- Analyze the role and applications of sensors.
- Design an application using sensors.

List of Experiment

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12	**Mini Project** Design an application using various sensors.	

Experiment-1

Aim: Conduct an experiment to understand the working operation of

a. Potential divider
b. Comparator

Components required:

Sl.no	Components	Quantity
01		

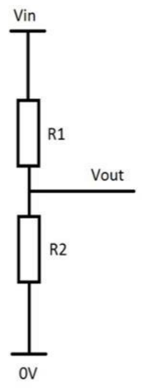
Theory :

What is a Potential Divider / Voltage Divider?

The voltage difference between any two points in a circuit is known as Potential Difference and it is this potential difference which makes current flow.

OR

A potential divider could be thought of as a voltage divider and it is often referred to as such. A Volt is just a unit of 'potential difference' in electric charge between two objects.



The formula for working out the voltage drop across two resistors in series is:

$$\text{Vout} = \frac{\text{Vin} \times \text{R2}}{\text{R1} + \text{R2}}$$

One of the most useful ways to use this circuit is to replace R2 with a variable resistor. If R2 can be controlled by turning a dial then Vout can also be controlled. This is used for tuning or volume control in many circuits such as in our FM Radio Kit V2.0 or 3W Stereo Amplifier Kit.
Another common use of the potential divider is to replace R2 with a sensor such as an LDR. Then as the resistance of the sensor changes, Vout changes as well. This change can then be used to trigger a transistor or can be fed into the input of a microcontroller.

The unit of potential difference generated between two points is called the **Volt** and is generally defined as being the potential difference dropped across a fixed resistance of one ohm with a current of one ampere flowing through it.

In other words, 1 Volt equals 1 Ampere times 1 Ohm, or commonly V = I*R.

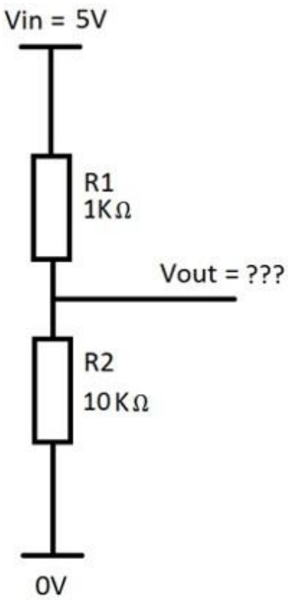
Ohm's Law states that for a linear circuit the current flowing through it is proportional to the potential difference across it so the greater the potential difference across any two points the bigger will be the current flowing through it.

For example, if the voltage at one side of a 10Ω resistor measures 8V and at the other side of the resistor it measures 5V, then the potential difference across the resistor would be 3V (8 – 5) causing a current of 0.3A to flow.

Example:

This is a worked example of using the formula above to calculate the missing Vout value for a circuit.

Look at the circuit below and take note of the values that are known. Vin is 5V, R1 is 1KΩ and R2 is 10KΩ



Next, substitute the known values into the formula:

$$\text{Vout} = \frac{\text{Vin} \times \text{R2}}{\text{R1} + \text{R2}}$$

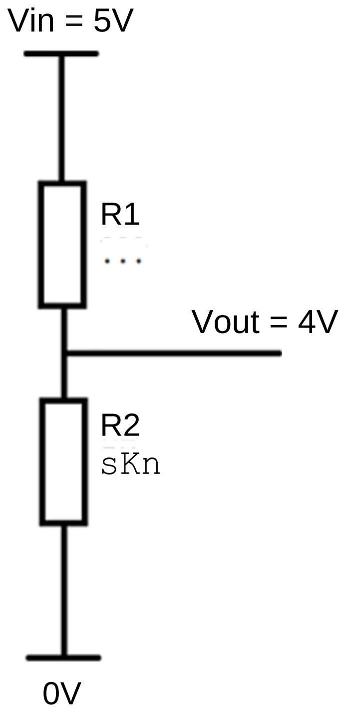
$$\text{Vout} = \frac{5\text{V} \times 10\text{K}\Omega}{1\text{K}\Omega + 10\text{K}\Omega}$$

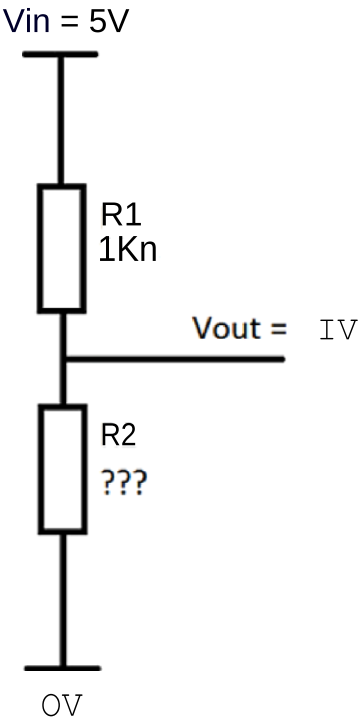
$$\text{Vout} = 4.55\text{V}$$

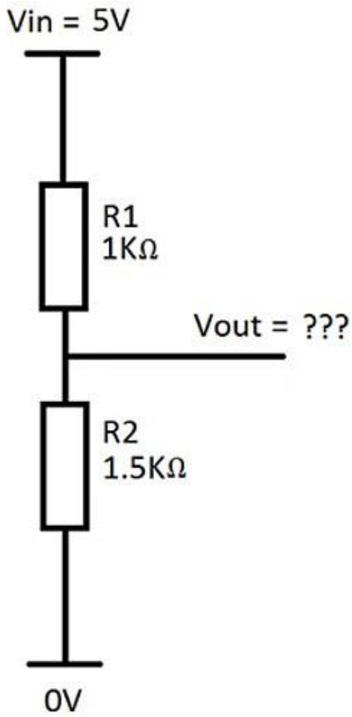
Example Questions:

Now try finding the missing values in these three examples.

Question 1:


Vin = 5V
R1
Vout = 4V
R2
sKn
0V


Vin = 5V
R1
1Kn
Vout = IV
R2
???
OV



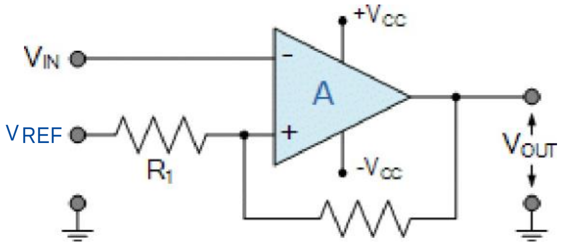
1) $4V = \frac{5V \times 5K\Omega}{R1 + 5K\Omega}$ $\quad R1 = \frac{5V}{4V} = 1.25K\Omega$

2) $1V = \frac{5V \times R2}{1K\Omega + R2}$ $\quad R2 = \frac{1V \times 1K}{5V} = 0.25K\Omega$

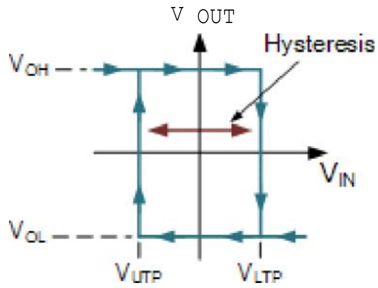
3) $Vout = \frac{5V \times 1.5K}{1K\Omega + 1.5K\Omega}$ $\quad Vout = \frac{7.5VK\Omega}{2.5K\Omega} = 3V$

<u>Comparator:</u>

Comparator circuit



+VCC
VIN
-
A
VREF
+
R1
-VCC
VOUT



V OUT
Hysteresis
VOH
VIN
VOL
VUTP
VLTP

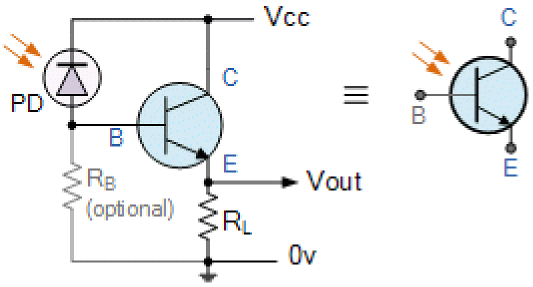
Experiment-2

Light Sensor

Aim:

a. Conduct an experiment to determine the sensitivity of the light sensor.
b. Analyze the application of light sensor using LDR and buzzer.

Theory



Light Sensors

Light Sensors are photoelectric devices that convert light energy (photons) whether visible or infra-red light into an electrical (electrons) signal

A **Light Sensor** generates an output signal indicating the intensity of light by measuring the radiant energy that exists in a very narrow range of frequencies basically called "light", and which ranges in frequency from "Infra-red" to "Visible" up to "Ultraviolet" light spectrum.

The light sensor is a passive devices that convert this "light energy" whether visible or in the infra-red parts of the spectrum into an electrical signal output. Light sensors are more commonly known as "Photoelectric Devices" or "Photo Sensors" because the convert light energy (photons) into electricity (electrons). Photoelectric devices can be grouped into two main categories, those which generate electricity when illuminated, such as *Photo-voltaics* or *Photo-emissives* etc, and those which change their electrical properties in some way such as *Photo-resistors* or *Photo-conductors*. This leads to the following classification of devices.

- • Photo-emissive Cells – These are photodevices which release free electrons from a light sensitive material such as caesium when struck by a photon of sufficient energy. The amount of energy the photons have depends on the frequency of the light and the higher the frequency, the more energy the photons have converting light energy into electrical energy.
- • Photo-conductive Cells – These photodevices vary their electrical resistance when subjected to light. Photoconductivity results from light hitting a semiconductor material which controls the current flow through it. Thus, more

light increase the current for a given applied voltage. The most common photoconductive material is Cadmium Sulphide used in LDR photocells.

- • Photo-voltaic Cells – These photodevices generate an emf in proportion to the radiant light energy received and is similar in effect to photoconductivity. Light energy falls on to two semiconductor materials sandwiched together creating a voltage of approximately 0.5V. The most common photovoltaic material is Selenium used in solar cells.
- • Photo-junction Devices – These photodevices are mainly true semiconductor devices such as the photodiode or phototransistor which use light to control the flow of electrons and holes across their PN-junction. Photojunction devices are specifically designed for detector application and light penetration with their spectral response tuned to the wavelength of incident light.

The Photoconductive Cell

A **Photoconductive** light sensor does not produce electricity but simply changes its physical properties when subjected to light energy. The most common type of photoconductive device is the *Photoresistor* which changes its electrical resistance in response to changes in the light intensity.

Photoresistors are Semiconductor devices that use light energy to control the flow of electrons, and hence the current flowing through them. The commonly used *Photoconductive Cell* is called the **Light Dependent Resistor** or **LDR**.

he Light Dependent Resistor

Typical LDR

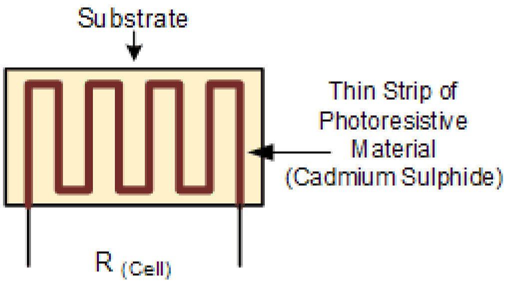
As its name implies, the **Light Dependent Resistor** (LDR) is made from a piece of exposed semiconductor material such as cadmium sulphide that changes its electrical resistance from several thousand Ohms in the dark to only a few hundred Ohms when light falls upon it by creating hole-electron pairs in the material.

