Unit-3

Sensors networks and Communication technologies.

Touch Sensor

Ultrasonic Sensor

PIR Sensor

Speed Sensor

Temperature Sensor

Different Types of Sensors and Their Applications

A sensor is defined as:

A device that produces an output signal for the purpose of sensing of a physical phenomenon.

Sensors are also referred to as **transducers**.

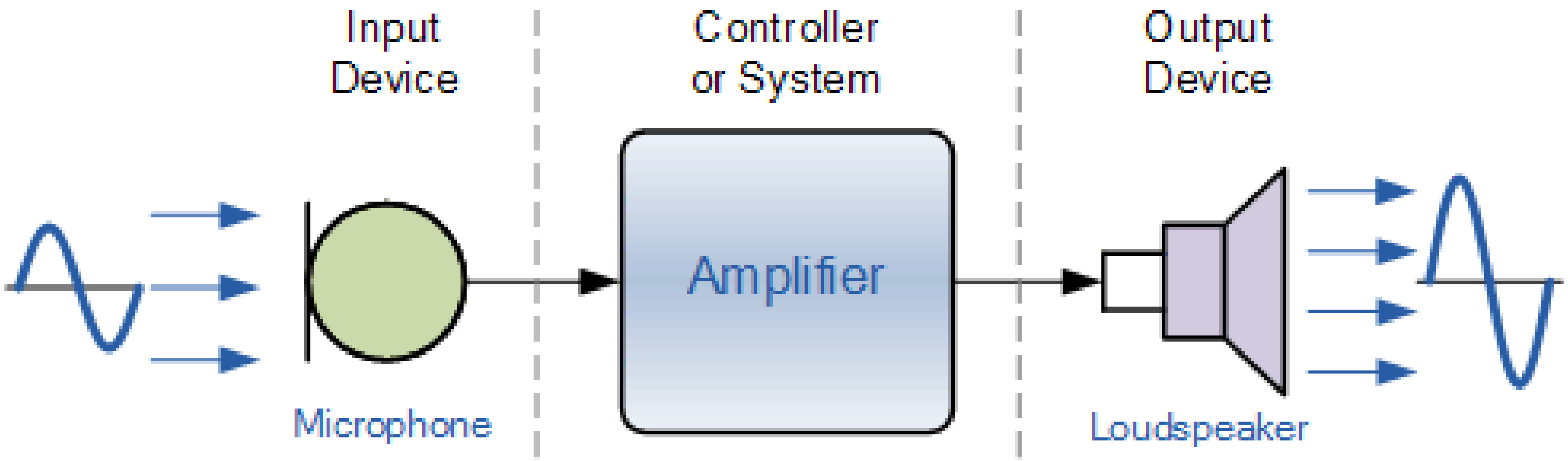
A
transducer is defined as **A device that converts a signal from one physical form to a corresponding signal, which has a different physical form.**
A transducer is an element or device used to convert information from one form to another. The change in information is measured easily.

A transducer is any device which converts one form of energy into another. Examples of common transducers include the following:

- A microphone converts sound into electrical impulses and a loudspeaker converts electrical impulses into sound (i.e., sound energy to electrical energy and vice versa).
- A solar cell converts light into electricity and a thermocouple converts thermal energy into electrical energy.
- An incandescent light bulb produces light by passing a current through a filament. Thus, a light bulb is a transducer for converting electrical energy into optical energy.
- An electric motor is a transducer for conversion of electricity into mechanical energy or motion.

In a transducer, the quantities at the input level and the output level are different. A typical input signal could be electrical, mechanical, thermal, and optical.

Transducer


Input
Device
Controller
or System
Output
Device
Amplifier
Microphone
Loudspeaker

A spring is a simple example of a transducer. When a certain force is applied to a spring, it stretches, and the force information is translated to displacement information,

Displacement **y** is proportional to force **F**, which can be expressed as where **k** is constant

F applied force

y deflection

k constant

Selection of a sensor or a transducer depends on

- Variables measured and application.
- The nature of precision and the sensitivity required for the measurement.
- Dynamic range
- Level of automation
- Complexity of the control system and modeling requirements.
- Cost, size, usage, and ease of maintenance.

Sensors are classified into categories based on the output signal, power supply, operating mode and the variables being measured.

- **Analog sensors:** Analog is a term used to convey the meaning of a continuous. The output changes in a continuous way, and this information is obtained on the basis of amplitude. The output is normally supplied to the computer using an analog-to-digital converter.

- **Digital sensors:** Digital refers to a sequence of discrete events. Each event is separate from the previous and next events. Digital sensors are known for their accuracy and precision, and do not require any converters when interfaced with a computer monitoring system.

Another form of classification, active or passive, is based on the power supply.

- **Passive sensors:** passive sensors require external power for their operation. The external signal is modified by the sensor to produce the output signal.

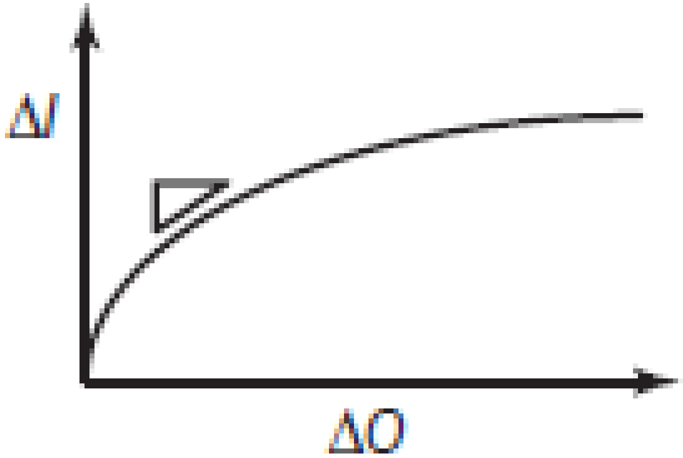
Typical examples of devices requiring an auxiliary energy source are strain gauges and resistance thermometers.

- **Active sensors:** In a active sensor, the output is produced from the input parameters. The active sensors (self generating) produce an electrical signal in response to an external stimulus.

Examples of passive types of sensors include piezoelectric, thermoelectric, and radioactive.

Important terminology

Sensitivity : Sensitivity is the property of the measuring instrument to respond to changes in the measured quantity. It also can be expressed as the ratio of change of output to change of input as shown in Figure



$$S = \frac{\Delta O}{\Delta I}$$

Resolution: Resolution is defined as the smallest increment in the measured value that can be detected. It is also known as the degree of fineness with which measurements can be made. For example, if a micro-meter with a minimum graduation of 1 mm is used to measure to the nearest 0.5 mm, then by interpolation, the resolution is estimated as 0.5 mm.

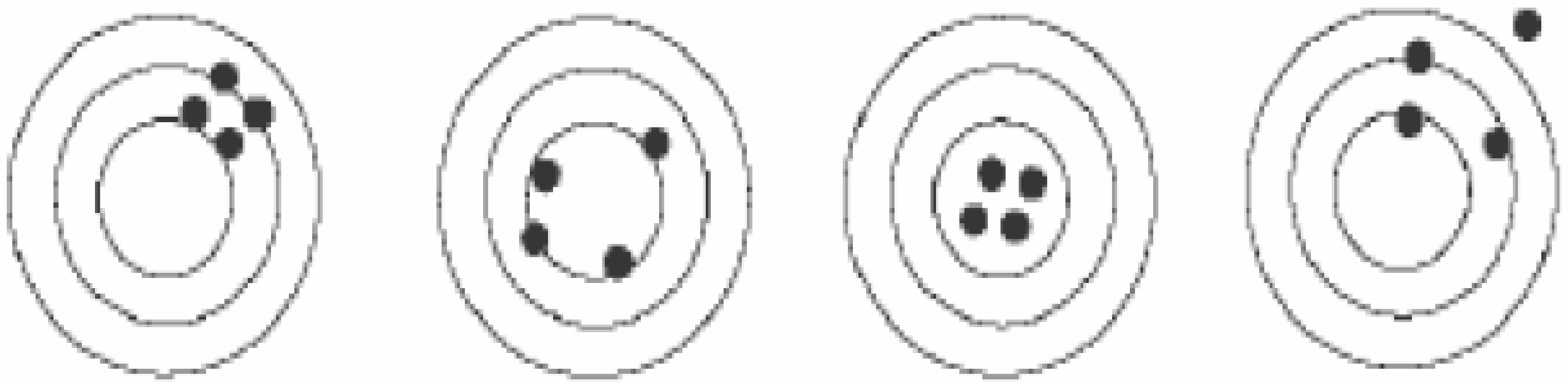
Accuracy: Accuracy is a measure of the difference between the measured value and actual value. Accuracy depends on the inherent instrument limitations. An experiment is said to be accurate if it is unaffected by experimental error. An accuracy of 0.001 means that the measured value is within 0.001 units of actual value. In practice, the accuracy is defined as a percentage of the true value.

$$\text{Percentage of true value} = \frac{\text{measured value} - \text{true value}}{\text{true value}}(100)$$

Precision:

Precision is the ability of an instrument to reproduce a certain set of readings within a given accuracy. Precision is dependent on the reliability of the instrument.

Precision $\not\rightarrow$ Accuracy



Precise not accurate	Not precise accurate	Precise + accurate	Not precise not accurate

Displacement/Position Transducer

Types:

Resistive transducer

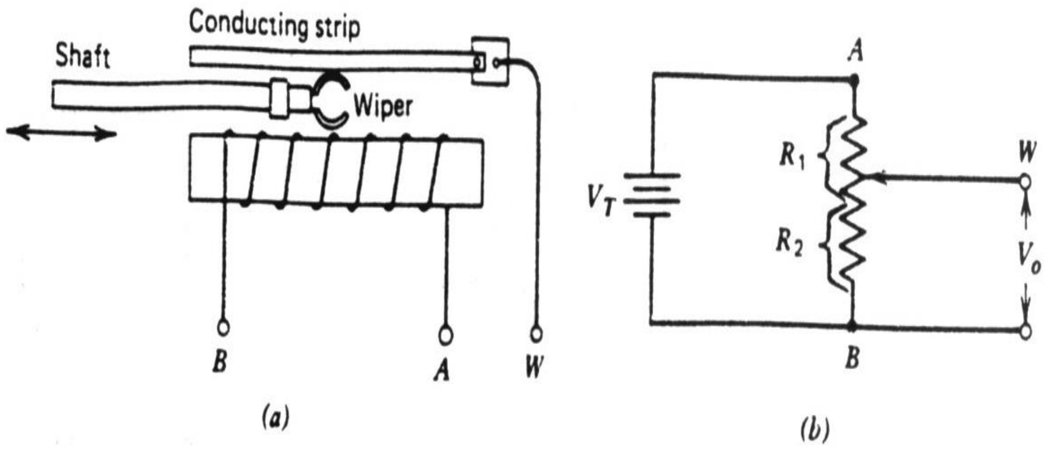
Inductive transducer

Capacitive transducer

Optical transducer

Displacement/ Position Transducer

- A common requirement in industrial measurement and control work is to be able to sense the position of an object, or the distance it has moved.



Resistive positive transducer, or displacement transducer.

Resistive Position Transducer(cont'd)

- Typical commercial units provide a choice of maximum shaft strokes from an inch or less to 5 feet or more. Deviation from linearity of the resistance versus-distance specification can be as low as 0.1% to 1.0%.
- Consider Fig. If the circuit is unloaded, the output voltage V_0 is a certain fraction of $V_{T,}$ depending on the position of the wiper:

$$\frac{V_0}{V_T} = \frac{R_2}{R_1 + R_2}$$

Resistive Position Transducer(cont'd)

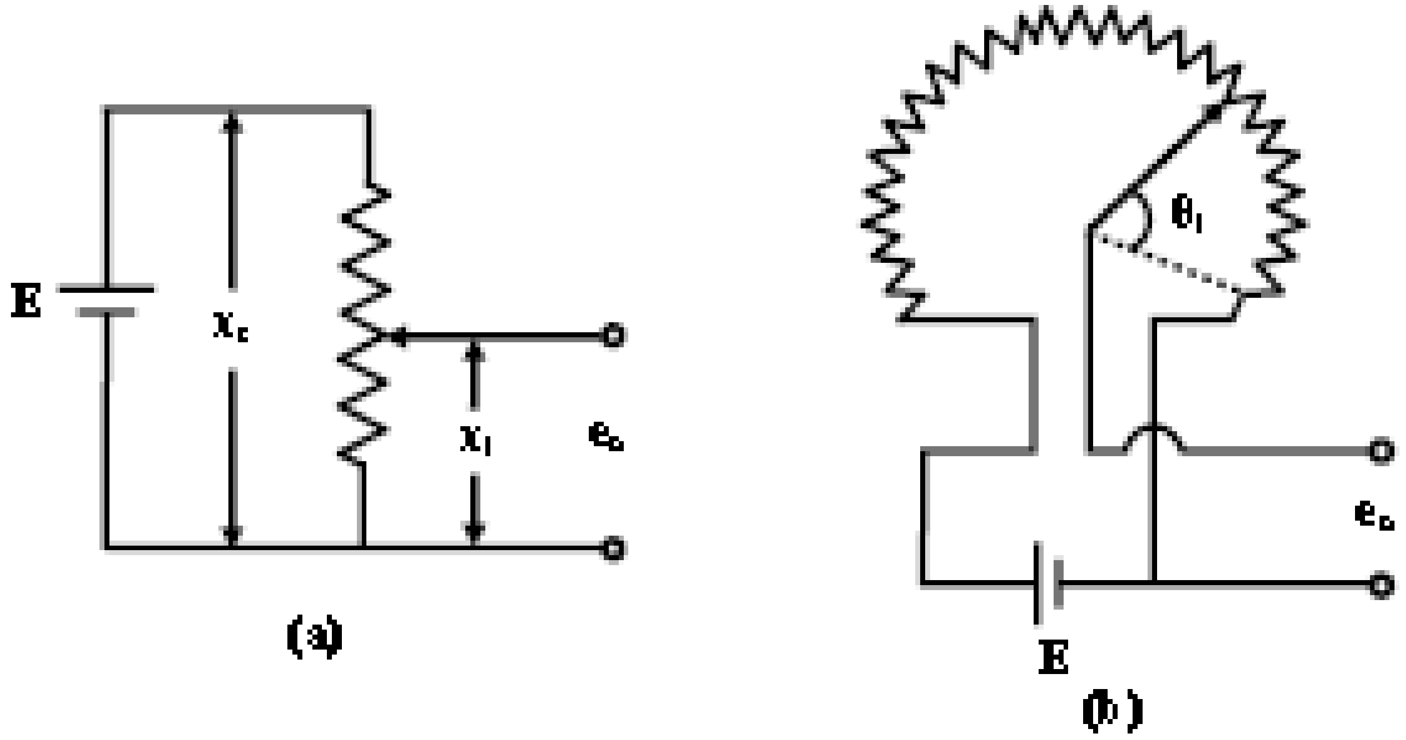
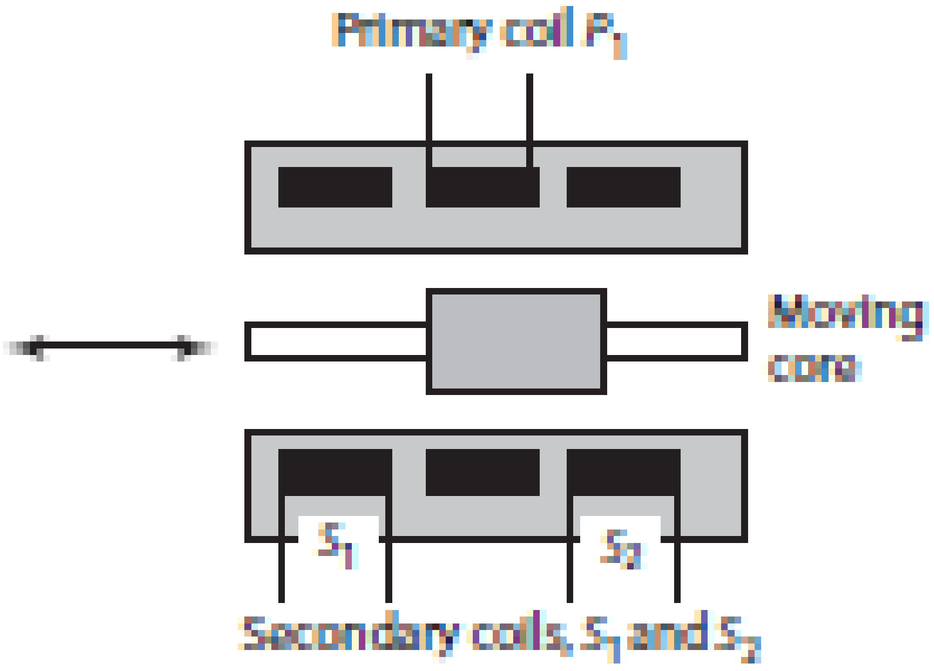
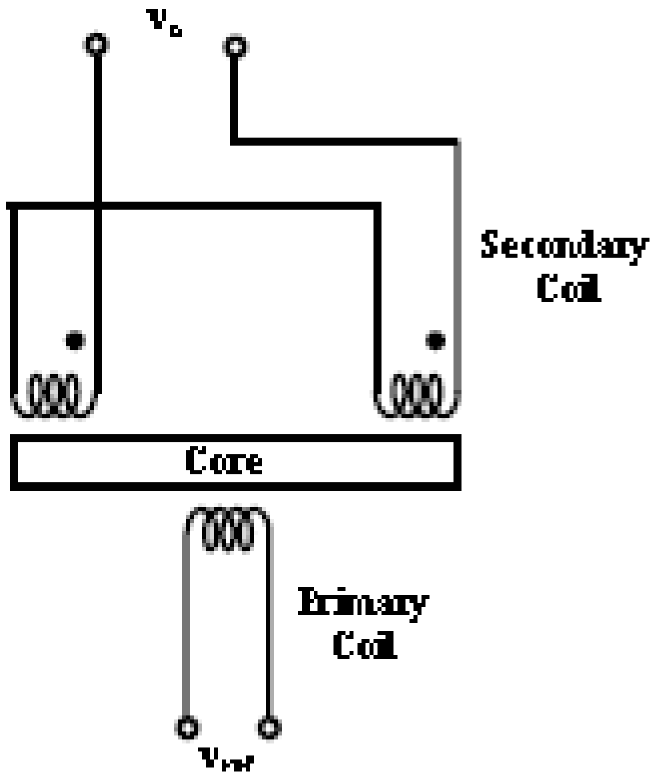


Fig.1 Potentiometer
(a) Linear
(b) Rotary

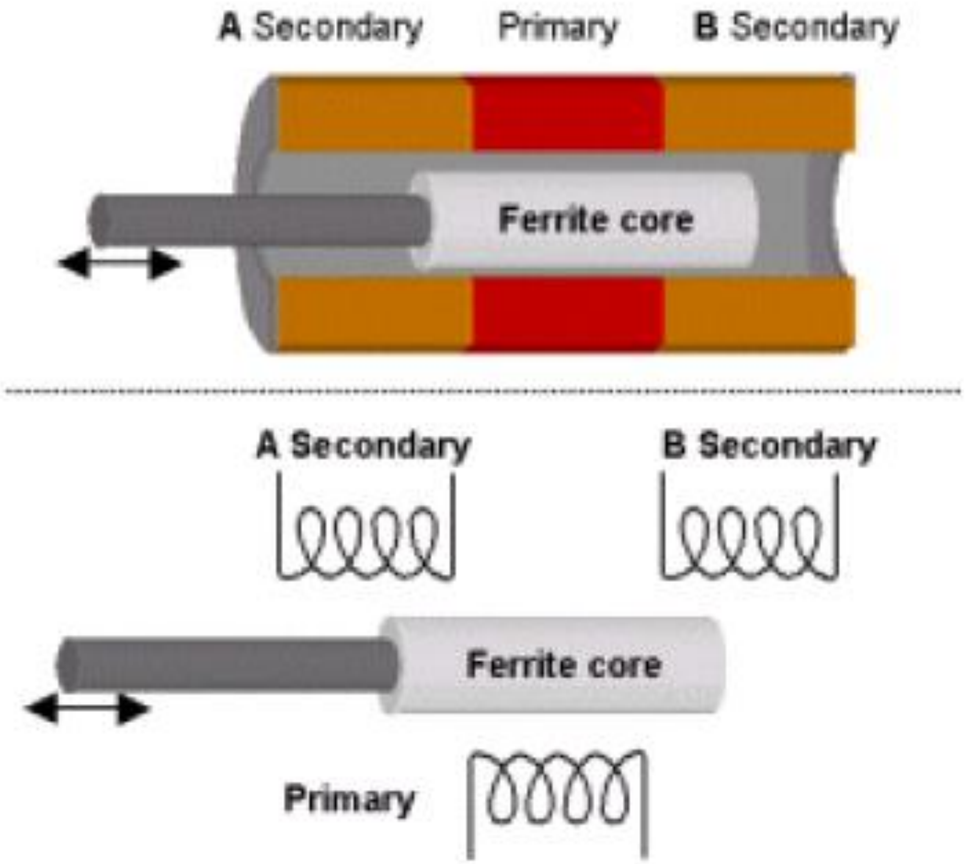
Inductive Position sensor:
LVDT





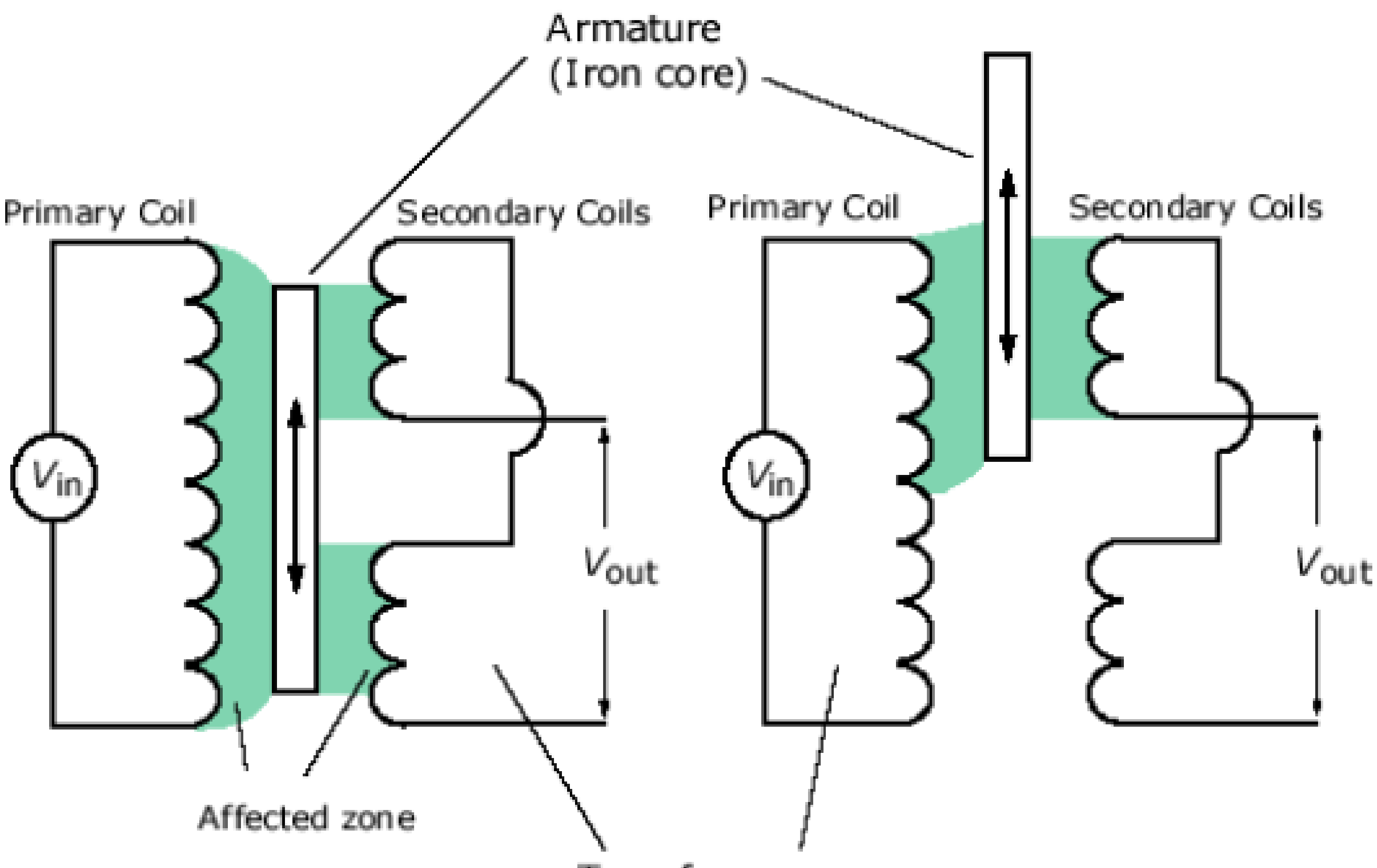
Linear Variable Differential Transformer (LVDT)

- Some examples of LVDTs.



Linear Variable Differential Transformer

- An example of LVDT electrical wiring.

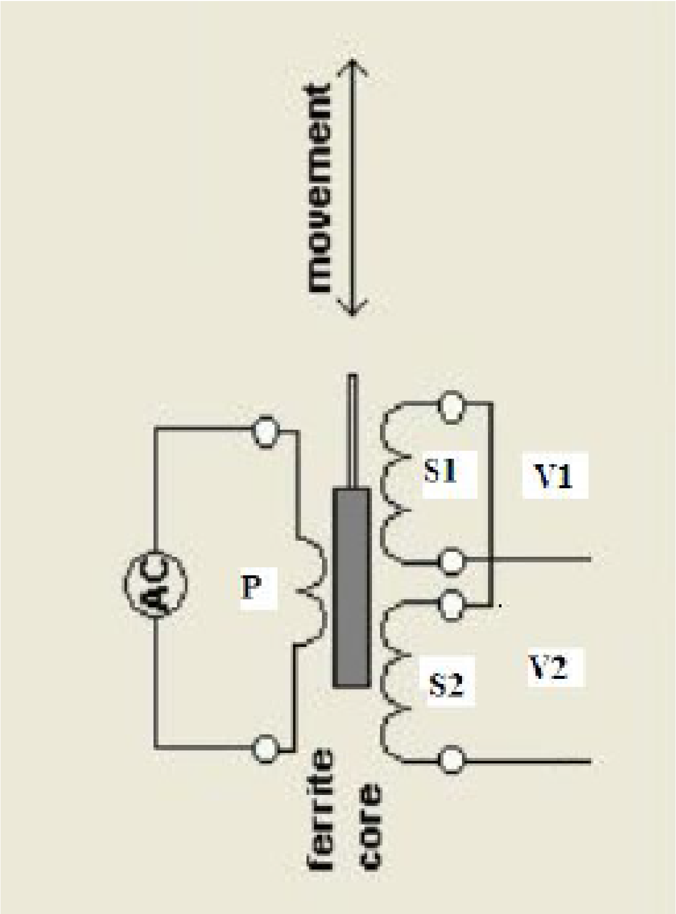


Linear Variable Differential Transformer

- An iron core slides within the tube and therefore affects the magnetic coupling between the primary and two secondaries.
- When the core is in the centre , the voltage induced in the two secondaries is equal.
- When the core is moved in one direction of centre, the voltage induced in one winding is increased and that in the other is decreased. Movement in the opposite direction reverses this effects.

Linear Variable Differential Transformer

- In next figure, the winding is connected 'series opposing' -that is the polarities of V1 and V2 oppose each other
- Consequently, when the core is in the ***center*** so that V1=V2, there is no voltage output, ***Vo = 0V***.



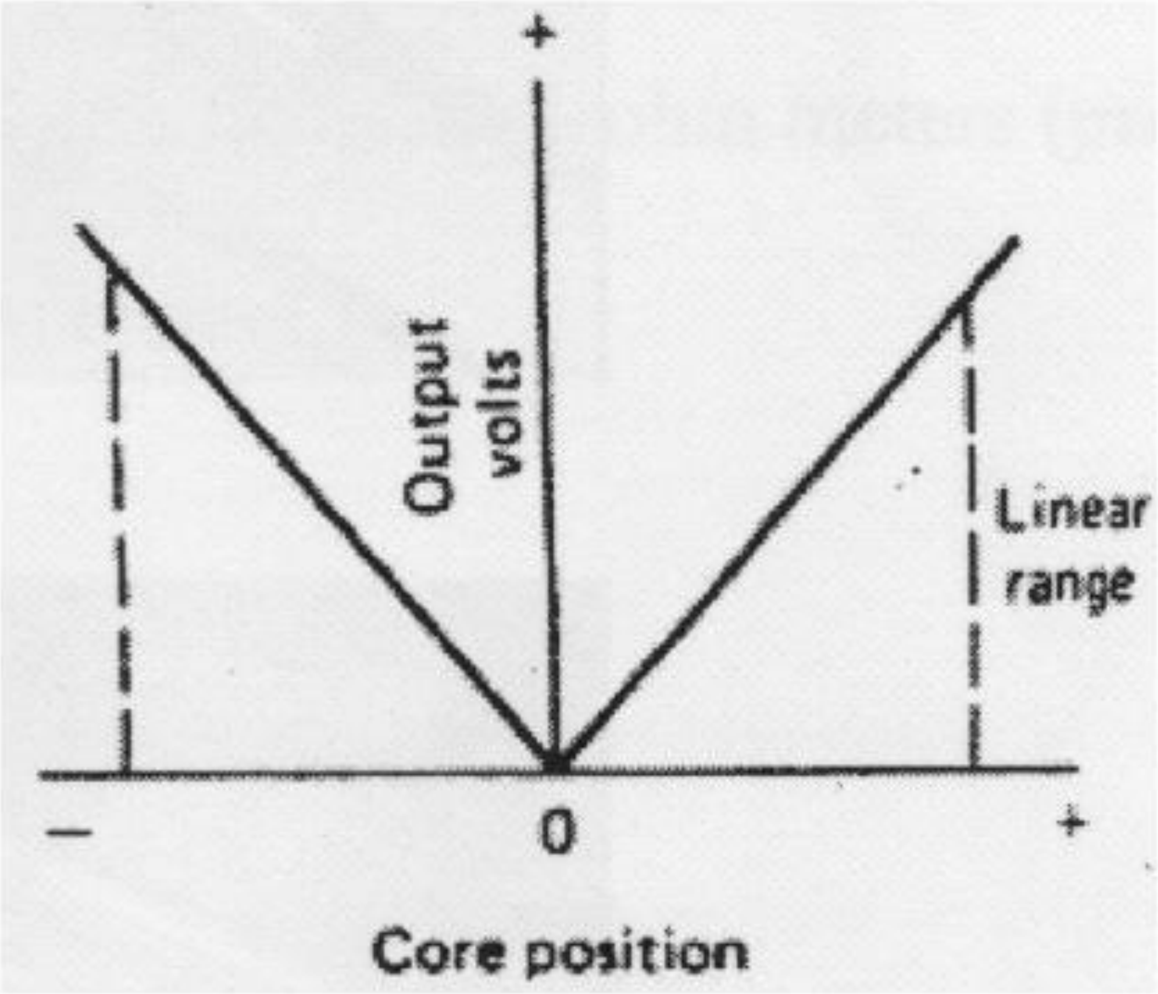
Linear Variable Differential Transformer

- When the core is moved in one direction from the center, the voltage induced in one winding is increased and that in the others is decreased.
- Movement in the opposite direction reverse the effect.

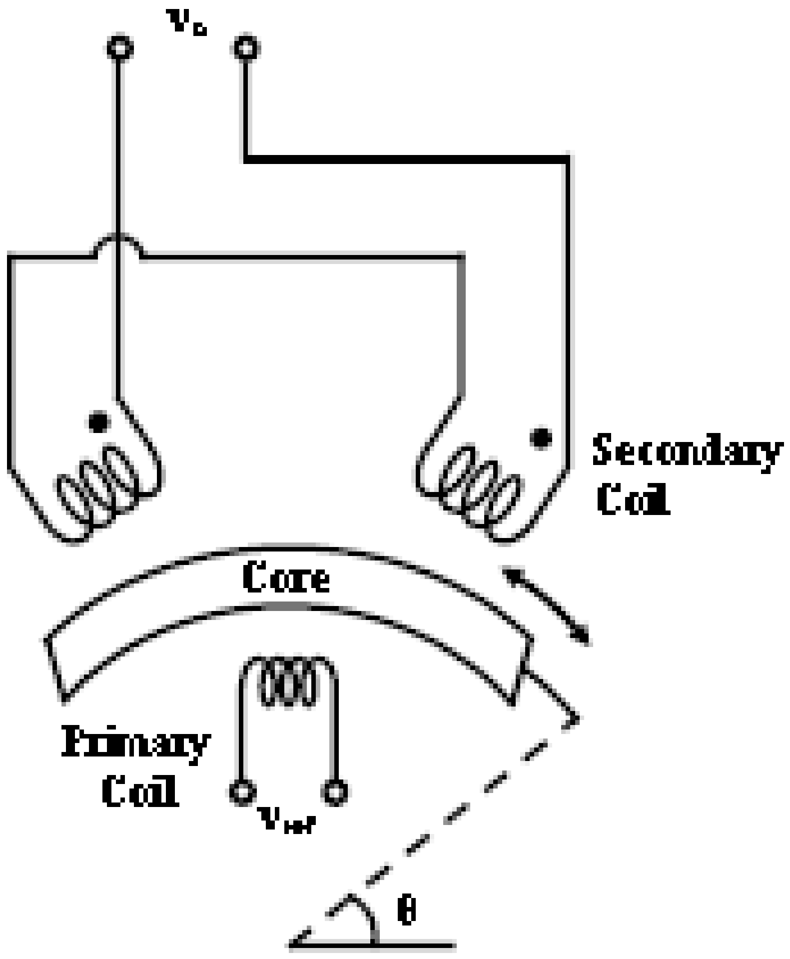
Variable Inductance Transducers – operation

Thus, the amplitude of Vo is a function of distance the core has moved. If the core is attached to a moving object, the LVDT output voltage can be a measure of the position of the object.

