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F.Y.BSc (Computer Science)

Semester-II

Electronics Paper-I

Subject- ELC-121 – Instrumentation Systems

According to new CBCS syllabus w.e.f.2019-2020

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Unit-II- Sensors and Actuators

- Temperature sensor (Thermistor, LM-35).
- Optical sensor (LDR), Passive Infrared sensor (PIR).
- Tilt sensor, ultrasonic sensor, Motion sensor, Image Sensor.
- Actuators: DC Motor, Stepper Motor

Introduction:

Sensor forms the first block of an instrumentation system. There are n-numbers of sensors for many varieties of parameters to be measured. Frequently required process variables are temperature, pressure, motion, humidity etc.

Sensor is very important because it actually feeds the status of the parameter to the measuring system, based on which the rest of the system function. Thus, sensor should give faithful information regarding the process variable, without any distortion.

Accuracy of the control system cannot be achieved unless the variables are measured by the sensor with a high degree of accuracy.

Temperature Sensor:

Temperature is one of the most commonly measured parameter in the world. Temperature Sensors measure the amount of heat energy or even coldness that is generated by an object or system, allowing us to "sense" or detect any physical change to that temperature and convert it into either an analogue or digital output.

Example: Microwave, fridge, AC, washing machine and all types of industries.

The choice of temperature sensor depends upon the temperature measurement range and the type of application.

Thermistors:

Thermistors are primary, passive, temperature sensors whose resistance changes with temperature. This thermal energy is converted into resistance change.

Thermistors or thermally sensitive resistors are the ones that change their physical appearance when subjected to change in the temperature. The thermistors are made up of ceramic material such as oxides of nickel, oxides of iron, manganese or cobalt coated in glass, copper which allows them to deform easily.

Most of the thermistors have a negative temperature coefficient (NTC) which means their resistance decreases with an increase in the temperature. But, there are a few thermistors that have a positive temperature coefficient (PTC) and, their resistance increases with a rise in the temperature.

The relation between resistance and temperature is highly non-linear. If R_T is the resistance of a thermistor at a temperature (T), then it is expressed by the equation,

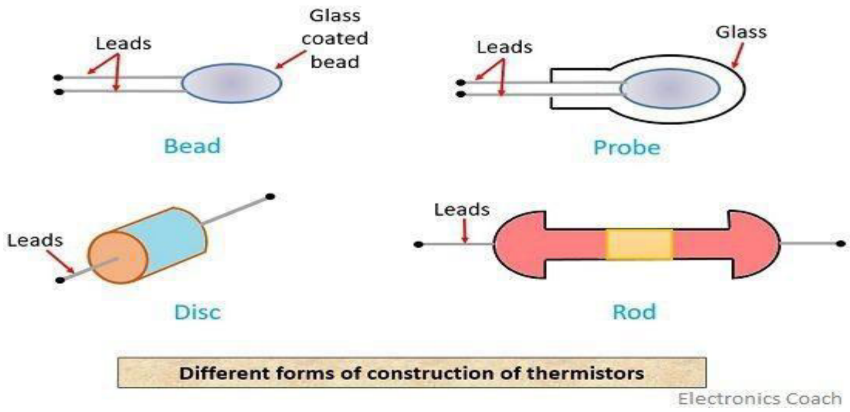
$$\mathbf{R_T = ae^{b/T}}$$

Where a and b are constants determined by the structure and material of the thermistors.

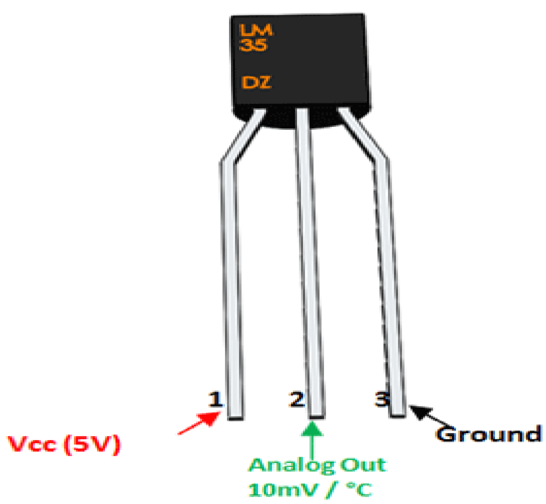
Thermistor Construction:

Because the thermistor is a bulk semiconductor, it can be fabricated in many forms and is available in variety of sizes and shapes. Thermistors may be in the forms of beads, rods and discs.