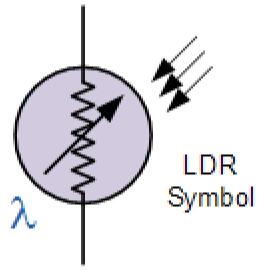
The net effect is an improvement in its conductivity with a decrease in resistance for an increase in illumination. Also, photoresistive cells have a long response time requiring many seconds to respond to a change in the light intensity.

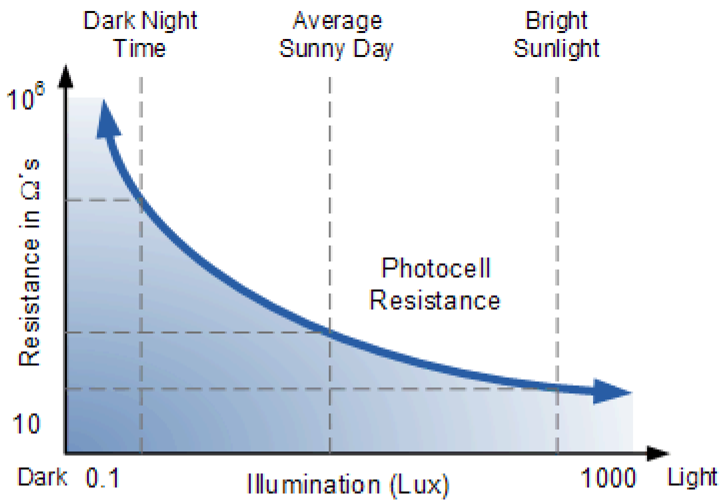
Materials used as the semiconductor substrate include, lead sulphide (PbS), lead selenide (PbSe), indium antimonide (InSb) which detect light in the infra-red range with the most commonly used of all photoresistive light sensors being **Cadmium Sulphide** (Cds).

Cadmium sulphide is used in the manufacture of photoconductive cells because its spectral response curve closely matches that of the human eye and can even be controlled using a simple torch as a light source. Typically then, it has a peak sensitivity wavelength (λp) of about 560nm to 600nm in the visible spectral range.

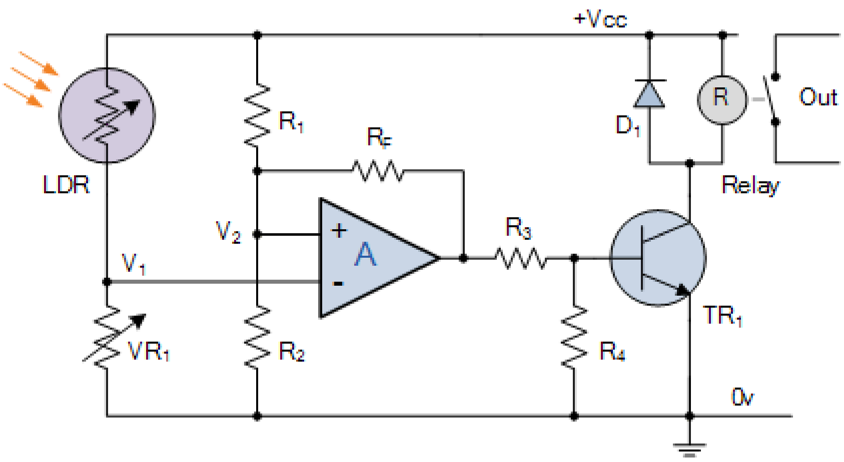
The Light Dependent Resistor Cell







Light Level Sensing Circuit



In this basic dark sensing circuit, the light dependent resistor LDR1 and the potentiometer VR1 form one adjustable arm of a simple resistance bridge network, also known commonly as a *Wheatstone bridge*, while the two fixed resistors R1 and R2 form the other arm. Both sides of the bridge form potential divider networks across the supply voltage whose outputs V1 and V2 are connected to the non-inverting and inverting voltage inputs respectively of the operational amplifier.

The operational amplifier is configured as a Differential Amplifier also known as a voltage comparator with feedback whose output voltage condition is determined by the difference between the two input signals or voltages, V1 and V2. The resistor combination R1 and R2 form a fixed voltage reference at input V2, set by the ratio of the two resistors. The LDR – VR1 combination provides a variable voltage input V1proportional to the light level being detected by the photoresistor.

As with the previous circuit the output from the operational amplifier is used to control a relay, which is protected by a free wheel diode, D1. When the light level sensed by the LDR and its output voltage falls below the reference voltage set at V2 the output from the op-amp changes state activating the relay and switching the connected load.

Likewise as the light level increases the output will switch back turning "OFF" the relay. The hysteresis of the two switching points is set by the feedback resistor Rf can be chosen to give any suitable voltage gain of the amplifier.

The operation of this type of light sensor circuit can also be reversed to switch the relay "ON" when the light level exceeds the reference voltage level and vice versa by reversing the positions of the light sensor LDR and the potentiometer VR1. The potentiometer can be used to "pre-set" the switching point of the differential amplifier to any particular light level making it ideal as a simple light sensor project circuit.

Circuit diagram

Result :

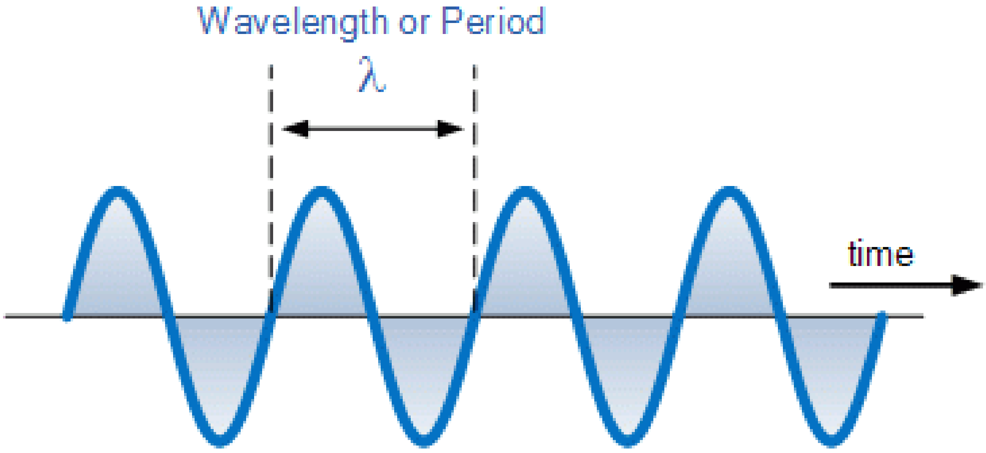
Experiment-3

Sound sensor

a. Conduct an experiment to determine the sensitivity of the sound sensor.
b. Analyze the application of sound sensor using clap switch circuit

Sound Transducers

Sound Transducers use electrical energy to create mechanical vibrations to disturbe the sourrounding air producing sound whether of an audible or inaudible frequency



Sound is the generalised name given to “acoustic waves”. These acoustic waves have frequencies ranging from just 1Hz up to many tens of thousands of Hertz with the upper limit of human hearing being around the 20 kHz, (20,000Hz) range.

The sound that we hear is basically made up from mechanical vibrations produced by an Audio Sound Transducer used to generate the acoustic waves, and for sound to be “heard” it requires a medium for transmission either through the air, a liquid, or a solid.

audio sound transducer
Sound Transducer

Also, the actual sound need not be a continuous frequency sound wave such as a single tone or a musical note, but may be an acoustic wave made from a mechanical vibration, noise or even a single pulse of sound such as a “bang”.

Audio Sound Transducers include both input sensors, that convert sound into and electrical signal such as a microphone, and output actuators that convert the electrical signals back into sound such as a loudspeaker.

We tend to think of sound as only existing in the range of frequencies detectable by the human ear, from 20Hz up to 20kHz (a typical loudspeaker frequency response), but sound can also extend way beyond these ranges.

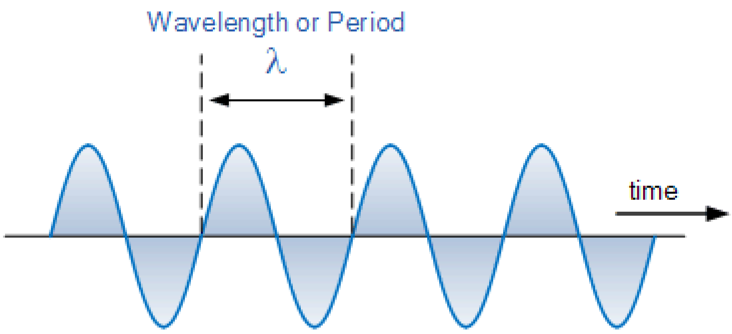
Sound transducers can also both detect and transmit sound waves and vibrations from very low frequencies called infra-sound up to very high frequencies called ultrasound. But in order for a sound transducer to either detect or produce "sound" we first need to understand what sound is.

What is Sound?

Sound is basically a waveform of energy that is produced by some form of a mechanical vibration such as a tuning fork, and which has a "frequency" determined by the origin of the sound for example, a bass drum has a low frequency sound while a cymbal has a higher frequency sound.

A sound waveform has the same characteristics as that of an electrical waveform which are Wavelength (λ), Frequency (f) and Velocity (m/s). Both the sounds frequency and wave shape are determined by the origin or vibration that originally produced the sound but the velocity is dependent upon the medium of transmission (air, water etc.) that carries the sound wave. The relationship between wavelength, velocity and frequency is given below as:

Sound Wave Relationship



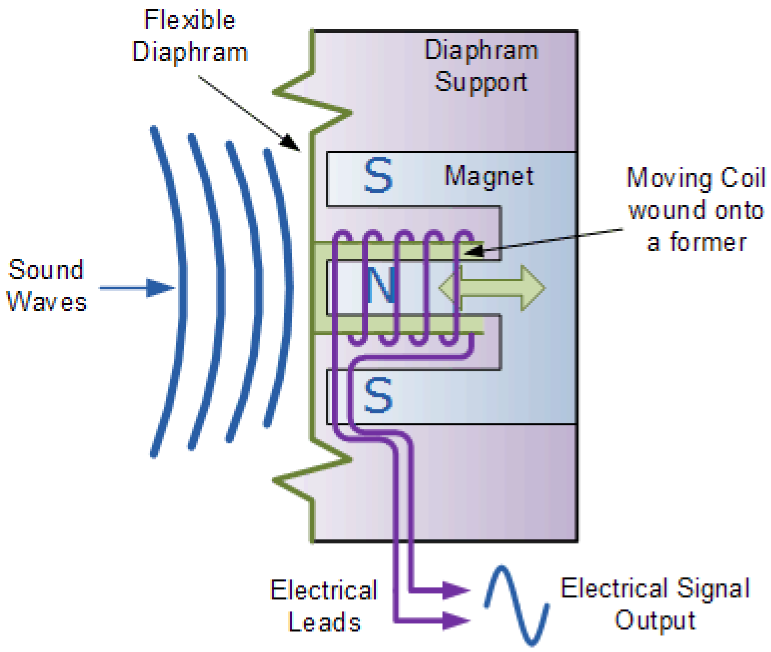
Where:

- Wavelength – is the time period of one complete cycle in Seconds, (λ)
- Frequency – is the number of wavelengths per second in Hertz, (f)
- Velocity – is the speed of sound through a transmission medium in m/s^{-1}
- **The Microphone Input Transducer**

- The **Microphone**, also called a "mic", is a sound transducer that can be classed as a "sound sensor". This is because it produces an electrical analogue output signal which is proportional to the "acoustic" sound wave acting upon its flexible diaphragm. This signal is an "electrical image" representing the characteristics of the acoustic waveform. Generally, the output signal from a microphone is an analogue signal either in the form of a voltage or current which is proportional to the actual sound wave.

