UNIT-4. Transducers

Introduction

- Basically transducer is defined as a device, which converts energy or information from one form to another.
- These are widely used in measurement work because not all quantities that need to be measured can be displayed as easily as others.
- A better measurement of a quantity can usually be made if it may be converted to another form, which is more conveniently or accurately displayed.

Introduction(cont'd)

- For example, the common ***mercury thermometer*** converts variations in temperature into variations in the length of a column of mercury.
- Since the variation in the length of the mercury column is rather simple to measure, the mercury thermometer becomes a convenient device for measuring temperature.

Introduction(cont'd)

- On the other hand, the actual temperature variation is not as easy to display directly.
- Another example is *manometer, which* detects pressure and indicates it directly on a scale calibrated in actual units of pressure.

Introduction(cont'd)

- **Thus the transducer is a device, which provides a usable output in response to specific input measured, which may be physical or mechanical quantity, property or condition.**

- **The transducer may be mechanical, electrical, magnetic, optical, chemical, acoustic, thermal nuclear, or a combination of any two or more of these.**

Mechanical transducers

- are simple and rugged in construction, cheaper in cost, accurate and operate without external power supplies but are not advantageous for many of the modern scientific experiments and process control instrumentation owing to their poor frequency response, requirement of large forces to overcome mechanical friction, in compatibility when remote control or indication is required, and a lot of other limitations. All these drawbacks have been overcome with the introduction of electrical transducers.

ELECTRICAL TRANSDUCERS

- Mostly quantities to be measured are non-electrical such as **temperature, pressure, displacement, humidity, fluid flow, speed** etc., but these quantities cannot be measured directly. Hence such quantities are required to be sensed and changed into some other form for easy measurement.
- Electrical quantities such as **current, voltage, resistance. inductance and capacitance** etc. can be conveniently measured, transferred and stored, and therefore, for measurement of non-electrical quantities these are to be converted into electrical quantities first and then measured.

ELECTRICAL TRANSDUCERS(cont'd)

- **The function of converting non-electrical quantity into electrical one is accomplished by a device called the electrical transducer.** Basically an electrical transducer is a sensing device by which a physical, mechanical or optical quantity to be measured is transformed directly, with a suitable mechanism, into an electrical signal (current, voltage or frequency). **The production of these signals is based upon electrical effects which may be resistive, inductive, capacitive etc in nature.**

ELECTRICAL TRANSDUCERS(cont'd)

- The input versus output energy relationship takes a definite reproducible function. The output to input and the output to time behavior is predictable to a known degree of accuracy, sensitivity and response, within the specified environmental conditions.

BASIC REQUIREMENTS OF A TRANSDUCER

- The main function of a transducer is to respond only for the measurement under specified limits for which it is designed. It is, therefore, necessary to know the relationship between the input and output quantities and it should be fixed.

- Transducers should meet the following basic requirements.

Basic Requirements Of a Transducer (cont'd)

- Ruggedness. It should be capable of withstanding overload and some safety arrangement should be provided for overload protection.
- Linearity. Its input-output characteristics should be linear and it should produce these characteristics in symmetrical way.
- Repeatability. It should reproduce same output signal when the same input signal is applied again and again under fixed environmental conditions e.g. temperature, pressure, humidity etc.

Basic Requirements Of a Transducer (cont'd)

- High Output Signal Quality. The quality of output signal should be good i.e. the ratio of the signal to the noise should be high and the amplitude of the output signal should be enough.
- High Reliability and Stability. It should give minimum error in measurement for temperature variations, vibrations and other various changes in surroundings.
- Good Dynamic Response. Its output should be faithful to input when taken as a function of time. The effect is analyzed as the frequency response.

Basic Requirements Of a Transducer (cont'd)

- No Hysteretic. It should not give any hysteretic during measurement while input signal is varied from its low value to high value and vice-versa.
- Residual Deformation. There should be no deformation on removal of local after long period of application.

Classification Of Transducers

- The transducers may be classified in various ways such as on the basis of electrical principles involved, methods of application, methods of energy conversion used, nature of output signal etc.

Transducers can be classified as

1. On the basis of transduction form used.
2. Primary and secondary transducers.
3. Passive and active transducers.
4. Analog and digital transducers.
5. As transducers and inverse transducers.

Classification Of Transducers(cont'd)

- ***Primary and Secondary Transducers:*** Transducers, on the basis of methods of applications, may be classified into primary and secondary transducers. When the input signal is directly sensed by the transducer and physical phenomenon is converted into the electrical form directly then such a transducer is called the primary transducer.

1-Primary and Secondary Transducers(cont'd)

- For example a thermistor used for the measurement of temperature fall in this category. The thermistor senses the temperature directly and causes the change in resistance with the change in temperature. When the input signal is sensed first by some detector or sensor and then its output being of some form other than input signals is given as input to a transducer for conversion into electrical form, then such a transducer falls in the category of secondary transducers.

Primary and Secondary Transducers(cont'd)

- For example, in case of pressure measurement, bourdon tube is a primary sensor which converts pressure first into displacement, and then the displacement is converted into an output voltage by an LVDT. In this case LVDT is secondary transducer.

ACTIVE AND PASSIVE SENSOR

- Passive Transducer require an external power supply to operate, called an *excitation signal* which is used by the sensor to produce the output signal.

- LVDT sensor or a strain gauge. Strain gauges are pressure-sensitive resistive bridge networks that are external biased (excitation signal) in such a way as to produce an output voltage in proportion to the amount of force and/or strain being applied to the sensor.
- Transistor, Op-amp are considered active devices because they can operate only when external power supply is provided to them

ACTIVE AND PASSIVE SENSOR

- Active Transducer does not need any additional power source or excitation voltage. Instead a passive sensor generates an output signal in response to some external stimulus. For example, a thermocouple or piezoelectric transducer which generates its own voltage output when exposed to heat.

Capacitive transducers(cont’d):-

- The capacitance of this unit is proportional to the amount of area on the fixed plate that is convered, that is, "'shaded" by the moving plate. This type *of* transducer will give signals proportional to curvilinear displacement or angular velocity

- A rectilinear capacitance transducer is shown in Fig. (5-b), and it consists *of* a fixed cylinder and a moving cylinder. These pieces are configured so that the moving piece fits inside the fixed piece but is insulated from it.

Capacitive transducers(cont'd):-

- Figure shows a transducer that varies the spacing between surfaces, that is, the thin diaphragm. The dielectric is either air or vacuum. Such devices are often used as capacitance microphones.

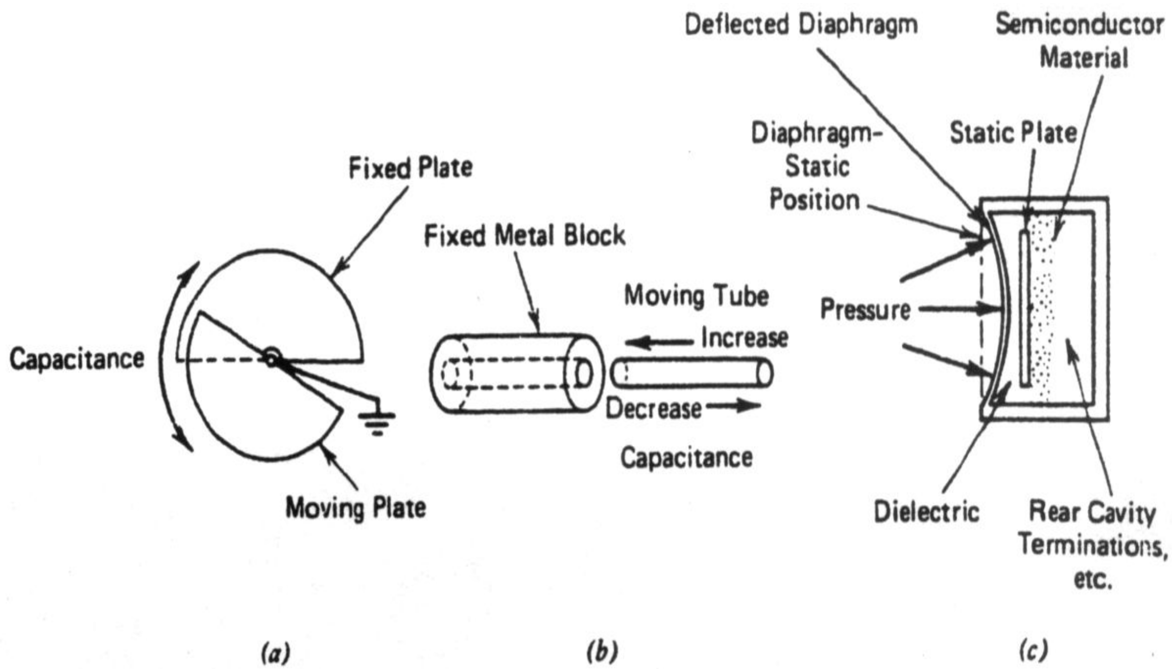


Fig (5) Capacitance transducers

Capacitive transducers(cont'd):-

- ***EXAMPLE :-***

An electrode-diaphragm pressure transducer has plates whose area is 5×10^{-3} m^2 and whose distance between plates is 1×10^{-3} m. Calculate its capacitance if it measures air pressure. The dielectric constant of air is k =1.

Solution:-

$$C = \frac{kA\varepsilon_o}{d}$$

$$= \frac{(1)(5x10^{-3}\,m^2)(8.854\,x10^{-12}\;F/m)}{1x10^{-3}\;m}$$

$$= 44.25\;pF$$

Capacitive transducers(cont’d):-

- Capacitance transducers can be used in several ways. One method is to use the varying capacitance to frequency-modulate an RF oscillator. This method is the one employed with capacitance microphones like Fig. (5).

- Another method is to use the capacitance transducer in an ac bridge circuit. The capacitance transducer has excellent frequency response and can measure of static and dynamic phenomena.

- Its disadvantage are sensitivity to temperature variations and the possibility of erratic or distorted signals owing to long lead length.

4.Variable Inductive Transducer:

- Passive inductive transducers require an external source of power. The action of the transducer is principally one of modulating the excitation signal.

- The differential transformer is a passive inductive transformer. It is also known as the linear variable differential transformer (LVDT) and is shown constructively in Fig. (6-a)

- It consists basically of a primary winding and two secondary windings, wound over a hollow tube and positioned so that the primary is between two secondaries.

Variable Inductive Transducer(cont’d):-

- An iron core slides within the tube and therefore affects the magnetic coupling between the primary and the two secondaries. When the core is in the center, the voltage induced in the two secondaries is equal.

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

Variable Inductive Transducer(cont’d):-

- In the schematic diagram shown in Fig. (6-b), the windings are connected "series opposing." That is, the polarities of V1 and V/2 oppose each other as we trace through the circuit from terminal A to terminal B. Consequently, when the core is in the center so that V, = V_2, there is no voltage output, V,=0.

Variable Inductive Transducer(cont'd):-

- When the core is away from center toward S_1, V_1 is greater than V_2 and the output voltage V_o will have the polarity of V_1.