A thermistor in the form of bead is smallest in size and the bead may have a diameter of 0.15mm to 1.25mm. Discs are made by pressing material under high pressure into cylindrical flat shapes with diameter ranging from 2.5 mm to 25 mm.



LM-35 (LM- Linear Monolithic)

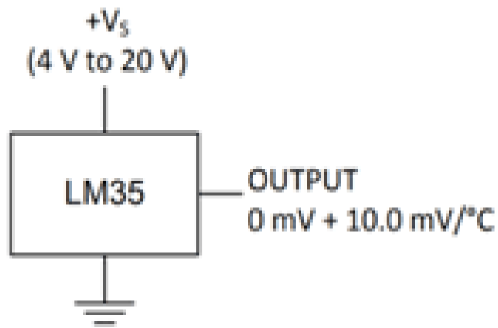


LM 35 is one of the frequently used temperature sensor. It is an integrated solid state analog temperature sensor whose output voltage changes according to temperature around it. That is it senses temperature and converts it into electrical quantity of voltage. It can be used for temperature range of -55°C to 150°C.

How to use LM35 Temperature Sensor:

LM35 is a precession Integrated circuit Temperature sensor, whose output voltage varies, based on the temperature around it. It is a small and cheap IC which can be used to measure temperature anywhere between -55°C to 150°C. It can easily be interfaced with any Microcontroller that has ADC function or any development platform like Arduino.

Power the IC by applying a regulated voltage like +5V (V_S) to the input pin and connected the ground pin to the ground of the circuit. Now, you can measure the temperate in form of voltage as shown below.



If the temperature is 0°C, then the output voltage will also be 0V. There will be rise of 0.01V (10mV) for every degree Celsius rise in temperature. The voltage can converted into temperature using the below formulae.

$V_{OUT} = 10mV/{}^{o}C * T$

Where,

- V_{OUT} is the LM 35 output voltage.
- T is the temperature in ^{o}C

Specifications / Features of LM35

- Calibrated Directly in Celsius (Centigrade)
- Linear + 10-mV/°C Scale Factor.
- 0.5°C Ensured Accuracy
- Rated for Full −55°C to 150°C **Range**.
- Suitable for Remote Applications.
- Low-Cost temperature sensor.
- Operates From 4 V to 30 V.
- Less than 60-μA Current Drain.
- Can easily interfaced to the control system.

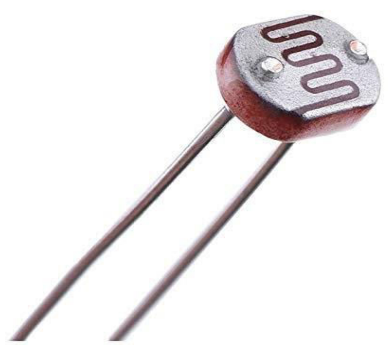
LM35 Temperature Sensor Applications:

- Measuring temperature of a particular environment
- Providing thermal shutdown for a circuit/component
- Monitoring Battery Temperature
- Measuring Temperatures for HVAC applications.

Optical Sensor: LDR

An LDR is a very commonly used optical sensor that shows resistance change with the light intensity that falls upon it. This allows them to be used in light sensing circuits. LDR work based of the principle of photoconductivity. Photoconductivity is an optical phenomenon in which the material's conductivity is changes with the radiation intensity. The change in conductivity produces change in resistance.

