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DEPARTMENT OF BIOMEDICAL ENGINEERING

III Semester- BM3301 SENSORS AND MEASUREMENTS

UNIT - 3

3.9 Optical Displacement Sensors and Optical Encoders.

3.9.1 Optical Displacement Sensors:

Optical transducers follow the following two types of principles for their operation:

(1) They consist of a system of **coded tracks** consisting of **transparent and opaque** sections and associated lamps and photocells to detect the corresponding switching sequence,

(2) They rely on the use of **Moire's fringe techniques**, capable of much higher resolution when used for incremental measurement.

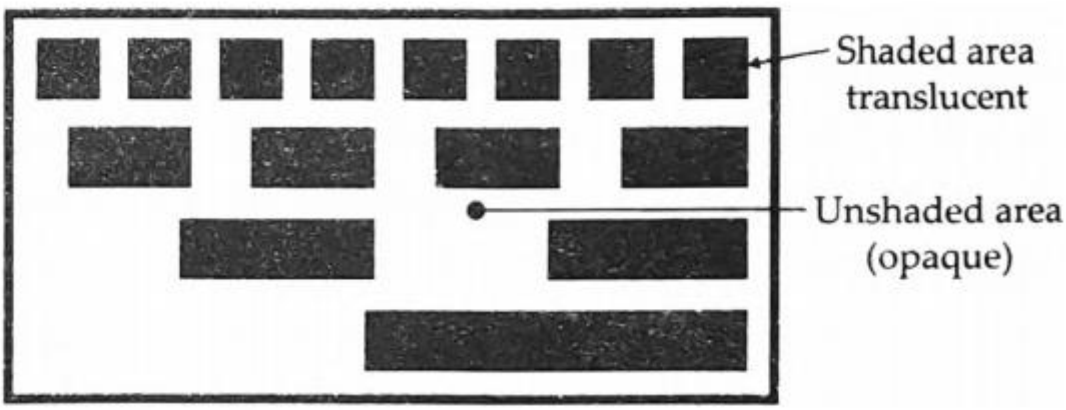


Fig. 3.9.1 Pattern of translucent and opaque sectors used in optical encoders.

- ✓ A sector (Fig. 3.9.1) may be designed with a pattern of opaque and translucent areas.
- ✓ A photo-electric sensor and a light source is placed on the two sides of the sector.
- ✓ The displacement is applied to the sector and therefore changes the amount of light falling on the photo-electric sensor.

- ✓ The pattern of illuminated sensor then carries the information as to the location of the sector.
- ✓ Figure 3.9.1 shows a possible sector of pattern of opaque and translucent areas.
- ✓ The number of levels in the encoder determines the accuracy with which device operates.

Moire Fringe Method :

The Moire Fringe Method is an optical method of amplifying displacement and uses two identical gratings. The gratings consist of a number of slits on an opaque screen, the slits being transparent. The pitch of the gratings is quite small, and may be between 0.005 mm to 0.05 mm.

Figure 3.9.2 shows two gratings of the same pitch, mounted face-to-face, with the ruling inclined at angle θ to each other. As shown in figure, a set of dark bands, called Moire fringes, is obtained, with fringe spacing very large as compared to pitch of the grating.

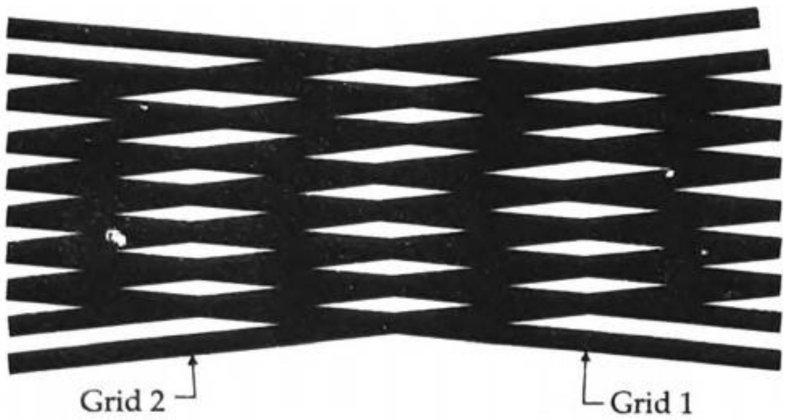


Fig.3.9.2 Moire Fringes.

