickly, but it will be performed predictably for a given task. Of course, the predictable response must be sufficiently fast to support the desired motion control performance. Operating systems able to provide deterministic operation are often referred to as real-time. These real-time operating systems (RTOS) are a necessity to achieve effective motion control.

RTOS systems still perform fundamental task management, scheduling, resource allocation and interrupt handling—but in a way guaranteeing critical processes will occur in a rigorously scheduled manner.

Motion control cards fit these requirements exactly. In practical terms, motion-based motor control functions must execute on the order of microseconds, while supervisory control works well with millisecond execution (see Figure 1).

An ideal motion control implementation combines multi-tasking convenience with deterministic performance, even though the two methods would seem to be at odds with each other. That is why an excellent method of reaching this goal is to use a hybrid system consisting of a traditional COTS PC with a specialized RTOS motion control subsystem. This is possible by using other industry standard technologies such as PCI interfaces to provide a high-performance motion control solution.

Achieving High-Performance Motion

Relying on standard hardware and software technologies is the best way to create a hybrid system of this type with the necessary reliability and economy. Fortunately, each of the requirements and constraints can be met by using off-the-shelf components. Table 1 points out some considerations when building a PC into a high-performance motion control solution.

Table 1, Requirements for Delivering High-Performance Motion Control with a PC

- Reserve multi-tasking for the PC platform
- Offload critical motion computing tasks to controller cards
- Package controller cards as standard high-speed PCI interfaces
- Use controller cards employing DSP and FPGA technology to provide the required performance
- Outfit the controller cards with an RTOS
- Ensure deterministic operation
- Include EtherCAT high-speed communication

Multi-tasking operations, such as supervisory control and operator interface functions, are reserved for the main PC platform. This keeps these demanding yet less time-critical tasks on a platform where they will run well and provide the best user experience.

Motion control tasks, on the other hand, are offloaded to dedicated controller cards. The PC generally does not need any special characteristics, and most any contemporary PC could be up to the task. However, for challenging environments or duty cycles, it is advisable to use an industrial PC (IPC) of some sort, as depicted in Figure 2.

Packaging controller cards into the PC mandates a high-speed interface between the two, and the standard PCI interface offers plenty of performance, and also supplies the necessary power to the cards. A typical controller card would incorporate DSP or FPGA technologies, which are optimized for high speed computations, and are therefore ideally suited to provide the level of performance demanded by motion applications.

In particular, FPGAs provide “state-of-the-art performance and flexibility to system architects to customize their projects with a flexible (programmable) electronic circuit structure,” making them ideally suited for motion applications (Reference 2). For similar reasons, a reduced instruction set computing (RISC) processor is often used in these applications.

Controller cards run an embedded RTOS to provide deterministic performance for the motion application, and can interface with the supervisory multi-tasking system without burdening or impacting either system.

The final step is to ensure the motion controller can communicate effectively with the actual servo drives. While general Ethernet and various industrial protocols have risen to prominence in many areas of automation, motion is a more demanding application, requiting high speed and deterministic communication.

One communication technology tailored for motion applications is EtherCAT. Building on established Ethernet technologies, EtherCAT utilizes a flexible hardware topology and a unique, constantly transmitting data frame to achieve high speeds. Additionally, this structure provides synchronization through timestamping, critical for high speed motion instructions.

Advantech, a global leader in providing automation products and solutions, offers a PCI-based motion controller card with all of these features. The PCIE-1203 includes two EtherCAT ports, and also supports on-board discrete inputs and outputs. It is powerful enough to support up to a total 32 axes of motion control, distributed among 6 motion groups. A common motion software development kit (SDK) helps users achieve rapid application development. In addition, the controller card uses Advantech’s real-time enhanced script (ARES), a powerful embedded motion control scripting language. Figure 3 shows the card’s compact form factor.

High performance motion control can readily be achieved in an open and flexible manner using PCs, dedicated controller cards, and numerous underlying hardware and software technologies. This combination provides excellent functionality and helps users achieve their goals.