The farther the core moves from the centre, the greater the difference in value between V1 and V2, and consequently the greater the value of Vo.



Inductive Rotational displacement sensor: RVDT



Advantages of LVDT

- It produces a high output voltages for small changes in core position.
- Low cost
- Solid and robust - capable of working in a wide variety of environments.
- No permanent damage to the LVDT if measurements exceed the designed range.

Capacitive transducers

- The capacitance of a parallel-plate capacitor is given by

$$C = \frac{\varepsilon \varepsilon_o A}{d}$$

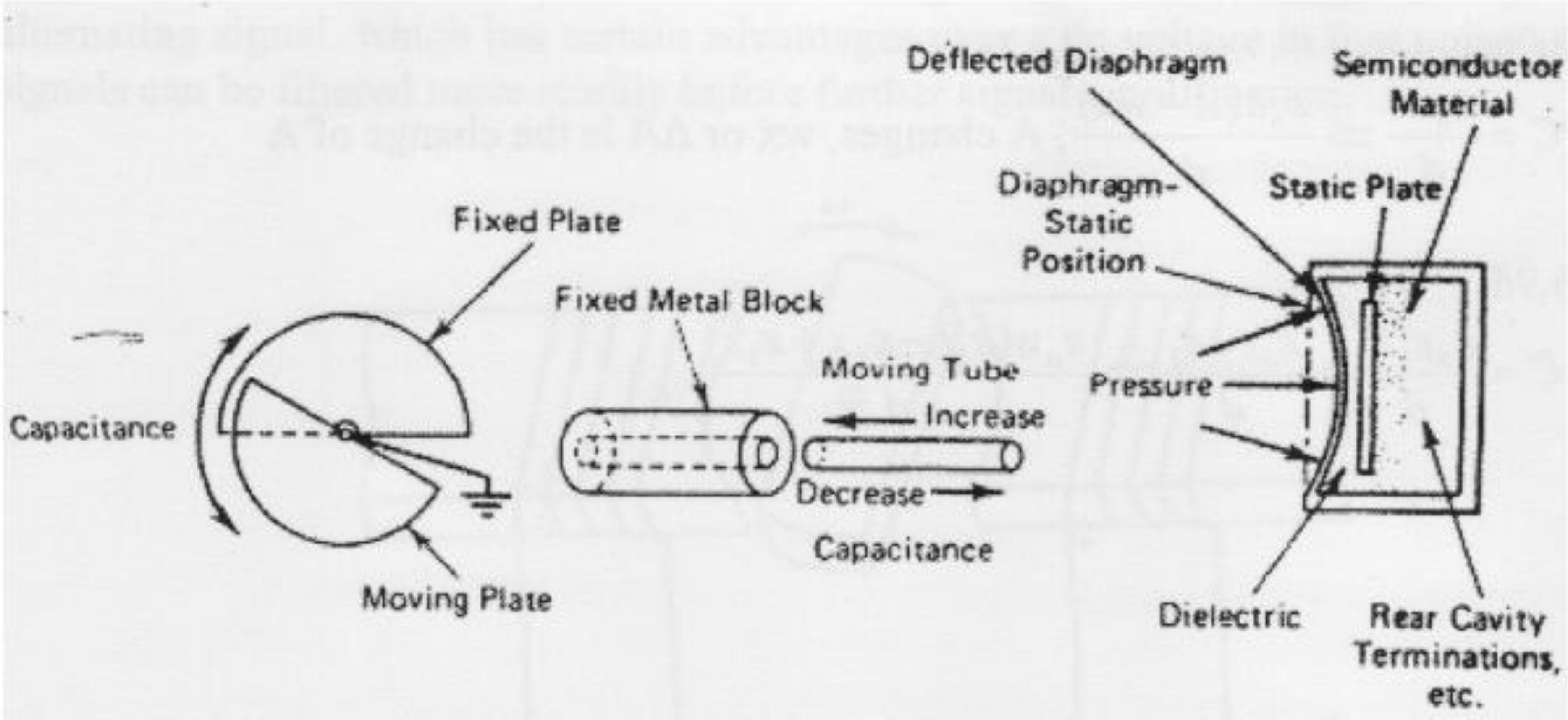
- *ε = dielectric constant*

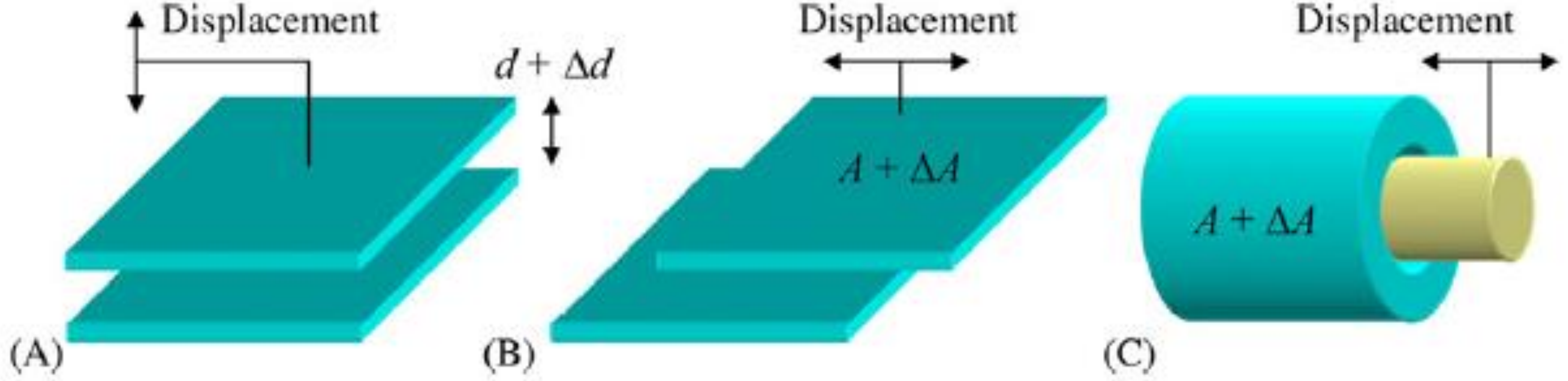
  ε_o = 8.854 x 10^{-12}, in farad per meter

  A = the area of the plate, in square meter

  d = the plate spacing in meters
- Since *C* is inversely proportional to *d*, any change in *d* will cause a change in *C*.

Capacitive transducers – physical design




Displacement
$d + \Delta d$
(A)
Displacement
$A + \Delta A$
(B)
Displacement
$A + \Delta A$
(C)

Digital Encoders

Encoders are widely used for applications involving measurement of linear or angular position, velocity, and direction of movement. The most popular encoders are linear- or rotary-type optical encoders.

Encoder Principle

An encoder is a circular device in the form of a disk on which a digital pattern is etched. The inscribed pattern is sensed by means of a sensing head. The rotary disk is normally coupled to a shaft. As the shaft rotates, a different pattern is generated for each resolvable position. The sensing mechanism can be a photoelectric device with slots acting as transparent optical windows.

There are two types of encoders; *incremental and absolute*. An incremental encoder provides a simple pulse each time the object to be measured has moved a given distance. An absolute encoder provides a unique binary word coded to represent a given position of the object.

Incremental Encoders

Incremental encoders for angular measurement consist of a sensing shaft attached to a disk which is divided into an equal number of sectors on the circumference. In the linear type of encoders, there are equal segments along the length of travel. The readings are sensed by direct electrical contact with a brush or wiper or optically using optical slits or gratings. Since it counts the lines on a disk, the more lines, the higher the resolution. This specification is expressed as pulses per revolution, which is an important factor in encoder selection.

Optical sensor: Linear

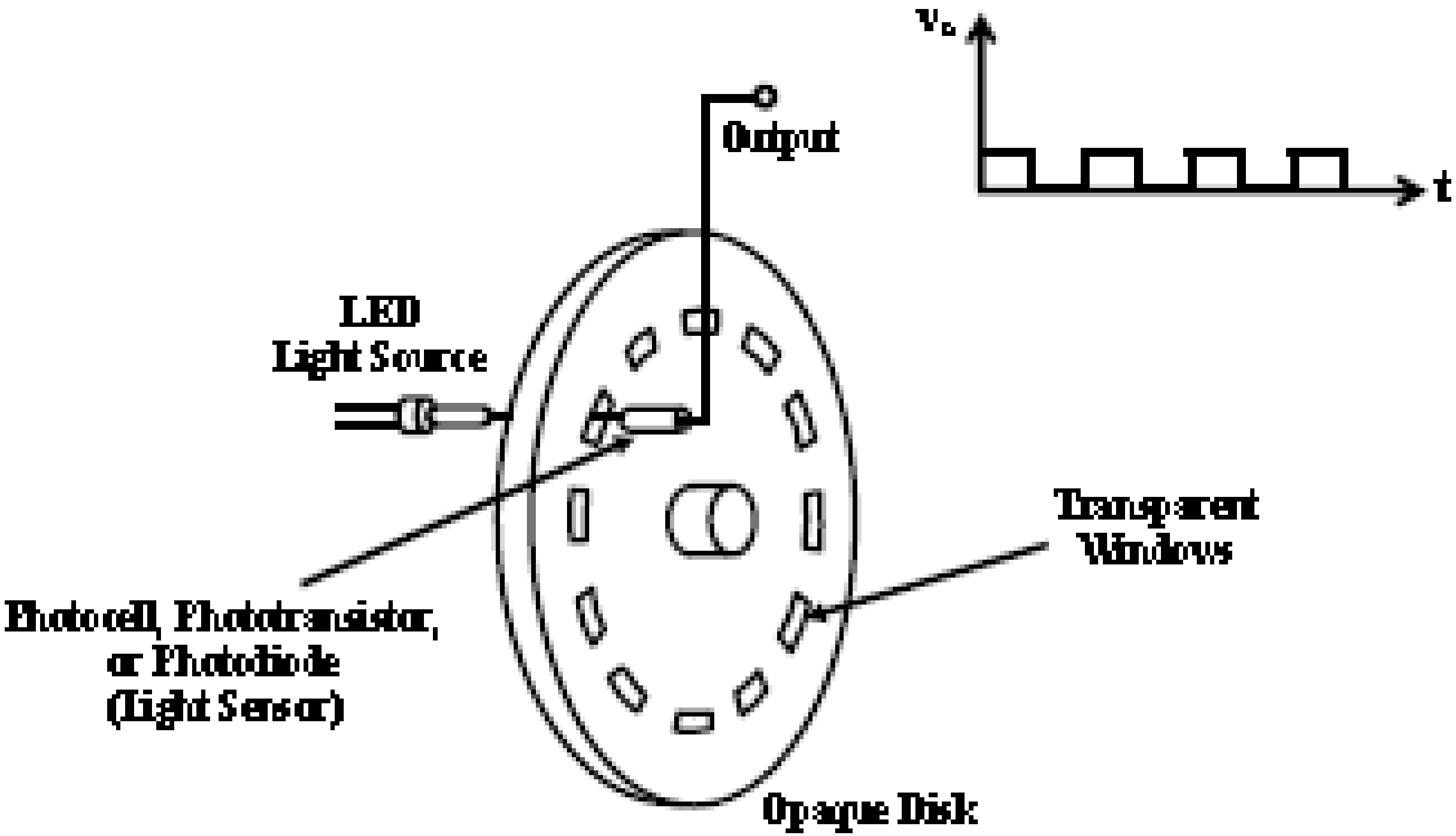


Fig. 9 Schematic arrangement of optical speed sensing arrangement.

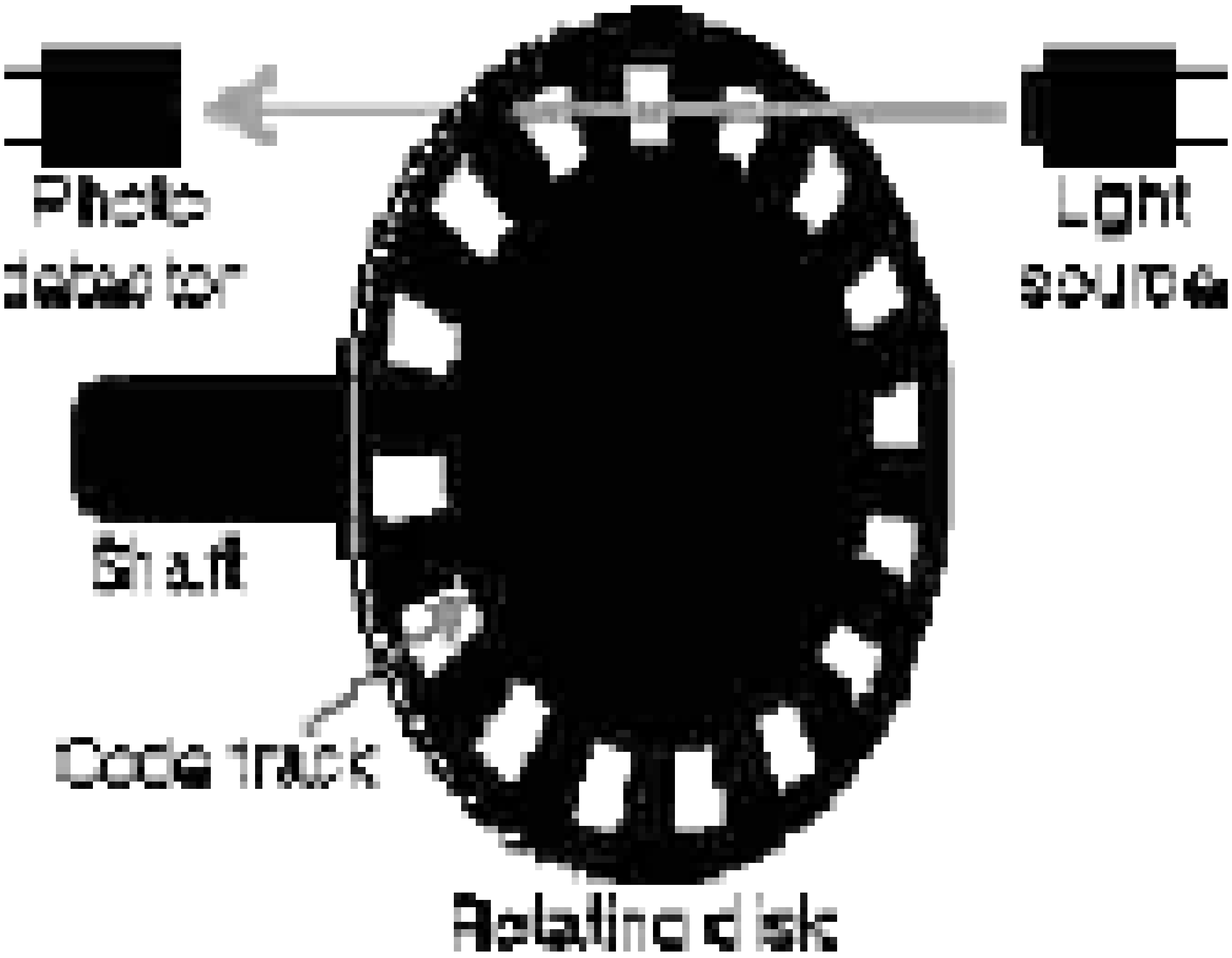
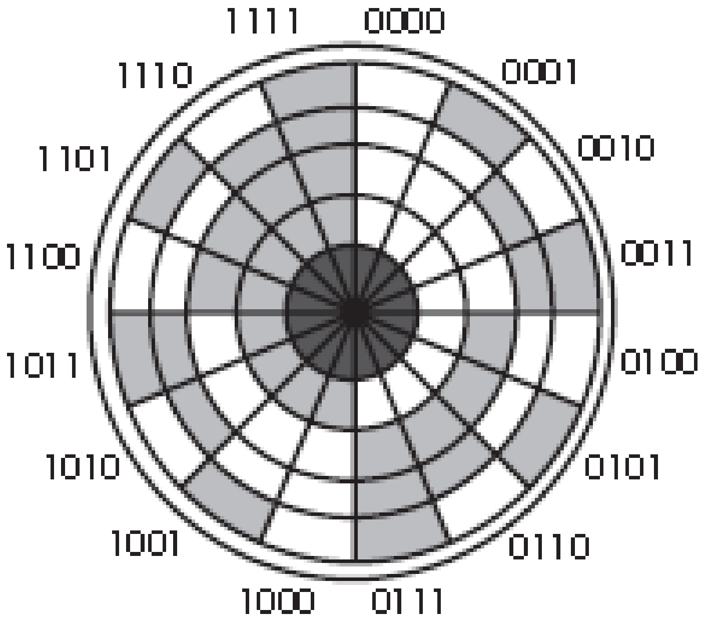


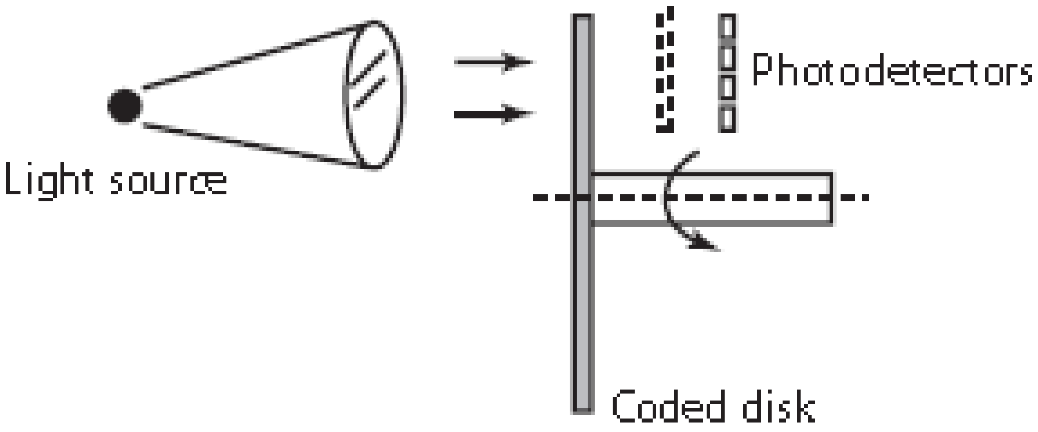
Photo
detector
Light
source
Shaft
Code track
Rotating disk

Absolute Encoders

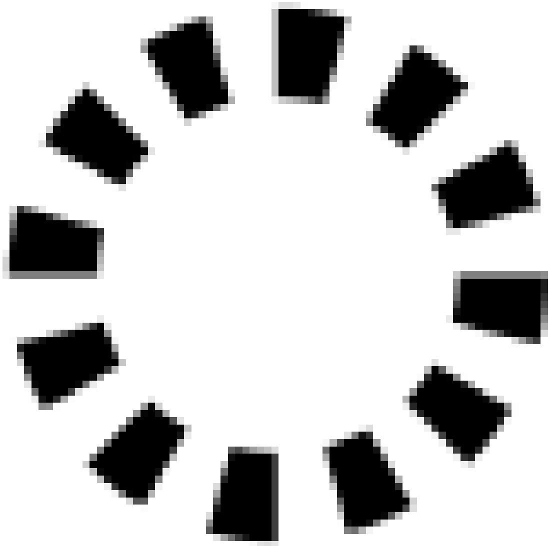
The absolute encoder normally has a light source which emits a beam of light onto a photoelectric sensor called a photo detector. This converts the receiving light into an electrical signal, An optical encoded wheel (circular absolute grating) is mounted between the light source and photo detector. The encoded wheel has several concentric circular tracks that are divided into sectors. Manufactured into the surface of the coded wheel are alternating opaque and transparent sections. When the opaque section of the wheel passes in front of the light, the detector is *turned off*, and no signal is generated. When the transparent section of the wheel passes in front, the detector is *turned on*, and a signal is generated. The result is a series of signals corresponding to the rotation of the coded wheel. By using a counter to count these signals, it is possible to find out how far the wheel has rotated.

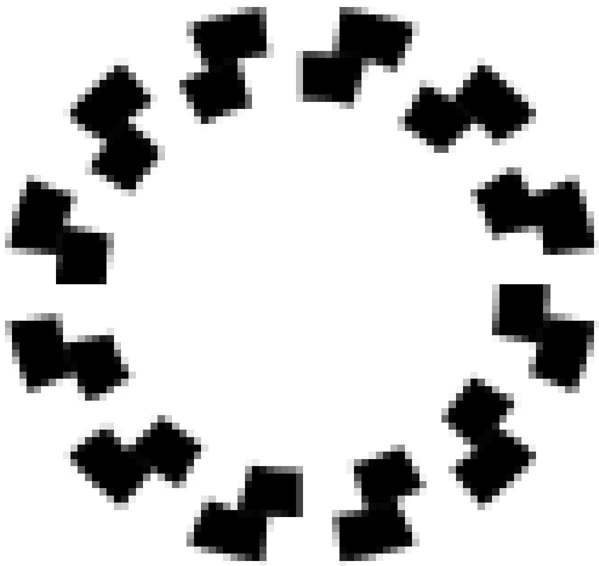
OPTICAL ENCODING

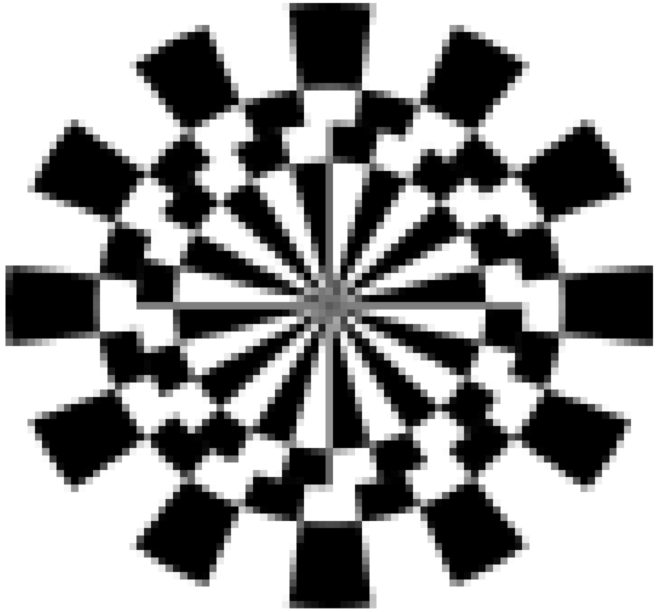


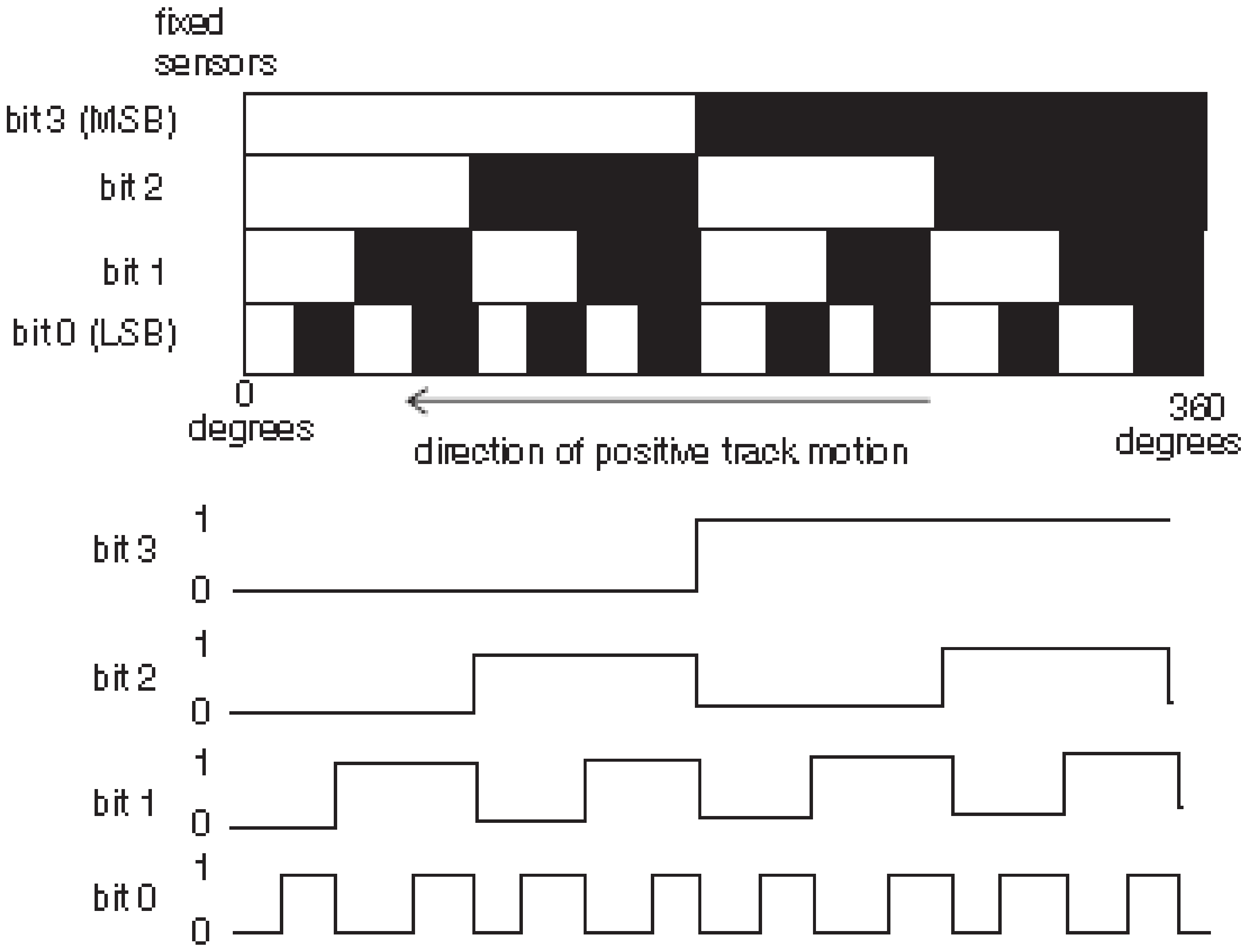


Incremental encoders are more commonly used than **absolute encoders** because of their simplicity and lower cost. Incremental encoders are used for both velocity and position measurement and are one of the most reliable and inexpensive devices available for this task.








fixed
sensors
bit3 (MSB)
bit 2
bit 1
bit0 (LSB)
0
degrees
direction of positive track motion
360
degrees
bit 3
1
0
bit 2
1
0
bit 1
1
0
bit 0
1
0

Strain gauges are suitable for the measurement of all kind of force-related quantities, for example normal and shear force, pressure, torsion, bending and stress.

Strain gauges are excellent devices for the measurement of force and torque in a mechatronic construction

Strain gauges respond primarily on strain, $\Delta l/l$.

A stress, by contrast, is a force divided by an area. As applied to a wire or a bar in tension or compression, for example, the *tensile* (pulling) stress is the applied force divided by the area over which it is applied, which will be the area of cross section of the wire or bar. For materials such as liquids or gases which can be compressed uniformly in all dimensions, the *bulk* stress is the force per unit area, which is identical to the pressure applied, and the strain is the change of volume divided by the original volume. The most common strain transducers are for tensile mechanical strain. The measurement of

Strain Gauge Transducers

- Stress is defined as the internal force per unit area. The stress equation is

$$S = \frac{F}{A}$$

Where

- S = the stress in kilograms per Square meter
- F = the force in kilograms
- A = the area in square meters

Stress vs. Strain

- Strain (e) is a measure of displacement usually in terms of micro-strain such as micro-inches of elongation for each inch of specimen length.
- Stress (s) is a measure of loading in terms of load per unit cross-sectional area
- Stress and strain are related by a material property known as the Young's modulus (or modulus of elasticity) E.

$$\sigma = \varepsilon E$$

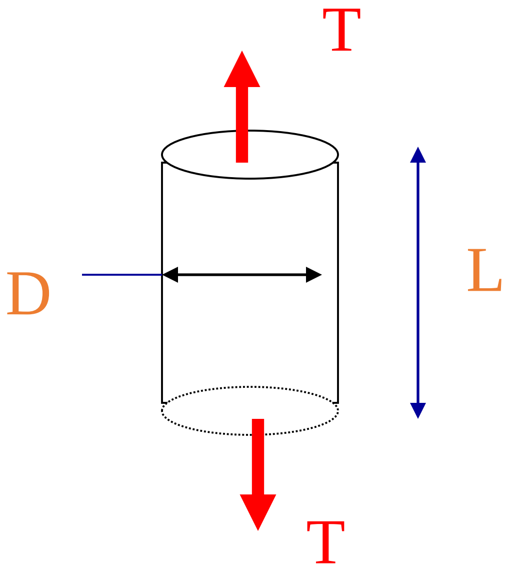
Strain Defined

- Strain is defined as relative elongation in a particular direction

$e_a = dL/L$ (axial strain)

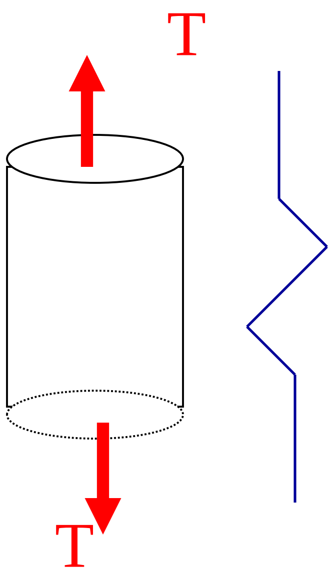
$e_t = dD/D$ (transverse strain)

$m = e_t / e_a$ (Poisson's ratio)

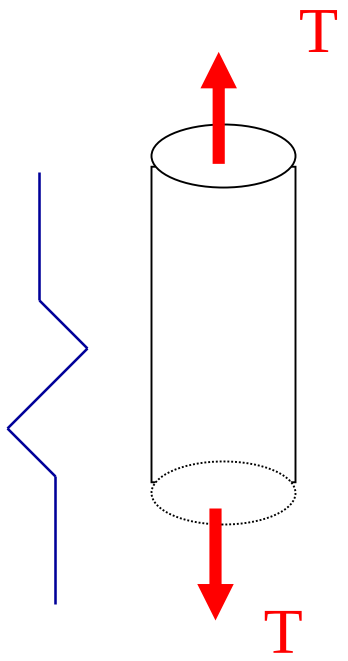


Strain gauges

- The electrical resistance of a conductor changes when it is subjected to a mechanical deformation



$R_{before} < R_{after}$



Resistance = f(A…)

- Electrical Resistance (R) is a function of…
  r the resistivity of the material (Ohms*m)
  L the length of the conductor (m)
  A the cross-sectional area of the conductor (m^2)

- $R = r * L/A$

- Note R increases with
  - Increased material resistivity
  - Increased length of conductor (wire)
  - Decreased cross-sectional area (or diameter)
  - Increased temperatures (can bias results if not accounted for)

Resistance strain gages

The use of strain gages is based on the fact that the resistance of a conductor changes when the conductor is subjected to strain. The resistance of an electrically conductive material changes with dimensional changes which take place when the conductor is deformed elastically. When such a material is stretched, the conductors become longer and narrower, which causes an increase in resistance.

There are several types of resistance strain gages: wire, foil and semiconductor base and used with the Wheatstone bridge.

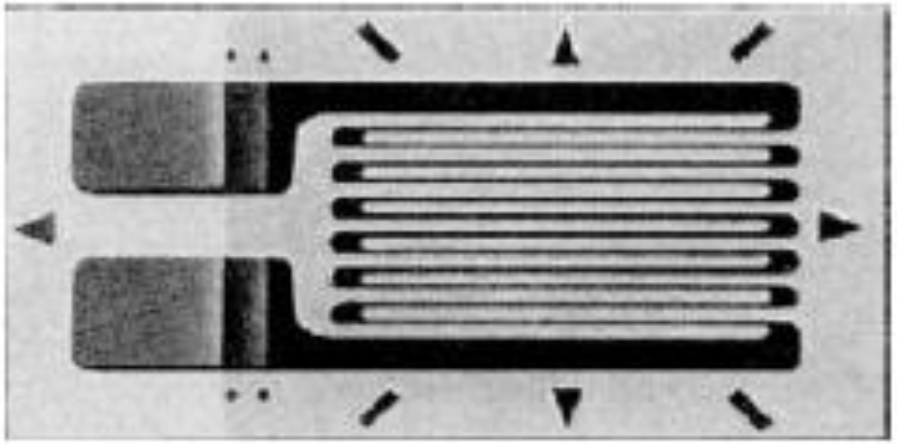
The wire gages

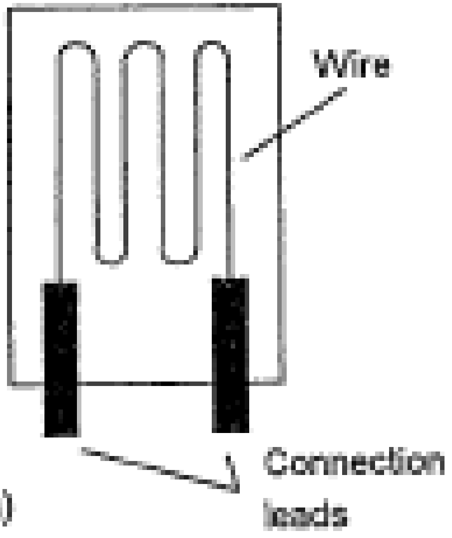
Wire gages can be divided into two types: flat wound and wrap around. In flat wound gages, the filament wire is zigzagged between two pieces of paper. With wrap around gages, the wire is wrapped around a paper support.