- The most common types of microphones available as sound transducers are *Dynamic*, *Electret Condenser*, *Ribbon* and the newer *Piezo-electric Crystal* types. Typical applications for microphones as a sound transducer include audio recording, reproduction, broadcasting as well as telephones, television, digital computer recording and body scanners, where ultrasound is used in medical applications. An example of a simple "Dynamic" microphone is shown below.

Dynamic Moving-coil Microphone Sound Transducer



The construction of a dynamic microphone resembles that of a loudspeaker, but in reverse. It is a moving coil type microphone which uses electromagnetic induction to convert the sound waves into an electrical signal. It has a very small coil of thin wire suspended within the magnetic field of a permanent magnet. As the sound wave hits the flexible diaphragm, the diaphragm moves back and forth in response to the sound pressure acting upon it causing the attached coil of wire to move within the magnetic field of the magnet.

The movement of the coil within the magnetic field causes a voltage to be induced in the coil as defined by Faraday's law of Electromagnetic Induction. The resultant output voltage signal from the coil is proportional to the pressure of the sound wave acting upon the diaphragm so the louder or stronger the sound wave the larger the output signal will be, making this type of microphone design pressure sensitive.

As the coil of wire is usually very small the range of movement of the coil and attached diaphragm is also very small producing a very linear output signal which is 90^o out of phase to the sound signal. Also, because the coil is a low impedance inductor, the output voltage signal is also very low so some form of "pre-amplification" of the signal is required.

As the construction of this type of microphone resembles that of a loudspeaker, it is also possible to use an actual loudspeaker as a microphone.

Obviously, the average quality of a loudspeaker will not be as good as that for a studio type recording microphone but the frequency response of a reasonable speaker is actually better than that of a cheap "freebie" microphone. Also the coils impedance of a typical loudspeaker is different at between 8 to 16Ω. Common applications where speakers are generally used as microphones are in intercoms and walki-talkie's.

The Loudspeaker Output Transducer

Sound can also be used as an output device to produce an alert noise or act as an alarm, and loudspeakers, buzzers, horns and sounders are all types of sound transducer that can be used for this purpose with the most commonly used audible type output sound actuator being the "Loudspeaker".

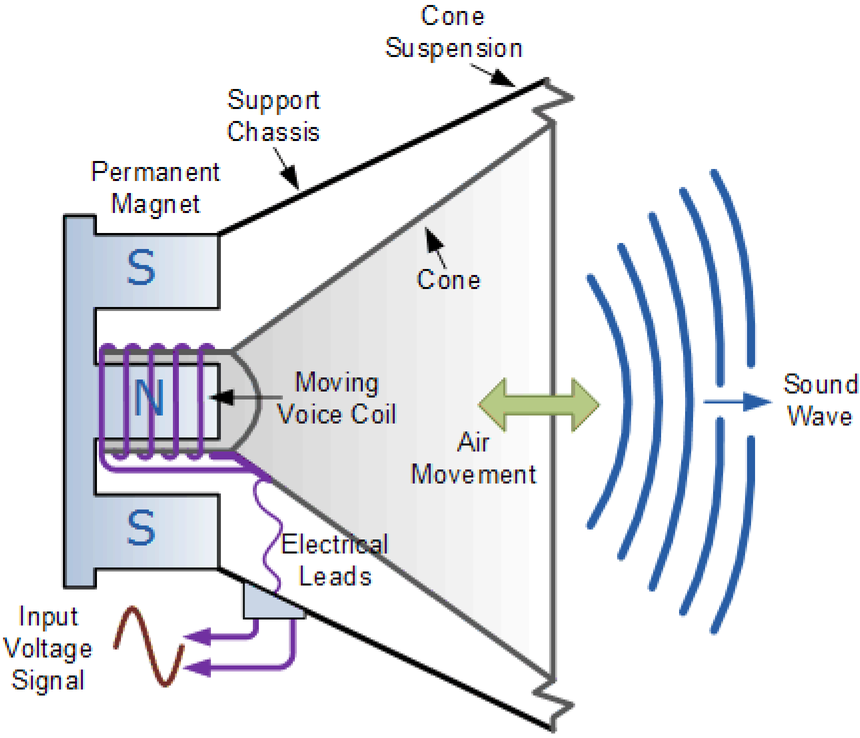
Loudspeaker Transducer

Loudspeakers are audio sound transducers that are classed as "sound actuators" and are the exact opposite of microphones. Their job is to convert complex electrical analogue signals into sound waves being as close to the original input signal as possible.

Loudspeakers are available in all shapes, sizes and frequency ranges with the more common types being moving coil, electrostatic, isodynamic and piezo-electric. Moving coil type loudspeakers are by far the most commonly used speaker in electronic circuits, kits and toys, and as such it is this type of sound transducer we will examine below.

The principle of operation of the **Moving Coil Loudspeaker** is the exact opposite to that of the "Dynamic Microphone" we look at above. A coil of fine wire, called the "speech or voice coil", is suspended within a very strong magnetic field, and is attached to a paper or Mylar cone, called a "diaphragm" which itself is suspended at its edges to a metal frame or chassis. Then unlike the microphone which is pressure sensitive input device, this type of sound transducer can be classed as a pressure generating output device.

The Moving Coil Loudspeaker



When an analogue signal passes through the voice coil of the speaker, an electro-magnetic field is produced and whose strength is determined by the current flowing through the "voice" coil, which in turn is determined by the volume control setting of the driving amplifier or moving coil driver. The electro-magnetic force produced by this field opposes the main permanent magnetic field around it and tries to push the coil in one direction or the other depending upon the interaction between the north and south poles.

As the voice coil is permanently attached to the cone/diaphragm this also moves in tandem and its movement causes a disturbance in the air around it thus producing a sound or note. If the input signal is a continuous sine wave then the cone will move in and out acting like a piston pushing and pulling the air as it moves and a continuous single tone will be heard representing the frequency of the signal. The strength and therefore its velocity, by which the cone moves and pushes the surrounding air produces the loudness of the sound.

As the speech or voice coil is essentially a coil of wire it has, like an inductor an impedance value. This value for most loudspeakers is between 4 and 16Ω and is called the "nominal impedance" value of the speaker measured at 0Hz, or DC.

Remember that it is important to always match the output impedance of the amplifier with the nominal impedance of the speaker to obtain maximum power transfer between the amplifier and speaker. Most amplifier-speaker combinations have an efficiency rating as low as 1 or 2%.

Although disputed by some, the selection of good speaker cable is also an important factor in the efficiency of the speaker, as the internal capacitance and magnetic flux characteristics of the cable change with the signal frequency, thereby causing both frequency and phase distortion. This has the effect of attenuating the signal. Also, with high power amplifiers large currents are flowing through these cables so small thin bell wire type cables can overheat during extended periods of use, again reducing efficiency.

The human ear can generally hear sounds from between 20Hz to 20kHz, and the frequency response of modern loudspeakers called general purpose speakers are tailored to operate within this frequency range as well as headphones, earphones and other types of commercially available headsets used as sound transducers.

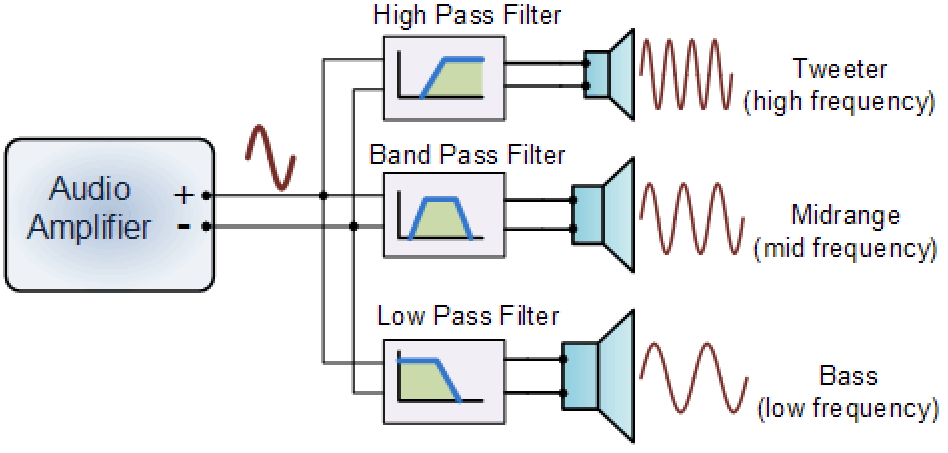
However, for high performance High Fidelity (Hi-Fi) type audio systems, the frequency response of the sound is split up into different smaller sub-frequencies thereby improving both the loudspeakers efficiency and overall sound quality as follows:

Descriptive Unit	Frequency Range
Sub-Woofer	10Hz to 100Hz
Bass	20Hz to 3kHz
Mid-Range	1kHz to 10kHz
Tweeter	3kHz to 30kHz

In multi speaker enclosures which have a separate Woofer, Tweeter and Mid-range speakers housed together within a single enclosure, a passive or active “crossover” network is used to ensure that the audio signal is accurately split and reproduced by all the different sub-speakers.

This crossover network consists of Resistors, Inductors, Capacitors, RLC type passive filters or op-amp active filters whose crossover or cut-off frequency point is finely tuned to that of the individual loudspeakers characteristics and an example of a multi-speaker "Hi-fi" type design is given below.

Multi-speaker (Hi-Fi) Design



In this tutorial, we have looked at different **Sound Transducers** that can be used to both detect and generate sound waves. Microphones and loudspeakers are the most commonly available sound transducer, but other lots of other types of sound transducers available which use piezoelectric devices to detect very high frequencies, hydrophones designed to be used underwater for detecting underwater sounds and sonar transducers which both transmit and receive sound waves to detect submarines and ships.

Experiment:4

IR Sensor

a. Conduct an experiment to determine the sensitivity of the Infra-Red sensor.
b. Analyze the application of IR sensor using burglar alarm circuit.

IR SENSOR

Introduction

Infrared technology addresses a wide variety of wireless applications. The main areas are sensing and remote controls. In the electromagnetic spectrum, the infrared portion is divided into three regions: near infrared region, mid infrared region and far infrared region.

The wavelengths of these regions and their applications are shown below.

- Near infrared region — 700 nm to 1400 nm — IR sensors, fiber optic
- Mid infrared region — 1400 nm to 3000 nm — Heat sensing
- Far infrared region — 3000 nm to 1 mm — Thermal imaging

The frequency range of infrared is higher than microwave and lesser than visible light.

