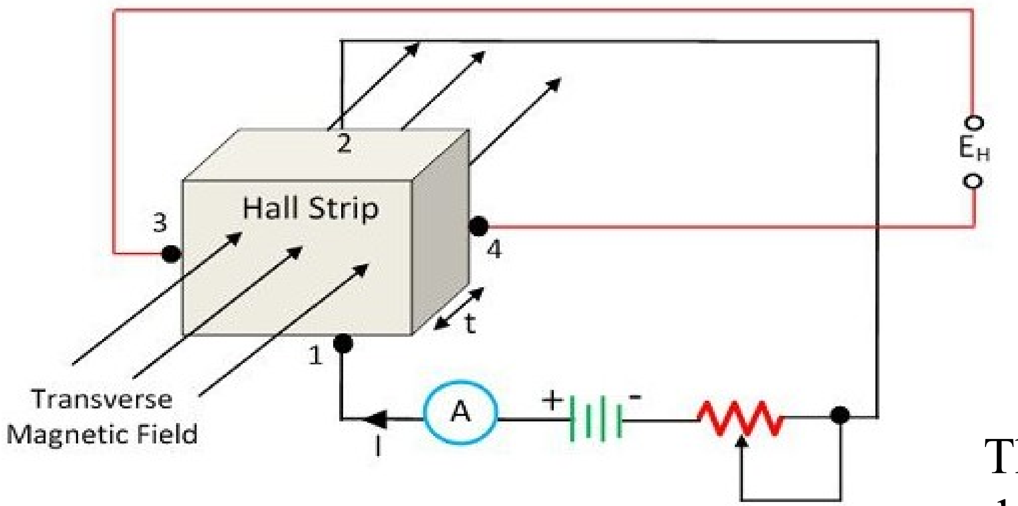
# Hall Effect, Piezoelectric, Fiber Optic & Biochemical sensors

# Hall Effect Transducer

A Hall effect transducer serves to measure a magnetic field and convert that measurement into voltage. Its output voltage is directly proportional to the magnetic field strength through it.
Hall Effect Transducers are the transducers which work on the principle of hall effect. According to hall effect, if a conducting material strip carries current in the presence of a transverse magnetic field; an EMF is produced between two edges of the conductor in a direction perpendicular to both the magnetic field and the direction of the current as shown in the figure below.
When the magnetic field is applied to the strip, the output voltage develops across the output leads 3 and 4. The developed voltage is directly proportional to the strength of the material.




$$E_H = K_H I B / t$$

$E_H$ - *Hall voltage developed*

$$K_H - Hall\ effect\ coefficient\ ; \frac{V-m}{A-Wbm^{-2}}$$

$$t - thickness\ of\ Strip\ ; m$$

The I is the current in ampere and the B is the flux densities in $Wb/m^2$

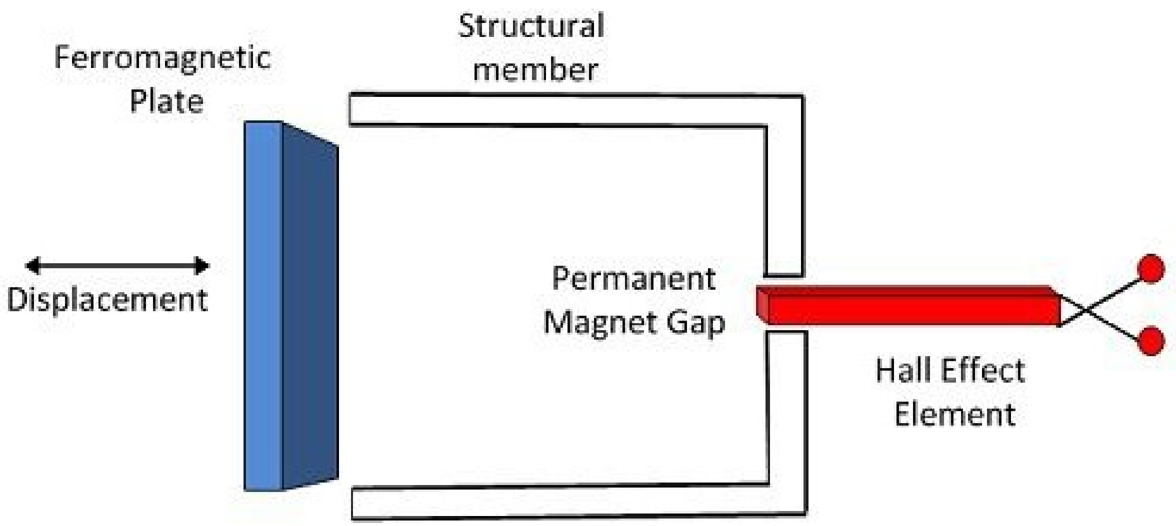
# Applications

### *Magnetic to Electric Transducer*

The Hall effect element is used for converting the magnetic flux into an electric transducer.

### *Measurement of Displacement*

The Hall effect element measures the displacement of the structural element. The magnetic field strength across the hall effect element changes by changing the position of the ferromagnetic field.