A movement of the grating in a direction perpendicular to the gratings would move the fringes in a direction perpendicular to the fringes by a larger amount. The movement of the fringes can be measured and from the same, movement of the grating can be calculated or alternatively, the number of fringes passing a given point can be counted, using a photo-electric transducer.

This method of displacement measurement is used for measuring the movement of work in machine tools with an accuracy of ± 0.001 percent over a large range.

The essential element of a moire fringe measuring system, be it linear or rotary, is a length of transparent material engraved transversely or in the case of a rotary transducer, radially with a precisely known number of lines per unit length or angle rotation. When two similarly engraved sections are super imposed at a slight angle, a beam of light projected through the twin layer produces a dark area; caused by the angular intersection of the individual lines.

Travel of one section in the direction of its long axis produces a movement of this dark area (fringe) at right angles to the movement; travel in the opposite direction produces a reversal of the fringe movement.

One complete movement of the fringe across the field represents a distance of one-line division, thus a very small movement is translated into an easily readable quantity resulting in a very accurate system for measurement-particularly when the engravings are finely spaced. Linear resolutions of 2.5 pm to an accuracy of ±1.2 pm in 250 mm travel are obtainable. Defects due to possible minor local blemishes are integrated out because the fringe signal is derived from the interference pattern of a considerable number of lines. The use of Moire fringe technique reproduces a typical fringe pattern and resulting waveforms on the outputs of four photo-cells evenly spaced across the track is shown in Fig. 3.9.3.

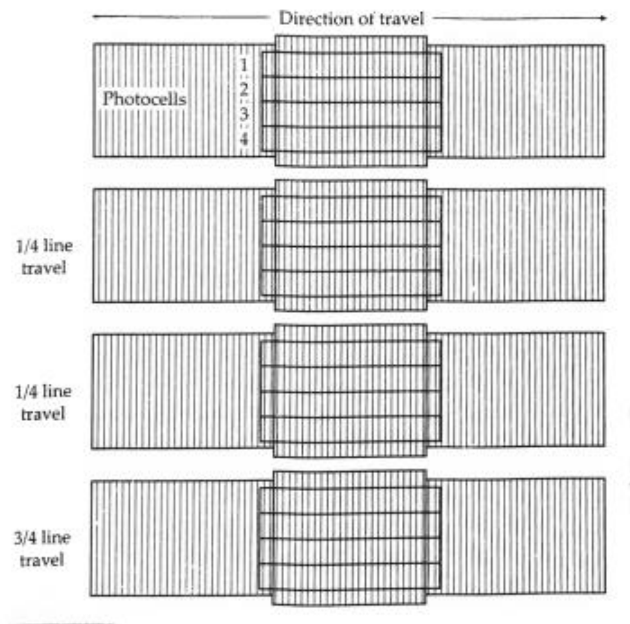


Fig. 3.9.3 Moire fringe measuring technique

3.9.2 Optical Encoders:

- ✓ The optical encoder is a transducer used for measuring rotational motion.
- ✓ Optical encoders are devices used to convert mechanical motion into electrical signals that can be interpreted by a computer or electronic system.
- ✓ Optical encoders use light to detect changes in position.

There are two basic generic styles of optical encoders:

(i) Absolute optical encoders
(ii) Incremental Optical encoders

(i) Absolute optical encoders:

An absolute optical encoder is a device that uses an encoder wheel to measure the position of a moving object relative to a fixed reference point. An eight-bit absolute optical shaft encoder is shown in **Fig. 3.9.4**. The output code is derived from independent tracks on the encoder disc corresponding to individual photo detectors. The output from these detectors would then be high or low (1 or 0) depending upon the code disc pattern for that particular position.

