5 - Digital Electronics

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Logic Gates - Mrs. M. S. Bhosale

Logic gates are the logic circuits which act as the basic building blocks of any digital system. It is an electronic circuit having one or more than one inputs & only one output.

Truth Table -

The operation of a logic gate or a logic circuit can be best understood with the help of a table called truth table. The truth table consists of all the possible combinations of the inputs & the corresponding state of O/P produced by that logic gate or logic circuit.

Boolean Expression -

The relation between the inputs & the outputs of a gate can be expressed mathematically by means of the Boolean Expression.

Classification of Logic gates -

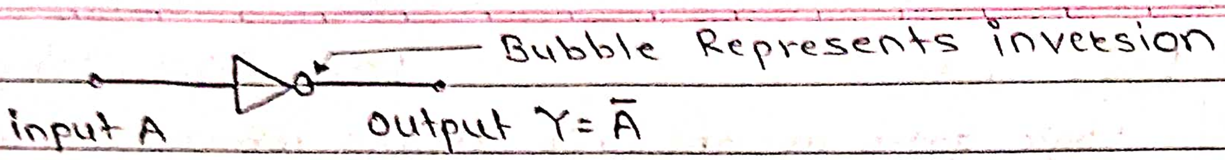
Logic Gates

Basic Gates	Universal Gates	Derived
NOT	NAND	Ex-OR
AND	NOR	Ex-NOR
OR		

(1) **Basic Gate -** Basic building block.

(A) **NOT gate / Inverter -**

The NOT gate or Inverter is a logic gate having one input & one output. It's symbol & Truth table are shown below -

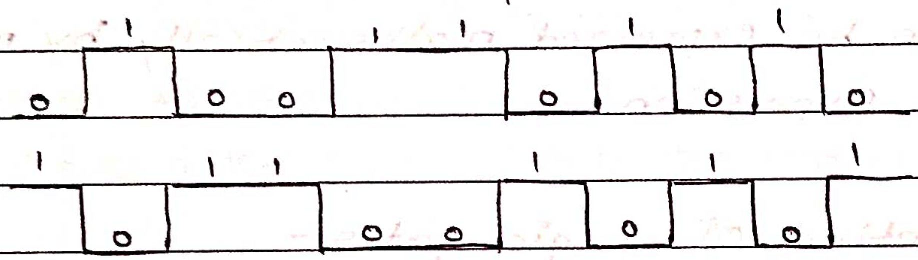


Truth Table -

I/P A	O/P $Y = \bar{A}$
0	1
1	0

NOT gate is also called as inverter because it's output is the inverted version or complement of it's input. The bubble in the symbol of a NOT gate indicates the inversion operation.

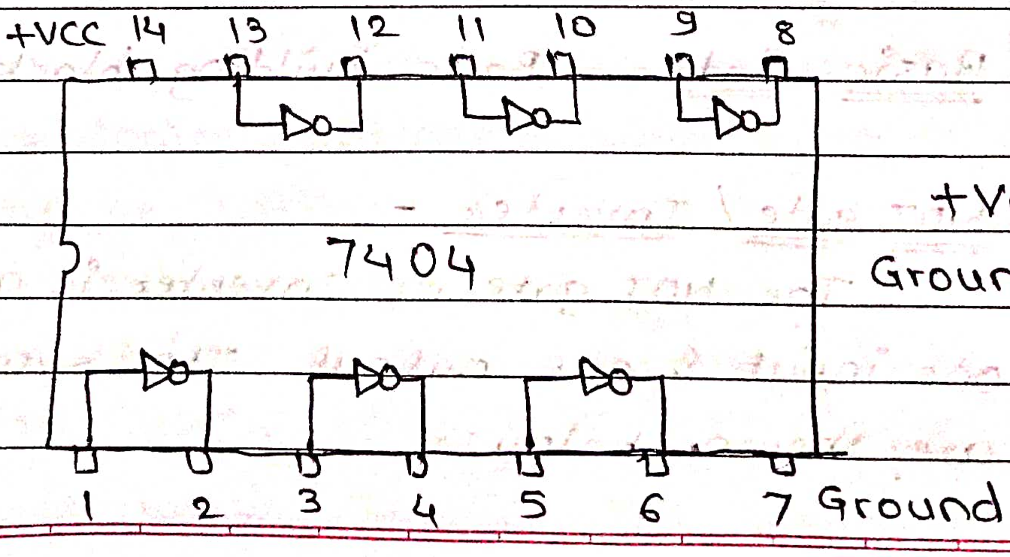
operation for pulsed input -



standard Package (IC gate) -

NOT gate is available in the monolithic integrated circuit (IC) form.

IC 7404 is a 14 pin TTL integrated ckt with six inverters inside. therefore it is called as hex inverter



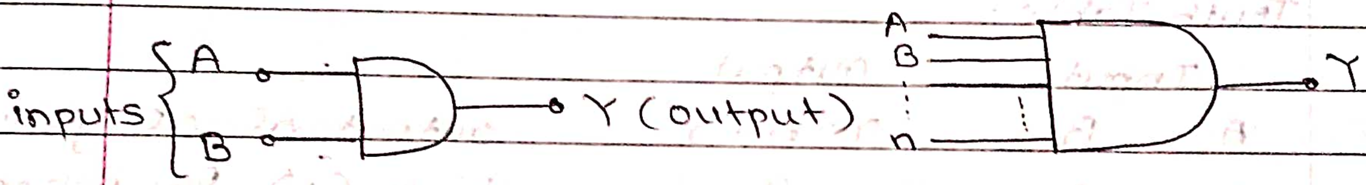
+VCC = 5V

Ground = 0V

(B) AND Gate -

AND is a one of the logic operators. It performs the logical multiplication on its inputs.
The output is high ($Y=1$) if & only if all the inputs to the AND gate are high (1). The output is low ($Y=0$) if any one or more i/p's are low (0).
AND gate can have two or more than two inputs & only one output.

Logical symbol & Truth table -



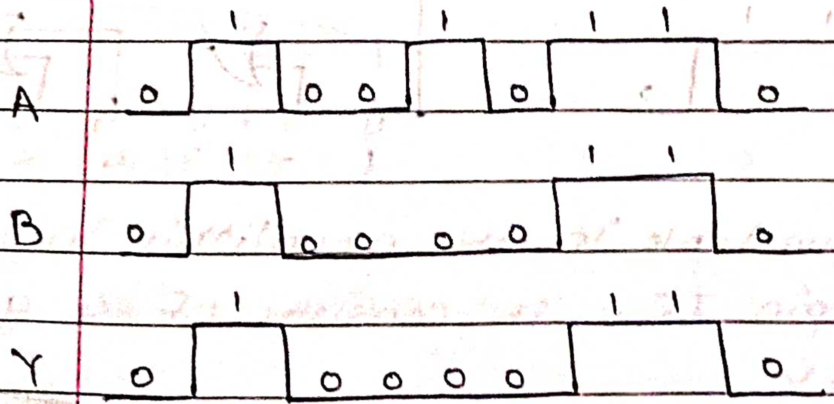
Boolean Expression - $Y = A \cdot B \cdot C \cdot \cdots n$

$Y = A \cdot B$

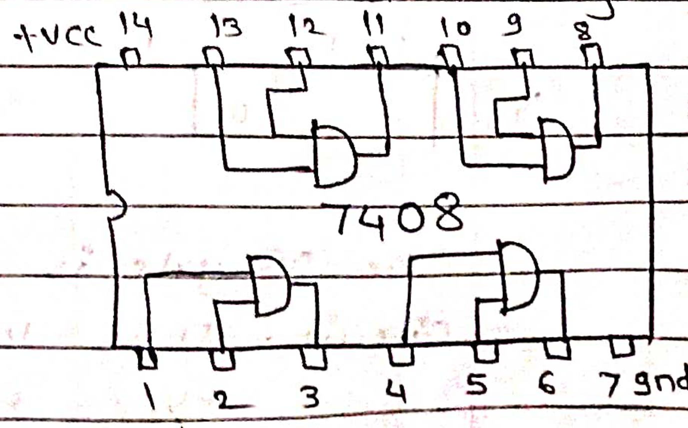
Inputs		Output
A	B	$Y = A \cdot B$
0	0	0
0	1	0
1	0	0
1	1	1

Dot between A & B represents multiplication

operation with pulsed inputs -



Standard Package.

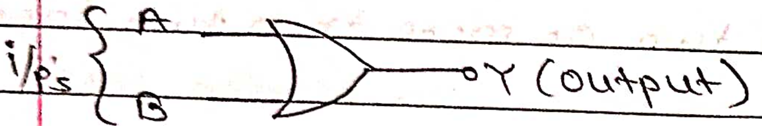


+VCC = +5V

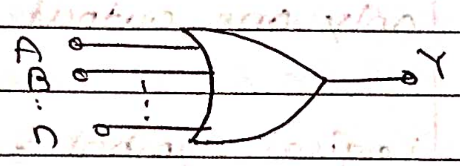
gnd = 0V

(c) **OR gate** – An OR gate performs the logical addition on its inputs therefore its o/p will be high (1) if any one or both the inputs are high (1).
The o/p will be low (0) if & only if both the i/p's are simulteneously low (0).

Logical symbol & Truth table –



Multiple i/p OR gate –



$Y = A + B$

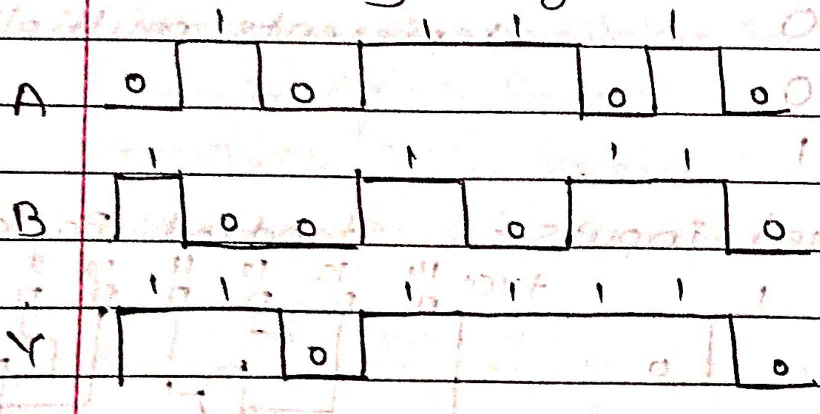
$Y = A + B + C + \cdots + n$

Truth Table –

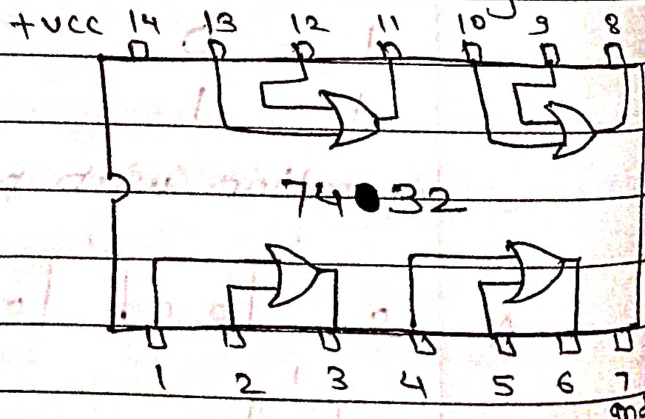
Inputs		Output
A	B	$Y = A + B$
0	0	0
0	1	1
1	0	1
1	1	1

Output of OR gate is high (1) ~~for~~ when one of its inputs or both inputs are at high (1).