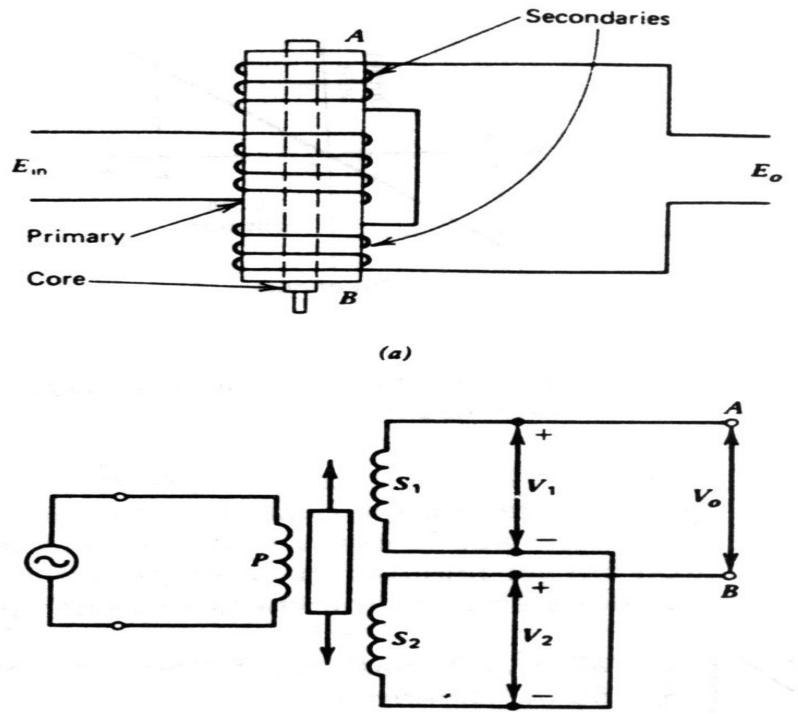


Fig (6) The linear variable differential transformer (a) Construction. (b) Schematic diagram.

Variable Inductive Transducer(cont'd):-

- When the core is away from center toward S_2. V_2 is greater than V_1, and the output will have the polarity of V_2. That is, the output ac voltage *inverts* as the core passes the center position. The farther the core moves from center.

- the greater the *difference* in value between V_1 and V_2, and consequently the greater the value of V_0. Thus, the amplitude of V_0 is a function of the distance the core has moved and the polarity or *phase* indicates which direction it has moved

Fig. (6).

Variable Inductive Transducer(cont'd):-

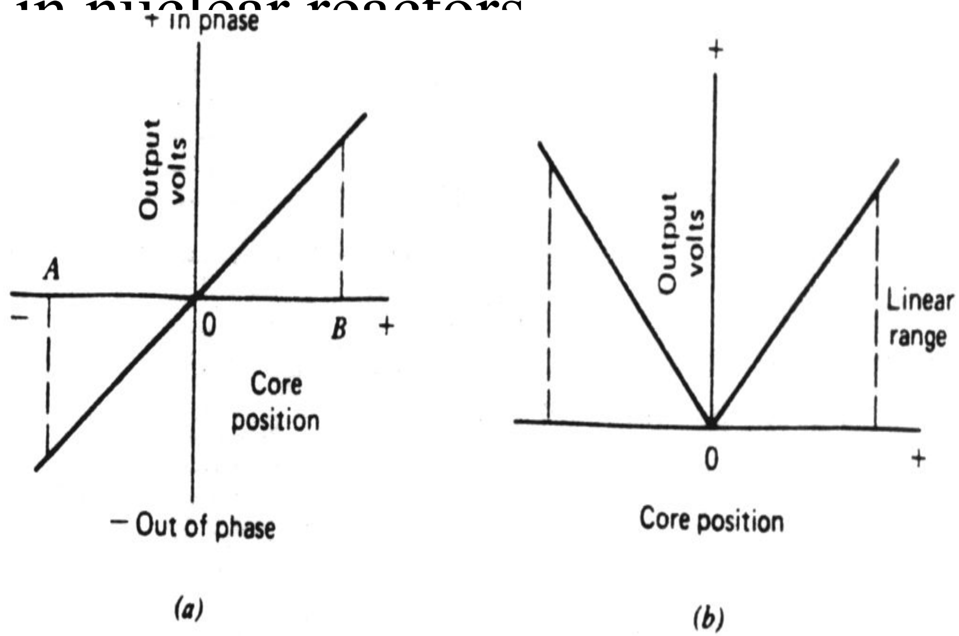
- If the core is attached to a moving object, the LVDT output voltage can be a measure of the position of the object.One advantage of the LVDT over the inductive bridge-type transducer is that it produces a higher output voltage for small changes in core position. Several commercial models that produce 50 to 300 mV/mm are available.

Variable Inductive Transducer(cont'd):-

- This means that a 1-mm displacement of the core can produce a voltage output of 300 mV. LVDTs are available with ranges from as low as ± 0.05 in to as high as ± 25 in., and they art sensitive enough to be used to measure displacement of well below 0.001 it.

Variable Inductive Transducer(cont’d):-

They can be obtained for operation at temperatures as low as -265°C and as high as +600°C, and they are also available in radiation-resistance designs for operation in nuclear reactors.



Fig(7) Output voltage of LVDT
(a) Phase relationship. (b) Absolute magnitude.

Variable Inductive Transducer(cont'd):-

- Typical applications that illustrate the capabilities of LVDTs include controls for jet engines in close proximity to exhaust gases and measuring roll positions and the thickness of materials in hot-stripe or hot-slab steel mills.

Variable Inductive Transducer(cont'd):-

- ***EXAMPLE:-***

  An ac LVDT has the following data: input 6.3V, output 5.2V, range ±0.50 in. Determine

  (a) The plot of output voltage versus core position for a core movement going from +0.45 to -0.3 in.

  b) The output voltage when the core is -0.25 in, from center.

Variable Inductive Transducer(cont'd):-

Solution

- (a) A core displacement of 0.5 in. produces 5.2 V. Therefore, a 0.45-in.

$$core\,movement\ produces\ \frac{(0.45)(5.2)}{0.5} = 4.68V.\,Similarly, a - 0.30 - in$$

$$core\ \ movement\ \ produces\ \frac{(-0.3)(-5.2)}{-0.5} = -3.12V$$

- (b) A core movement of –0.25 produces $\frac{(-0.25)(-5.2)}{-0.5} = -2.6V$

2-Strain Gauge Transducers

- The strain gauge is an example *of* a passive transducer the; uses electrical resistance variation in wires to sense the strain produced by a force on the wires. It is a very versatile detector and transducer for measuring weight pressure mechanical force, or displacement.

Strain Gauge Transducers(cont'd)

- The construction of a bonded strain gauge Fig (3) shows a fine-wire element looped back and forth on a mounting plate, which is usually cemented to the member undergoing stress. A tensile stress tens to elongate the wire and thereby increase its length and decrease its cross-sectional area. The combined effect is an increase in resistance as seen from

Eq. (1)

$$R = \frac{\rho L}{A} \qquad (1)$$

Where

- ρ = the specific resistance of the conductor material in ohm
- L = the length of the conductor in meters
- A = the area of the conductor in square meters

Strain Gauge Transducers(cont'd)

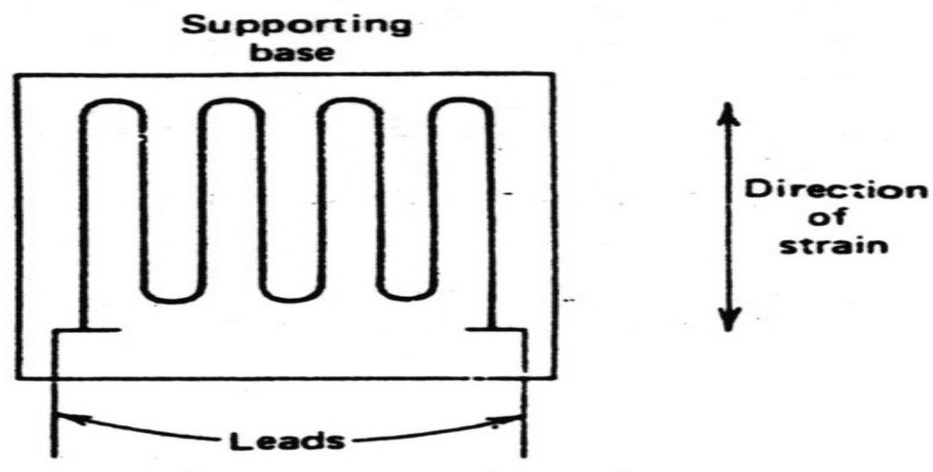


Fig (3) Resistive strain gauges; wire construction

Strain Gauge Transducers(cont'd)

- As a consequence of strain two physical qualities are of particular interest: (1) the change in gauge *resistance* and (2) the change in *length*. The relationship between these two variables expressed as a ratio is called the gauge factor.
- K. Expressed mathematically as

$$K = \frac{\Delta R / R}{\Delta L / L}$$

(2)

<u>Where</u>

- K = the gauge factor
- R = the initial resistance in ohms (without strain)
- ΔR = the change in initial resistance in ohms
- L = the initial length in meters (without strain)
- ΔL = the change in initial length in meters

Strain Gauge Transducers(cont'd)

- Note that the term ΔL lL in the denominator is the same as the unit strain G. Therefore. Eq. (2) can be written as

$$K = \frac{\Delta R / R}{G}$$

(3)

Robert Hooke pointed out in the seventeenth century that for many common materials there is a constant, ratio between stress and strain.

Strain Gauge Transducers(cont'd)

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

$$S = \frac{F}{A} \qquad (4)$$

Where

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

Strain Gauge Transducers(cont'd)

- The constant of proportionality between stress and strain for a linear stress-strain curve is known as the modulus of elasticity of the material. E or Young's modulus. Hooke's law is written as

$$E = \frac{S}{G} \qquad (5)$$

Where

- E =Young's modulus in kilograms per square meter
- S= the stress in kilograms per square meter
- G = the strain (no units)

Strain Gauge Transducers(cont'd)

- For strain gauge applications, a' *high degree of sensitivity is* very desirable. A high gauge factor means a relatively large resistance change for a given strain. Such a change is more easily measured than a small resistance change. Relatively small changes in strain can be sensed.

Strain Gauge Transducers(cont’d)

- *EXAMPLE 3*

  A resistant strain gauge with a gauge factor of *2 is* fastened to a steel member, which is subjected to a strain of 1 X 10^{-6}. If the original resistance value of the gauge is 130 . Calculate the change in resistance.

Solution

$$K = \frac{\Delta R / R}{\Delta L / L} = \frac{\Delta R / R}{G}$$

$$\Delta R = KGR = (2)\,(1x10^{-6})\,(130\Omega) = 260\,\mu\Omega$$

Example 4

- A round steel bar, *0.02* m in diameter and 0.40 m in length, is subjected to a tensile force of 33.000 kg, where $E = 2x10^{10}$ kg/m². Calculate the elongation, *L,* in meters.

- Solution:

$$A(\pi\left(\frac{D}{2}\right)^2 = \pi\left(\frac{0.02\,m}{2}\right)^2 = 3.14\,x\,10^{-4}\ m^2$$

$$E = \frac{S}{G} = \frac{F/A}{\Delta L/L}$$

$$\Delta L = \frac{FL}{AE} = \frac{33.000kg\ x\ 0.40m}{(3.14\,x\,10^{-4}\ m^2)(2\,x\,10^{10}\ kg/m^2)}0$$

$$= 2.1\,x\,10^{-3}\ m$$

Strain Gauge Transducers(cont’d)

- 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.

