Basic Feedback Guide

Content contributed by Motor Consultants, LLC

Feedback is used in closed loop systems in applications all over the world to control speed and/or position, and it has an important role in keeping equipment operating smoothly and accurately. Feedback is available in a variety of devices as well as models. It is important to understand how feedback operates, so the best benefits can be used in the application.

Open Loop VS Closed Loop

Many applications operate open loop and many operate closed loop. In an open loop system, the operation can become uncontrolled; in a closed loop system the process is controlled. The difference is feedback. An open loop system is a process in which the signal travels from the control to the motor. An example of an open loop system is as follows: a motor is used in a bin sorting application, and everything proceeds as expected as long as the motor can pick and place parts in the proper bin. However if for some reason the mechanism jams and the motor can't move, the control is not aware of the situation and will continue sending commands that are essentially ignored, so the parts do not get sorted.

In a closed loop system the signal travels from the control to the motor, as above, however the difference is that there is another signal, a feedback signal, which returns to the control, thus informing the control the operation was successfully. If the feedback informs the control that the operation was not successful, then the control could alert an operator that the process was not completed correctly. Closed loop systems use feedback for speed/position information and process control in many applications.

There are a variety of devices available in the marketplaces which are employed to derived information about the application's speed and/or position thus controlling and guaranteeing that the process occurs correctly. These include: tachometer, Hall sensors, encoder, and resolver.

Tachometer

Tachometers are rotating electromagnetic devices typically connected to a motor shaft, and when the tachometer shaft is rotated, it outputs a signal, ie output a voltage. The faster the tach shaft is turned, the larger the magnitude of voltage developed (i.e. the output signal is directly proportional to speed). This output voltage also provides a polarity (+ or -) which indicates direction of rotation (CW or CCW). A basic tachometer assembly is illustrated in figure 1 and consists of a tach rotor, magnets and brushes.

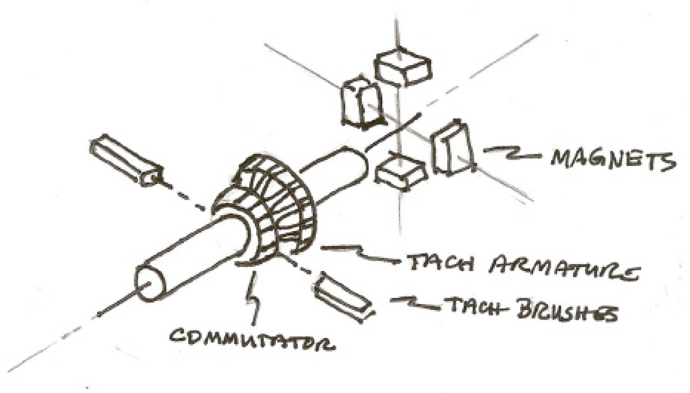

Figure 1 – Typical tachometer construction

Analog, or DC tachometers as they are often termed, play an important role because of their ability to provide speed and direction information. This information can be fed to a meter (for visual speed readings) or used in servo control for stabilization purposes. The DC tach provides the simplest, most direct method of acquiring this information.

As an example of utilizing a tach for velocity information, consider a conveyor which must move loads at a constant speed. The motor is required to rotate at 3600 rpm. With a tachometer voltage constant of 2.5 volts/Krpm, the voltage read on the tach terminals should be:

3.600 Krpm x 2.5 volts/Krpm = 9 volts.

If the voltage is indeed 9 volts, then the motor is rotating at the correct speed. The control will monitor this voltage assuring desired speed is maintained.

Hall Sensors

Hall sensors are solid state devices which are used to sense or detect magnetic fields. As a magnet passes by the Hall sensor, the sensor's output changes from "on" to "off"- - it's a digital signal and the output is either "high" or "low".

The basic Hall assembly illustrated in figure 2 consists of three (3) Hall sensors (placed 60 mechanical degrees apart), a magnet "wheel" (attached to the motor shaft) and parts to hold the sensors in place. In some motors, the design is arranged so the Halls sense or detect the motor magnets thus eliminating the magnet wheel.