Operation with pulsed i/p –
OR Timing Diagram.



Standard Package –



The OR gate is available in the monolithic integrated circuit. It is 14 pin IC. It consists of 4 gates.

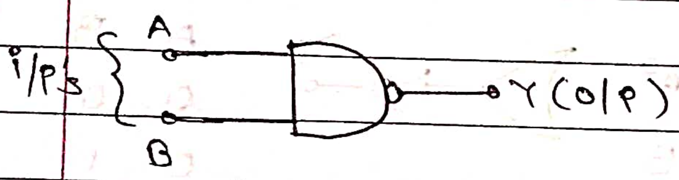
+Vcc = +5V

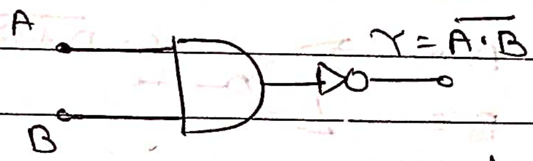
ground / gnd = 0V

(2) Universal Gates - Any basic gate can be designed by using universal gates.

(A) <u>NAND gate</u> - The term NAND can be split as NOT-AND which means that the NAND operation can be implemented with the combination of an AND gate & a NOT gate.

Logical symbol & Truth table -



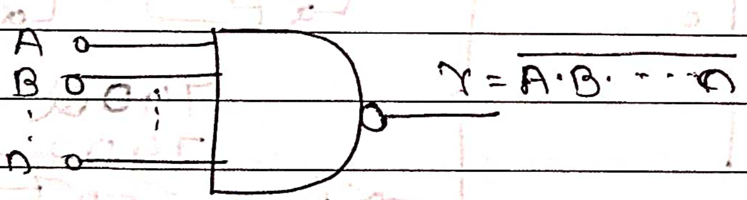


Truth table shows that the o/p is low (0) if & only if both the inputs are high (1) simulteneously. For all other combinations the o/p voltage will be high (1).

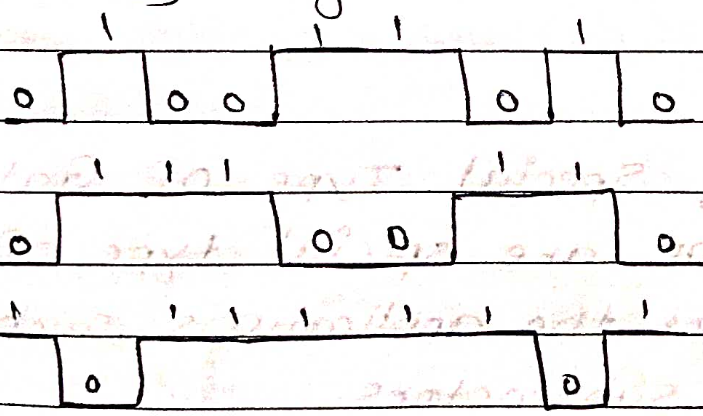
Inputs		o/p.
A	B	$Y = \overline{A \cdot B}$
0	0	1
0	1	1
1	0	1
1	1	0

We can construct AND, OR, NOT gates using NAND.

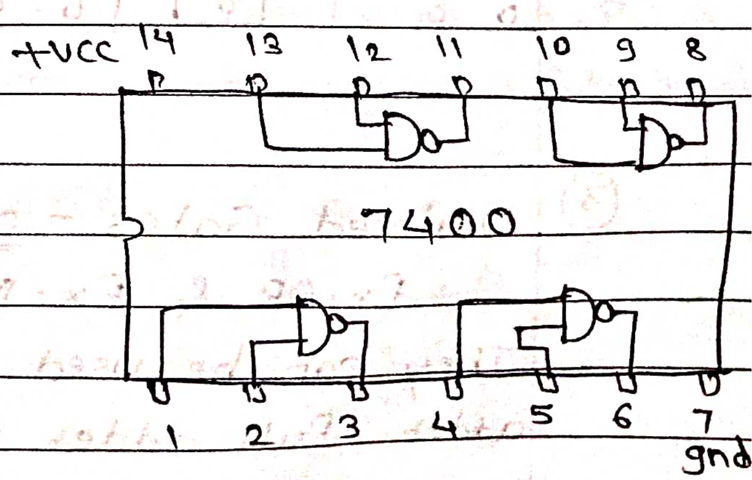
multiple i/p NAND gate -



Timing Diagram -



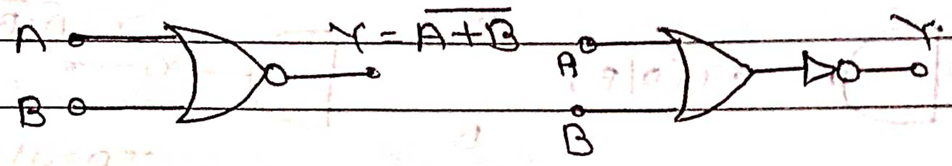
standard package -



IC 7400 consists of 4 NAND gates.

(B) **NOR gate** – The word NOR can be split as NOT-OR which means that a NOR operation can be implemented with the combination of an OR gate & a NOT gate. The output of a NOR gate is high (1) if & only if all its inputs are low (0) simulteneously. The o/p of a two i/p NOR gate is low (0) if any one or all the i/p's are at high (1) level.

Logical symbol –



I/p's		o/p
A	B	$Y = \overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

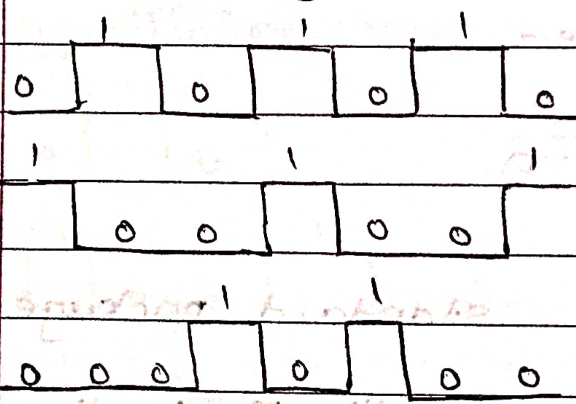
Boolean Expression –

$$Y = \overline{A+B}$$

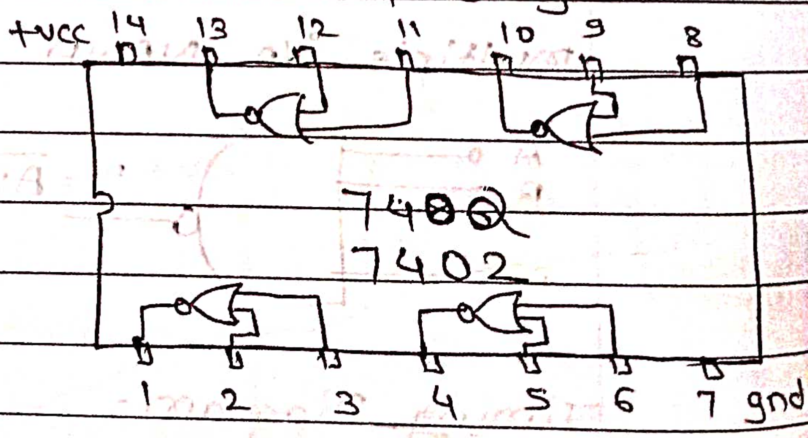
multiple i/p NOR gate.

$$Y = \overline{A+B+C+\cdots+n}$$

Timing diagram –



standard package –



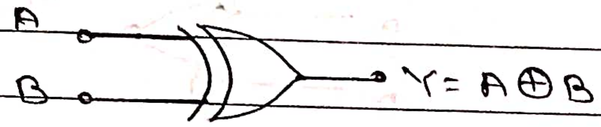
(3) Derived Gates – OR Special Type of Gates.

Ex-OR & Ex-NOR are special type of gates. They can be used for the applications such as half adder, full adder & subtractors.

Ⓐ **Ex-OR gate** - The exclusive OR gate is abbreviated as Ex-OR gate or X-OR gate.

An Ex-OR gate can have two or more inputs & one O/P.

Logical symbol & Truth table -

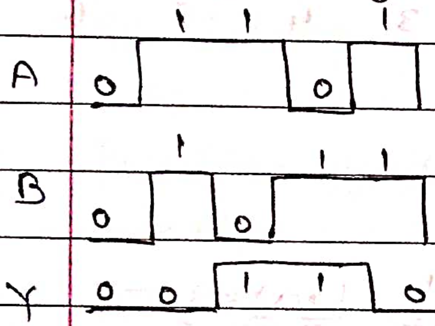


$A \oplus B = \bar{A} \cdot B + A \cdot \bar{B}$

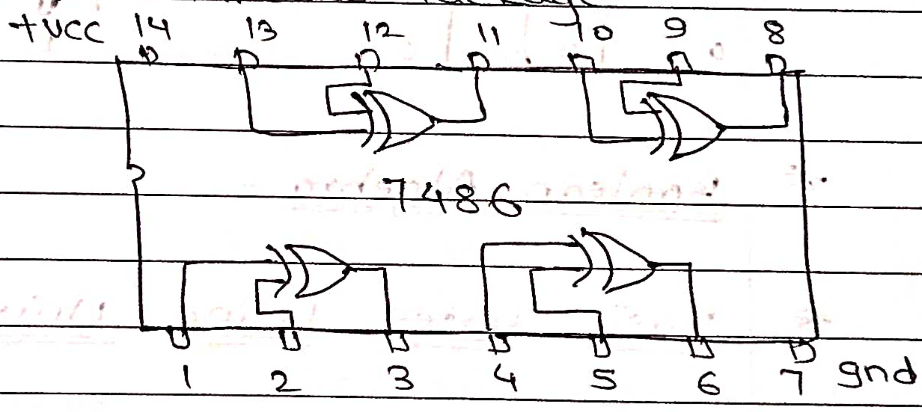
I/P's		O/P $Y = A \oplus B$
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

When both the i/p's are at identical levels ($A = B$) then the output is low (0). & o/p is high (1) when $A \neq B$.