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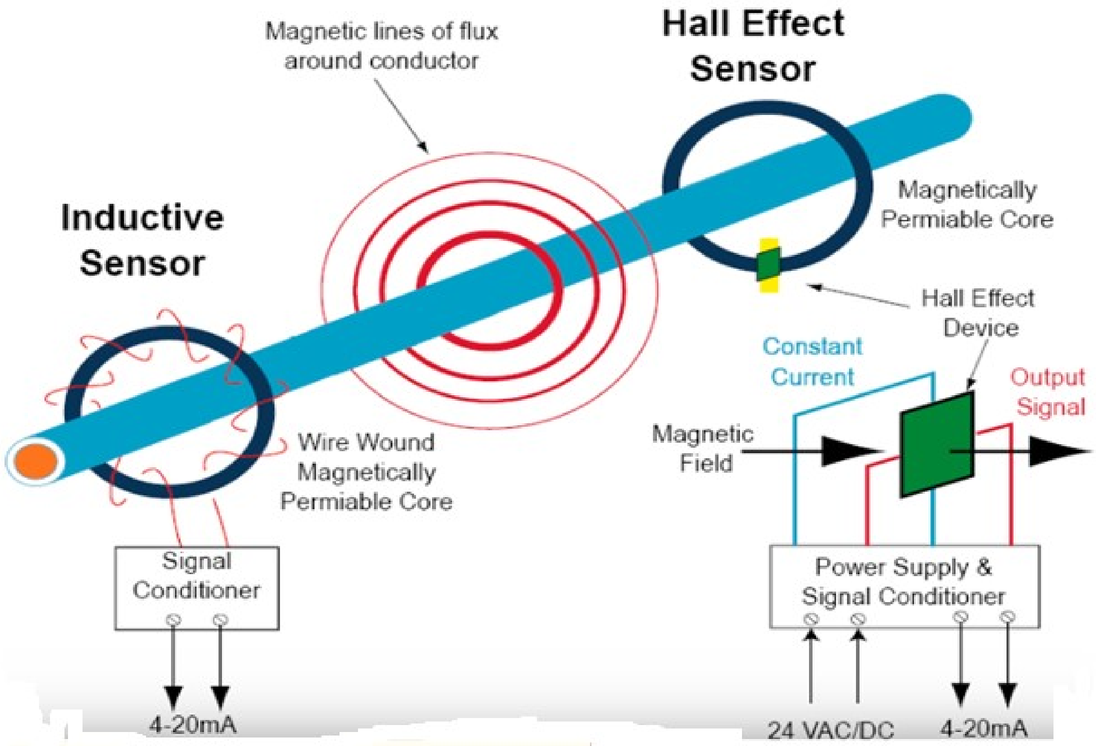
## *Measurement of Current*

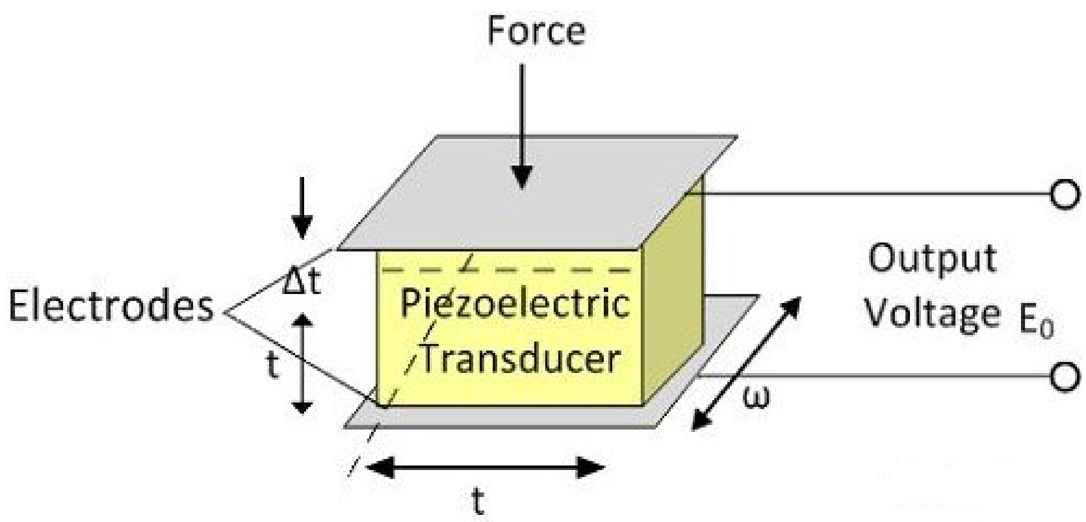
The Hall effect sensor has a core, Hall effect device and signal conditioning circuitry. The current conductor passes through a magnetically permeable core that concentrates the conductor's magnetic field. The Hall effect device is mounted in the core at a right angle to the concentrated magnetic field. A constant current in one plane excites the Hall device.

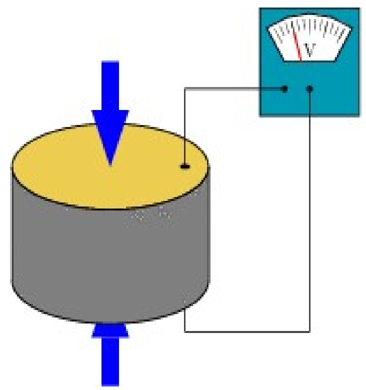



When the energized Hall device is exposed to a magnetic field from the core, it produces a potential difference (voltage) that can be measured and amplified into process level signals such as 4-20mA or a contact closure.
For measurement of AC currents inductive sensor is used.

# Piezo-Electric Transducer

There are certain materials that generate an electric potential or voltage when mechanical strain is applied to them or conversely when the voltage is applied to them, they tend to change the dimensions along certain plane. This effect is called as the **PIEZOELECTRIC EFFECT.**



A piezoelectric disk generates a voltage when deformed (change in shape is greatly exaggerated)

