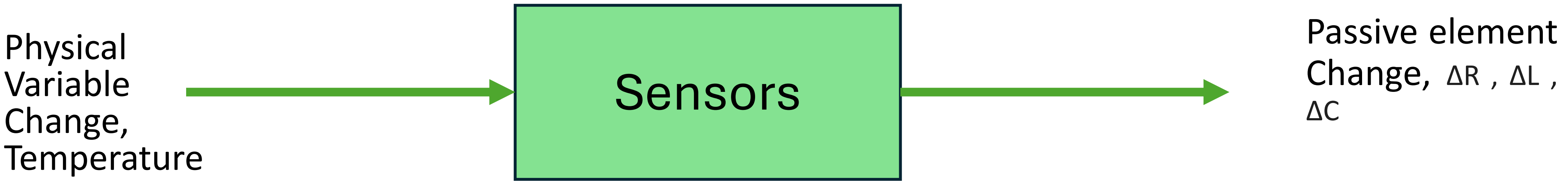
Sensors & Transducer

Measurement System:

- Collection of information on the system status.
- Feeding to the microprocessors.
- Control the system
- MS= Sensors, Transducers and Signal processing devices.

Sensors & Transducer

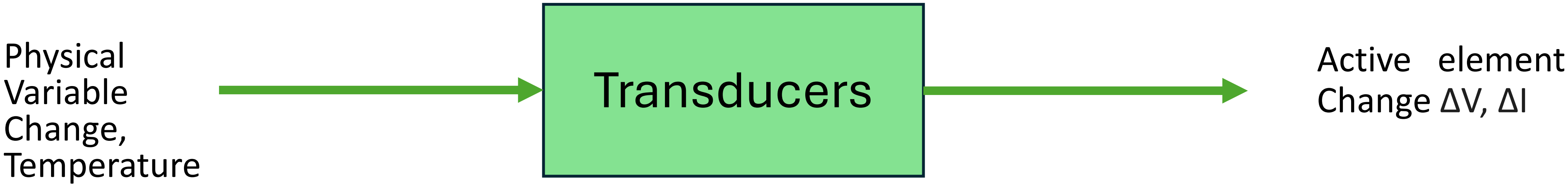
Introduction to Sensors & Transducers:



The term **sensor** is used for an element which produces a signal relating to the quantity being measured. Thus, in the case of, say, an electrical resistance temperature element, the quantity being measured is temperature and the sensor transforms an input of temperature into a change in resistance.

Sensors & Transducer

Introduction to Sensors & Transducers:



The term **transducer** is often used in place of the term sensor. Transducers are defined as elements that when subject to some physical change experience a related change. Thus, sensors are transducers. however, a measurement system may use transducers, in addition to the sensor, in other parts of the system to convert signals in one form to another form.

Sensors & Transducer

Smart Sensors

Some sensors come combined with their signal conditioning all in the same package. such an integrated sensor does still, however, require further data processing. However, it is possible to have the sensor and signal conditioning combined with a microprocessor all in the same package. Such an arrangement is termed a smart sensor.

A smart sensor can have such functions as the ability to compensate for random errors, to adapt to changes in the environment, give an automatic calculation of measurement accuracy, adjust for non-linearities to give a linear output, self-calibrate and give self-diagnosis of faults. Such sensors have their own standard, IEEE 1451, so that smart sensors conforming to this standard can be used in a ‘plug-and-play’ manner, holding and communicating data in a standard way.

Information is stored in the form of a teDs (transducer electronic Datasheet), generally in eeProM, and identifies each device and gives calibration data.

Sensors & Transducer

Performance Terminology:

The following terms are used to define the performance of transducers, and often measurement systems.

1. **Range & Span :**

The range of a transducer defines the limits between which the input can vary. The span is the maximum value of the input minus the minimum value. thus, for example, a load cell for the measurement of forces might have a range of 0 to 50 kN and a span of 50 kN.

2. Error :

Error is the difference between the result of the measurement and the true value of the quantity being measured:

$$\text{Error} = \text{Measured value} - \text{True value}$$

Sensors & Transducer

Performance Terminology:

3. Accuracy :

Accuracy is the extent to which the value indicated by a measurement system might be wrong. It is thus the summation of all the possible errors that are likely to occur, as well as the accuracy to which the transducer has been calibrated.

A temperature-measuring instrument might, for example, be specified as having an accuracy of 62°c. This would mean that the reading given by the instrument can be expected to lie within plus or minus 2°c of the true value.

Accuracy is often expressed as a percentage of the full range output or full-scale deflection. The percentage of full-scale deflection term results from when the outputs of measuring systems were displayed almost exclusively on a circular or linear scale.

A sensor might, for example, be specified as having an accuracy of 65% of full range output. Thus, if the range of the sensor was, say, 0 to 200°c, then the reading given can be expected to be within plus or minus 10°c of the true reading.

Sensors & Transducer

Performance Terminology:

3. Sensitivity :

The sensitivity is the relationship indicating how much output there is per unit input, i.e. output/input. For example, a resistance thermometer may have a sensitivity of 0.5 V/°c.

This term is also frequently used to indicate the sensitivity to inputs other than that being measured, i.e. environmental changes. thus, there can be the sensitivity of the transducer to temperature changes in the environment or perhaps fluctuations in the mains voltage supply.

A transducer for the measurement of pressure might be quoted as having a temperature sensitivity of 60.1% of the reading per °c change in temperature.

Sensors & Transducer

Performance Terminology:

4. Hysteresis Error:

Transducers can give different outputs from the same value of quantity being measured according to whether that value has been reached by a continuously increasing change or a continuously decreasing change. this effect is called hysteresis.

Below Figure shows such an output with the hysteresis error as the maximum difference in output for increasing and decreasing values.

Sensors & Transducer

Performance Terminology:

4. Hysteresis Error:

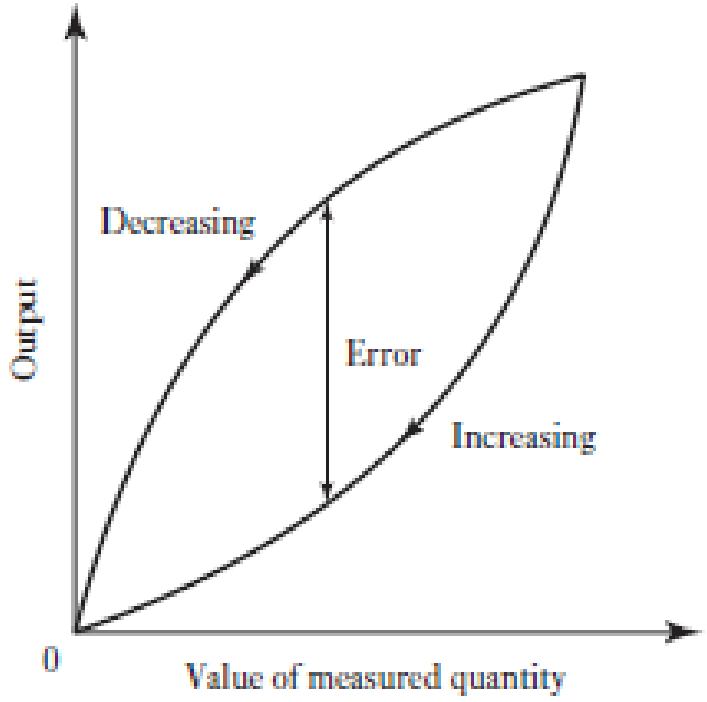


Fig: Hysteresis Error

Sensors & Transducer

Performance Terminology:

5. Non- Linear Error:

For many transducers, a linear relationship between the input and output is assumed over the working range, i.e., a graph of output plotted against input is assumed to give a straight line. Few transducers, however, have a truly linear relationship and thus errors occur because of the assumption of linearity.

The error is defined as the maximum difference from the straight line. Various methods are used for the numerical expression of the non-linearity error. The differences occur in determining the straight-line relationship against which the error is specified.

One method is to draw the straight line joining the output values at the end points of the range; another is to find the straight line by using the method of least squares to determine the best fit line when all data values are considered equally likely to be in error; another is to find the straight line by using the method of least squares to determine the best fit line which passes through the zero point.

Sensors & Transducer

Performance Terminology:

5. Non- Linear Error:

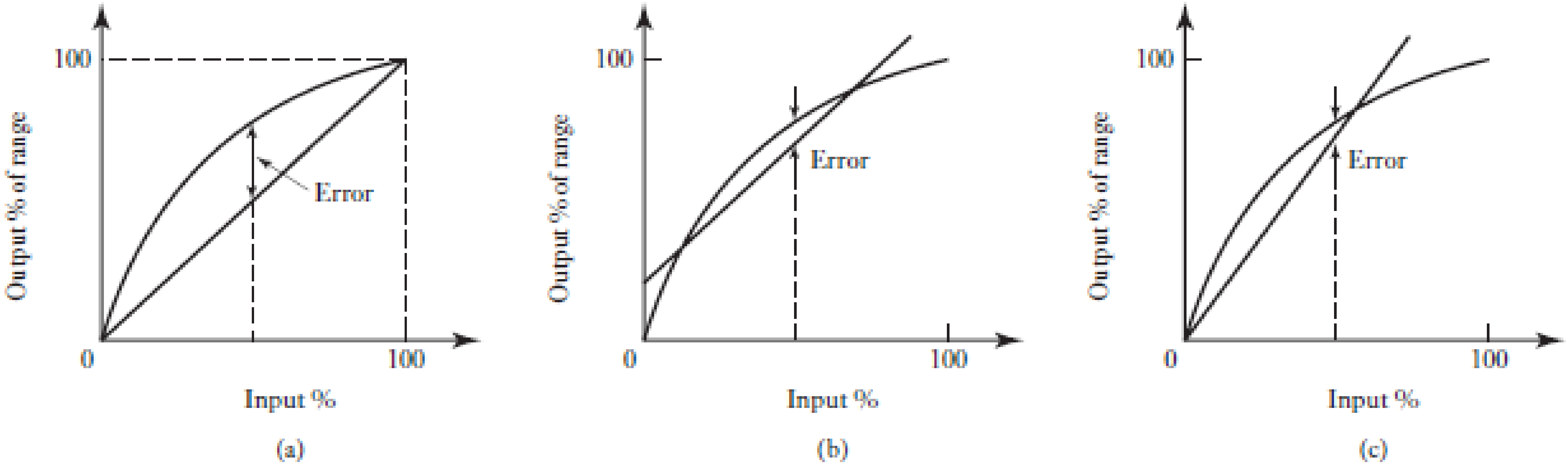


Figure 2.2 Non-linearity error using: (a) end-range values, (b) best straight line for all values, (c) best straight line through the zero point.

Sensors & Transducer

Performance Terminology:

6. Repeatability / Reproducibility:

7. Stability:

8. Dead Band / Time

9. Resolution :

10. Output Impedance:

Sensors & Transducer

Displacement, Position & Proximity Sensors :

Displacement sensors are concerned with the measurement of the amount by which some object has been moved; position sensors are concerned with the determination of the position of some object in relation to some reference point.

Proximity sensors are a form of position sensor and are used to determine when an object has moved to within some critical distance of the sensor. they are essentially devices which give on/off outputs.

Displacement and position sensors can be grouped into two basic types: contact sensors in which the measured object comes into mechanical contact with the sensor, or non-contacting where there is no physical contact between the measured object and the sensor.

For those linear displacement methods involving contact, there is usually a sensing shaft which is in direct contact with the object being monitored. the displacement of this shaft is then monitored by a sensor. the movement of the shaft may be used to cause changes in electrical voltage, resistance, capacitance or mutual inductance. For angular displacement methods involving mechanical connection, the rotation of a shaft might directly drive, through gears, the rotation of the transducer element. non-contacting sensors might involve the presence in the vicinity of the measured object causing a change in the air pressure in the sensor, or perhaps a change in inductance or capacitance.