Benefits of a Combined Multi-Tasking and Real-Time Motion Control Solution

Hybrid motion control systems which combine PCs with motion control cards represent an optimal solution. End users will realize a number of benefits when selecting this configuration, as listed in Table 2 and described in following paragraphs.

Table 2, Benefits of a PC-Based Motion Control Solution

- PCs are a ubiquitous platform, so users are very familiar with the technology
- The Windows OS offers an easy to use, multi-tasking environment
- PCs can incorporate HMIs, eliminating the need for a separate component
- PCs are open and can thus host many different types of software
- PCs provide connectivity to upper level computing systems
- Combining the hardware/software platform, instead of using multiple platforms, saves space and cuts costs
- Established embedded RTOSs are reliable, predictable, scalable and compact
- Implementing control in system on chip (SoC) hardware with a RTOS simplifies software portability for the supervisory platform
- Motion-specific controller scripting, such as Advantech's ARES, simplifies and speeds development

Using commercial or industrial PCs for motion control solutions is the most significant reason designers and engineers will realize savings and ease of use benefits. PCs are a common, cost-effective and well understood product. They are a very accessible technology for the engineers and technicians likely to be working with motion control systems.

Beyond the common PC hardware platform, the Windows operating system (OS) is the most popular OS worldwide for desktops and laptops. It provides a mature and highly developed user interface, and a natural multi-tasking environment with exceptional ease of use.

In great part, PC usability is derived from the detailed video displays offered by the hardware and OS. During software development, these displays make if far more convenient and even intuitive for users to configure the system.

Once a hybrid PC motion solution is in operation there is another significant advantage, which is the PC can act as a powerful human machine interface (HMI) for the application. This eliminates the need for an additional interface component, and results in a tightly integrated system.

Just as PCs can facilitate human interaction, they can also enable digital domain actions and communications. Windows PCs are open in the sense they can be used to run any number of programs complementary to the motion application. This can include local historization of process values, event logging, or related calculations or algorithms.

PCs can also provide connectivity to upper level computing systems such as supervisory controls, or even a manufacturing execution system or an enterprise resource planning system. This level of flexibility is simply not available on dedicated or custom platforms.

Consolidating PC and motion control elements into a single hardware and software platform typically reduces costs, and almost always minimizes the complexity compared to coordinating multiple different platforms.

While the motion control card represents a more specialized piece of the puzzle, it still uses standardized features, making life easier for end users. For instance, the established embedded RTOSs are reliable, predictable, scalable and compact. They are a highly-tested and known quantity, optimized for this type of use.

On the hardware side, motion control cards incorporate system on chip (SoC) hardware which integrates microcontrollers, coprocessors, signal handling and other components into a compact package. This is the reason a powerful motion control card can be incorporated into a PC card format. It also means the resulting card is modular for most any type of PC, which simplifies portability to any number of supervisory platforms.

Motion control cards also include certain mission-specific capabilities, for example motion-specific controller scripting, such as Advantech's ARES. This type of built in support simplifies the work required by end users, and speeds development. Next, we'll look at some actual applications which take advantage of these benefits.

High Speed Pick and Place

Pick and place equipment is a specific type of machinery common in many packaging, material handling, manufacturing and machining operations. These types of machines often use linear mechanisms to move tools or grippers in multiple axes in order to pick up (pick) and drop off (place) parts. This is a form of robotics, but often looks like carriages or gantries moving in X, Y and Z axes. This MachineDesign.com article compares some technical aspects of motion control and robotics applications (Reference 3).

While this type of equipment could be simplistically automated with basic reversing motors and limit switches, it is far more attractive to operate it with servo motors for several reasons. Servo motors on each axis can be driven at their own highest accelerations and velocities to move payloads at the fastest rate, without exceeding conditions which would cause the product to drop or be damaged. Working in conjunction, the servos can be controlled to transport the parts through an optimal path profile, which is often a smooth continuous curve.