Strain Gauge Transducers(cont'd)

- The strain gauge is generally used as one arm of a bridge. The simple arrangement shown in Fig. (4-*a)* can be employed when temperature variations are not sufficient to affect accuracy significantly, or in applications for which great accuracy is not required.

Strain Gauge Transducers(cont'd)

- However, since gauge resistance is affected by temperature, any change of temperature will cause a change in the bridge balance conditions. This effect can cause an error in the strain measurement. Thus, when temperature variation is significant, or when un usual accuracy is required an arrangement such as that illustrated in Fig. (4) may be used.

Strain Gauge Transducers(cont'd)

- Here two gauges of the same type are mounted on the item being tested close enough together that both are subjected to the same temperature. Consequently, the temperature will cause the same change of resistance in the two, and the bridge balance will not be affected by the temperature. However one of the two gauges is mounted so that its sensitive direction is at right Angles to the direction of the strain.

Strain Gauge Transducers(cont'd)

- 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. 4-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.

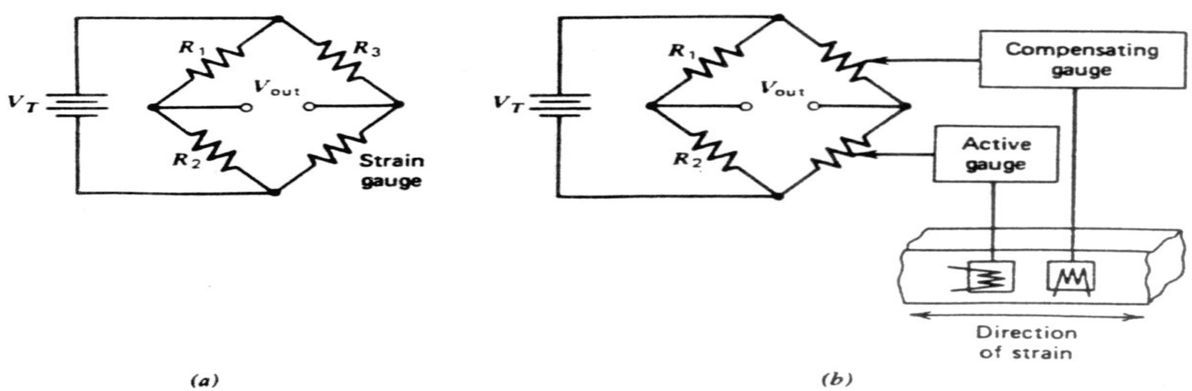


Fig (4) Basic gauge bridge circuits.

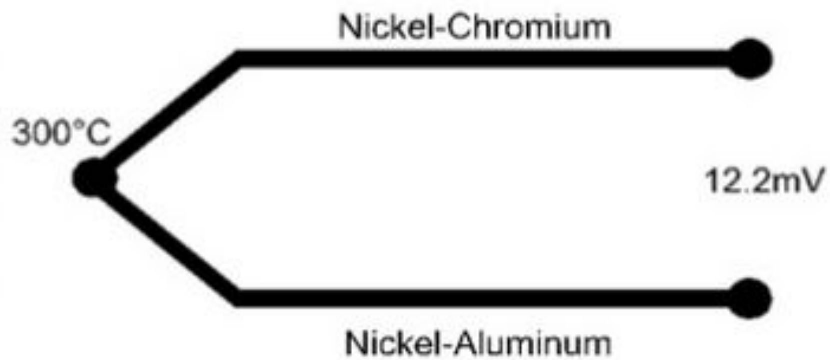
6.Temperature Transducer:-

- Temperature transducers can be divided into two main categories.

1. Thermocouples.
2. Thermistors.

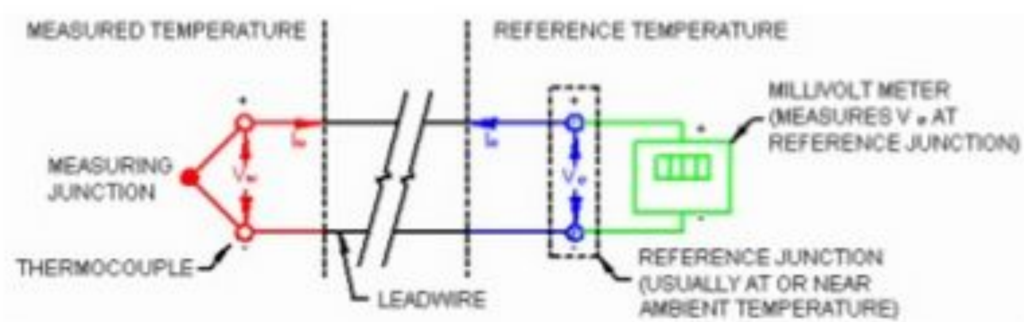
Thermocouples

A **thermocouple** is a temperature-measuring device consisting of two dissimilar conductors that contact each other at one or more spots. It produces a voltage when the temperature of one of the spots differs from the reference temperature at other parts of the circuit.



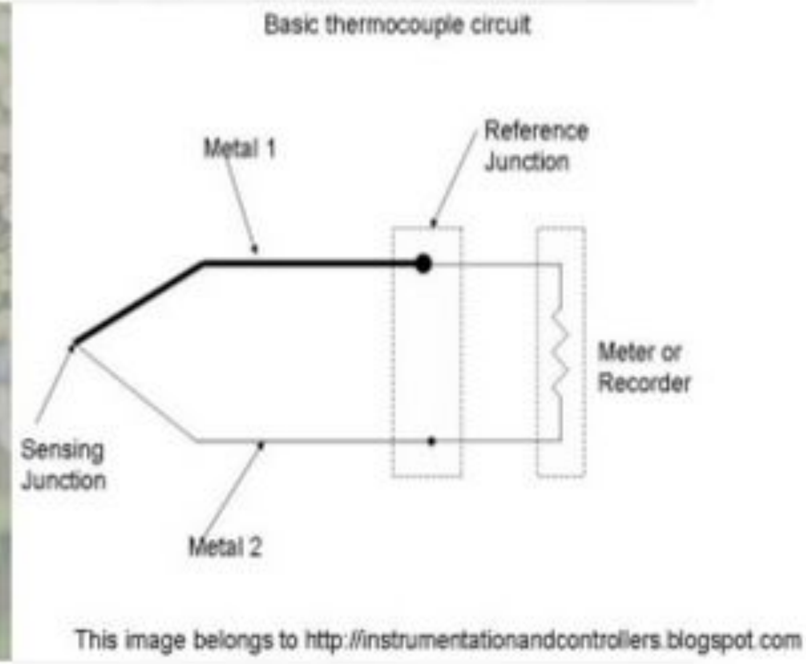
Misconception in Thermoelectricity

The EMF generated by the Seebeck effect is due to the temperature gradient along the wire.
The EMF is not generated at the junction between two dissimilar wires.



Principle of operation

Thermocouples are based on the principle that two wires made of dissimilar materials connected at either end will generate a potential between the two ends that is a function of the materials and temperature difference between the two ends (also called the Seebeck Effect).

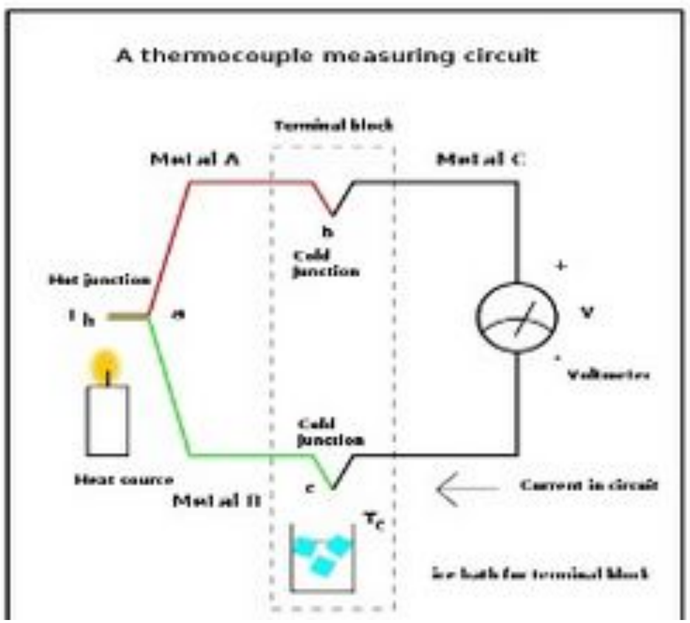


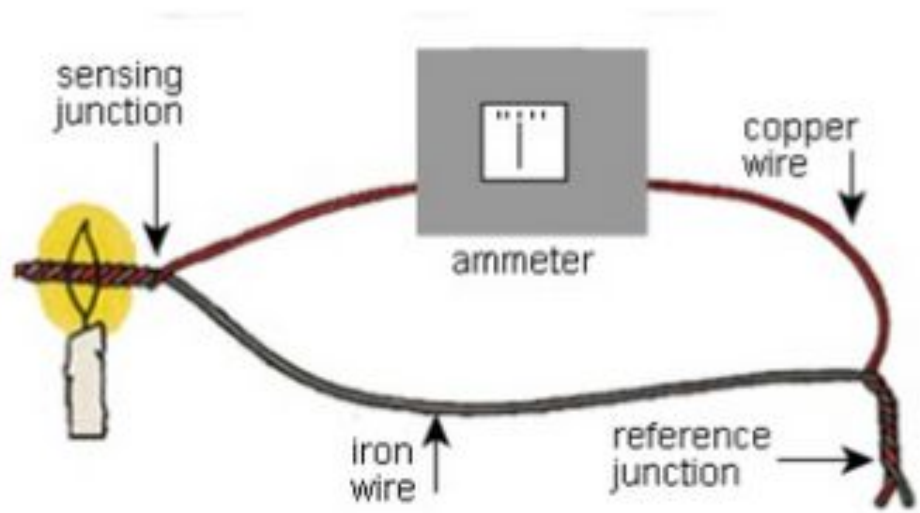
Thermocouples: Seebeck effect

The Seebeck effect is the conversion of thermal energy/temperature differences directly into electrical energy or electricity.

This effect measures the ease at which excess electrons will circulate in an electrical circuit under the influence of thermal difference.

The change in the voltage is proportional to the temperature difference between the junctions when the ends are connected to form a loop.





Measuring Temperature

• With the known reference junction temperature, the measured voltage is a unique function of the materials of the thermocouple wires and the temperature of the sensing junction.

• Finally, the voltage depends on the composition of metals used in the wires to form the thermocouple. This problem is solved by restricting the materials used to construct thermocouples. When wires and wire pairs are manufactured, standard calibration curves can be used to determine the temperature based on measured voltage.

• The following table lists common thermocouple pairs.

