Tips for choosing high-accuracy linear positioning systems: Part 3

PRESTON MILLER, Anorad Corp. & MAT LAMMERS, Anorad B.V.

Electronic, optic, computer, inspection, automation, and similar industries have diverse positioning-system specifications. No one system is right for all. To be sure the system you choose is right for your application, use a modular approach to system design.

The components that make up your high-accuracy positioning system — bearings, position-measuring system, motor-and-drive system, and controller — must work together as well as possible. Part 1 (*PTD*, 10/93, p. 51) covered system base and bearings. Part 2 (*PTD*, 4/94, p. 47) covered position measurement. Here, we discuss stage, drive, and encoder design; the drive amplifier; and controllers.

Stage, drive, and encoder design

Figure 1 shows the three commonly used methods of assembling linear stages when using linear encoders:

- Drive and encoder are positioned in or as close as possible to the center of mass of the slide.
- The drive is located in the center of mass; the encoder attaches to one side.
- The drive is located on one side; the encoder, on the other.

Figure 2 summarizes relative values of general properties of these systems.

The ideal system has the drive in the center of the slide mass with the encoder. However, this is usually impractical. The usual compromise locates the drive slightly off to one side; the encoder, slightly off to the other. This gives a good approximation of a central drive with the motion feedback next to the drive system. Central drives are preferred because the drive force introduces no unwanted force vectors into the slide to cause twisting or cocking. Because the bearing system constrains the slide tightly, cocking would produce increased friction, wear, and load-position inaccuracy.

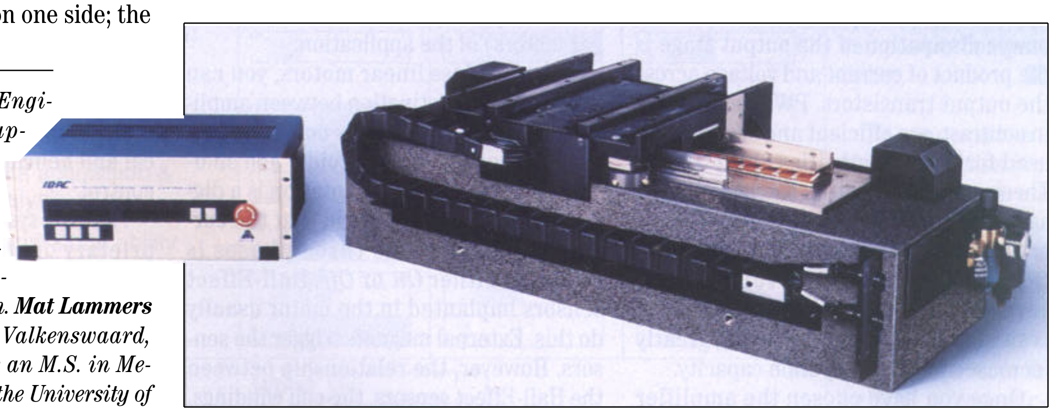
An alternative method uses a gantry style system with two drives, one on each side of the slide. The resulting drive force emulates a central drive. With this method, you can locate the position feedback in the center. If this is impossible, you can locate encoders on each side and control the table with special gantry drive software.

Drive amplifier

Servo drive amplifiers receive control signals, usually ±10 Vdc, from the controller and provide operating voltage and current output to the motor. In general, there are two types of power amplifiers: the linear amplifier and the Pulse-Width-Modulated (PWM) amplifier.

Linear amplifiers are inefficient and therefore are used mainly on low-power drives. The primary limitations on the output power-handling capacity of a linear amplifier are thermal characteristics

***Preston Miller** is Senior Engineer, Anorad Corp., Hauppauge, N.Y. He holds a B.S. in Industrial Technology from Eastern Michigan University, and has 14 years' experience in industrial controls and laser system design. **Mat Lammers** is Director of Anorad B.V., Valkenswaard, The Netherlands. He holds an M.S. in Mechanical Engineering from the University of Eindhoven, and has 9 years' experience in the design and construction of high-accuracy air-bearing machines.*



Air bearing stage with linear electric motor and intelligent digital axis controller. Linear servomotors serve well in applications needing high acceleration and deceleration, high velocity, or precise velocity control even at low speed.

