Servo System Control

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A basic servo system consists of a servo motor and drive which acts as the “brawn,” an encoder which is the “eye” and finally a controller which is the “brain”. A key area of concern is control, after all, it tells the servo what position to go to, how fast to get there and how long to stay there. Based on feedback from the encoder the controller measures the error of its commanded velocity or position and makes adjustments so the command becomes the actual position or velocity. This is called closing the loop. In addition to the controller’s responsibility to close the loop and generate motion profiles for each axis of servo, it also coordinates these profiles to ensure that multiple axes of servos meet at precisely the desired rendezvous points. Most AC servos today are capable of accepting both analog and position inputs from controllers. Analog control encompasses torque and velocity types. The level of torque or velocity is directly proportional to a +/- 10 volt signal output by the controller. Position controller output a pulse/direction signal or clockwise/counterclockwise signal. The amount and frequency of the output pulses from the controller will tell the servo how far and how fast to move.

So how does one make the proper control selection when building a machine? It would be easy to specify a sophisticated stand-alone controller to guarantee the performance and accuracy of the motion system. But perhaps there might be a less expensive or easier to integrate solution, like PLC control. The servo control system is usually just one component of the total machine control solution. Other parts of the motion solution could include HMI, control of machine interlocks, sensors, temperature control or PID control of a particular process, all of which must be integrated into the system. So now the job of selecting a motion controller gets a little more clouded with several different and sometimes conflicting demands, which must all be met in the complete system. So selecting the best choice for the motion portion may not be the best choice for the overall solution. Another common problem in selecting a motion controller is trying to squeeze big time motion performance out of a simple brick PLCs or other simple controllers. Though these controllers may be capable of simple point to point control with a high frequency pulse output, they were only designed for the simplest of motion applications in mind.. Every type of controller has a place in the motion control industry, the key is finding the right fit for each type of control. Easier said than done. This article will put the many different options for motion control into perspective and give the reader a foundation for control selection.

The control choices are many and include stand-alone, PC based, PLC co-processor types, micro PLC and combination drive/controllers. We will address the majority of the servo controllers and their basic capabilities. Which type of controllers will thrive in which application is a question that has no clear-cut answer. Deciding on the type of control you need, for instance between analog closed loop and semi-open loop pulse train, will help you narrow your choices. Response times, complex path (electronic cams or flying shear) operations, print or product registration and communications with other machine control system components are all factors which can help you eliminate control choices from the list. Once the motion application needs are understood, in the context of the overall control of the machine, now the commercial needs should be addressed. What is the cost of the total machine control system that meets the demands of the application? What is the cost of the programming software? How easy is that controller to program and troubleshoot, not only for the builder, but for the end-user?   How soon must your product be released to the market? Finally, how much value will the control type add to your machine? Will it make the machine faster, more flexible, produce less waste or monitor and log the process more closely? Will it easily tie into the variety of other automation products commonly used in motion applications or throughout the plant environment? All of these aspects will make the machinery more valuable to the user, whether it is being used in-house or sold as OEM equipment.

Micro PLC

The micro PLC fitting into this category would be the shoebox and the brick type PLC. When considered for motion control, these types of PLCs should be kept for the simplest of applications, probably for only one or maybe two axes. Anything requiring simple pulse control like a stepper or pulse input servo applications involving 5-10 different positional moves or set speeds might be a good fit. If cost is also an issue, a micro PLC solution could be the first controller to consider.

Some micro PLC manufacturers offer acceleration and deceleration instructions and pulse train outputs of up to 50Khz or more. Though these devices may come with many simplified functions in the programming software, the programming can be extensive and cumbersome in more complicated applications. This will not only prove costly in the up front engineering but can also significantly load the scan time of the PLC processor. Rapid reaction of the PLC to external interrupts (even high speed interrupts) is far less accurate and repeatable than what is commonly found on dedicated motion controllers. On the fly program changes are generally not possible due to the sequential compilation of the micro PLCs ladder program.. In a great many simpler applications the micro PLC pulse train position control will be sufficient to meet the needs of the application, without the expense and complication of a full closed loop motion controller. A machine generally needs a small PLC to control it, so the advantage of incorporating position control is very appealing. However, some care should be taken to ensure that the application is not too big for this simple solution.

Servo Drives With On-Board Controllers

Servo drives with on-board controllers, sometimes referred to as “smart drives,” bring some advantages to the table. These intelligent drives can simplify the engineering and specification for OEM machinery, since the motion control and drive are integrated into one package. At the individual axis control level these units can operate seamlessly with optimal execution times since the control and drive are already integrated.