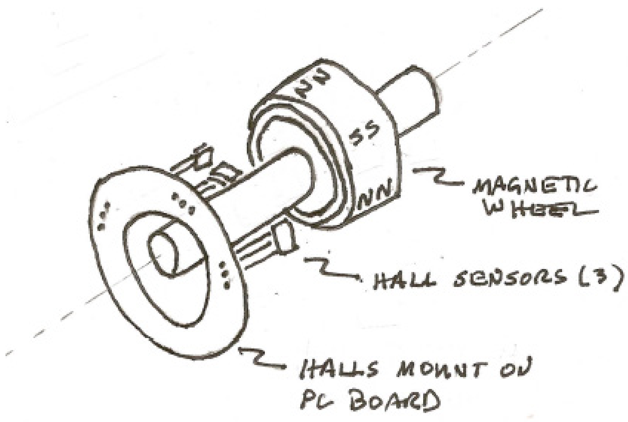

Figure 2 Typical Hall sensor and magnetic "wheel" assembly

As the shaft rotates, the magnet "wheel" passes by the Hall sensors, and as illustrated in figure 3 the Hall output change state. These square wave signals provide information to the control.

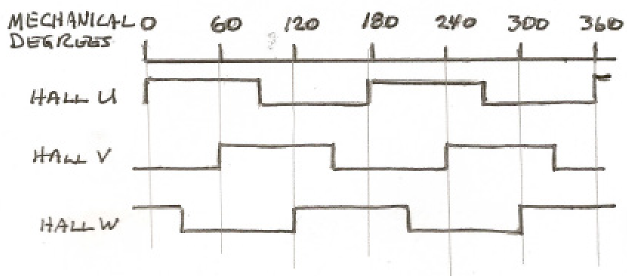

Figure 3 Hall sensor output signals

Time between these pulses is used to derive data for speed control or speed regulation. This scheme works best at higher speeds. At very low speeds the pulses are far apart, thus it becomes extremely difficult to accurately regulate speed. Note that since position of the Halls on the motor housing are known, therefore rotor position is known.

As an example of using Hall sensors consider a brushless motor application. Hall sensors used for "electronic commutation" are turning "on" and "off" as a magnetic field passes by, providing information about rotor position. The control uses this information to turn "on" specific power devices applying power to specific stator windings. This maintains the relationship between the rotor permanent magnet field and the stator winding field at the proper angle for rotation.

Encoder

An encoder may be termed a rotary encoder, digital encoder, optical encoder, digital tachometer or incremental encoder. It's simply a mechanical-to-electrical conversion device, turning mechanical motion into velocity or position information for motion control systems.

A basic encoder illustrated in figure 4 consists of a light source, a mask, a coded disk (with opaque lines), photo sensors (also termed photo array) and electronics. The path of light is thru the mask, thru the coded disk and is detected by the photo sensors. As the encoder's shaft is rotated, the light is alternately passed thru or blocked, thus an alternate light and dark pattern is detected by the sensors. The electronics convert this into an electrical signal representing square waves (light "passing thru" or "blocked" converts to "high" or "low" pattern). Note this example explanation uses a light source to explain how an encoder works, however there are other technologies available such as magnetic.

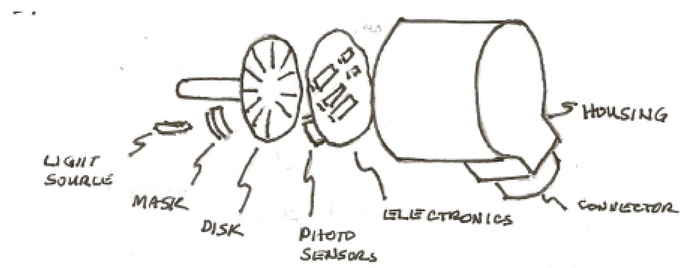

Figure 4 Basic encoder construction

The number of lines etched on the coded disk is dependent on the resolution desired for the application - - increasing resolution increases accuracy in the application. If the disk has 1000 lines, there would be 1000 "high"/"low" cycles or 1000 pulses per revolution (ppr). By counting the number of pulses, the position of the shaft relative to its starting position is known. Adding another measured value (ie time) to the information, it is possible to determine velocity.

Another pattern of lines is added to the coded disk; and these two lines are usually termed "A channel" and "B channel". They are arranged with an offset of ½ cycle (ie quadrature) as illustrated in figure 5. When the encoder reverses direction, then channel B goes high before channel A, thus using this relationship it's possible to determine direction of rotation. Sometimes a third channel is added; this channel has one pulse per revolution and is typically referred to as an "index" or "home" pulse (Z channel). Additionally some encoder models include a channel that simulates Hall sensors.