For optical sensing and optical communication, photo optics technologies are used in the near infrared region as the light is less complex than RF when implemented as a source of signal. Optical wireless communication is done with IR data transmission for short range applications.

An infrared sensor emits and/or detects infrared radiation to sense its surroundings.

The working of any Infrared sensor is governed by three laws: Planck's Radiation law, Stephen – Boltzmann law and Wien's Displacement law.

Planck's law states that "every object emits radiation at a temperature not equal to 0^0K". Stephen – Boltzmann law states that "at all wavelengths, the total energy emitted by a black body is proportional to the fourth power of the absolute temperature". According to Wien's Displacement law, "the radiation curve of a black body for different temperatures will reach its peak at a wavelength inversely proportional to the temperature".

The basic concept of an Infrared Sensor which is used as Obstacle detector is to transmit an infrared signal, this infrared signal bounces from the surface of an object and the signal is received at the infrared receiver.

There are five basic elements used in a typical infrared detection system: an infrared source, a transmission medium, optical component, infrared detectors or receivers and signal
processing. Infrared lasers and Infrared LED's of specific wavelength can be used as infrared sources. The three main types of media used for infrared transmission are vacuum,

atmosphere and optical fibers. Optical components are used to focus the infrared radiation or to limit the spectral response.

Optical lenses made of Quartz, Germanium and Silicon are used to focus the infrared radiation. Infrared receivers can be photodiodes, phototransistors etc. some important specifications of infrared receivers are photosensitivity, detectivity and noise equivalent power. Signal processing is done by amplifiers as the output of infrared detector is very small.

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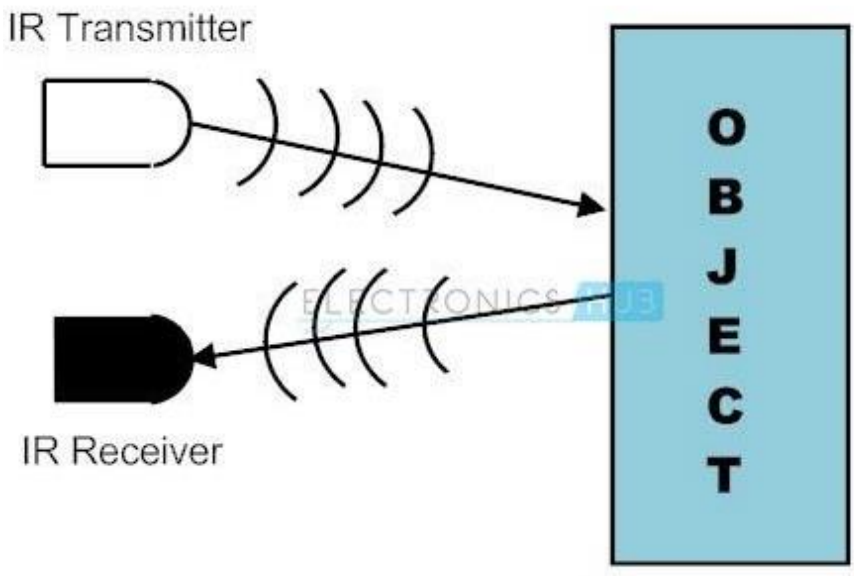
Types of IR Sensors

Infrared sensors can be passive or active. Passive infrared sensors are basically Infrared detectors. Passive infrared sensors do not use any infrared source and detects energy emitted by obstacles in the field of view. They are of two types: quantum and thermal. Thermal infrared sensors use infrared energy as the source of heat and are independent of wavelength. Thermocouples, pyroelectric detectors and bolometers are the common types of thermal infrared detectors.

Quantum type infrared detectors offer higher detection performance and are faster than thermal type infrared detectors. The photosensitivity of quantum type detectors is wavelength dependent. Quantum type detectors are further classified into two types: intrinsic and extrinsic types. Intrinsic type quantum detectors are photoconductive cells and photovoltaic cells.

Active infrared sensors consist of two elements: infrared source and infrared detector. Infrared sources include an LED or infrared laser diode. Infrared detectors include photodiodes or phototransistors. The energy emitted by the infrared source is reflected by an object and falls on the infrared detector.



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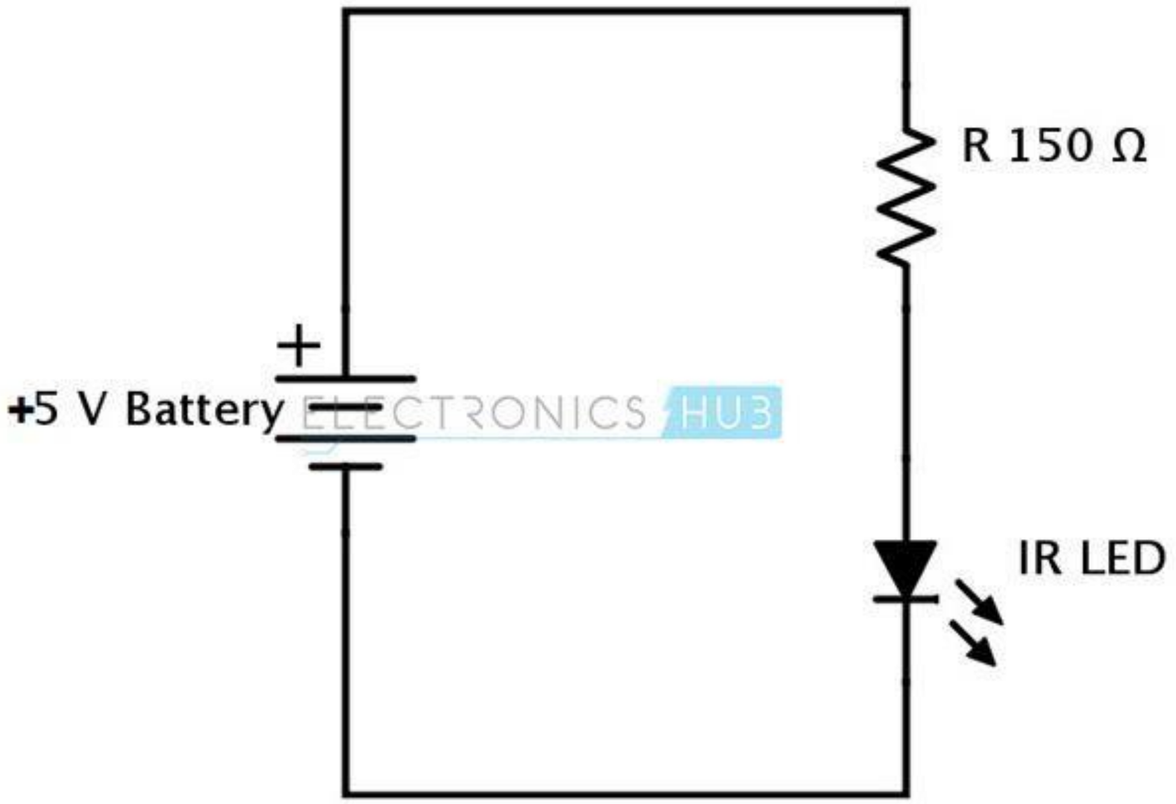
IR Transmitter

Infrared Transmitter is a light emitting diode (LED) which emits infrared radiations. Hence, they are called IR LED's. Even though an IR LED looks like a normal LED, the radiation emitted by it is invisible to the human eye.

The picture of a typical Infrared LED is shown below.

There are different types of infrared transmitters depending on their wavelengths, output power and response time.

A simple infrared transmitter can be constructed using an infrared LED, a current limiting resistor and a power supply. The schematic of a typical IR transmitter is shown below.



When operated at a supply of 5V, the IR transmitter consumes about 3 to 5 mA of current. Infrared transmitters can be modulated to produce a particular frequency of infrared light. The most commonly used modulation is OOK (ON – OFF – KEYING) modulation.

IR transmitters can be found in several applications. Some applications require infrared heat and the best infrared source is infrared transmitter. When infrared emitters are used with Quartz, solar cells can be made.

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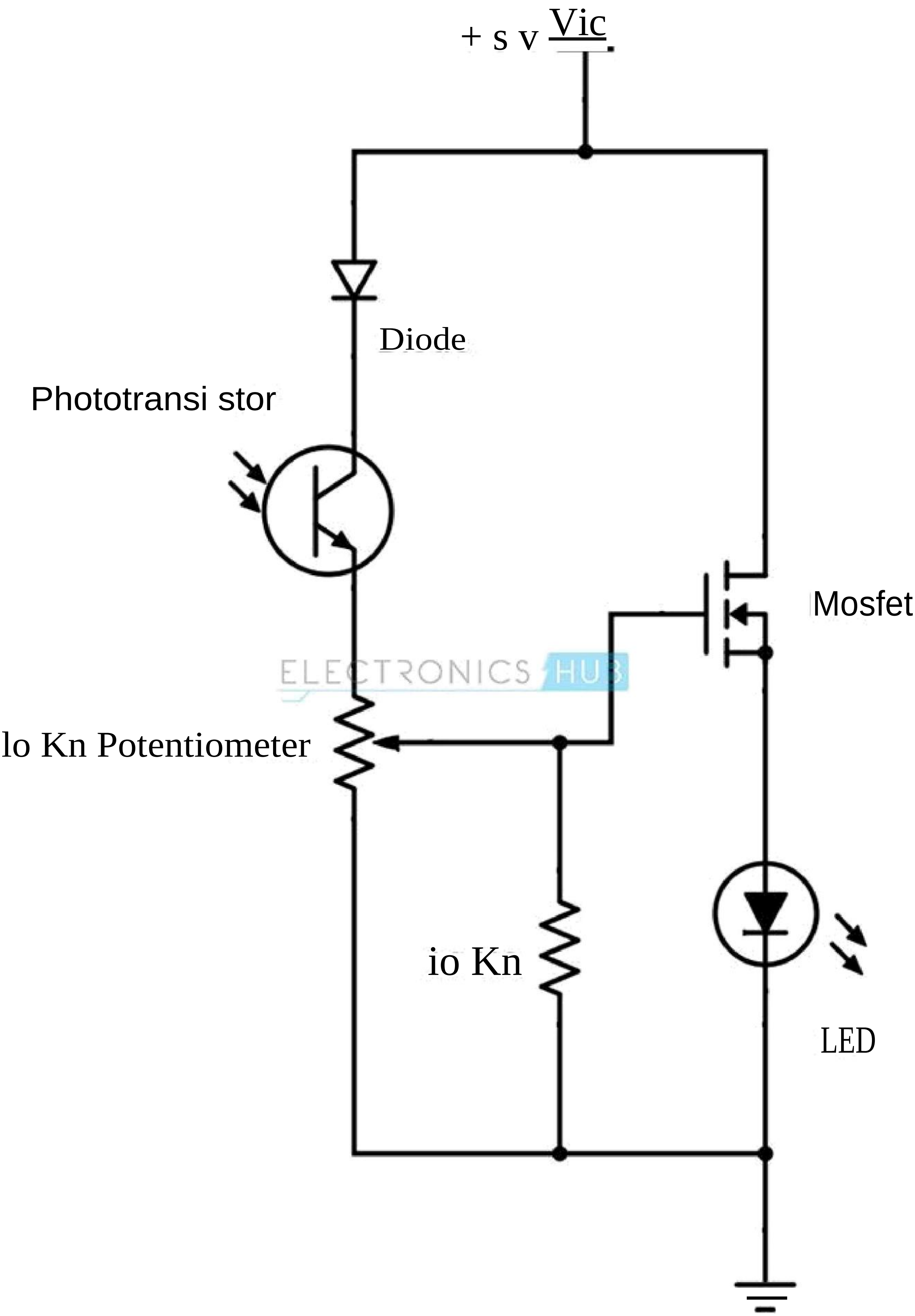
IR Receiver

Infrared receivers are also called as infrared sensors as they detect the radiation from an IR transmitter. IR receivers come in the form of photodiodes and phototransistors. Infrared Photodiodes are different from normal photo diodes as they detect only infrared radiation. The picture of a typical IR receiver or a photodiode is shown below.