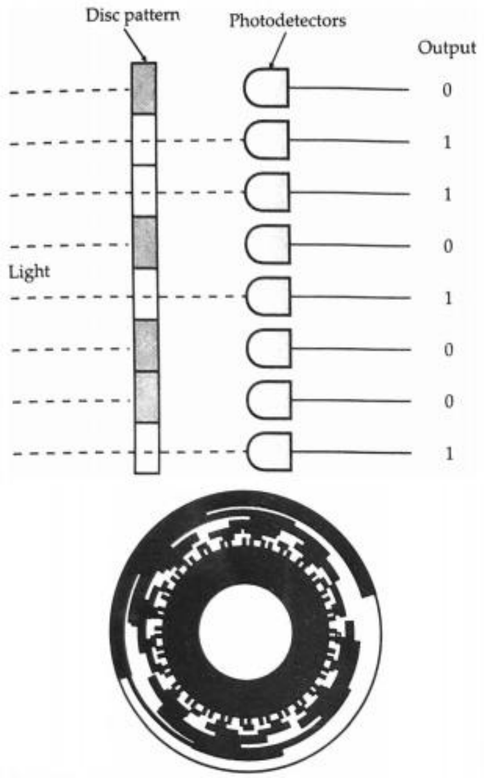


Fig. 3.9.4 An 8 -bit absolute optical shaft encoder

Absolute Encoders are used in applications where a device is inactive for long periods of time or moves at slow rates, such as for flood control, telescopes, cranes etc. Absolute encoders use the natural binary code or Gray code and BCD in addition to many other codes.

(ii) Incremental Optical Encoders:

Output is a ***pulse signal*** that is generated when the transducer disk rotates as a result of the motion that is being measured.

By counting pulses or by timing the pulse width using a clock signal, both angular displacement and angular velocity can be determined.

The incremental encoder creates a series of equally spaced signals corresponding to the mechanical increment required. For example, if we divide a shaft rotation into 100 parts, an encoder would be selected to supply 1000 square wave cycles per revolution. By using a counter to count these cycles, we can find out how much the shaft has rotated. Suppose the count is 100, then the shaft has rotated through 360 x (100 /1000) =360°.

The simpler type of incremental encoder is the tachometer encoder. Its output wave form and code track on the disc are shown in ***Fig. 3.9.5***. A tachometer encoder is sometimes called a single-track incremental encoder because it has only one output and cannot detect direction. The output is usually a square wave. Information about velocity is available by looking at the time interval between pulses or at the number of pulses within a time period.

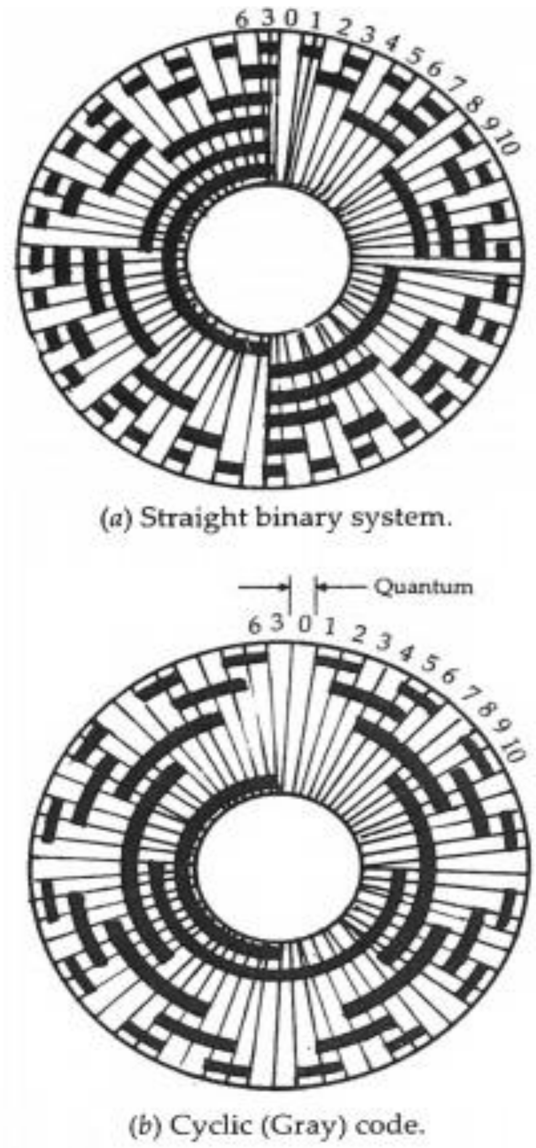


Fig.3.9.5 Shaft Encoders.

Optical encoders tend to follow one of two principles of operation; they consist of either a system of coded tracks consisting of transparent and opaque sections and associated lamps and photocells to detect the corresponding switching sequence, or they rely on the use of moire fringe techniques, capable of much higher resolution when used for incremental measurement.