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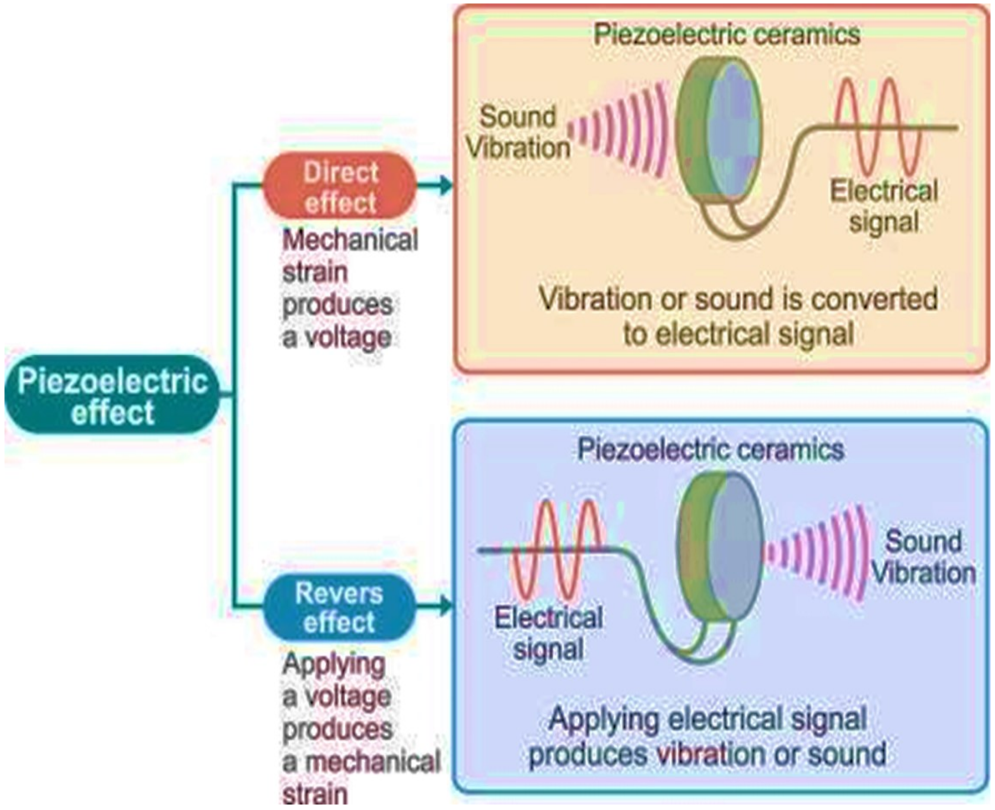
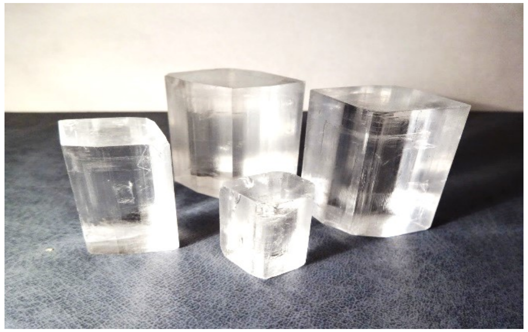


*Rochelle salt*

*Quartz*

# Measurement of the force using piezo-electric crystal

- The polarity of the charge depends on the direction of the applies forces.

$$Charge\ Q = d \times F\ Coulomb$$

Where, d = charge sensitivity of the crystal
F = applied force in Newton

- The force changes the thickness of the crystals.

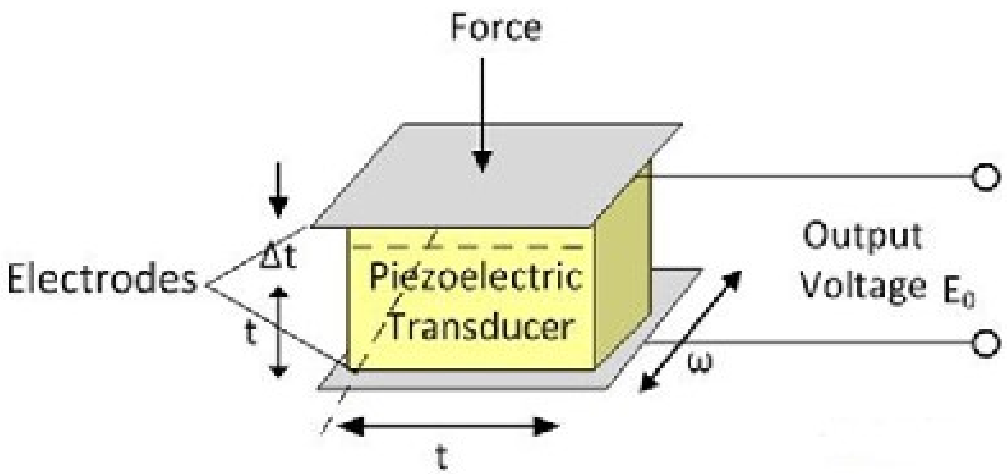
$$F = \frac{AE}{t} \Delta t\ Netwon$$

Where, A – area of crystals in meter square
t – the thickness of crystals in meter
E – Young's modulus N/$m^2$

- The young modulus is,

$$E = \frac{stress}{strain} = \left(\frac{F}{A}\right) \cdot \frac{1}{\Delta t / t}$$

$$E = \frac{Ft}{A \Delta t} N/m^2$$



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- On substituting the value of force in the equation of charge, we get

$$Q = dAE\left(\frac{\Delta t}{t}\right)$$

- The output voltage is obtained because of the electrode charges.

$$E_o = \frac{Q}{C_p} = \frac{dF}{\varepsilon_r \varepsilon_0 A/t}$$

$$E_0 = \frac{d}{\varepsilon_r \varepsilon_0} tP$$

$$E_0 = gtP$$

$$g = \frac{d}{\varepsilon_r \varepsilon_0}$$

Where, F/A= P = pressure or stress N/m$^2$

- The $g$ is the voltage sensitivity of the crystals.

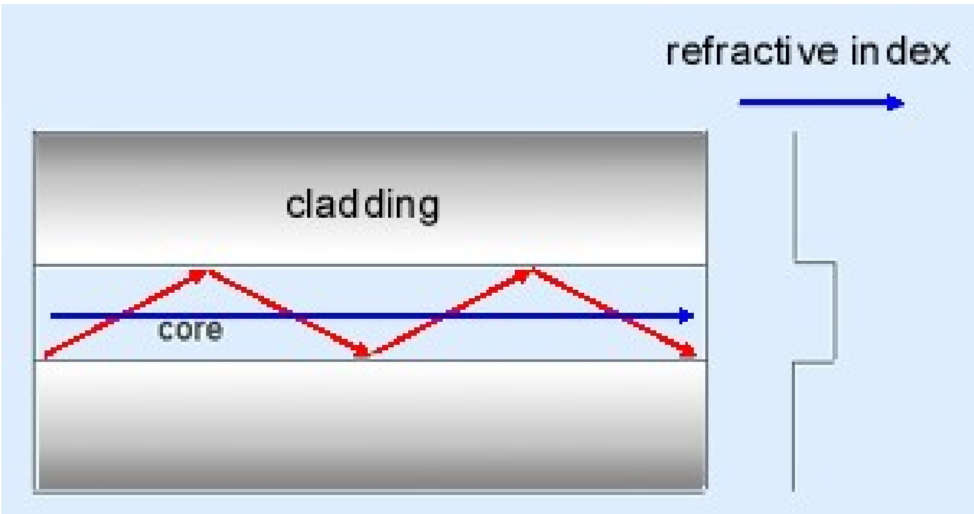
$$g = \frac{E_0}{tP} = \frac{E_0/t}{P}$$

Where $E_0$ – electric field strength, V/m

- The voltage sensitivity of the crystals is expressed by the ratio of the electric field intensity and pressure.