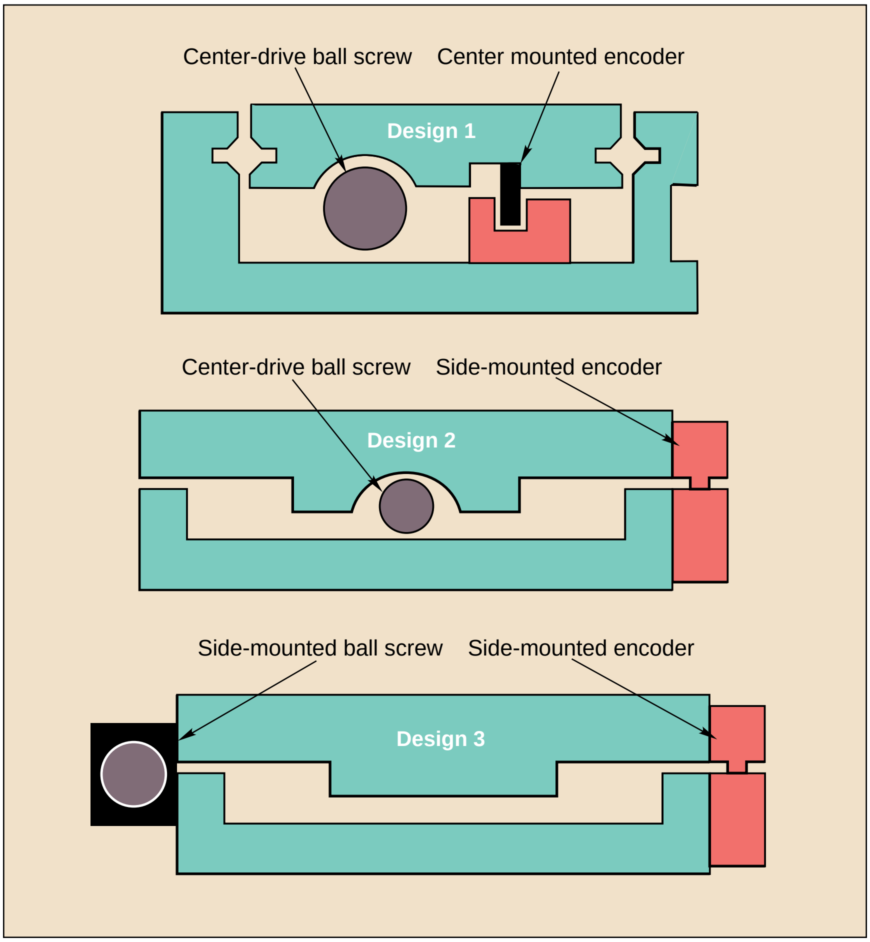


Figure 1 — Three common stage designs to accommodate a linear encoder. See Figure 2 for their relative merits.

of the output stage and breakdown characteristics of output transistors. The power dissipation of the output stage is the product of current and voltage across the output transistors. PWM amplifiers, in contrast, are efficient and are typically used for power capacities above 100 W. These amplifiers switch the output voltage at frequencies up to 50 MHz. The average value of output voltage is proportional to the command voltage. The advantage of this type is that the voltage is switched *On* and *Off*, causing greatly increased power dissipation capacity.

Once you have chosen the amplifier type, the next step is to ensure that the amplifier can provide the required continuous current and output voltage at the required levels for the maximum motor rotation speed (or linear velocity for linear motors) of the application.