Timing diagram -



Standard Package -

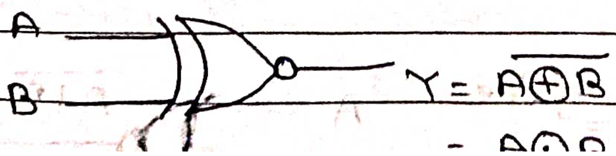


Ⓑ **Ex-NOR gate** - It is a shortform of exclusive NOR. means NOT exclusive OR. The O/P of an Ex-NOR gate is high (1) if both the inputs are identical ($A = B$) & the output is low (0) if the inputs are not identical ($A \neq B$).

Boolean Expression - $Y = \overline{A \oplus B} = \overline{\bar{A} \cdot B + A \cdot \bar{B}}$

$= \bar{A}\bar{B} + AB$

$= A \odot B$

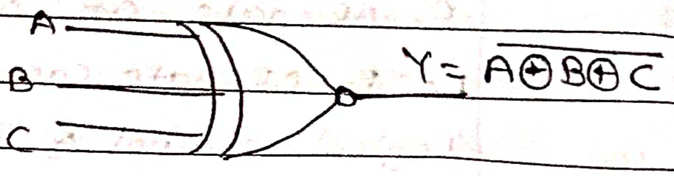


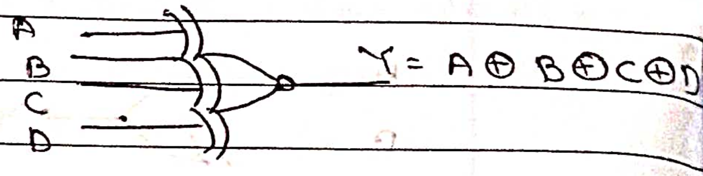
$= A \odot B$

Truth Table -

I/P's		O/P
A	B	$Y = A \odot B$
0	0	1
0	1	0
1	0	0
1	1	1

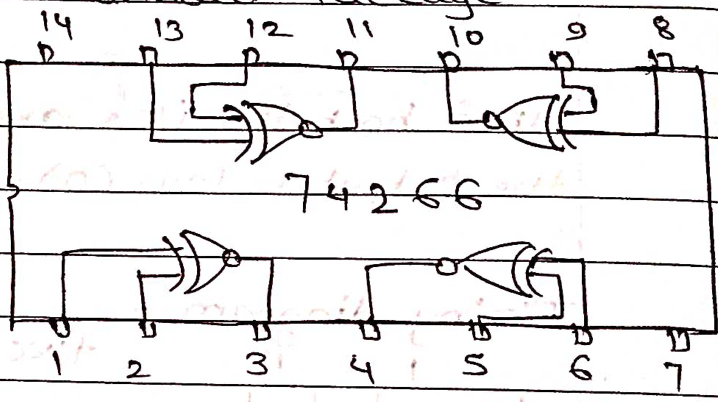
Multiple i/p Ex-NOR -





Timing diagram -

Standard Package -

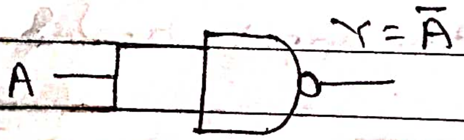


* Boolean Algebra -

* Basic Gates Using Universal Gates -

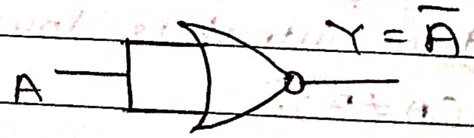
NOT gate using NAND & NOR -

(1) Using NAND -



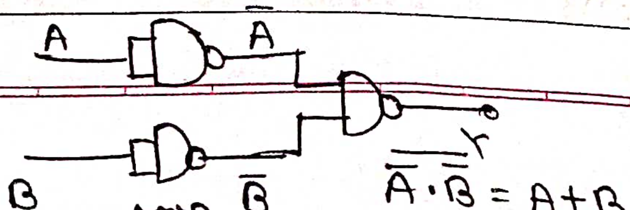
NOT gate

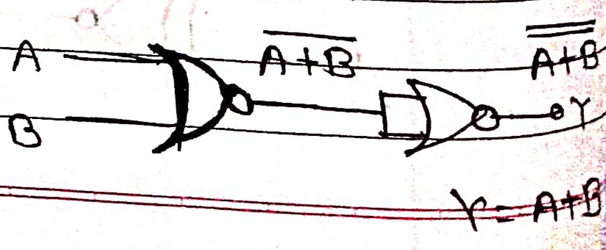
(2) Using NOR -



NOT

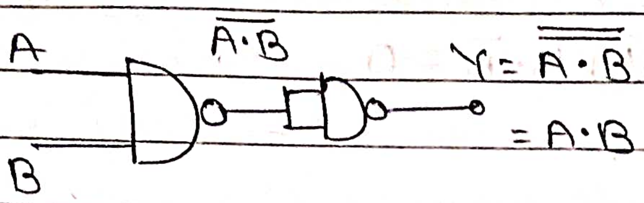
(2) Using NAND - OR gate

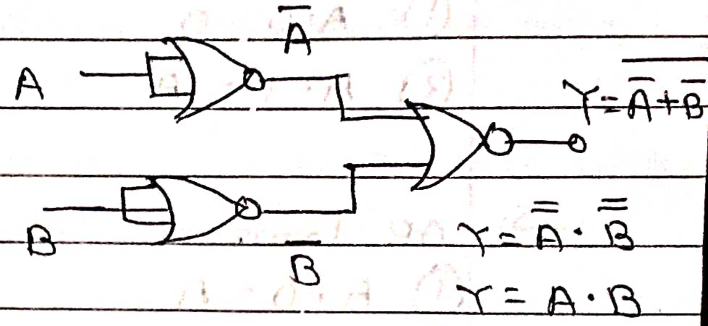




Using NOR

③ AND gate using NAND & NOR.





Boolean Algebra –

Boolean Algebra is used to analyze & simplify the digital (logic) circuits. It is also called as Binary Algebra. It was invented by George Boole in 1854.

Rules – ① only two values are used 1 & 0 i.e. High/Low

② If $A = 0$ then $\overline{A} = 1$ & if $A = 1$ then $\overline{A} = 0$.

③ ORing means addition of all variables.

④ ANDing means multiplication of all variables.

Boolean Laws –

1. Commutative law
2. Associative law
3. Distributive law
4. AND law
5. OR law
6. Inversion law.
7. De Morgan's Theorem.

1. Commutative law –

① $A \cdot B = B \cdot A$ ② $A + B = B + A$.

2. Associative law –

① $(A \cdot B) \cdot C = A \cdot (B \cdot C)$ ② $(A + B) + C = A + (B + C)$

3. Distributive law –

$$A \cdot (B + C) = A \cdot B + A \cdot C$$

4. AND laws -

① $A \cdot 0 = 0$ ③ $A \cdot A = A$

② $A \cdot 1 = A$ ④ $A \cdot \overline{A} = 0$

5. OR laws -

① $A + 0 = A$ ② $A + 1 = 1$

③ $A + A = A$ ④ $A + \overline{A} = 1$

6. Inversion law -

$$\overline{\overline{A}} = A$$

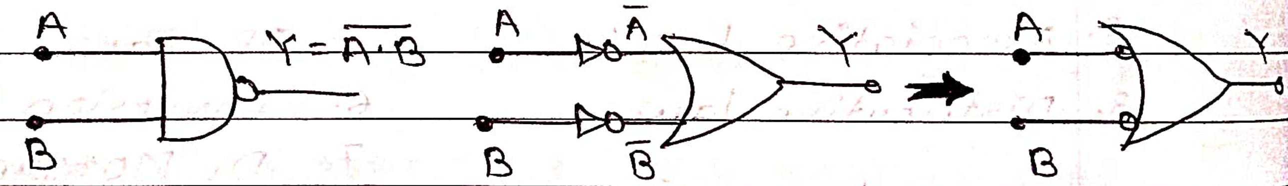
7. DeMorgan's Theorem -

① $\overline{A \cdot B} = \overline{A} + \overline{B}$ $\longrightarrow$ NAND = Bubbled OR

statement - complement of a product is equal to the addition of the complements.

LHS represents the NAND gate whereas the RHS of this theorem represents an OR gate with inverted i/p's

LHS—



Truth Table -

A	$\overline{A}$	B	$\overline{B}$	$A \cdot B$	① $\overline{A \cdot B}$	② $\overline{A} + \overline{B}$
0	1	0	1	0	1	1
0	1	1	0	0	1	1
1	0	0	1	0	1	1
1	0	1	0	1	0	0

Thus from truth table - $\overline{A \cdot B} = \overline{A} + \overline{B}$

& columns ① & ②

① $Y = ABC\bar{D} + \bar{A}B\bar{C}\bar{D} + \bar{A}BC\bar{D} + ABC\bar{D}$ ⑤ $Y = (\overline{A\cdot B}) + (\overline{A+B})\cdot(B+C)$

② $Y = AB + A(B+C) + B(B+C)$ ⑥ $Y = (A+\bar{B})(A+C)$

③ $Y = (A+B+C)(A+B)$

④ $Y = A\bar{B}D + A\bar{B}\bar{D}$

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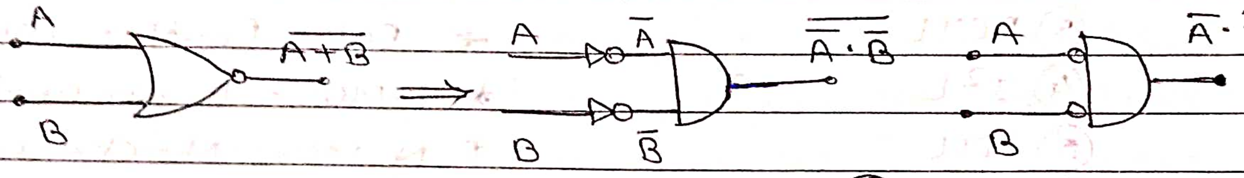
② $\overline{A+B} = \bar{A}\cdot\bar{B}$ NOR = Bubbled AND.

statement - complement of addition is equal to the product of complements.

The LHS of this theorom represents a NOR gate with inputs A & B whereas the RHS represents an AND gate with inverted inputs.

NOR = Bubbled AND.



Truth Table -

A	$\bar{A}$	B	$\bar{B}$	A+B	$\overline{A+B}$ (I)	$\bar{A}\cdot\bar{B}$ (II)
0	1	0	1	0	1	1
0	1	1	0	1	0	0
1	0	0	1	1	0	0
1	0	1	0	1	0	0

Thus from truth table & columns (I) & (II) $\overline{A+B} = \bar{A}\cdot\bar{B}$.

1.1 Introduction :

- Instrumentation has become the heart of the industrial applications due to the possibility of system automation.
- Instrumentation is being used in industry on a large scale since 1930.
- With the introduction of electronics, availability of reliable electrical equipments, sophisticated monitoring systems etc., the use of instrumentation increased to a great extent in the last three or four decades.
- A **transducer** converts the measurand into a usable electrical signal. The transducer is a device which is capable of converting the physical quantity into a proportional electrical quantity such as voltage or current.