TABLE 9.1 Characteristics of Standard Thermocouples

Type	Materials	Lead-wire color	Operating range (°C)	Approximate sensitivity (mV/°C)
T	Copper/constantan	Blue	−250 to 400	0.052
E	Chromel/constantan	Purple	−270 to 1000	0.076
J	Iron/constantan	Black	−210 to 760	0.050
K	Chromel/alumel	Yellow	−270 to 1372	0.039
R	Platinum/platinum–13% rhodium	Green	−50 to 1768	0.011
S	Platinum/platinum–10% rhodium	Green	−50 to 1768	0.012
C	Tungsten, 5% rhenium/tungsten, 26% rhenium	White, red trace	0 to 2320	0.020

Measuring Temperature

• There are many factors that must be considered in selecting thermocouples for a given application. It includes

- Sensitivity (voltage per degree temperature change)
- Linearity of output
- Stability and corrosion resistance
- Temperature range
- Cost

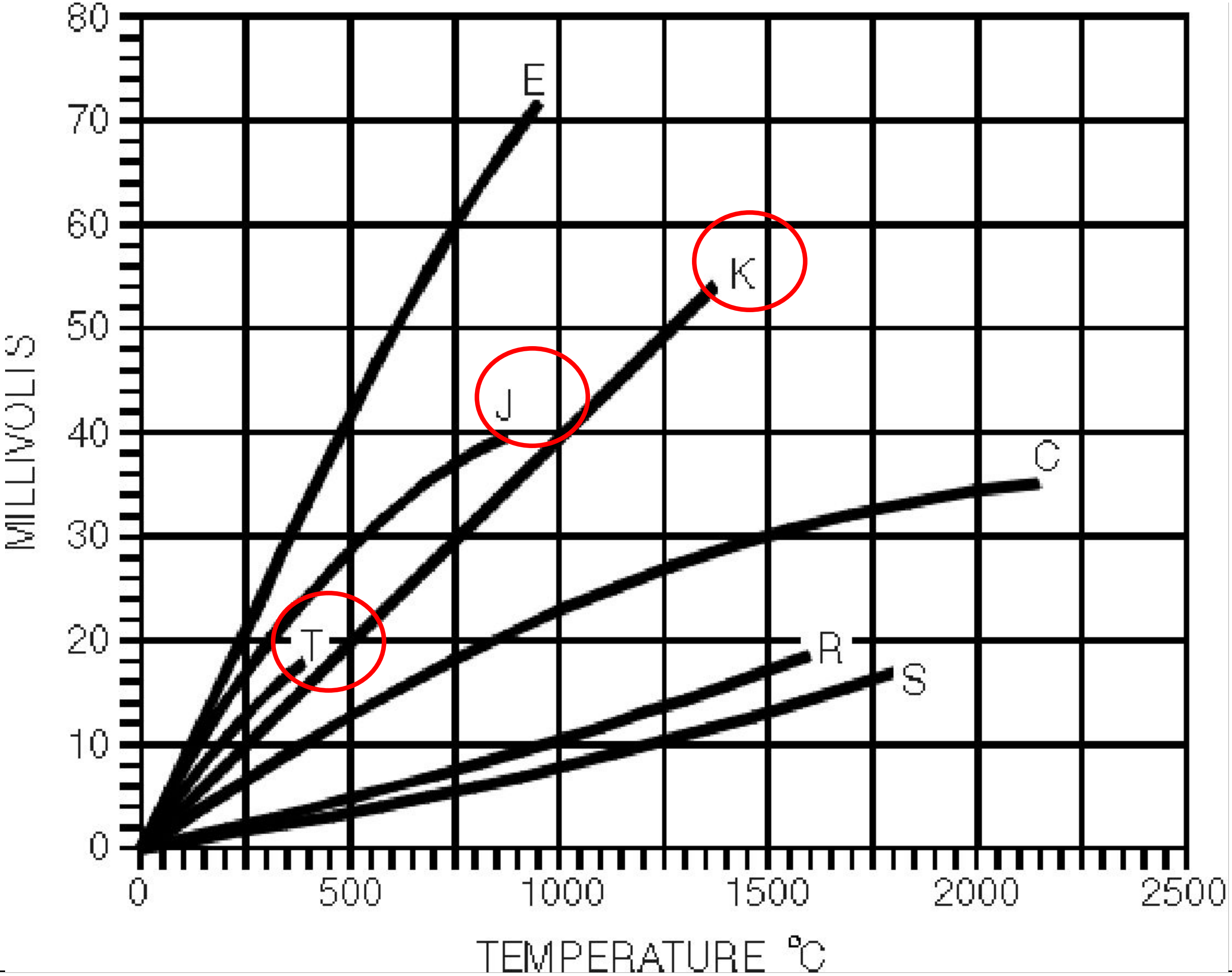
• Type R and type S thermocouples are very expensive and not very sensitive; however, they are satisfactory at high temperatures (up to 1768°C) and are resistant to a number of corrosive chemicals.

• Type C thermocouples are usable to very oxidizing environment.

Type K thermocouples are popular for general use since they are moderately priced, reasonably corrosion resistant, and usable at temperatures up to 1372° C. They also have relatively linear output, which means that for applications in which accuracy requirements are not to severe, the temperature can be computed by assuming a linear relationship between temperature and voltage.

Thermocouple Material Vs EMF

Types T, J, and K are most commonly used thermocouples



Temperature Transducer (cont'd):-

2. Thermocouples:-

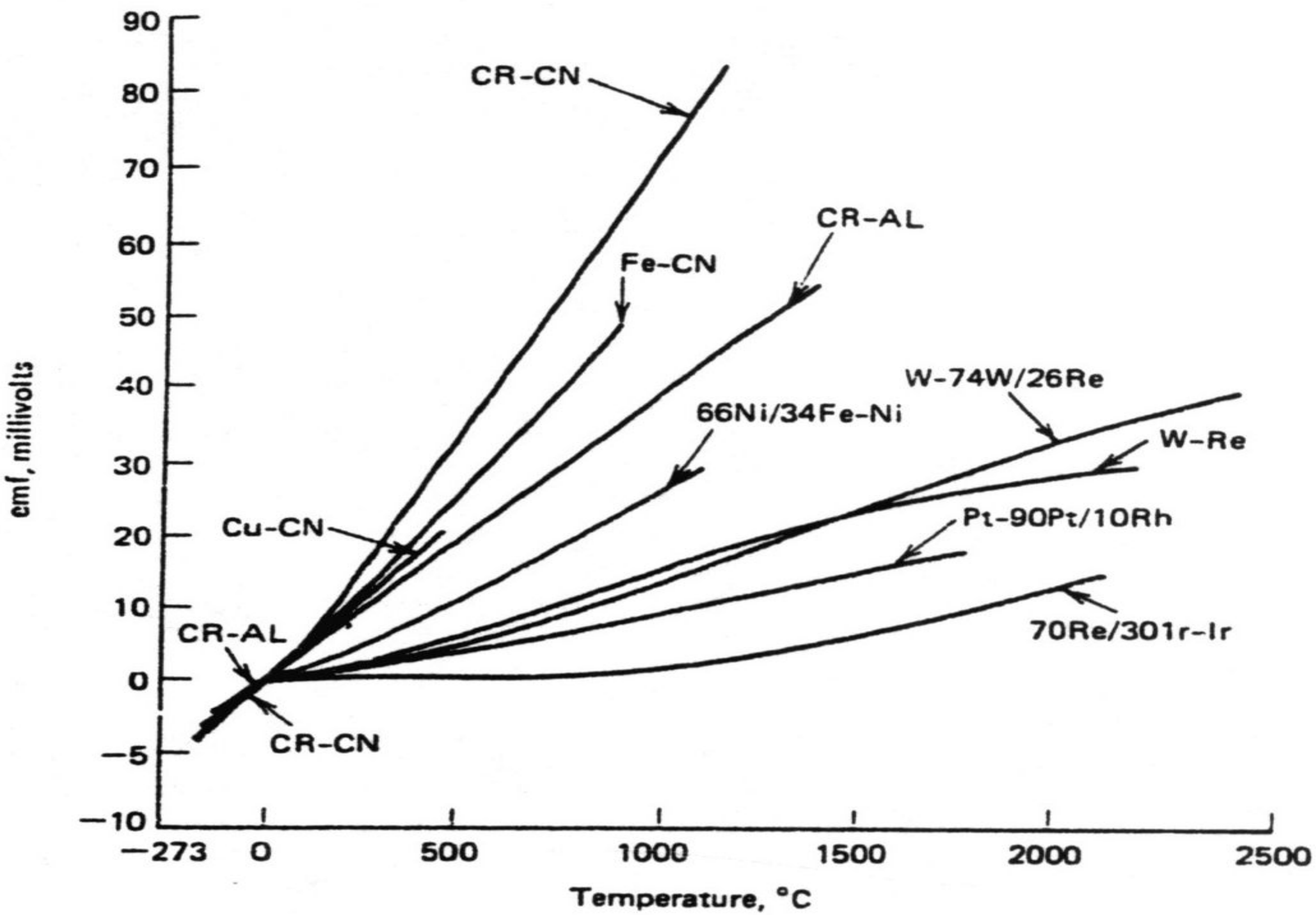


Fig (11) Calibration curves for several thermocouple combinations.

- The magnitude of the thermal emf depends on the wire materials used on the temperature difference between the junctions. Figure (11) shows thermal emfs for some common thermocouple materials. The values shown are based on a reference temperature of 32°F. The effective emf of thermocouple is given as

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

Where

- c and k =constants of the thermocouple materials
- T_1 =the temperature of the "hot" junction
- T_2 =the temperature of the "cold" or "reference" junction

Temperature Transducer (cont'd):-

3. Thermistors.:-

- Typical thermistor are shown in Fig and the electrical symbol of the device is depicted in the same figure.

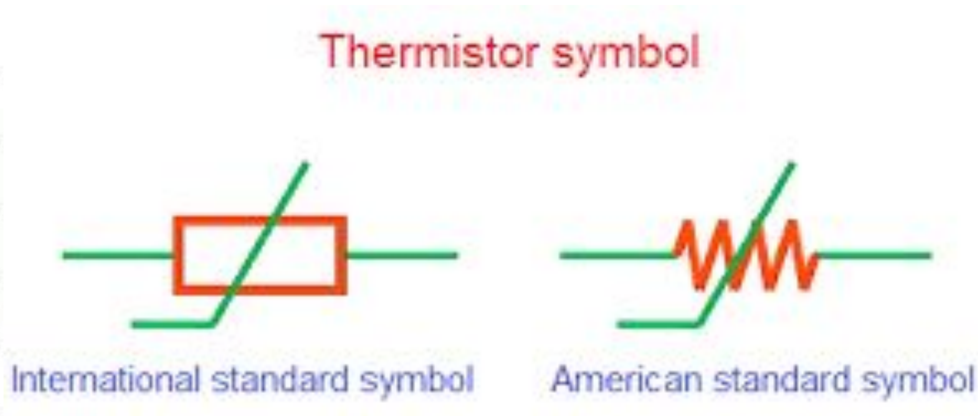


Fig (13) thermistor configuration and the electrical symbol for a thermistor. (Courtesy Yellow Springs Instrument Company, Yellow Springs, Ohio.)

Temperature Transducer (cont'd):-

Thermistors.:-

- The electrical resistance *of* most materials changes with the temperature. By choosing materials that are very sensitive to temperature, we can make devices that are useful in temperature control circuits as well as in temperature measurement.

- A thermistor is a semiconductor made by sintering mixtures of metallic oxide, such as oxides of manganese, nickel, cobalt, copper, and uranium. Thermistors have a *negative* temperature coefficient. That is, their resistance decreases as their temperature rises.

Temperature Transducer (cont'd):-

Thermistors.:-

- Thermistors can be connected in series-parallel arrangements for applications requiring greater power-handling capability.

- High-resistance units find application in measurements that employ wires or cables with small quantities of lead. Thermistors are chemically stable and can be used in nuclear environments.