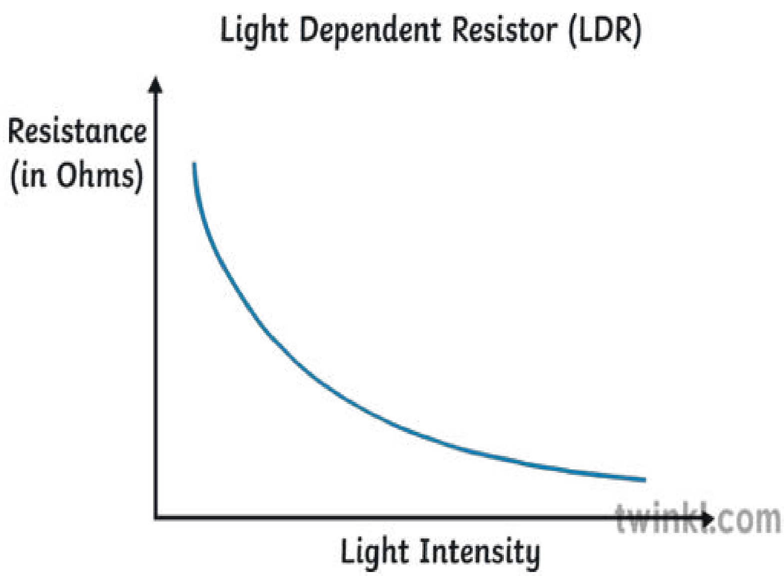
As LDR is dependent on light intensity, it is also called as photoconductors or photo resistive devices.



Working Principles:

The working principle of an LDR is photoconductivity, which is nothing but an optical phenomenon. When the light is absorbed by the material then the conductivity of the material enhances. When the light falls on the LDR, then the electrons in the valence band of the material are excited to the conduction band. But, the photons in the incident light must have energy superior to the band gap of the material to make the electrons jump from one band to another band (valance to conduction).

Hence, when light having ample energy, more electrons are excited to the conduction band which grades in a large number of charge carriers. When the effect of this process and the flow of the current starts flowing more, the resistance of the device decreases.



There is maximum limit on wavelength of light and is given by

$$\lambda_{max} = hc/E_g$$

where, λ_{max} = maximum radiation wavelength (m)

h = Planck's constant $6.63 * 10^{-34}$ J-S

c = Velocity of radiation $3 * 10^{8}$ m/s

E_g = Semiconductor energy gap (J) which depends upon crystal structure of different for different materials

LDR Materials:

The semiconductors normally used for the photoconductor are cadmium sulphide (Cds), cadmium selenide (CdSe), Lead sulphide (Pbs) and Lead selenide (PbSe).

Passive infrared Sensor (PIR)

A passive infrared sensor (PIR sensor) is an electronic sensor that measures infrared (IR) light radiating from objects in its field of view. Since it does not generate or radiate any energy for detection purpose and needs external power supply for its working, it is called as passive infrared sensor.

They are most often used in PIR-based motion detectors. PIR sensors are commonly used in security alarms and automatic lighting applications.

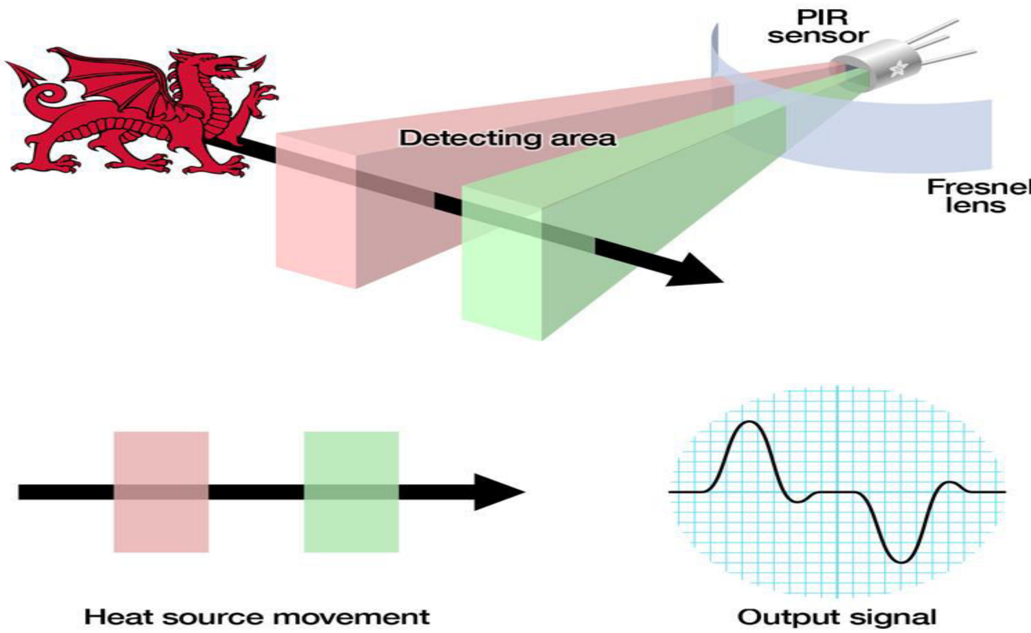
PIR sensors detect general movement, but do not give information on who or what moved. For that purpose, an imaging (active) IR sensor is required.