For brushless linear motors, you can make another distinction between amplifiers. Two types of motor commutation are in general use: trapezoidal and sinusoidal. Trapezoidal commutation is a digital type of commutation in that the current for each of the three phases is switched either *On* or *Off*. Hall-Effect sensors implanted in the motor usually do this. External magnets trigger the sensors. However, the relationship between the Hall-Effect sensors, the coil windings, and the magnets is critical and always involves a small position tolerance. The response timing of the sensors, therefore, always occurs somewhat slightly out of phase with true coil and magnet positions. This leads to a slight variation in application of current to the coils, leading to unavoidable vibration.

Trapezoidal commutation is less suitable for very precise scanning and constant-velocity applications. However, it is less expensive than sinusoidal commutation, so it is used extensively for high speed, point-to-point systems or on systems where motion smoothness will not affect processing.

With sinusoidal commutation, *On-Off* switching does not occur. Rather, by means of electronic switching, the 360-deg current phase shift of the three phases is modulated in a sinusoidal pattern. This results in smooth, constant force from the motor. Sinusoidal-shaped commutation is therefore well-suited for making precision contours and for applications calling for precise constant velocity such as scanning and vision uses.

Controllers

There are more classes of controllers than we can discuss adequately here. Basically, controllers may be broken into several categories depending on programming language and control logic.

Programmable Logic Controllers (PLCs) use a "ladder" logic scheme. They are used mainly for controlling multiple discrete Input/Output (I/O) functions although a few offer limited motion-control capabilities.

Numerical control (NC) systems are programmed via an industry-standard language, RS274D or a variant. They can perform complex motions such as spherical and helical shapes with multiple-axis control.

Non-NC systems use a variety of proprietary operating systems including easy-to-use interface programs for basic motion profiles. Most of these controllers consist of a basic controller module without a monitor or keyboard. The controller communicates with a host through an RS-232 port. The host can be a Personal Computer (PC), a dumb terminal, or a handheld communications unit.

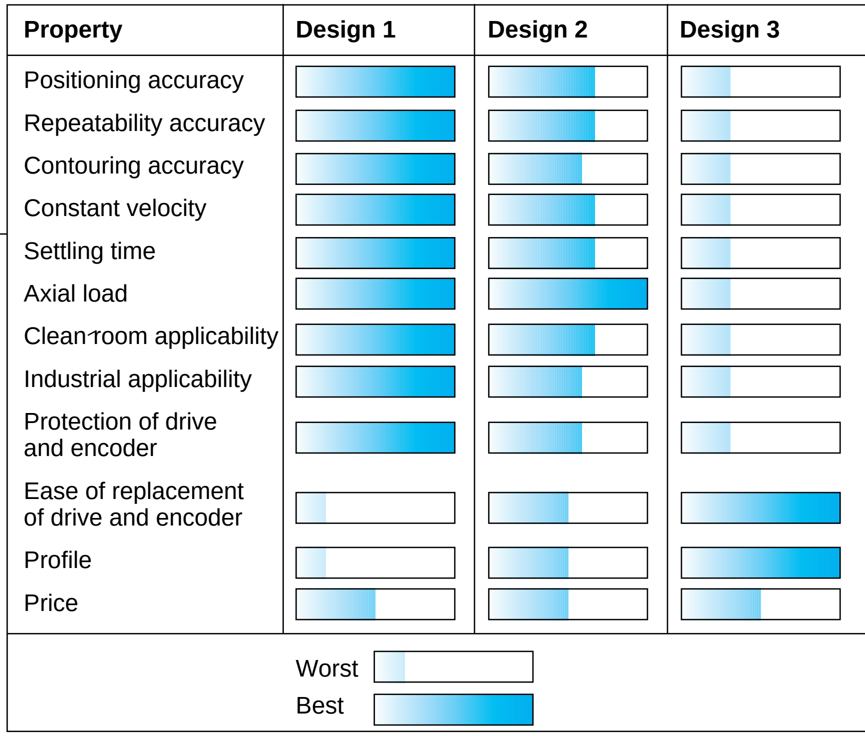


Figure 2 — The relative merits of the three encoder-mount designs of Figure 1.