# Fiber Optic Sensor

- A fiber-optic sensor system consists of a fiber-optic cable connected to a remote sensor, or amplifier. The fiber optic cable consists of a glass or plastic core surrounded by a layer made of cladding material.
- The difference in densities between the core and the layer enables the cables to act based on the total internal reflection principle, which states that the light striking a boundary between two components will be totally reflected without any loss in light energy.
- The reflected light is then transmitted to a sensor/detector that converts the light energy into an electrical signal.



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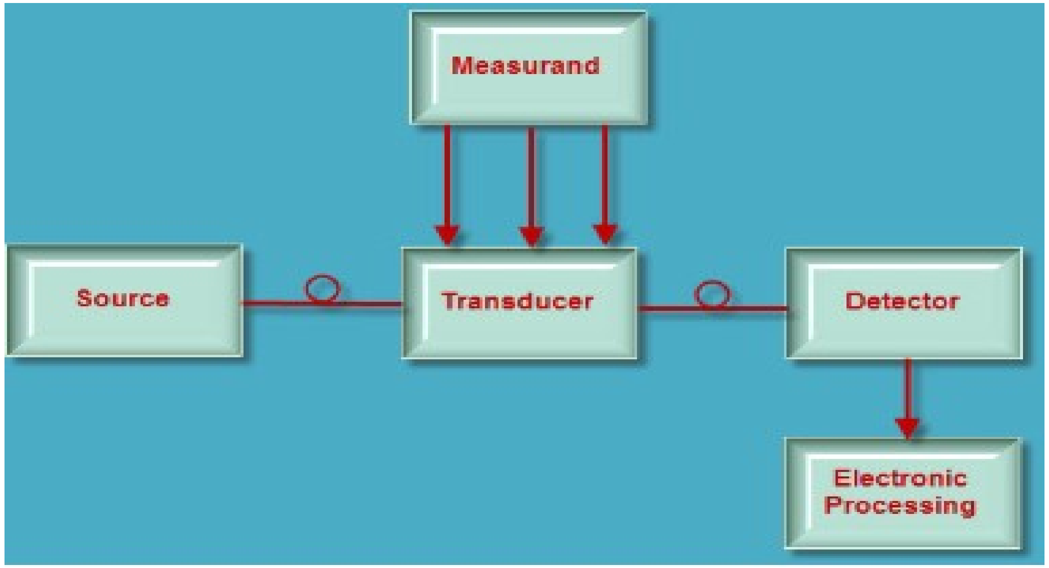
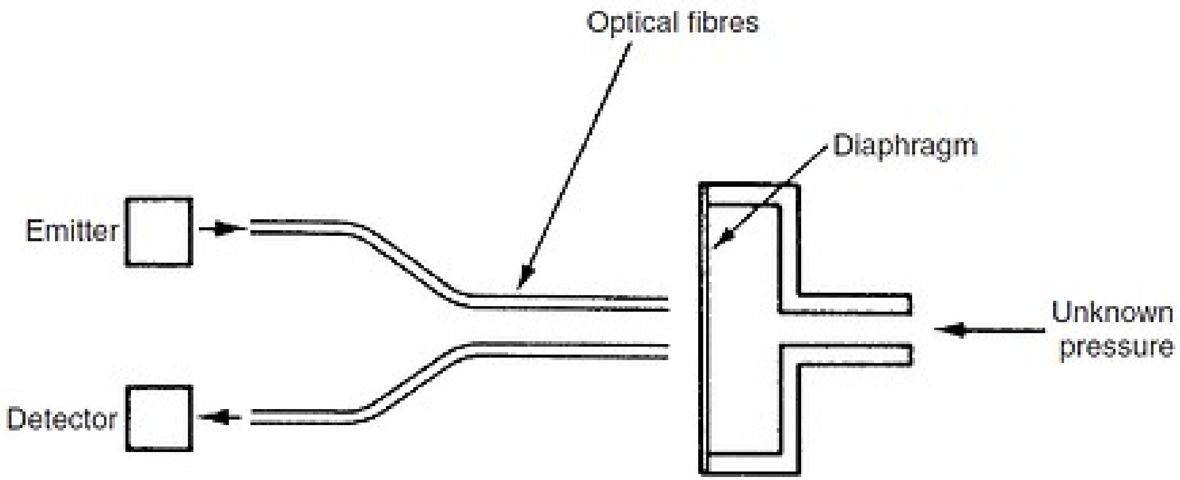
- These sensors are used to sense quantities like temperature, pressure, vibrations, displacements or concentration of chemical species.
- Fibers have so many uses in the field of remote sensing because they require no electrical power at the remote location and they have tiny size.




The general block diagram of fiber-optic sensor is shown above. The block diagram consists of optical source (LED, LASER, and Laser diode), optical fiber, sensing element, optical detector and end-processing devices (optical-spectrum analyzer, oscilloscope). These sensors are classified into three categories based on the operating principles, sensor location and application.