Working Principles:

All objects with a temperature above absolute zero emit heat energy in the form of electromagnetic radiation. Usually this radiation isn't visible to the human eye because it radiates at infrared wavelengths, but it can be detected by electronic devices designed for such a purpose.

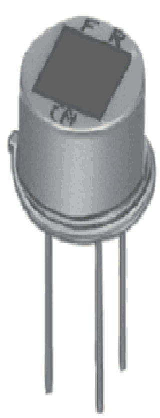
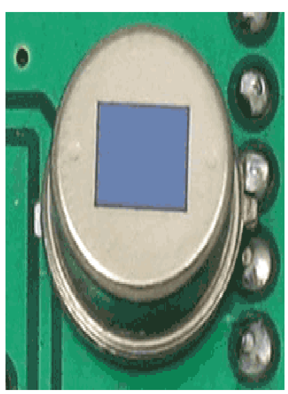
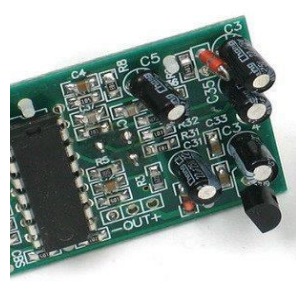
A PIR sensor can detect changes in the amount of infrared radiation impinging upon it, which varies depending on the temperature and surface characteristics of the objects in front of the sensor. When an object, such as a person, passes in front of the background, such as a wall, the temperature at that point in the sensor's field of view will rise from room temperature to body temperature, and then back again. The sensor converts the resulting change in the incoming infrared radiation into a change in the output voltage, and this triggers the detection.

Objects of similar temperature but different surface characteristics may also have a different infrared emission pattern, and thus moving them with respect to the background may trigger the detector as well.



Construction:

PIR has core made up of solid state pyroelectric material. This material generates energy when exposed to heat. Materials used are gallium nitride (GaN), caesium nitrate ($CsNO_3$), polyvinyl fluorides, derivatives of phenyl pyridine, and cobalt phthalocyanine.


Examples of PIR sensor modules: BIS 0001, RE 200B, NL11NH etc. Out of these BIS 0001 (Microwave Power PIR Motion Detector IC) is widely used. This chip detects the motion, processes it and produces a digital output pulse.

Tilt Sensor:

Tilt sensors are used to detect orientation or inclination of an object. They are also called as "mercury switches", "tilt switches" or "rolling ball sensors". They are small, inexpensive, low-power and easy-to-use. These are found in toys, gadgets, cameras, robots and video game controller. It also finds applications in automobile sectors for security sestems, automobile air bags. They are also useful in studying human movement.