For the integrated circuit test handler machine shown in Figure 4, these streamlined movements yielded 20% greater throughput. While this automation could have been

achieved with separate supervisory and motion control subsystems, this would have been more expensive and complicated.
This OEM vendor instead uses a PCIE-1203 motion control card installed in a PC, with the PC acting as a supervisory control and HMI station. Adding an Advantech AMAX-3285IO EtherCAT Motion Slave Module facilitates connection to position encoders, allowing the servo motors to be tightly controlled.

3D Glass Hot Compaction

PC integrated motion control is often the best choice for OEM equipment because it can provide a consolidated solution, as with this glass hot compaction system. This equipment takes a sheet of glass material, heats it with an infrared heater, and then autofeeds it into a tool press section where pressure can be applied in a controlled manner (Figure 5).

An EtherCAT-controlled motor must be operated to move the press into position while minimizing impact on the material, and then to develop the necessary pressure by monitoring the applied torque. This motor is therefore operated in both position-command and torque-command modes to achieve a final glass contour.

Combining PC and motion control functionality into one platform allowed the OEM equipment vendor to simplify the design while reducing complexity and cost, and to provide powerful supervisory control and responsive motion control.

Conclusion and Outlook

Many industrial systems take advantage of the performance offered by servo motors for motion control. When engineered properly, these types of motion control systems offer far better speed, precision and overall throughput than traditional simplistic automation using reversing motors and limit switches, for instance.

Since motion control is a demanding high-speed application, implementation used to require very specialized components which had to be integrated into the greater system. In recent years, as PCs and Ethernet technologies have risen in performance and prominence in almost all areas of industrial automation, engineers and designers have been looking to more closely integrate motion control with common PC platforms.

While PCs are certainly fast and user friendly, their multi-tasking nature and operating systems limit them to comparatively imprecise millisecond speeds, which is not sufficient for motion control with its deterministic microsecond speed requirements. Designers and engineers needed a way to combine both sets of requirements into one integrated platform.

PC-compatible motion control cards are the answer to bridging the two worlds. Designed with mission-specific processors and an RTOS, these cards have plenty of

horsepower for handling motion control, while interfacing with the supervisory PC at PCI speeds. The cards' EtherCAT networking interfaces enable optimized direct communication among motion devices using an industry standard protocol.

This hybrid solution not only provides optimal motion control, but lets the user consolidate many functions and supervisory software capabilities into an open PC-based solution. Today's end users now have an excellent choice for implementing cost-effective and easy to use motion control.

Figures:

Figure 1, PC-Based Hybrid Motion Control Architecture, A *hybrid architecture combines the necessary microsecond direct control of servo motors with millisecond supervisory control by PC applications.*

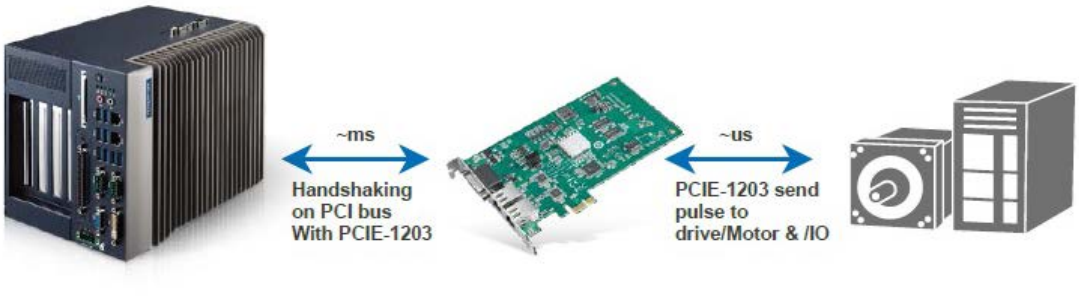


Figure 2, High Speed Pick and Place Application. *For many applications, such as this integrated circuit test handler machine, tightly optimized motion control results in throughput increases of 20% or more.*