1.2 Transducer Definition :

- Transducer is a device which converts a physical quantity to be measured into an equivalent electrical signal (voltage or current).
- The physical quantity to be measured can be temperature, pressure, displacement, flow, vibration, etc.
- The electrical signal obtained from the transducer is then used to control the physical quantity automatically and/or to display the same, as shown in Fig. 1.2.1.

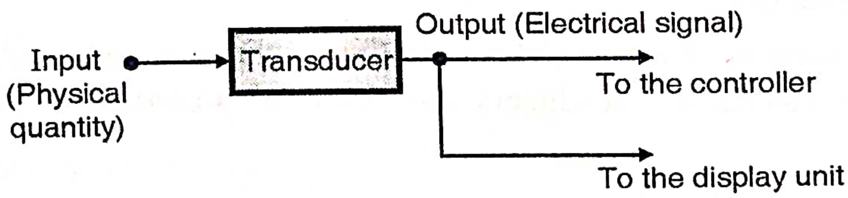


Fig. 1.2.1 : Transducer

- A transducer is also called as a **pick up** element. It contains two parts that are closely related to each other i.e the sensing or detecting element and the transduction element.

- The sensing or detecting element is called as the **sensor**. It is a device producing measurable response to change in physical conditions.
- The transduction element converts the sensor output to suitable electrical form.
- Fig. 1.2.2 shows block diagram of a transducer.

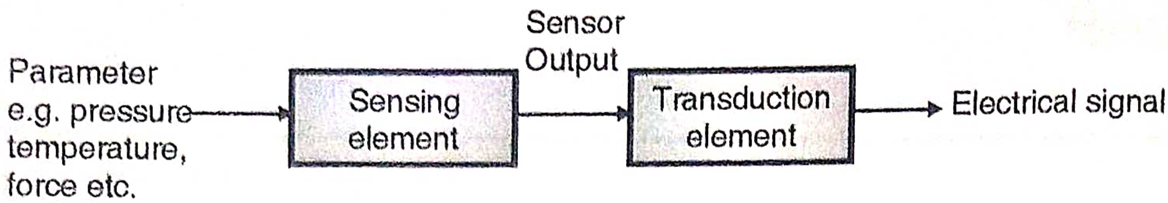


Fig. 1.2.2 : Transducer block diagram

- Generally the range of electrical signal used is 0 to 5V or 4 to 20 mA, 4 to 20 mA range is commonly used to represent an analog signal.
- A current of 4 mA represents zero output while a current of 20 mA represents a full scale value. The zero condition represents open circuit is the transmission line. Hence, the standard range is offset from zero.
- Sometimes the transducer is a part of system and works with other elements to achieve desired output. This kind of circuit is called as a **signal conditioning circuit.**

- An electrical transducer must have the following characteristics.

Some of the important characteristics of a transducer are as follows :

1. **Ruggedness :** It is the ability of a transducer to withstand overloads. A good transducer must have a high degree of ruggedness.
2. **Linearity :** The relation between the output and input of a transducer should be linear. Linearity is a very important characteristics while selecting a transducer.
3. **Repeatability :** It is the ability of a transducer to reproduce the output signal exactly when the same input is applied repeatedly under the same environmental conditions.
4. **Accuracy :** It is defined as closeness of the actual output produced by a transducer, to the ideal or true value of the quantity being measured. For any transducer the accuracy should be as high as possible.
5. **High stability and reliability :** There should be a minimum amount of error in measurement and it should be unaffected by temperature, vibrations and other environmental variations.
6. **Speed of response :** It shows how quickly a transducer responds to the changes in the quantity being measured. The speed of response should be as high as possible.
7. **Sensitivity :** The sensitivity of a transducer is defined as the output produced per unit change in the input quantity being measured. For example the sensitivity of a thermocouple is expressed in mV°/C. The sensitivity should be as high as possible.
8. **Small size :** A transducer must have small size, proper shape and minimum volume so that it can be placed at any location for measurements.
9. **Dynamic range :** The operating range of the transducer must be wide to allow its use under a wide range of measurement conditions.

.5 Types of Transducers :

The electrical transducers are classified according to their structure, application area, method of energy conversion, etc.

The transducers are classified as :

- Active and passive transducers.
- Analog and digital transducers.
- Depending on the basis of transduction principle used.
- Primary and secondary transducer
- Transducers and inverse transducer.

1.5.1 Active and Passive Transducers :

Active transducers :

1. These transducers do not need any external source of power for their operation. Therefore they are also called as **self generating type transducers.** The active transducers can be further classified as shown in Fig. 1.5.1.

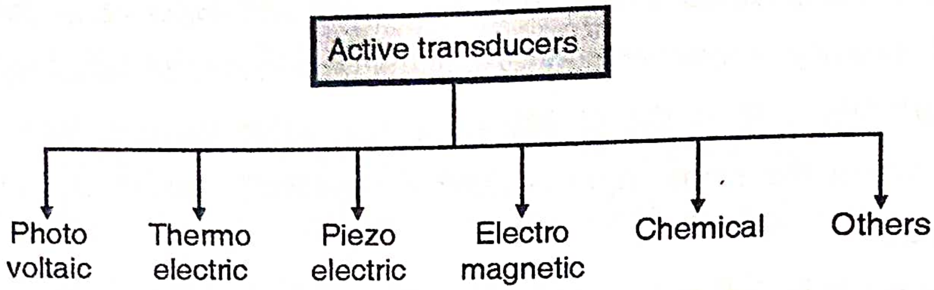


Fig. 1.5.1 : Classification of active transducers

2. The active transducers are self generating devices which operate under the energy conversion principle.
3. At the output of active transducers we get an equivalent electrical output signal e.g. temperature to electric potential, without any external source of energy being used.

Passive transducers :

- These transducers need external power supply for their operation. So they are not "self generating type" transducers.
- A DC power supply or an audio frequency generator is used as an external power source.
- These transducers produce the output signal in the form of variation in resistance, capacitance or some other electrical parameter in response to the quantity to be measured.
- Passive transducers are further subdivided as shown in Fig. 1.5.2.

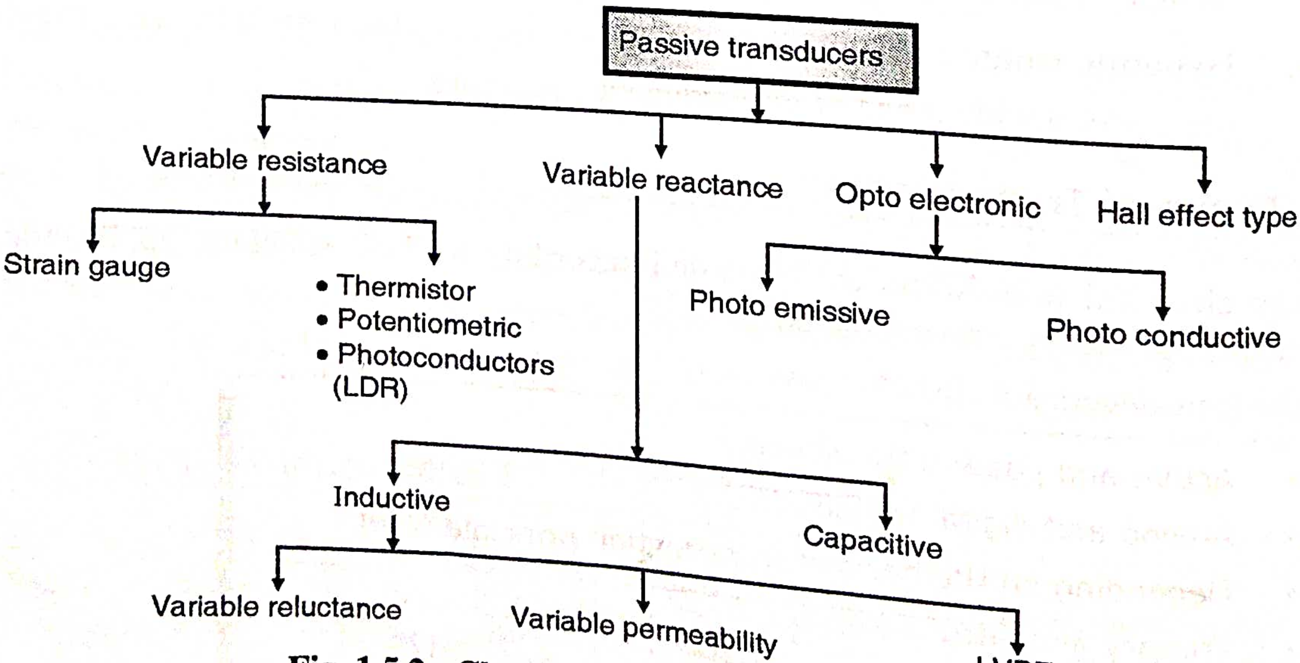


Fig. 1.5.2 : Classification of passive transducers

1.5.2 Analog and Digital Transducers :

Depending on the nature of output obtained from a transducer, it is classified into two categories namely analog transducers and digital transducers.

Analog transducers :

The output of these transducers is in the analog form that means it is a continuous function of time. The examples of analog transducer are thermocouple, LVDT, strain gauge, etc.

Digital transducers :

The output of these transducers is in the digital form that means it is in the form of digital pulses discrete in time. These pulses form a unique code for each value sensed.

1.5.3 Primary and Secondary Transducers :

(1) Some transducers contain the mechanical as well as electrical devices. The mechanical device converts the physical quantity to be measured into a mechanical signal. Such mechanical devices are called as the primary transducers, because they deal with the physical quantity to be measured.

(2) The electrical device then converts this mechanical signal into a corresponding electrical signal. Such electrical devices are known as the secondary transducers.

(3) Refer Fig. 1.5.3 in which the diaphragm acts as a primary transducer. It converts pressure (the quantity to be measured) into displacement (the mechanical signal).

The displacement is then converted into electrical signal using LVDT. Hence LVDT acts as the secondary transducer.