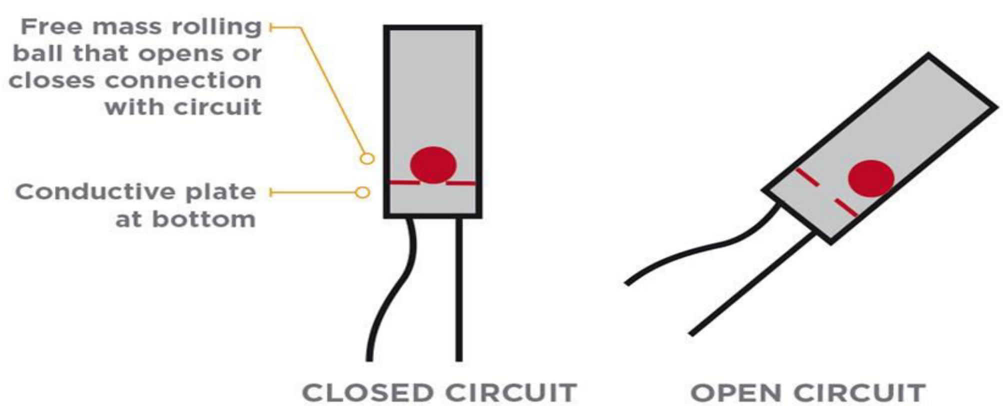
Construction:

They are usually made by a cavity of some sort (cylindrical is popular, although not always) and a conductive free mass inside, such as a blob of mercury or rolling ball. One end of the cavity has two conductive elements (poles).

The advantage of mercury blob is that, it becomes dense enough that it does not bounce and so the switch is not susceptible to vibrations. But the disadvantage is that they are extremely toxic because of mercury usage. On the other hand, ball-type sensors are easy to make, wont shatter, and pose no risk of pollution.

Working Principles:

When the sensor is oriented in downward direction so that poles are downwards, the ball rolls down towards the poles. The two poles get shorted and act as if switch is closed. When balls rolls upwards the poles are separated from each other and it acts as open switch.



Different types of tilt sensor:

Tilt sensors can be of

i. Force balance sensors
ii. Solid state micro-electromechanical systems (MEMS)
iii. Electrolytic tilt sensors

Features of Tilt Sensor:

1. Detect orientation or inclination very easily
2. Smaller in size and very easy to use
3. Low cost
4. Low power
5. They are reliable and robust

Ultrasonic Sensor:

An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal. Ultrasonic sensor consists of transmitter and receiver.

Transmitter transmits ultrasonic waves which travel trough the medium (either liquid or air).

An ultrasonic sensor uses a transducer to send and receive ultrasonic pulses that relay back information about an object's proximity.

High-frequency sound waves reflect from boundaries to produce distinct echo patterns.

Ultrasonic sensors work by sending out a sound wave at a frequency above the range of human hearing. The transducer of the sensor acts as a microphone to receive and send the ultrasonic sound. Our ultrasonic sensors, like many others, use a single transducer to send a pulse and to receive the echo. The sensor determines the distance to a target by measuring time lapses between the sending and receiving of the ultrasonic pulse.

Motion Sensor:

A motion sensor is a device that detects moving objects, particularly human beings. It forms a input to a motion detector system which automatically performs a task or alerts about user motion. Such systems have wide use in domestic and commercial applications. The applications for which you all are familiar are:

1. Such systems are used for security where the home owner or security service is alerter when system detects the motion of a possible intruder. Such a detector may also trigger a security camera to record the possible intrusion.
2. In smart home for automated lighting and appliance control, motion sensors are used to find occupancy. Optimum use of electrical energy is possible here.
3. Activating automatic door openers in businesses and public buildings.
4. Activating street lights or indoor lights in walkways, such as lobbies and staircases.

Mostly low-cost motion sensors can detect up to distances of at least 4 to 5m. There are some costly detectors which can have much longer ranges. Tomographic motion detection systems can cover much larger areas because they use radio waves.

Working Principle:

The sensors detect motion of moving objects by sensing emitted or reflected signal from the moving object. Depending upon the signal type the electronic motion sensors are classified as

1. Optical motion Sensor: use optical signal; e.g. PIR sensor
2. Microwave motion Sensor: use microwave signal
3. Ultrasonic motion Sensor: use ultrasonic waves
4. Topographic motion Sensor: uses radio waves

All these are passive sensors. Sometimes the detector system has a transmitter for illumination. The signal can be emitted by the object, or by some ambient emitter such as the sun or a radio station of sufficient strength.