The foil gages

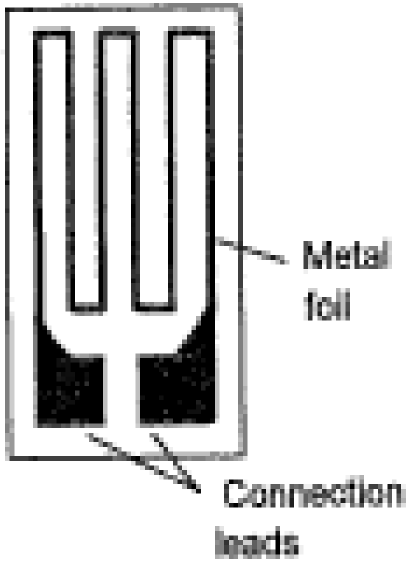
Foil gages are made from very thin metal strips (2–10 micrometers thick). They are essentially a printed circuit, and therefore require the best manufacturing techniques and careful handling to ensure good quality measurements.

It is possible to mass-produce foil gages, whereas wire gages must still be largely manufactured by hand.





(a)



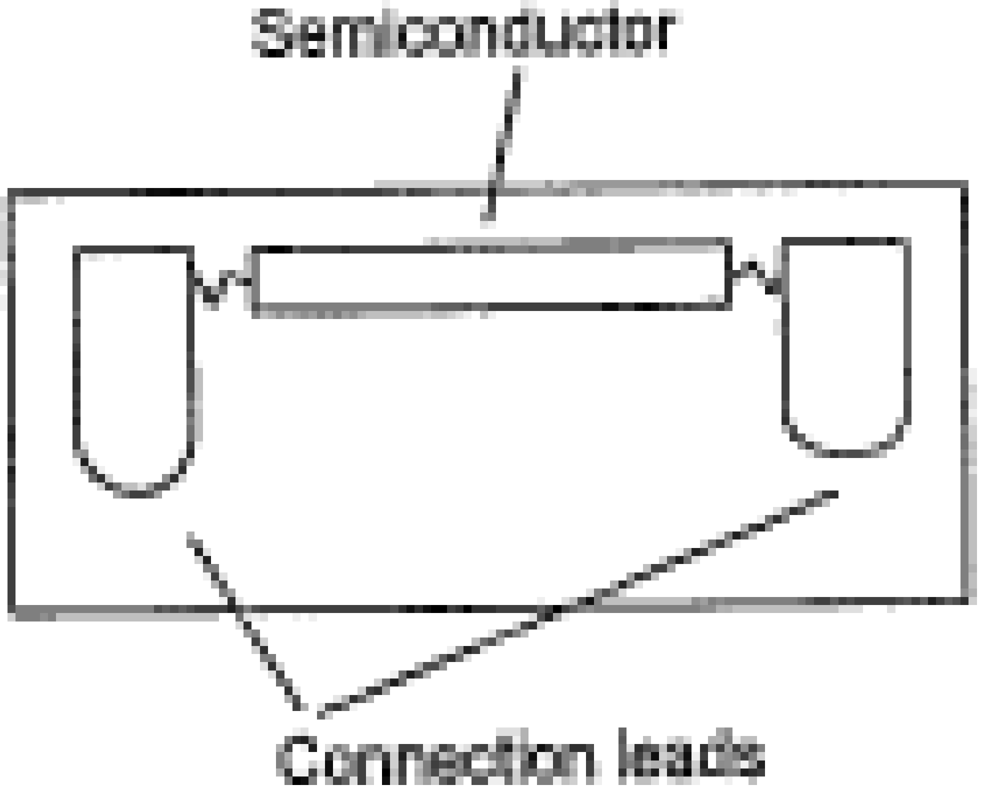
(b)

Semiconductor strain gages

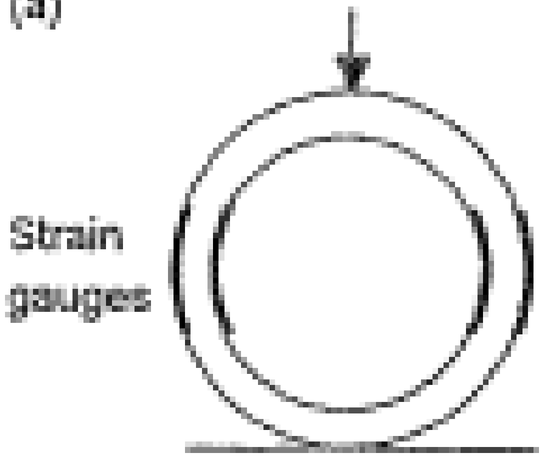
Semiconductor strain gages are widely used today, and these differ in many aspects from the metallic wire and foil strain gages. Most importantly, they produce much greater sensitivity (10 to 50 times). This was at one time thought to herald the downfall of metallic gages, but semiconductor gages are very limited as a general-purpose gage, and so there is a place for both types in modern strain measurement.

Semiconductor strain gauge

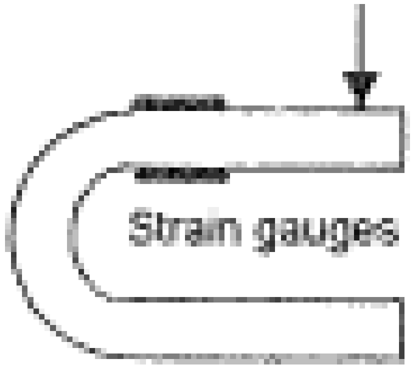
- Semiconductor strain gauges are often used in high-output transducers as load cells. These gauges are extremely sensitive, with gauge factors from 50 to 200. They are however, affected by temperature fluctuations and often behave in a nonlinear manner. The strain gauge is generally used as one arm of a bridge. The simple arrangement shown in Fig. (*2-a*) can be employed when temperature variations are not sufficient to affect accuracy significantly, or in applications for which great accuracy is not required.


Semiconductor
Connection leads

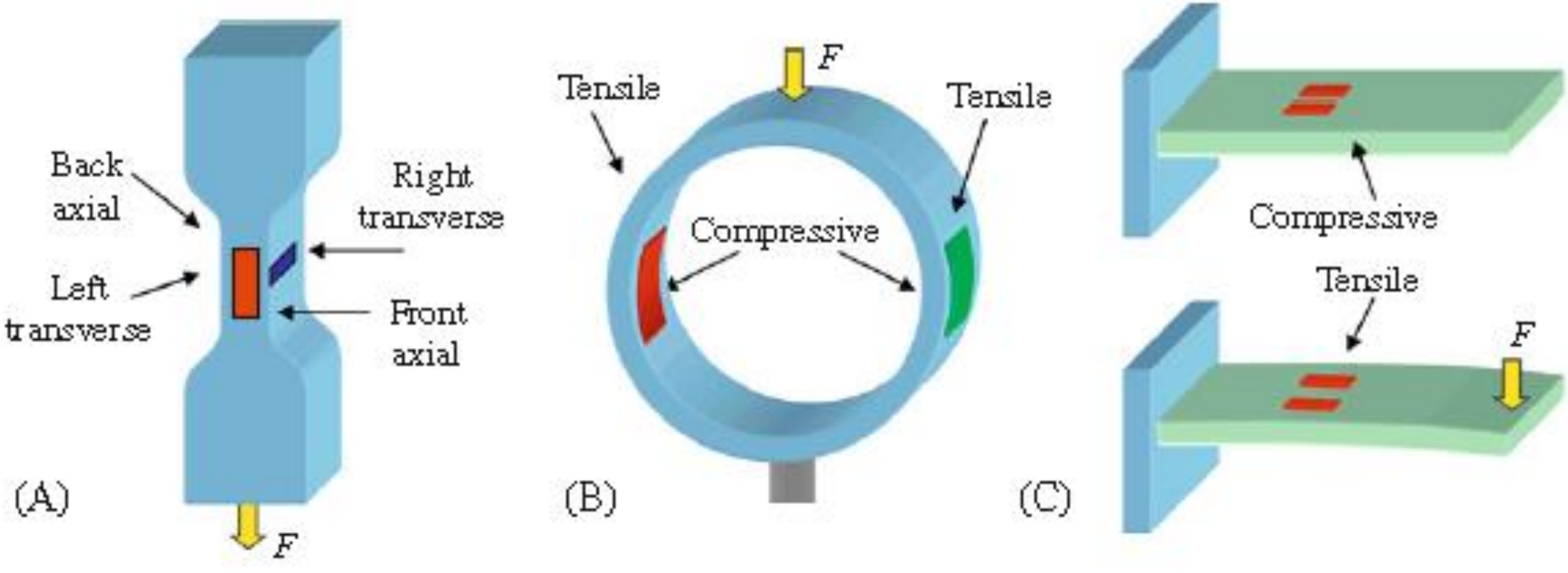
(a)



(b)

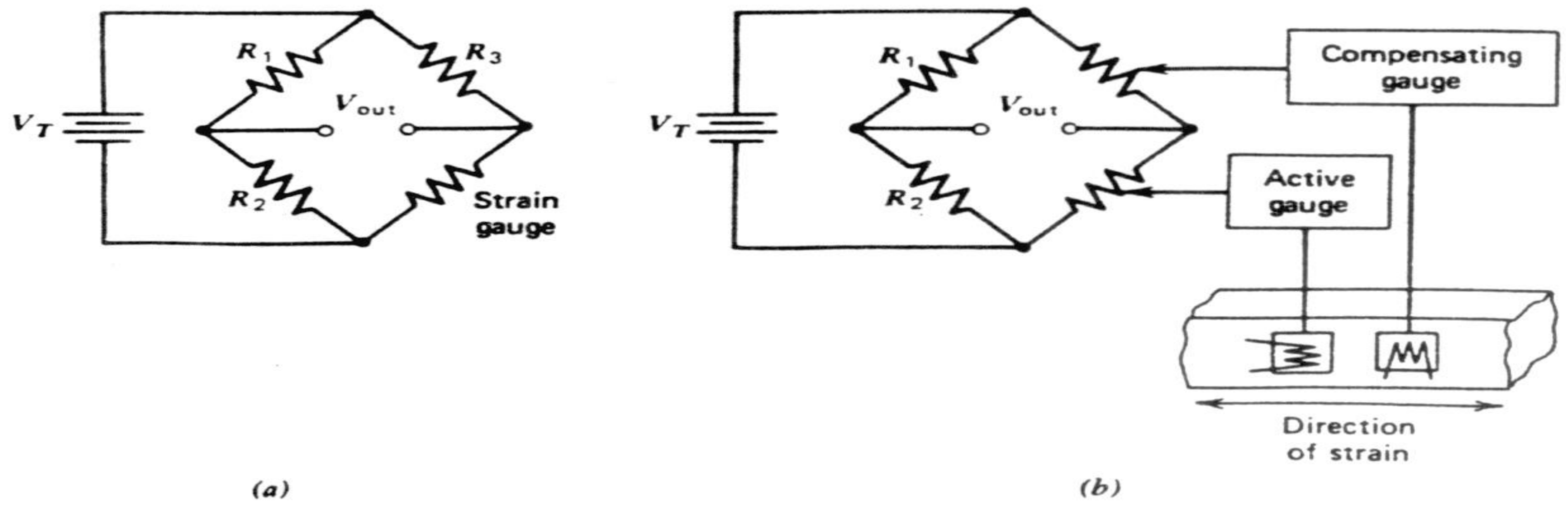


(c)


Back axial
Left transverse
Right transverse
Front axial
(A)
F
Tensile
F
Tensile
Compressive
(B)
Compressive
Tensile
F
(C)

Strain Gauge

- The resistance of this dummy gauge is not affected by the deformation of the material. Therefore, it acts like a passive resistance (such as R_3 of Fig. b) with regard to the strain measurement. Since only one gauge responds to the strain, the strain causes bridge unbalance just as in the case of the single gauge.



The sensitivity of a strain gauge is expressed in relative resistance change per unit of strain:

$$K = \frac{\mathrm{d}R/R}{\mathrm{d}l/l}$$

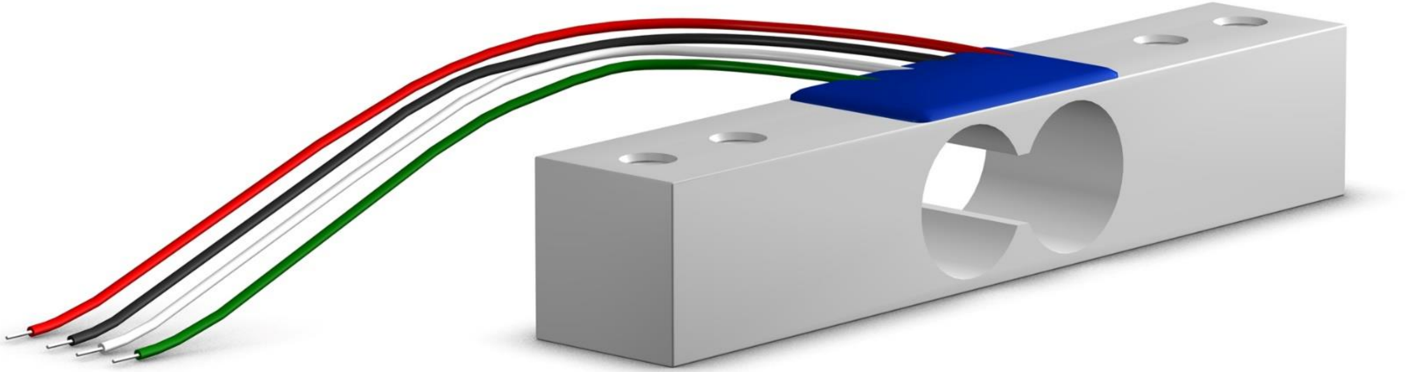
K is called the gauge factor of the strain gauge.

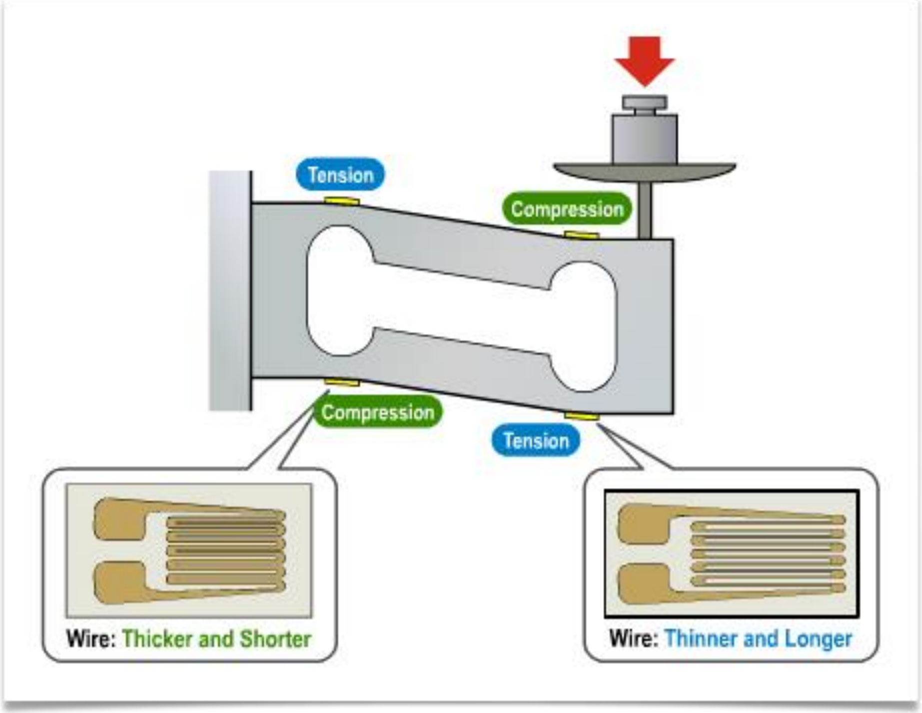
the gauge factor of a metal strain gauge is K=2. In other words: the relative resistance change equals twice the strain.

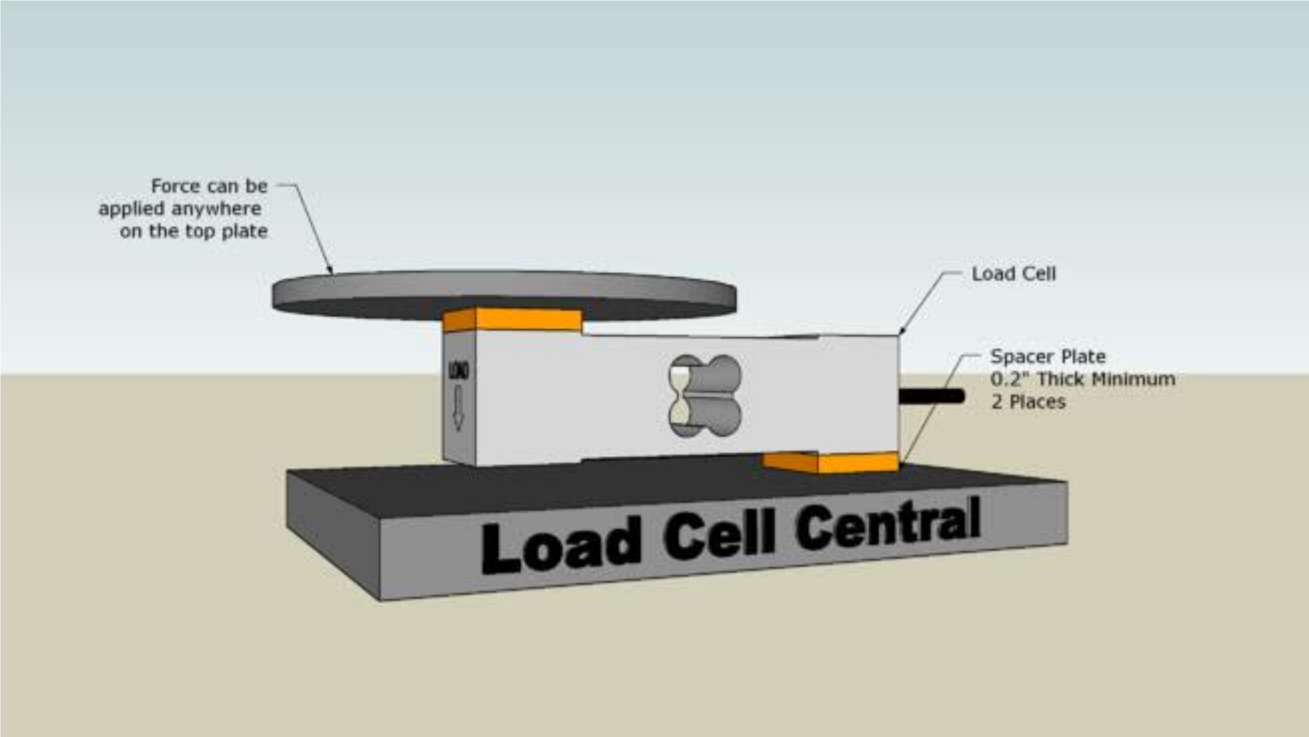
LOAD CELLS

Load cells are used in electronic weighing systems. A load cell is a force transducer that converts force or weight into an electrical signal. Basically, the load cell uses a set of strain gauges, usually four connected as a Wheatstone-bridge circuit. The output of the bridge circuit is a voltage that is proportional to the force on the load cell. This output can be processed directly, or digitized for processing.

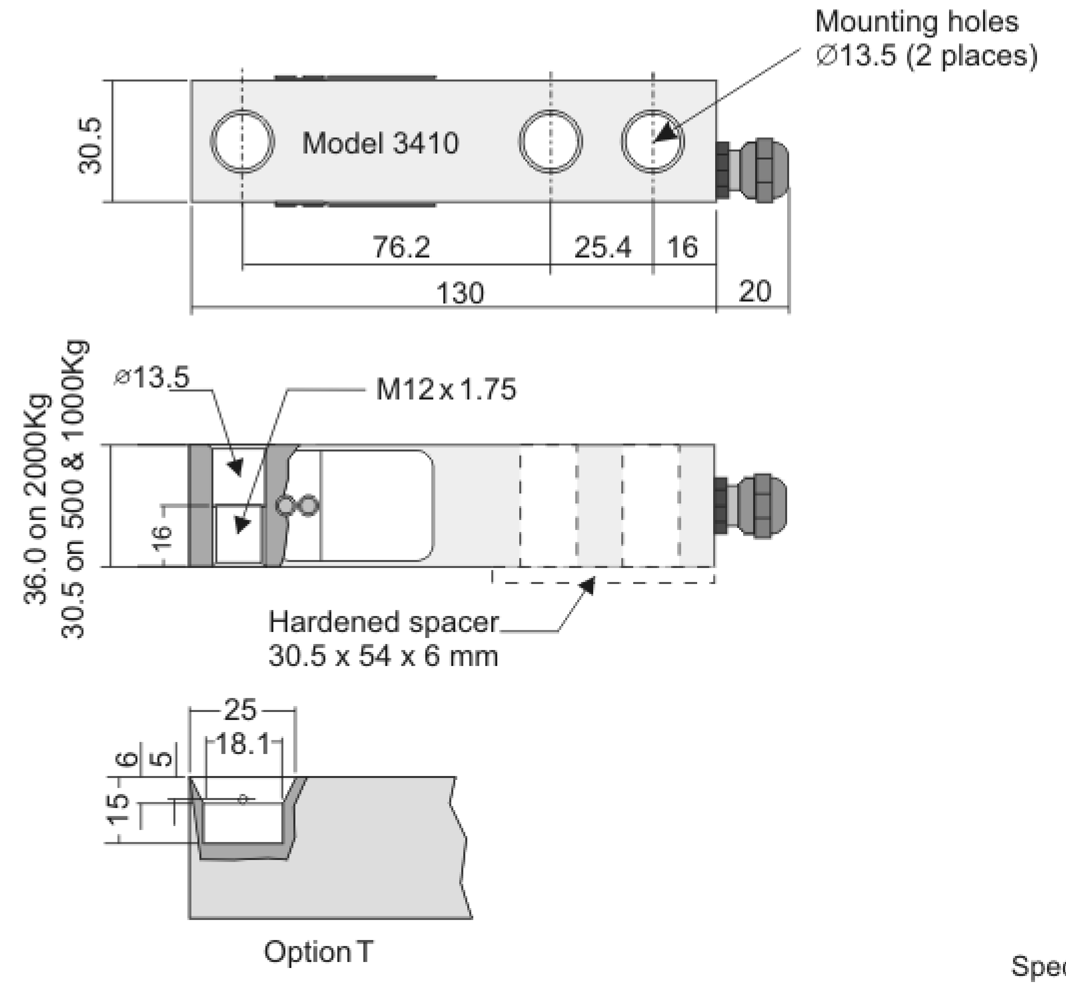

METTLER TOLEDO




Tension
Compression
Compression
Tension
Wire: Thicker and Shorter
Wire: Thinner and Longer

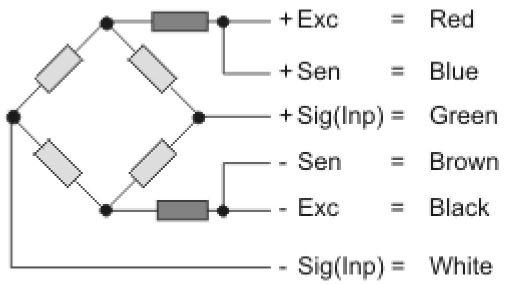

Force can be
applied anywhere
on the top plate
Load Cell
Spacer Plate
0.2" Thick Minimum
2 Places
LOAD
Load Cell Central


Eilersen www.eilersen.com
Type MD
Serial No 11-48284
Capacity 2.000kg
CE



Electrical Connections

6-Wire Cable, 5 metres long



All Dimensions in mm
Specifications are subject to change without prior notice

TRANSDUCERS

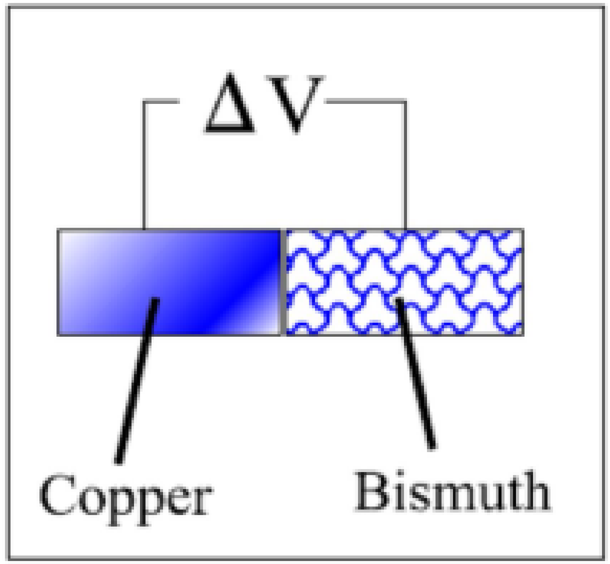
- Temperature transducers
  - Thermocouples
  - Resistance - Temperature Detectors (RTD)
  - Thermistors

What is a Thermocouple

It's a temperature sensitive device which works thanks to the Seebeck effect:

"a voltage is generated in a circuit containing two different metals by keeping the junctions between them at different temperatures"

Estonian physician Thomas Seebeck (1770–1831)



Pros and *Cons* in temperature measuring using Thermocouples

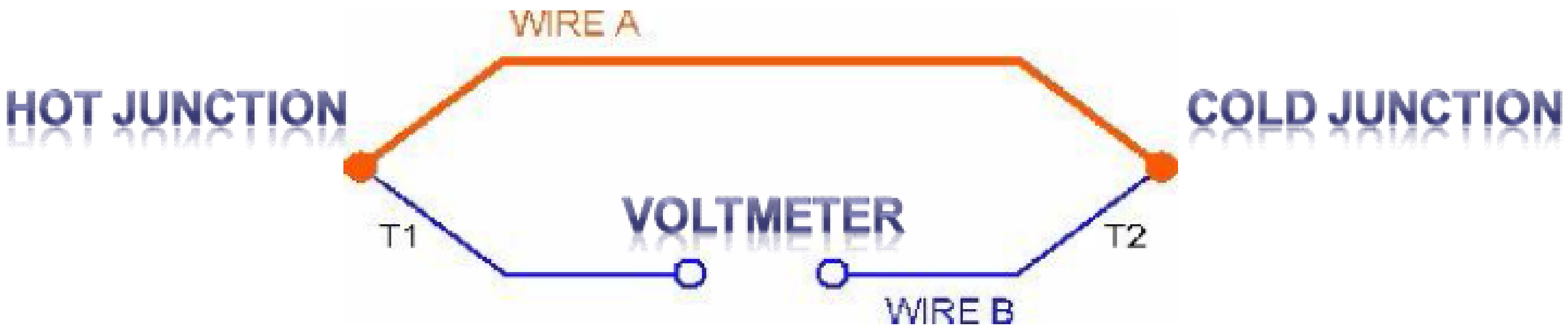
- *Pros*
  - They are inexpensive.
  - They are rugged and reliable.
  - They can be used over a wide temperature range.
- *Cons*
  - low output voltage
  - low sensitivity
  - non-linearity
  - electrical connections.

How does a thermocouple look like ?

Here it is!

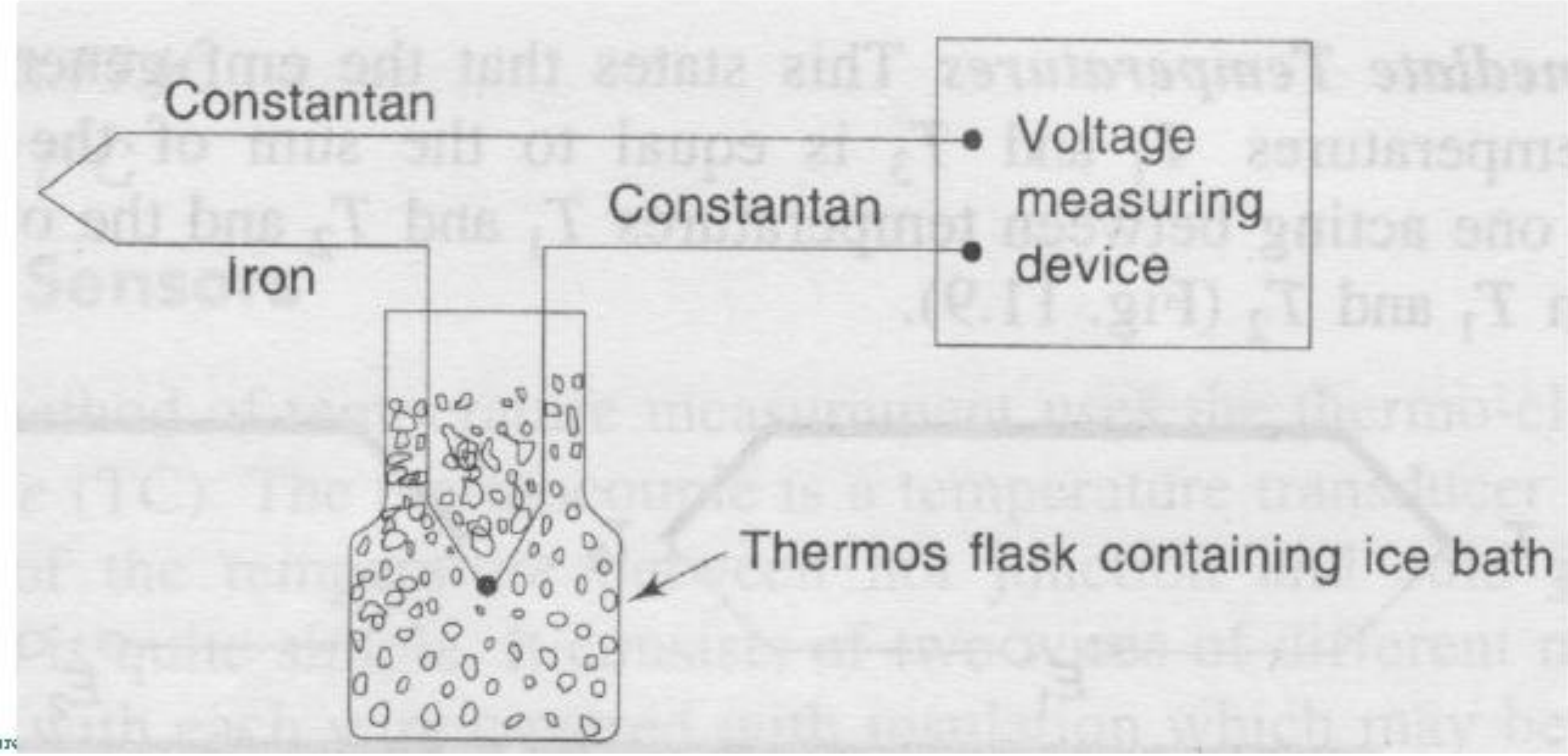
please note the two wires (of two different metals) joined in the junction.

How does a thermocouple work ?



High impedance voltmeter !

In normal operation, cold junction is placed in an ice bath

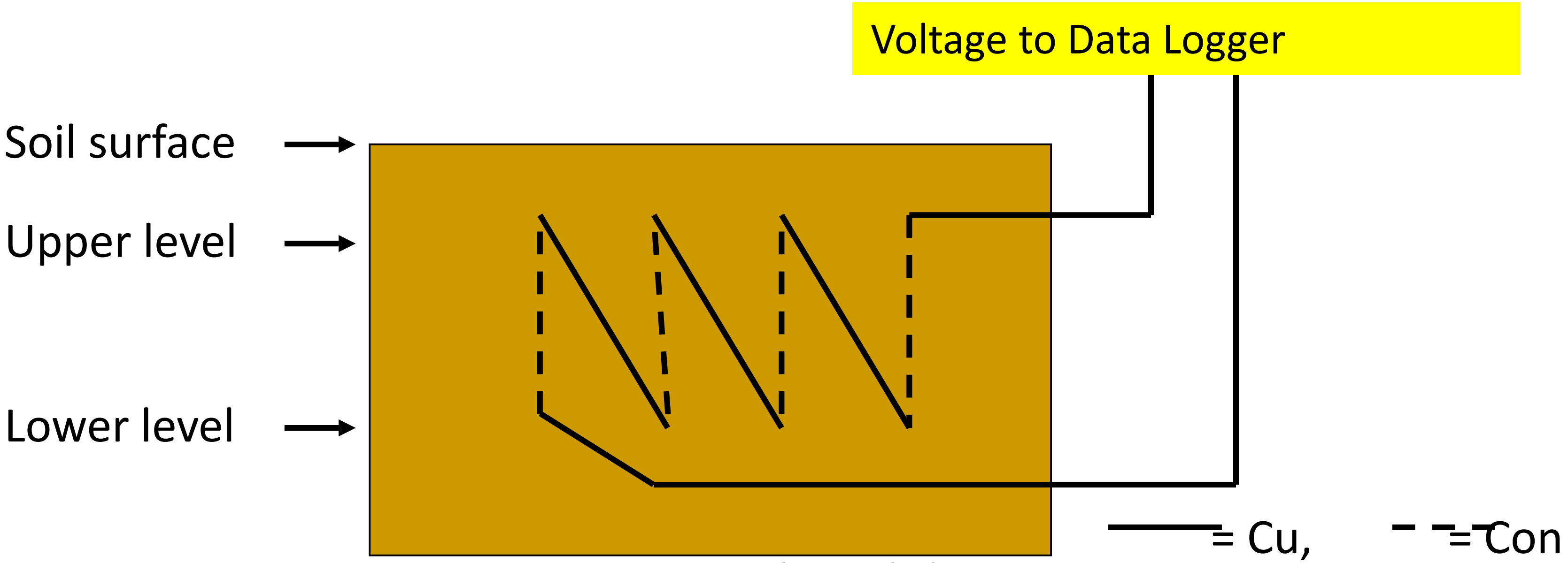


Can construct "thermopile" of several thermocouples connected in series.