These drives are best used for single axis applications, and can offer a cost effective yet complex path for motion control solutions in machines that are otherwise quite simple. This topology can become difficult to manage as you increase the numbers of axes, or need to interface to an HMI or PLC controlling the machine. This creates several centers of control that need to be coordinated, which is less than ideally achieved through a large amount of handshaking digital inputs and outputs, and writing serial interface drivers. Without careful management and programming, it is very easy to arrive at a situation where the different centers of control get out of synch with each other. Where there is a need for additional axes or a greater communication requirements with an overall machine controller, this is probably not the best choice.

Dedicated Or Stand Alone Motion Controllers

These have been specifically designed to control larger numbers of servo axes from one center of control. Because of their roots as dedicated motion controllers, these systems have had a reputation for being very proprietary in nature. They can be difficult to integrate with other elements of the overall machine control. Many systems still rely on the digital I/O and serial communications drivers. Some systems now offer network connection to the overall machine controller, using networks such as DeviceNet, Profibus and CANbus. That manufacturers need to develop these interfaces is evidence that machine builders need to interface the specialist motion controller.

Some stand alone dedicated motion controllers have very limited PLC functionality built in. Motion controllers are generally extremely good at complex path motion control, but poor at handling and interlocking large amounts of I/O because of the sequential nature of the programming languages. The machine designer has to be very conscious of these limitations.

Some manufacturers offer easy icon-based programming languages, which allow you to program the devices by dragging and dropping function icons on your computer screen. Although these software packages are easy to use in straightforward applications, they are not without their pitfalls. Underneath the veneer of the graphical programming environment lies a text based program that is compiled from it. The resulting program can be quite inefficient, in terms of the amount of standard blocks of code that it generates for the processor to run. This code is generated offline on the PC and then downloaded to the controller. The process can be quite time consuming, and not a little frustrating when only small frequent changes are being made. More traditional programming languages used for stand-alone controllers would include G-Code, BASIC and C. These languages do not appear to be as user friendly, but generally allow for more custom tailored applications and at the same time allow for faster compilation and execution of the controller's code. The speed of these controllers is perhaps their biggest asset, along with their proven success in applications.

Another advancement that makes these types of controllers appealing are the developments of high-speed motion networks such as SERCOS or Mechatrolink. These networks use a dedicated motion protocol which make the interface between the servo drive or drives, sensors and the controller relatively quickly. Even though these networks are carrying high-speed short messages, they can quickly approach the limits of the network bandwidth, and have to revert to slower position demand update rates when used for larger numbers of axes.

These motion networks are also offered to be used in other types of servo control but are found most prominently in stand-alone, CNC and PC type motion control systems. SERCOS fits well with stand-alone controllers because it is only necessary for complex applications. It of course could be used on more typical applications but the cost may not justify such interface. Even with all of these developments, stand alone devices are becoming more flexible in nature. Using such a device for complex applications almost always will make it necessary for another level of control whether that be secondary or the host.

The Modular PLC With A Co-Processor

The modular PLC with co-processor modules brings a night to day change in performance, features and options for motion control over the micro PLC, and is an excellent choice for motion control. So it is very important to consider modular type PLCs in a completely different category to micro, especially where motion control is concerned. The use of co-processor modules is what sets these two apart. The co-processor will handle the burden of the motion commands so they will not tax the CPU of the PLC. Also, other coprocessor modules can handle communications, networking, temperature control and PID control etc. This increases the motion control performance of the system because the motion controller module does not have to wait for the sequential scan of the PLC.

With a separate co-processor that is a fully featured motion controller, running its own motion control programs with its own high speed I/O, PLCs can potentially get the best of both worlds. We can have all of the benefits of the power of a dedicated motion controller, and combine that with the machine control functions and interconnectivity of the PLC. If your machine requires extra digital I/O, process control, analog inputs, high speed counters, bar code readers, RFID tagging, this information is available to your “motion control system”. For example is becomes very simple to take information from several load cells to vary the electronic gear ratio between two or more axes, to achieve very stable tension control.

Though many PLC manufacturers offer motion options for their PLCs they do not always offer a comprehensive range of motion functions. So it is very important to check the motion capabilities of a particular PLC manufacturer before specifying their product. Some PLCs have motion control co-processors that close the position loop on the servo motor, but have position demands generated in the PLC ladder and sent over the backplane to the motion controller. The system designer must be very careful as this can introduce significant communication delays of as much as 10mS, depending on the population of the backplane.