Different types of IR receivers exist based on the wavelength, voltage, package, etc. When used in an infrared transmitter – receiver combination, the wavelength of the receiver should match with that of the transmitter.

A typical infrared receiver circuit using a phototransistor is shown below.


+ s v Vic
Diode
Phototransi stor
Mosfet
ELECTRONICS HUB
lo Kn Potentiometer
io Kn
LED

It consists of an IR phototransistor, a diode, a MOSFET, a potentiometer and an LED. When the phototransistor receives any infrared radiation, current flows through it and MOSFET turns on. This in turn lights up the LED which acts as a load. The potentiometer is used to control the sensitivity of the phototransistor.

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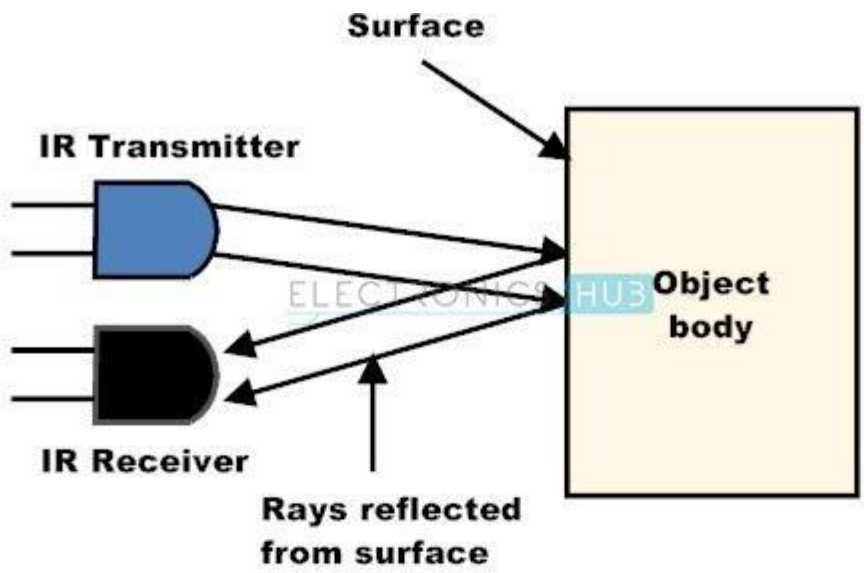
Principle of Working

The principle of an IR sensor working as an Object Detection Sensor can be explained using the following figure. An IR sensor consists of an IR LED and an IR Photodiode; together they are called as Photo – Coupler or Opto – Coupler.



When the IR transmitter emits radiation, it reaches the object and some of the radiation reflects back to the IR receiver. Based on the intensity of the reception by the IR receiver, the output of the sensor is defined.

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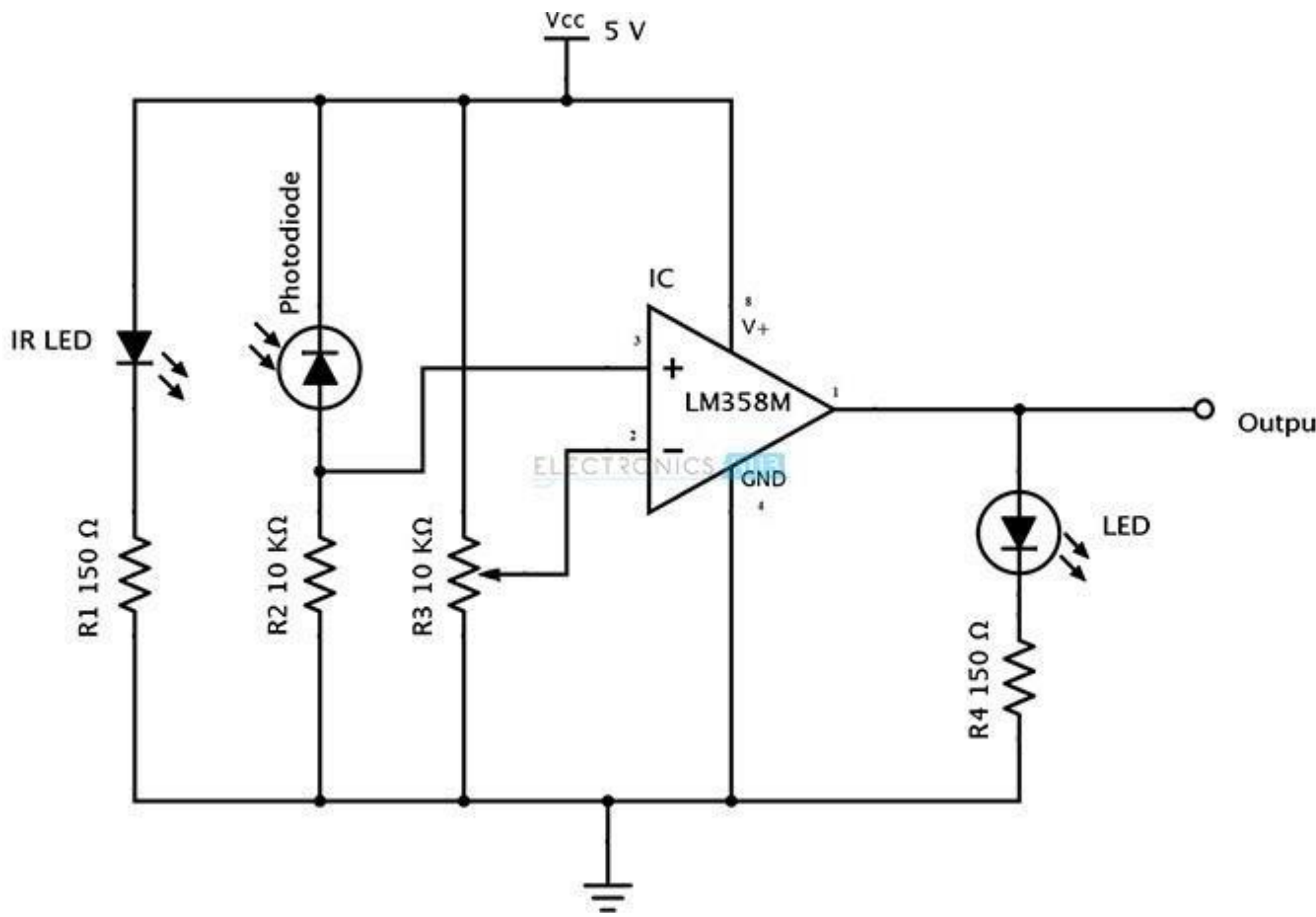
Obstacle Sensing Circuit or IR Sensor Circuit

A typical IR sensing circuit is shown below.



It consists of an IR LED, a photodiode, a potentiometer, an IC Operational amplifier and an LED.

IR LED emits infrared light. The Photodiode detects the infrared light. An IC Op – Amp is used as a voltage comparator. The potentiometer is used to calibrate the output of the sensor according to the requirement.

When the light emitted by the IR LED is incident on the photodiode after hitting an object, the resistance of the photodiode falls down from a huge value. One of the input of the op – amp is at threshold value set by the potentiometer. The other input to the op-amp is from
the photodiode's series resistor. When the incident radiation is more on the photodiode, the voltage drop across the series resistor will be high. In the IC, both the threshold voltage and the voltage across the series resistor are compared. If the voltage across the resistor series to photodiode is greater than that of the threshold voltage, the output of the IC Op – Amp is high. As the output of the IC is connected to an LED, it lightens up. The threshold voltage can be adjusted by adjusting the potentiometer depending on the environmental conditions.

The positioning of the IR LED and the IR Receiver is an important factor. When the IR LED is held directly in front of the IR receiver, this setup is called Direct Incidence. In this case, almost the entire radiation from the IR LED will fall on the IR receiver. Hence there is a line of sight communication between the infrared transmitter and the receiver. If an object falls in this line, it obstructs the radiation from reaching the receiver either by reflecting the radiation or absorbing the radiation.

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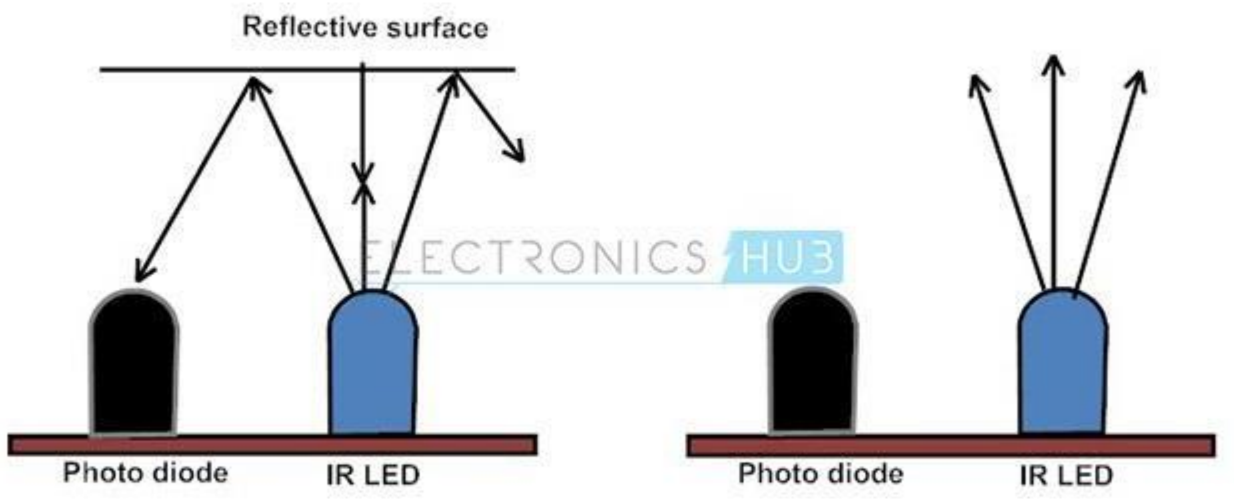
Distinguishing Between Black and White Colors

It is universal that black color absorbs the entire radiation incident on it and white color reflects the entire radiation incident on it. Based on this principle, the second positioning of the sensor couple can be made. The IR LED and the photodiode are placed side by side.
When the IR transmitter emits infrared radiation, since there is no direct line of contact between the transmitter and receiver, the emitted radiation must reflect back to the photodiode after hitting any object. The surface of the object can be divided into two types: reflective surface and non-reflective surface. If the surface of the object is reflective in nature i.e. it is white or other light color, most of the radiation incident on it will get reflected back and reaches the photodiode. Depending on the intensity of the radiation reflected back, current flows in the photodiode.