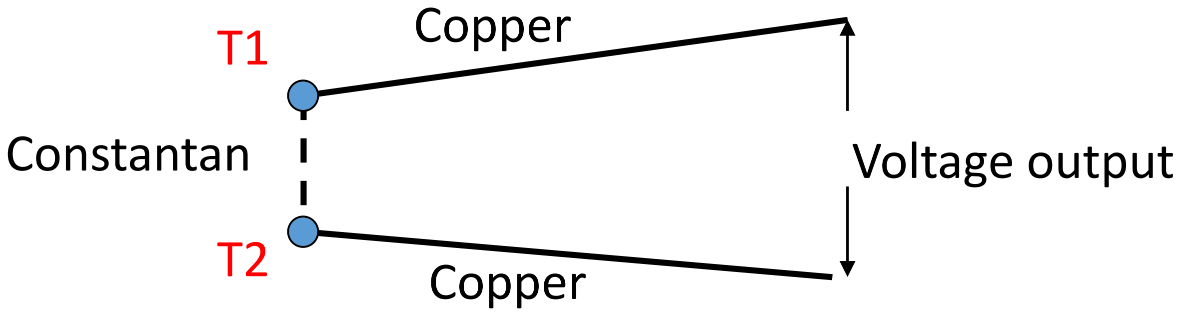
- Increases signal strength. Calibration factor increases according to the number of junction pairs in the "pile".

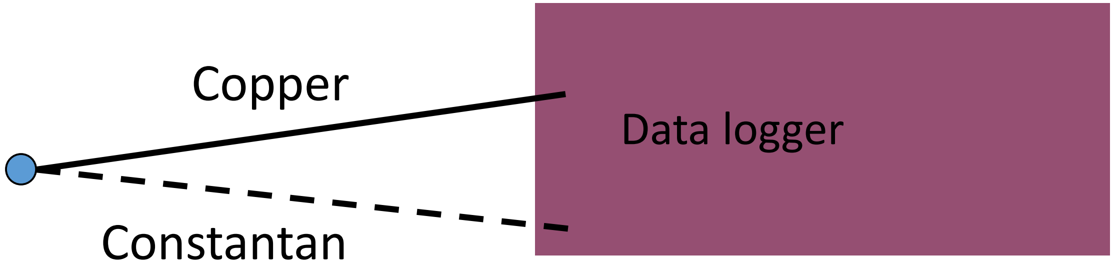
- Allows for spatial averaging, if desired.

- For example, measuring soil temperature gradients…



Thermo***couple*** measures temperature ***difference*** (T1 – T2) between two junctions





What types of thermocouples can we have ?

		temp. range (°C)
• Type K	: Chromel - Alumel	-270 / 1370
• Type J	: Iron-Constantan	-210 / 1050
• Type E	: Chromel -Constantan	-270 / 790
• Type N	: Nicros -Nisil	-260 / 1300
• Type T	: Copper-Constantan	-270 / 400

It is important to note that thermocouples measure the temperature difference between two points, not absolute temperature

More features:

- Type K — 'General Purpose' and low cost thermocouple, very popular
- Type J — Limited range (-40 to +750°C), less popular than type K.
- Type E — High output (68 mV/°C) → well suited to low temperature (cryogenic) use
- Type N — High stability and resistance to high temperature oxidation, designed as an 'improved' type K, it's becoming more popular.
- Type T — They are used for moist or sub-zero temperature monitoring applications because of superior corrosion resistance

Alloys used:

- Constantan: 55% Copper and 45% Nickel
- Cromel: 90% Ni + 10% Cr
- Alumel: 95% Ni + 2% Mn + 2% Al + 1% Silicon
- Nicrosil: 14.4%Cr +1.4 Silicon + 0.1% Mn + Ni
- Nisil: same as Nicrosil but different %

Magnitude of thermal EMF

The temperature is usually expressed as a polynomial function of the measured voltage. Sometimes it is possible to get a decent linear approximation over a limited temperature range.

$$E = c(T_1 - T_2) + k(T_1^2 - T_2^2)$$

where

c and k = constants of the thermocouple materials

T1 = the temperature of the 'hot' junction

T2 = the temperature of the 'cold' or 'reference' junction

Which one is the best?

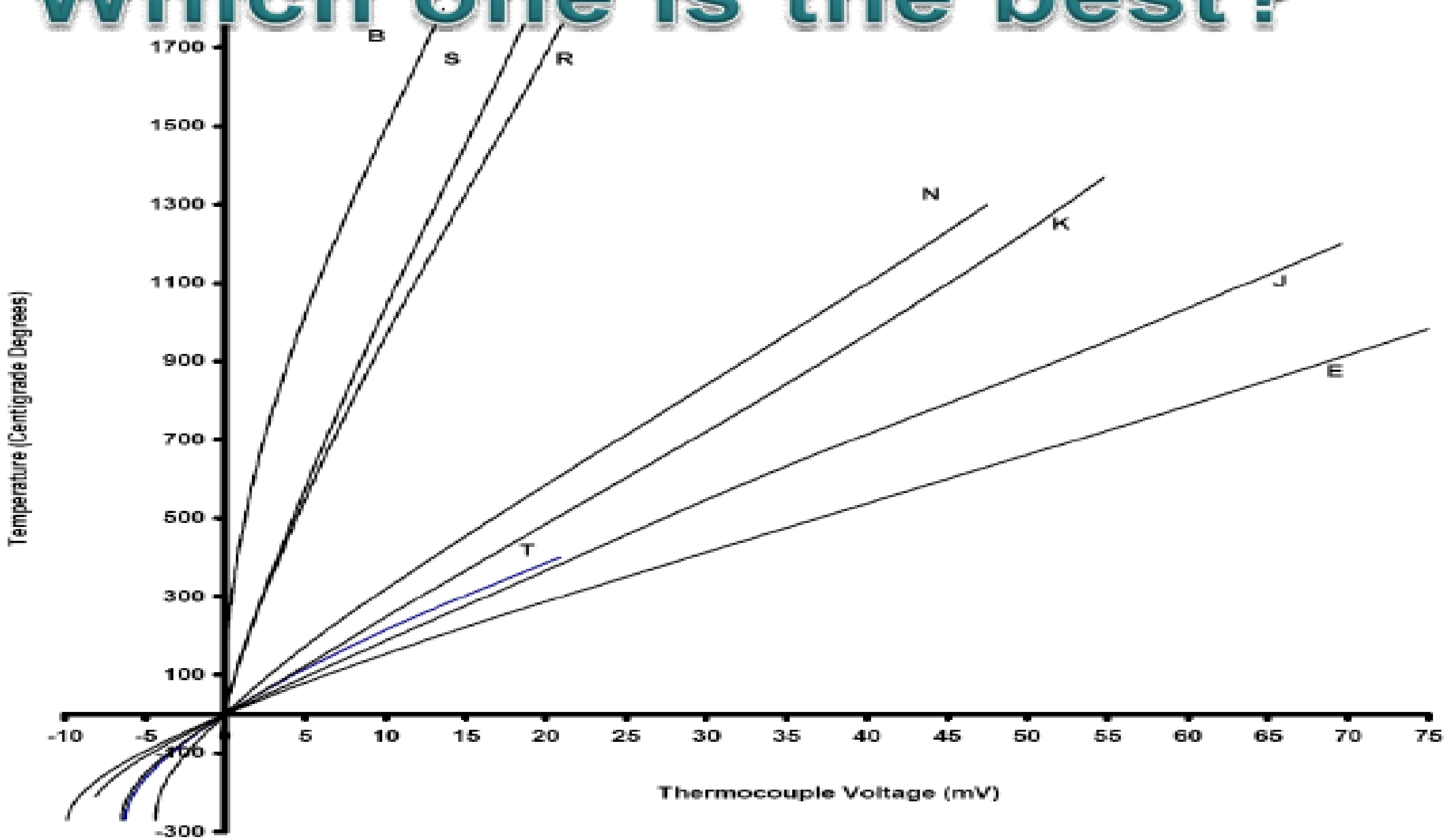
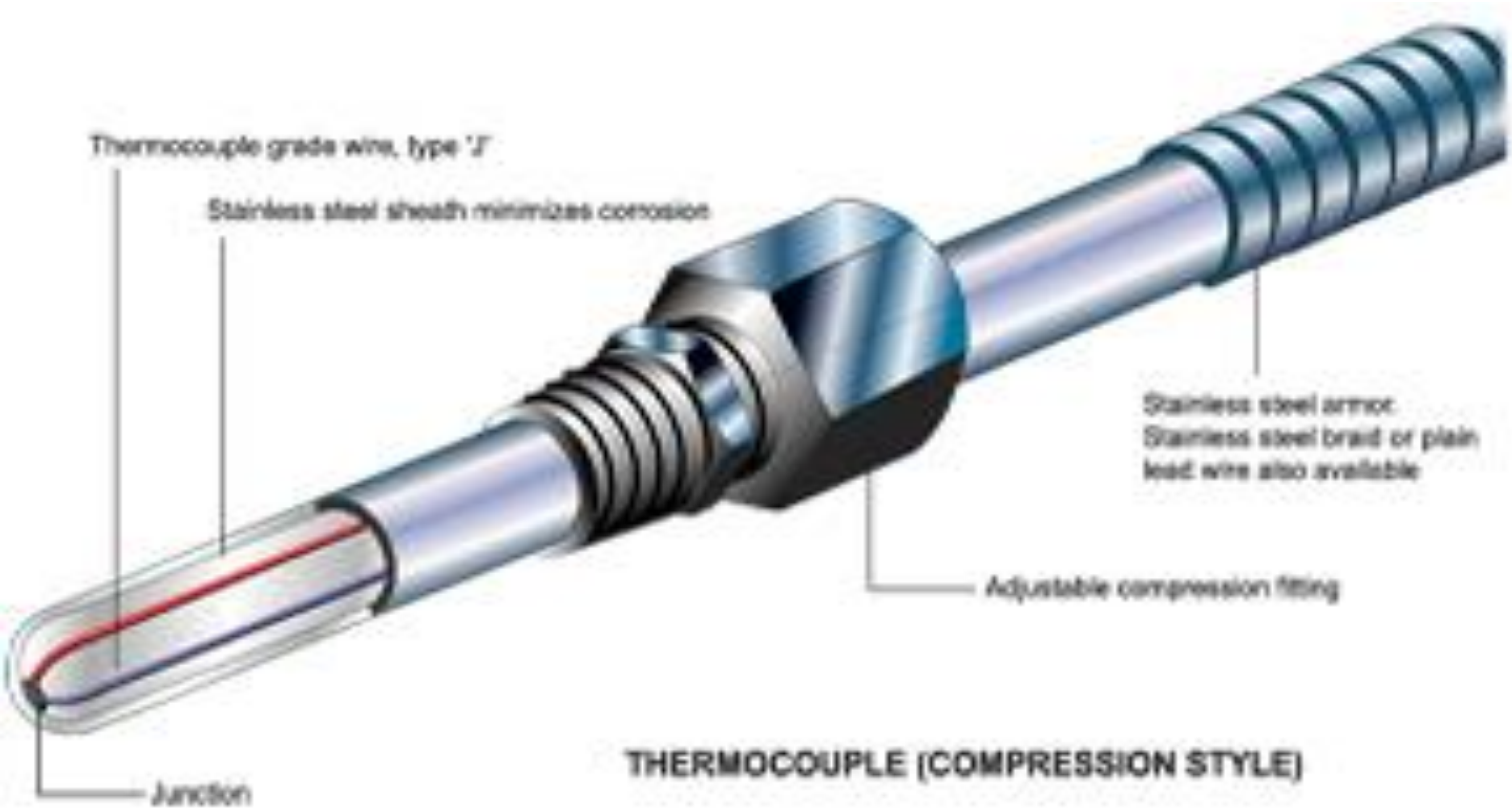


Figure 3
Voltage–Temperature Characteristics of B, E, J, K, N, R, S, and T Type Thermocouples

Thermocouple - applications

- Thermocouples are most suitable for measuring over a large temperature range, up to 1800 K.
- They are less suitable for applications where smaller temperature differences need to be measured with high accuracy, for example the range 0–100 °C with 0.1 °C accuracy. For such applications, Thermistors and RTD's are more suitable.

Thermocouple Type	Temperature Range (°C)				
	Short Term Use	Continuous Use	Class 1 Tolerance	Class 2 Tolerance	Class 3 Tolerance
Type E	- 40 to +900	0 to +800	-40 to +800	-40 to +900	-200 to +40
Type J	- 180 to +800	0 to +750	-40 to +750	-40 to +750	N/A
Type K	- 180 to +1300	0 to +1100	-40 to +1000	-40 to +1200	-200 to +40
Type N	- 270 to +1300	0 to +1100	-40 to +1000	-40 to +1200	-200 to +40
Type R	-50 to +1700	0 to +1600	0 to +1600	0 to +1600	N/A
Type S	- 50 to +1750	0 to +1600	0 to +1600	0 to +1600	N/A
Type T	- 250 to +400	- 185 to +300	-40 to +350	-40 to +350	-200 to +40
Type B	0 to +1820	+200 to +1700	N/A	+600 to +1700	+600 to +1700



THERMOCOUPLE (COMPRESSION STYLE)


2M
ZRG SGS

Resistance Temperature Detectors (RTD)

Resistance temperature detectors (RTDs)

RTDs are temperature sensors that exploit the predictable change in electrical resistance of some materials with changing temperature.

Temperature ↑ Metal Resistance ↑

The resistance ideally changes **linearly** with temp.

Principle of operation

RTDs are manufactured from metals whose resistance increases with temperature.

Within a limited temperature range, this resistivity increases linearly with temperature:

$$R_t = R_0\left[1 + \alpha\left(t - t_0\right)\right]$$

where:

R_t = resistance at temperature t

R_o= resistance at a standard temperature t_o

α = temperature coefficient of resistance (°C^{-1})

PRTs (platinum RTDs)

- They are the most popular RTD type
- Nearly linear over a wide range of temperatures
- Small enough to have response times of a fraction of a second
- They are among the most precise temperature sensors available with resolution and measurement uncertainties of ±0.1 °C or better

Why Platinum

- Chemical stability
- Availability in a pure form
- Highly reproducible electrical properties
- Platinum probes will read 100Ω at 0°C and at 100°C the DIN grade *(i.e. pure platinum intentionally contaminated with other platinum group metals)* platinum RTD will read 138.5Ω
- Only platinum RTDs have an international standard *(α = 0.00385 Ω/Ω/°C)*

How does an RTD look like ?

- Usually they are provided encapsulated in probes
- They have an external indicator, controller or transmitter, or enclosed inside other devices where they measure temperature as a part of the device's function (i.e. temperature controller, precision thermostat…)

...more

- price $ 65.00
- Temperature Range: -200 to 260°C
- High-Accuracy
- Platinum Elements
- 3-Wire Construction Standard, 2 and 4-Wire Constructions Available

- Wall mount transducer
- Temperature, Temperature/Humidity and Barometric Pressure Transmitter Models
- Low-Cost Miniature Design
  Stylish Design Blends in well with Your Office, Computer Room or Laboratory Décor
- $46.00 Wall mount RTD sensor

Pros and *Cons* in temperature measuring using RTDs

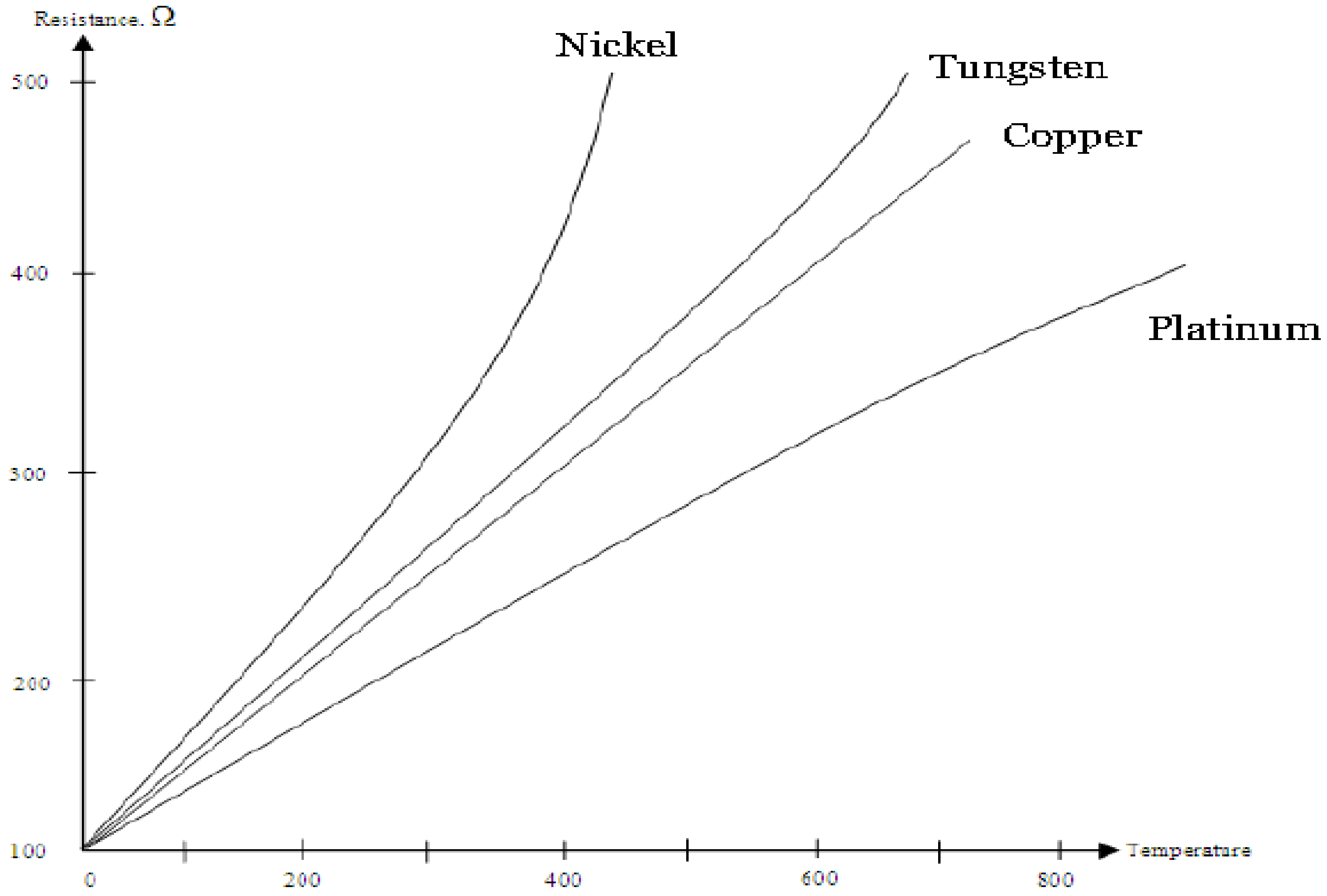
Pros

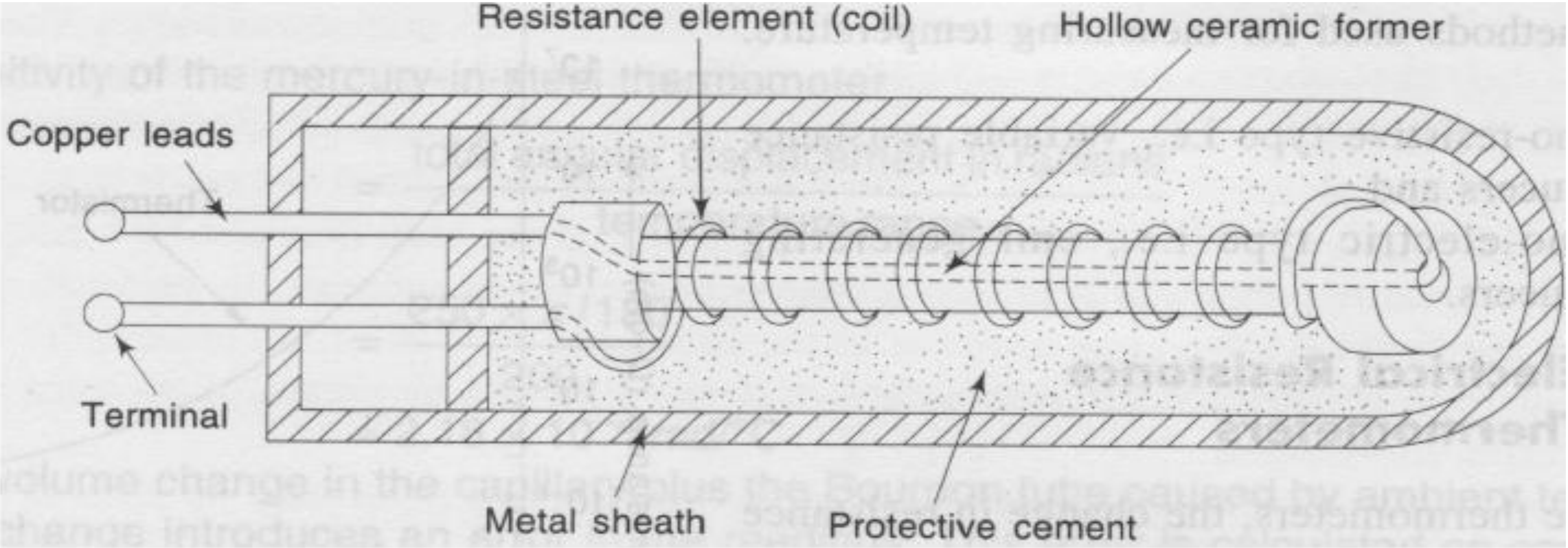
- stable output for long period of time
- ease of recalibration
- accurate readings over relatively narrow temperature ranges

...more

Cons (compared to thermocouples)

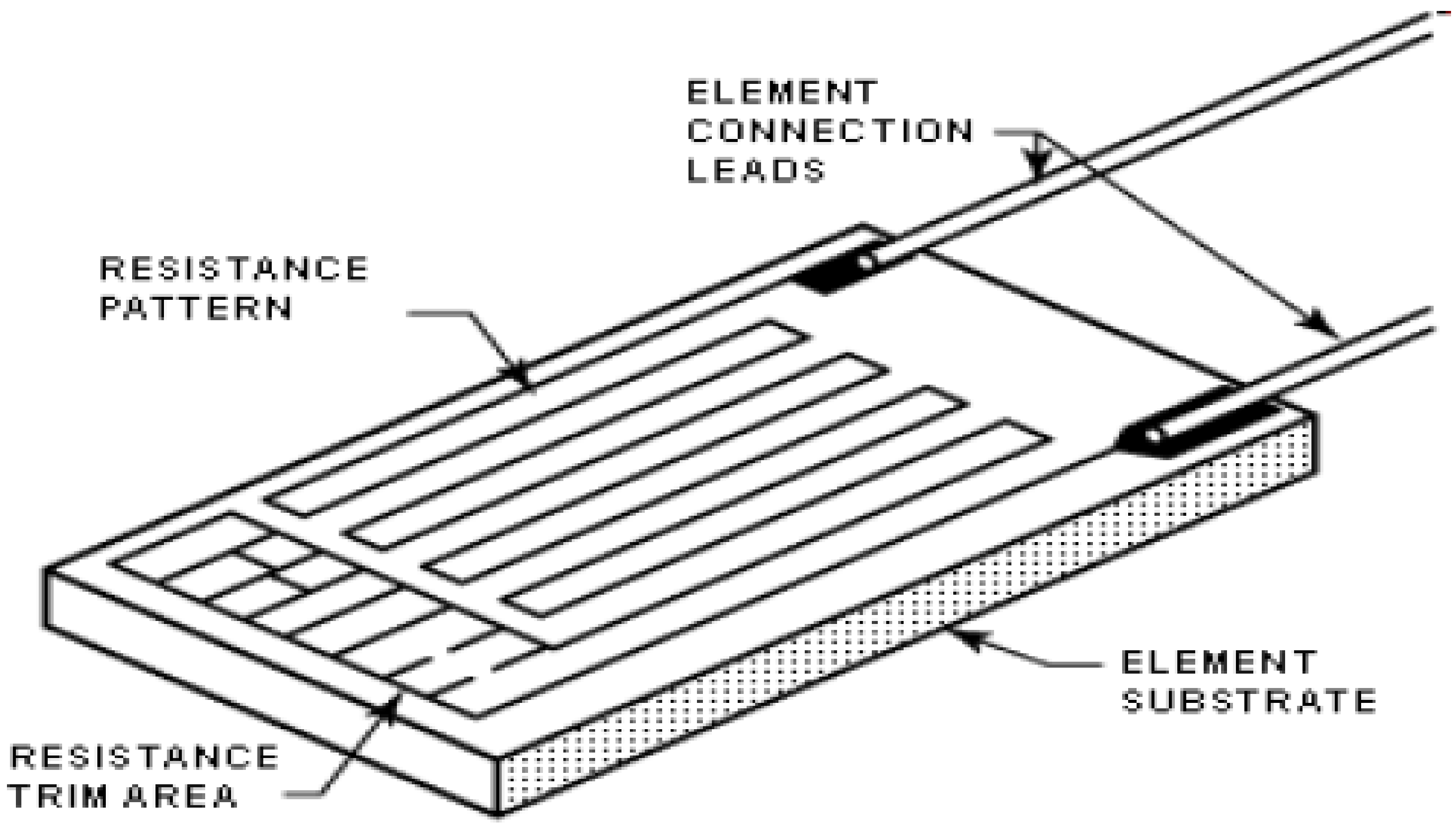
- Smaller overall temperature range
- Higher initial cost
- Less rugged in high vibration environments
- Active devices requiring an electrical current to produce a voltage drop across the sensor that can be then measured by a calibrated read-out device


Resistance. Ω
500
400
300
200
100
0
200
400
600
800
Temperature
Nickel
Tungsten
Copper
Platinum



- The coiled element sensor, made by inserting the helical sensing wires into a packed powder-filled insulating mandrel, provides a strain-free sensing element.
- All work is done manually under a microscope.
- Strain-free elements required for industrial measurements below −200°C.
- They also insure superior interchangeability and stability to the highest temp.

...more



- The thin film sensing element is made by depositing a thin layer of platinum in a resistance pattern on a ceramic substrate.
- A glassy layer is applied for seal and protection.

Temperature Coefficients of Resistance of Some RTD Metals

Metal	Temperature Coefficient of Resistance α (/°K)
Copper	0.0043
Nickel	0.0068
Platinum	0.0039

ts (RdF Corp.
ermission).

Thermistor

Milestones of Thermistors
THERMal resISTORS

- 1833: negative temperature coefficient of silver sulphide was first observed by *M. Faraday*
- Before 2003 only ceramic materials (a mix of different metal oxides) were used for production of Thermistors
- After 2003 *AdSem* started manufacturing of Si and Ge high temperature NTC Thermistors with better performance than any ceramic NTC Thermistors

Types

- NTC - Negative Temperature Coefficient, used mostly in temperature sensing

  Temperature ⬆ semiconductor resistance ⬇
- PTC - Positive Temperature Coefficient, used mostly in electric current control
- Symbol

Key features

- the change in electrical resistance when subjected to a corresponding change in body temperature is
  - Predictable
  - Precise
  - Stable
- extremely high temperature coefficient of resistance
- typical temperature range of -100° to over +600° F
- Thermistors are generally accepted to be the most advantageous sensor for many applications including temperature measurement and control.

- ***Material Used for Construction –***

Unlike other resistors (fixed or variable), these are made of ceramics and polymers, which composed of metal oxides that are dried and sintered to obtain a desired form factor.

In case of NTC thermistor, cobalt, nickel, iron and copper oxides are preferred.

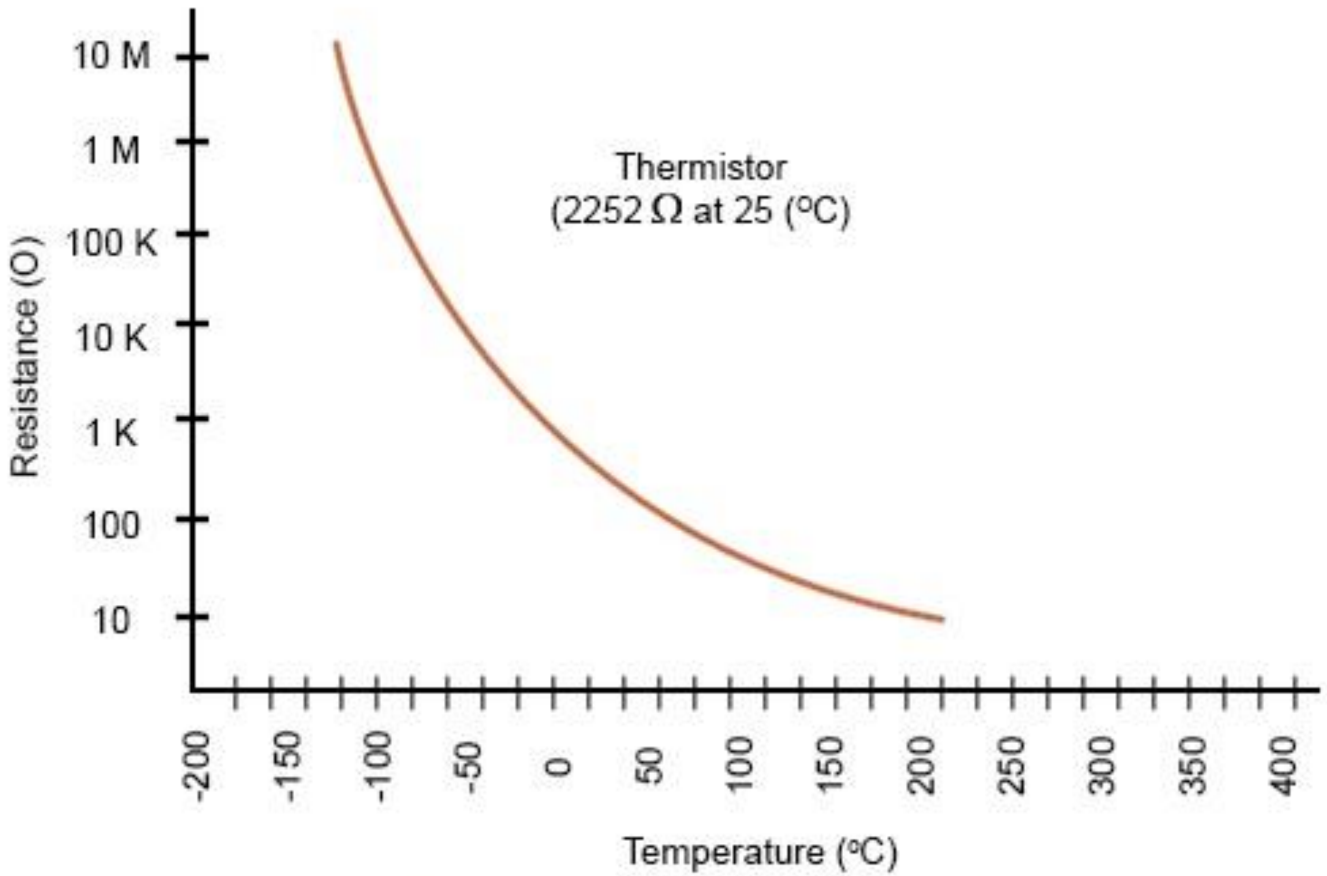
$$R = R_o\, e^{\beta\left(\frac{1}{T} - \frac{1}{T_o}\right)} \qquad \text{..... (1)}$$

Where,

R = Resistance of Thermistor at the temperature T (in K)

R_0 = Resistance at given temperature T0 (in K)

β = Material specific-constant



Thermistor Characteristic NTC Curve

www.CircuitsToday.com

THERMISTOR APPLICATIONS

CONSUMER ELECTRONICS

- Air conditioners
- Audio amplifiers
- Cellular telephones
- Clothes dryers
- Computer power supplies
- Dishwashers
- Electric blanket controls
- Electric water heaters
- Electronic thermometers
- Fire detectors
- Home weather stations
- Oven temperature control
- Pool and spa controls
- Rechargeable battery packs
- Refrigerator and freezer temp. control
- Small appliance controls
- Solar collector controls
- Thermostats
- Toasters
- Washing machines

And…

AUTOMOTIVE

- Audio amplifiers
- Automatic climate control
- Coolant sensors
- Electric coolant fan temp. control
- Emission controls
- Engine block temperature sensors
- Engine oil temperature sensors
- Intake air temperature sensors
- Oil level sensors
- Outside air temperature sensor
- Transmission oil temp. sensors
- Water level sensors

