A Motion Control Primer

George Stroud, Marketing Publicity Manager, VMIC

The industrial world is one that is full of motion. There are a variety of industrial, scientific, and commercial applications that require motion control. Designers of motion control systems must incorporate many disciplines of industrial automation into their design. The system must precisely control and monitor multiple processes in real-time. A controller is required to manage the overall system. The controller must be capable of real-time performance and be able to quickly monitor and control the processes. If this is a distributed process, it must also be able to communicate quickly with a master control point at a centralized location.

Monitoring of status signals must be performed. AC and DC signals ranging up to hundreds of volts must be handled. These high-voltage signals must be converted into levels the controller can understand. Controller output signals must be capable of running indicator lamps and running relays that handle the higher current loads. These are all considered to be digital I/O in nature because of the simple on/off function.

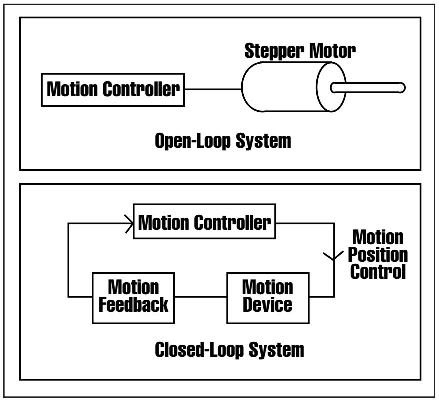

Figure 1.

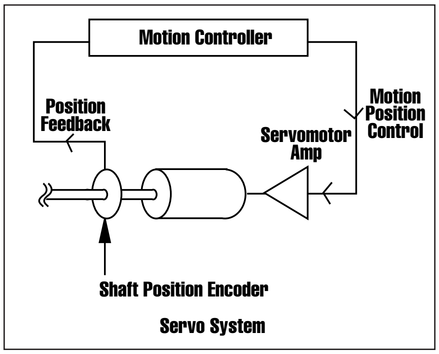

Figure 2.

Environmental analog I/O operating parameters may exist in the processes that require monitoring. These physical parameters such as flow, pressure, temperature, or weight must constantly be monitored. Indicator panels with analog meters must be driven to show the operating conditions. Analog output voltages may also be used to drive a servomotor amplifier.

Mechanical devices provide the muscle in a motion system and must be controlled and monitored. Applications may require a linear or rotational force, speed, and/or position to be controlled. This could take the physical form of hydraulics, pneumatics, electromechanical, and mechanical devices. Some examples of electromechanical devices are: AC motors, DC motors, stepper motors, and actuators.

DC motors are used to convert electrical energy into rotational mechanical energy. These motors are controlled by open-loop and closed-loop systems (See Figure 1). In an open-loop system, the motor's present position is not monitored. In a closed-loop system, the motor’s position is fed back into the control process.

The feedback mechanisms may take many forms. Incremental shaft encoders can be used to generate pulses that represent the shaft position. Synchro / resolvers may be used to indicate dynamic rotational position in a servo system. A servo closed-loop system is shown in Figure 2. The host computer sends signals to the servo power amplifier that in turn provides power to the motor. The motor's rotational position is fed back into the host computer, closing the control loop. Quadrature position measurement may also be used to monitor dynamic rotational position and direction.

(Throughout this text, references are made to specific VMIC board products. Readers are advised that the levels of functionality and integration vary from one manufacturer's products to another's. ED.)

This article describes a typical motion control system. For our purposes, a rack of VMIC VMEbus equipment is shown (Figure 3). The CPU (VMIVME-7589) is a single-board single-slot Pentium processor computer. It is complemented by the hard/floppy disk drive interface (VMIVME-7452). The high-density digital I/O requirements are handled by VMIC's128-bit boards (VMIVME-1182 and VMIVME-2128). The analog sensor inputs are handled by an autocalibrated 16-bit high-resolution board with on-board DSP intelligence (VMIVME-3126A). The analog output driving the servo amplifier is a 16-bit analog output board (VMIVME-4116). The synchro/resolver task is handled by VMIC's VMIVME-4941. The counter/controller (VMIVME-2540) is shown providing event counting and/or timer/period measurements. The VMIVME-2541 is shown performing Quadrature Positional measurements, stepper motor control and/or waveform generation. Tying the industrial system together is VMIC's industrial automation Soft Logic software, IOWorks.

The conveyor belt example is that of a manufacturing floor conveyor belt system. Parts are dropped onto a moving conveyor belt, detected for alignment and stamped with a bar code identification and collected in a receiving bin. This example is provided to show the numerous control and status monitoring points that are involved in implementing a real-world system.