# Fiber Optic Pressure Sensor

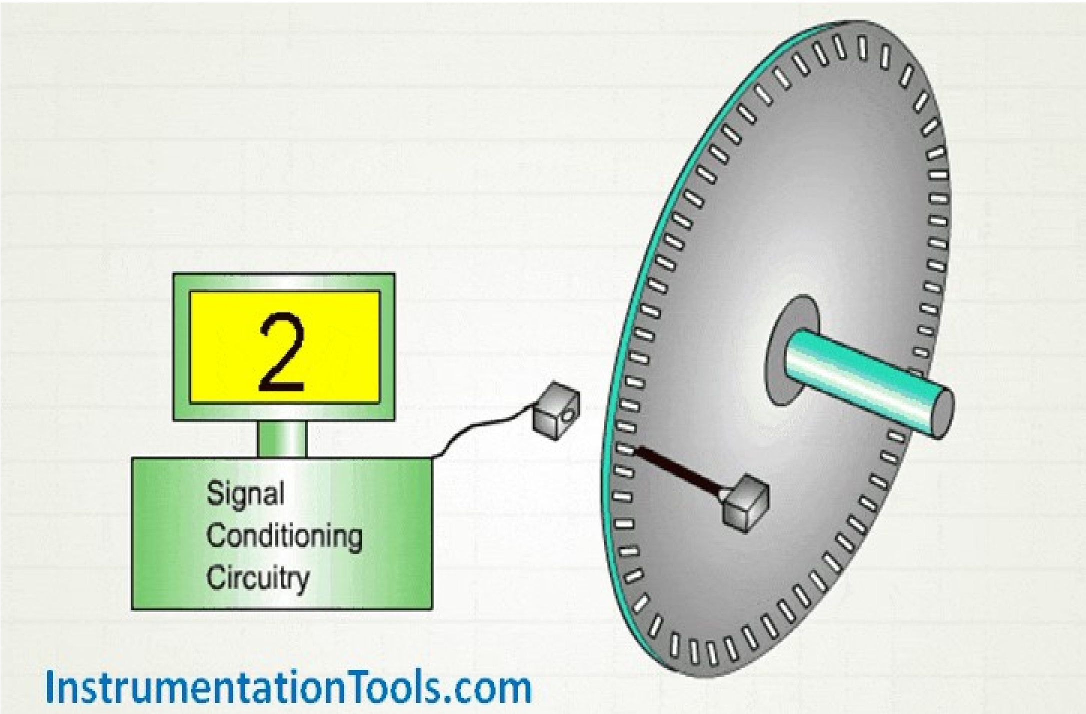


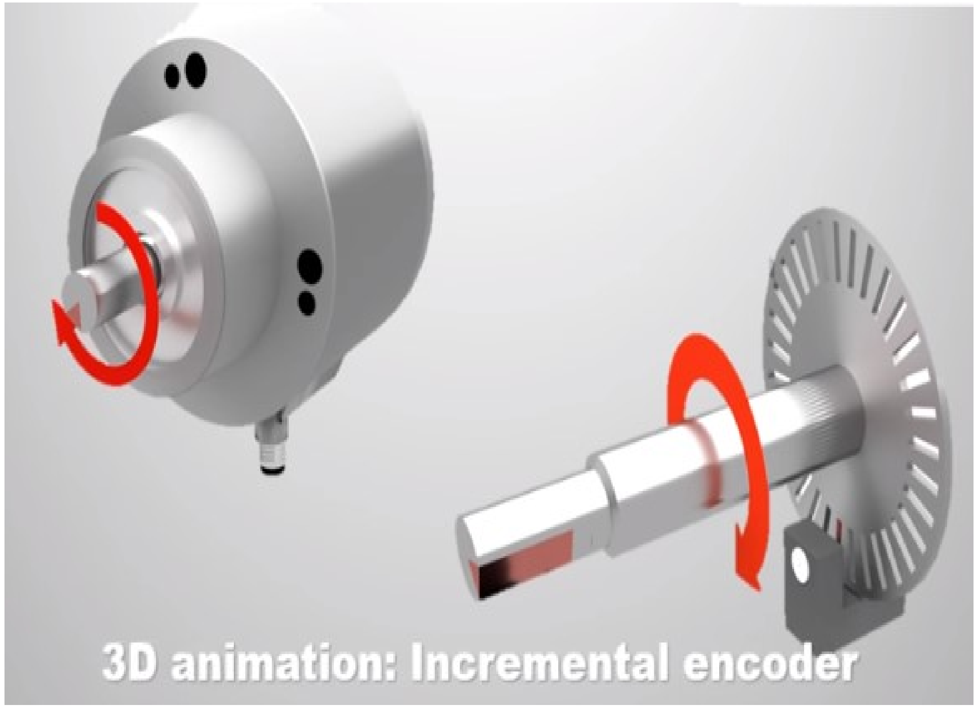

The external unknown pressure is given to the diaphragm. The diaphragm expands and contracts as the pressure increases and decreases. The Fotonic sensor is a displacement sensor containing two groups of fiber optics, one set connected to a light source and termed the transmitting fibers, and the other set connected to a photo detector (photodiode) and known as the receiving fibers. These two groups of fibers are bundled into a common probe. A portion of the reflected light is caught by the receiving fibers and transmitted to the photo detector where its intensity is measured. The intensity of the reflected light is a function of distance (gap) between the probe tip and the target surface.

# Encoders

# Incremental Encoder

An **incremental encoder** is a type of **encoder** that converts angular motion or position of a shaft into a train of pulses to identify position or motion. **Incremental encoders** are one of the most commonly used rotary **encoders**.



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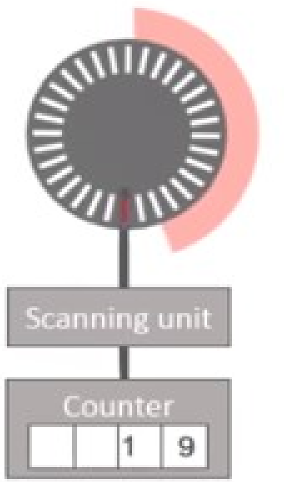
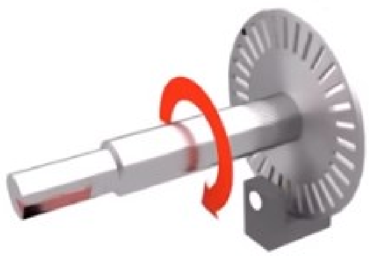
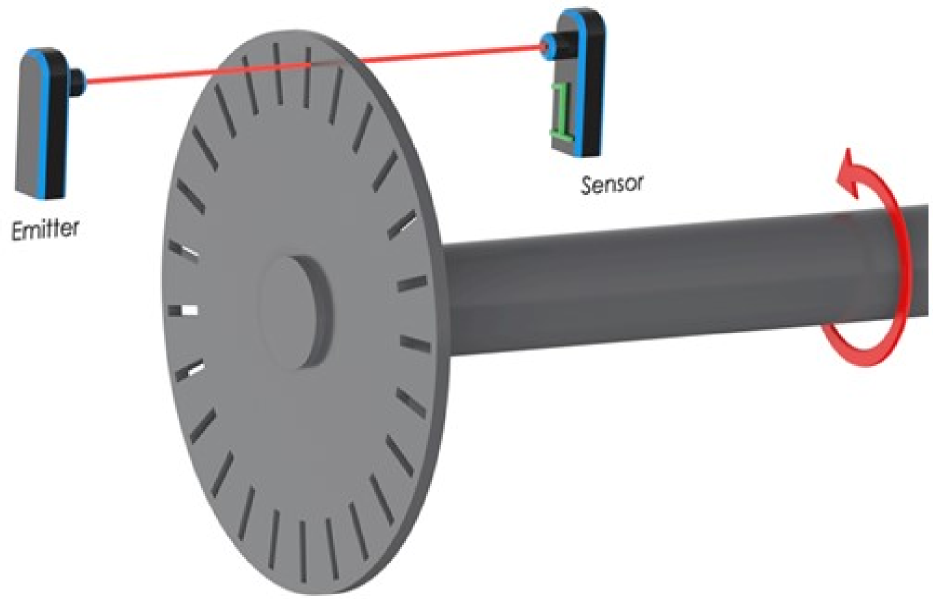
An incremental encoder generates a pulse for each incremental step in it's rotation. Although the incremental encoder does not output absolute position, it can provide high resolution at an acceptable price.