And…

MEDICAL ELECTRONICS

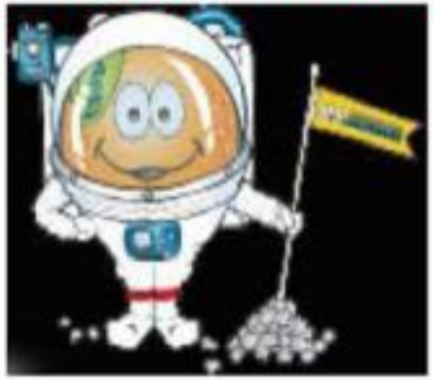
- Blood analysis equipment
- Blood dialysis equipment
- Blood oxygenator equipment
- Clinical fever thermometers
- Esophageal tubes
- Infant incubators
- Internal body temperature monitors
- Internal temperature sensors
- Intravenous injection temp. regulators
- Myocardial probes
- Respiration rate measurement equipment
- Skin temperature monitors
- Thermodilution catheter probes

INDUSTRIAL ELECTRONICS

- Commercial vending machines
- Crystal ovens
- Fluid flow measurement
- Gas flow indicators
- HVAC equipment
- Industrial process controls
- Liquid level indicators
- Microwave power measurement
- Photographic processing equipment
- Plastic laminating equipment
- Solar energy equipment
- Thermal conductivity measurement (diamond testers etc.)
- Thermocouple compensation
- Thermoplastic molding equipment
- Thermostats
- Water purification equipment

And…

MILITARY and AEROSPACE



- Aircraft temperature
- Bathythermography
- Fire control equipment
- Missiles and spacecraft temperature
- Physiological monitoring
- Satellites

FOOD HANDLING and PROCESSING

- Coffee makers
- Deep fryers
- Fast food processing
- Perishable shipping
- Temperature controlled food storage systems
- Thermometers for use in food preparation

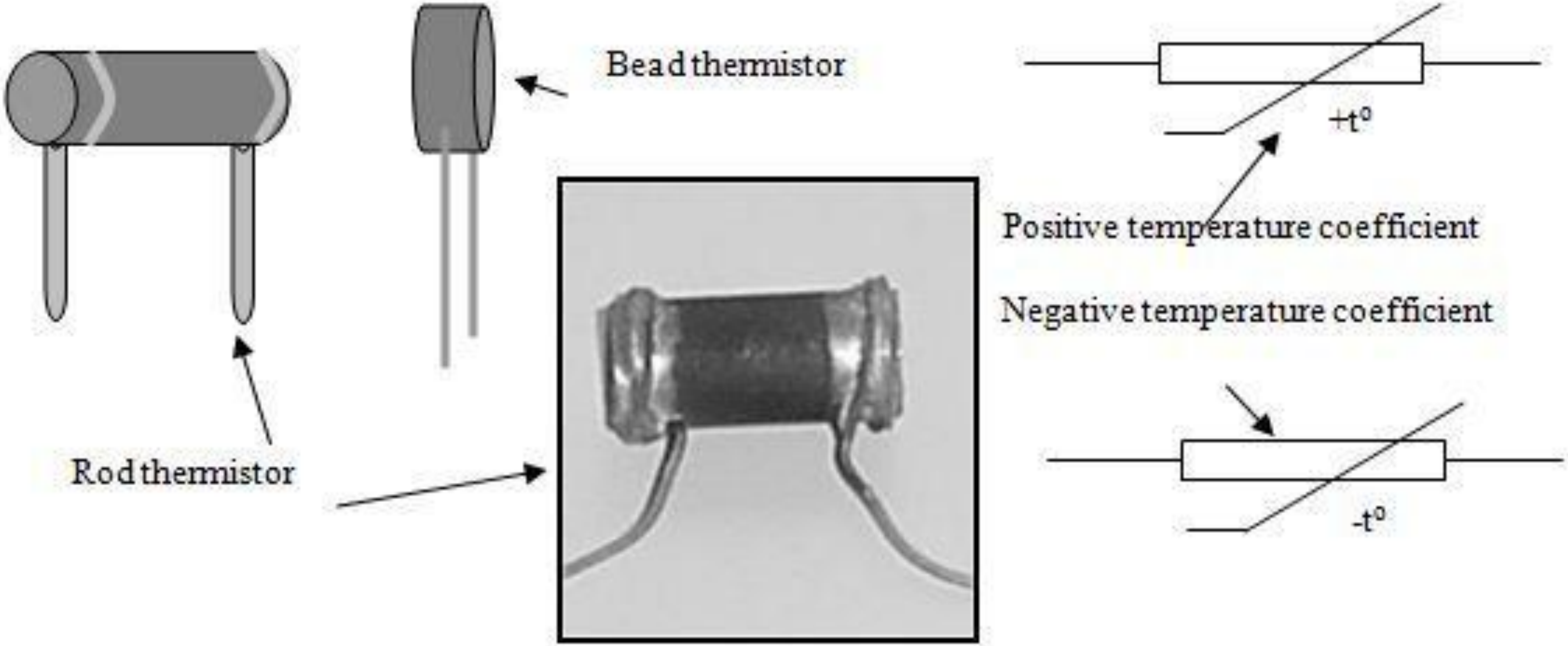
And

COMMUNICATION and INSTRUMENTATION

- Amplifier over temperature sensing
- Cellular telephones
- Copper coil winding temperature compensation
- Oscillator temperature compensation
- Rechargeable battery packs
- Transistor gain stabilization
- Transistor temperature compensation

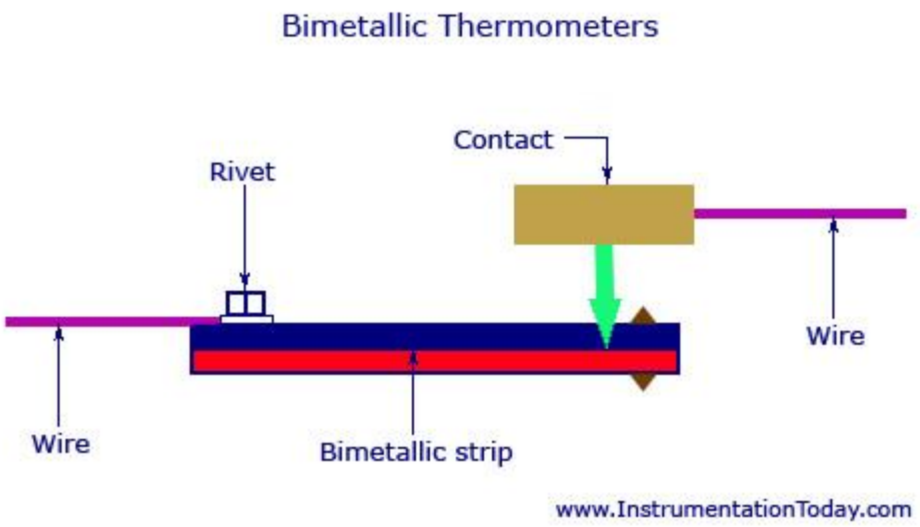
COMPUTER

- Power supplies (inrush current limiting)
- Uninterruptible power supplies (over temperature sensing)


Bead thermistor
+t°
Positive temperature coefficient
Negative temperature coefficient
Rod thermistor
-t°

Bi-Metal Strip Thermometer

Unequal thermal expansion of different materials is used in this device. If strips of the two materials (typically metals) are firmly bonded, thermal expansion causes this element to bend toward the material with lower expansion. This motion can be measured using a displacement sensor, or indicated using a needle and scale. Households thermostats commonly use this principle for temperature sensing and control (on-off).



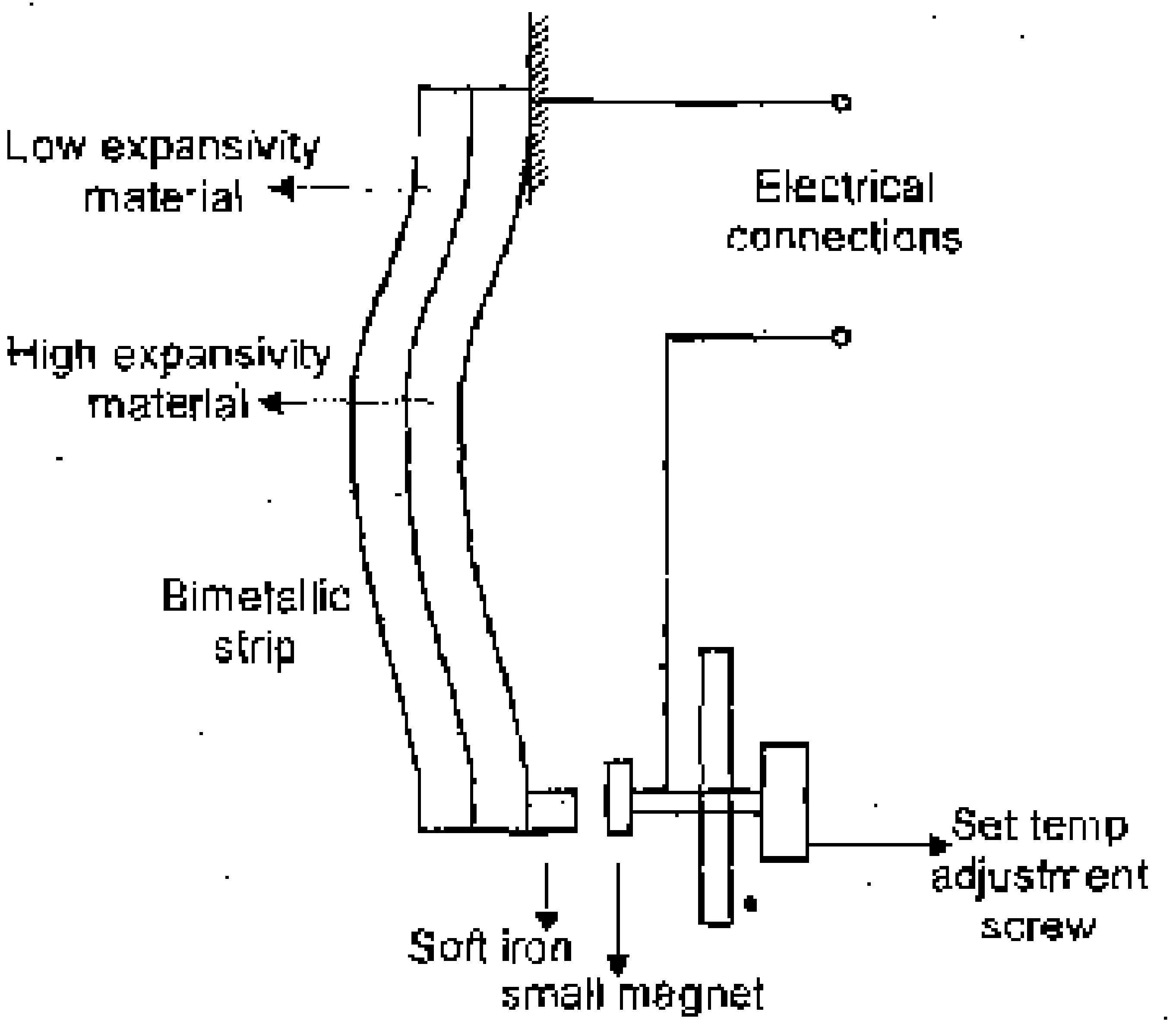
Bimetallic Strips:

□ A Bimetallic thermostat consists of two different metal strips bounded together and they cannot move relative to each other.

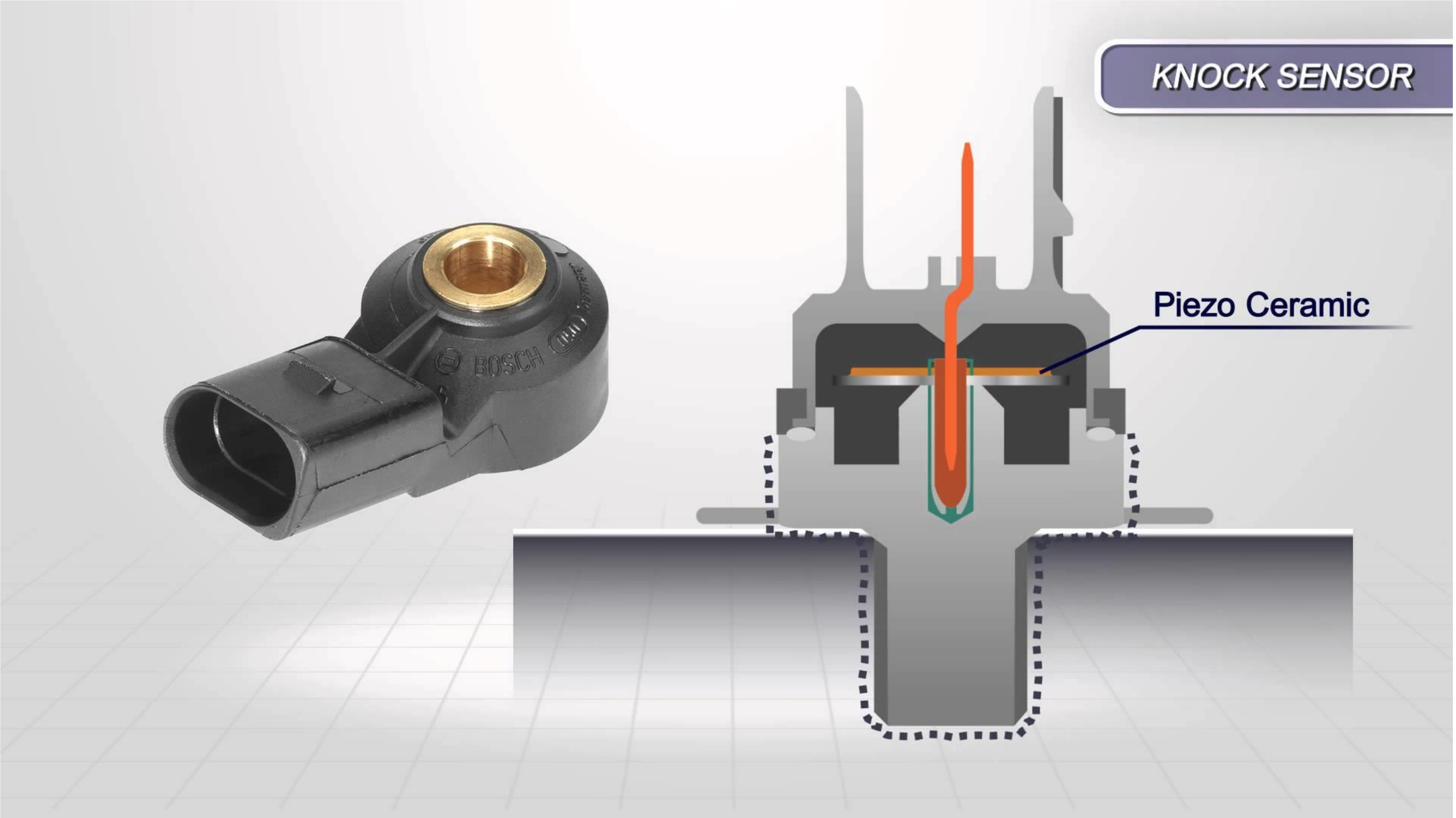
□ These metals have different coefficients of expansion and when the temperature changes the composite strips bends into a curved strip, with the higher coefficient metal on the outside of the curve.

□ The basic principle in this is all metals try to change their physical dimensions at different rates when subjected to same change in temperature.

□ This deformation may be used as a temperature- controlled switch, as in the simple thermostat.



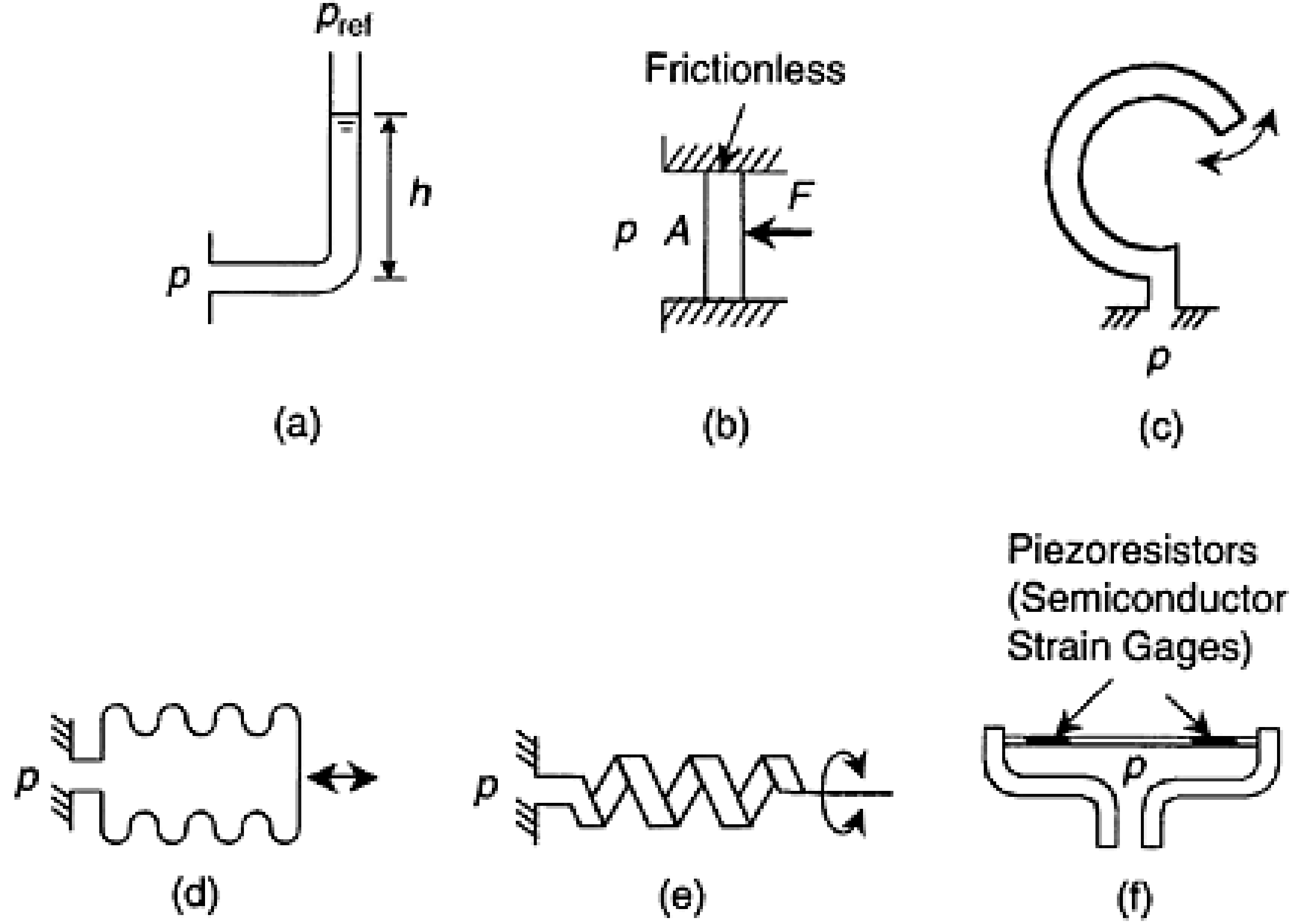
Low expansivity material
High expansivity material
Bimetallic strip
Electrical connections
Set temp adjustment screw
Soft iron
small magnet


KNOCK SENSOR
Piezo Ceramic
BOSCH

Pressure Sensors

Common methods of pressure sensing are the following:

1. Balance the pressure with an opposing force (or head) and measure this force. Examples are liquid manometers and pistons.
2. Subject the pressure to a flexible front-end (auxiliary) member and measure the resulting deflection. Examples are Bourdon tube, bellows, and helical tube.
3. Subject the pressure to a front-end auxiliary member and measure the resulting strain (or stress). Examples are diaphragms and capsules.



Typical pressure sensors: (a) Manometer; (b) Counterbalance piston; (c) Bourdon tube; (d) Bellows; (e) Helical tube; (f) Diaphragm.

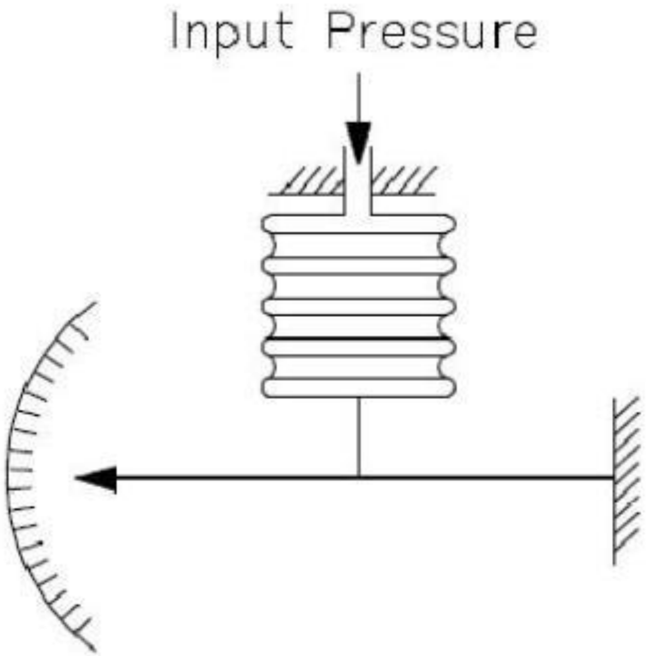
In the manometer shown in Figure (a), the liquid column of height h and density r provides a counter balancing pressure head to support the measured pressure p with respect to the reference (ambient) pressure $p$ref. Accordingly, this device measures the gauge pressure given by

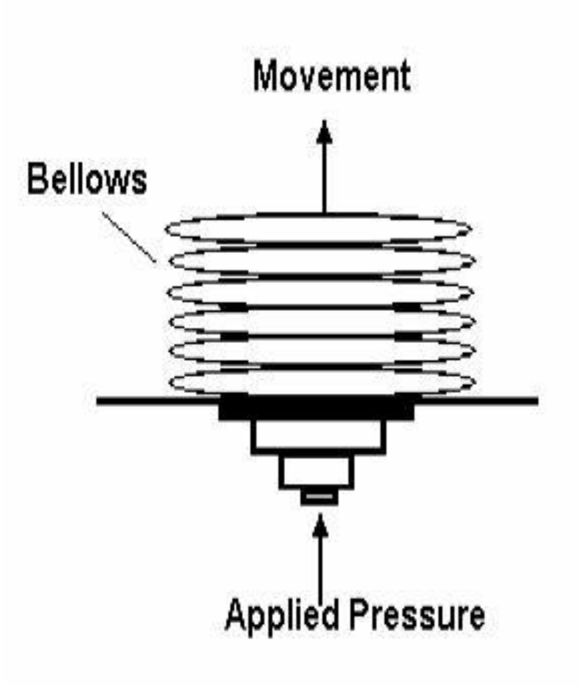
p-$p$ref=rgh

where g is the acceleration due to gravity. In the pressure sensor shown in Figure (b), a frictionless piston of area A supports the pressure load with an external force F. The governing equation is

$$p = \frac{F}{A}$$

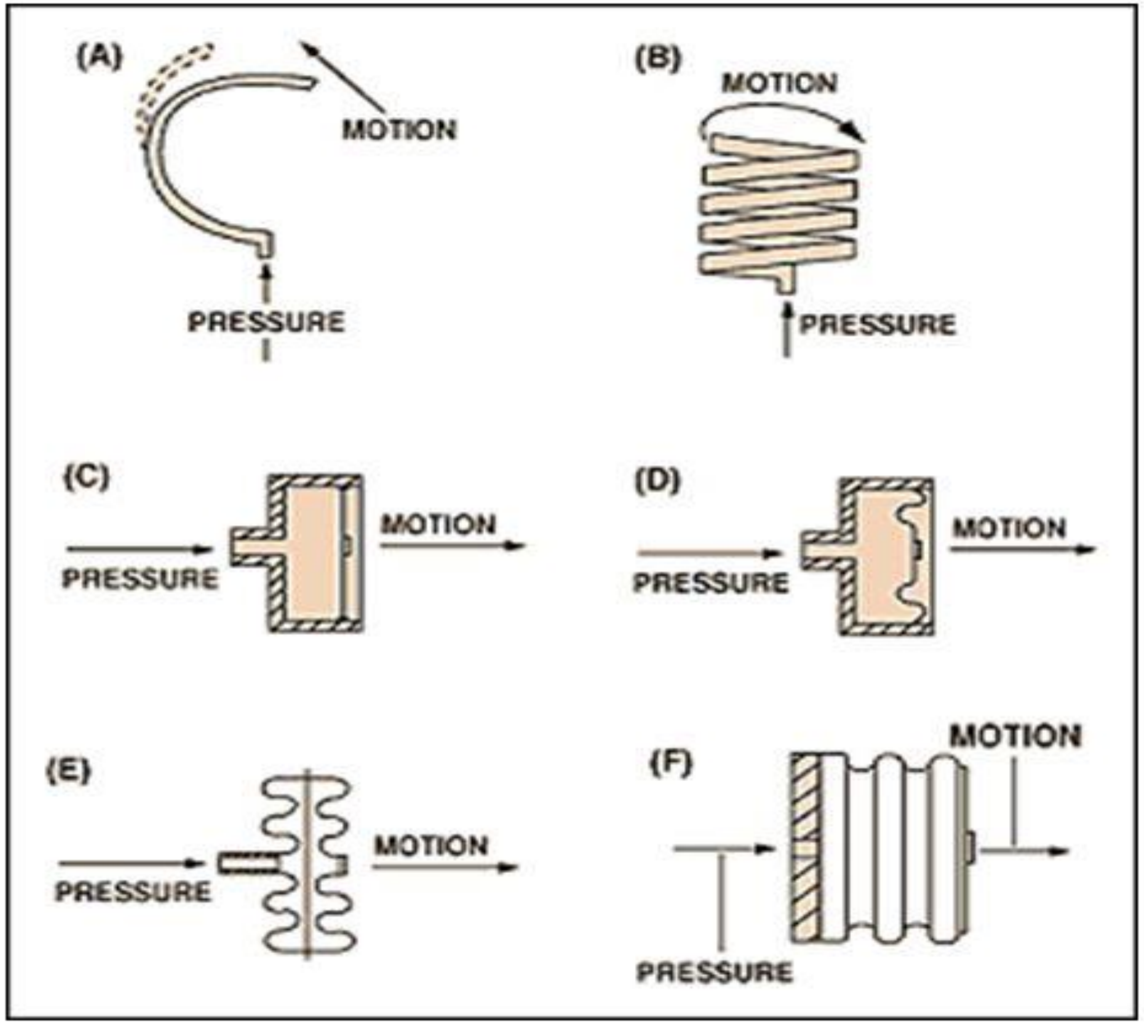
The pressure is determined by measuring F using a force sensor. The Bourdon tube shown in Figure (c) deflects with a straightening motion as a result of internal pressure. This deflection can be measured using a displacement sensor (typically, arotatory sensor) or indicated by a moving pointer. The bellows deflect with internal pressure, causing a linear motion, as shown in Figure (d). The deflection can be measured using a sensor such as LVDT or a capacitive sensor, and can be calibrated to indicate pressure. The helical tube shown in Figure (e) undergoes a twisting (rotational) motion when deflected by internal pressure. This deflection can be measured by an angular displacement sensor (RVDT, resolver, potentiometer, etc.), to provide pressure reading through proper calibration. Figure (f) illustrates the use of a diaphragm to measure pressure. The membrane (typically metal) will be strained due to pressure. The pressure can be measured by means of strain gauges (piezoresistive sensors) mounted on the diaphragm.

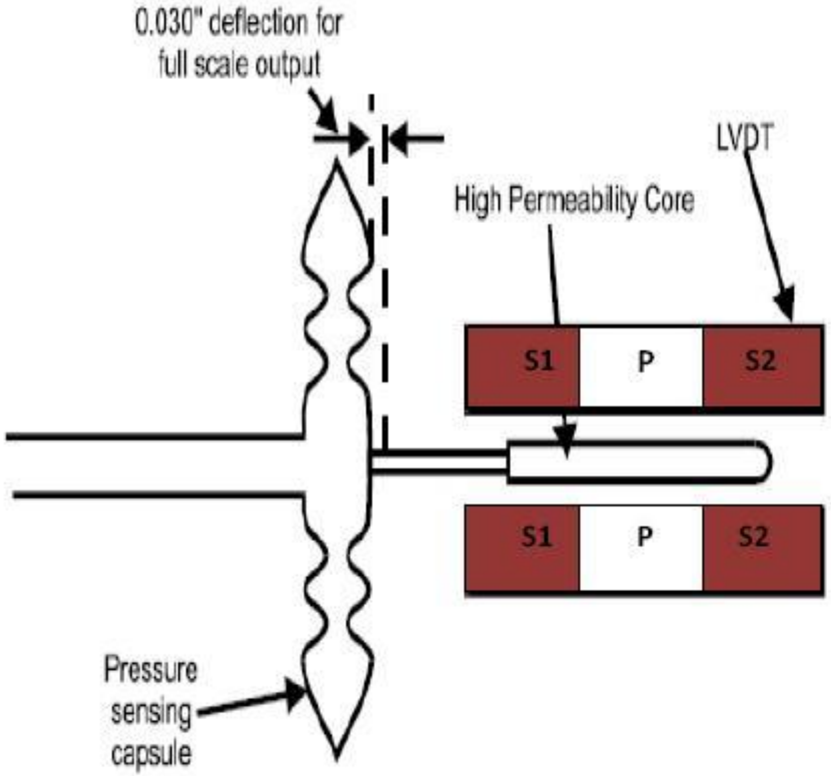

Input Pressure


Movement
Bellows
Applied Pressure

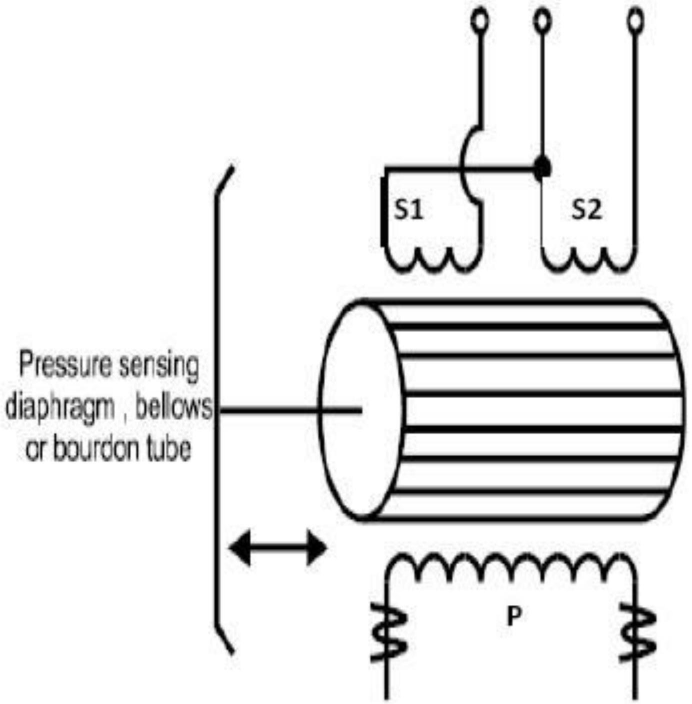
Sensing Elements

- The main types of sensing elements are Bourdon tubes, diaphragms, capsules, and bellows
- All except diaphragms provide a fairly large displacement that is useful in mechanical gauges and for electrical sensors that require a significant movement

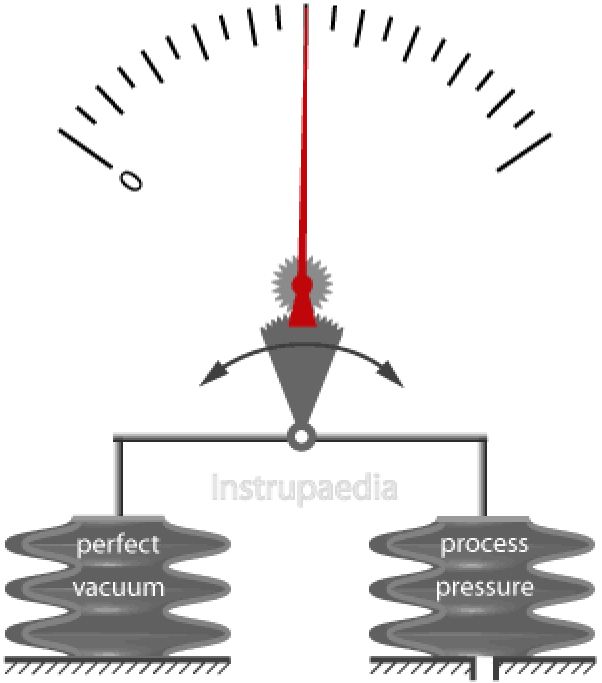




0.030" deflection for full scale output
LVDT
High Permeability Core
S1
P
S2
S1
P
S2
Pressure sensing capsule



S1
S2
Pressure sensing diaphragm , bellows or bourdon tube
P


0
Instrupaedia
perfect
vacuum
process
pressure

Tactile Sensors

Tactile sensors are used in many applications ranging from fruit picking to monitoring human prosthetic implants; however, the major area of application is in the biomedical field and robots. Tactile sensors are used for the following.

