ENCODERS

Encoders are mechanical to electrical transducers whose output is derived by “reading” a coded pattern on a rotating disk or a moving scale. Encoders are classified by the

- method used to read the coded element: contact or non-contact
- type of output: absolute digital word or series of incremental pulses
- physical phenomenon employed to produce the output: electrical conduction, magnetic, optical, capacitive

CONTACT ENCODERS

Contact encoders are those which employ mechanical contact between a brush or pin sensor and the coded disk. The disk contains a series of concentric rings or tracks which are thin metallic strips joined at their base as shown in Figure 3-1. The four tracks shown in Figure 3-1 represent a binary code consisting of 2^0, 2^1, 2^2, 2^3. The associated contact sensors are identified at B_0, B_1, B_2, B_3, and encode the numerals 0 through 15. As the disk rotates, the sensors alternately contact conductive strips and adjacent insulators, producing a series of square wave patterns.

Uniform and non-uniform disc patterns can be utilized depending on the application. Virtually any pattern which can be produced photographically can be imaged on an encoder disc. The typical application is measurement of shaft position which utilizes a uniform pattern. Any non-uniformity in the disc is a source of error. Non-uniform segment spacing produces position error and eccentricity causes an error which is a sinusoidal function of the shaft angle.

Performance specifications are limited for factors such as, practical segmenting limitations on discs, bridging of disc segments, and wear of contacts.

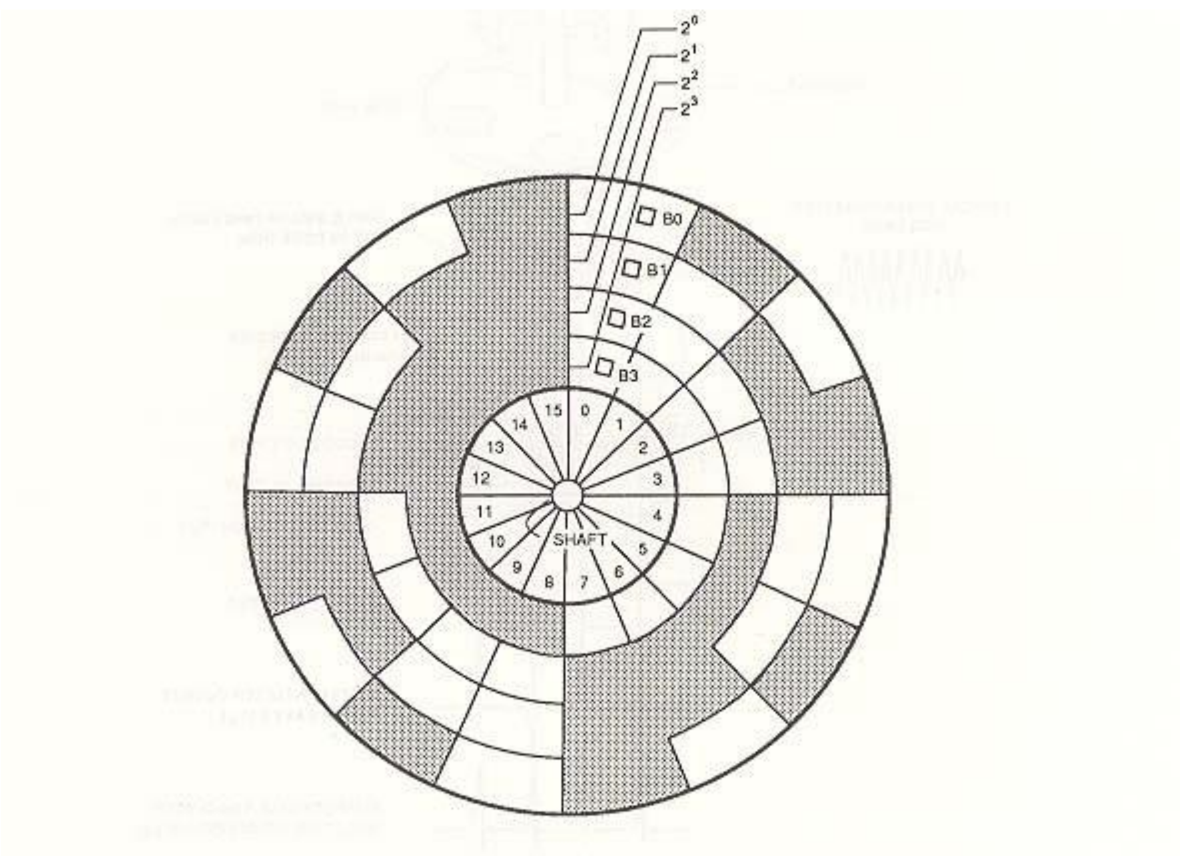

Figure 3-1. Absolute Contact Encoder Disk

NON-CONTACT ENCODERS

Non-contact encoders are those which employ physical phenomena other than electrical conduction to read the coded disc. The most common types are magnetic, capacitive, and optical.

