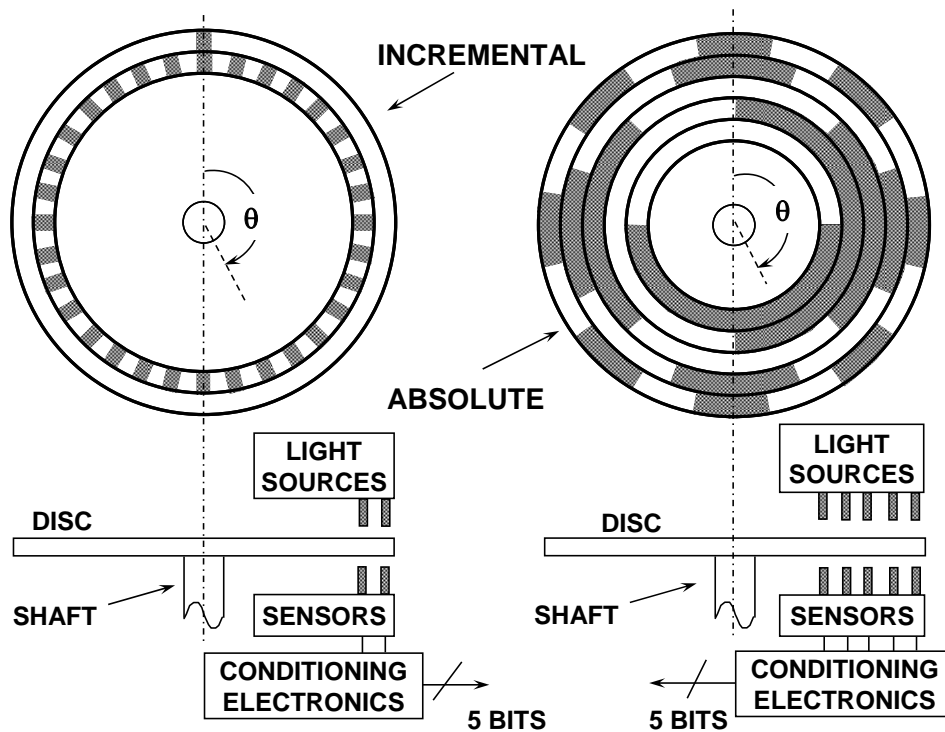


## Optical Encoders

by Walt Kester

Among the most popular position measuring sensors, optical encoders find use in relatively low reliability and low resolution applications. An *incremental* optical encoder (left-hand diagram in Figure 1) is a disc divided into sectors that are alternately transparent and opaque. A light source is positioned on one side of the disc, and a light sensor on the other side. As the disc rotates, the output from the detector switches alternately on and off, depending on whether the sector appearing between the light source and the detector is transparent or opaque.

Thus, the encoder produces a stream of square wave pulses which, when counted, indicate the angular position of the shaft. Available encoder resolutions (the number of opaque and transparent sectors per disc) range from 100 to 65,000, with absolute accuracies approaching 30 arc-seconds (1/43,200 per rotation). Most incremental encoders feature a second light source and sensor at an angle to the main source and sensor, to indicate the direction of rotation. Many encoders also have a third light source and detector to sense a once-per-revolution marker. Without some form of revolution marker, absolute angles are difficult to determine. A potentially serious disadvantage is that incremental encoders require external counters to determine absolute angles within a given rotation. If the power is momentarily shut off, or if the encoder misses a pulse due to noise or a dirty disc, the resulting angular information will be in error.



**Figure 1: Incremental and Absolute Optical Encoders**

The *absolute* optical encoder (right-hand diagram in Figure 1) overcomes these disadvantages but is more expensive. An absolute optical encoder's disc is divided up into N sectors (N = 5 for example shown), and each sector is further divided radially along its length into opaque and transparent sections, forming a unique N-bit digital word with a maximum count of  $2^N - 1$ . The digital word formed radially by each sector increments in value from one sector to the next, usually employing Gray code. Binary coding could be used, but can produce large errors if a single bit is incorrectly interpreted by the sensors. Gray code overcomes this defect: the maximum error produced by an error in any single bit of the Gray code is only 1 LSB after the Gray code is converted into binary code. A set of N light sensors responds to the N-bit digital word which corresponds to the disc's absolute angular position.

Industrial optical encoders achieve up to 16-bit resolution, with absolute accuracies that approach the resolution (20 arc seconds). Both absolute and incremental optical encoders, however, may suffer damage in harsh industrial environments.

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