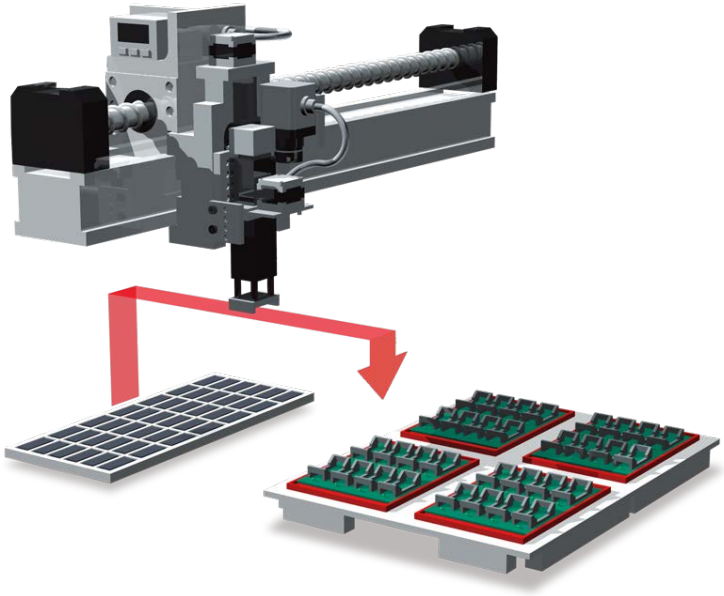
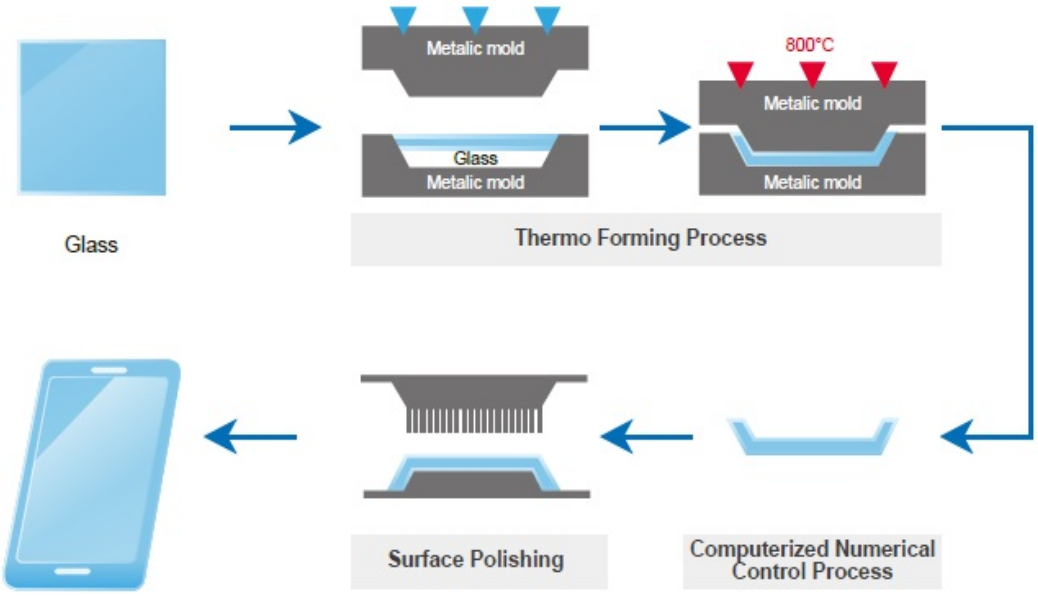


Figure 3, 3D Glass Hot Compaction. *PCs with integrated motion control cards can provide a consolidated solution for demanding applications, such as this glass hot compaction system.*



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Reference 3, What's the Difference Between Motion-Control and Robotics Systems?, Carlos Gonzalez, Machine Design, http://www.machinedesign.com/motion-control/what-s-difference-between-motion-control-and-robotics-systems