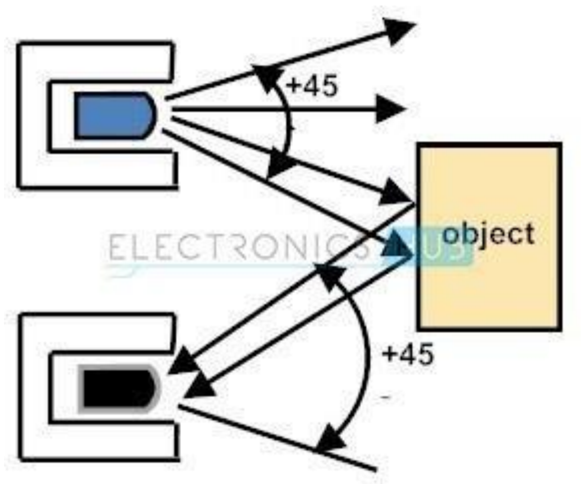
If the surface of the object is non-reflective in nature i.e. it is black or other dark color, it absorbs almost all the radiation incident on it. As there is no reflected radiation, there is no radiation incident on the photodiode and the resistance of the photodiode remains higher allowing no current to flow. This situation is similar to there being no object at all.

The pictorial representation of the above scenarios is shown below.



The positioning and enclosing of the IR transmitter and Receiver is very important. Both the transmitter and the receiver must be placed at a certain angle, so that the detection of an object happens properly. This angle is the directivity of the sensor which is +/- 45 degrees.

The directivity is shown below.



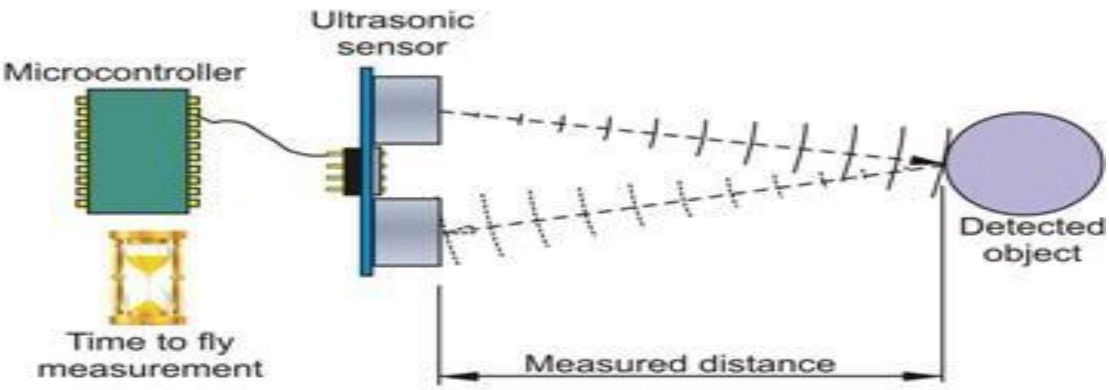
In order to avoid reflections from surrounding objects other than the object, both the IR transmitter and the IR receiver must be enclosed properly. Generally the enclosure is made of plastic and is painted with black color.

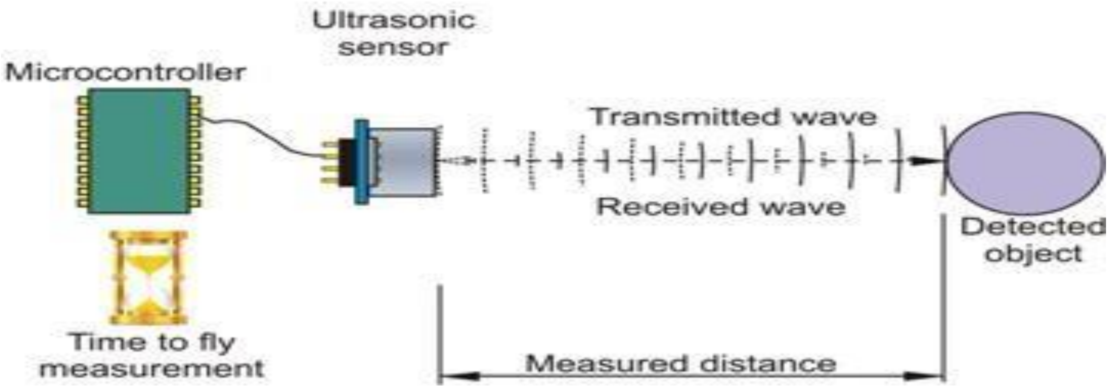
Experiment 5

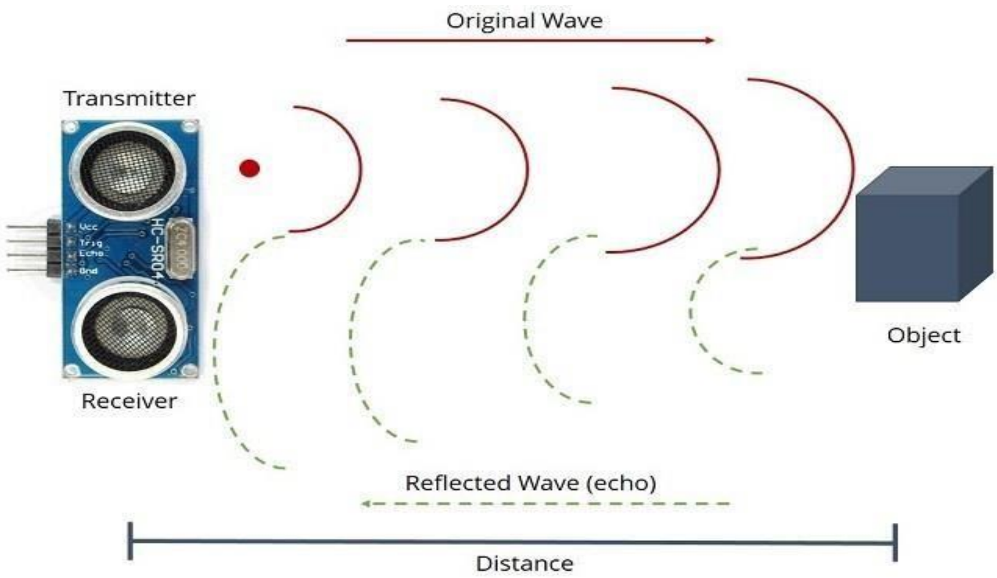
<u>Ultrasonic Sensor</u>

Aim:-

A) Conduct an experiment to determine the sensitivity of the ultrasonic sensor.
B)Analyze the application of ultrasonic sensor using distance meter circuit



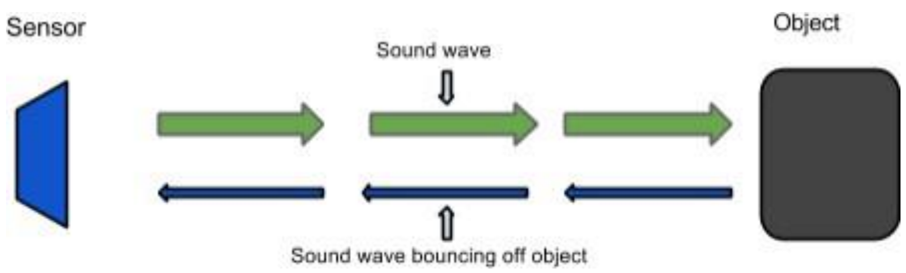


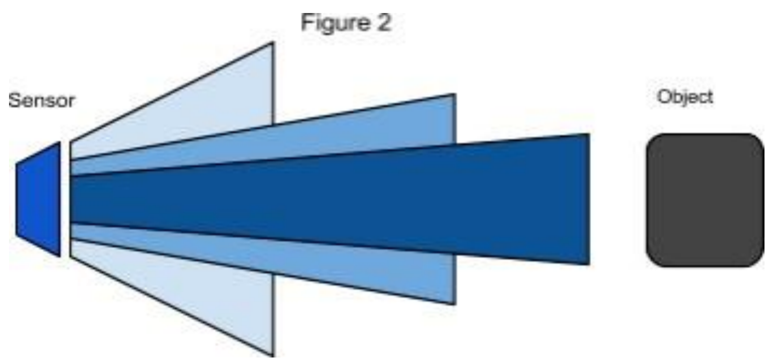


Theory:-

1. How Ultrasonic Sensors Work

Ultrasonic sensors use sound to determine the distance between the sensor and the closest object in its path. How do ultrasonic sensors do this? Ultrasonic sensors are essentially sound sensors, but they operate at a frequency above human hearing. The sensor sends out a sound wave at a specific frequency. It then listens for that specific sound wave to bounce off of an object and come back (Figure 1). The sensor keeps track of the time between sending the sound wave and the sound wave returning. If you know how fast something is going and how long it is traveling you can find the distance traveled with equation 1. Equation 1. $d = v \times t$ The speed of sound can be calculated based on the a variety of atmospheric conditions, including temperature, humidity and pressure. Actually calculating the distance will be shown later on in this document. It should be noted that ultrasonic sensors have a cone of detection, the angle of this cone varies with distance, Figure 2 show this relation. The ability of a sensor to detect an object also depends on the objects orientation to the sensor. If an object doesn't present a flat surface to the sensor then it is possible the sound wave will bounce off the object in a way that it does not return to the sensor.





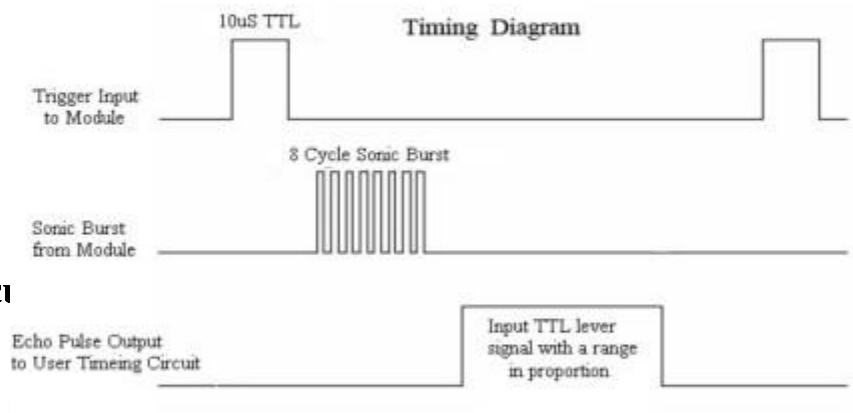
2. Taking Distance Measurements

The HCSR04 can be triggered to send out an ultrasonic burst by setting the TRIG pin to HIGH. Once the burst is sent the ECHO pin will automatically go HIGH. This pin will remain HIGH until the the burst hits the sensor again. You can calculate the distance to the object by keeping track of how long the ECHO pin stays HIGH. The time ECHO stays HIGH is the time the burst spent traveling. Using this measurement in equation 1 along with the speed of sound will yield the distance travelled. A summary of this is listed below, along with a visual representation in Figure 2.

