## DC Brush Motor Drives

Linear and Switching Amplifiers

Linear amplifiers – this type of amplifier operates in such a way that, depending on the direction of motor rotation, either TR1 or TR2 will be in series with the motor and will always have a voltage (V) developed across it (Fig. 2.16).

This characteristic is the primary limitation on the use of linear amplifiers (since there will always be power dissipated in the output stages of the amplifier). To dissipate this power, large transistors and heat sinks will be required, making this type of amplifier unsuitable for use in high power systems. However, the linear amplifier does offer the benefit of low radiated electrical noise.

Fig. 2.16 Linear servo amplifier
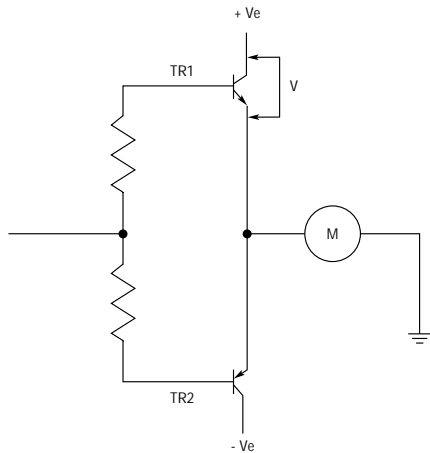
Switching amplifiers – this amplifier is the most commonly used type for all but very low-power requirements and the most commonly used method of output control is by pulse width modulation (PWM).

Power dissipation is greatly reduced since the output transistors are either in an "on" or an "off" state. In the "off" state, no current is conducted and so no power is dissipated. In the "on" state the voltage across the transistors is very low (1-2 volts), so that the amount of power dissipated is small.

Such amplifiers are suitable for a wide range of applications (including high power applications).

The operation of a switching or chopper amplifier is very similar to that of the chopping stepper drive already described. Only one switch set is required to drive a DC brush motor, making the drive simpler. However, the function of a DC drive is to provide a variable current into the motor to control the torque. This may be achieved using either analog or digital techniques.

Analog and Digital Servo Drives

Unlike stepper drives, amplifiers for both brush and brushless servo motors are either analog or digital. The analog drive has been around for many years, whereas the digital drive is a relatively recent innovation. Both types have their merits.

Overview – The Analog Drive

In the traditional analog drive, the desired motor velocity is represented by an analog input voltage usually in the range ±10 volts. Full forward velocity is represented by +10v, and full reverse by -10v. Zero$_{(D)}$ volts represents the stationary condition and intermediate voltages represent speeds in proportion to the voltage.

The various adjustments needed to tune an analog drive are usually made with potentiometers. With a little experience, this can usually be performed quite quickly, but in some difficult applications it may take longer. Repeating the adjustments on subsequent units may take the same time unless there is an easy way of duplicating the poten-tiometer settings. For this reason, some proprietary drives use a plug-in "personality card" that may be fitted with preset components. However, this not only increases the cost but may preclude the possibility of fine tuning later.

Overview – The Digital Drive

An alternative to the analog system is the digitally-controlled drive in which tuning is performed by sending data from a terminal or computer. This leads to easy repetition between units and, since such drives are invariably processor-based, facilitates fully-automatic self tuning. The input signal to such a drive may also be an analog voltage but can equally take the form of step and direction signals, like a stepper drive.

Digital drives are used more in conjunction with brushless servo motors than with DC brush motors. Such drives are almost wholly digital with the exception of the power stage that actually delivers current to the motor. Velocity feedback is derived either from an encoder or resolver and again is processed as digital information. It becomes logical to incorporate a position controller within such a drive, so that incoming step and direction signals can be derived from a conventional stepper-type indexer. Equally, the positioner may be controlled by simple commands using a high-level motion control language – see the X-code products in this catalog.

### A Comparison of Analog and Digital Drives

The analog drive offers the benefit of lower cost and, in the case of a drive using tach feedback, very high performance. The wide bandwidth of the brush tach allows high gains to be used without inducing jitter at standstill, resulting in a very "stiff" system.

The digital drive, while more costly, is comparatively easy to set up and adjustments can be quickly repeated across several units. Automatic self-tuning can be a distinct advantage where the load parameters are unknown or difficult to measure. The digital drive also offers the possibility of dynamic tuning – sometimes vital where the load inertia changes dramatically during machine operation. Such an option is clearly out of the question with a potentiometer-adjusted drive.

Drive Technologies

Analog DC Drive Operation

The elements of an analog velocity amplifier are shown in Fig. 2.17. The function of the system is to control motor velocity in response to an analog input voltage.

Fig. 2.17 Elements of an analog servo system
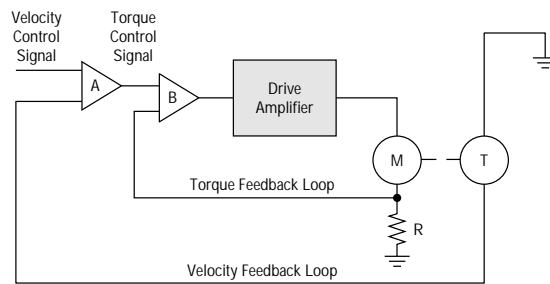
Motor velocity is measured by a tach generator attached to the motor shaft. This produces a voltage proportional to speed that is compared with the incoming velocity demand signal, and the result of this comparison is a torque demand. If the speed is too low, the drive delivers more current, which in turn creates torque to accelerate the load. Similarly, if the speed is too high or the velocity demand is reduced, current flow in the motor will be reversed to produce a braking torque.