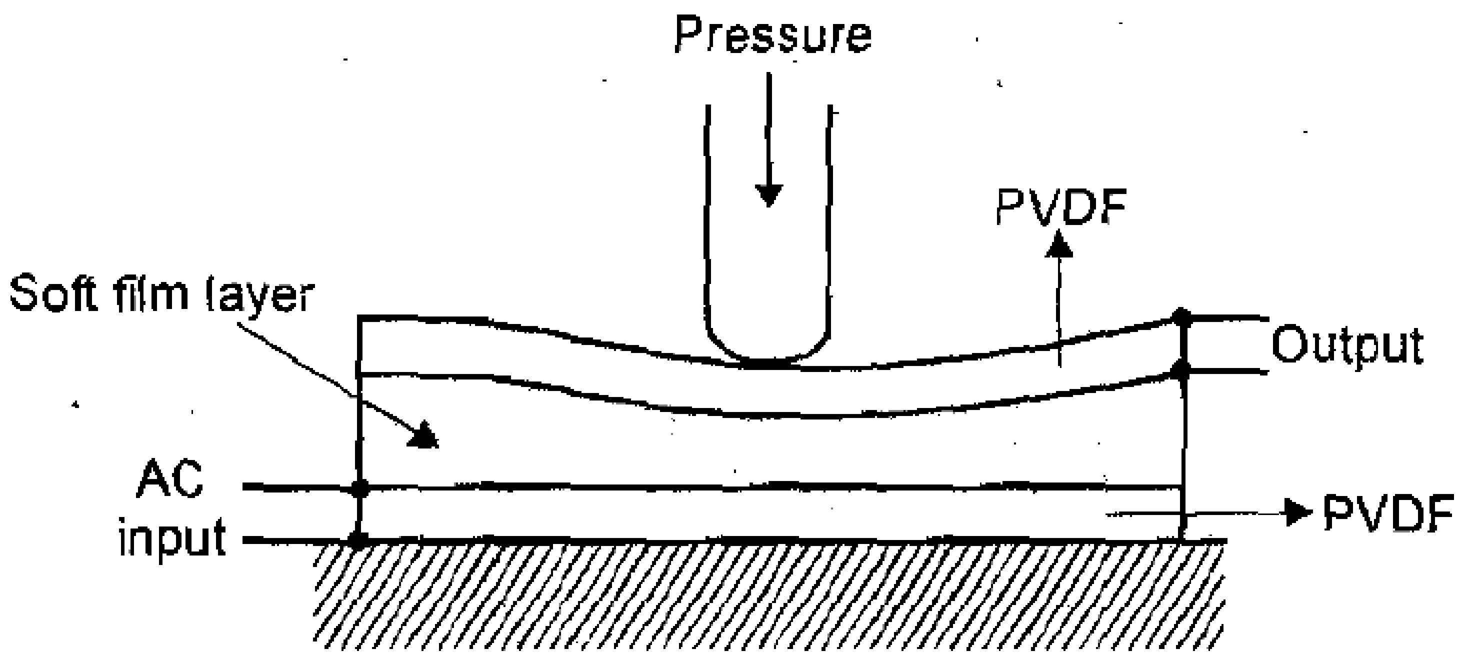
- Study the forces developed by the human foot during motion.
- Study the forces developed during various types of hand functions.
- Monitor the artificial knee and sense the forces developed.

Tactile Sensors

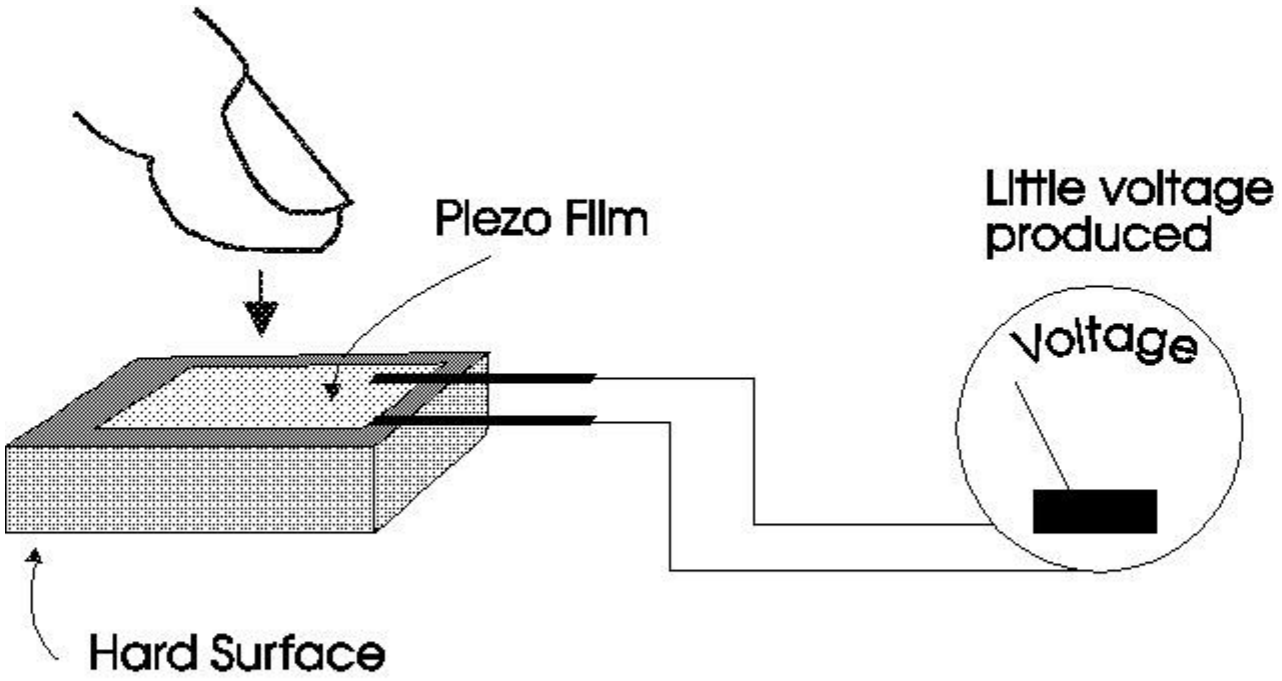
It is used on fingertips of robot hands and for touch display screen

- It uses piezoelectric polyvinylidene fluoride (PVDF) film
- Two layers are separated by sift film
- The lower PVDF film has an *alternating voltage applied* to it *results in mechanical oscillations*
- Intermediate film transmits the vibration to upper film

Tactile Sensors



Tactile Sensors



Tactile Sensors cont…

Other areas of application include the field of robotics, where tactile sensors can be placed on the gripper of the manipulator to provide feedback information from the workpiece. Besides being used as a touch sensor, gripping force sensors detect the force with which the object is gripped, pressure sensors detect the pressure applied to the object, and slip sensors can detect if the object is slipping.

Tactile Sensors cont…

A tactile sensing system has the ability to detect the following.

1. Presence of a part
2. Part shape, location, and orientation
3. Contact pressure distribution
4. Force magnitude and direction

The major components of tactile sensors include:

- Touch surface
- Transducer
- Structure and control interface

Tactile Sensors cont…

Some tactile sensors are designed using piezoelectric films. Piezoelectric (Piezo) film consists of poly-vinylidene fluoride (PVDF) that has undergone special processing to enhance its piezoelectric properties. Piezo film develops an electrical charge proportional to induced mechanical stress or strain. As a result, it produces a response proportional to the rate of stress rather than to the stress magnitude. This sensor is passive—that is, its output signal is generated by the piezoelectric film without the need for an excitation signal. The piezoelectric tactile sensor can be fabricated with the PVDF film strips imbedded into a rubber skin. To measure surface vibration, the film is bonded to the surface. As the surface vibrates, it stretches the surface in a cyclical manner, generating a voltage. Piezo-film voltage output is relatively high.

Piezoelectric Sensors

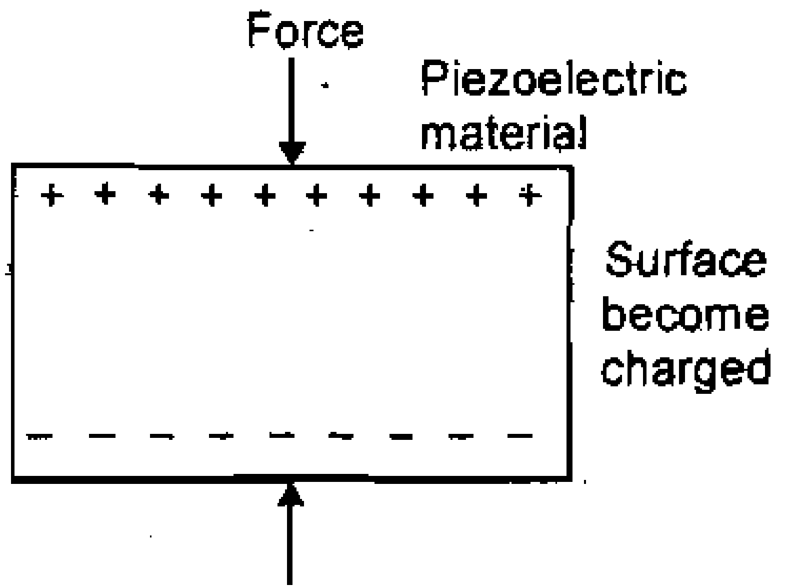
Some substances, such as barium titanate, single-crystal quartz, and lead zirconate-titanate (PZT) can generate an electrical charge and an associated potential difference when they are subjected to mechanical stress or strain. This piezoelectric effect is used in piezoelectric transducers. Direct application of the piezoelectric effect is found in pressure and strain measuring devices, touch screens of computer monitors, and a variety of micro-sensors.

Many indirect applications also exist. They include piezoelectric accelerometers and velocity sensors and piezoelectric torque sensors and force sensors.

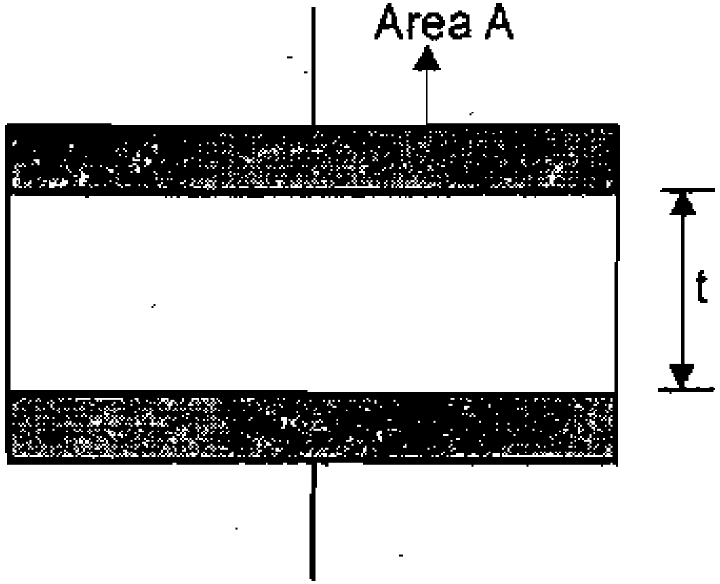
The piezoelectric effect arises as a result of charge polarization in an anisotropic material (having non-symmetric molecular structure), as a result of an applied strain. This is a reversible effect. In particular, when an electric field is applied to the material so as to change the ionic polarization, the material will regain its original shape.

$$\mathbf{q = kx = SF}$$

The net charge q on a surface is proportional to the amount x by which the charges have been displaced, and since the displacement is proportional to the applied force F. Where k is a constant and S a constant termed the charge sensitivity



Piezoelectricity



Piezoelectric capacitor

Sensitivities of Several Piezoelectric Material

Material	Charge Sensitivity S_q (pC/N)	Voltage Sensitivity S_v (mV · m/N)
Lead zirconate titanate (PZT)	110	10
Barium titanate	140	6
Quartz	2.5	50
Rochelle salt	275	90

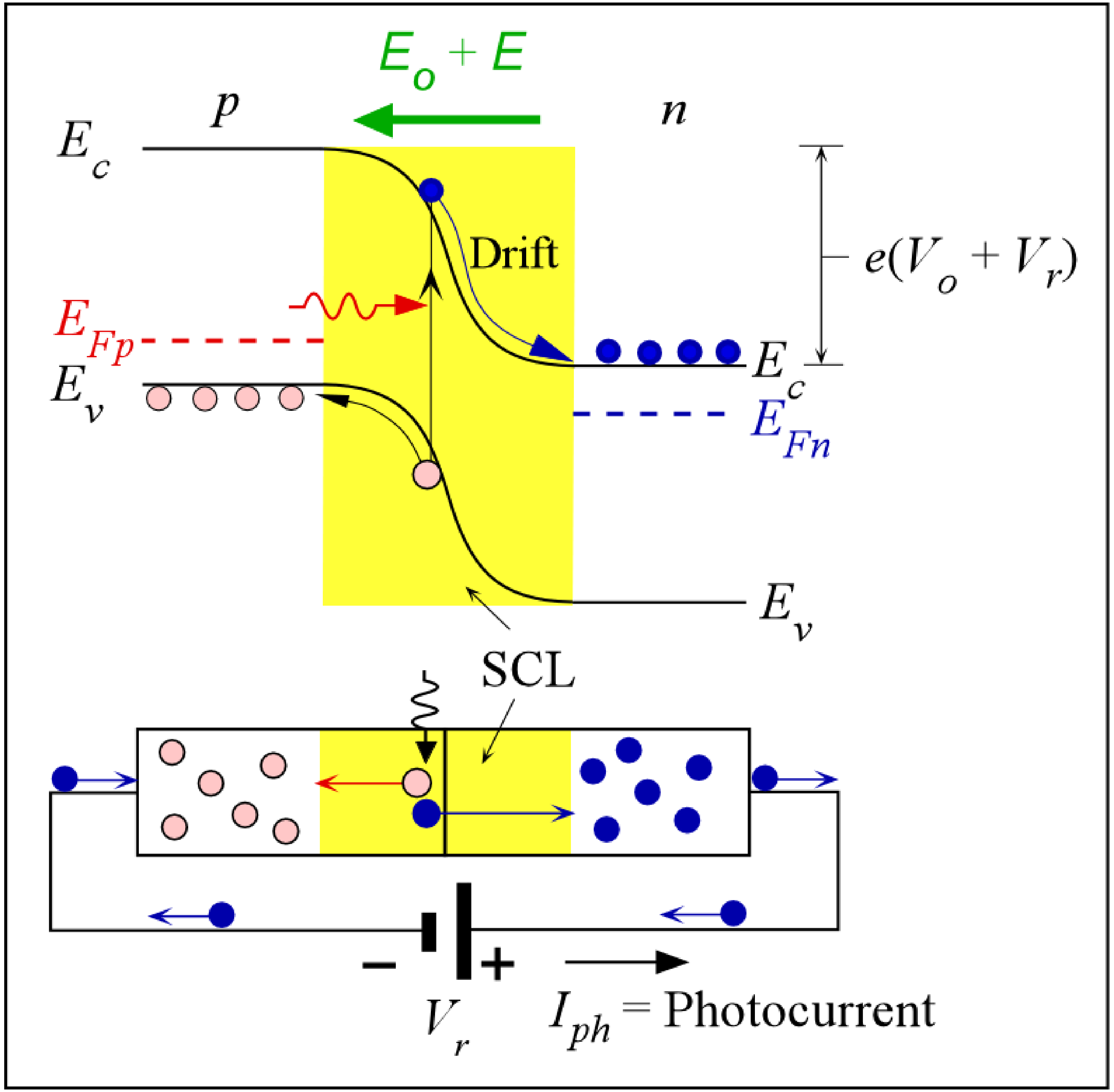
The piezoelectric material acts as a capacitor with the piezoelectric crystal acting as the dielectric medium. The charge is stored because of the inherent capacitance of the piezoelectric material itself. The piezoelectric effect is reversible. If a varying potential is applied to the proper axis of the crystal, it changes the dimension of the crystal, thereby deforming it.

Material	Density ($\times 10^3 kg/m^3$)	Permitivity ε_r	Young's Modulus E ($10^{10} N/m^2$)	Piezoelectric Charge Sensitivity d (pF/N)
Quartz(SiO_2)	2.65	4.5	7.7	2.3
Barium Titanate $BaTiO_3$	5.7	1700	11	78
PZT	7.5	1200	8.3	110
PVDF	1.78	12	0.3	20 to 30 (based on crystal axes)

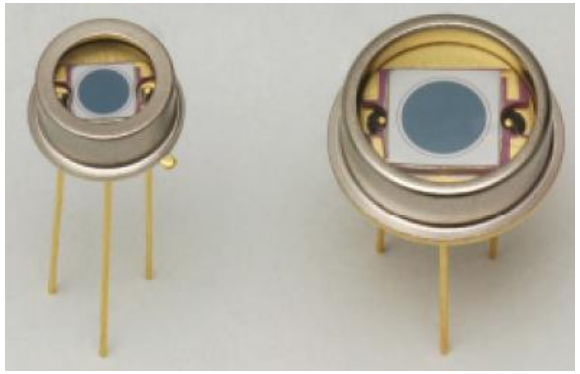
A piezoelectric element used for converting mechanical motion to electrical signals is thought of as both a charge generator and a capacitor. This charge appears as a voltage across the electrodes. The magnitude and polarity of the induced surface charges are proportional to the magnitude and direction of the applied force.

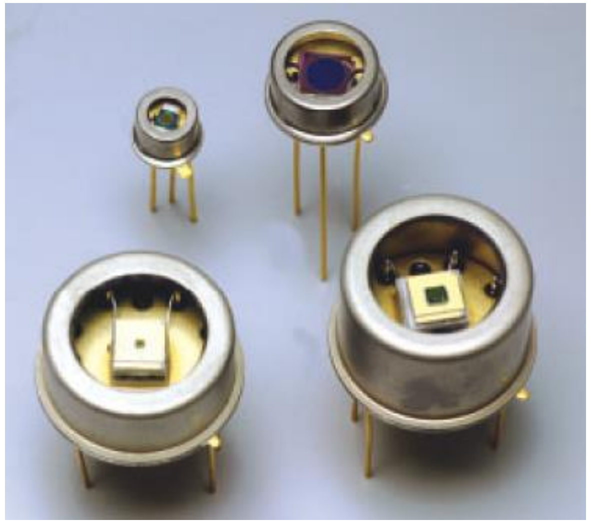
Photodetection with semiconductors: basic phenomena

Photodetection in semiconductors works on the general principle of the creation of electron-hole pairs under the action of light. When a semiconductor material is illuminated by photons of an energy greater than or equal to its bandgap, the absorbed photons promote electrons from the valence band into excited states in the conduction band, where they behave like free electrons able to travel long distances across the crystal structure under the influence of an intrinsic or externally-applied electric field. In this way the separation of electron-hole pairs generated by the absorption of light gives rise to a *photocurrent.*

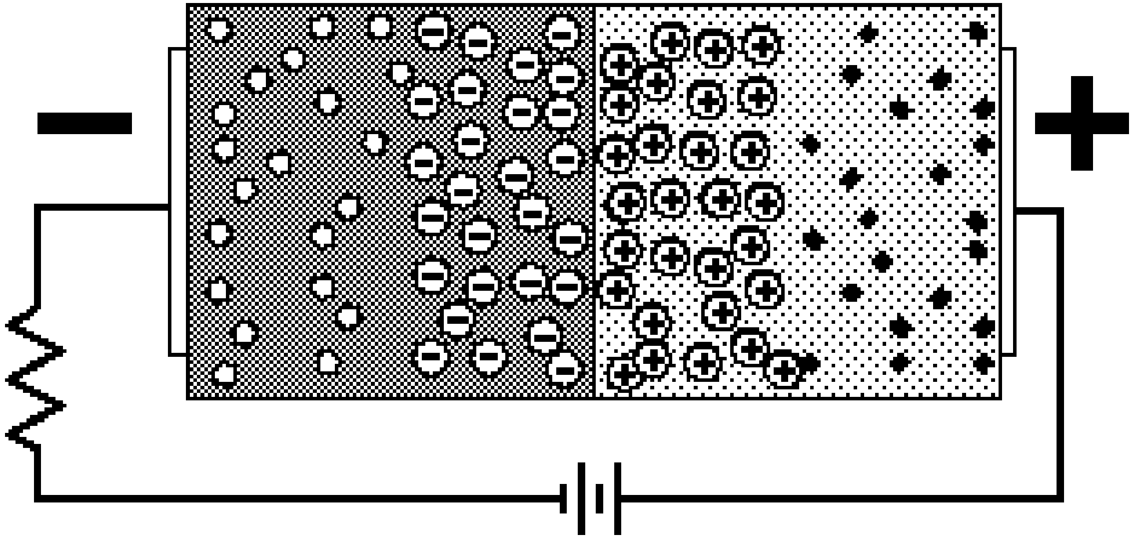


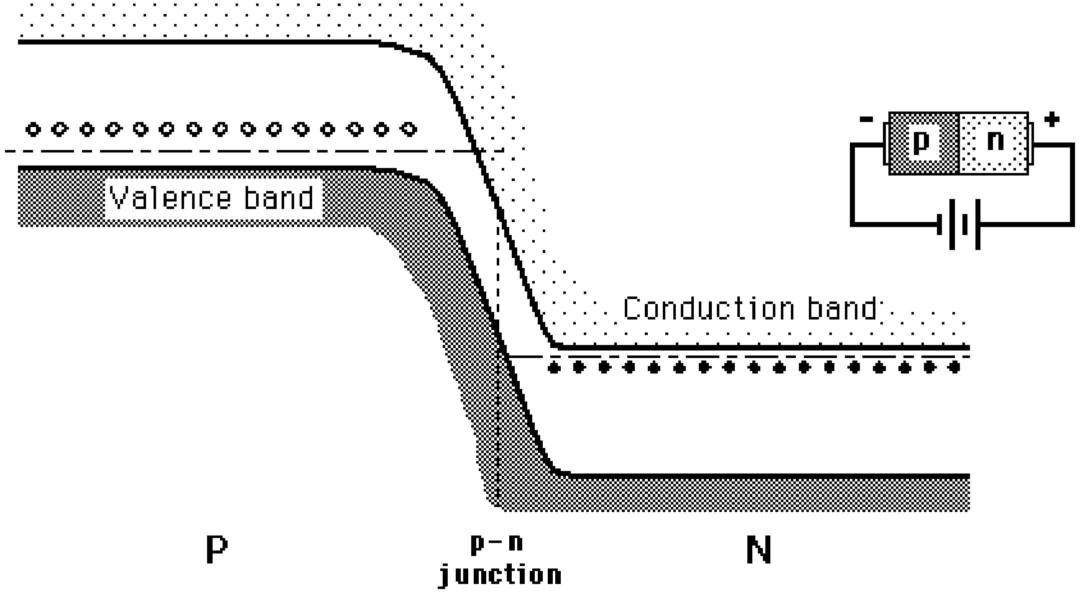
$E_o + E$
p
n
E_c
Drift
$e(V_o + V_r)$
E_{Fp}
E_v
E_c
E_{Fn}
E_v
SCL
V_r
I_{ph} = Photocurrent





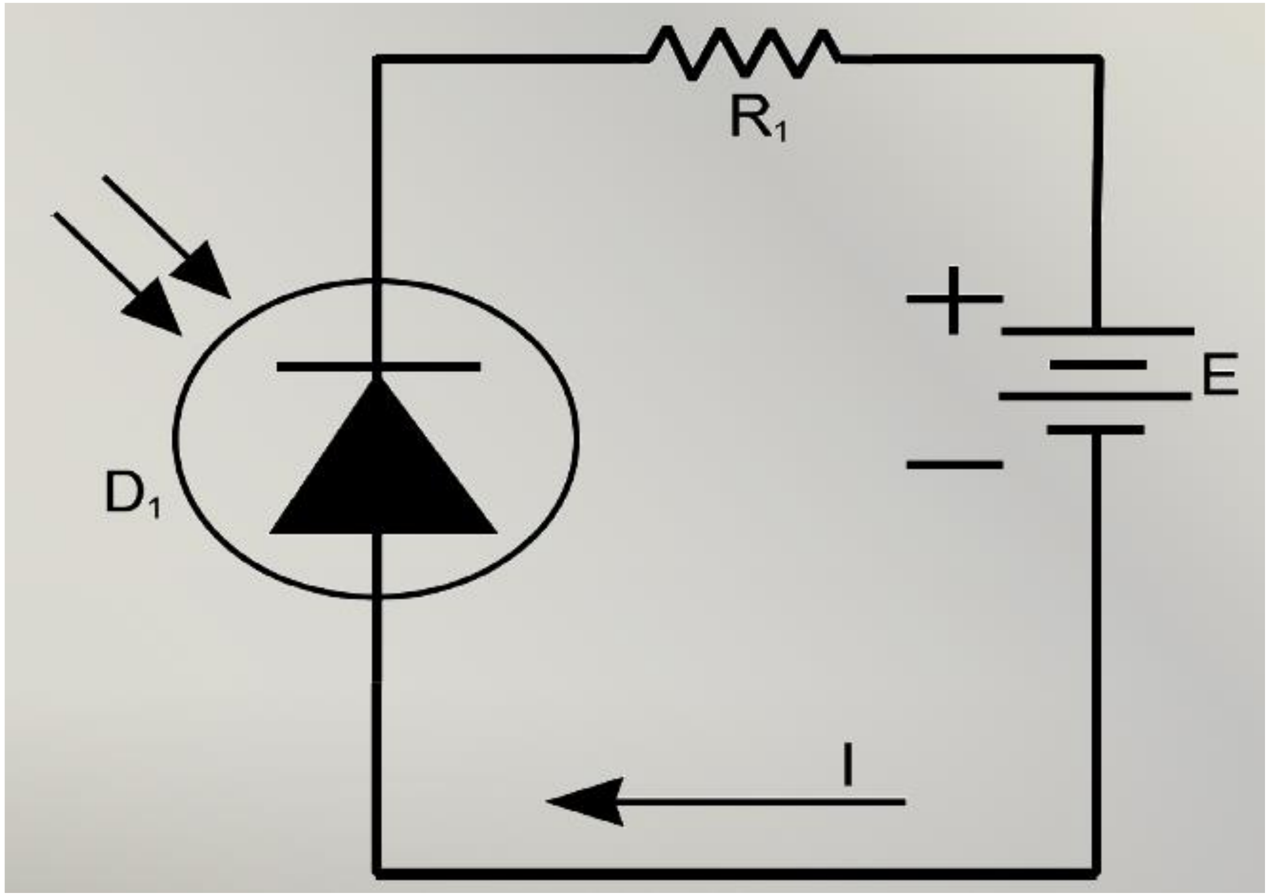
Photodiodes



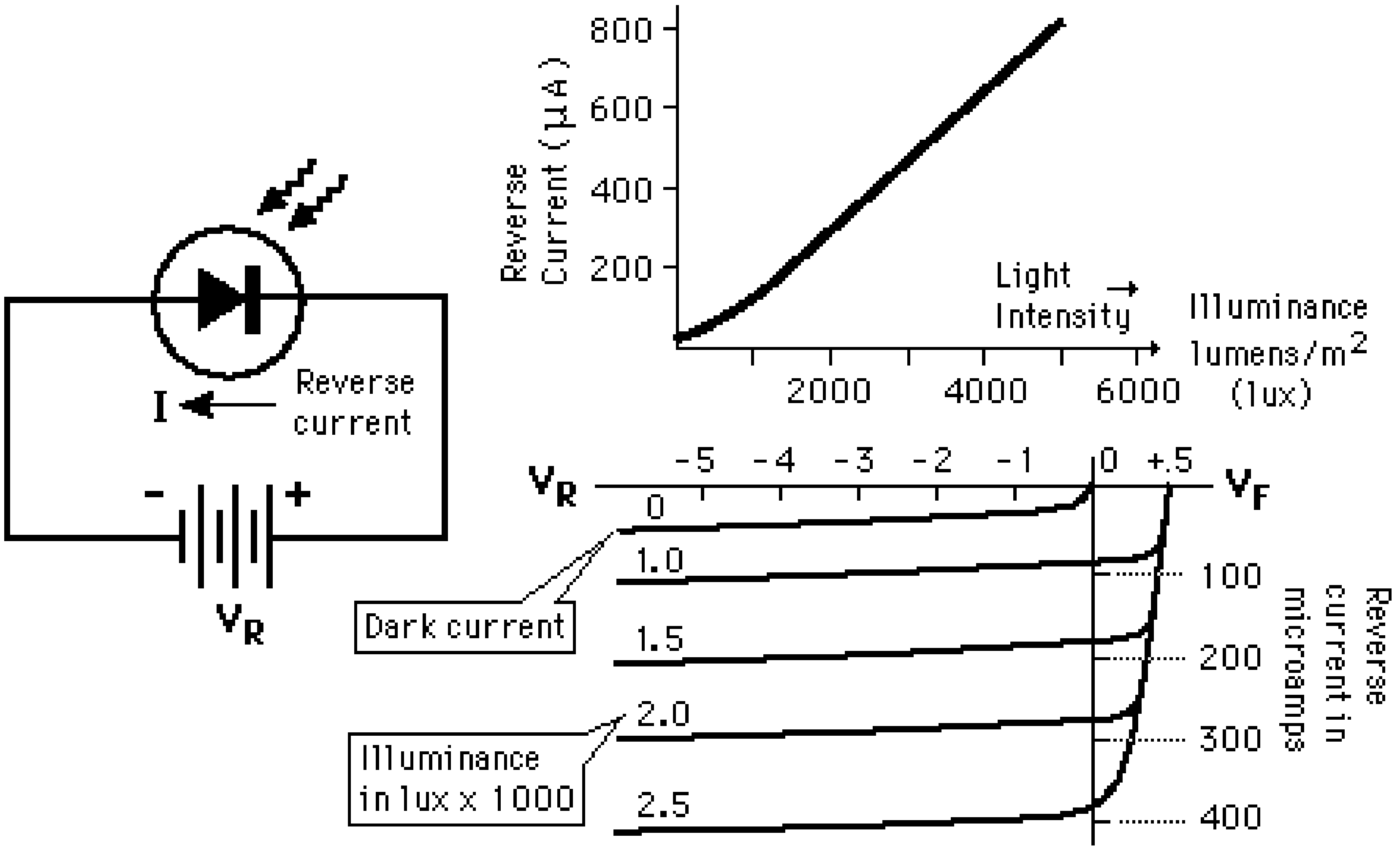


- The application of a reverse voltage to the p-n junction will cause a transient current to flow as both electrons and holes are pulled away from the junction.
- When the potential formed by the widened depletion region equals the applied voltage, the current will cease

Photodiodes



Photodiodes

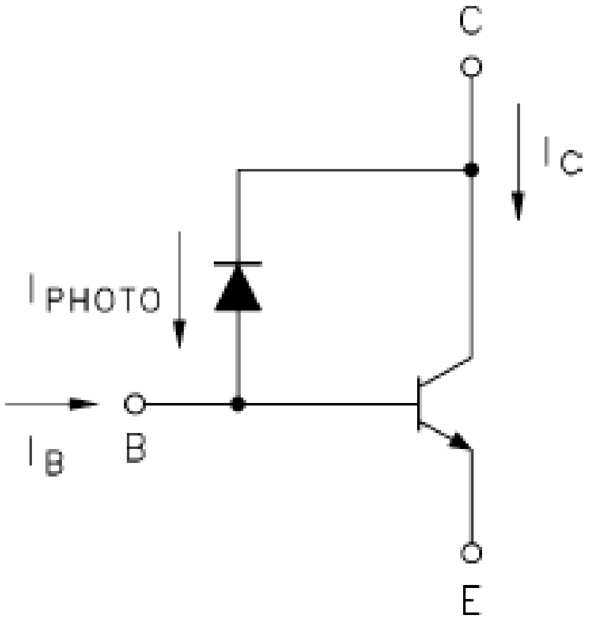


Photodiodes

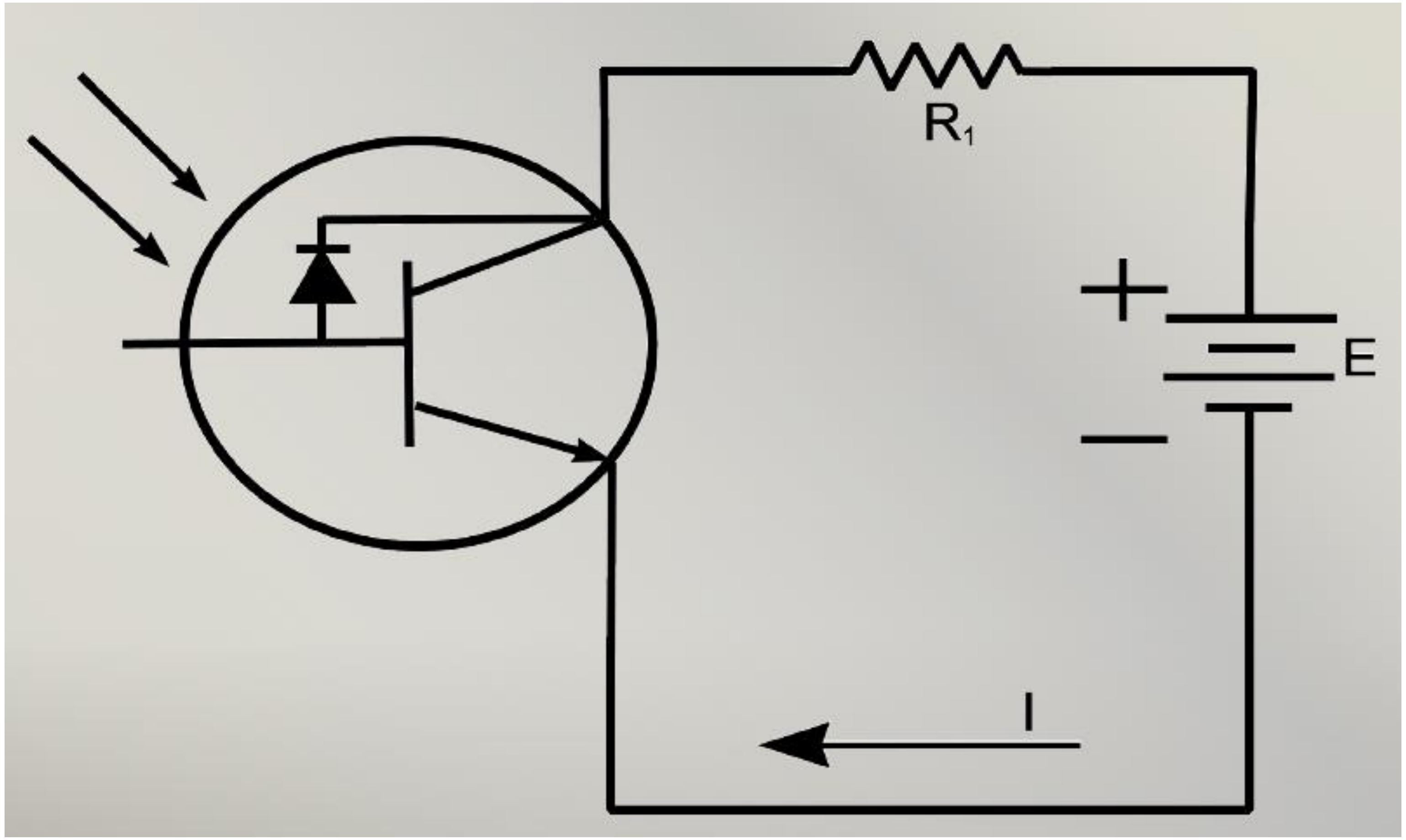
- *Photodiodes* meet most the requirements, hence widely used as photo detectors.
- Positive-Intrinsic-Negative (*pin*) photodiode
  - No internal gain, robust detector
- Avalanche Photo Diode (*APD*)
  - Advanced version with internal gain *M* due to self multiplication process
- Photodiodes are sufficiently *reverse biased* during normal operation → no current flow without illumination, the intrinsic region is fully depleted of carriers

PHOTOTRANSISTORS

Most widely used photodetectors are p-n junction photodiode, PIN photodiode, Avalanche photodiode (APD) and phototransistor. Phototransistor is a 3-terminal photo detector and has an internal gain. Phototransitor can be operated with either electrical signal or optical signal. Hence, phototransistor has been used in implementing hybrid circuits.