Schematics of an incremental measuring system with an encoder





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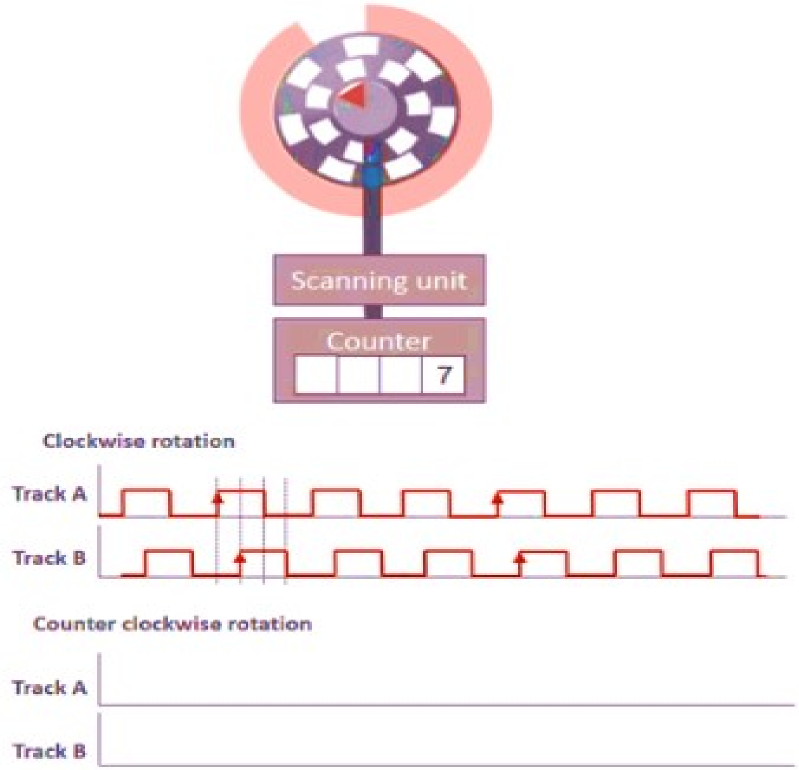
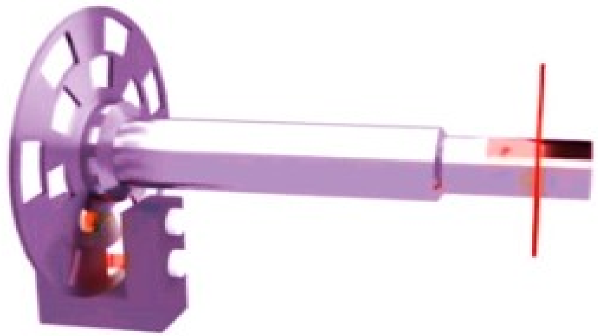
The most common type of incremental encoder uses two output channels (A and B) to sense position. Using two code tracks with sectors positioned 90° out of phase, the two output channels of the quadrature encoder indicate both position and direction of rotation.

- If A leads B, for example, the disk is rotating in a clockwise direction.
- If B leads A, then the disk is rotating in a counter-clockwise direction.