The absolute digitiser comprises an assembly consisting of a Gray-coded pattern photographically reproduced on a glass disc mounted on the input shaft. The code consists of ten annular tracks each with a pattern of opaque and transparent sections. The code reading system employs a filament lamp and collimating lens from which light passes through the disc and a narrow radial slit, to be detected by ten photovoltaic cells. Depending on the angular position of the shaft, certain cells receive light from the transparent portions of the disc and enable the outputs from all ten cells to reproduce the shaft position directly in parallel-Gray-coded form. The output, which is noise free, is suitable for amplification and subsequent processing for use in digital servo systems, computers, data logging and visual displays. ***Fig. 3.9.6*** shows the shaft encoders using straight binary and Gray codes.

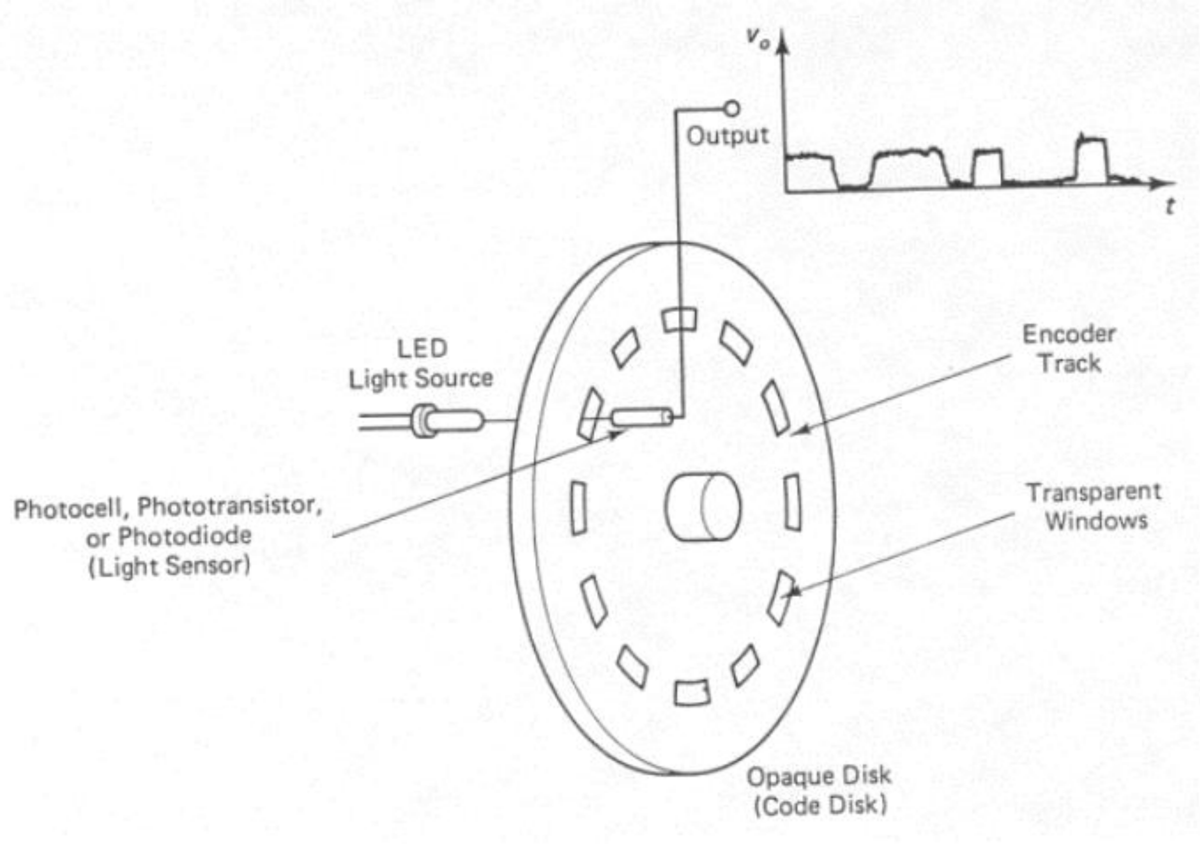
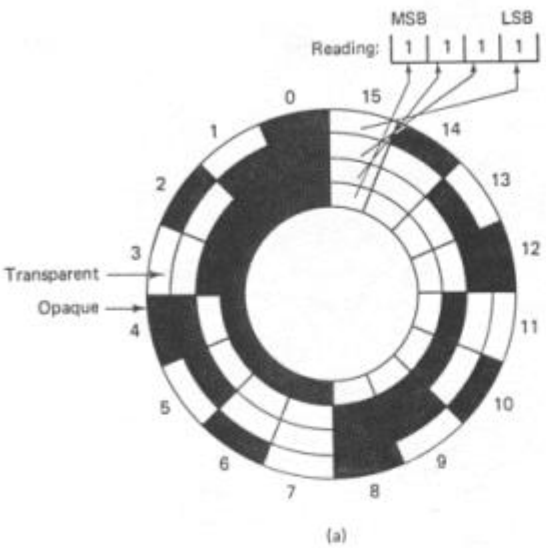
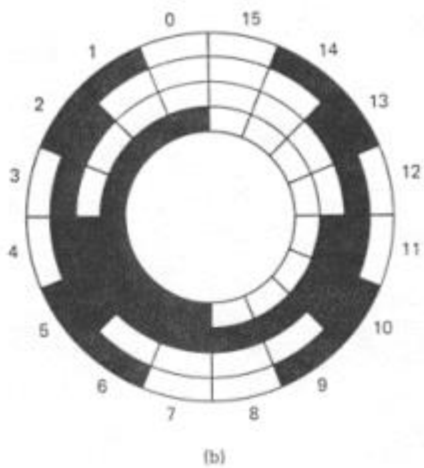