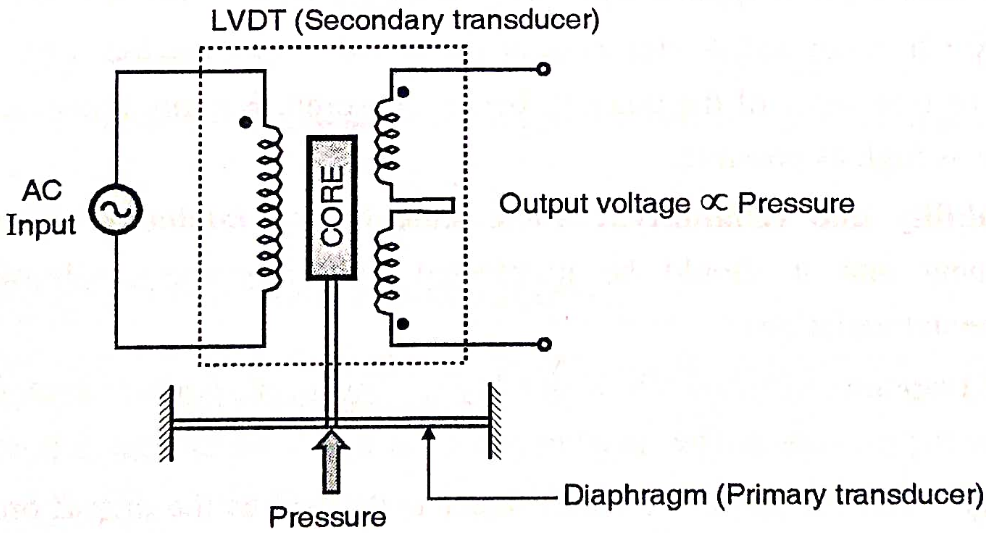


Fig. 1.5.3 : Primary and secondary transducers

1.5.4 Transducer and Inverse Transducer :

Transducers convert non-electrical quantity to electrical quantity while inverse transducers convert electrical quantity to a non electrical quantity.

There are different examples of inverse transducers that follow the above definitions. The piezoelectric crystal comes into both the category i.e. transducer and inverse transducer. The operation of piezoelectric crystal as a transducer will be discussed in the further sections :

The piezoelectric crystal also acts as an inverse transducer because when a voltage is applied across its surfaces, it changes its dimensions causing a mechanical displacement.

- A PMMC instrument is also a inverse transducer in which current carrying coil moves in a stationary magnetic field because in this, the current carried by it is converted into the force which causes displacement.
- An analog ammeter or voltmeter convert current into mechanical displacement. However, such devices that include indicating instruments like pen recorders, oscilloscopes that convert the electrical signals to mechanical movement are placed at the output stage and are called as **output transducers.**

No.	Class of Transducer	Applications
3.	Ele[illegible]netic flowmeters	(i) Flow measurement of slurries, sludge and electrically conducting liquid.
4.	Ultrasonic [illegible]s	(i) Flow measurement of liquids.
5.	Bourdon Tubes, [illegible]ms	(i) Pressure measurement
6.	Bellows	(i) Measurement of absolute, gauge and differential pressures.
7.	Thermocouples	[illegible] Temperature measurement Pyrometers
8.	Loadcell	(i) [illegible]rce measurement (ii) [illegible]t measurement
9.	In-line rotating torque sensor, In-line stationary torque sensor,	(i) To[illegible]easurement
10.	Microphones	(i) Sound mea[illegible]ent
11.	Hall effect	(i) Magnetic flux [illegible]urement (ii) Displacement m[illegible]ement (iii) Measurement of cu[illegible]
12.	Piezoelectric sensors	(i) Force measurement (ii) Pressure measurement (iii) Mass to frequency converte[illegible] (iv) Temperature measurements (v) Accelerometers

1.9 Motion Transducers

1.9.1 Linear Variable Differential Transformer (LVDT) :

- It is a passive differential inductive transducer.
- This is a variable inductance displacement transducer. The construction of LVDT is as shown in Fig. 1.9.1(a).

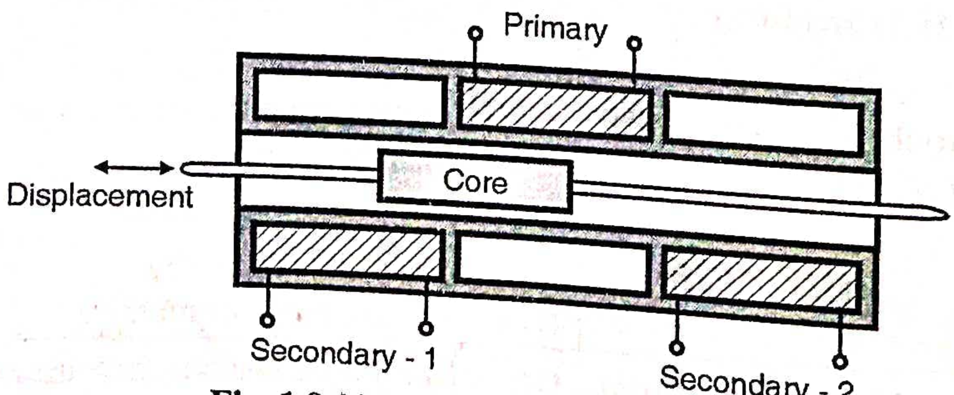
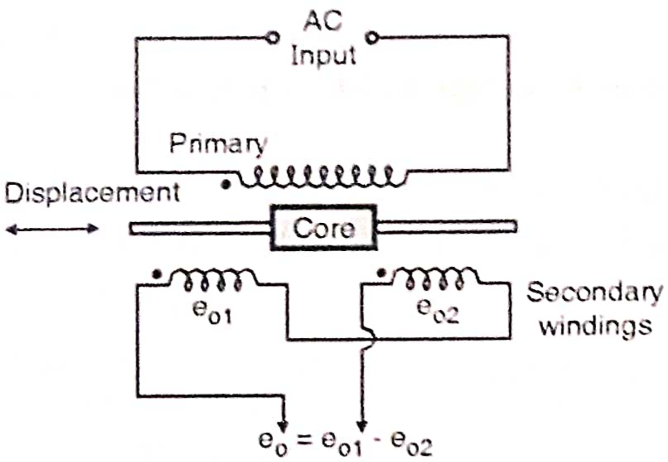


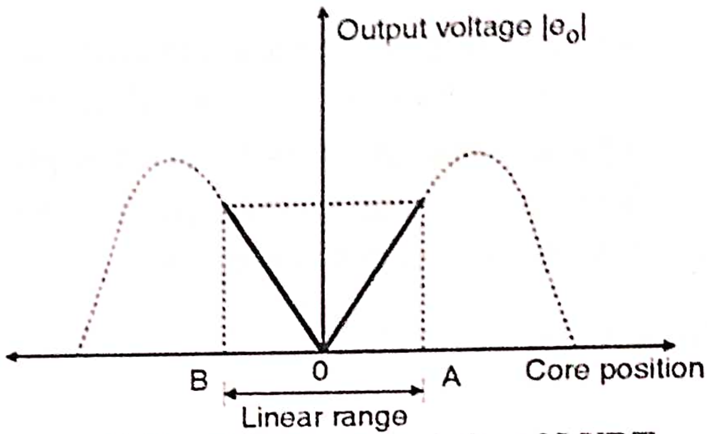
Fig. 1.9.1(a) : Construction of LVDT

1.9.1.1 Construction of LVDT :

1. Refer to Fig. 1.9.1(b), the LVDT consists of a primary winding and two identical secondary windings. These windings are axially spaced and wound on a cylindrical coil former.
2. A rod shaped magnetic core is positioned centrally inside the coil assembly. This rod provides a low reluctance path for the magnetic flux linking the coils (windings).
3. The moving object, displacement of which is to be measured, is coupled to this movable rod.



(b) Connections of LVDT windings



(c) Transfer characteristics of LVDT

Fig. 1.9.1

4. The two secondary winding are connected in series opposition as shown in Fig. 1.9.1(b). Hence the voltages induced into these windings are of opposite polarities. The output voltage is given by,

$$\boxed{e_o = e_{o1} - e_{o2}} \quad ...(1.9.1)$$

- Where e_{o1} and e_{o2} are the emfs induced in the two secondary windings.
- The transfer characteristics of LVDT is shown in Fig. 1.9.1(c).
- It is the graph of output voltage against the core position.

1.9.1.2 Operation of LVDT :

(i) The primary winding is connected to the ac source.

(ii) Assume that the core is exactly at the centre of the coil assembly. Then the flux linked to both the secondary windings will be equal.

(iii) Due to equal flux linkage, the secondary induced voltages are equal but they have opposite polarities.

(iv) The output voltage of LVDT i.e. "e_o" is therefore zero corresponding to the central position of the core. This position of the core is called as the **"null position"**.

(v) Now if the core is displaced from its null position towards secondary-1 then the flux linked to secondary-1 increases and flux linked to secondary-2 decreases.

(vi) Therefore the induced voltage "e_{01}" is now greater than "e_{02}" and the output voltage of LVDT i.e. "e_0" will be positive as shown in Fig. 1.9.1(c).

(vii) Similarly if the core is displaced downwards i.e. towards the secondary-2 then "e_{02}" will be greater than "e_{01}" and the output voltage "e_0" will be negative.

- Thus the magnitude of output signal is made to vary "linearly" with the mechanical displacement.
- Hence the word "Linear," is used in LVDT. The output is obtained "differentially" between the two secondary windings. Hence the word "differential" is used in LVDT.

1.9.1.3 Principle of Operation of LVDT :

- The LVDT produces a differential voltage at its output which is proportional to the position of the core, from its null position.
- Thus a voltage proportional to the displacement of core is obtained at the LVDT output.
- The operation of LVDT with the help of its transfer characteristics and equivalent circuits is as shown in Fig. 1.9.2.