- Their wide range of characteristics also permits them to be used in limiting and regulation circuits, as time delays, for the integration of power pulses, and as-memory units.

Temperature Transducer (cont’d):-

Thermistors.:-

- A thermistor in one leg of a Whetstone bridge circuit will provide pre temperature information. In most applications accuracy is limited only by readout device.

- Thermistors are nonlinear over a temperature range, although units today are available with a better than 0.2% linearity over a temperature range of to 100°C. The typical sensitivity of a thermistor is approximately 3 mV/°C at 200°C.

Advantages and disadvantages of thermistors

Advantages of thermistors

- The resistance of thermistors changes rapidly with small change in temperature.
- Low cost
- Small size
- It is easy to carry thermistors from one place to another place.

Disadvantages of thermistors

- Thermistors are not suitable over a wide operating range
- The resistance versus temperature characteristics is non-linear.

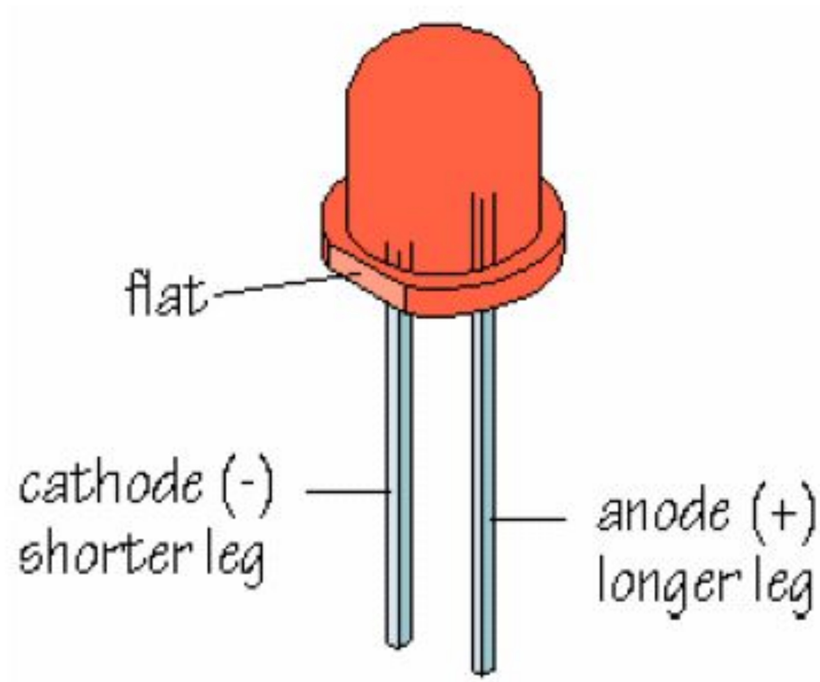
Applications of thermistors

- Thermistors are used in medical equipments
- Thermistors are used in hot ends of 3d printers.
- Thermistors are used in home appliances such as ovens, hair dryers, toasters, refrigerators, etc.
- Modern coffee makers use thermistors to accurately measure and control water temperature.
- Thermistors are used in computers.
- Thermistors are used as temperature sensors.
- Thermistors are used as inrush current limiter.

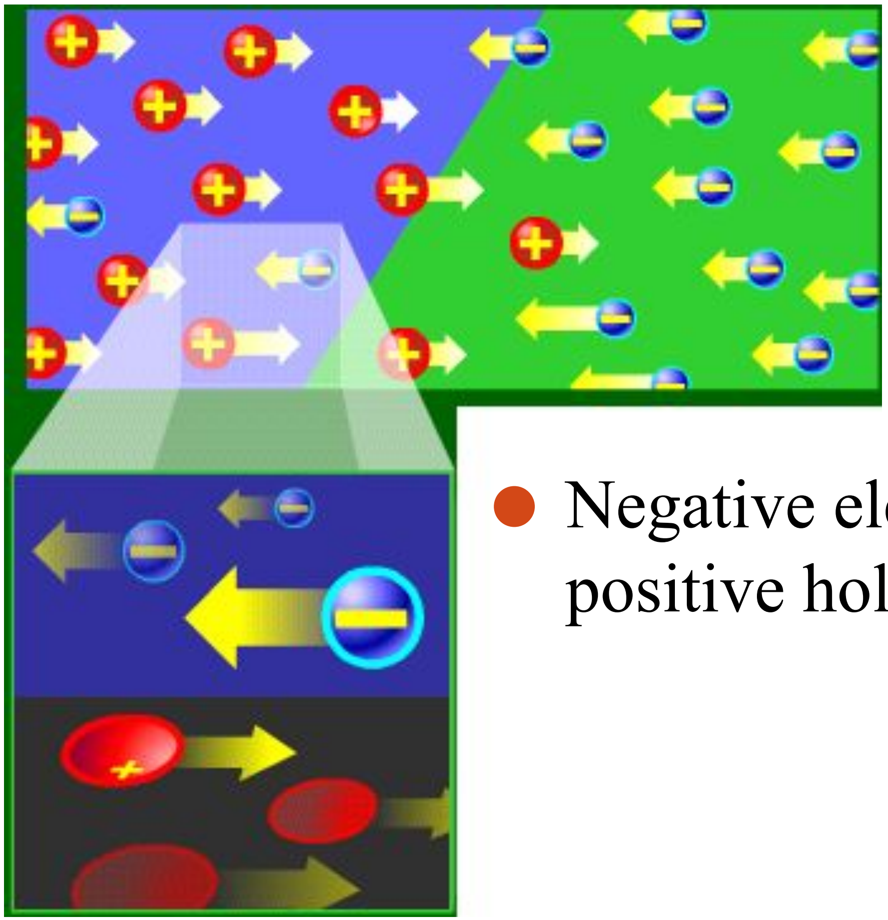
Light Emitting Diode: LED

What is an LED?

- Light-emitting diode
- Semiconductor
- Has polarity

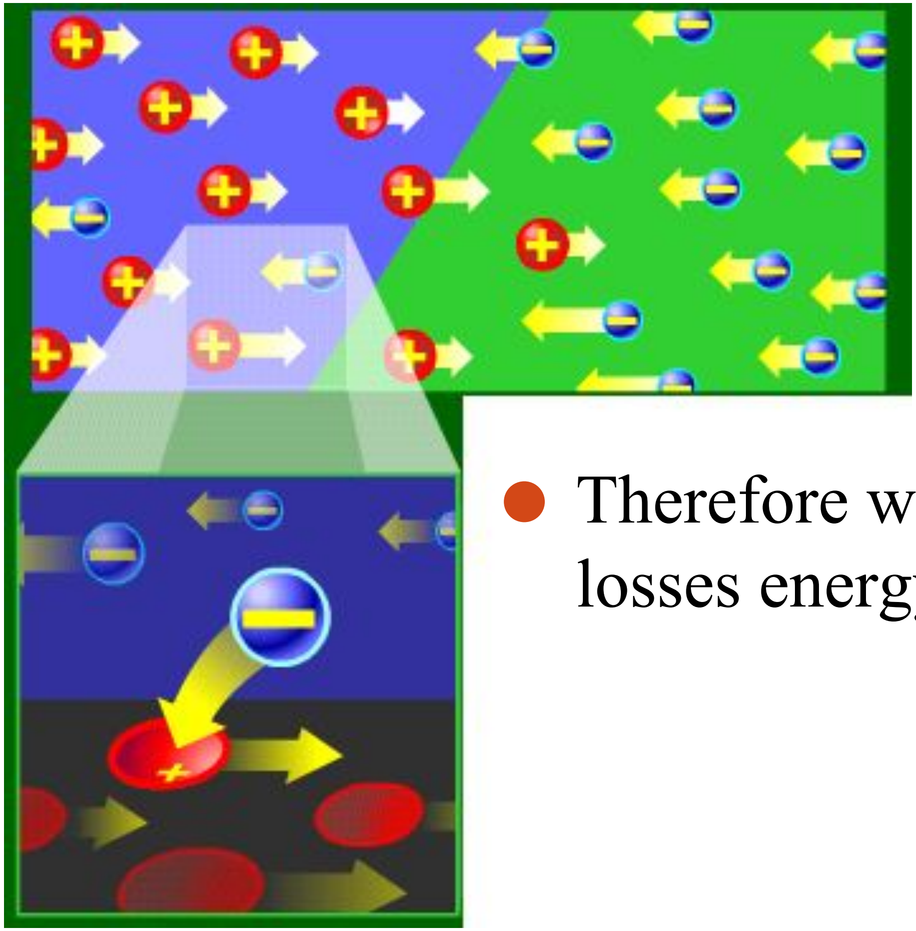


LED: How It Works



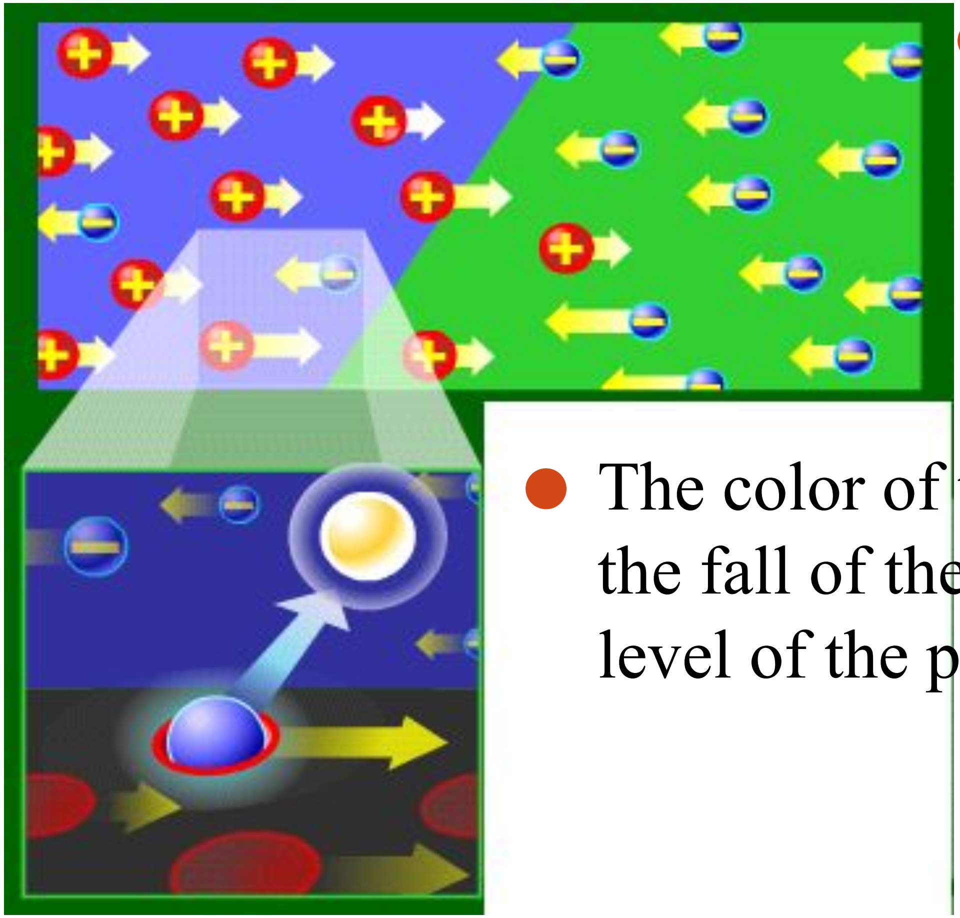
- When current flows across a diode
- Negative electrons move one way and positive holes move the other way

