Course audit

# Motion control made easy

## Day 1 Orientation

**Topics of discussion:**

- System operation
- Stability and tuning
- Programming example

Motion control systems are used throughout industry to generate precise mechanical moves. Every second of every day they can be found working diligently, charting and executing the courses of cutting tools, sensors, markers, and innumerable other devices. Naturally applications for such systems are very wide and cover many fields of technology.

Motion control has changed dramatically over the past two decades. Today it is possible to construct a control system out of readily available building blocks, in total contrast with the situation 20 years ago, where most components had to be built by the designer. As a result, the system designer today does not have to be a motion control expert; in fact, most designers are not even electrical engineers.

### System operation

The elements of a motion control system, illustrated in Figure 1, include a motor (which converts electric current into torque), an amplifier (which supplies the current), a position sensor, and a controller. Figure 2 shows the functional operation of these elements.

Consider first the motor which generates rotary torque in proportion to applied current. The torque, once it overcomes friction, accelerates the motor. To decelerate the motor, the polarity of the current is reserved, producing an opposing torque.

Motor current is supplied by the driver or amplifier. This device produces a current *I* in proportion to the applied voltage *V*.

The motion controller acts as the brain of the system. Besides performing control functions, it generates the command signal to the amplifier. The position sensor, considered the eyes of the system, produces an output that is fed back to the "brain" or controller. Many systems use optical encoders, which generate electric pulses in proportion to the rotation. By counting encoder pulses, the controller can figure out motor position.

To get a better feel for closed-loop control, refer to Figure 2 and follow the path of the nominal position input *R*. The controller compares the position feedback signal *C* with *R* to form the position error *E*. The error is then filtered (also part of the controller) producing a voltage signal *V* to drive the amplifier which generates motor current *I*. The resulting change in motor position is measured by the sensor, and the process begins again.