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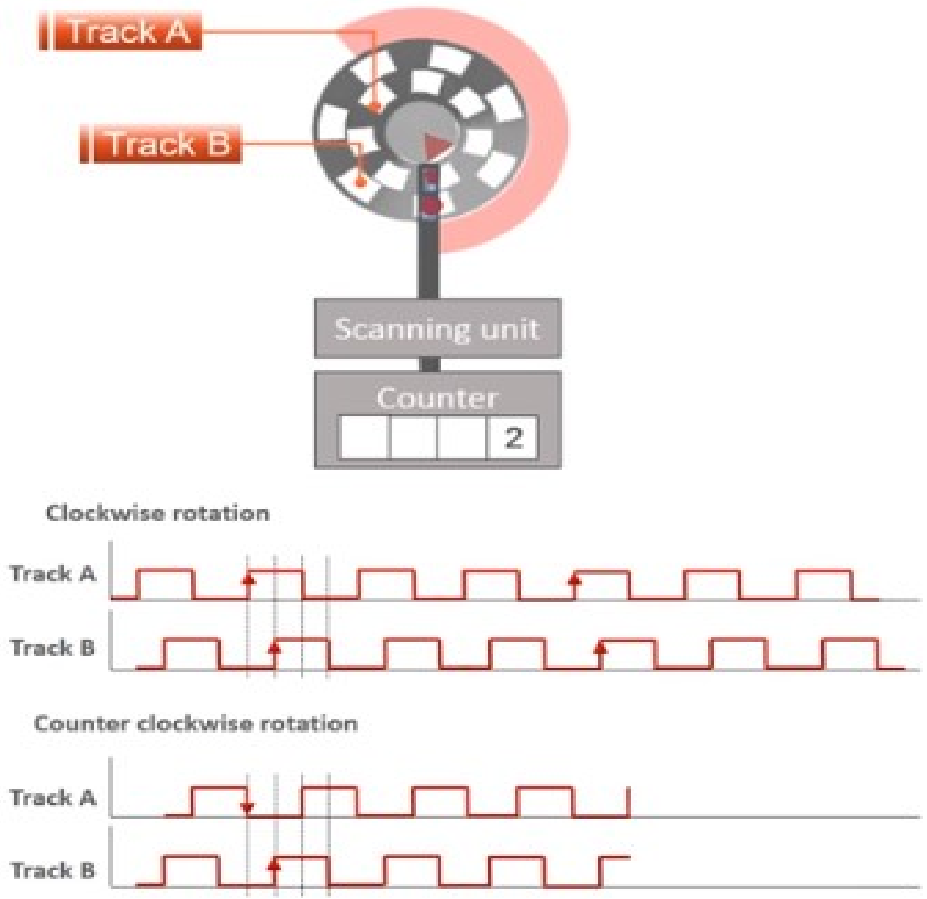
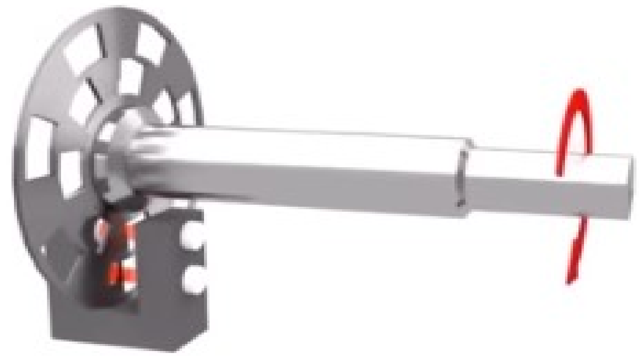
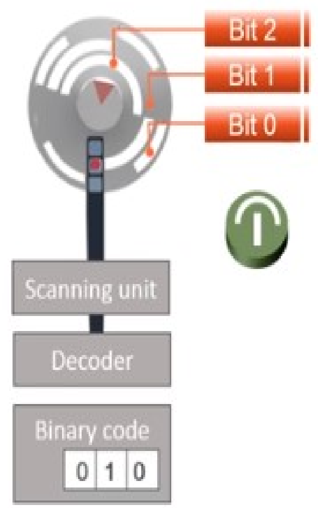

Track A
Track B
Scanning unit
Counter
2
Clockwise rotation
Track A
Track B
Counter clockwise rotation
Track A
Track B

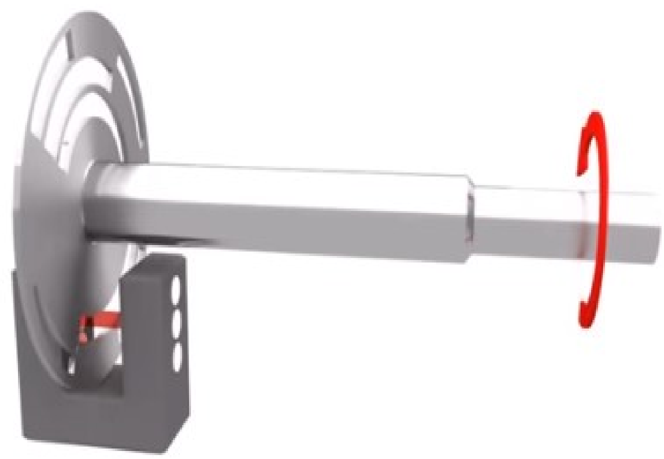


# Absolute Encoder

Absolute encoders have a unique code for each shaft position. Or in other words, every position of an absolute encoder is distinctive. The absolute encoder interprets a system of coded tracks to create position information where no two positions are identical. Another feature is that absolute encoders do not lose position whenever power is switched off.




Schematics of an absolute measuring system with an encoder using the binary code



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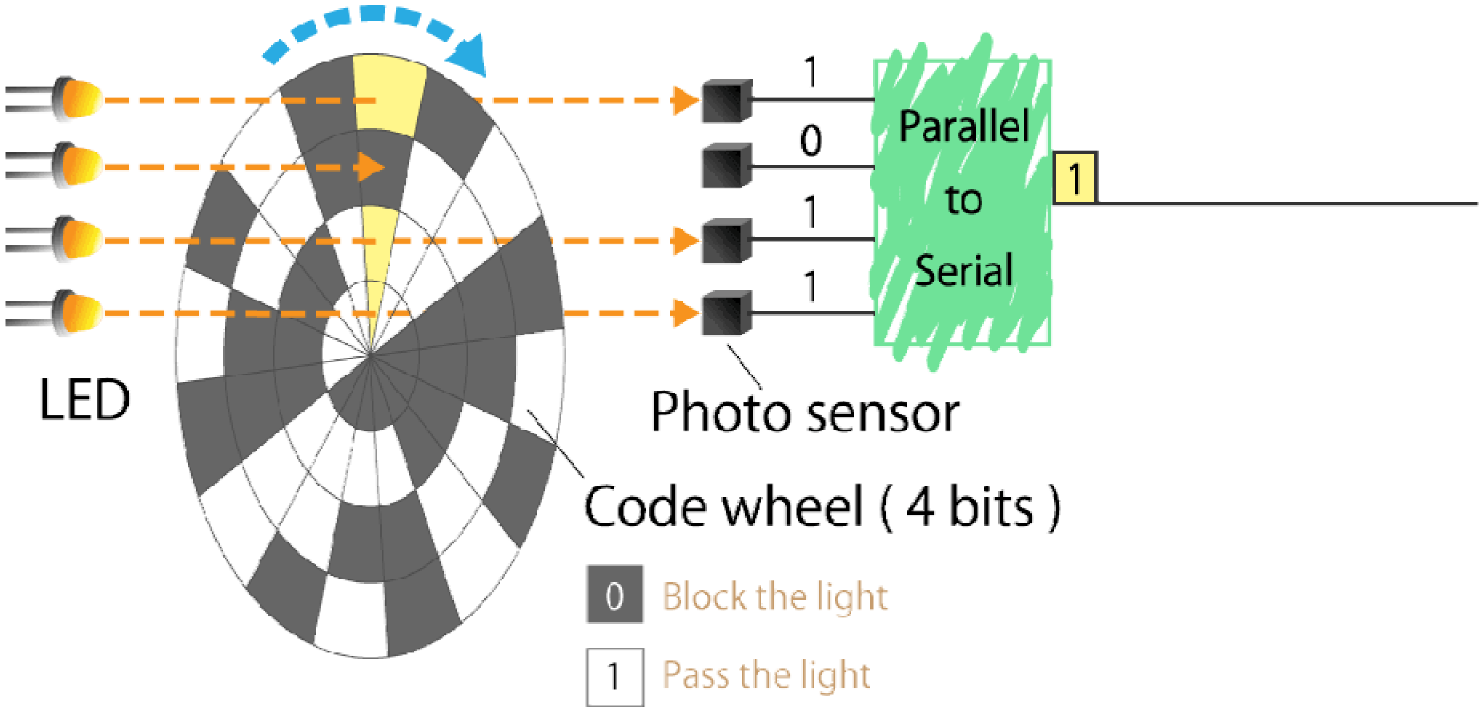
Absolute encoders can be either single-turn or multi-turn. Single-turn encoders are well suited to short travel motion control applications where position verification is needed within a single turn of the encoder shaft. Multi-turn encoders, on the other hand, are better for applications that involve complex or lengthy positioning requirements.