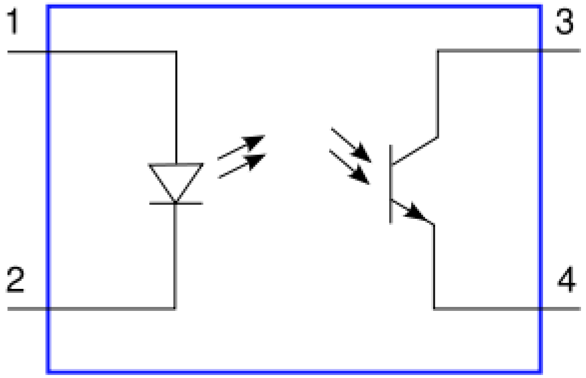


Phototransistor Equivalent Circuit



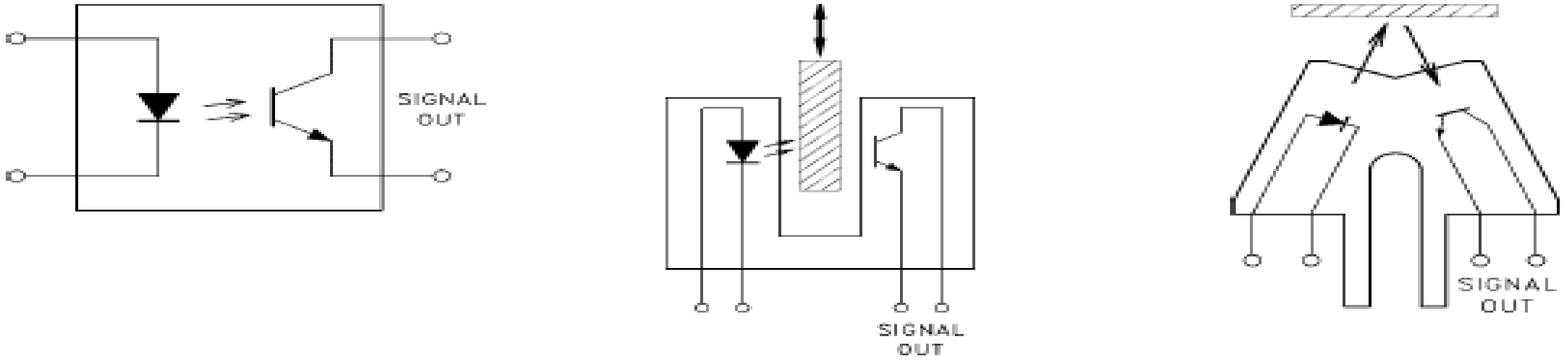
- The photodiode resistance will change as the light changes, causing the base current to change as well
- This changing current will be amplified by the transistor, resulting in a change in collector current
- The current gain of the transistor is the reason the current carrying capability of the phototransistor in generally much larger than that of the photodiode alone

DETECTOR	GAIN	OUTPUT CURRENT
Photodiode	1x	100nA
Phototransistor	500x	50 μA



Applications

Phototransistors can be used as ambient light detectors. When used with a controllable light source, typically an IRED, they are often employed as the detector element for optoisolators and transmissive or reflective optical switches.



Optoisolator

The optoisolator is similar to a transformer in that the output is electronically isolated from the input.

Optical Switch

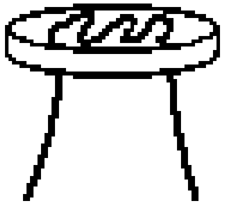
An object is detected when it enters the gap of the optical switch and blocks the light path between the emitter and detector.

Retro Sensor

The retro sensor detects the presence of an object by generating light and then looking for its reflectance off of the object to be sensed.

Photo Resistors

- Low cost, two lead photo-resistors using a cadmium sulfide (CdS) element show a dramatic decrease in resistance when illuminated and are commonly used as a light sensing element for security lights, etc. so that they will turn on at night.
- In the dark, the resistance is very high, in the 1 megaohm range. When illuminated, the resistance may drop to a few hundred ohms. They are typically more sensitive to green light, and they have a very high sensitivity compared to other types of sensors.
- Not practical for high speed switching or modulation for communications purposes due to a memory effect, requiring on the order of a second for the resistance to rise to its dark resistance.



Hall effect sensors

The Hall effect is an ideal sensing technology. The Hall element is constructed from a thin sheet of conductive material with output connections perpendicular to the direction of current flow. When subjected to a magnetic field, it responds with an output voltage proportional to the magnetic field strength. The voltage output is very small (μV) and requires additional electronics to achieve useful voltage levels. When the Hall element is combined with the associated electronics, it forms a Hall effect sensor

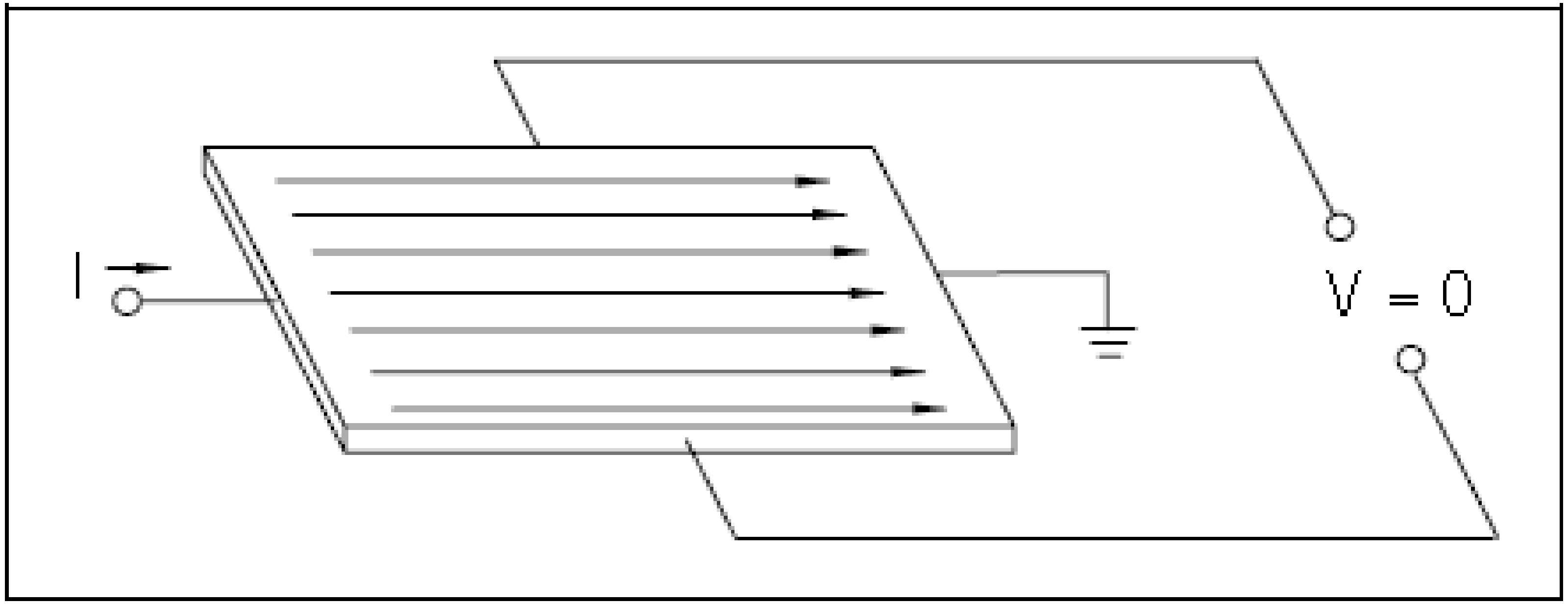
Although the Hall effect sensor is a magnetic field sensor, it can be used as the principle component in many other types of sensing devices (current, temperature, pressure, position, etc.).

General features of Hall effect based sensing devices are:

- True solid state
- Long life (30 billion operations in a continuing keyboard module test program)
- High speed operation - over 100 kHz possible
- Operates with stationary input (zero speed)
- No moving parts
- Logic compatible input and output
- Broad temperature range (-40 to +150°C)
- Suitable for repeatable operation

Theory of the Hall Effect

When a current-carrying conductor is placed into a magnetic field, a voltage will be generated perpendicular to both the current and the field. This principle is known as the Hall effect.



$$V_H \propto I \times B$$

When a perpendicular magnetic field is present, as shown in Figure , a Lorentz force is exerted on the current. This force disturbs the current distribution, resulting in a potential difference (voltage) across the Hall voltage (VH).

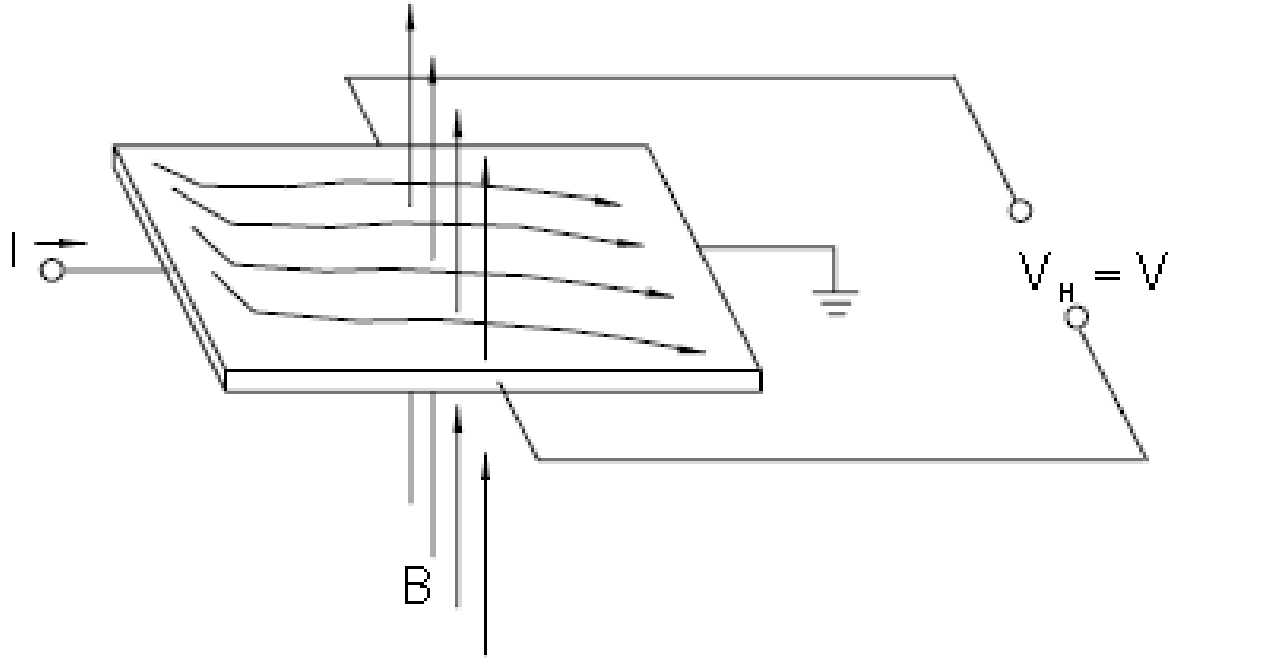
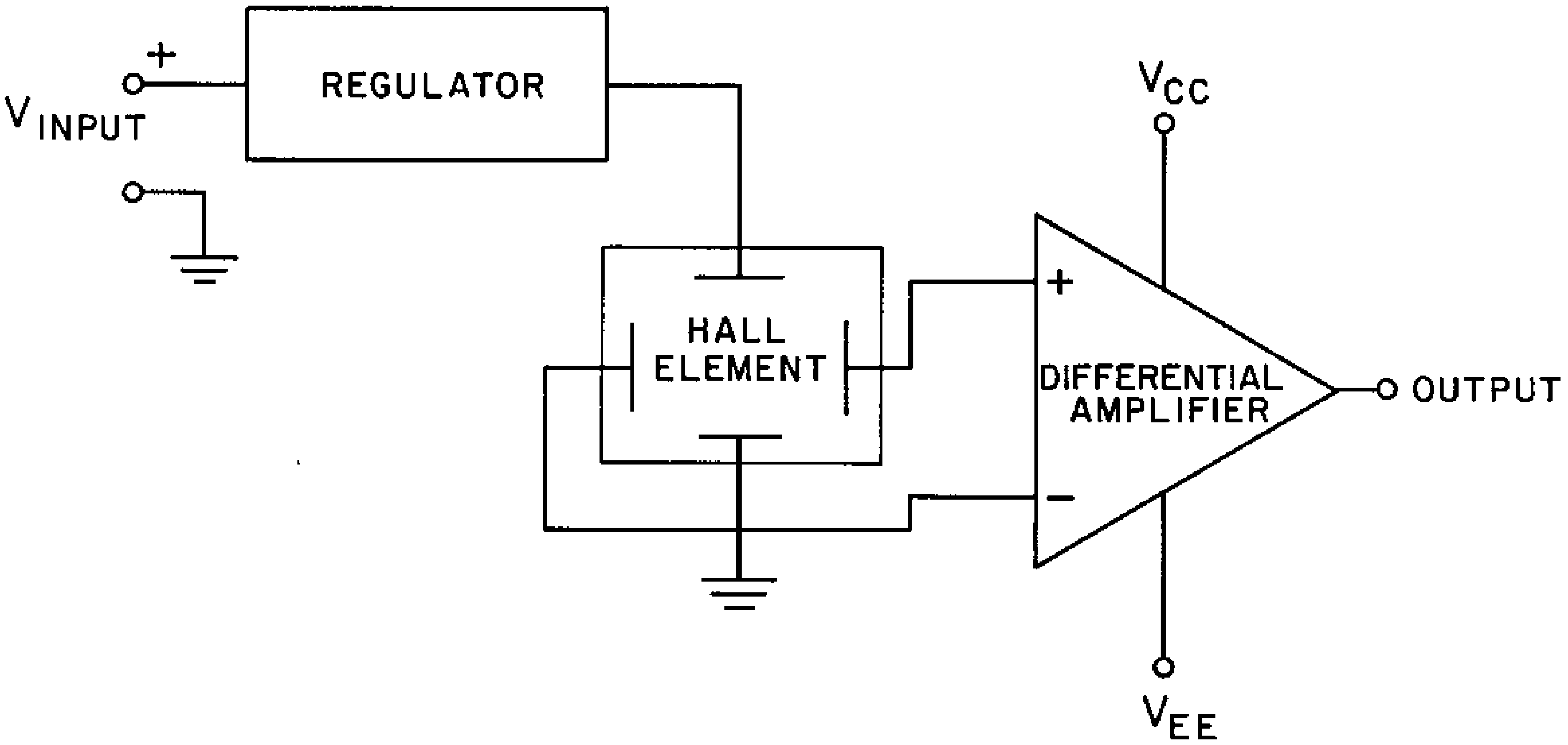
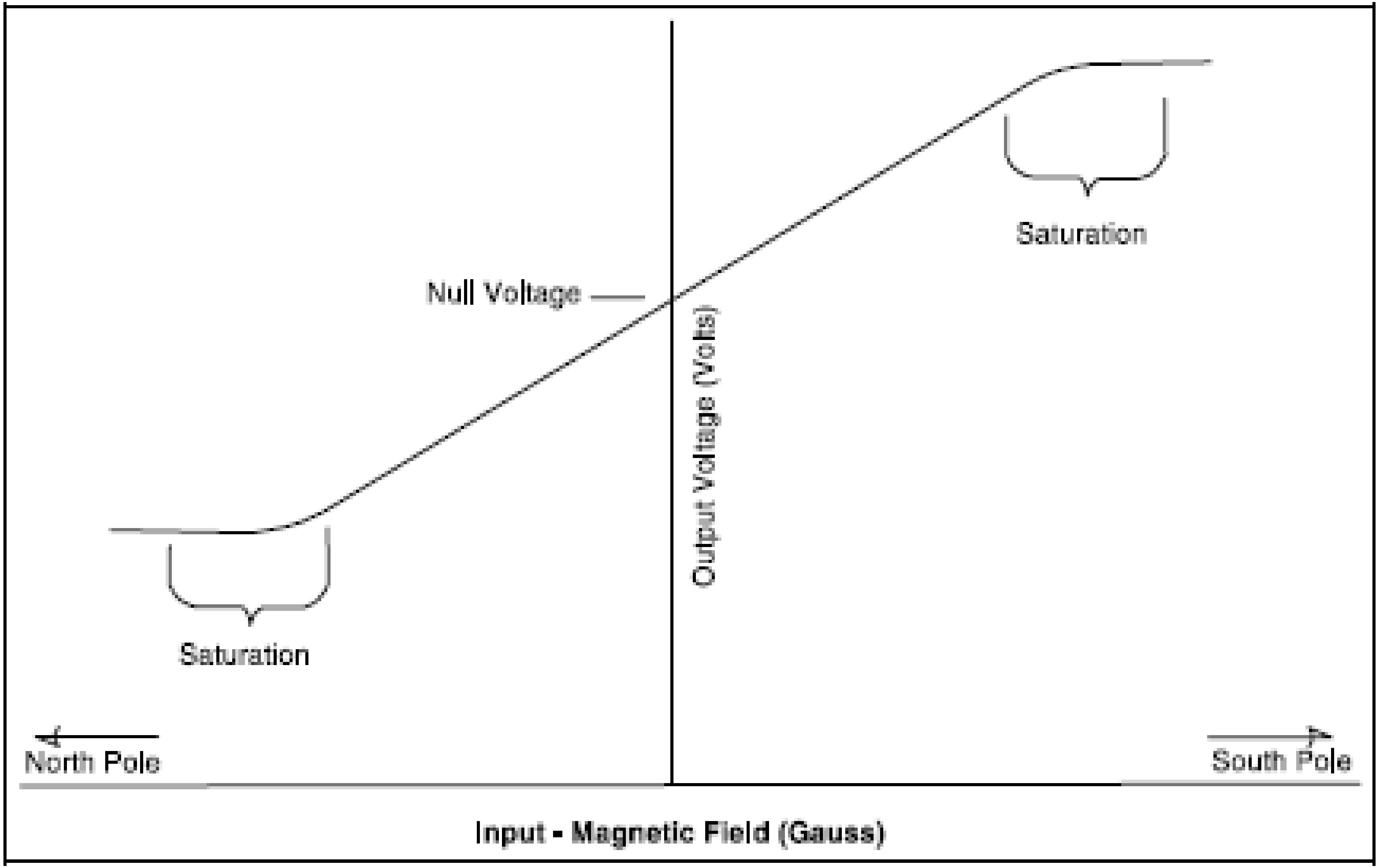


Figure 2-2 Hall effect principle, magnetic field present

$$V_H \propto I \times B$$

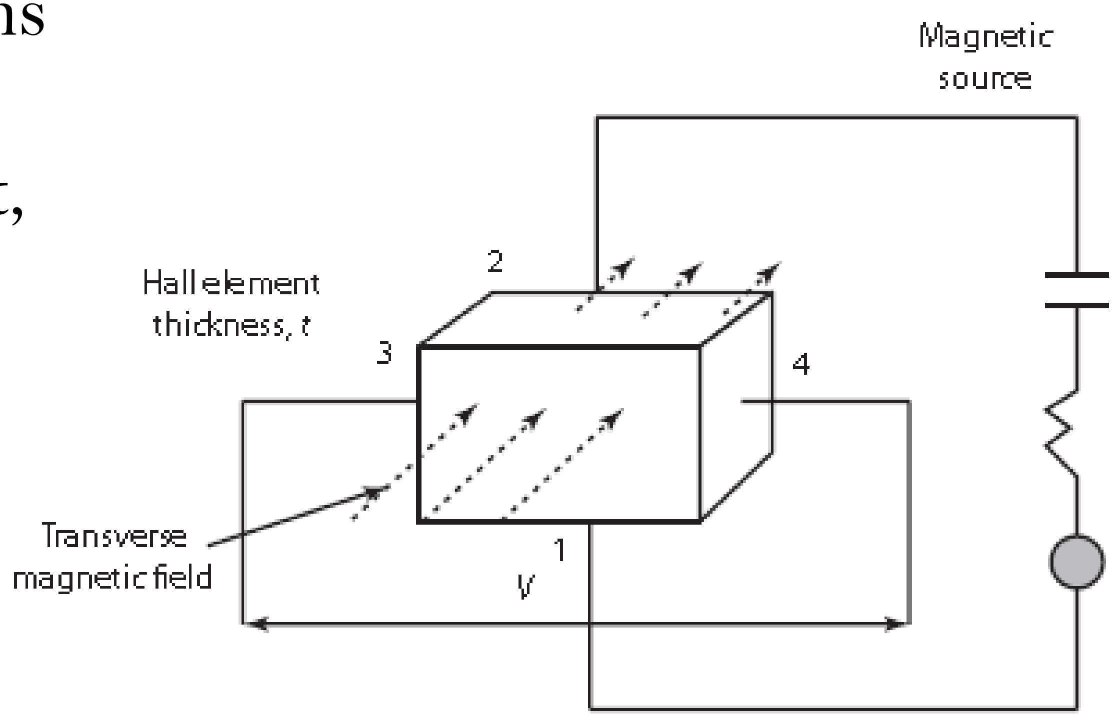
Hall effect sensors can be applied in many types of sensing devices. If the quantity (parameter) to be sensed incorporates or can incorporate a magnetic field, a Hall sensor will perform the task.




Saturation
Null Voltage
Output Voltage (Volts)
Saturation
North Pole
South Pole
Input - Magnetic Field (Gauss)

The output voltage is represented in terms of element thickness, the flux density of the field, the current through the element, and the Hall coefficient as

HALL EFFECT PRINCIPLE



$$V = H\frac{IB}{t}$$

where

H Hall coefficient, which can be defined as transverse electric potential gradient per unit magnetic field per unit current density. The units are V-m per A-Wb/m2

I current through the element (A)

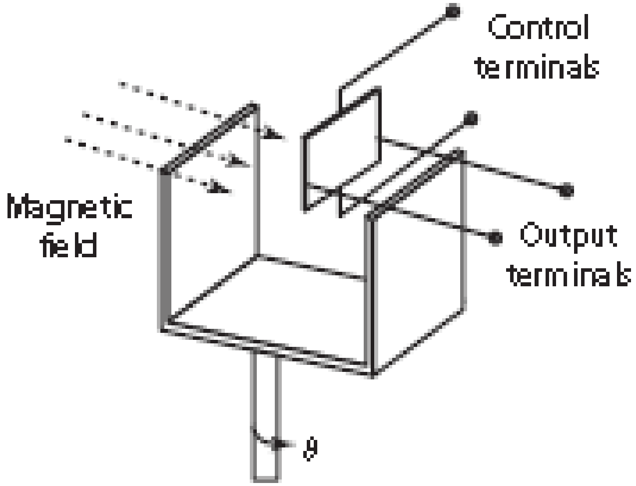
B flux density of the field (Wb/m2)

t thickness of the element (m)

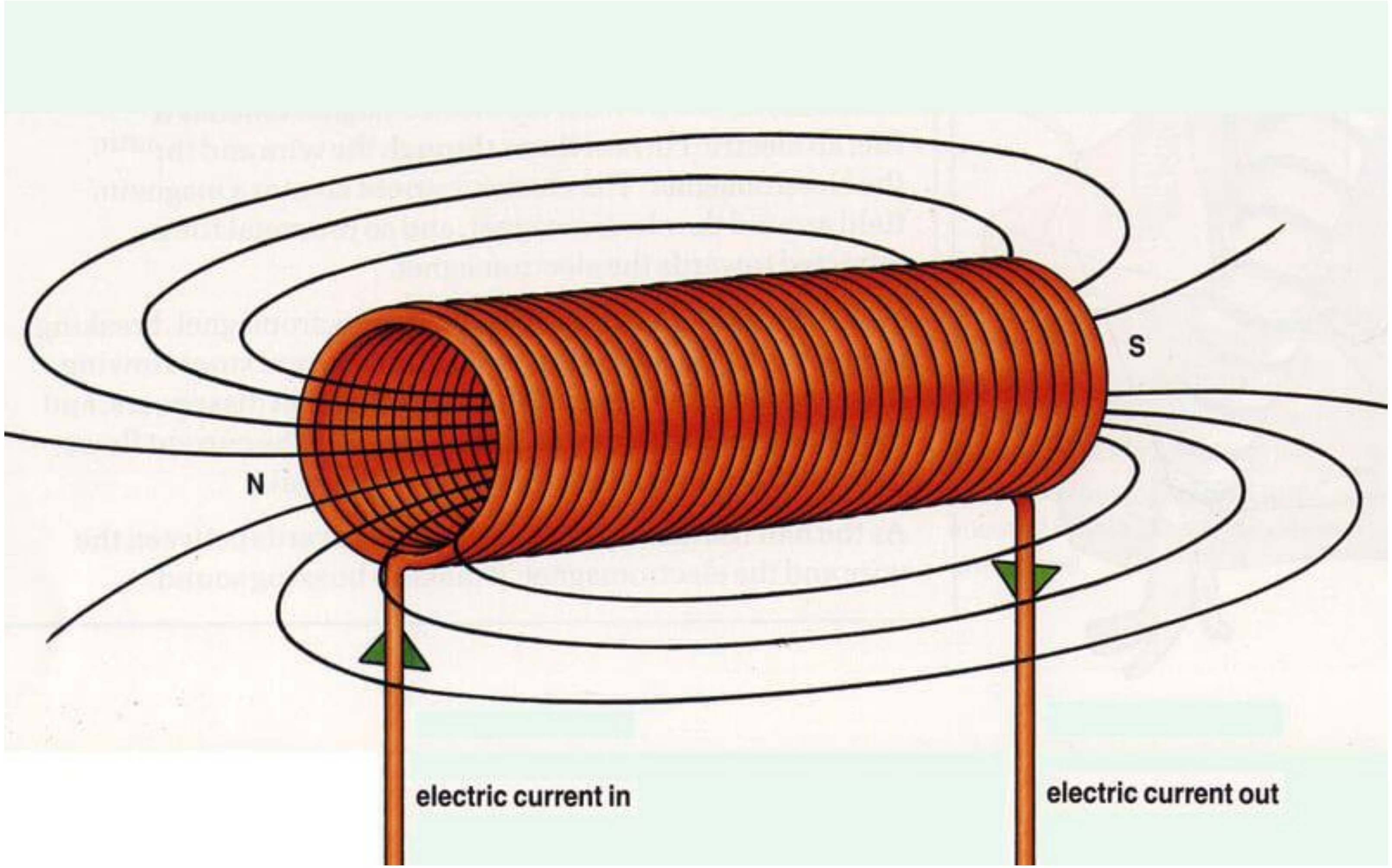
Output voltage generated for a rotation of θ degrees is summarized as

$$V = HIB \frac{\sin \alpha}{t}$$

ROTATIONAL TRANSDUCER



Solenoid

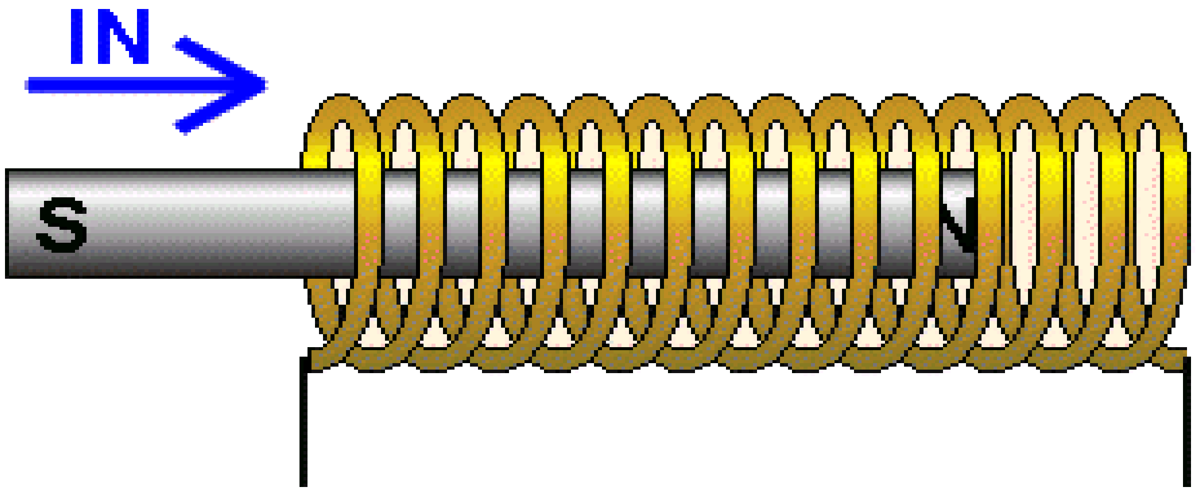


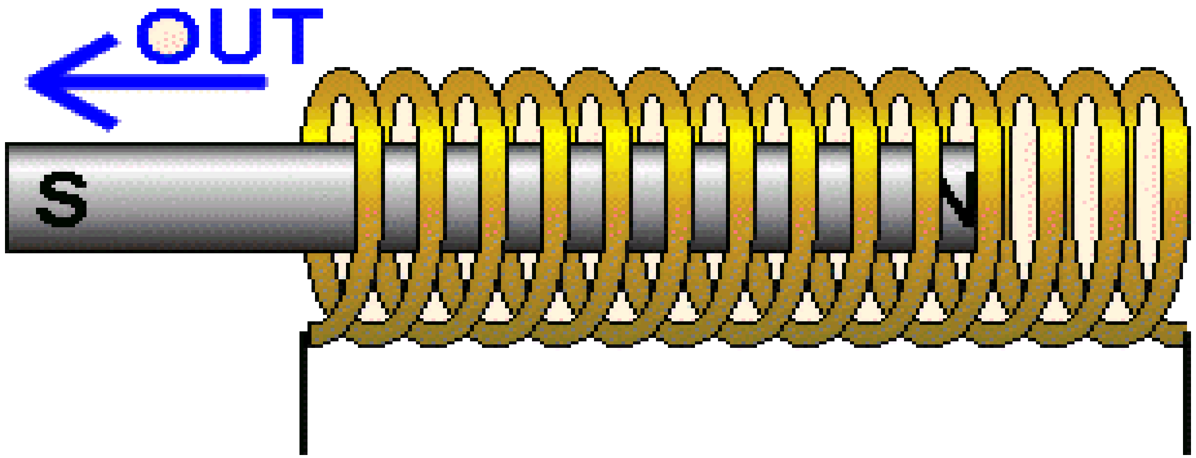
The solenoids are simple electrical components and it has a vast impacts on daily life. The term itself is derived from the Greek name "solen", which illustrates a channel or a pipe. The second part of the name is taken from the Greek name "eidos", which refers to an outline. Basically, it is a component in the form of a pipe. The solenoid is used in a variety of applications, and there are numerous types of solenoid designs available. Each of them has their own properties that make it useful in many precise applications.

What is a Solenoid and Its Working Principle

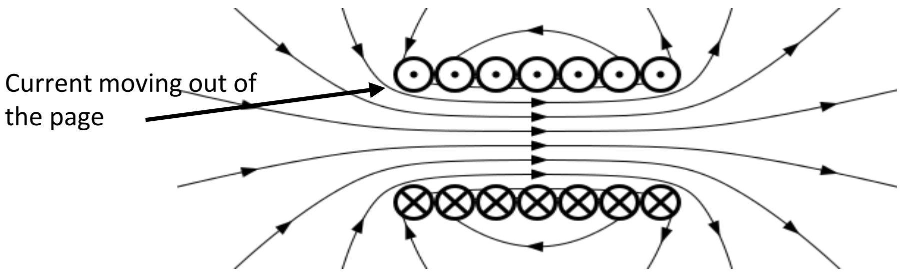
A solenoid is a very simple component, that includes a coil of wire that is covered around a core made out of a metal. When a current is applied to the solenoid, it has the effect of assembling a consistent magnetic field. Electricity changes to magnetism then it changes to electricity and, therefore, these two forces are united into one.