Almost all up-to-date controllers are digital controllers. They provide a level of reliability and ease of use that was unheard of in analog controllers. Velocity feedback information is usually derived from the axis position signal. All servo parameters are adjusted through software rather than laboriously adjusting drive amplifier "pots," which tend to drift after use and with temperature changes. Most modern controllers also offer autotuning of all axis servo parameters.

The more advanced controllers also include distributed processing and Digital Signal Processor (DSP) axis control. A DSP is in essence a processor specially designed to make mathematical computations very quickly (at least ten times faster than a microprocessor). This can provide servo sample times in the order of 125 µsec. The advantage is precise control of the axis for constant velocity control and smooth contouring.

A Proportional-Integral-Derivative (PID) filter algorithm and velocity and acceleration feed-forward enhance servo control of the axis. In addition, S-curve programming of acceleration and deceleration profiles controls jerk that usually goes with starting and stopping table motion. This gives smoother, more controlled operation, leading to quicker settling times for both position and velocity.

Controllers also include extensive digital or analog input/output capabilities. The user program or subroutine can be altered depending on position, time, or status information, the values of variables, mathematical operations, external or internal I/O events, or error interrupts. The user's process can be easily automated.

In addition, most controllers can increase position feedback resolution through electronic multiplication. Although 4× multiplication is common, some advanced controllers can multiply by as much as 256×. Though this provides no improvement in accuracy, it does have a real increase in axis position stability and — more importantly in many uses — repeatability. Figure 3 summarizes various characteristics of the three controller types.

In your overall approach, besides the factors mentioned above, you must consider other factors that may modify component decisions, such as budget, environment, life expectancy, ease of maintenance, MTBF, and end user preferences. The modular approach allows system assembly from standard, readily available components that will meet even the most demanding application requirements if a system is analyzed from the base up for overall component compatibility. ■

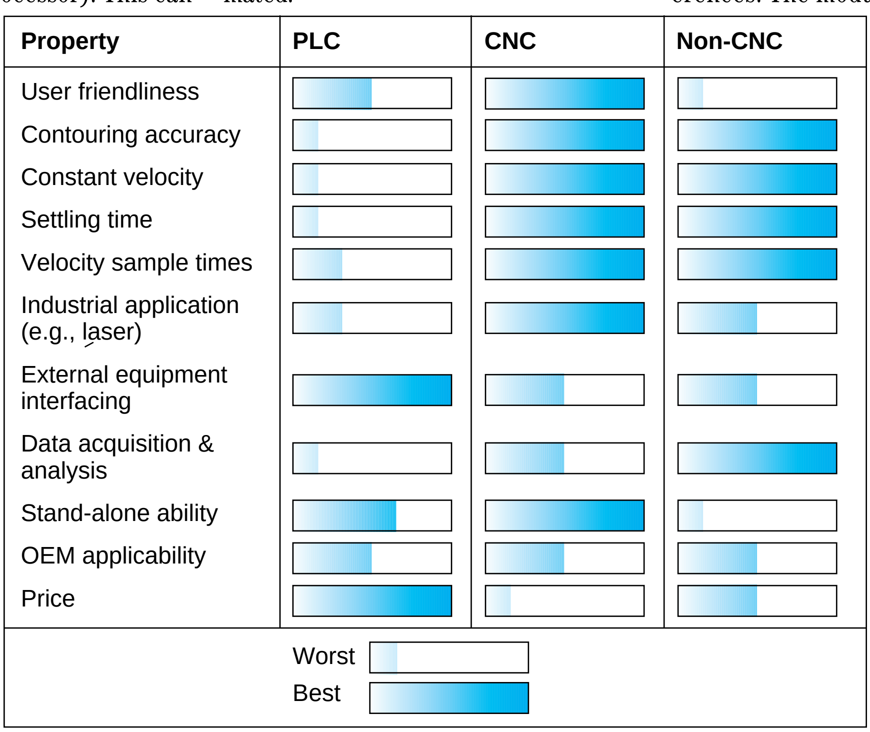


Figure 3 — Relative merits of three controller types.