Magnetic Encoders

Magnetic encoders were developed to replace contact encoders in applications limited by rotational speed. Magnetic encoders operate by detecting resonant frequency change, a magnetization change, or a magnetic saturation in an inductor. For each method, flux induction by the magnetically coded disc affects the change by aiding or inhibiting an existing state. Thus, for each principle, two normal states exist corresponding to a logical one or zero.

The resonant frequency type utilizes a tuned circuit, the frequency of which represents one logical state, and the detuning of the circuit representing the opposite logical state.

In the magnetic saturation method, the inductor is either saturated or nonsaturated. Alternately, the reluctance of the magnetic circuit is effectively translated to logical ones and zeros.

Resolution is limited by the size of the magnetized spot and complicated by interaction between magnetized spots on adjacent tracks. Magnetic encoders overcome the basic speed limitation of contact encoders and offer greater longevity by eliminating physical contact between disc and sensor. Also, magnetic encoders function well in environments hostile to contact types where any of the magnetic scanning techniques can be successfully employed. However, high ambient fluxes or radiation densities can destroy the disc pattern or inhibit saturated core operation. Greater precaution against mutual electromagnetic interference is required when magnetic encoders are included in the system. Figure 3-2 illustrates the principle stages of typical magnetic encoding.

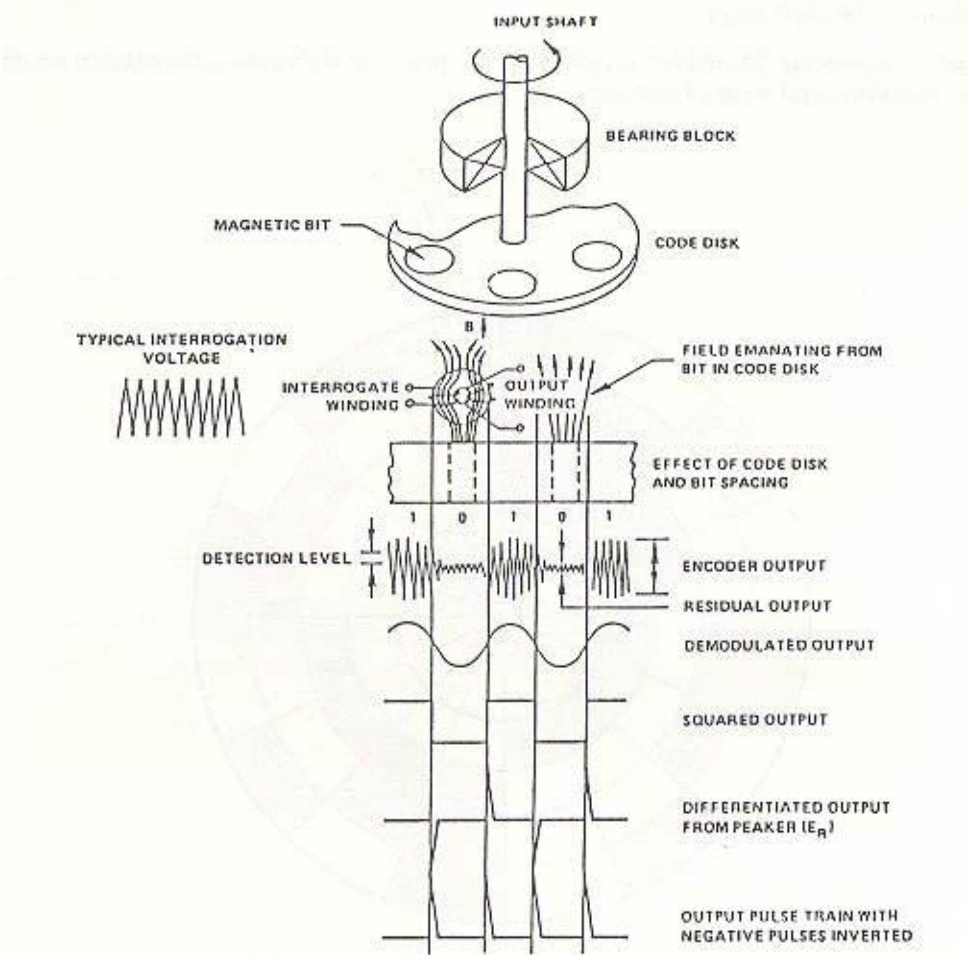

Figure 3-2. Typical Magnetic Coding

Capacitive Encoders

Capacitive encoders are the least used of the non-contacting types and were developed in response to unique needs. Readout is effected electrostatically using a phase shift measuring system or a frequency control technique to develop the digital output.