An attractive thing about the uniform field in a solenoid is that, if the solenoid has an immeasurable length, the magnetic field would be the similar everywhere along the element. In a solenoid, sometimes this translates to very small electrical components being able to do a marvelous amount of work. For instance, a powerful solenoid can simply slam shut a valve that would be demanding for even the burliest plumber to close by hand.

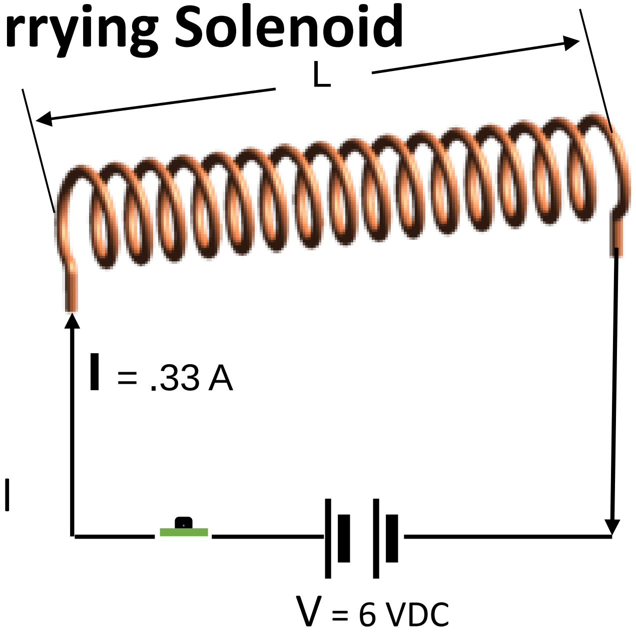

IN
S


OUT
S

Magnetic Field in a Current Carrying Solenoid



Cross-section through the center of the core



It is constructed by winding a long wire into a tight coil with many circular loops in a free space where the magnetic permeability, μ_0 is equal to $4\pi \times 10^{-7}$ Tm/A .

If the solenoid has N turns (loops) and carries a current, I where the length of a wire is L the magnetic field strength, B is:

$$B = \frac{\mu_0 N I}{L}$$

where L = 2.5 in (coil exposed) = .063m; N = 50; V = 6 V; I = .33A

(Ref: Physics eq. 19.14)

$B = 55 \times 10^{-5}$ T (11 times stronger than the Earth's magnetic field 5×10^{-5})

The magnetic field created by a solenoid is proportional to both the number of turns in the winding, *N*, and the current in the wire, I, hence the product, *NI*, is called ampere-turns.

Solenoid

- A solenoid is a coil of wire.
- When current runs through the wire, it causes the coil to become an “electromagnet”.
- Air-core solenoids have nothing inside of them.
- Iron-core solenoids are filled with iron to intensify the magnetic field.

Different Types of Solenoids

There are various Types of Solenoids are available in the market. They differ in terms of their material, design and function. But all kinds of solenoids depend on the same electrical principles.

- AC Laminated Solenoid
- DC Solenoid
- Linear Solenoid
- Rotary Solenoid

AC Laminated Solenoid

An AC laminated solenoid is famous for the amount of force that can be performed in their first stroke. They can also use a longer stroke than a DC solenoid. They are obtainable in several different configurations and ranges.

DC Solenoid

A DC C–Frame solenoid uses only a frame, formed like the letter C, which is covered around the coil. This kind of solenoid has an extensive range of different applications. Even though they are famous in a DC configuration, they can also be designed to be used with AC power.

DC D–Frame Solenoid

A DC D–Frame solenoid gears have a two-piece frame that is covered around the coils. These are used in several different applications like industrial applications. Like the C–Frame, these solenoids can also be designed in AC alternatives, for applications when the properties of an AC solenoid are more attractive than a DC solenoid.

Linear Solenoid

This kind of solenoids is more familiar with the most people. These are capable of using a pulling or pushing force on a mechanical device and can be utilized for a variety of metering tasks. These solenoids are used in a different applications. For instance, a solenoid on the starter device of a vehicle which includes a motor. Whenever electrical current flows through the solenoid, then it will move in a linear fashion to get two contacts together. When the two contacts are getting together, they let power to flow from the battery supply to the different components of the automobile and the automobile to start. The best application of the solenoid is electric lock. When the lock is attached to the bolt on a door, it can immediately protect a door sufficient to hold up to a great deal of violence.

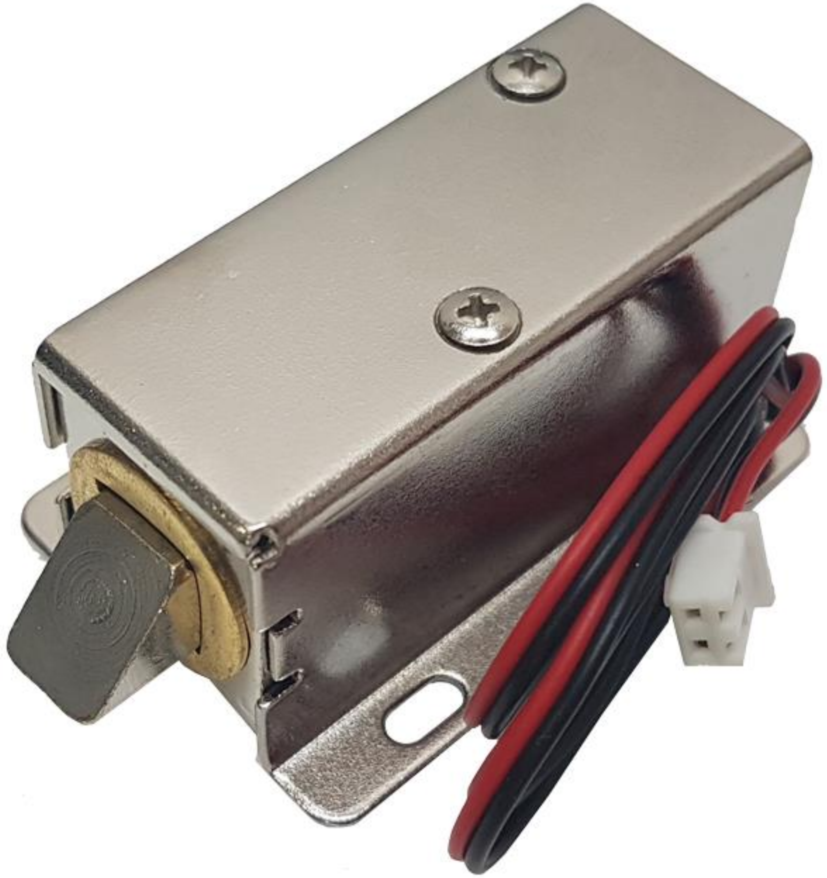
Rotary Solenoid

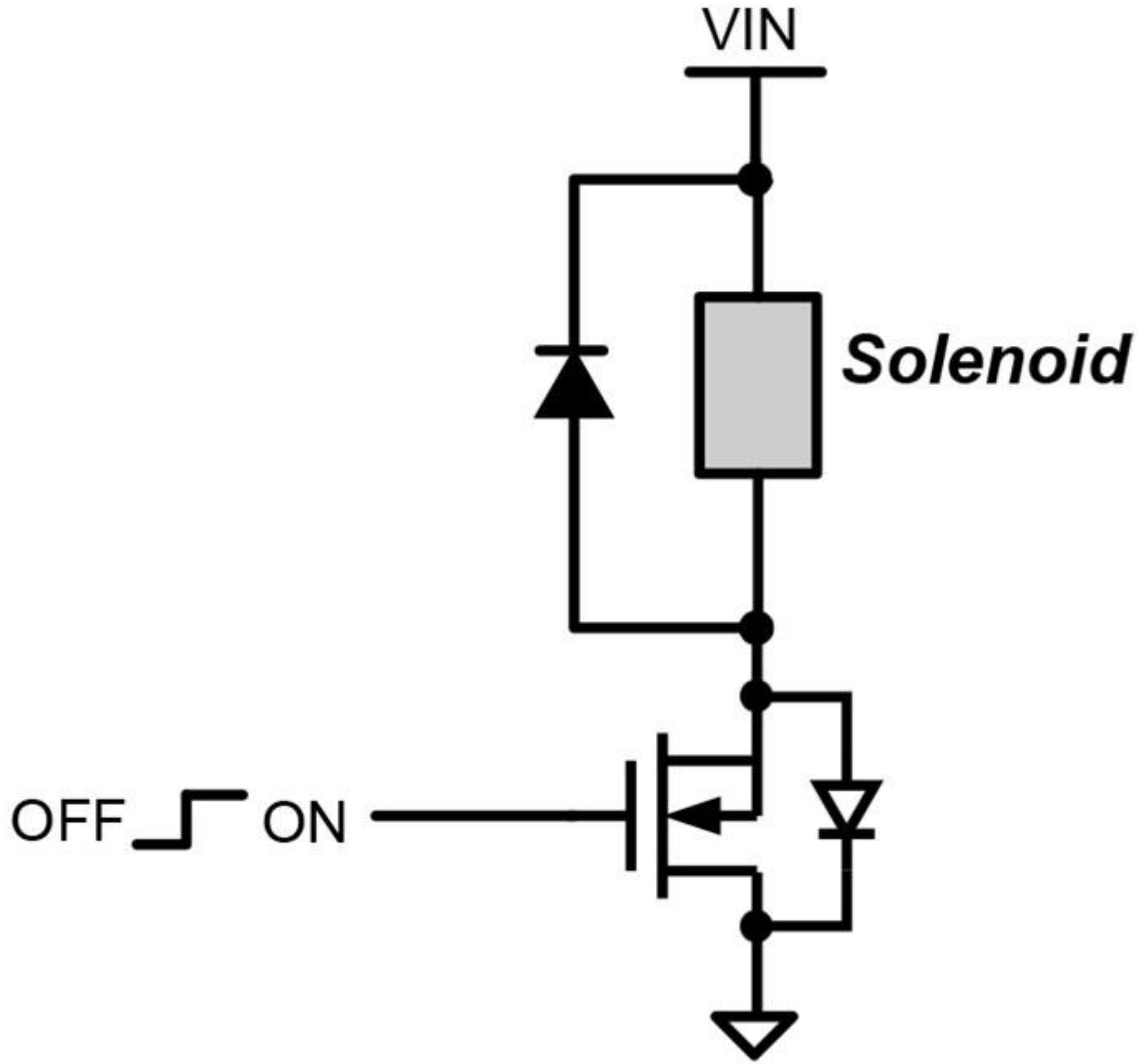
Rotatory solenoid is a good example of mechanical force which can be used in different methods to make easy of an automatic control process and quite easy to make life easier. In this solenoid, there is the similar coil and core design, though it is somewhat changed. In a rotary solenoid, a disc is used instead of the solenoid being a simple device with a core and coil. The body of the solenoid is lined up with the grooves and ball bearings are used to make easier motion. Triggering the solenoid makes the core to be drawn back into the coil. This force is converted into a rotation force in the disc. Most of the devices are also inbuilt with a spring. When the power supply is detached from the solenoid, the spring makes the core to be drawn out of the coil, releasing the disc and transferring it back to its unique position.

Applications of Solenoid

- A solenoid is an essential coil of wire that is used in electromagnets, inductors, antennas, valves, etc. The application of a solenoid differs in numerous types like medical, locking systems, industrial use, the bottom line and Automotive Solenoid Applications.
- A solenoid is used to control a valve electrically, for example, the solenoid core is used to apply mechanical force to the valve.
- These can also used in particular types of door locking systems, which use an electromagnet and offer a very secure closure.
- The solenoid is used in many different appliances and products like computer printers, fuel injection gear used on cars and in various industrial settings.
- The main advantage of the solenoid is, whenever an electricity is applied, the reaction of the solenoid is immediate.
- That quick response is one of the most significant factors in resolving the applications of solenoids.


FESTO

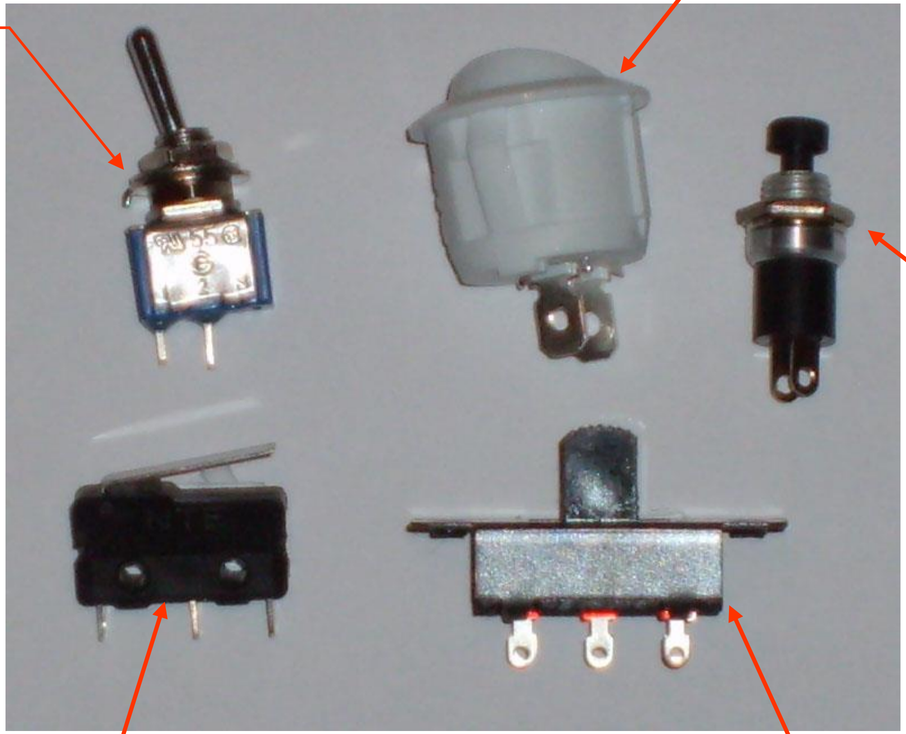



VIN
Solenoid
OFF
ON

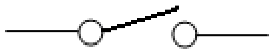
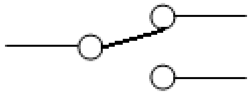
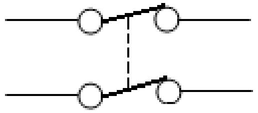
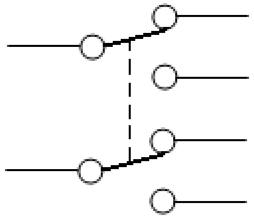
Switches & Relays

Switches

Mechanical Switches



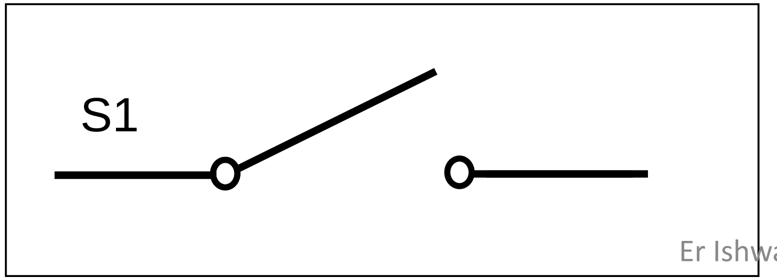
Switches

Type of Switch	Symbol
Single Pole Single Throw (SPST)	
Single Pole Double Throw (SPDT)	
Double Pole Single Throw (DPST)	
Double Pole Double Throw (DPDT)	

What is a Switch?

- A switch is a device that allows you to stop the flow of current entirely. These are usually mechanical devices that separates two bits of metal (contacts). When the metal doesn't touch, current doesn't flow. When the metal touches, is called a closed circuit. When the metal doesn't touch, is called an open circuit. (closed = ON, open = OFF)

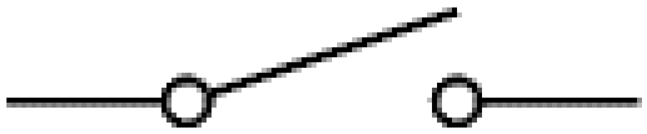
Basic Switch Schematic Symbol



Single Pole, Single Throw = SPST

A simple on-off switch. This type can be used to switch the power supply to a circuit.

Circuit Symbol



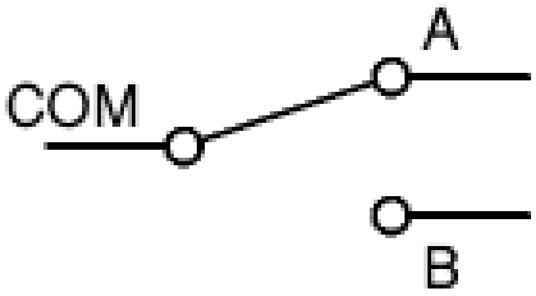
Example

SPST toggle switch

Single Pole, Double Throw = SPDT

- This switch can be on in both positions, switching on a separate device in each case. It is often called a **changeover switch.** For example, a SPDT switch can be used to switch on a red lamp in one position and a green lamp in the other position.

Circuit Symbol



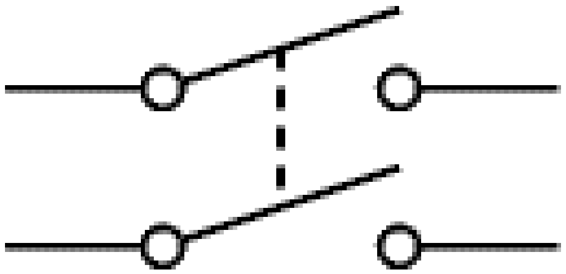
Example

SPDT rocker switch

Double Pole, Single Throw = DPST

- A pair of on-off switches which operate together (shown by the dotted line in the circuit symbol).

Circuit Symbol



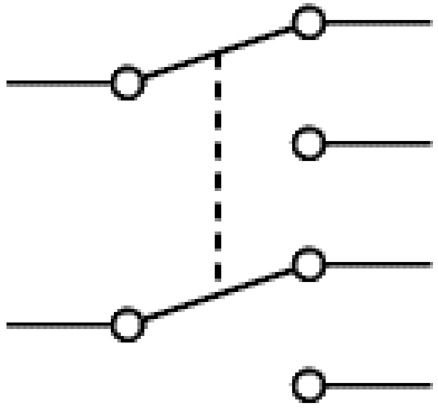
Example

DPST rocker switch

Double Pole, Double Throw = DPDT

- A pair of on-on switches which operate together (shown by the dotted line in the circuit symbol).

Circuit Symbol



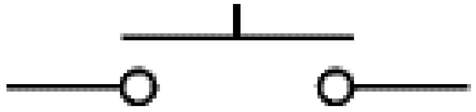
Example

DPDT slide switch

Push Button Switches (NO/NC)

- A Normally Open (NO) switch returns to its normally open (off) position when you release the button.

Circuit Symbol



Example

Push-to-make switch

- A Normally Closed (NC) switch returns to its normally closed (on) position when you release the button.

Circuit Symbol

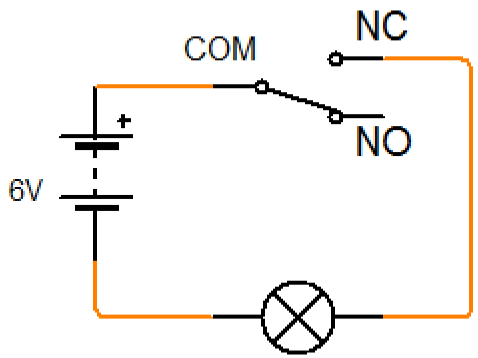
Example

Push-to-break switch

Switches

Microswitch

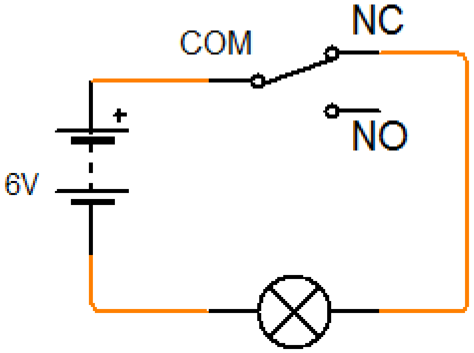
- Normally Open (NO)
  - Circuit off and switched on



Switches

Microswitch

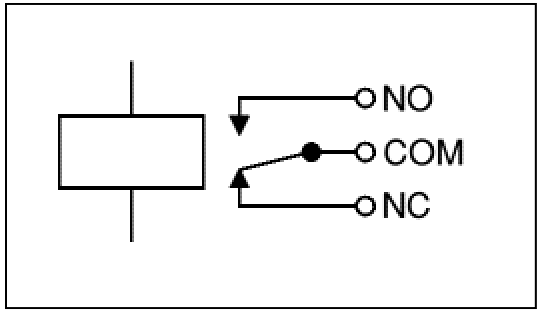
- Normally Closed (NC)
  - Circuit on and switched off

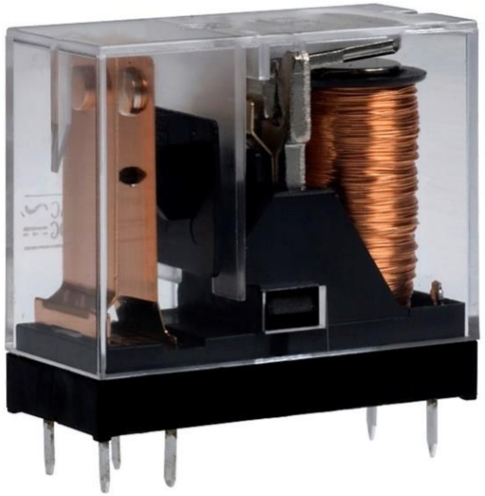


A relay is an electromagnetic switch used to switch High Voltage or Current using low power circuits. For example, we can use it for controlling home appliances with a normal low voltage electronic circuit. Electromagnetic relays uses an electromagnet to operate a switching mechanism mechanically. It also provides isolation between low power circuit and high power circuits.

What is a Relay?

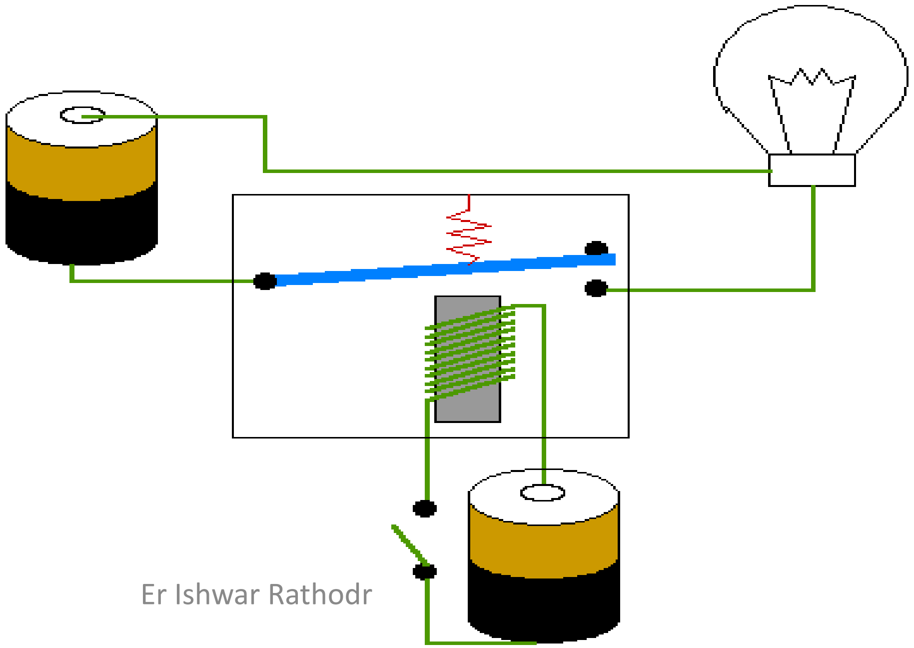
- A Relay is an electromechanical switch, operated by passing current through a coil of wire wound around a steel core, which acts as an electromagnet, pulling the switch contact down to make or break a circuit.





How to they work?

- A small current is passed though the coil which generates a magnetic field. This magnetic field pulls the armature down towards the coil. At the end of the armature is a contact. When the armature moves its contact touches the contact of the controlled circuit. This creates a closed circuit.
  (this is not always the case as some relays are normally closed)

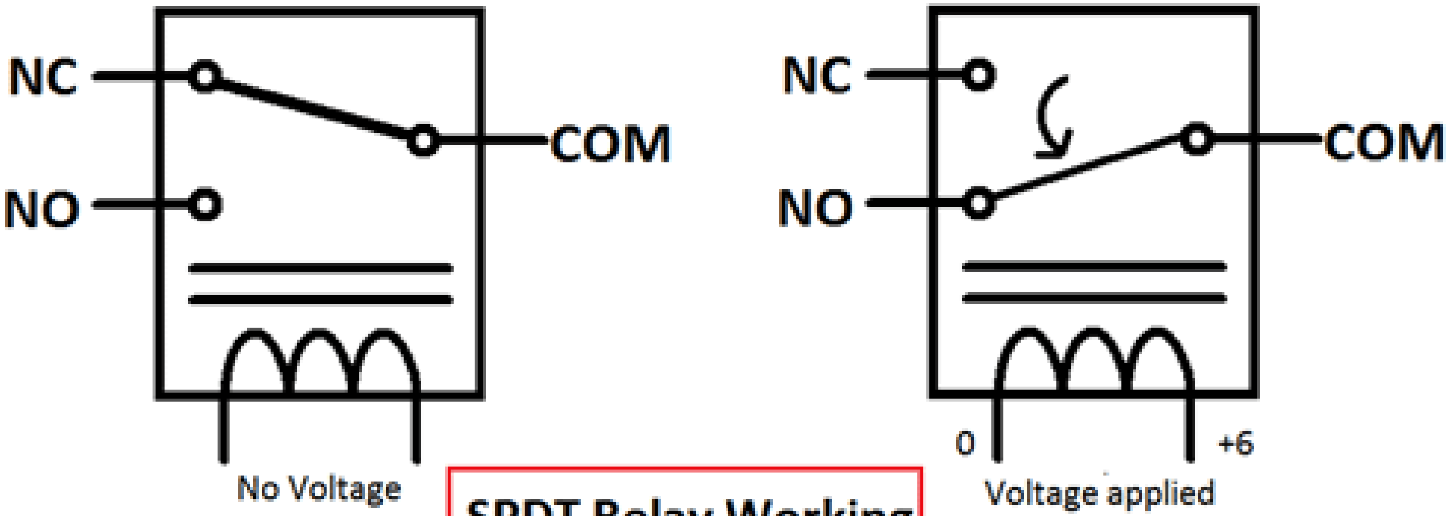


Why are they used?

- Generally speaking a relay is used to control a circuit, typically a circuit with a higher voltage or current.
- Other purposes:
  - Safety
  - Remote control

What are they used for?

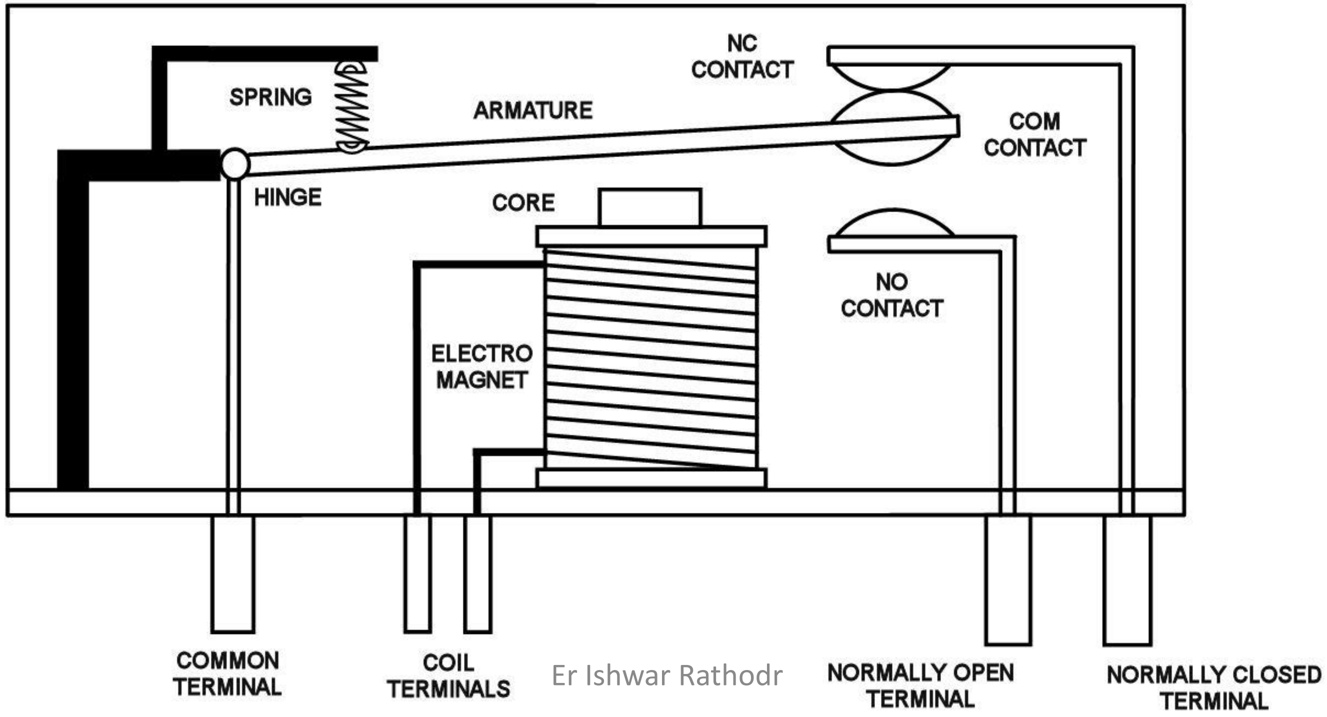
- Door Bells
- Industrial Machinery
- Remote Lighting Systems
- Etc…



SPDT Relay Working

Control vs. Controlled Circuit

- The circuit that turns the relay on and off is the control circuit.
- The circuit that is activated or deactivated with the switching of the relay is called the controlled circuit.



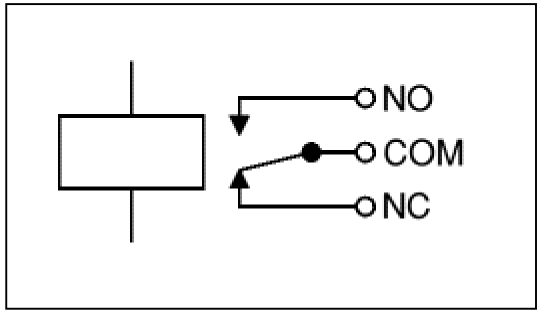
Er Ishwar Rathodr

Relay contacts
Normally Open vs. Normally Closed

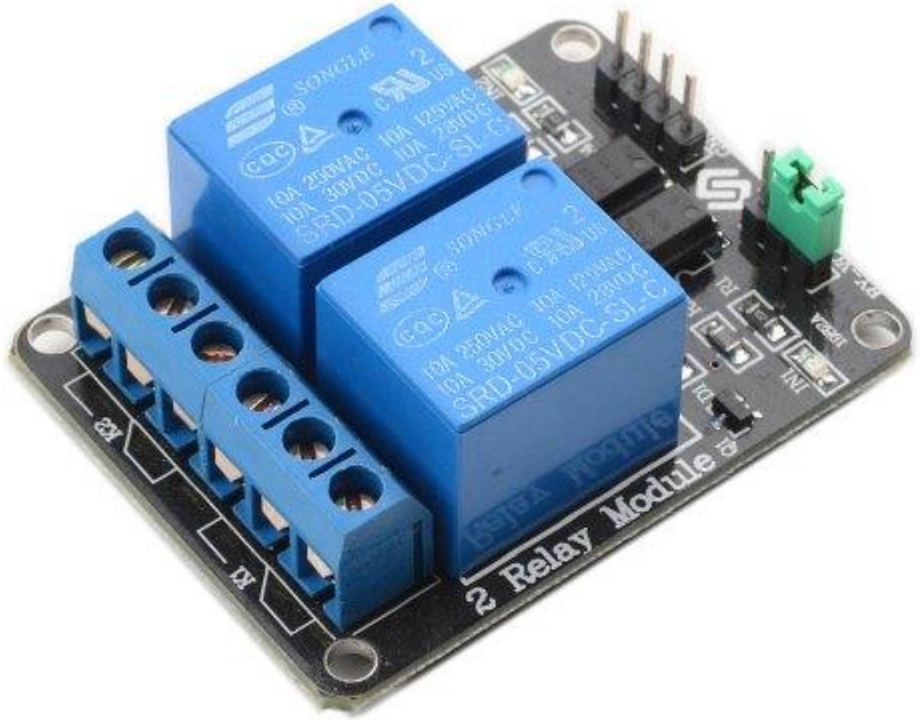
- The number of contacts in a relay can vary. In many there are two sets of contacts referred to as Normally Closed and Normally Open.

- **The Normally Closed** set of contacts are in contact with the contact on the armature when the relay is not activated.

- **The Normally Open** contacts are not in contact with the armature when the relay is not activated




YH185B
012-1H9
87
86
30
85
14VDC
60A
S0734


SONGLE
10A 250VAC 10A 125VAC
10A 30VDC 10A 28VDC
SRD-05VDC-SL-C
2 Relay Module