Applications include point-to-point position control, complex path operations, print or product registration and torque control. Most effective in the range of 2 to 60 axes, the modular PLC can provide many advantages. The motion module controllers themselves incorporate some very intuitive software, which can make the programming very simple. A limited knowledge of ladder logic is necessary, that knowledge will come in most handy in programming other type devices which you can connect to the PLC. The PLC can be used to store the complete recipe of machine setup information for a range of products. This information can be loaded, altered or stored via the HMI or a SCADA system. Because of the speed and flexibility of communications over the backplane, there is much more that can be achieved in terms of closely integrating the PLC and the dedicated motion controller co-processor. The motion control setup parameters (for example, product length) can be stored as a subset of the machine setup parameters, and downloaded to the motion controller as a new product is selected. The motion control can be programmed in such a manner that the PLC interlocking has much more direct control over the motion control program. For example the PLC could check that the machine was datumed correctly or that sealers were at the correct temperature before allowing the machine to run. Also this combination offers much in the way of detailed error reporting via one system either to a local engineer, or remote technical support.

Ladder logic is the predominant programming language in the industrial automation industry. However there are other languages that are now available to program PLCs. So a first time user without an extensive electrical background may find a function block programming language easier to understand. Many of the PLC manufacturers are conforming to a European standard (IEC 1131-3) which will make all PLC programming software very similar in look, feel and function, including expanded programming language acceptance. IEC 1131-3 is not just geared to PLC but other types of controllers as well. Motion control is not just an add-on feature to the PLC anymore. PLC based motion controllers are capable of torque, speed, position and complex path motion control. They are so capable in fact that they are well suited for applications that just five to ten years ago it would have been necessary to use stand-alone control. All of the communications and complex functionality such as camming and web-tensioning can be realized using a PLC co-processor module. The modular PLC brings *one* centralized controller, vendor reduction, performance, expanded functionality, easy integration and a familiar programming environment.

<u>PC Control (Soft PLC Motion)</u>

For years industrial computers have been controlling Computer Numerically controlled (CNC) applications in the motion control industry. These computer controllers with integrated PC bus boards and dedicated embedded software make this type of control more difficult to integrate with other machine functions.

Incorporating third party components by developing communications drivers into a machine can be expensive, significantly increasing engineering time and adding unnecessary technical risk.

Today's PC-based motion control can be done a couple of different ways, still with dedicated PC-bus boards or through software programs alone. PC bus based motion has all of the capabilities that PLC and stand-alone motion control have however you now must place all of your faith in the operating system of the PC. True these OSs are becoming more stable and gaining industry approval, however, there is still nothing that has been widely accepted by the automation industry.

Initially the cost of the PC hardware may seem very attractive when compared with stand alone industrial PLCs. However, once you add the motion controller cards, specialty I/O cards, I/O, communications cards, software and drivers, the price advantage of PC control becomes very marginal indeed. Perceived cost savings are not the only driving factors in the moves towards PC machine control. Users enjoy the idea of integrating all control into one package. Software applications offer ease of programming, troubleshooting and monitoring.

Software based PC motion is similar in many ways to PC-board based control. The advantages and disadvantages are pretty much the same since they both rely on a PC as the control platform. But the difference lies in the fact that the motion control is all dependent on the software not the combination of the software and hardware (PC card). Software-based motion control depends on digital technology for high speed communication between the servo drive and the controller. These interfaces include SERCOS (which was previously mentioned), Macro and other motion networks based on Firewire. SERCOS, which is by far the technology leader in this type of digital interfaces, has membership of over 16 collaborating manufacturers and seems to be the most popular choice. Software based motion controllers eliminate the cost of the motion PC board, but adds the cost of the digital interface, which in many cases is more significant that the cost of the PC board alone. There still are many questions which surround the reliability of open architecture PC control that may deter more conservative end users.

Wrap-Up

It should now be apparent that each controller has a place in the growing motion control industry. The ever-improving modular PLC is an excellent choice today, offering a centralized controller, high performance and easy programming and integration. Ultimately the selection comes down to the control product that provides the best balance of safety, flexibility, functionality, reliability, maintainability and simplicity.

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Captions:

(File: *MC221*) Omron's MC221 motion control module for Omron CS1 PLCs. Also featured is Omron's CX-Motion software, which is used to program motion data into a PLC.

(File: *Pulse IO Board*) Omron's CQM1H PLC has a Pulse I/O board that is equipped with 2 ports which each support a high-speed input at up to 50KHz and a high-speed output at up to 50KHz. A Pulse I/O Board can be used for simple 2-axis positioning or speed control with the frequency conversion instruction.

(File: *CPM2A Omron PLC*) An example of micro PLC motion control. The output pulse frequency can be set to be a specified multiple of the input pulse frequency and that multiple can be changed from the ladder program. This function can be used to adjust the feed rate of packaging film so that the brand name or other printing remains in the correct location during packaging.