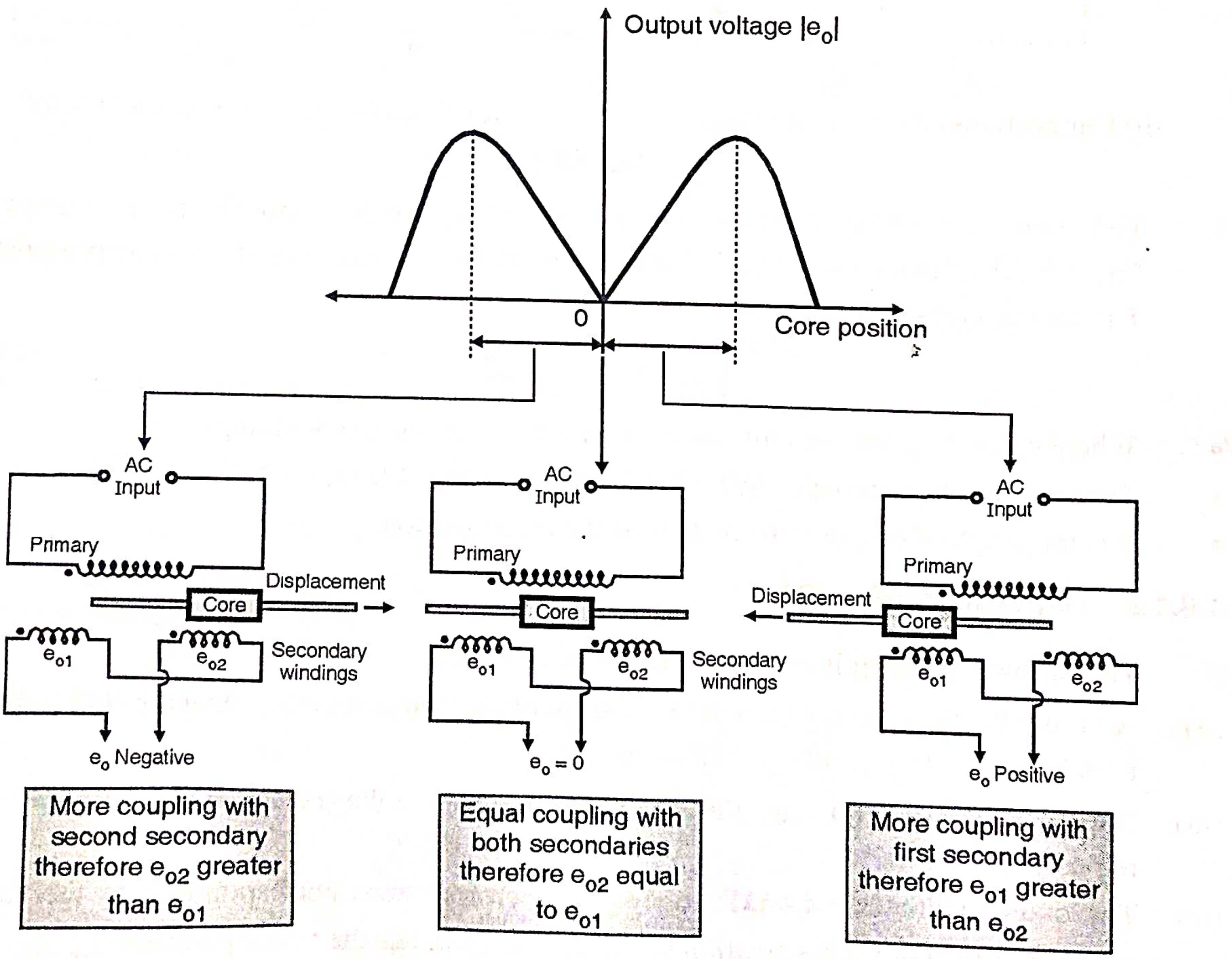


Fig. 1.9.2 : Operation of LVDT

1.9.1.5 Advantages of LVDT :

1. Very fine resolution
2. High accuracy
3. Very good stability
4. Linearity of transfer characteristic (better than 0.25 %)
5. Ease of fabrication and installation
6. Ability to operate at high temperature.
7. High sensitivity (2mV/Volt/10 microns at 4 kHz excitation).
8. Stable and easy to maintain.
9. Cab bear high degree of shock and vibration specially when the core spring is loaded with adverse effects.
10. Simple in construction.
11. Low hysteresis and repeatability is excellent.
12. Consume low power (typically less than 1 W)

1.9.1.6 Disadvantages of LVDT :

1. LVDT is sensitive to the external magnetic fields. To minimize this effect magnetic shielding is necessary.
2. Complicated circuitry is needed.
3. Due to mass of the core, LVDT is not suitable for dynamic measurement (fast displacements).
4. Larger displacements are needed to get appreciable differential output.
5. Temperature affects performance.
6. Dynamic response is limited.
7. Affected by vibrations.

1.9.1.7 Applications of LVDT :

LVDT can be used for the following :

1. In addition to displacement measurement the LVDT is used in measurement of pressure, load, acceleration, force, weight etc.
2. Measurement of displacement ranging from fraction of a mm to a few cm.
3. As a secondary transducer for measurement of force, pressure weight.
4. Measurement of liquid level in tank.
5. Measurement of tension in a chord.
6. Measurement and control of thickness of metal sheet being rolled

1.12.10 Thermistors :

- Thermistors are also temperature dependent resistors. They are made of semiconductor materials which have a negative temperature coefficient of resistivity.
- The variation of resistance with changes in temperature is nonlinear. Thermistors can be used to measure temperatures in the range of – 100° C to 300° C.
- The resistance of a thermistor can be expressed as,

$$R_T = R_0 \exp\left[\beta\left(\frac{1}{T}-\frac{1}{T_0}\right)\right]$$

Where R_T = Resistance at T °K,

R_0 = Resistance at T_0 °K

and β = Characteristics temperature.

- The thermistors provide a large change in resistance for small changes in temperature. In some cases the resistance of thermistor at room temperature may decrease as much as 6 percent for each 1°C rise in temperature.
- Typically we can get a change of 80 ohms/°C which is much larger than a 7 ohms/°C change obtained from a platinum wire resistance sensor. Thus thermistors have a high resolution.
- The variation in the resistance of a thermistor is as shown in Fig. 1.12.14.

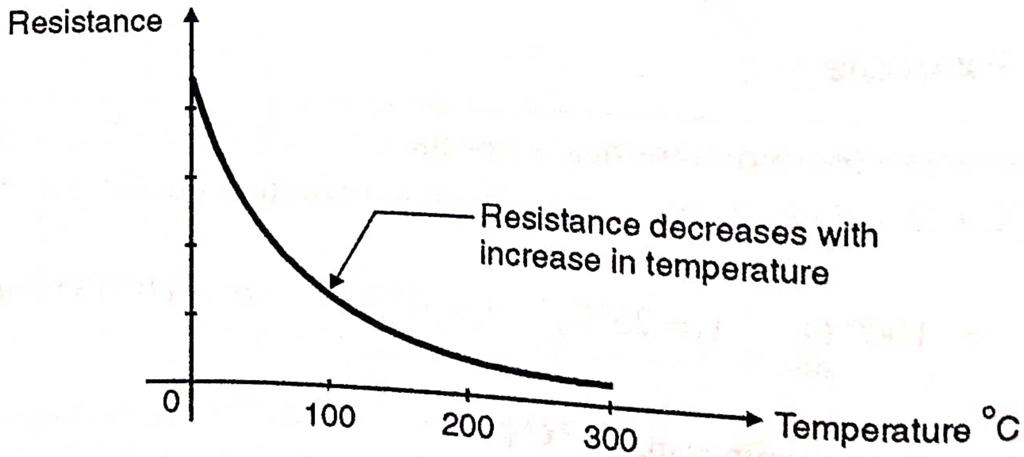


Fig. 1.12.14 : Variation in resistance of a thermistor with temperature

The resistance decreases with increase in temperature, hence this is called as the negative temperature coefficient thermistor [NTC].

The resistance of thermistors varies from 0.5 Ω to 0.75 MΩ.

The resistance-temperature characteristics of a thermistor are non-linear. Fig. 1.12.14 shows this.

Fig. 1.12.15 shows V-I characteristics of the thermistor.

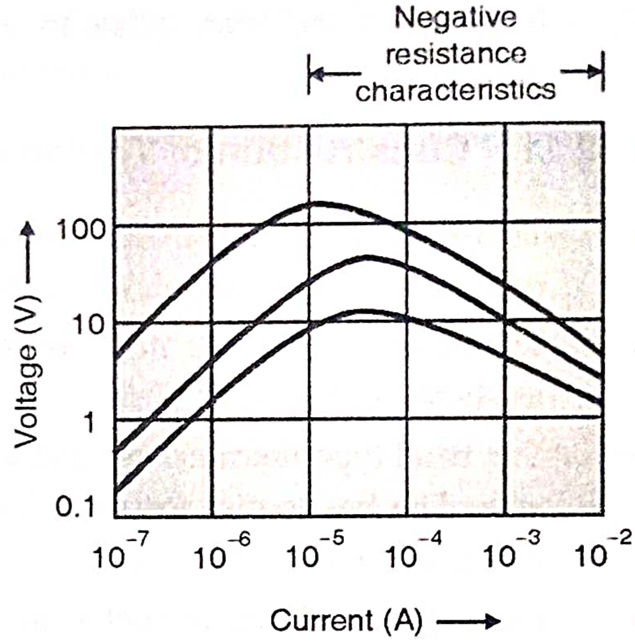


Fig. 1.12.15 : V-I characteristics of thermistor

The voltage drop across the thermistor increases with the increase in current till a peak value is reached. After reaching the peak value the voltage drop decreases as the current increases. Thermistor exhibits negative resistance characteristics in this region.

When large current and large voltages are applied to thermistors, the heat produced is sufficient to raise the temperature of the thermistor above the ambient temperature. This causes the resistance of the thermistor to decrease. As the amount of current drawn increases, the resistance of the thermistor continues to decrease.

The current increases till the heat dissipated is equal to the power supplied i.e. the resistance of thermistor is a function of power dissipated. This characteristic is called **self heating**. It can be used to measure flow, pressure, liquid level, composition of gases, etc.

Fig. 1.12.16 shows the current time (I-t) characteristics of a thermistor.

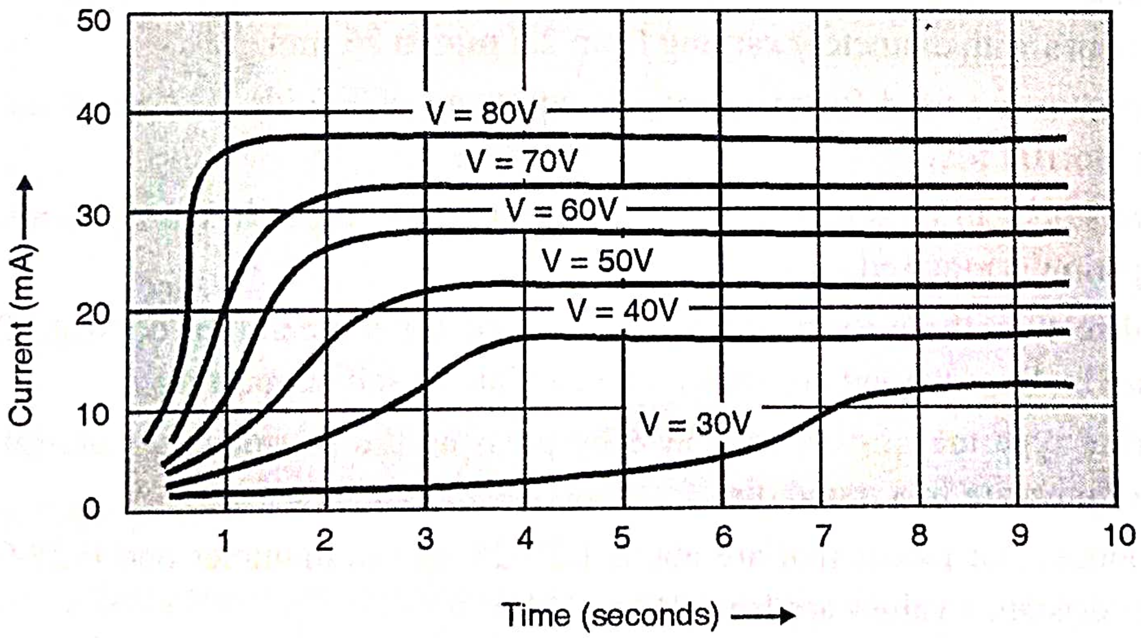


Fig. 1.12.16 : Current time characteristics of thermistor

- It indicates the time delay to reach maximum current as a function of the applied voltage.