Fig. 3.9.6 Shaft encoders using straight binary and Gray codes.

Schematic Representation of an Optical Encoder One Track and One Pick-Off Sensor





Schematic Diagram of an Absolute Encoder Disk Pattern
(a) Binary code
(b) Gray code

Elements of the Optical Encoder:

- The optical encoder uses an opaque disk (code disk) that has one or more circular tracks, with some arrangement of identical transparent windows (slits) in each track.
- A parallel beam of light (e.g., from a set of light emitting diodes) is projected to all tracks from one side of the disk.
- The transmitted light is picked off using a bank of photosensors on the other side of the disk that typically has one sensor for each track.
- The light sensor could be a silicon photodiode, a phototransistor, or a photovoltaic cell.
- Since the light from the source is interrupted by the opaque areas of the track, the output signal from the probe is a series of voltage pulses. This signal can be interpreted to obtain the angular position and angular velocity of the disk.
- Note that an incremental encoder disk requires only one primary track that has equally spaced and identical window (pick-off) areas. The window area is equal to the area of the inter-window gap. Usually, a reference track that has just one window is also present in order to generate a pulse (known as the index pulse) to initiate pulse counting for angular position measurement and to detect complete revolutions.
- In contrast, absolute encoder disks have several rows of tracks, equal in number to the bit size of the output data word. Furthermore, the track windows are not equally spaced but are arranged in a specific pattern on each track so as to obtain a binary code (or gray code) for the output data from the transducer.
- It follows that absolute encoders need as least as many signal pick-off sensors as there are tracks, whereas incremental encoders need one pick-off sensor to detect the magnitude of rotation and an additional sensor at a quarter-pitch separation (pitch = center-to-center distance between adjacent windows) to identify the direction of rotation, i.e., the offset sensor configuration.
- Some designs of incremental encoders have two identical tracks, one a quarter-pitch offset from the other, and the two pick-off sensors are placed radially without any circumferential offset, i.e., the offset track configuration.

- Signal interpretation depends on whether the particular optical encoder is an incremental device or an absolute device. – We will focus on the incremental optical encoder.
- The output signals from either the offset sensor configuration or the offset track configuration are the same.
- Note that the pulse width and pulse-to-pulse period (encoder cycle) are constant in each sensor output when the disk rotates at constant angular velocity. When the disk accelerates, the pulse width decreases continuously; when the disk decelerates, the pulse width increases continuously.
- The quarter-pitch offset in sensor location or track position is used to determine the direction of rotation of the disk. It is obtained by determining the phase difference of the two output signals, using phase detection circuitry. One method for determining the phase difference is to time the pulses using a high frequency clock signal.

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