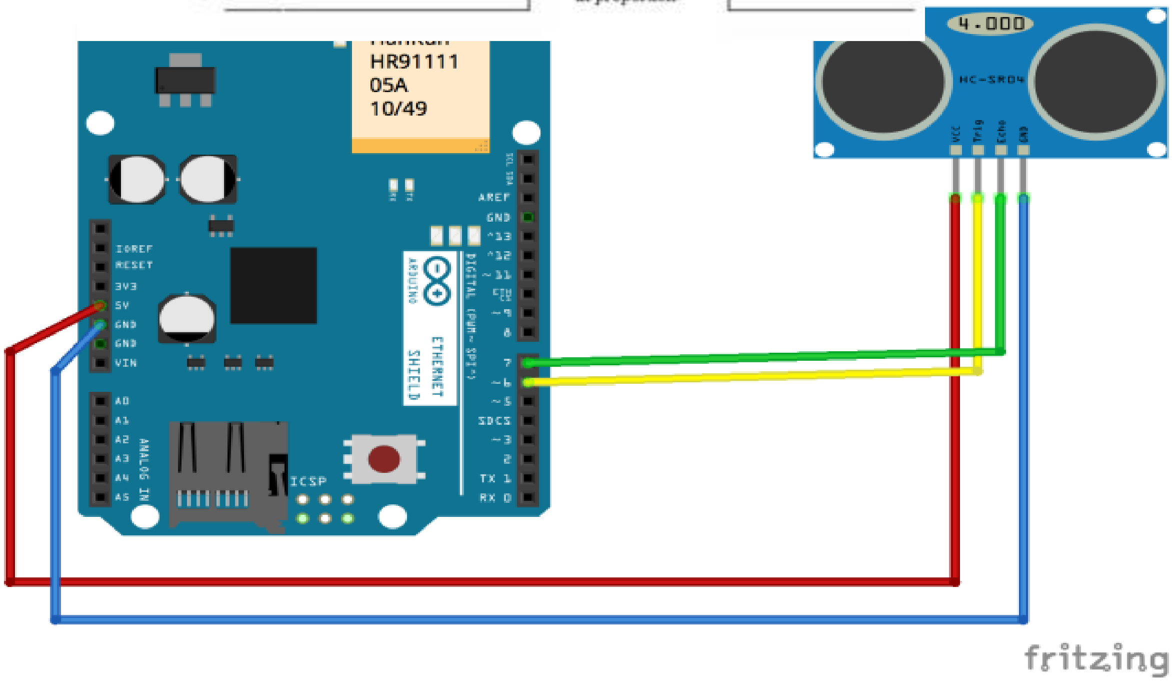
1. Set TRIG to HIGH
2. Set a timer when ECHO goes to HIGH
3. Keep the timer running until ECHO goes to LOW

4. Save that time
5. Use equation 1 to determine the distance travelled

Figure 3
Source 2



Circı



Program:-

```
#define pingTrig 6
#define pingEcho 7
#define ldrvalue 0

int led = 13 ;
void setup()
{Serial.begin(9600);
pinMode(pingTrig, OUTPUT);
pinMode(pingEcho, INPUT);
delay(200);
  pinMode(led, OUTPUT);
}

void loop()
{
  long duration, inches, cm,value;
  digitalWrite(pingTrig, LOW);
  delayMicroseconds(2);
  digitalWrite(pingTrig, HIGH);
  delayMicroseconds(10);
  digitalWrite(pingTrig, LOW);

  duration = pulseIn(pingEcho, HIGH);

  cm = duration / 29 / 2;
  inches=cm/2.5;

  Serial.print("-->");Serial.println(cm);
  Serial.print("-->");Serial.println(inches);
  if(cm < 30 )
 {
    digitalWrite(led,HIGH);
    delay(200);
    digitalWrite(led,LOW);
    delay(200);
}}
```

Observation:-

Slno.	Centimeters	Inches	LED(ON/OFF)

Result:-

Sensitivity of the sensor was determined and output was verified.

Experiment 6
Soil Moisture Sensor

AIM:-

A) Conduct an experiment to determine the sensitivity of the soil moisture sensor.
B) Design an irrigation system using soil moisture sensor.

Theory:-

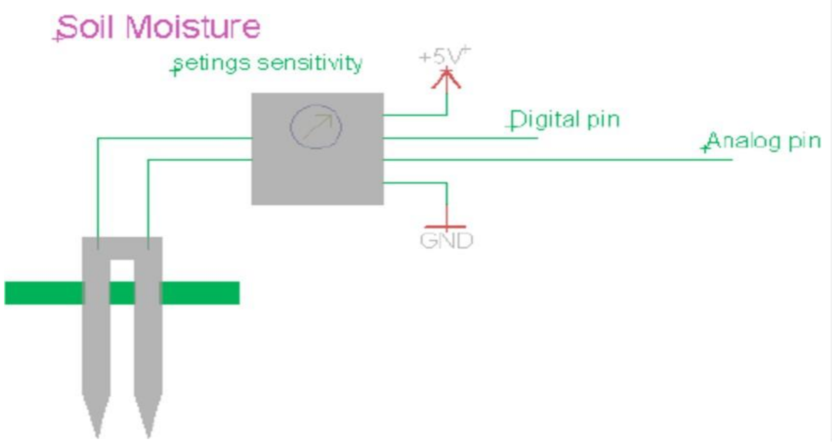
The **Moisture sensor** is used to measure the water content(moisture) of soil.when the soil is having water shortage,the module output is at high level, else the output is at low level.This sensor reminds the user to water their plants and also monitors the moisture content of soil.It has been widely used in agriculture,land irrigation and botanical gardening.

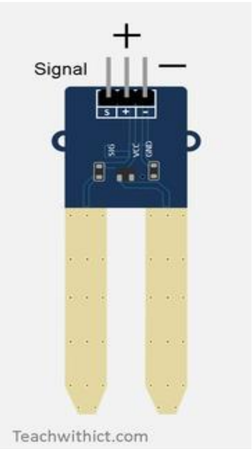
SPECIICATIONS

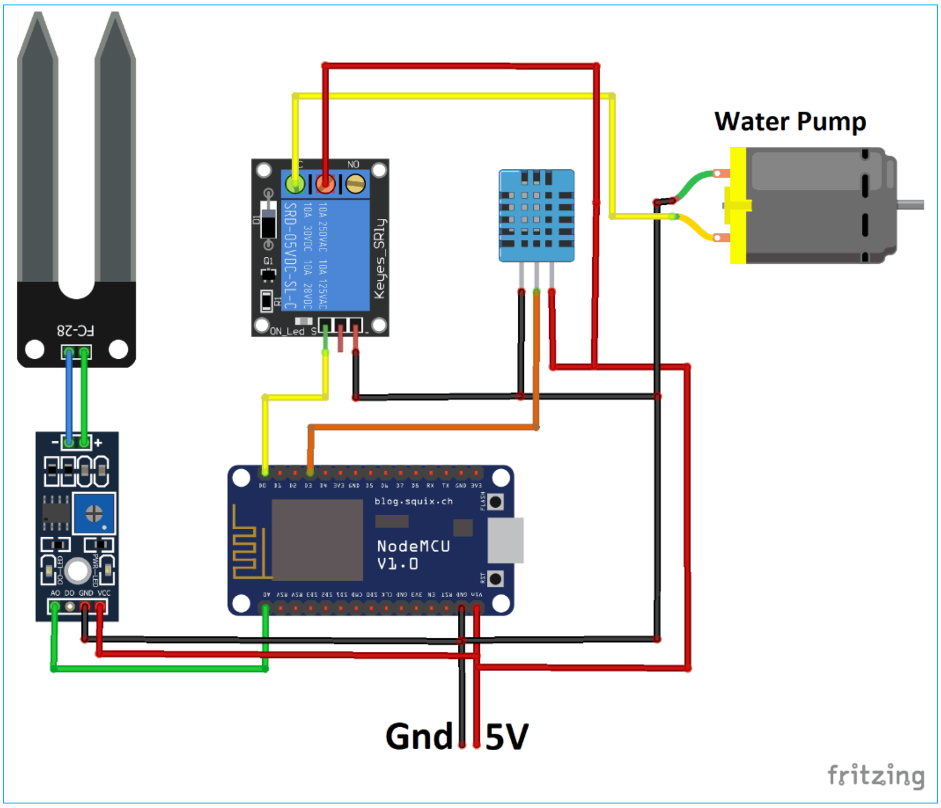
- Working Voltage:**5V**
- Working Current:**<20mA**
- Interface type:**Analog**
- Working Temperature:**10°C~30°C**

Working Principle of Moisture Sensor

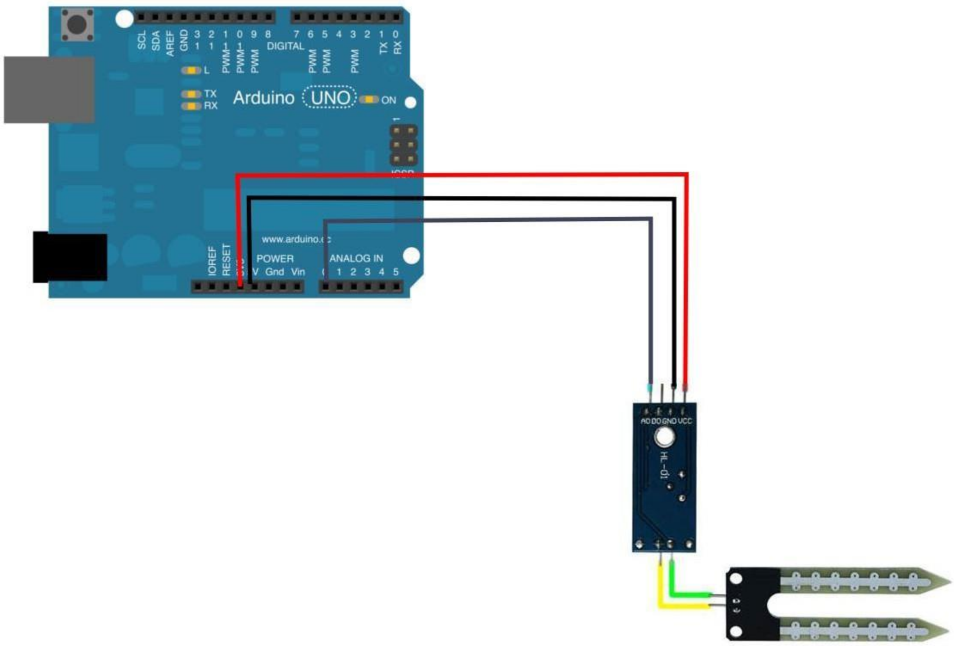
The Soil Moisture Sensor uses capacitance to measure dielectric permitivity of the surrounding medium. In soil, dielectric permitivity is a function of the water content. The sensor creates a voltage proportional to the dielectric permitivity, and therefore the water content of the soil. The sensor averages the water content over the entire length of the sensor. There is a 2 cm zone of influence with respect to the flat surface of the sensor, but it has little or no sensitivity at the extreme edges.The Soil Moisture Sensor is used to measure the loss of moisture over time due to evaporation and plant uptake,evaluate optimum soil moisture contents for various species of plants,monitor soil moisture content to control irrigation in greenhouses and enhance bottle biology experiments.