1.12.11 Construction of Thermistors :

- Thermistors are constructed using the materials such as sintered mixtures of metallic oxides of manganese, nickel, cobalt, iron, copper, etc.
- Thermistors are available in various configurations such as small beads, disks, rods etc. as shown in Fig. 1.12.17.
- The bead type thermistors have a diameter of 0.015 mm to 1.25 mm and are smallest in size. The beads may be sealed in the tips of solid glass rods to form probes that are easier to mount.
- Glass probes have diameter of approximately 2.5 mm and their length varies from 2.5 mm to 25 mm.

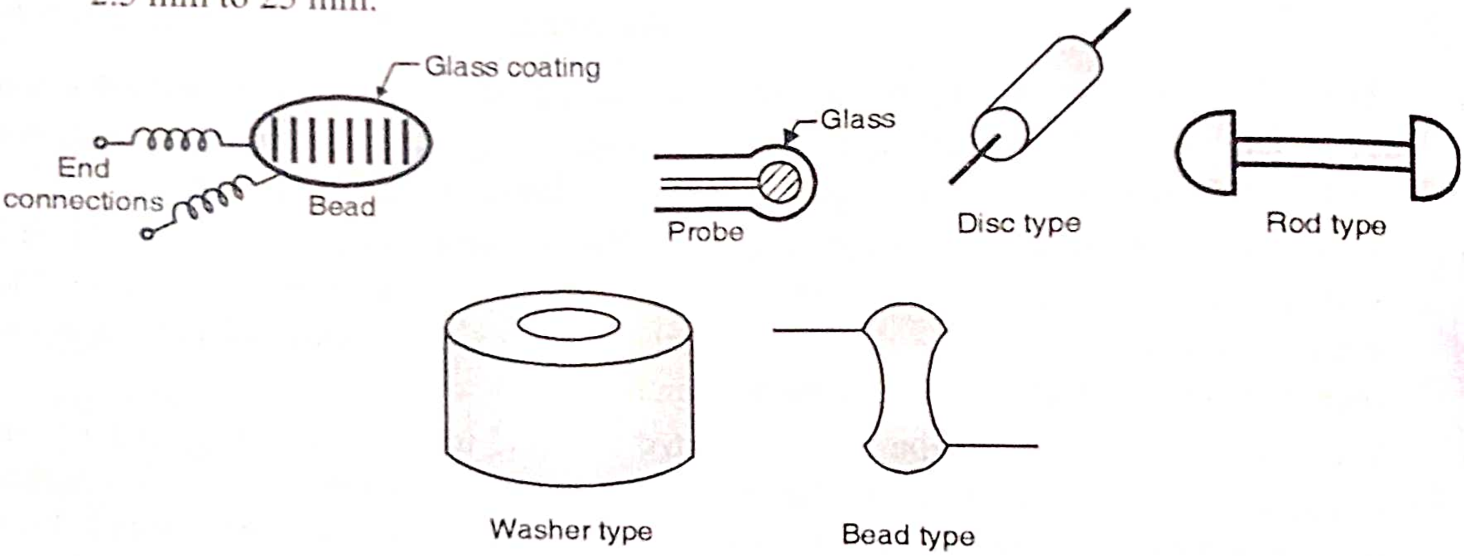


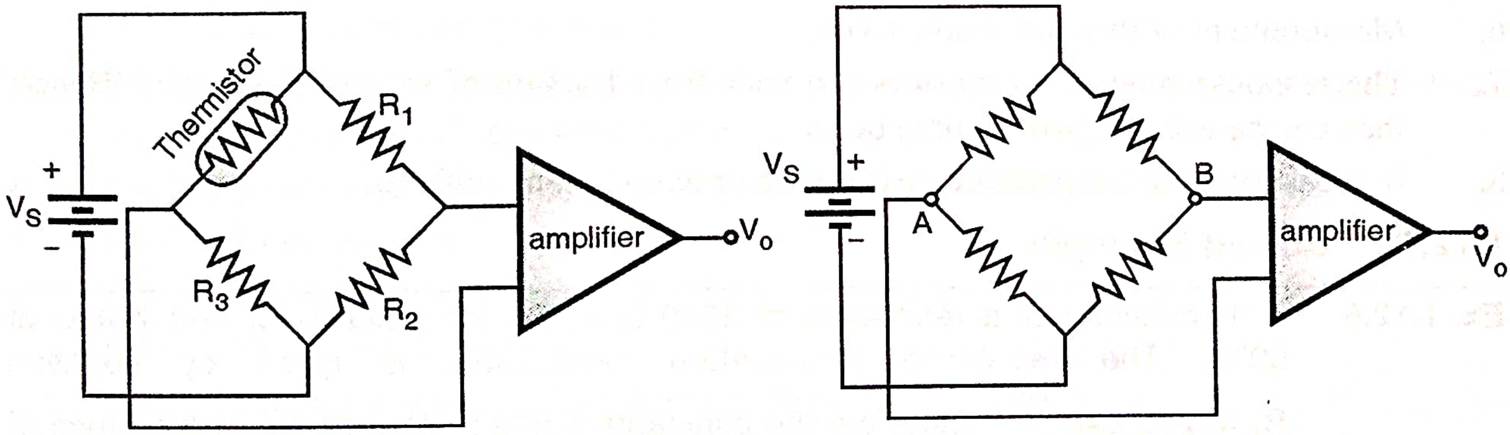
Fig. 1.12.17 : Configurations of thermistors

- The discs are made by pressing thermistor material under high pressure into cylindrical flat shapes with diameters varying from 2.5 mm to 25 mm.
- The probes are used for measuring temperature of liquids. The resistance ranges from 300 Ω to 100 MΩ.
- Thermistors can be obtained in disc, washer or rod types in cases where greater power dissipation is required.
- The disc type thermistors are generally used for temperature control. They are about 10 mm in diameter and are mounted on a plate or self supporting.
- The disc type thermistors are made by pressing the thermistors material under several tons of pressure in a round die.
- It produces flat pieces that are about 1.25-25 mm in diameter and 0.25-0.75 mm thick. Their resistance values are from 1Ω to 1MΩ.
- They are sintered and wated with silver on two flat surfaces.

- The washer type thermistors are also manufactured like the disc type thermistors, except that a hole is created in the centre, so that a bolt can be mounted.
- The rod type thermistors are manufactured through dies. They are long cylindrical units having diameter of 1.25 mm, 2.75 mm and 4.25 mm. Their length is 12.5 mm-50 mm. Generally leads are attached to the ends the rods. The resistance of rod type thermistors varies from 1 kΩ-50 kΩ.
- Rod type thermistors can produce high resistance units. Also their power handling capacity is high. This makes them advantages over other types of thermistors.
- The thermistors can be connected in series / parallel depending on the power handling capacity of the instrument.
- Thermistors can be used in nuclear environments as they are chemically stable. They can also be used for integration of power pulses, as memory units as time delays etc due to their wide range of characteristics.
- Thus, thermistors are non-linear devices. They have a sensitivity of 3 mV/ °C at 200°C.

1.12.12 Measurement Technique Using Thermistor :

- The changes in the thermistor resistance due to changes in temperature can be converted into proportional voltage changes using the standard Wheatstone bridge as shown in Fig. 1.12.18(a) and (b).
- The voltage proportional to the resistance changes is produced at the bridge output.
- This voltage can be applied to an OP-AMP for amplification and used it for controlling the temperature.
- The Wheatstone bridge shown in Fig. 1.12.18(b) has higher sensitivity because it uses two thermistors instead of one.



(a) (b)

Fig. 1.12.18 : RTD resistance measurement

1.12.13 Advantages of Thermistor :

The advantages of thermistors are as follows :

1. They are suitable for precision temperature measurements, temperature control and temperature compensation.

2. High resolution (80 Ω/°C).
3. Small size, compact, rugged and inexpensive.
4. Ideally suitable for measurement of temperature distribution or temperature gradient.
5. When properly aged, they exhibit good stabilities.
6. Fast response over narrow temperature range.
7. Good sensitivity in the NTC region.
8. Cold junction compensation not required due to dependence of resistance on absolute temperature.
9. Contact and lead resistance problems are not encountered due to large resistance.

1.12.14 Disadvantages of Thermistor :

The disadvantages of thermistors are as follows :

1. Temperature versus resistance characteristics is nonlinear.
2. Not suitable for wide range operation. (Range is – 100° C to 300° C).
3. Low excitation current to avoid self heating.
4. Needs external dc power supply for its operation.
5. Need of shielded power lines, filter etc due to high resistance.

1.12.15 Applications of Thermistor :

Some of the typical applications of a thermistor are as follows :

1. As a temperature sensor with or without compensation.
2. In biomedical instrumentation.
3. Measurement of power at high frequencies.
4. Measurement of level, flow and pressure of liquids.
5. Measurement of composition of gases.
6. Measurement of thermal conductivity.
7. The response time of thermistors can vary from fraction of second to minutes. Hence, they can be used to provide time delay.
8. In measuring the temperature distribution or temperature gradient.

1.20.4 Photodiode :

- The photodiode can be used to serve the same purpose as that of a photoconductive cell.
- A photodiode is a reverse biased p-n junction diode. When it is not exposed to light the current that passes through the diode is small leakage current. As light passes through the diode the current passing through it increases.
- When a photodiode is operated with application of reverse voltage it operates like a photoconductive cell. When the photodiode operates without the application of reverse voltage it functions like a photovoltaic cell.

- Comparing the photodiodes with photoconductors, the photodiode has better frequency response, spectral response linearity and low noise.
- The response time of a photodiode is very fast.
- Fig. 1.20.6 shows a switching circuit using photodiode.

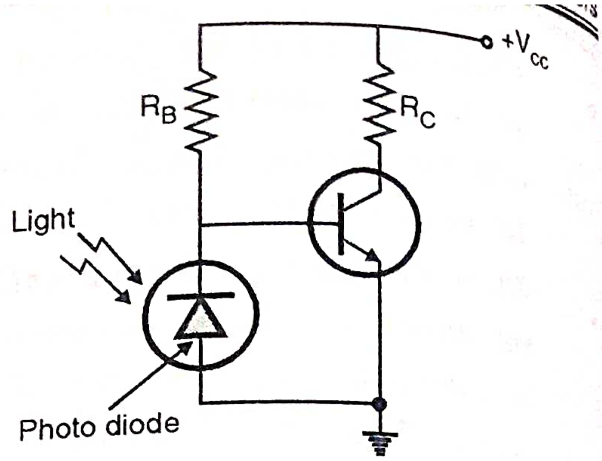


Fig. 1.20.6 : Switching circuit using photodiode

- The transistor is normally on due to the bias resistor R_B. When the photodiode is illuminated i.e. light falls on the photodiode, the base current is reduced and the transistor turns off.