Sensors & Transducer

Commonly Used Sensors:

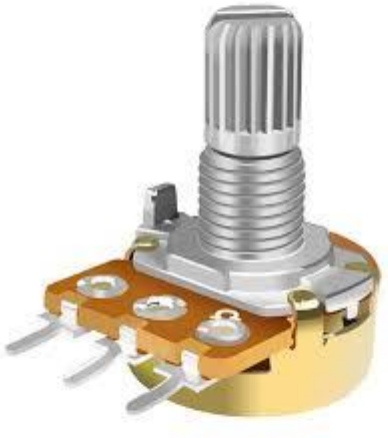
1. Potentiometer sensor:
2. Stain- gauge elements
3. Capacitive elements
4. Differential transformers
5. Eddy current Proximity sensors
6. Inductive proximity switch
7. Optical encoders
8. Pneumatic sensors
9. Proximity sensors
10. Hall effect sensors

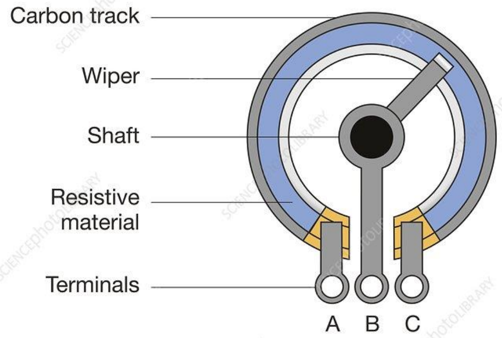
Sensors & Transducer

Commonly used sensors:

1. Potentiometer sensor:

A potentiometer consists of a resistance element with a sliding contact which can be moved over the length of the element. Such elements can be used for linear or rotary displacements, the displacement being converted into a potential difference. The rotary potentiometer consists of a circular wire-wound track or a film of conductive plastic over which a rotatable sliding contact can be rotated.



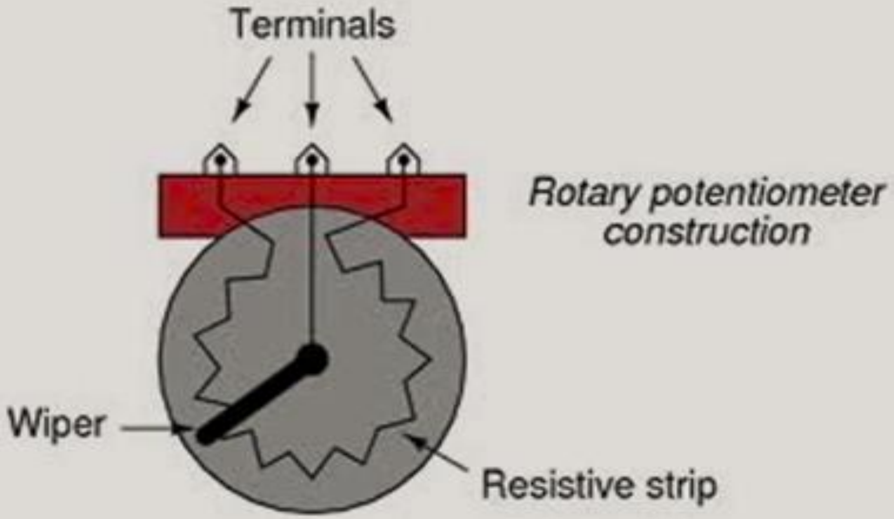


Sensors & Transducer

Commonly used displacement sensors:

Potentiometer Sensors

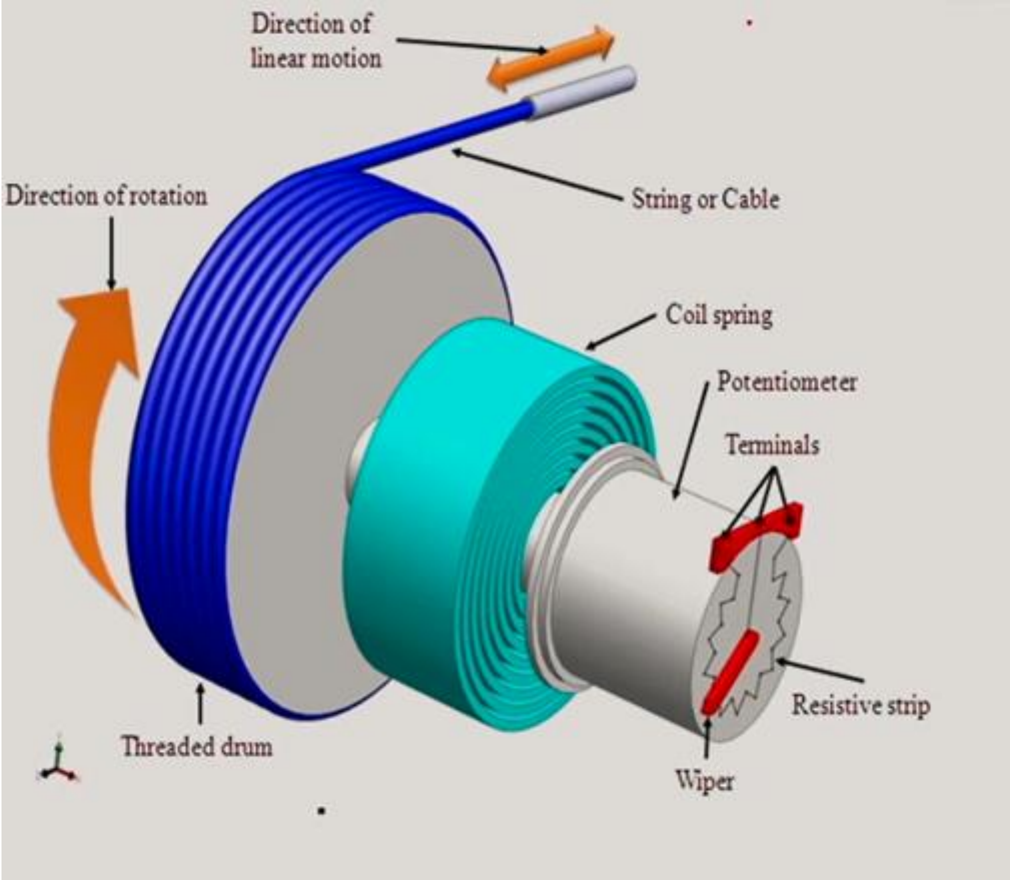
- Resistance element with sliding contact
- Linear or rotary
- Linear / Circular wire-wound track or film of conductive plastic
- Displacement is measured based on potential difference

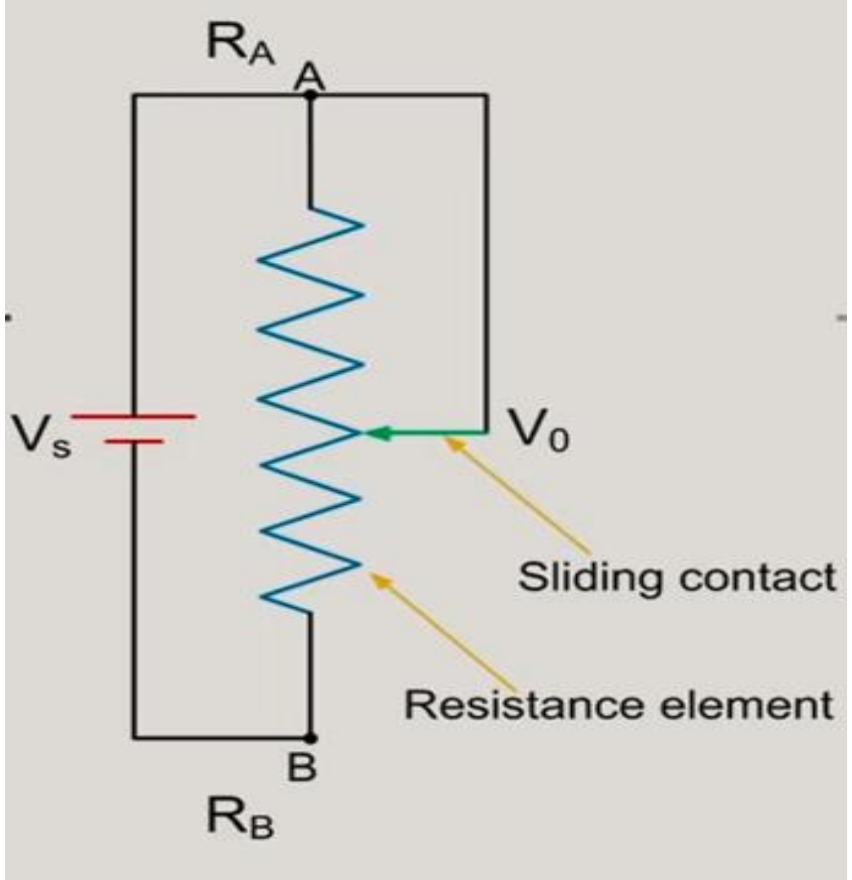


- Plastic resin embedded with carbon powder

Sensors & Transducer

Commonly used displacement sensors:





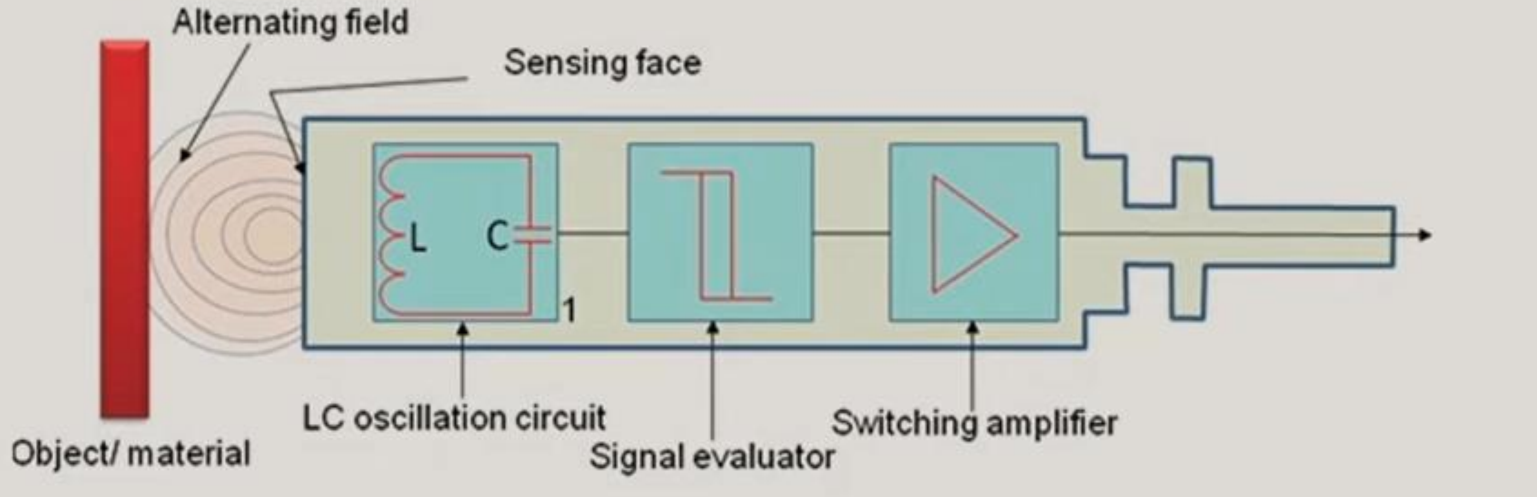
Application: Throttle Valve , Adjustment of Voltage , Throttle Cable free acceleration, Electronic suspension,

Sensors & Transducer

Commonly Used Sensors:

Inductive proximity switch

- Coil wound on a core -> close to a metallic object -> inductance changes -> triggers a switch
- Detection of metallic objects