LED: How It Works



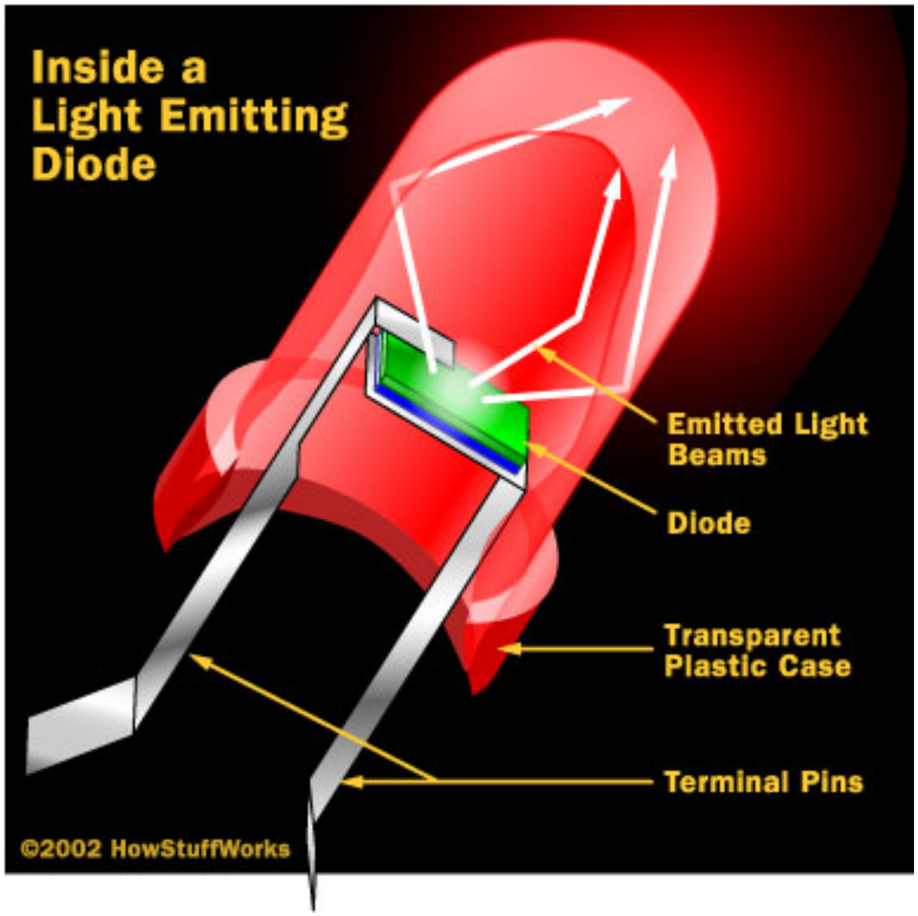
- The wholes exist at a lower energy level than the free electrons
- Therefore when a free electrons falls it losses energy

LED: How It Works



- This energy is emitted in a form of a photon, which causes light
- The color of the light is determined by the fall of the electron and hence energy level of the photon

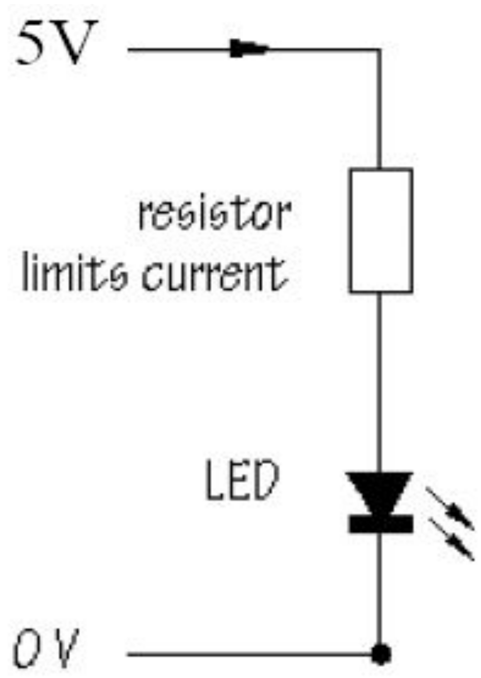
Inside a Light Emitting Diode



1. Transparent Plastic Case
2. Terminal Pins
3. Diode

How to Connect a LED:

- Requires 1.5~2.5V and 10 mA
- To prevent overloading, use resistor 470 Ω



PHOTODIODE

A photodiode is a p-n junction or pin semiconductor device that consumes light energy to generate electric current. It is also sometimes .referred as photo-detector, photo-sensor, or light detector

Photodiodes are specially designed to operate in reverse bias condition. Reverse bias means that the p-side of the photodiode is connected to the negative terminal of the battery and n-side is connected to the positive .terminal of the battery

Photodiode is very sensitive to light so when light or photons falls on .the photodiode it easily converts light into electric current

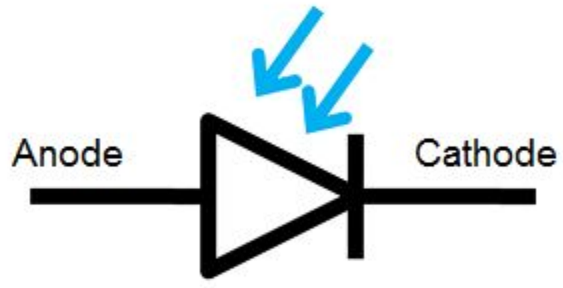
The construction and working of photodiode is almost similar to the normal p-n junction diode. PIN (p-type, intrinsic and n-type) structure is mostly used for constructing the photodiode instead of p-n (p-type and n-type) junction structure because PIN structure provide fast response time. PIN photodiodes are mostly used in .high-speed applications

In a normal p-n junction diode, voltage is used as the energy source to generate electric current whereas in photodiodes, both voltage and .light are used as energy source to generate electric current

A normal p-n junction diode allows a small amount of electric current under reverse bias condition. To increase the electric current under reverse bias condition, we .need to generate more minority carriers

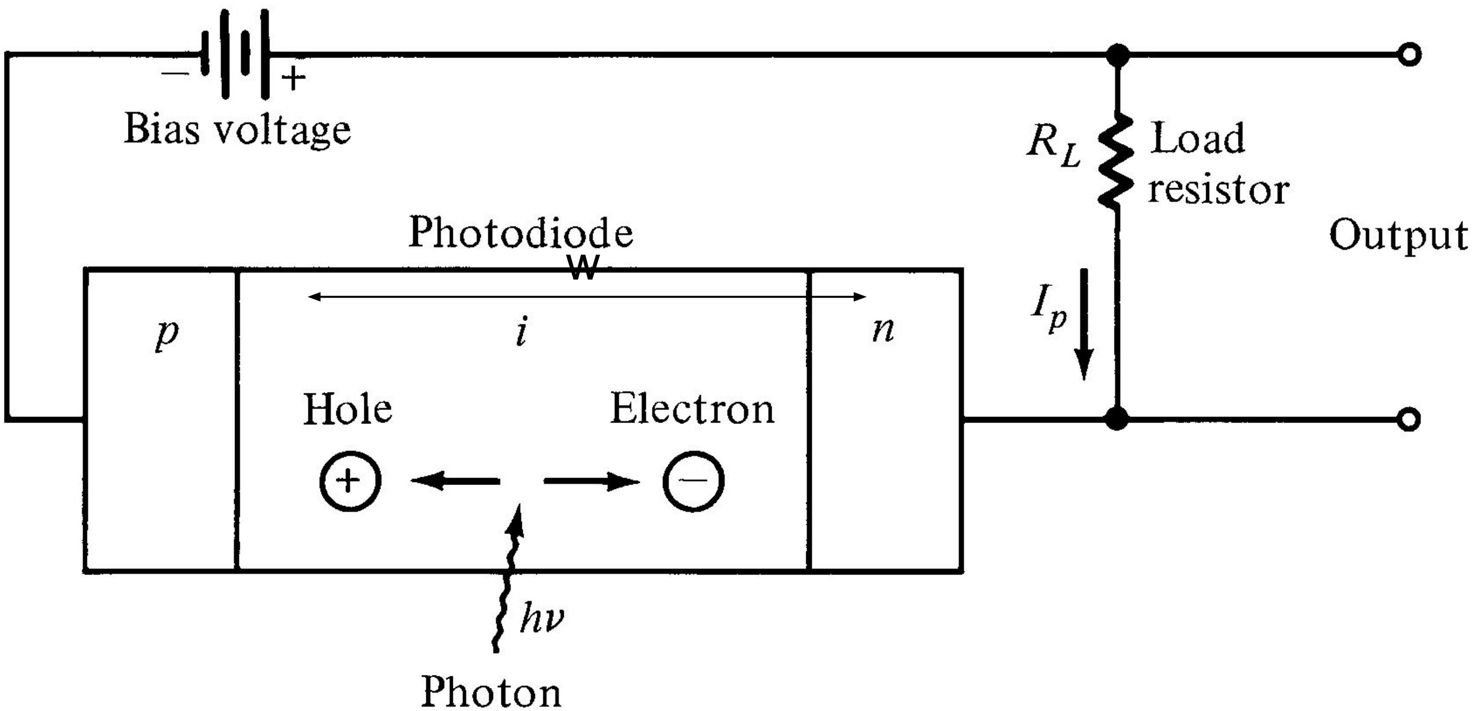
The external reverse voltage applied to the p-n junction diode will supply energy to .the minority carriers but not increase the population of minority carriers However, a small number of minority carriers are generated due to external reverse bias voltage. The minority carriers generated at n-side or p-side will recombine in the same material before they cross the junction. As a result, no electric current flows due to these charge carriers. For example, the minority carriers generated in the p-type material experience a repulsive force from the external voltage and try to move towards n-side. However, before crossing the junction, the free electrons recombine with the holes within the same material. As a result, no electric current flows. To overcome this problem, we need to apply external energy directly to the .depletion region to generate more charge carriers

A special type of diode called photodiode is designed to generate more number of charge carriers in depletion region. In photodiodes, we use light or photons as the .external energy to generate charge carriers in depletion region



Photodiode symbol

Photodiode



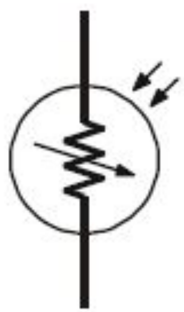
The high electric field present in the depletion region causes photo-generated carriers to Separate and be collected across the reverse –biased junction. This give rise to a current .Flow in an external circuit, known as **photocurrent**

Applications

- P-N photodiodes are used in similar applications to other photodetectors, such as photoconductors, charge-coupled devices, and photomultiplier tubes.
- Photodiodes are used in consumer electronics devices such as compact disc players, smoke detectors, and the receivers for remote controls in VCRs and televisions.