Although capacitive devices are not generally available as standard hardware, up to 19-bit, single turn units have been produced. Theoretically, the capacitive technique can be used to accomplish any of the encoding tasks performed by the contact, optical, or magnetic type. However, practical problems of design, manufacture, and operation have limited the use of capacitive detection.

Optical Encoders

The optical encoder was the earliest of the non-contact devices developed to eliminate the wear problems inherent with contact encoders. Present day optical encoders provide the highest resolution and encoding accuracy and can be operated efficiently at high speeds.

Optical encoder discs have opaque and transparent segments (see Figure 3-3). The discs can be produced by exposing a photographic emulsion to light, by plating metal on the substrate or by etching segments into a metal substrate. Each type has characteristics that may make it preferable in certain applications.

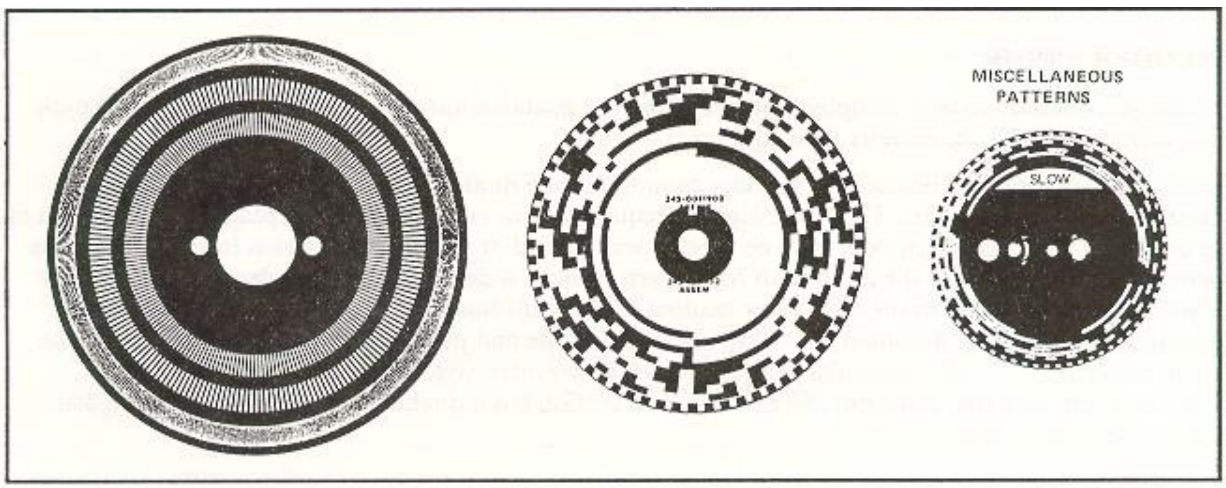

Figure 3-3. Encoder Disks

Readout is effected by an array of carefully aligned photoelectric sensors positioned on one side of the disc. A light source on the other side provides excitation. As the disc rotates in response to an input variable, the opaque area on the disc passes between the light beam modulating the sensor output in accordance with the selected code. Optical systems focus the light on the sensors. Light columnating LED’s, mirrors, prisms, lenses, fiber optics, laser diodes, and optical slits or diffraction gratings perform this function.

Light detection can be performed by one of several devices. Materials for all types of light detecting devices are selected from groups III, IV, V of the periodic table and lie halfway in the spectrum between metals and non-metals. As such they are semiconductors. Each device responds to light in a different manner., Silicon or selenium based photovoltaic cells generate an electric current when exposed to light. The resistance of photoconductive cells varies with light intensity. The composition of photoconductive devices is usually cadmium sulfide or cadmium selenide, depending on the desired response of the device or the portion of the light spectrum for which sensitivity is desired. Current capabilities varies with the intensity of light. Photodiodes are similar to photoconductive cells. Photodiodes are used because their very small surface areas allow very high frequency response. They are generally run with back bias and the reverse leakage current is modulated with the light.

Phototransistors are photodiodes with built-in transistor amplification. Photodiodes have better frequency response and are less sensitive to temperature than phototransistors. In phototransistors, silicon controlled rectifiers (SCR’s) act as sensitive high current switches when exposed to light.