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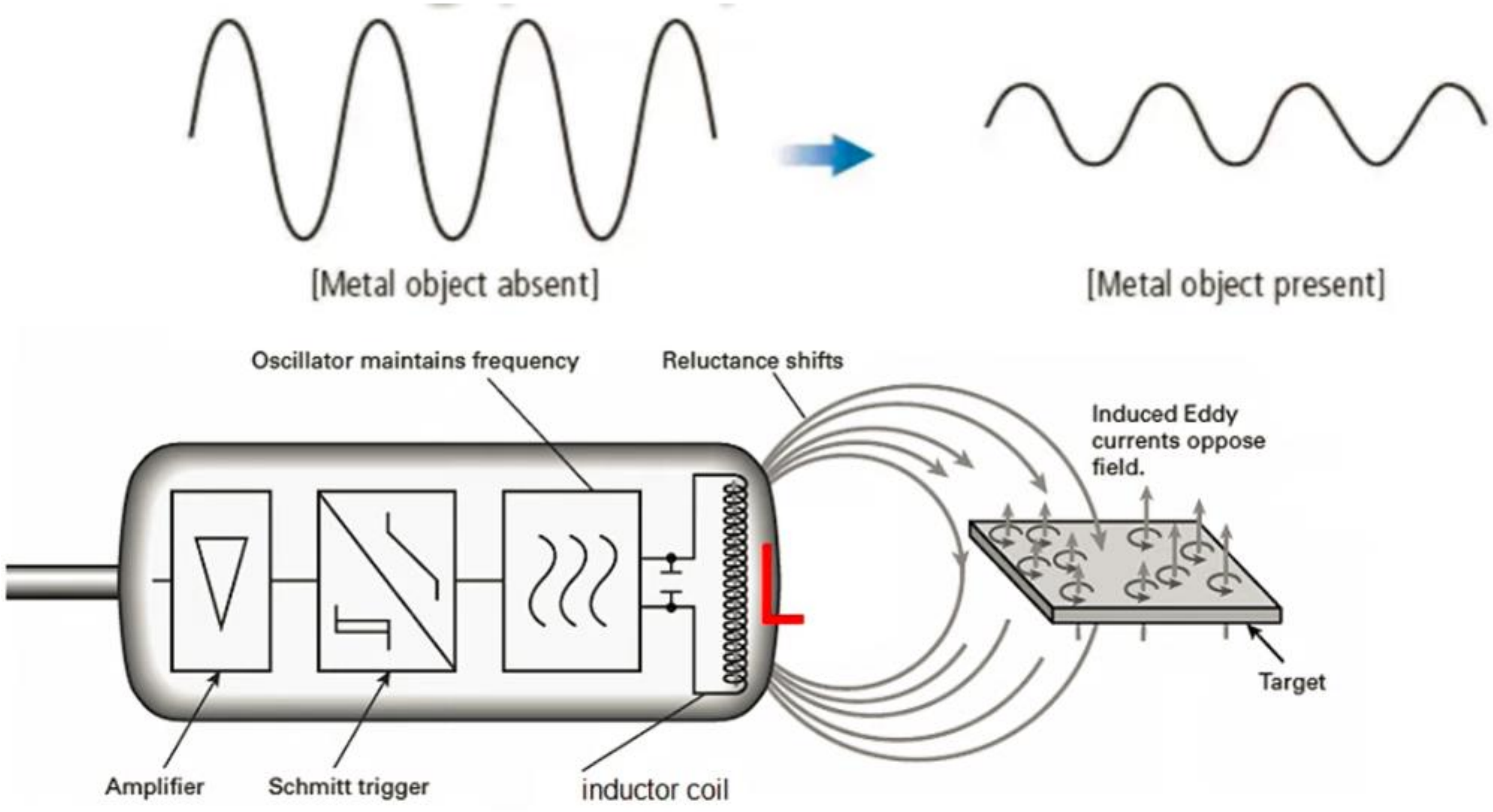
Commonly Used Sensors:

Inductive proximity switch



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Commonly Used Sensors:

Inductive proximity switch

Sensors & Transducer

Commonly Used Sensors:

Inductive proximity switch

Sensors & Transducer

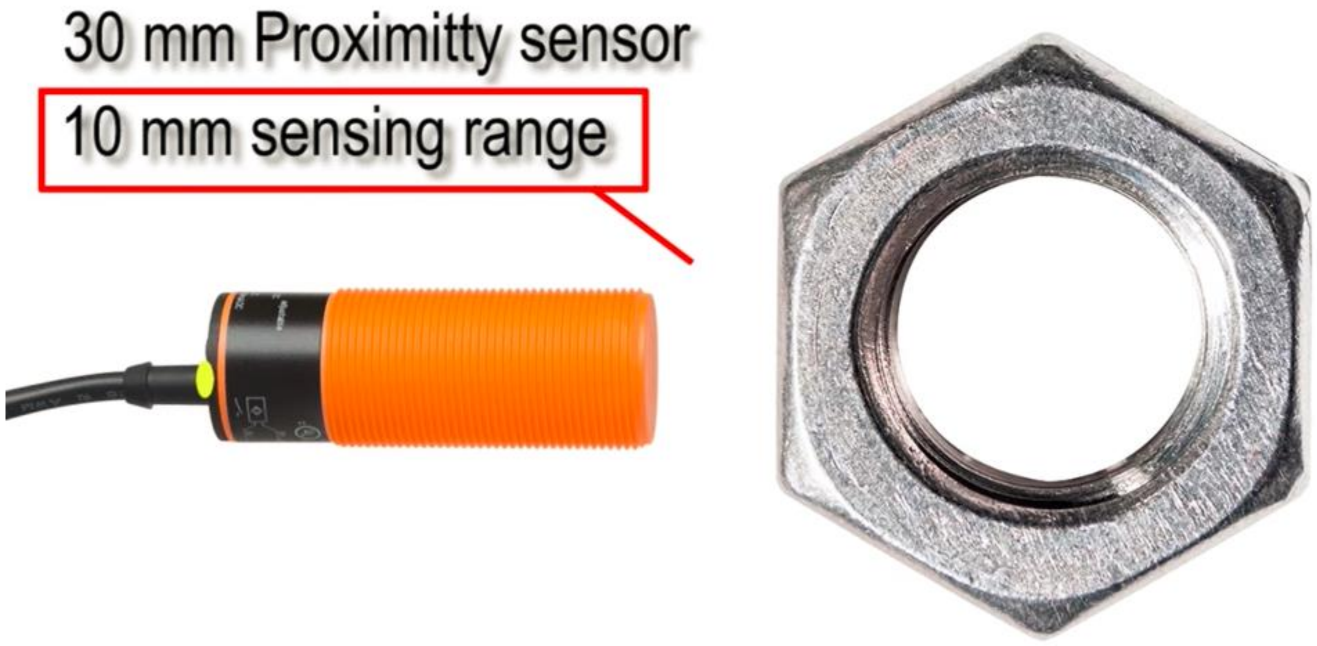
Commonly Used Sensors:

Inductive proximity switch

Sensors & Transducer

Commonly Used Sensors:

Inductive proximity switch



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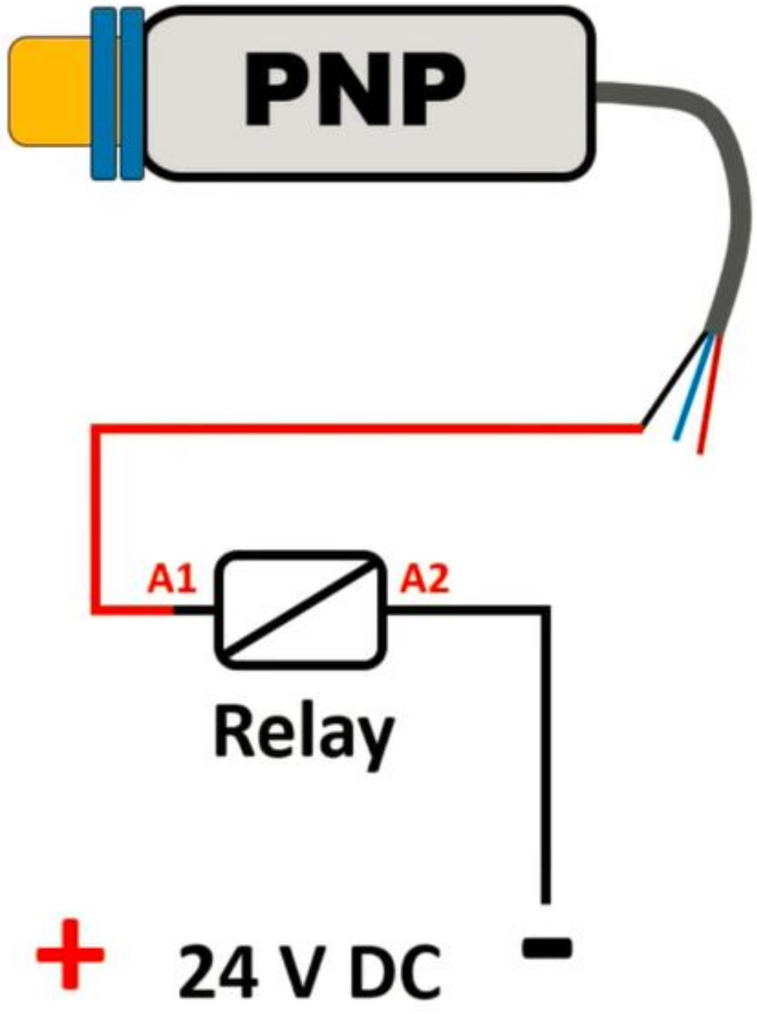
Commonly Used Sensors:

Inductive proximity switch

Sensors & Transducer

PNP Inductive proximity switch



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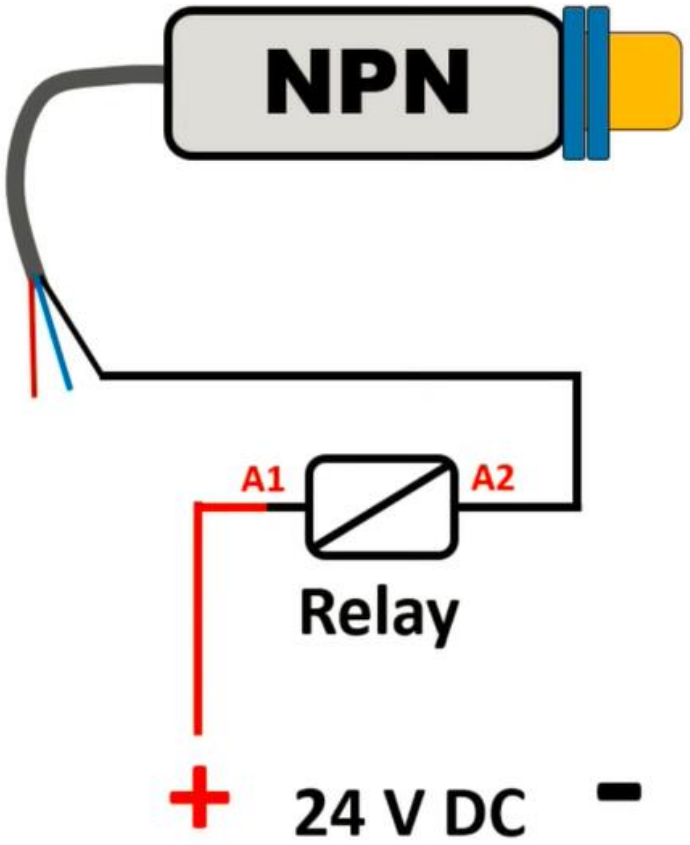
NPN Inductive proximity switch



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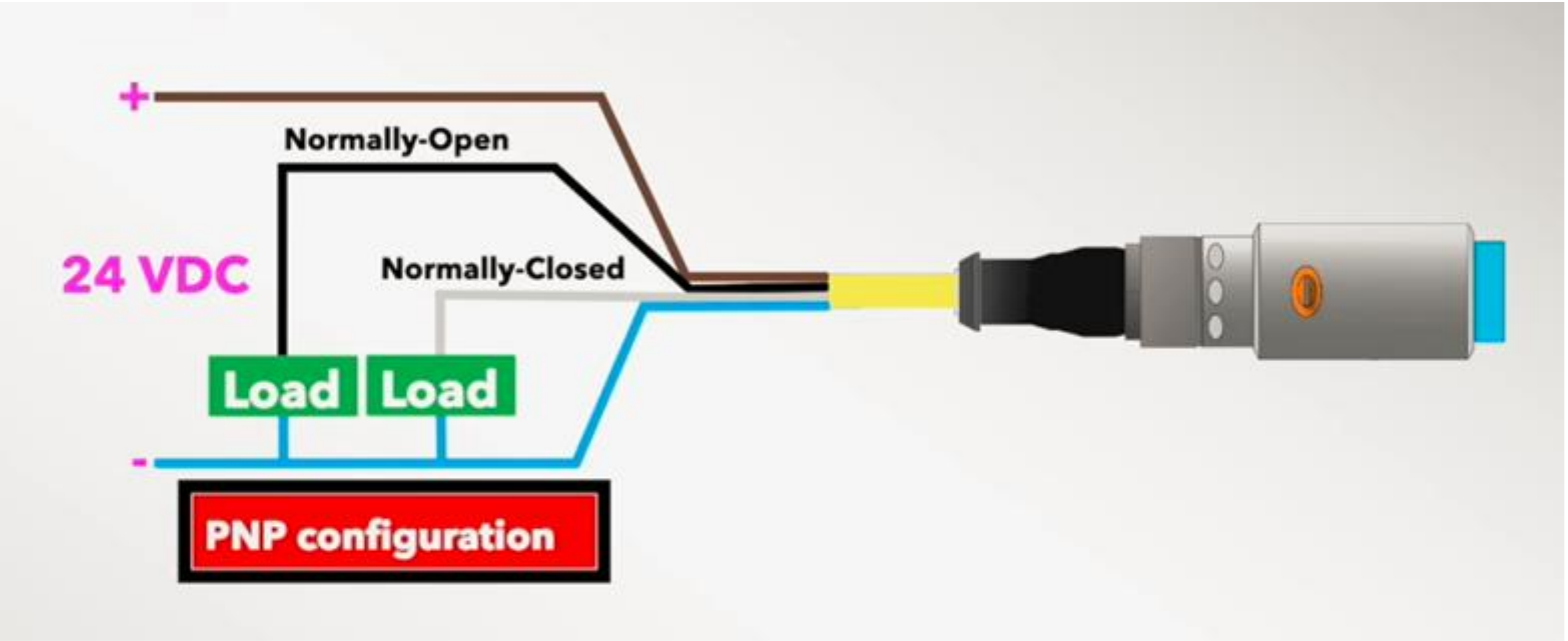
4 Wire proximity switch Connection :