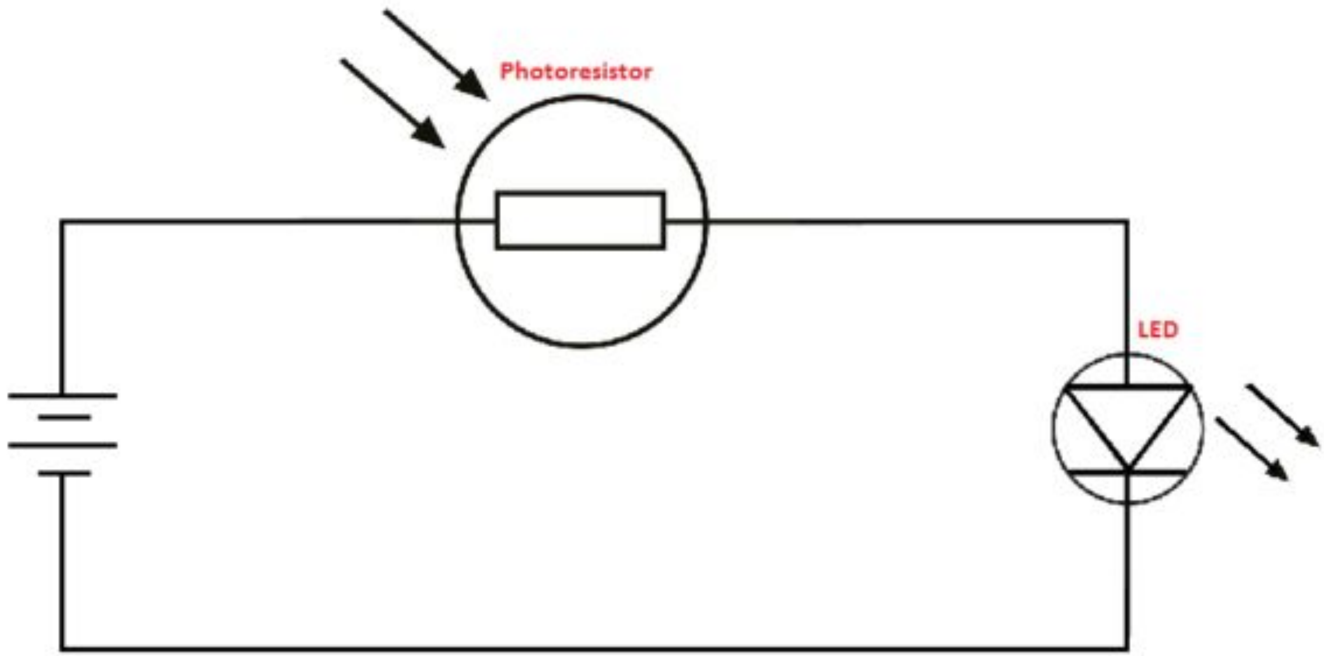
The Photoresistor

- Like the potentiometer, the photoresistor is a variable resistor



- Unlike the potentiometer, it is not [directly] human controlled

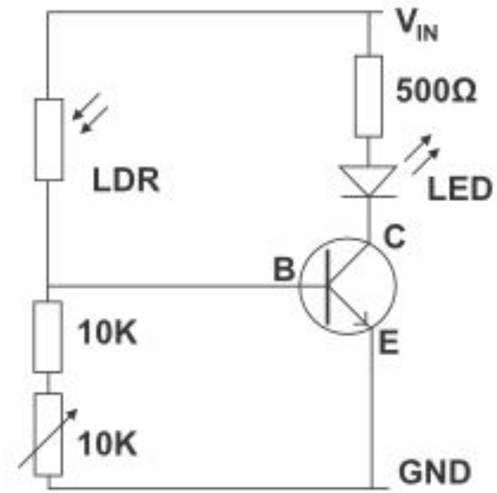
Photo resistors, also known as light dependent resistors (LDR), are light sensitive devices most often used to indicate the presence or absence of light, or to measure the light intensity. In the dark, their resistance is very high, sometimes up to 1MΩ, but when the LDR sensor is exposed to light, the resistance drops dramatically, even down to a few ohms, depending on the light intensity. LDRs have a sensitivity that varies with the wavelength of the light applied and are nonlinear devices. They are used in many applications but are sometimes made obsolete by other devices such as photodiodes and phototransistors. Some countries have banned LDRs made of lead or cadmium over environmental safety .concerns



Basic Photoresistor Circuit www.CircuitsToday.com

Light sensor

If a basic light sensor is needed, an LDR circuit such as the one in the figure can be used. The LED lights up when the intensity of the light reaching the LDR resistor is sufficient. The 10K variable resistor is used to set the threshold at which the LED will turn on. If the LDR light is below the threshold intensity, the LED will remain in the off state. In real-world applications, the LED would be replaced with a relay or the output could be wired to a microcontroller or some other device. If a darkness sensor was needed, where the LED would light in the absence of light, the LDR and the two 10K resistors should be swapped.



Light sensor circuit example

Audio compressors

Audio compressors are devices which reduce the gain of the audio amplifier when the amplitude of the signal is above a set value. This is done to amplify soft sounds while preventing the loud sounds from clipping. Some compressors use an LDR and a small lamp (LED or electroluminescent panel) connected to the signal source to create changes in signal gain. This technique is believed by some to add smoother characteristics to the signal because the response times of the light and the resistor soften the attack and release. The delay in the response time in these applications is on the order of 0.1s.

Usage

- We are going to use them just as we did the potentiometer
  - An RC circuit
  - Charge the capacitor
  - Let the capacitor drain through the photoresistor
  - Value of the photoresistor (and capacitor) will determine the time constant of the circuit

8. Photo Electric Transducers:

- A photoelectric transducer can be categorized as photoemissive, photoconductive, or photovoltaic. In photoemissive devices, radiation falling on a cathode causes electrons to be emitted from the cathode surface.

- In photoconductive devices, the resistance of a material is changed when it is illuminated. Photovoltaic cells generate an output voltage proportional to radiation intensity.

- The incident radiation may be infrared, ultraviolet, gamma rays, or X rays as well as visible light.

Photo Electric Transducers (cont’d):-

8.2. Photoconductive Cells or Photocells

- Another photoelectric effect that has proved very useful is the photoconductive effect, which is used in photoconductive cells or photocells.

- In this type of device the electrical resistance of the material varies with the amount of light striking it.A typical form of construction is shown in Fig. (18-a).

Photo Electric Transducers (cont'd):-

8.2. Photoconductive Cells or Photocells

- The photoconductive material, typically cadmium sulfide, cadmium selenide, or cadmium sulfoselenide, is deposited in a zigzag pattern, to obtain a desired resistance value and power rating.

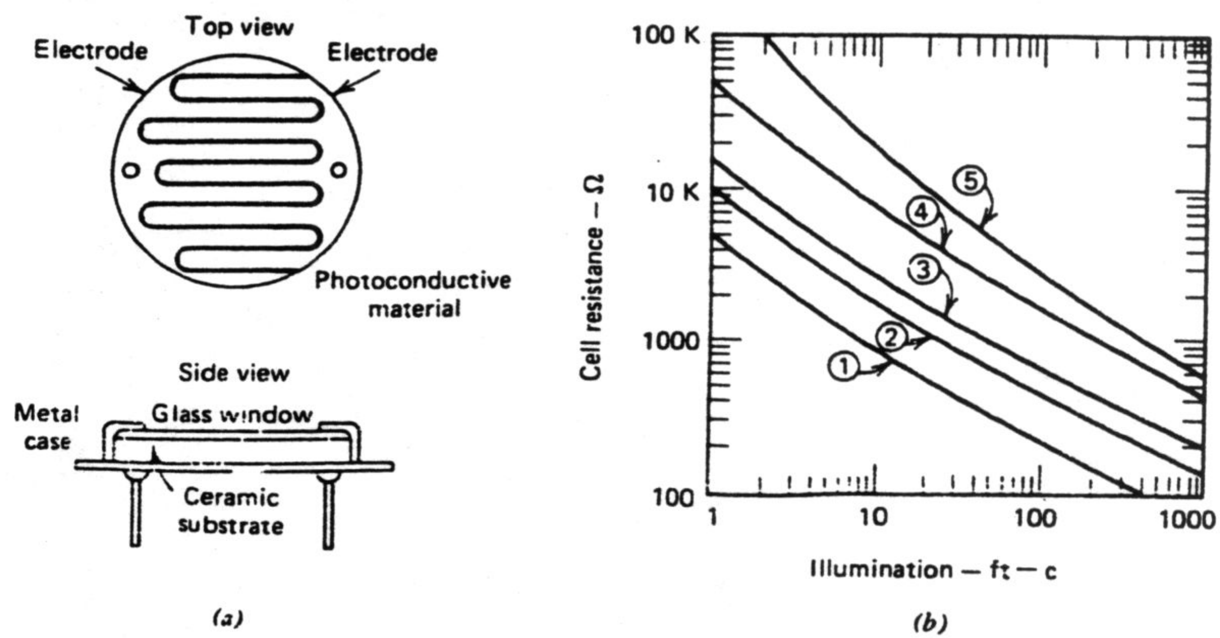


Fig (18) Photoconductive cell. (a) Construction. (b) Typical curves of resistance versus illumination.

Photo Electric Transducers (cont’d):-

8.2. Photoconductive Cells or Photocells

- The material separates two metal-coated areas acting as electrodes, all on an insulating base such as ceramic. The assembly enclosed in a metal case with a glass window over the photoconductive material. Photocells of this type are made in a range of sizes, having diameters of one-eighth inch to over one inch..

Photo Electric Transducers (cont'd):-

8.2. Photoconductive Cells or Photocells

- The small sizes are suitable where spa is critical, for example, in equipment for reading punched cards and similar applications. However, the very small units have very low power dissipation ratings.

- A typical control circuit utilizing a photoconductive cell is illustrated in Fig. The potentiometer is used to make adjustments to compensate for manufacturing tolerances in photocell sensitivity and relay-operating sensitivity.

Photo Electric Transducers (cont'd):-

8.2. Photoconductive Cells or Photocells

- When the photocell has the appropriate light shining on it, its resistance will be low and the current through the relay will consequently be high enough to operate the relay. When the light is interrupted, the resistance will rise, causing the relay current to decrease enough to deenergize the relay.

Photo Electric Transducers (cont'd):-

8.2. Photoconductive Cells or Photocells

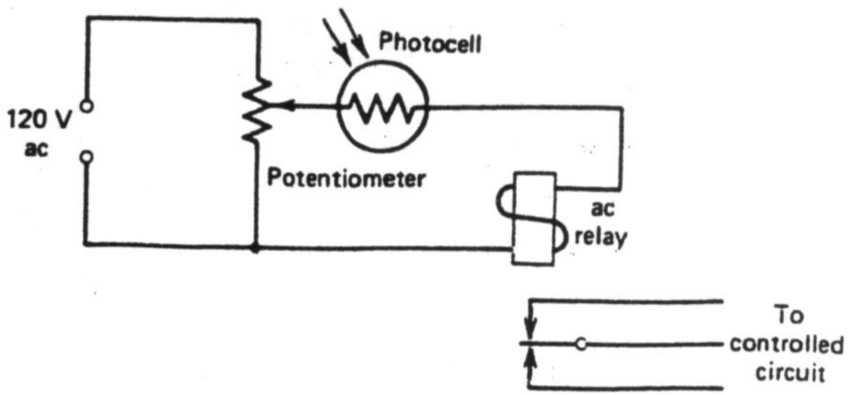


Fig (19) Photocell and relay control circuit.