# Bio-Chemical Sensors

A biochemical sensor is a device which is capable of converting a chemical (or biological) quantity into an electrical signal. Basic components of the sensor include analyte molecule, chemically sensitive layer, and transducer

•**Analyte**: A substance of interest that needs detection. For instance, glucose is an 'analyte' in a biosensor designed to detect glucose.
•**Bioreceptor**: A molecule that specifically recognises the analyte is known as a bioreceptor. Enzymes, cells, aptamers, deoxyribonucleic acid (DNA) and antibodies are some examples of bioreceptors. The process of signal generation (in the form of light, heat, pH, charge or mass change, etc.) upon interaction of the bioreceptor with the analyte is termed bio-recognition.
•**Transducer**: The transducer is an element that converts one form of energy into another. In a biosensor the role of the transducer is to convert the bio-recognition event into a measurable signal. This process of energy conversion is known as signalization. Most transducers produce either optical or electrical signals that are usually proportional to the amount of analyte–bioreceptor interactions.

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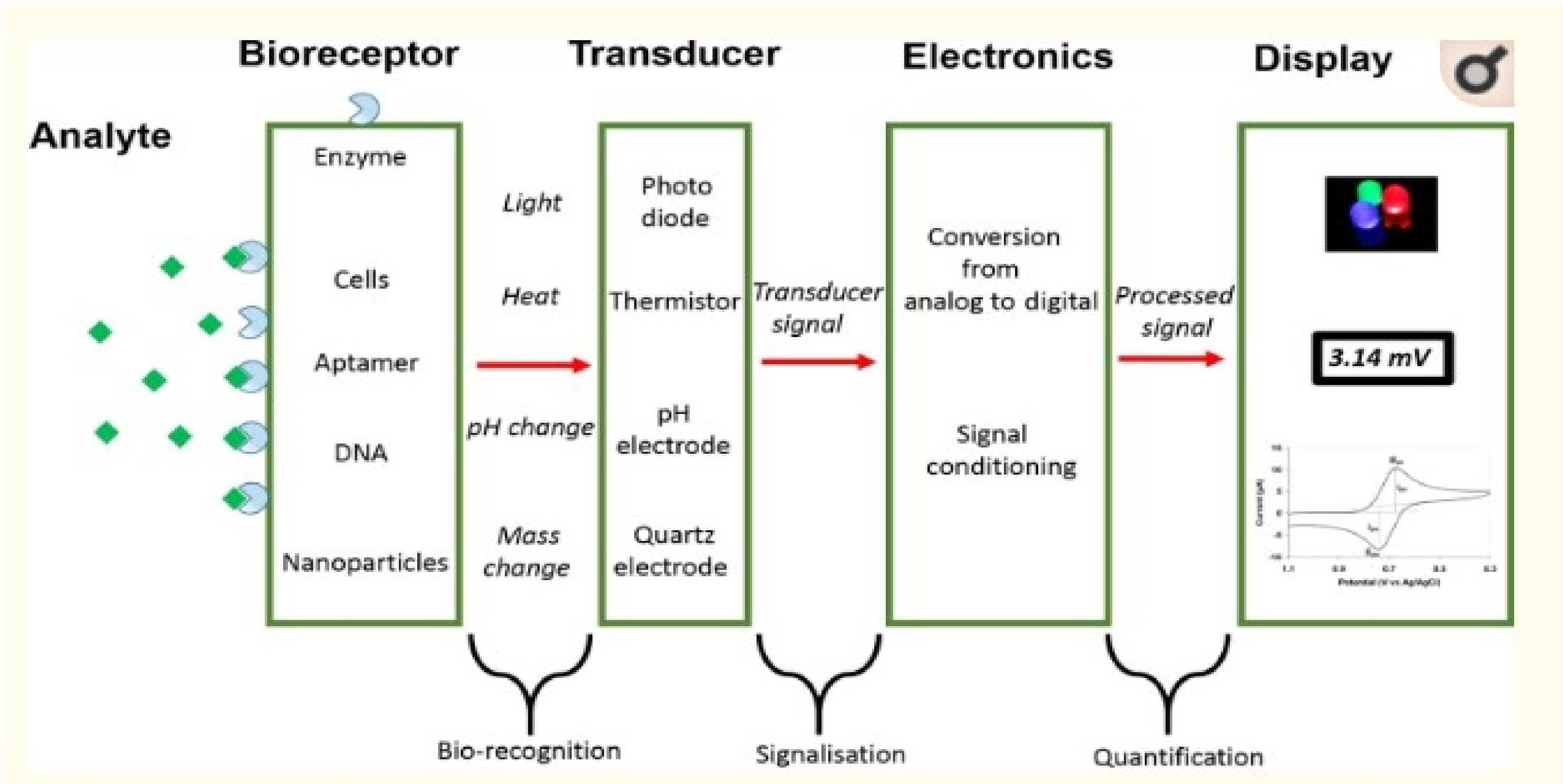


Biosensors are employed in applications such as disease monitoring, drug discovery, and detection of pollutants, disease-causing micro-organisms and markers that are indicators of a disease in bodily fluids (blood, urine, saliva, sweat).

# Thank You