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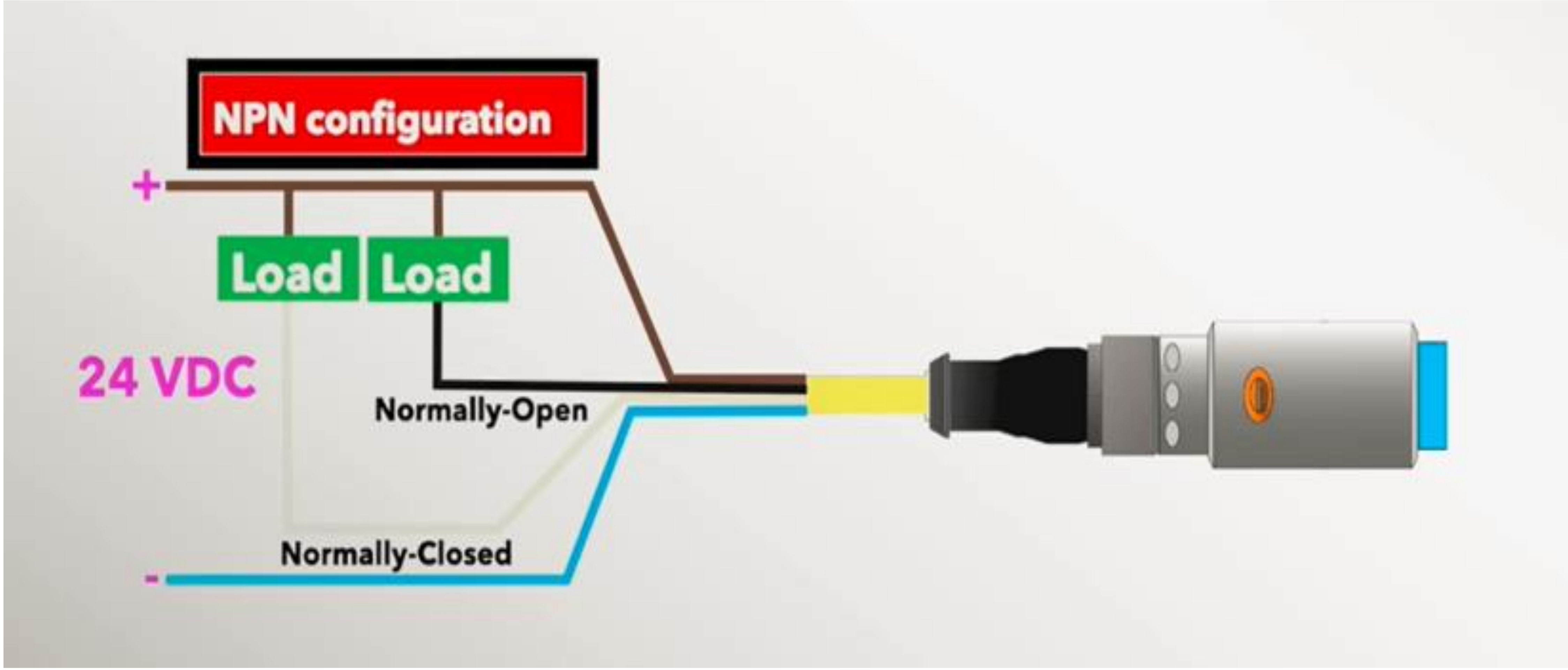
4 Wire proximity switch Connection :

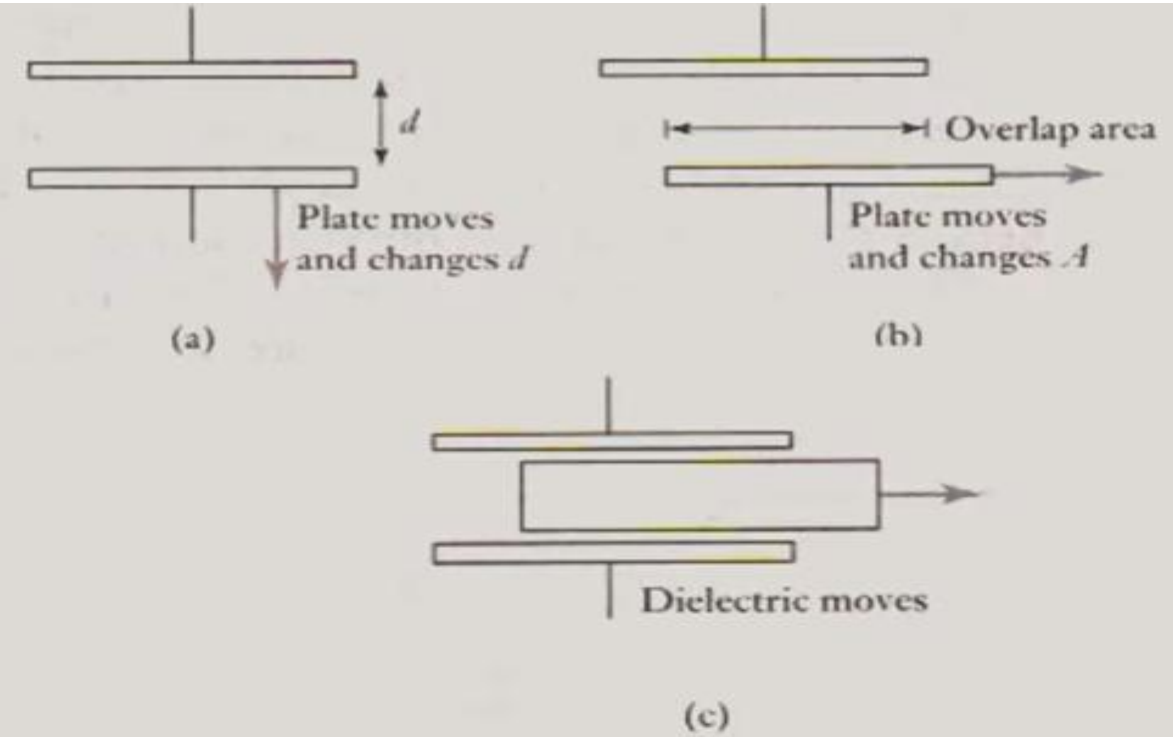


Sensors & Transducer

Capacitive proximity switch:

- Monitoring of displacement
- Non-contact type displacement sensor
- $C = (\varepsilon_r \varepsilon_o A)/d$
- ε_r = relative permittivity of dielectric between the plates

  $\varepsilon_r = 1$ for vacuum
- ε_o = permittivity of free space $\varepsilon_0 \approx 8.854 \times 10^{-12}$ F m^{-1}



A = area of overlap
d = plate separation

Permittivity relates to a material's ability to transmit (or "permit") an electric field.

Sensors & Transducer

Capacitive proximity switch:

Capacitance is inversely proportional to change in distance so, D + Δx Results C- ΔC **.**

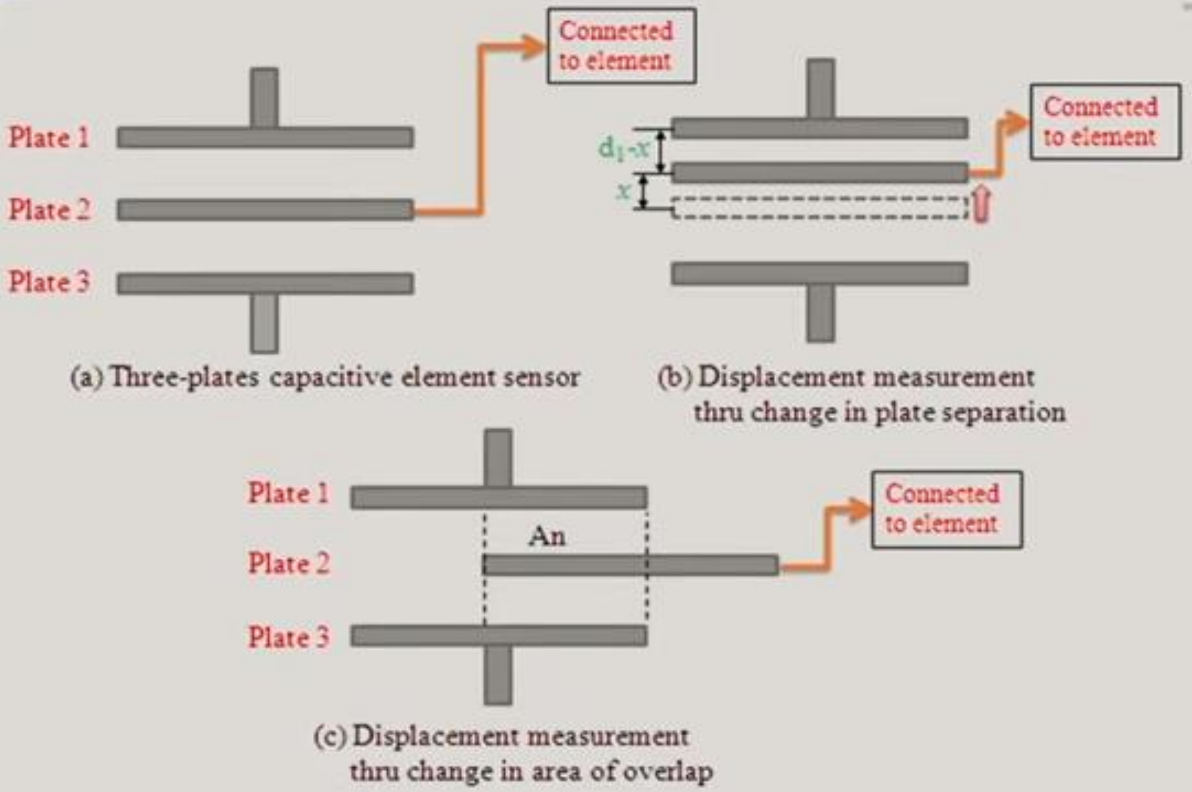
Capacitance is directly proportional to change in Cross sectional area so, A –ΔA Results C- ΔC

Capacitance (C)= F(d, A, movement of dielectric medium)

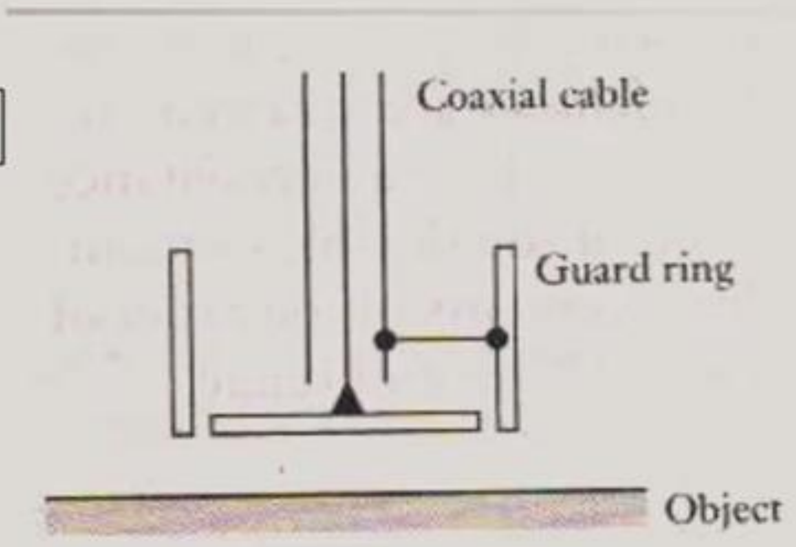
Change in capacitance is further utilized to get displacement.