Stepper Motor Positional Control Overview

Stepper motors are used for accurate rotational positioning. Unlike servomotors that require a closed-loop analog feedback mechanism, the stepper motor may be used in an open-loop system. The stepper motor’s 360 degree rotation is divided into a number of fixed degrees per step. The coarsest ones are 90 degrees per step, while high-resolution stepper motors are capable of 0.72 degrees per step. Stepper motors come in two styles: permanent magnet and variable reluctance. As you rotate the permanent magnet stepper motor’s shaft, you can feel the indexed quality of its design. Variable reluctance motors have three or four motor windings with a common return. The permanent magnet motors have two independent windings. A center-tapped winding is used in unipolar permanent magnet motors. Stepper motors use open-loop control systems, which are less sophisticated than servomotor implementations using a closed-loop feedback mechanism. Stepper motor applications are used in systems requiring low acceleration with static loads. A servomotor is better applied when high accelerations with variable loads are involved. This is due to the closed-loop system's feedback and response characteristics. A typical everyday use of a stepper motor is found in a desktop computer's floppy disk drive. These older drives all typically have a +12 VDC, four-phase, unipolar, 3.6° per step stepper motor.

The VMIVME-2541 table stepper motor (TSM) function provides the capability to drive two-phase stepper motors in full- or half-step unipolar and bipolar drive modes. It can accelerate the motors, run them at constant speed (or slew), and decelerate them independently of the Host/User. The Host needs only to initialize the function once and then supply a desired position each time a move is required. The acceleration/deceleration profile is freely configurable by the user via a variable length table that offers up to 82 step rates. The VMIVME-2541 can control up to eight motors in full-step mode, four motors in half-step mode, or a combination of both. Given a move request by the Host, the VMIVME-2541 independently accelerates, slews, and decelerates the motor to the desired position. The current motor position is maintained by the VMIVME-2541 as a 16-bit parameter that can be read by the Host at any time. The algorithm employed in the VMIVME-2541 reevaluates the requested destination on every step. This means that the Host can change the desired position at any time during a movement, and the VMIVME-2541 will adjust its strategy to get to the new desired position as quickly as possible.

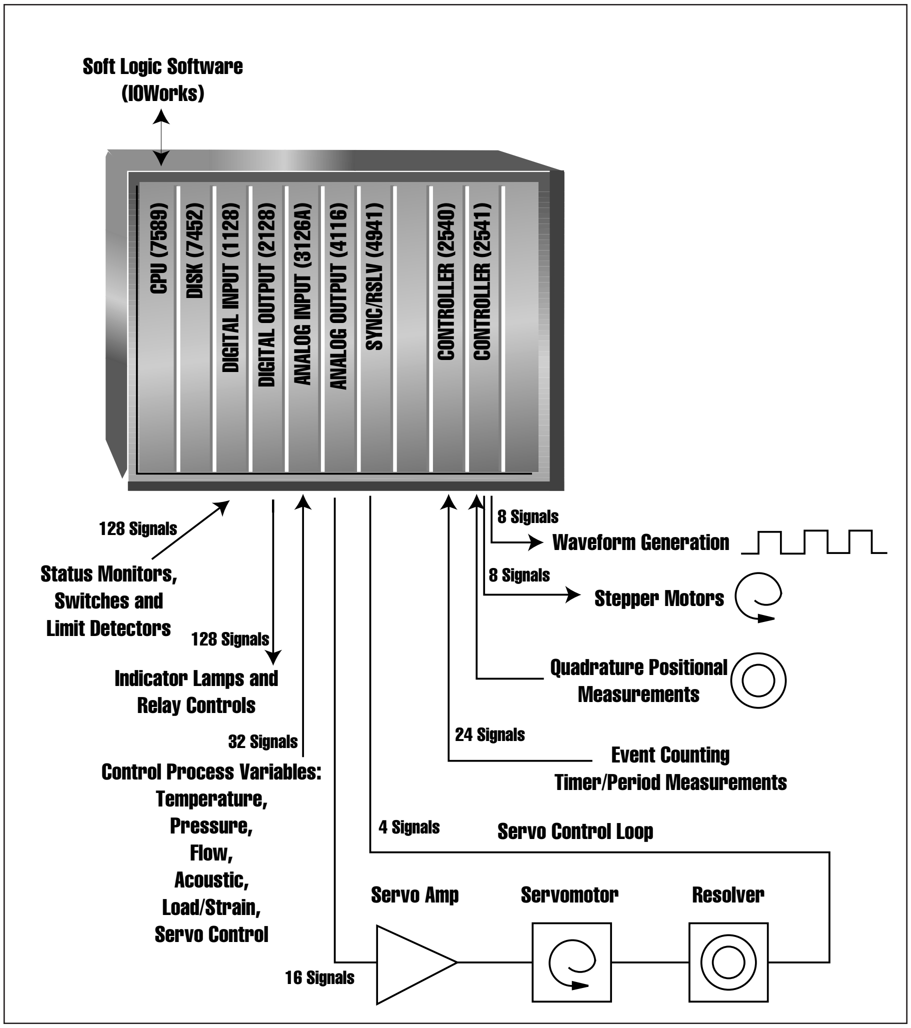

Figure 3.