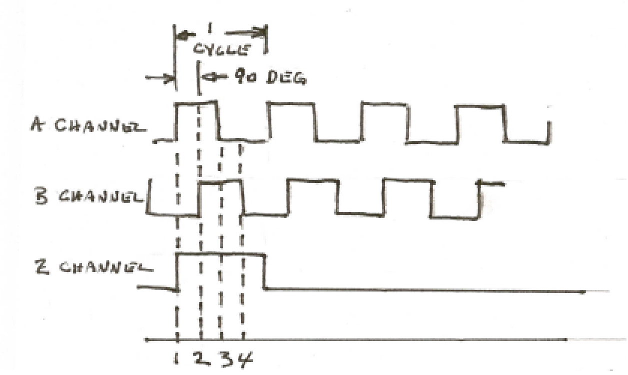

Figure 5 Encoder signals

Controls will read positive and negative transitions of the encoder pulses, resulting in the number of pulses/revolution (ppr) being multiplied by 4 times - - thus the counts per revolution (cpr) for a 1000 ppr encoder will be 4000 cpr. This is the resolution of the encoder which is used to determine accuracy.

Encoders are classified into two basic types: incremental and absolute. The discussion above covered incremental encoder. The absolute encoder provides a "specific address" or "whole word" for each shaft position throughout 360 degrees. This code is derived from independent multiple tracks on the disc.

Absolute encoders can provide different types of output. The most common are parallel absolute output and serial synchronous interface (SSI). For parallel output, each bit of the data word is output in parallel on a separate data line. SSI transmits encoder position information on a single pair of conductors rather than one conductor per bit. A clock pulse train from a control tells the encoder when to send out data bits.

Since position information is directly on the coded disk assembly, the disk has a built–in "memory system" and a power failure will not cause position information to be lost. Therefore, it will not be required to return to a "home" or "start" position upon re–energizing machine power.

As an example of using an encoder consider a cut-to-length application. An encoder is connected to a measuring wheel that rests on the uncut material. As the material moves along a conveyor, the encoder outputs a series of pulses representing the distance the material has moved. The control counts these pulses and when the appropriate number of pulses has been received, the control sends a command to a blade to cut at the measured length.

Resolver

Resolvers are similar to motors - that is, there is a rotor and stator. A reference "signal" is placed on the rotor, and as it revolves, the output of the signal changes directly proportional to the angle thru which the rotor has moved.

A simple resolver, as illustrated in figure 6, contains a single input winding, and two output windings. A reference AC "signal" is applied onto the input winding (R1–R2), which is then induced onto the rotor and then passes onto the output windings (S1-S2 and S3-S4). The windings are 90 degrees apart and the envelope of the signal provides a sine and cosine output. These signals are then fed into the control.

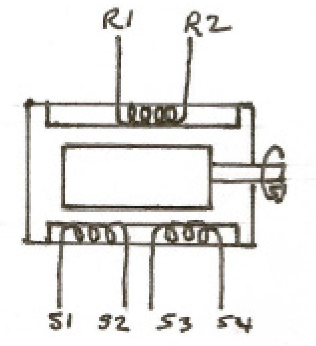

Figure 6 A basic resolver

The magnitude of the output voltage of the sine and cosine signals is proportional to the angle the resolver rotor has moved thru and thus provides position information. The leading or lagging sine/cosine relationship provides direction information.
There are various types of resolvers. The type described above would be termed a single speed resolver; that is, the output signal goes through one sine wave as the rotor goes through 360 mechanical degrees. If the output signal went through four sine waves, as the rotor goes through 360 mechanical degrees, it would be termed a 4-speed resolver.

Each feedback device has its own characteristics, parameters, operating range, and advantages. Figure 7 presents an overview of feedback devices.

	Tachometer	Hall Sensors	Incremental Encoder	Absolute Encoder	Resolver
Primary Use	Speed	Electronic Commutation	Relative Position	Absolute Position	Relative Position
Secondary Use		Speed, Position	Speed, Electronic Commutation	Speed, Electronic Commutation	Speed, Electronic Commutation
Output	Voltage Proportional to Speed	Digital	Digital	Digital Serial / Parallel Communication	Sinusoidal Output (Analog)
Advantages	Low Cost	Lowest Cost, No parts to wear	Digital Works Easily With Electronics	Digital Absolute, Remembers Position	No Internal Electronics, Withstand Higher Temperatures

Figure 7 Overview of various feedback devices

Each application should be reviewed to determine needs, and then the best features and advantages of the feedback device can be used in the application.