1.20.4.1 Drawbacks of Photodiodes :

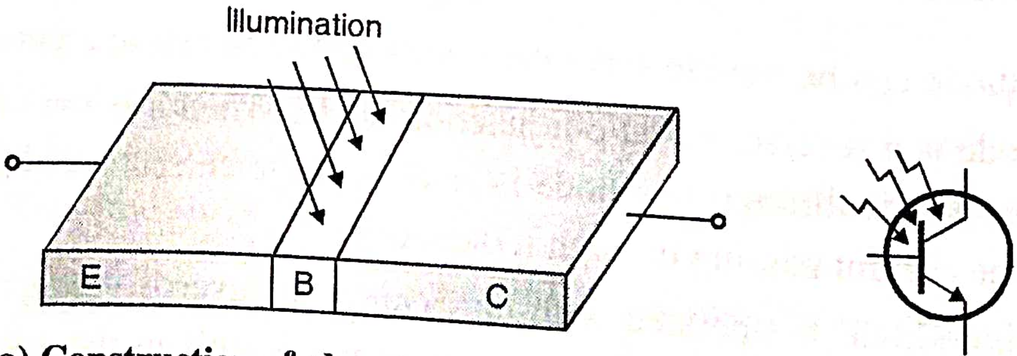
1. Small active area.
2. The rapid increase in dark current with temperature.
3. Need of amplification at low illumination levels.

1.20.4.2 Applications of Photodiodes :

1. In sound track readers due to fast response time.
2. In switching elements.
3. Detectors of modulated light in optical communication systems.
4. Photo cell or a photovoltaic cell.

1.20.5 Phototransistors :

- By the addition of a junction to the photodiode, its sensitivity can be increased. Due to the addition of the junction the sensitivity may increase upto 100 times. The resulting N-P-N device is called as a **phototransistor**. Fig. 1.20.7(a) shows the construction of a phototransistor and Fig. 1.20.7(b) shows its symbol.



(a) Construction of phototransition **(b) Symbol**

Fig. 1.20.7

- When light falls on the central region (i.e. on the base) the electron hole pairs are released. Due to this the barrier potential across the junctions lowers increasing the flow of electrons from the left to centre to right.
- For a given illumination on small area large output current is provided by the phototransistor than the photodiode and the photocell.
- Fig. 1.20.8 shows a relay control circuit using phototransistor. The light incident on the phototransistor causes the current to increase. The voltage drop across the 20 kΩ resistance increases and the relay is energised. The current is raised to operational level.
- In absence of light current through phototransistor is very small. This reduces the voltage drop across the resistance and relay is deenergized.

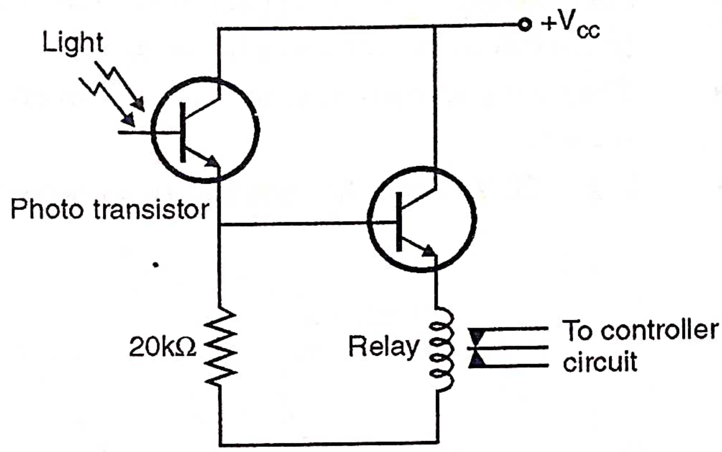


Fig. 1.20.8 : Relay control circuit using phototransistor

1.20.5.1 Advantages of Phototransistors :

1. They are small in size.
2. They consume less power.
3. They operate immediately as they are turned on.
4. They require less voltage for their operation.
5. Their operating life is long.
6. They have high gain and are used in digital applications.

1.20.5.2 Applications of Phototransistors :

1. They are used in linear light meters.
2. For operating relays.
3. In shaft encoders to translate angular motion to digital code.
4. As switching devices for digital circuits.
5. Punch cards.
6. Counting of objects.
7. Pattern recognition.

1.20.6 Photovoltaic Cell :

- The photovoltaic cells generate a voltage that is proportional to the electromagnetic radiation intensity. The name photovoltaic is because of the voltage generation characteristic.

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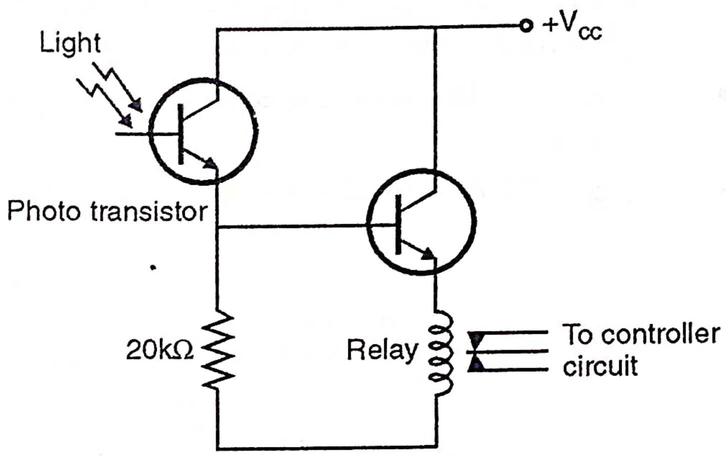

Fig. 1.20.8 : Relay control circuit using phototransistor

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5.5.4 Magnetic and Photoelectric Pulse Counting Methods :

Speed Transducer: Tachometer

(a) Variable reluctance tachometer (Magnetic pulse counting methods) :

- It consists of a toothed rotor mounted on the shaft whose speed is to be measured.
- It measures the rpm of a rotating body. It is also a proximity type of instrument. Toothed wheel is mounted on the shaft whose speed is to be measured.
- A permanent magnet is placed near the toothed wheel which is made of Ferro magnetic material (mild steel). This material causes variation of flux in the magnetic circuit due to changes in air gap.
- The variations of flux produce an emf in the pickup coil. Consequently a voltage is induced in the toil. This is in the form of pulses.
- The output of the instrument is fed to a pulse counter (electronic counter). The number of counts per second is. Then displayed in the form of a digital readout.
- A permanent magnet is placed near the toothed rotor. The toothed rotor is made ferromagnetic material which causes variation of flux in the magnetic circuit due to changes in air-gap.
- The variations of flux, produce an induced e.m.f. in the pick-up coil. This is in the form of pulses.

The output of the instrument is fed to a frequency counter (electronic counter) from which the r.p.m. of the rotor can be determined.

$$\text{Speed n} = \frac{\text{Pulse/second speed}}{\text{Number of teeth}}$$

- This type is frequently used to measure angular velocity.

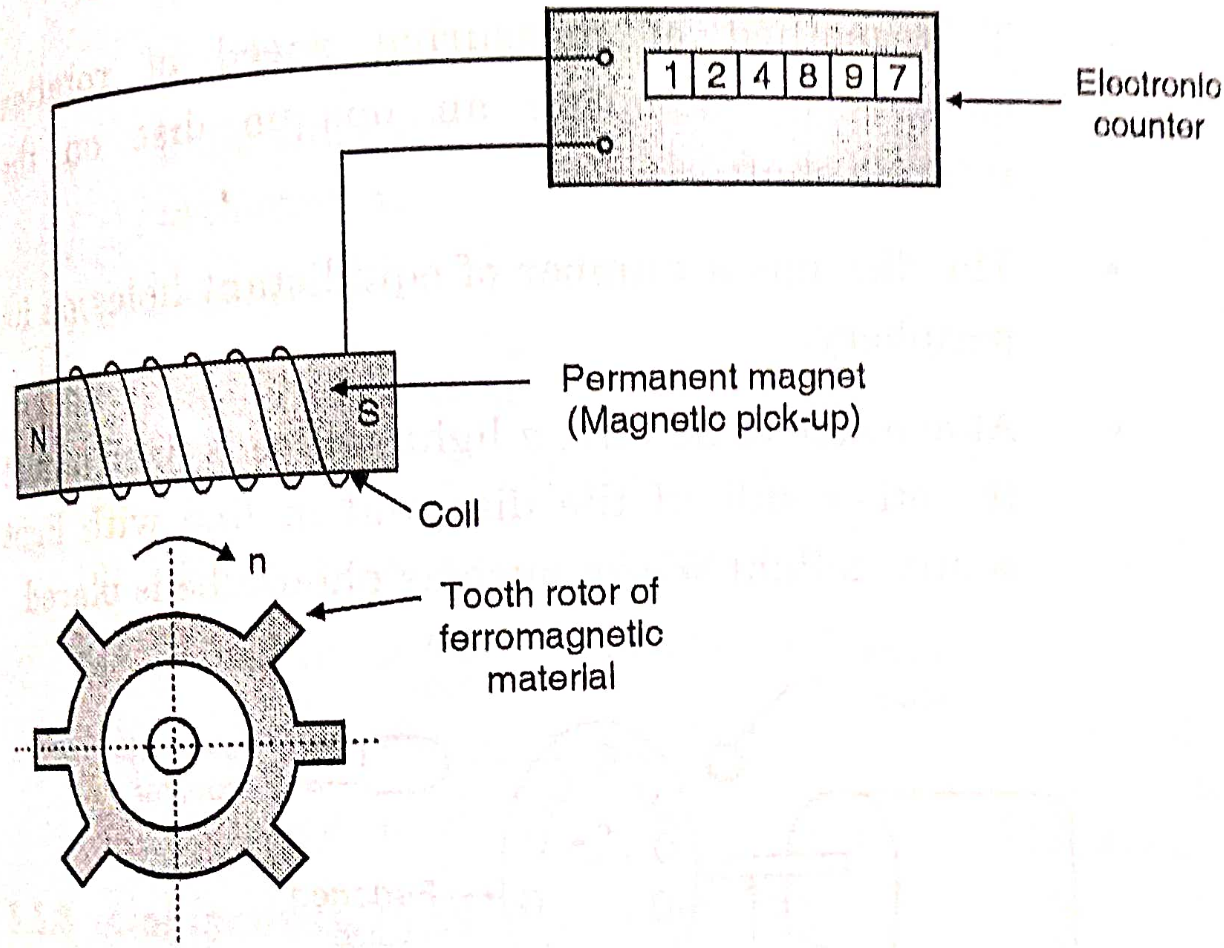

Fig. 5.5.4 : Variable reluctance tachometer

Advantages :

(i) It is simple and rugged in construction.

(ii) Negligible maintenance.

(iii) Calibration is easy.

(iv) The information from this can be easily transmitted.