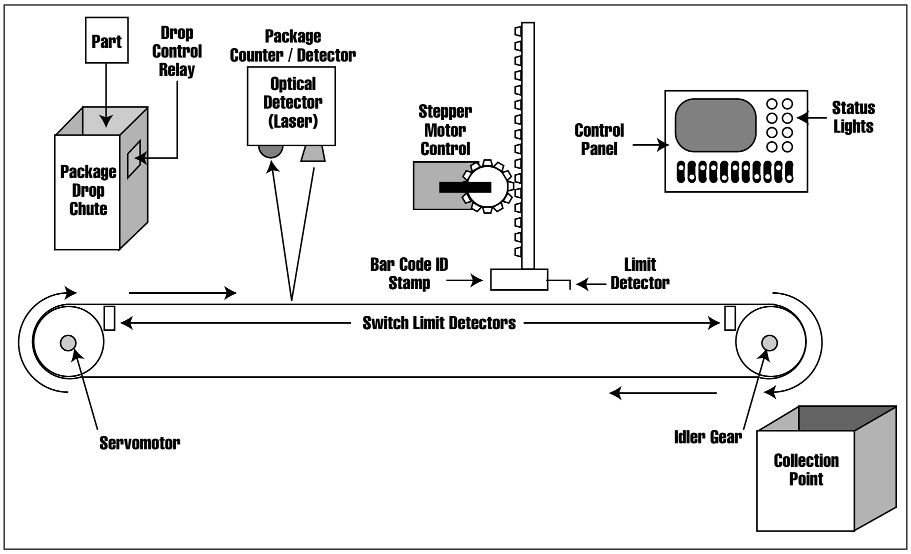

Figure 4.

Quadrature Position Measurement

Quadrature Position Measurement is a method of determining the position or angle with high resolution using only two sensor bits and VMIC's VMIVME-2540 and -2541 are both capable of Quadrature Position Measurement. Quadrature position sensors produce two square wave signals, 90 degrees out of phase with each other. The combination of these two signals is referred to as the quadrature pair. Each complete cycle of the quadrature pair contains four transition edges, hence the name. The magnitude of the position parameter is determined by counting all transition edges in the quadrature pair. By comparing the transitions to a time base, velocity can be derived.

The direction of movement is determined by which quadrature signal leads the other. One signal is arbitrarily selected as the primary signal and the other is designated as the secondary. If the phase of the primary signal leads the secondary signal phase, the sign of change is positive. If the secondary signal leads the primary signal, the sign of the change is negative. Combining these techniques, a quadrature signal pair can provide all the necessary position information on a single axis.

The VMIVME-2541 provides quadrature position measurement at up to 3 MHz transition rates. The VMIVME-2541 tracks the cumulative position by counting up when the quadrature signal pair indicates positive movement, and counting down when the quadrature signals indicate negative movement. The VMIVME-2541 also provides overflow and underflow statues bits to indicate if the zero position has been passed. Quadrature counting requires the use of two of the high-speed channels on the VMIVME-2541. Rate can also be determined by using a separate channel to time the signal edge transitions.

Synchro/Resolver Boards

Synchro/resolver boards support the control and testing of mechanical actuators in numerous fields, including robotics, trainers, simulators, missile guidance, and fire control. In addition to providing the basic synchro and resolver functions that relate mechanical angles to electrical signals, these boards permit the application of sophisticated digital processing within servo loops, and provide the inherently high reliability of electronic assemblies. A further dicussion of synchro/resolver functions and issues is available upon request from VMIC (George.Stroud@vmic.com).
VMIC is on the Web at www.vmic.com

Industry loses respected software engineer

We are saddened to learn of the passing of QNX Software Systems' Dan Hildebrand on July 7, 1998 after a courageous battle with cancer. Dan was born in Winnipeg Manitoba on February 26, 1961. He received his education at Red River Community College and the University of Manitoba Computer Engineering Faculty. He joined QNX in 1987 and served as a senior software architect. Dan had a unique ability to take his knowledge and explain it in clear, understandable terms. This gift also involved him in marketing, corporate communications, and most of QNX's important customer accounts. Dan will be missed by friends, family and the many associates who were fortunate to have known him.

Ray Alderman