Light sources for optical encoders may be solid state or incandescent, depending on the manufacturers design and application of the encoder.

Recently, enhancements to optical encoder operating performances has strengthened its position in the motion control markets. Ongoing improvements in resolution capabilities, frequency response, accuracy, mechanical bearing assemblies, and environmental packaging serve to maintain the optical encoder as the dominant choice for feedback devices.

INCREMENTAL VS. ABSOLUTE OUTPUT

In a preceding discussion, reference was made to a coded disc pattern like that in Figure 3-1, for which the encoder output is a digital word representing the absolute angular position of the encoder shaft; hence the designation absolute encoder.

If the coded disc pattern is replaced with a uniform pattern such as a series of equally spaced radial fines, encoder output becomes a series of incremental pulses that can be counted to determine shaft position relative to some reference point. This configuration is called an incremental encoder. This type routinely provides zero reference and dual channel outputs for homing and direction sensing functions, respectfully.

Comparatively, there are strengths and weaknesses to each device. The absolute encoder does not have to be homed after a power loss or noise burst. Incrementals are simpler to use and less expensive.

ENCODER ERROR

Incremental encoder error is composed of three types: 1) quantization error, 2) instrument error, 3) cycle interpolation error (if the encoder is so equipped).

Quantization error exists because the encoder cannot indicate motion occurring within one resolution quantum at transition points. This is the highest frequency error component and repeats every quantum of input motion. In a perfect encoder with no mechanical, optical or electronic deviation from the ideal, the correct angular position of the input shaft for a given readout is defined as the angular position midway between the transition from the next lower readout to the transition for the next higher readout. The quantization error is the deviation of the input shaft from the mid position for a given readout, with the maximum error ±1/2 of the angular rotation between two successive bits. For example, a rotary incremental encoder that generates 360 pulses per revolution has a quantization error of ±1/2 angular degrees (see Figure 3-4).

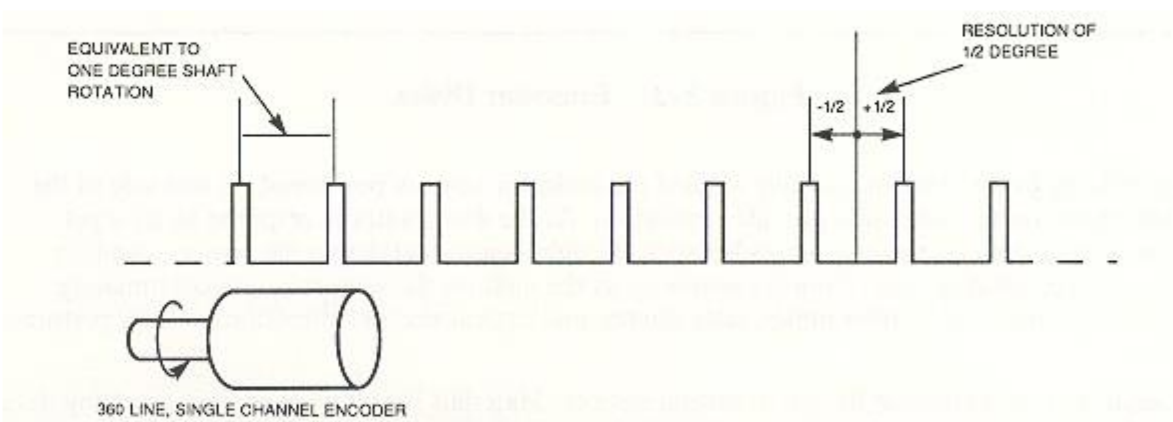

Figure 3-4. Encoder Resolution

Instrument error is the sum of disc and reticle pattern errors and mechanical imperfections within the encoder. Factors such as bearing types, line to space ratio tolerances, substrate flatness, optical setup, and encoder alignment contribute to this type error. Manufacturers will usually specify these types of errors and quantify them relative to specific encoders or encoder groups.

Cycle interpolation error (if the encoder is so equipped) is due to imperfections in the analog signals from the photodetector and their subsequent processing. These imperfections consist of phase shifts or dc offsets in the quadrature encoder signals that create position errors in the signals zero crossings, which affect the count produced by a given amount of movement, as zero crossings are counted as a measure of movement. The effect of these errors are magnified by interpolating a line cycle into smaller increments of motion. To minimize such errors, disc line counts should be kept as high as possible to allow usage of the lowest possible interpolation factor. In general, cycle interpolation error is about one-half quantum (resolution interval) for higher interpolation factors and one-eighth quantum for lower interpolation factors.