Sensors & Transducer

Capacitive proximity switch:



Push – pull displacement sensor



Capacitive proximity sensor

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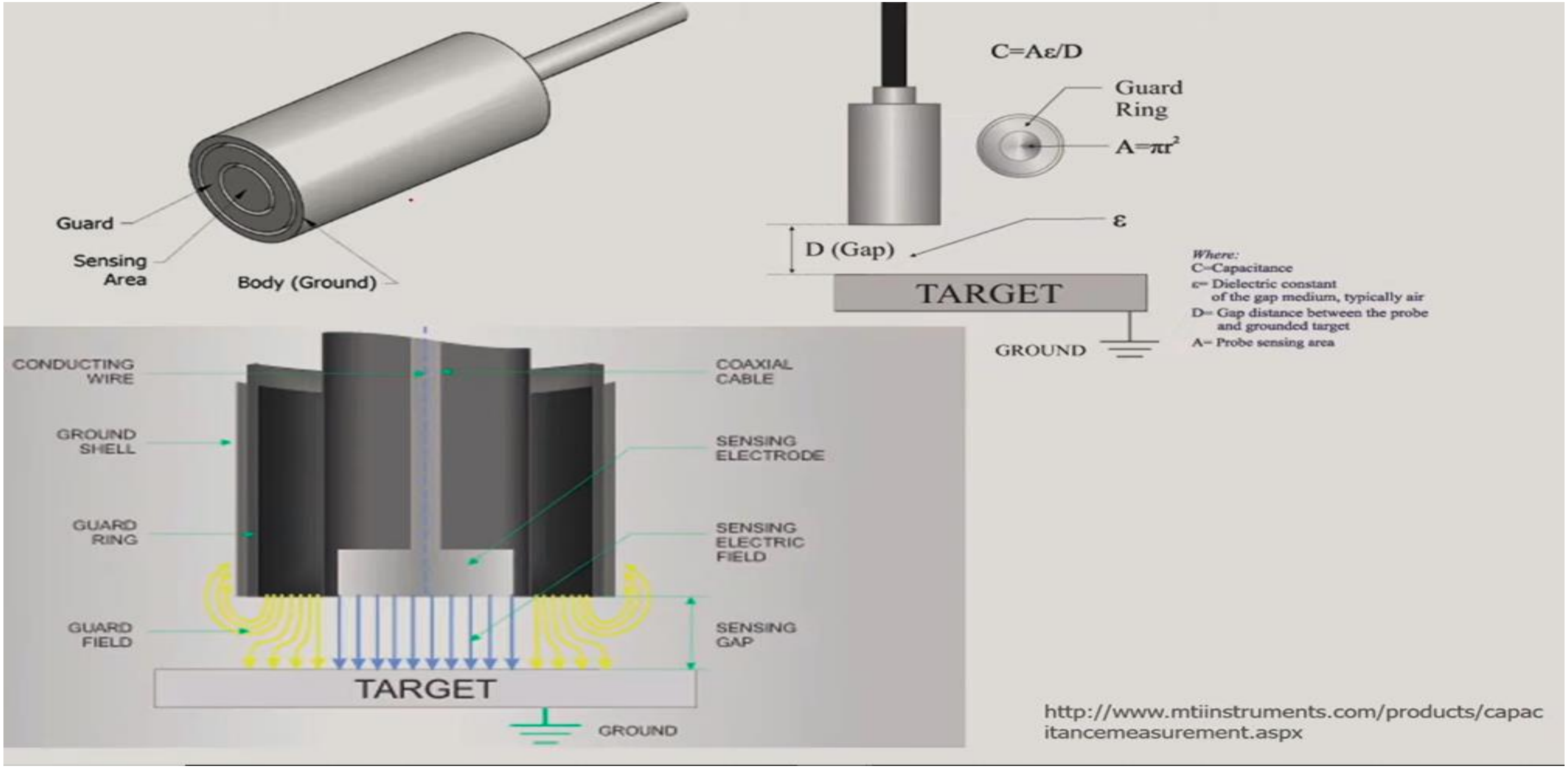
Capacitive proximity switch:



http://www.mtiinstruments.com/products/capacitancemeasurement.aspx

Sensors & Transducer

Application of Capacitive proximity switch:

- **Feed hopper level monitoring**
- **Grease level monitoring**
- **Level control of liquids**
- **Metallurgy Applications**
  - **To measure the shape error in the parts being produced.**
  - **To analyze and optimize the rotation of spindles in various machine tools such as surface grinders, lathes, milling machines, and air bearing spindles by measuring errors in the machine tools themselves.**

Sensors & Transducer

Optical Encoders:

An encoder is a device that provides a digital output because of a linear or angular displacement. Position encoders can be grouped into two categories: incremental encoders, which detect changes in rotation from some datum position; and absolute encoders, which give the actual angular position.

A beam of light passes through slots in a disc and is detected by a suitable light sensor. When the disc is rotated, a pulsed output is produced by the sensor with the number of pulses being proportional to the angle through which the disc rotates. Thus, the angular position of the disc, and hence the shaft rotating it, can be determined by the number of pulses produced since some datum position. In practice three concentric tracks with three sensors are use. The inner track has just one hole and is used to locate the 'home' position of the disc.

The other two tracks have a series of equally spaced holes that go completely round the disc but with the holes in the middle track offset from the holes in the outer track by one-half the width of a hole. This offset enables the direction of rotation to be determined. In a clockwise direction the pulses in the outer track lead those in the inner; in the anti-clockwise direction they lag. The resolution is determined by the number of slots on the disc. With 60 slots in 1 revolution then, since 1 revolution is a rotation of 360°, the resolution is 360/60 = 6°.

Sensors & Transducer

Optical Encoders:

Sensors & Transducer

Optical Encoders:

Color	Function
Red	motor power (connects to one motor terminal)
Black	motor power (connects to the other motor terminal)
Green	encoder GND
Blue	encoder Vcc (3.5 – 20 V)
Yellow	encoder A output
White	encoder B output

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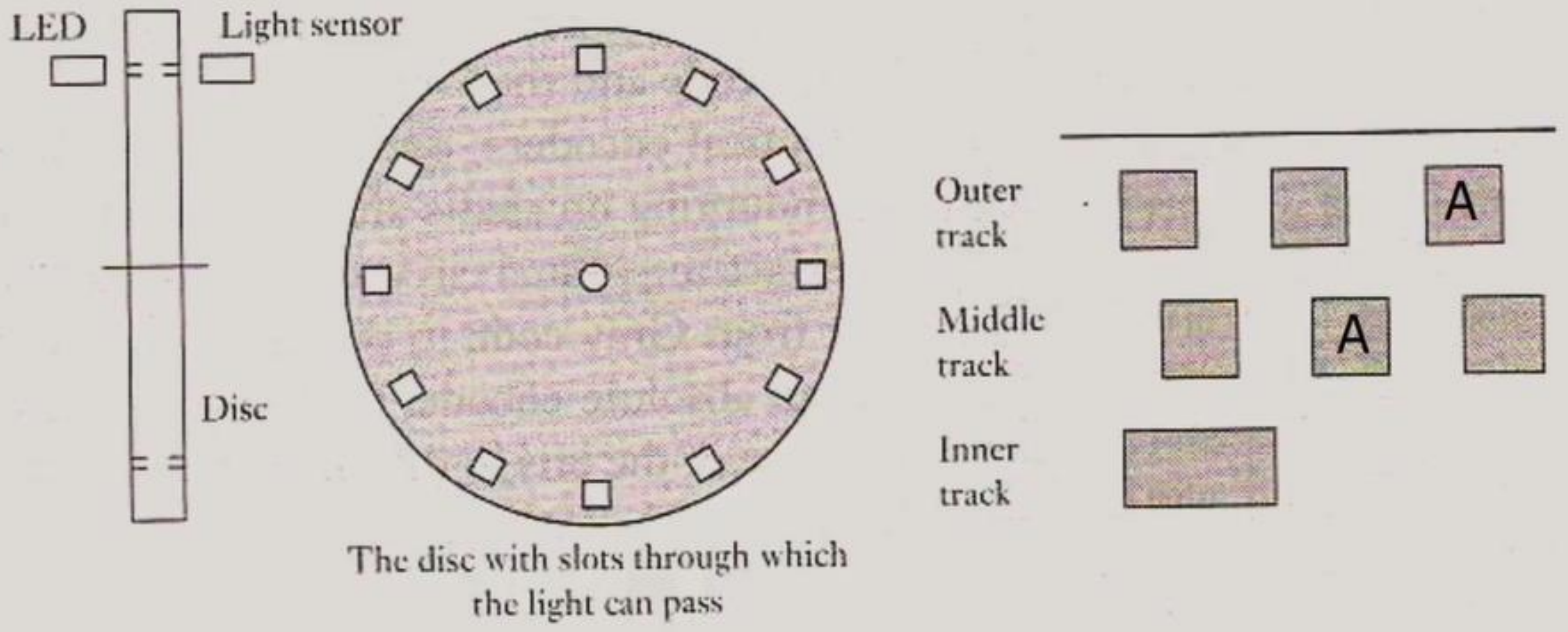
Optical Encoders:



(a)

(b)

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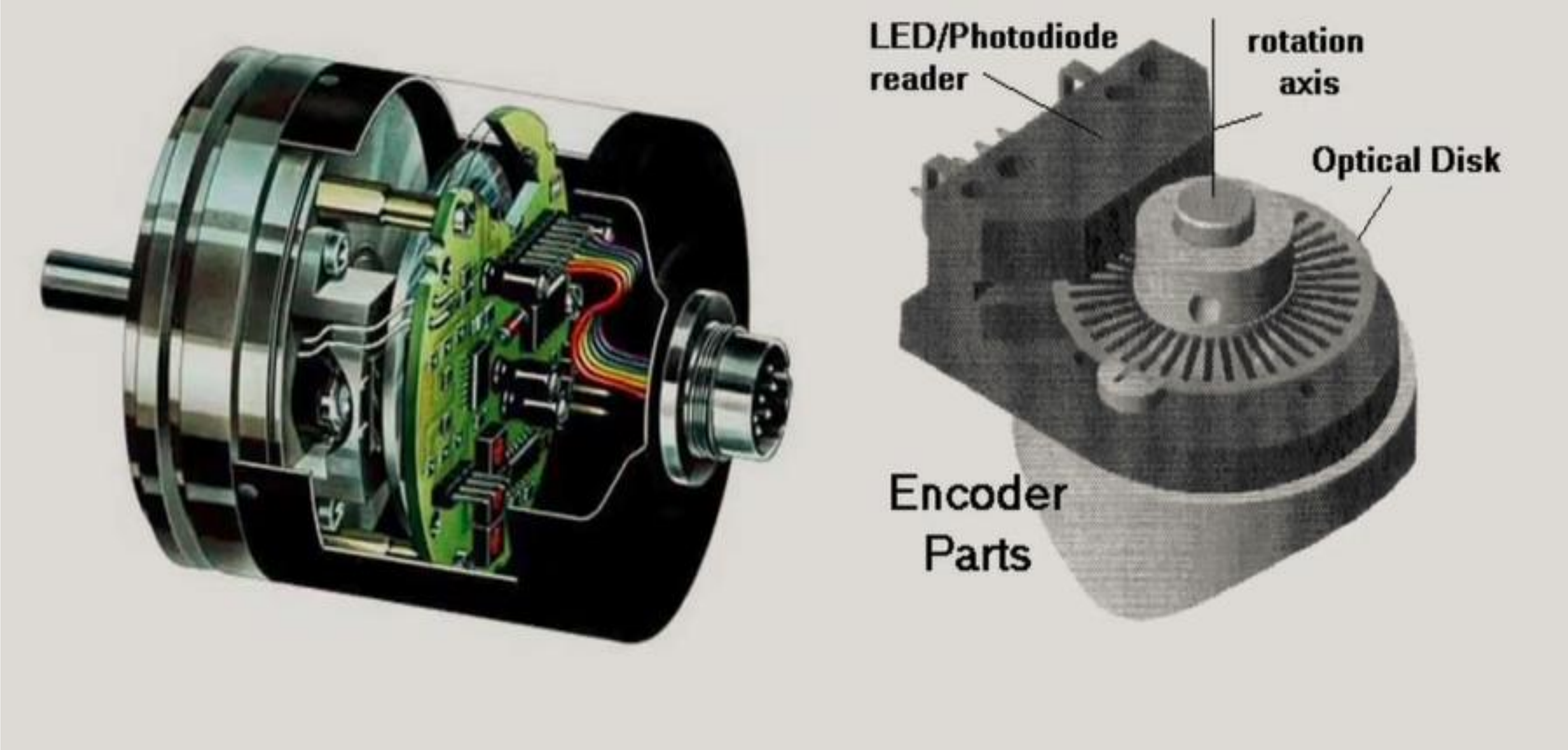
Optical Encoders:



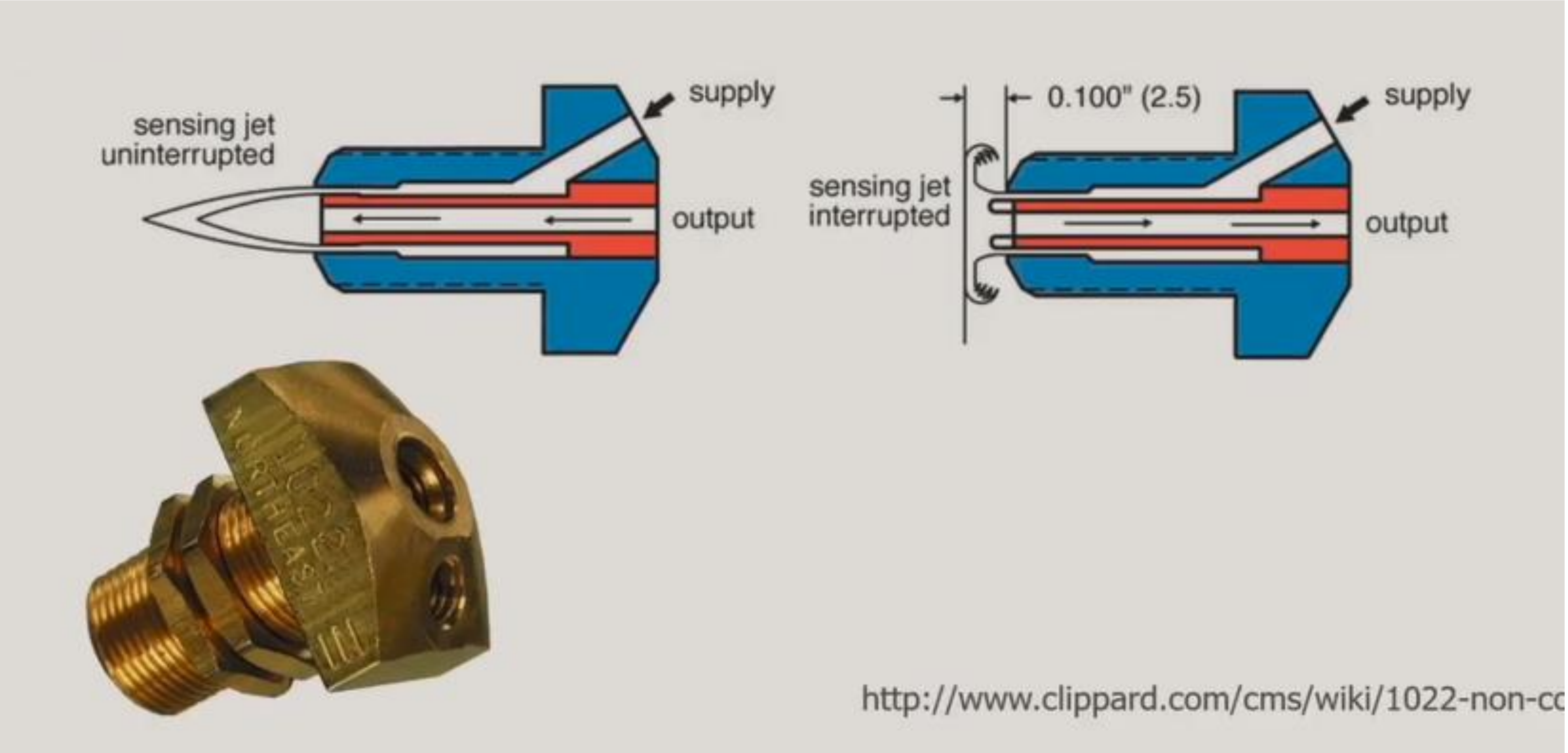
Sensors & Transducer

Pneumatic Sensors:

Pneumatic sensors involve the use of compressed air, displacement or the proximity of an object being transformed into a change in air pressure. Low-pressure air is allowed to escape through a port in the front of the sensor. This escaping air, in the absence of any close-by object, escapes and in doing so also reduces the pressure in the nearby sensor output port. However, if there is a close-by object, the air cannot so readily escape, and the result is that the pressure increases in the sensor output port. The output pressure from the sensor thus depends on the proximity of objects. Such sensors are used for the measurement of displacements of fractions of millimeters in ranges which typically are about 3 to 12 mm.

Sensors & Transducer

Pneumatic Sensors:



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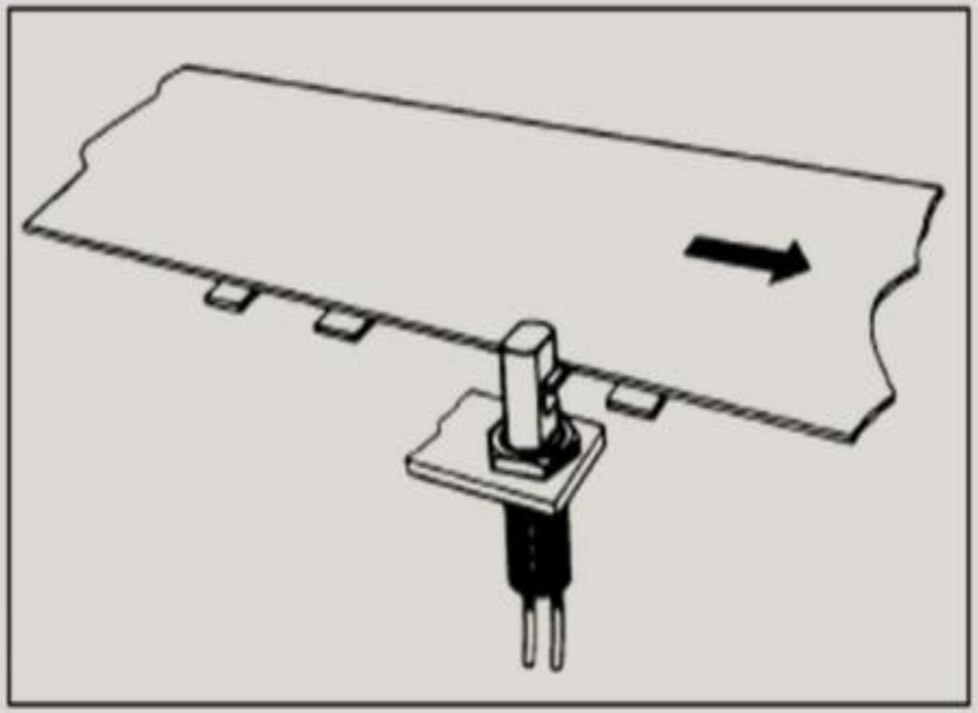
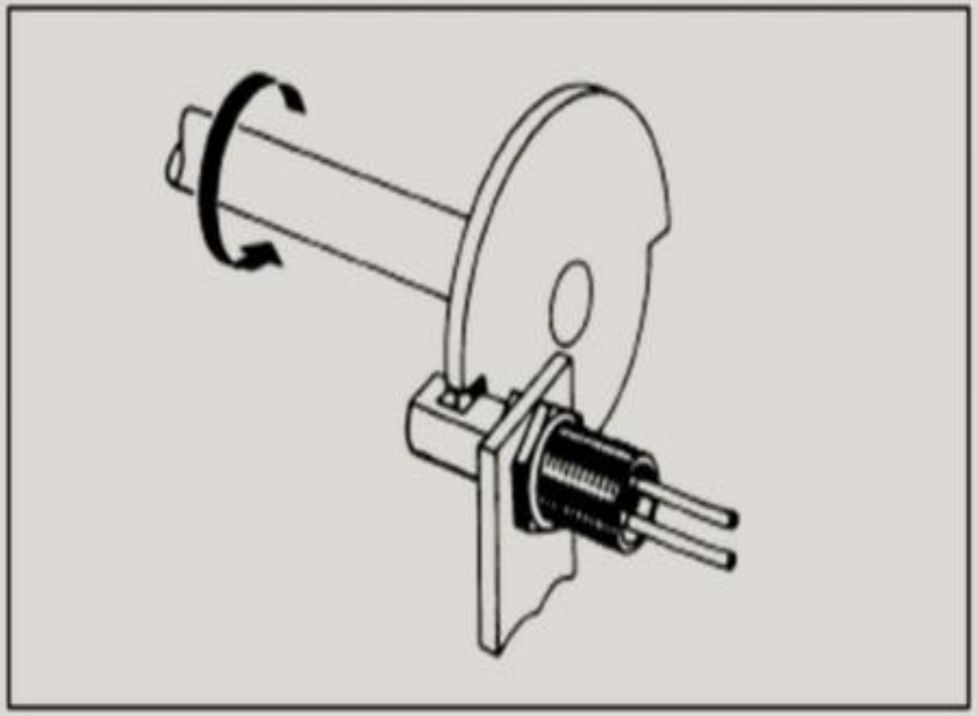
Pneumatic Sensors:



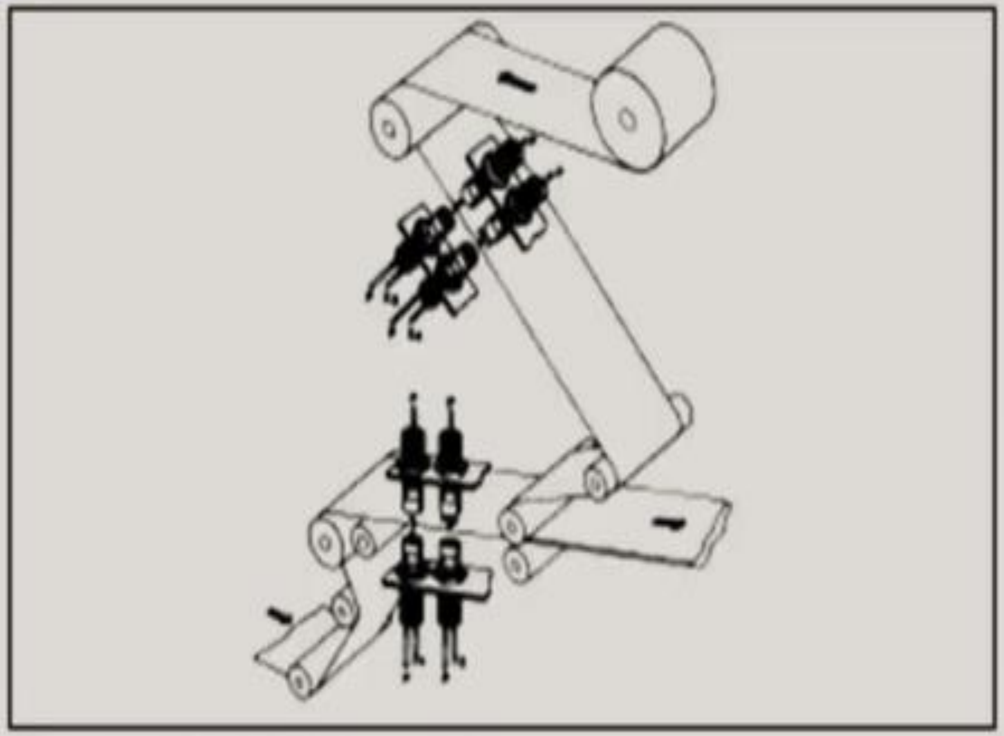
Monitoring of strip



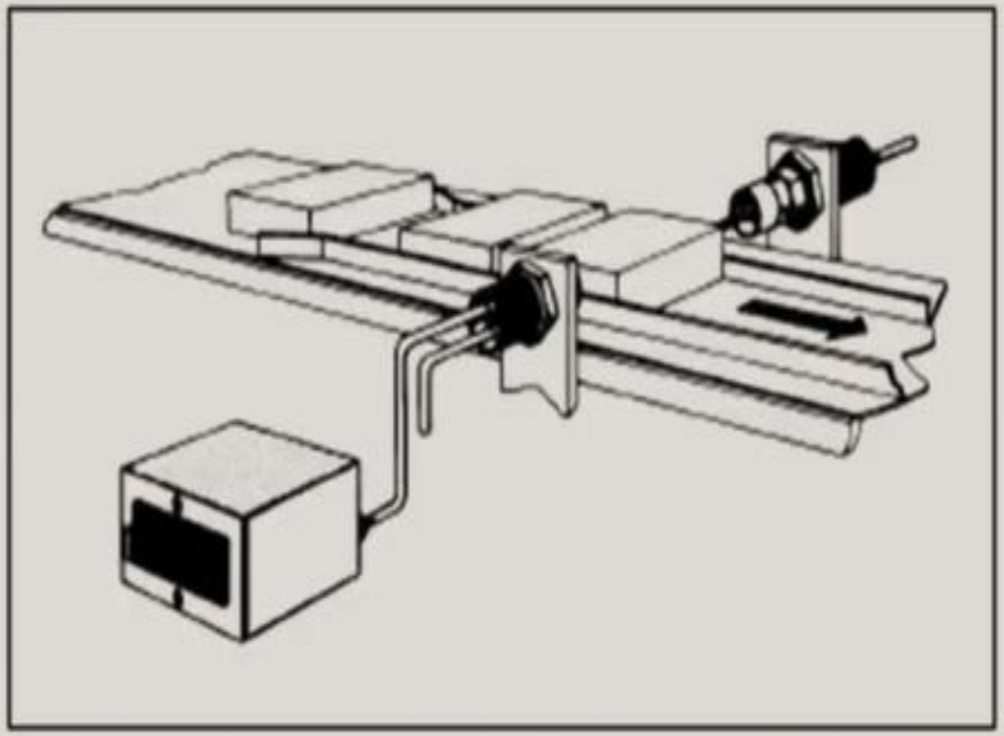
Rotation of a shaft

Sensors & Transducer

Pneumatic Sensors:



Edge control (air-barrier)



Parts counting/pressure indicates (air-barrier)

Sensors & Transducer

Photo electric Sensors:

A photoelectric sensor is used to detect the presence (or absence) of an object, or for measuring the distance between a point and an object. It uses visible red light or infrared light from a transmitter and has a photoelectric receiver. A photoelectric sensor becomes a popular choice in automation since they provide quick and reliable results without having to physically touch the object.

Types of photo electric sensors:

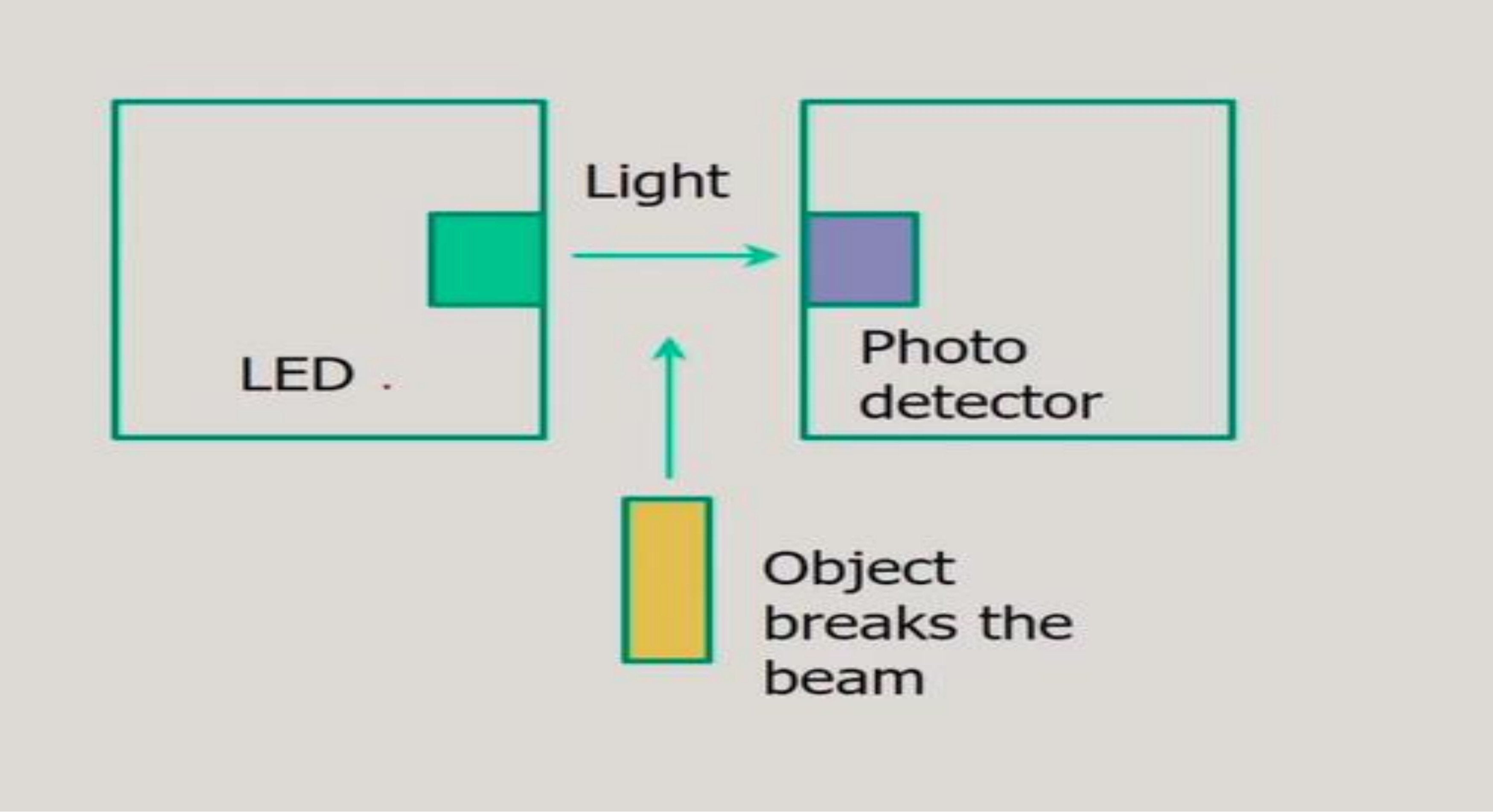
1. Diffuse type photoelectric sensors

2. Through-beam type photoelectric sensors

3. Retro-reflective type photoelectric sensors

Sensors & Transducer

Photo electric Sensors working :



Sensors & Transducer

Photo electric Sensors:

1. Diffuse type photoelectric sensors:

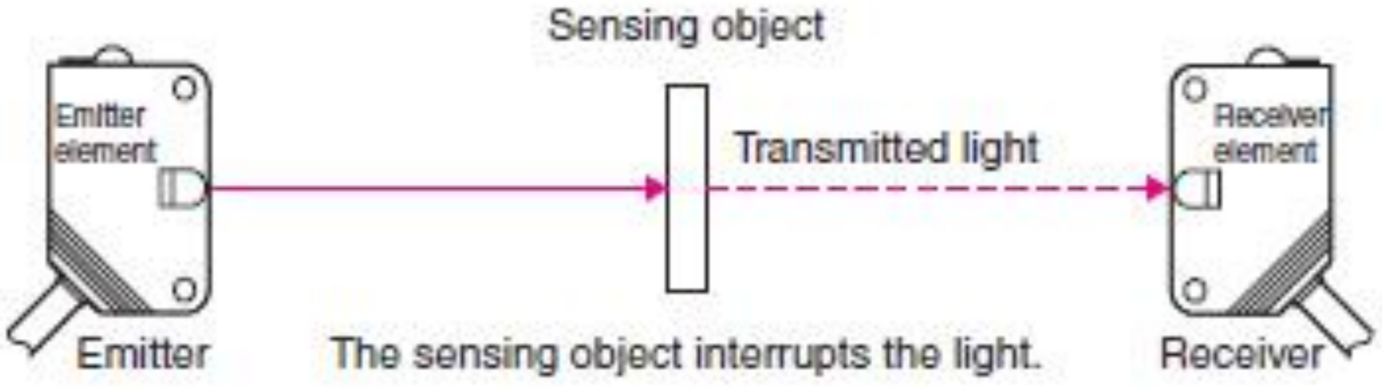
A light beam is transmitted in the direction of the object in question. The light is reflected from the object which is received by the receiver of the sensor confirming the presence of the object. The amount of light received is used by the sensor to measure the distance to the object.

Sensors & Transducer

Photo electric Sensors:

2. Through-beam type photoelectric sensors

A light beam is transmitted from the transmitter on to a receiver while the object of interest is placed between the two. The object interrupts the light and changes the amount of light that falls on the receiver. This is used for sensing the object.



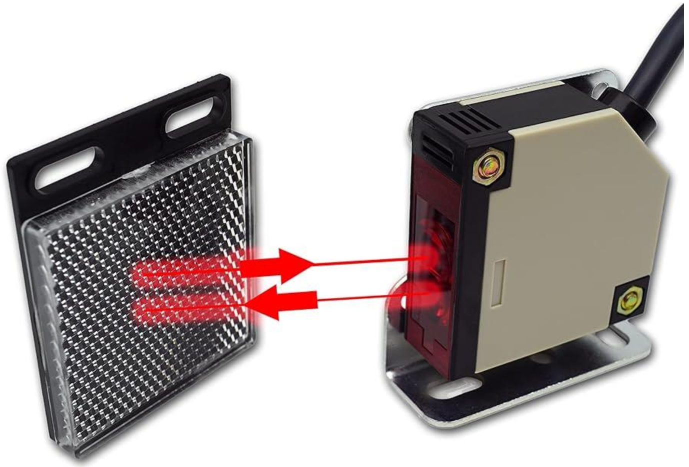
Sensors & Transducer

Photo electric Sensors:

3. Retro-reflective type photoelectric sensors

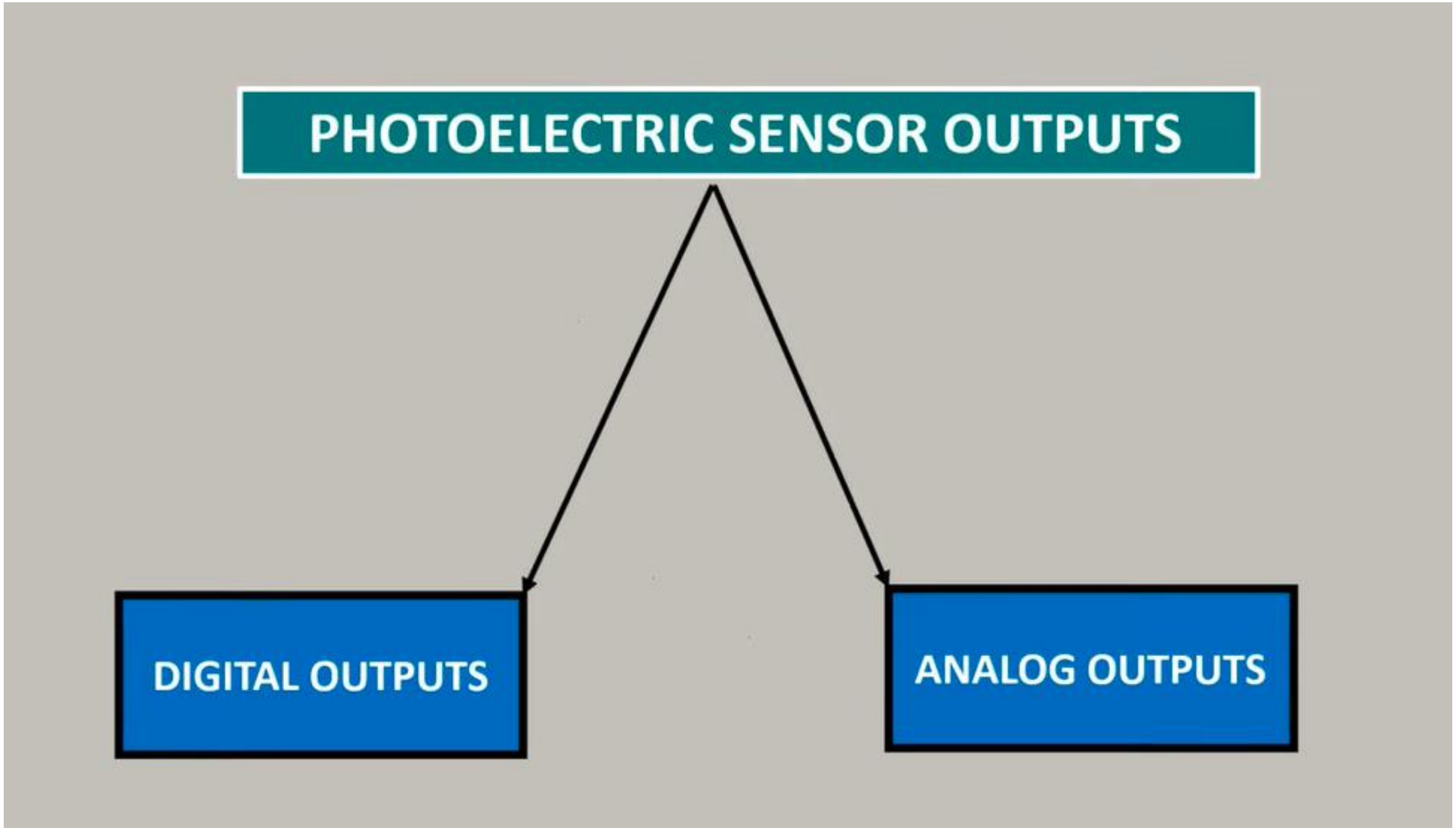
A light beam from the transmitter falls on to a reflector. The reflector reflects the light on to the receiver. The object of interest falls between the transmitter and the reflector and interrupts the light beam.