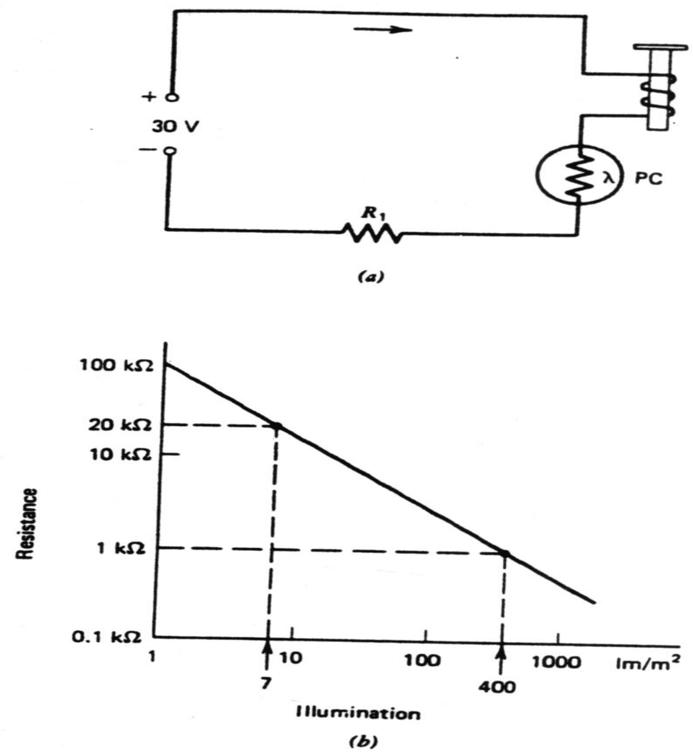


Fig (20) (a) Relay control by a photoconductive (PC) cell and (b) PC cell illumination characteristics.

Photo Electric Transducers (cont'd):-

8.3. The Photovoltaic Cell

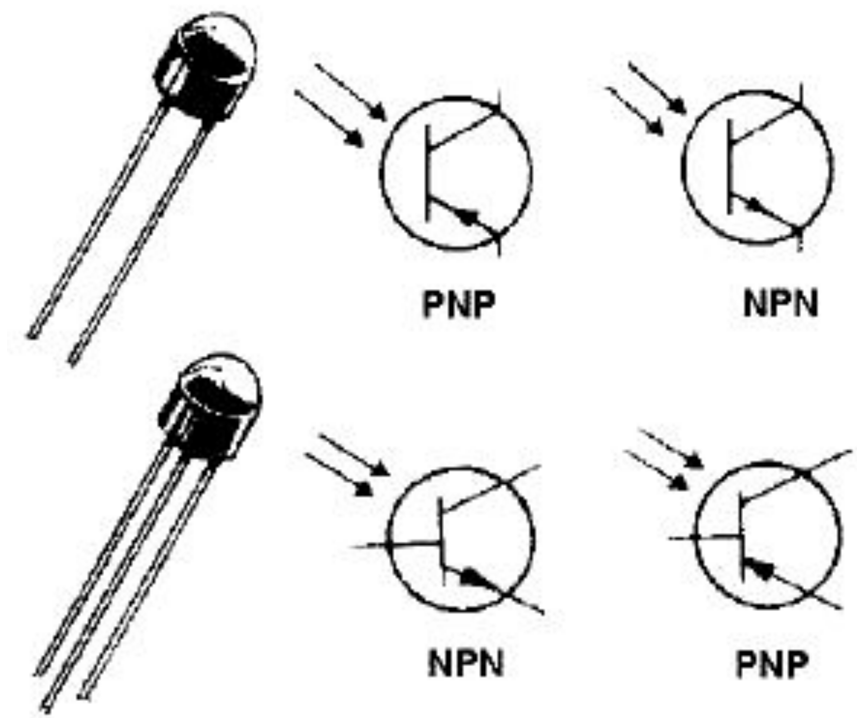
- The photovoltaic cell, or "solar cell," as it is sometimes called, will produce an electrical current when connected to a load. Both silicon (Si) and selenium (Se) types are known.

- Photovoltaic cells may be used in a number of applications. Multiple-unit silicon photovoltaic devices may be used for sensing light as a means of reading punched cards in the data processing industry.

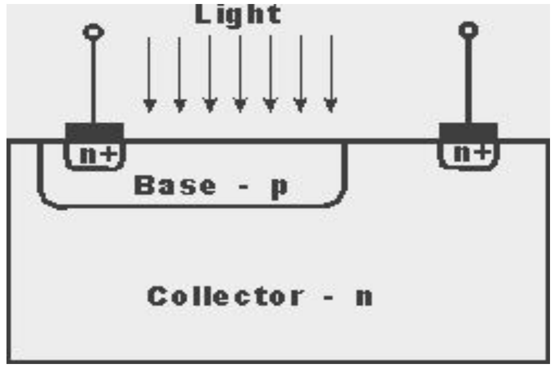
- Gold-doped germanium cells with controlled spectral responses act as photovoltaic devices in the infrared region of the spectrum and may be used as infrared detectors.

Phototransistors

- Behave like regular transistors, but:
  - Use light-sensitive collector-base junction to control collector-emitter current (I_{CE})
  - Base often unconnected, otherwise biased to adjust sensitivity to light
  - Small collector-emitter leakage current when no light is incident, called dark current



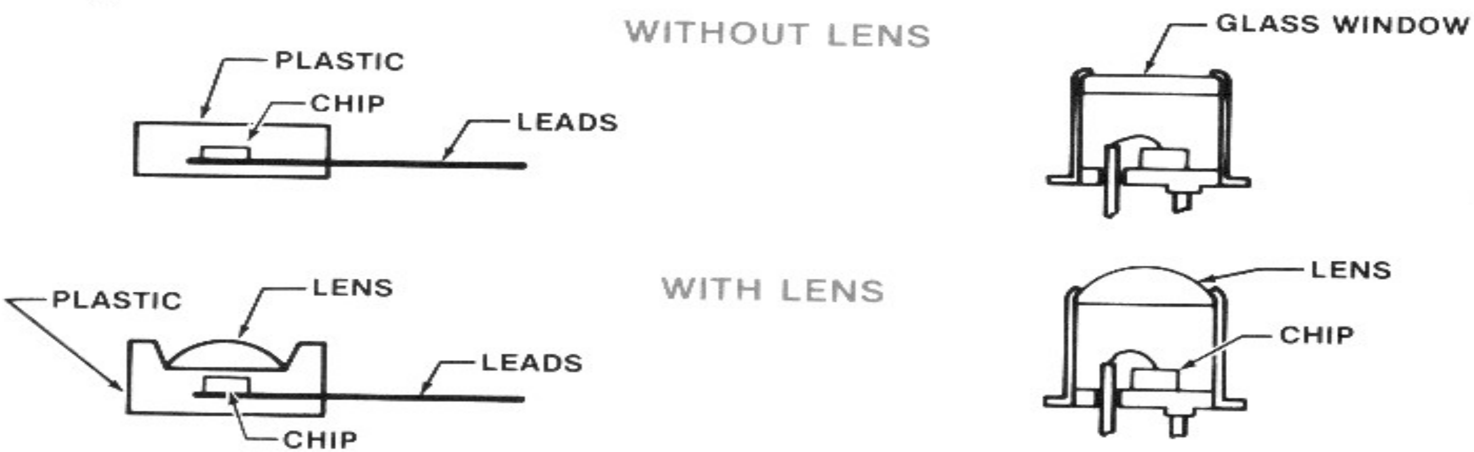
Phototransistor Structure and Packaging



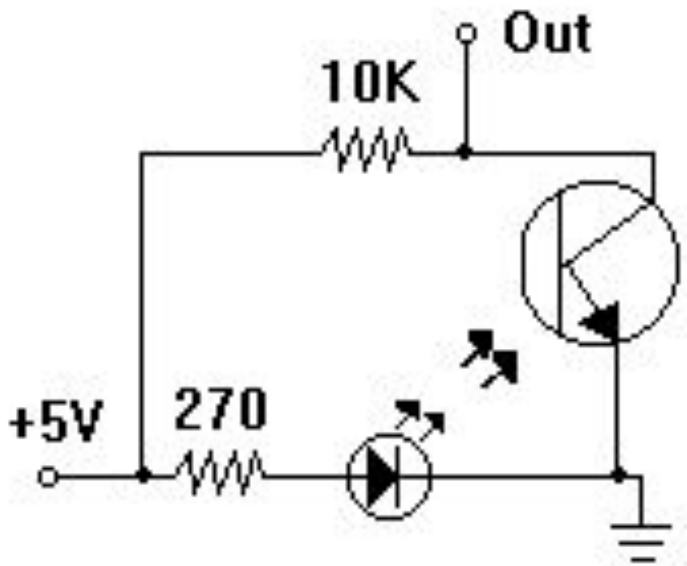
http://www.radio-electronics.com/info/data/semicond/phototransistor/photo_transistor.php

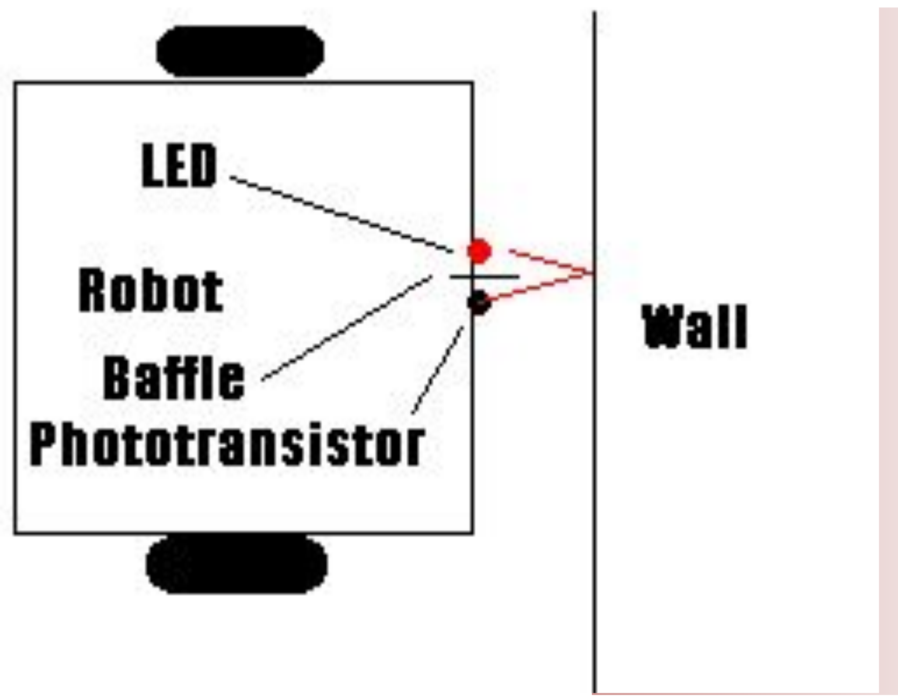
PLASTIC

HERMETIC



Phototransistor Application: Obstacle Detection





- Adjust baffle length to vary detection range
- Use IR LED and Photodiode to avoid visible light interference
- Use multiple sensors in a row to detect narrow obstacles

Phototransistors: Additional Notes

- Must be properly biased (as with regular transistors)
- Used in linear and saturation/cut-off regions

- Sensitive to temperature changes
- Must be protected against moisture
- Hermetic packaging more expensive, but more tolerant of severe environments than plastic packaging