To see how it all works together, consider a case where the motor has to move

**Closed loop control system**

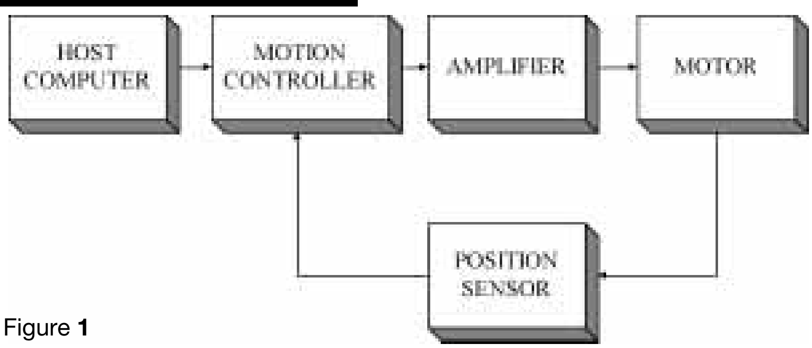


Figure **1**

**Functional diagram**

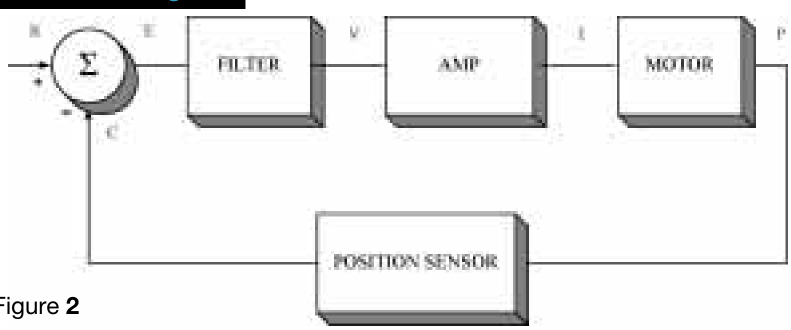


Figure **2**

## Motion cycle

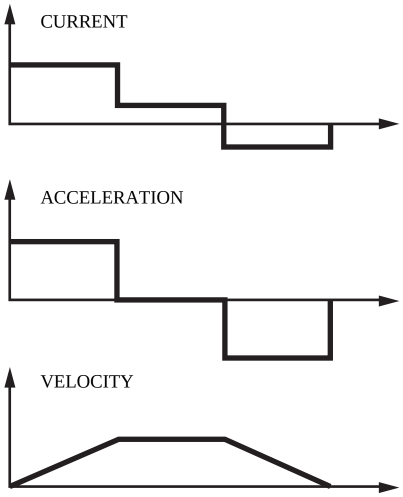


Figure **3**

## Velocity profile

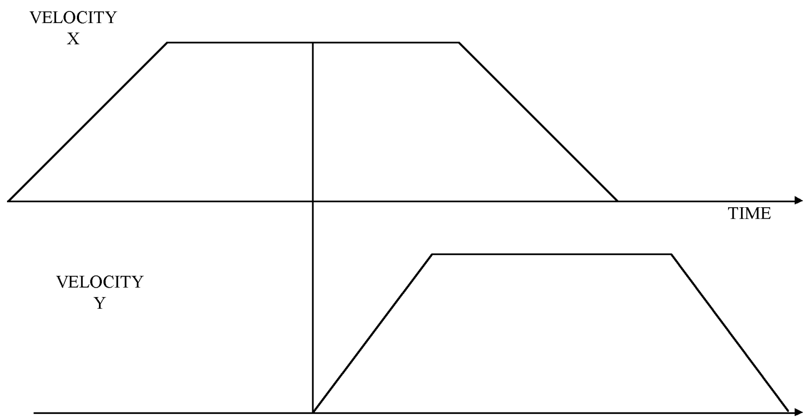


Figure **6**

## Sample motion program

| Instruction | Interpretation |
|---|---|
| PRX = 8000 | Distance for X |
| SPX = 20000 | Speed for X |
| ACX = 100000 | Acceleration for X |
| DCX = 100000 | Deceleration for X |
| BGX | Start X move |
| AD4000 | Wait for X to reach 4000 |
| PRY = 80000 | Distance for Y |
| SPY = 20000 | Speed for Y |
| ACY = 100000 | Acceleration for Y |
| DCY = 100000 | Deceleration for Y |
| BGY | Start Y move |

## Underdamped

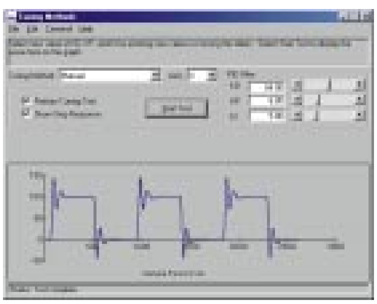

Figure **4**

## Damped response

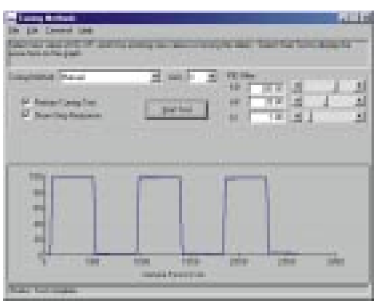

Figure **5**

along a trapezoidal velocity profile. Figure 3 shows the corresponding velocity, acceleration, and motor current signals.

The top curve displays the motor current. During the first interval, the current has to be sufficiently high to overcome friction and accelerate the motor. During the second phase, velocity is constant and the current drops to a level that is just high enough to overcome friction. The third interval is the deceleration. Here the current is negative, but its magnitude is less than that of the acceleration phase because friction is now working for the controller instead of against it.

## System tuning

The filtering function in a controller requires special attention. Someone, or something, must carefully select filter parameters, a process called system tuning or compensation.

Filter parameters determine the intensity of the response of the controller, and therefore, the nature of the motion. The most common filter is of a type called *PID*. The first parameter *P* determines the gain or intensity of the response, while *D* is associated with damping or stability, and *I* with accuracy. Although the selection of PID parameters can be quite complex, suppliers of motion controllers usually offer computer programs that do the tuning for you. Many even display the corresponding motion response.

The effect of tuning is illustrated in Figures 4 and 5. In Figure 4, the parameters are set such that the system is underdamped. The motor is commanded to move back and forth between two positions, but because of poor damping, it overshoots the target each time and takes a relatively long time to settle. Increasing the gain and damping parameters, as shown in Figure 5, provides a much better response. Here, because of proper damping, the system makes fast moves with short settling time.

## Motion programming

Once the system is stable, it can be programmed to move to any location. Programming languages vary from one motion controller to another, but there are similarities. All languages specify velocity, acceleration, and distance, for example. The terms may be different, but the intent is the same.