Depending on the requirement, the photoelectric sensor is selected. More sophisticated sensors that are aimed at higher accuracy come with the ability to suppress the background making it possible for them to precisely detect objects.



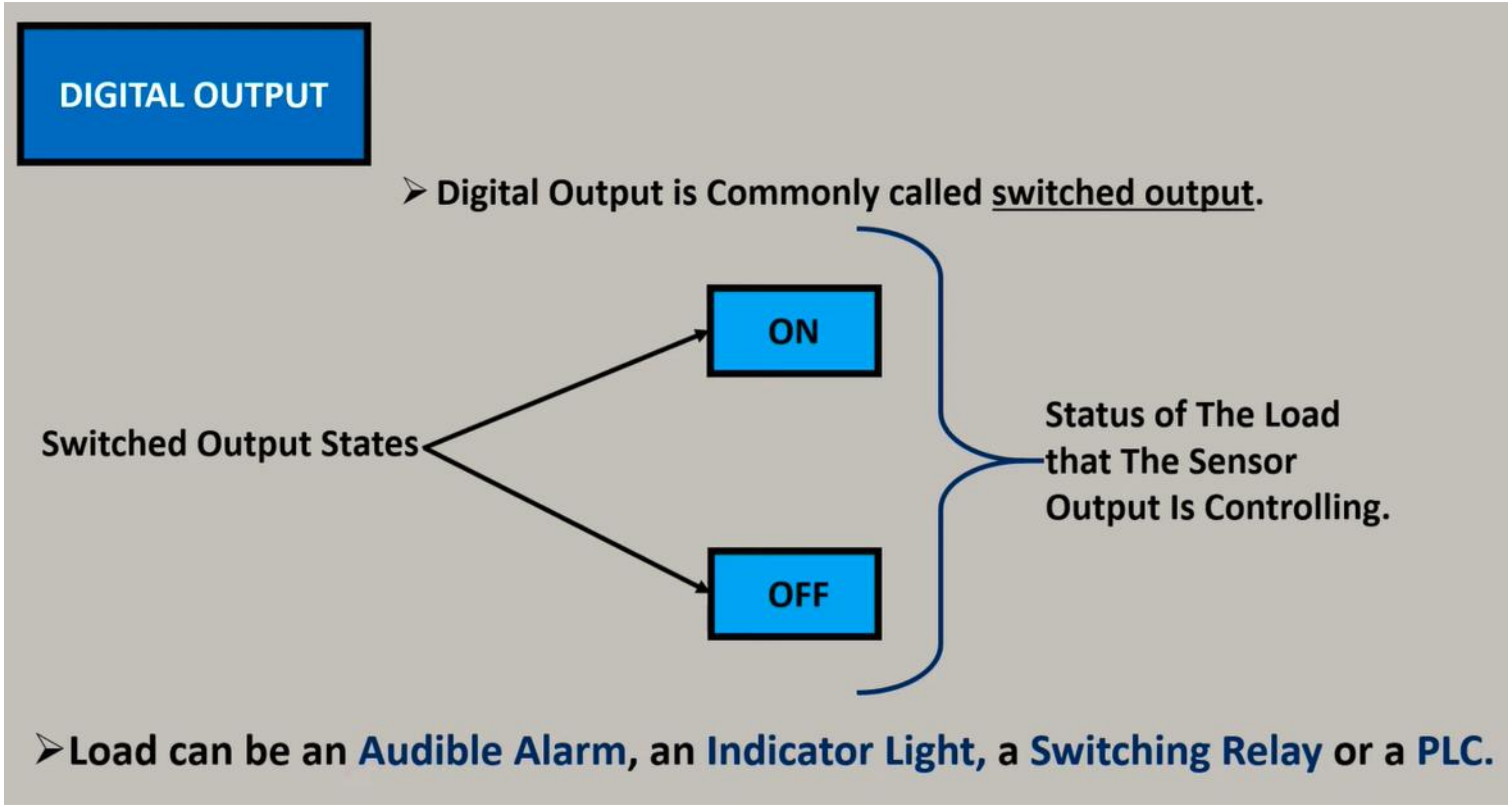
Sensors & Transducer

Photo electric Sensors Output:



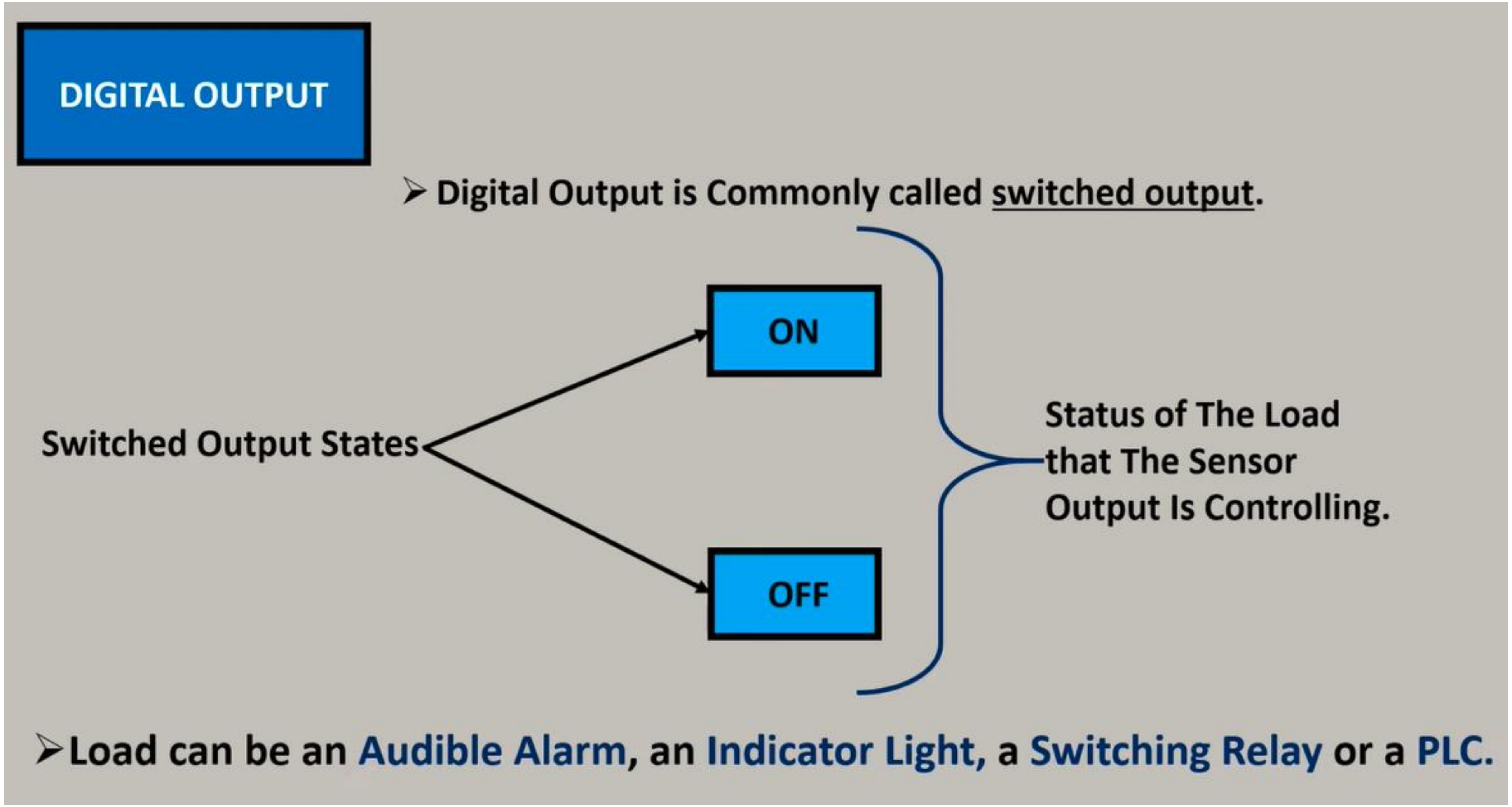
Sensors & Transducer

Photo electric Sensors Output:



Sensors & Transducer

Photo electric Sensors Output:



Sensors & Transducer

Photo electric Sensors Output:

- **In Inductive or Capacitive Proximity Sensors we use Normally Open & Normally Close to define the sensors output, when an object is detected.**

- **In photoelectric sensors Light ON & Dark ON is used to define what the sensors output is doing in absence or presence of light at the receiver of the photoelectric sensor.**

Sensors & Transducer

Photo electric Sensors Output:

Light ON mode

- In This Mode Output Turns ON When Receiver Detects Light From Emitter.

Dark ON mode

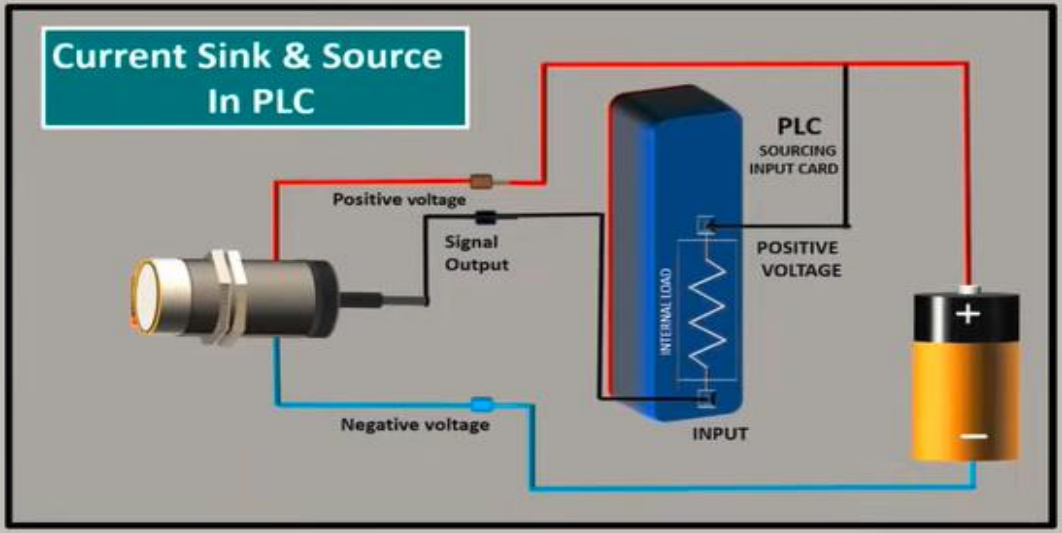
- In This Mode Output Turns ON When Receiver Detects No Light From Emitter.

Sensors & Transducer

Photo electric Sensors Output:

Sinking & Sourcing

- A sensor output can source or sink power.
- Sourcing power means the sensor output supplies a positive voltage when sensor turns ON. This is called PNP output.
- A sinking output connects load to the negative supply voltage or ground. This is called NPN output.



Sensors & Transducer

Photo electric Sensors Output:

ANALOG OUTPUTS

- **Analog Output Varies Over a Range of Voltage or Current and is Proportional to Sensing Parameter.**
- **The Output of an Analog Photoelectric Sensor is Proportional to the Strength of the Received Light Signal.**
- **Sensors with Analog Outputs are used to Monitor an Objects Position or Size or Translucency.**
- **To Provide a Continuously Variable Control Signal for Another Analog Devices like a Motor Speed Control.**

Sensors & Transducer

Photo electric Sensors Applications:

Object detection: They can detect the presence or absence of an object, especially in confined spaces.

Level Control: In the food and beverage industry, these sensors are often used to monitor the level of a liquid or solid substance within a container.

Packaging: They can detect irregularities in packaging material, ensuring product quality.