This type of amplifier is often referred to as a four-quadrant drive. This means that it can produce both acceleration and braking torque in either direction of rotation. If we draw a diagram representing direction of rotation in one axis and direction of torque in the other (see Fig. 2.18), you will see that the motor can operate in all four "quadrants". By contrast, a simple variable-speed drive capable of running only in one direction and with uncontrolled deceleration would be described as single-quadrant.

*Fig. 2.18 Four-quadrant operation*
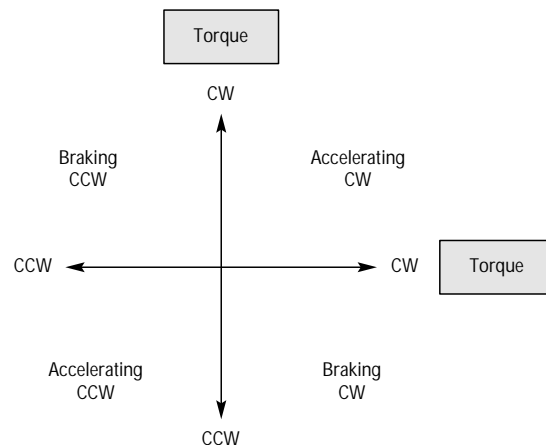
The velocity amplifier in Fig. 2.17 has a high gain so that a small velocity difference will produce a large error signal. In this way, the accuracy of speed control can be made very high even when there are large load changes.

A torque demand from the velocity amplifier amounts to a request for more current in the motor. The control of current is again achieved by a feedback loop that compares the torque demand with the current in the motor. This current is measured by a sense resistor R, which produces a voltage proportional to motor current. This inner feedback loop is frequently referred to as a torque amplifier since its purpose is to create torque in response to a demand from the velocity amplifier.

The torque amplifier alone may be used as the basis of a servo drive. Some types of position controller generate a torque output signal rather than a velocity demand, and there are also applications in which torque rather than speed is of primary interest (winding material onto a drum, for instance). Most analog drives can be easily configured either as velocity or torque amplifiers by means of a switch or jumper links. In practice, the input signal is still taken to the same point, but the velocity amplifier is bypassed.

Fig. 2.19 Digital servo drive
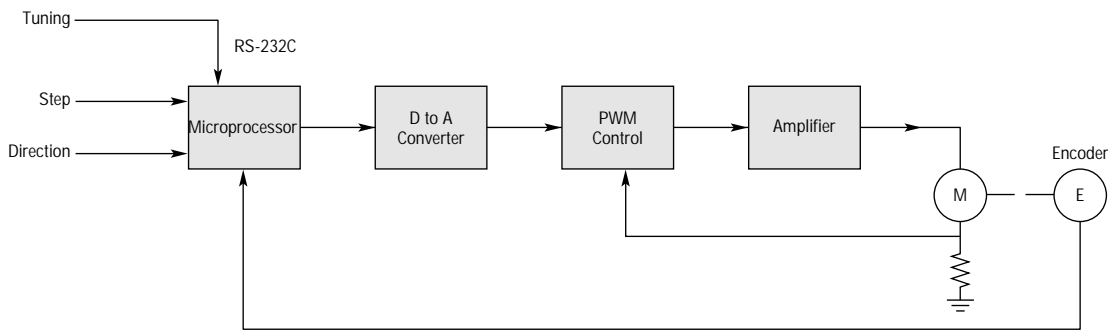
Digital Servo Drive Operation

Fig. 2.19 shows the components of a digital drive for a servo motor. All the main control functions are carried out by the microprocessor, which drives a D-to-A convertor to produce an analog torque demand signal. From this point on, the drive is very much like an analog servo amplifier.

Feedback information is derived from an encoder attached to the motor shaft. The encoder generates a pulse stream from which the processor can determine the distance travelled, and by calculating the pulse frequency it is possible to measure velocity.

The digital drive performs the same operations as its analog counterpart, but does so by solving a series of equations. The microprocessor is programmed with a mathematical model (or "algorithm") of the equivalent analog system. This model predicts the behavior of the system. In response to a given input demand and output position. It also takes into account additional information like the output velocity, the rate of change of the input and the various tuning settings.

To solve all the equations takes a finite amount of time, even with a fast processor – this time is typically between 100µs and 2ms. During this time, the torque demand must remain constant at its previously-calculated value and there will be no response to a change at the input or output. This "update time" therefore becomes a critical factor in the performance of a digital servo and in a high-performance system it must be kept to a minimum.

The tuning of a digital servo is performed either by pushbuttons or by sending numerical data from a computer or terminal. No potentiometer adjustments are involved. The tuning data is used to set various coefficients in the servo algorithm and hence determines the behavior of the system. Even if the tuning is carried out using pushbuttons, the final values can be uploaded to a terminal to allow easy repetition.

In some applications, the load inertia varies between wide limits – think of an arm robot that starts off unloaded and later carries a heavy load at full extension. The change in inertia may well be a factor of 20 or more, and such a change requires that the drive is re-tuned to maintain stable performance. This is simply achieved by sending the new tuning values at the appropriate point in the operating cycle.