Consider how you might program two motors to move a distance of 8,000 encoder counts at a maximum speed of 20,000 count/sec. Assume the acceleration rate is 100,000 count/sec$^2$. Let the second motor (Y) start its move when the first (X) has reached a distance of 4,000 counts. A sample program follows along with corresponding velocity profiles (Figure 6).

***Dr. Jacob Tal** is president and cofounder of Galil Motion Control Inc., Mountain View, Calif. He also teaches motion control seminars at various locations across the U.S. For information on Galil or Jacob's seminars, contact Jacob at (800) 377-6329 or **jacobt@galilmc.com.***

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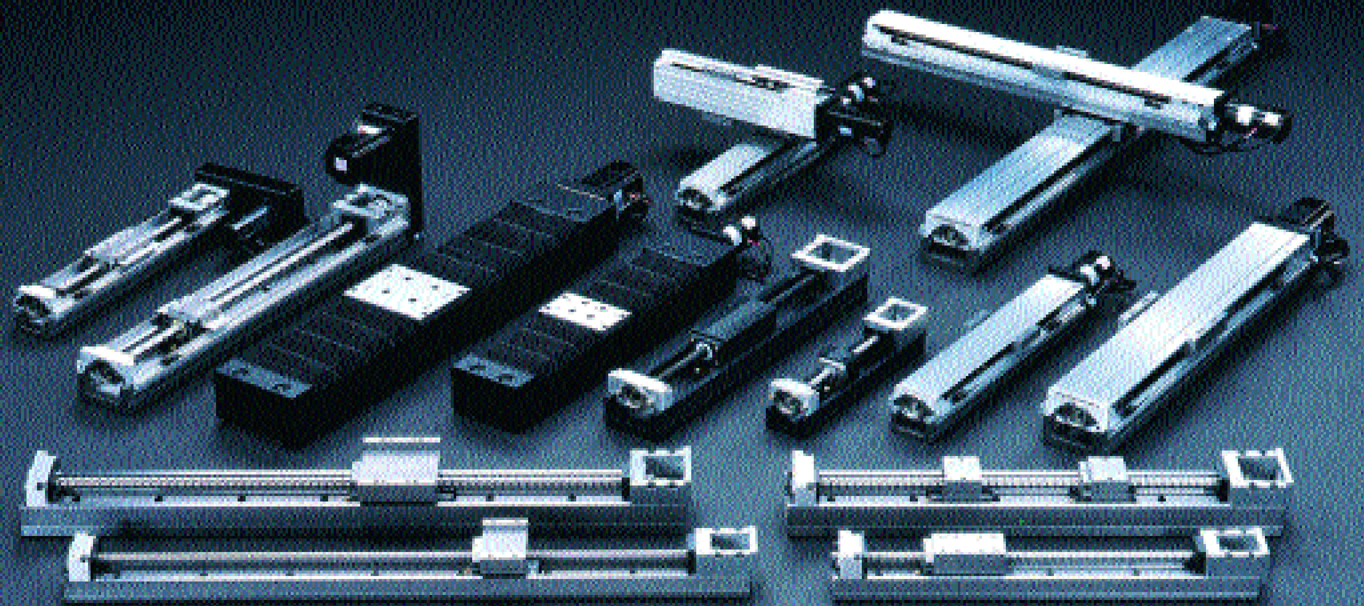

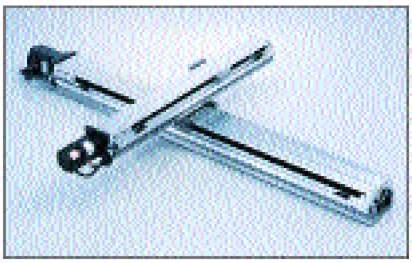

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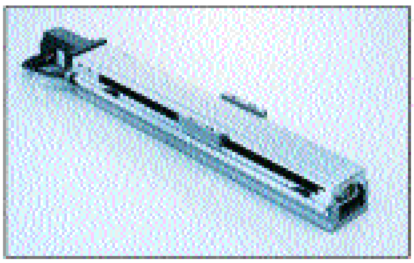

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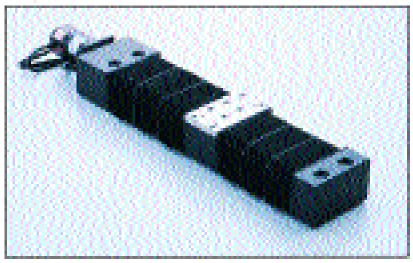

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