Circuit diagram:-



Program:-

```
int sensorPin = A0;

int sensorValue = 0;

int led =13;
```

```
void setup()
{ pinMode(led,OUTPUT);
 Serial.begin(9600);
}
void loop()
{
 sensorValue = analogRead(sensorPin);
 delay(1000);
 Serial.print("sensor = " );
 Serial.println(sensorValue);
 if(sensorValue<500)
     digitalWrite (led,HIGH);
 else
     digitalWrite(led,LOW);
 delay(1000);
}
```

Observation:-

Sl no	Soil type	Range	Reading
01	wet soil		
02	Dry soil		
03	Sand		

Result:-

Sensitivity of the soil sensor was determined and observed successfully.

Experiment 7
Gas Sensor

Aim:-

A) Conduct an experiment to determine the sensitivity of the gas sensor.
B) Design an application for air-o-monitor using gas sensor

Theory:-

A gas sensor is a device which detects the presence or concentration of gases in the atmosphere. Based on the concentration of the gas the sensor produces a corresponding potential difference by changing the resistance of the material inside the sensor, which can be measured as output voltage. Based on this voltage value the type and concentration of the gas can be estimated.

The type of gas the sensor could detect depends on the sensing material present inside the sensor. Normally these sensors are available as modules with comparators as shown above. These comparators can be set for a particular threshold value of gas concentration. When the concentration of the gas exceeds this threshold the digital pin goes high. The analog pin can be used to measure the concentration of the gas.

Different Types of Gas sensors

Gas sensors are typically classified into various types based on the type of the sensing element it is built with. Below is the classification of the various types of gas sensors based on the sensing element that are generally used in various applications:

- Metal Oxide based gas Sensor.
- Optical gas Sensor.
- Electrochemical gas Sensor.
- Capacitance-based gas Sensor.
- Calorimetric gas Sensor.
- Acoustic based gas Sensor.

MQ2 gas sensor is an electronic sensor used for sensing the concentration of gases in the air such as LPG, propane, methane, hydrogen, alcohol, smoke and carbon monoxide.

MQ2 gas sensor is also known as chemiresistor. It contains a sensing material whose resistance changes when it comes in contact with the gas. This change in the value of resistance is used for the detection of gas.

Working Principle

This sensor contains a sensing element, mainly aluminium-oxide based ceramic, coated with Tin dioxide, enclosed in a stainless steel mesh. Sensing element has six connecting legs attached to it. Two leads are responsible for heating the sensing element, the other four are used for output signals.

Oxygen gets adsorbed on the surface of sensing material when it is heated in air at high temperature. Then donor electrons present in tin oxide are attracted towards this oxygen, thus preventing the current flow.

Applications

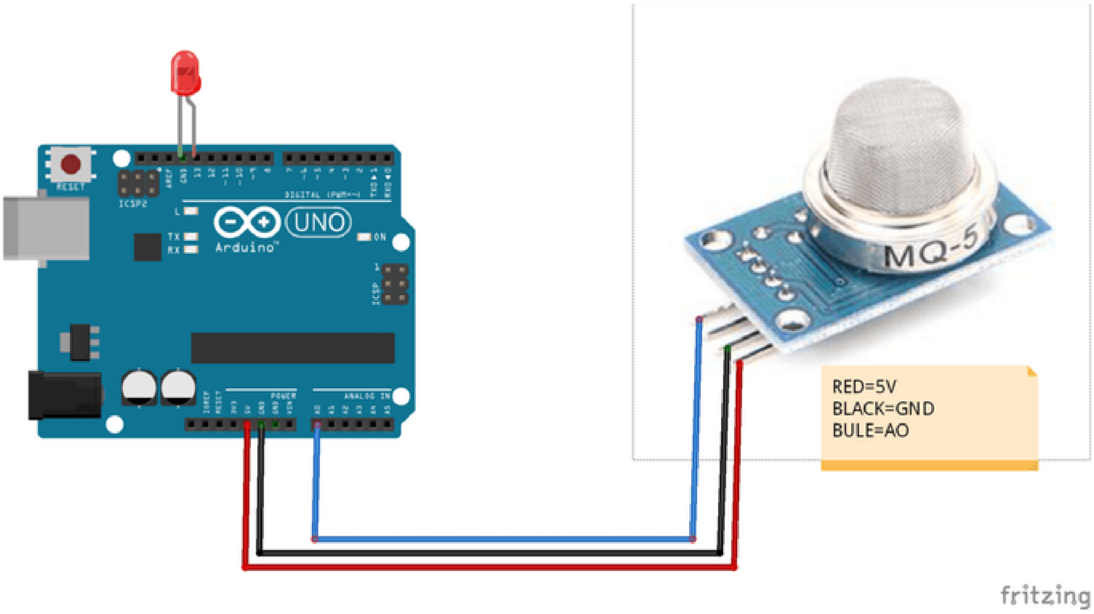
These sensors are used to detect the presence of gases in the air such as methane, butane, LPG and smoke but they are unable to distinguish between gases. Thus, they cannot tell which gas it is.

Module version of this sensor can be used without interfacing to any microcontroller and is useful when detecting only one particular gas. This can only detect the gas. But if ppm has to be calculated then the sensor should be used without module.

This sensor is also used for Air quality monitoring, Gas leak alarm and for maintaining environmental standards in hospitals. In industries, these are used to detect the leakage of harmful gases.

Some of the alternatives of the MQ2 gas sensor are MQ-6, M-306A, AQ-3 sensors.

Circuit Diagram:-



Program:-

```
int sensorPin = A0;

int sensorValue = 0;

int led =13;

void setup()

{ pinMode(led,OUTPUT);

 Serial.begin(9600);
```

```
}
void loop()
{
 sensorValue = analogRead(sensorPin);
 delay(1000);
 Serial.print("sensor = " );
 Serial.println(sensorValue);
 if(sensorValue<500)
   { digitalWrite (led,HIGH);
      delay(1000);
           digitalWrite(led,LOW);
    }
}
```

Observation:-

Sl no	Gas type	Range	Effect(danger/safe)
01	Carbon		
02	Methane		
03			
04			

Result:-

Sensitivity of the GAS[MQ2,MQ3] sensor was determined and observed successfully.

Experiment 8
Liquid Sensor

AIM:-

a. Conduct an experiment to determine the sensitivity of the liquid sensor.

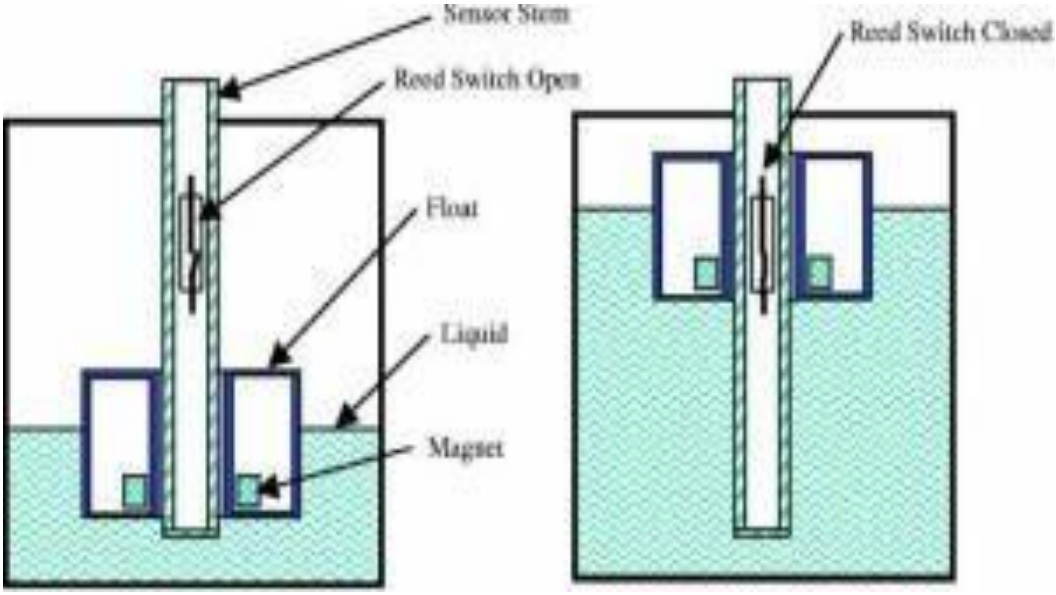
b. Design a system to indicate the petrol level in the vehicle using liquid level sensor.

Theory:-

Liquid level sensors are termed as the sensors used for detecting liquid levels or interfaces between liquids such as water and oil or solids and liquids. These sensors can also be defined as transducers or as integrated systems with instrumentation and control capabilities. This type of liquid level sensor is one of the most important sensors and plays a vital role in variety of industrial and consumer applications.

Industrial applications include liquid-level sensing in transport tanks, storage tanks and water treatment tanks, and also in the petrochemical industries for sensing liquids such as petrol, diesel and other fuels. Liquid level measurement is significant in household applications including electronic devices such as, water dispensers, water evaporators, steamers, monitoring system of boilers, heating systems, washing machines, steam irons, juice squeezers, automated-coffee machines, etc. Level sensors are designed for specific applications compared to general applications.

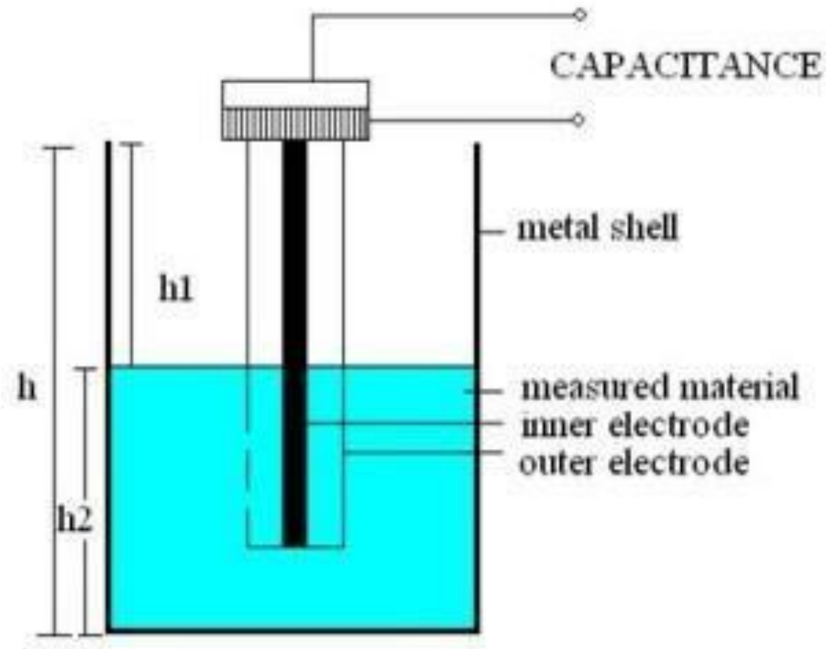
Level Detection and Measurement by Using a Float Sensor



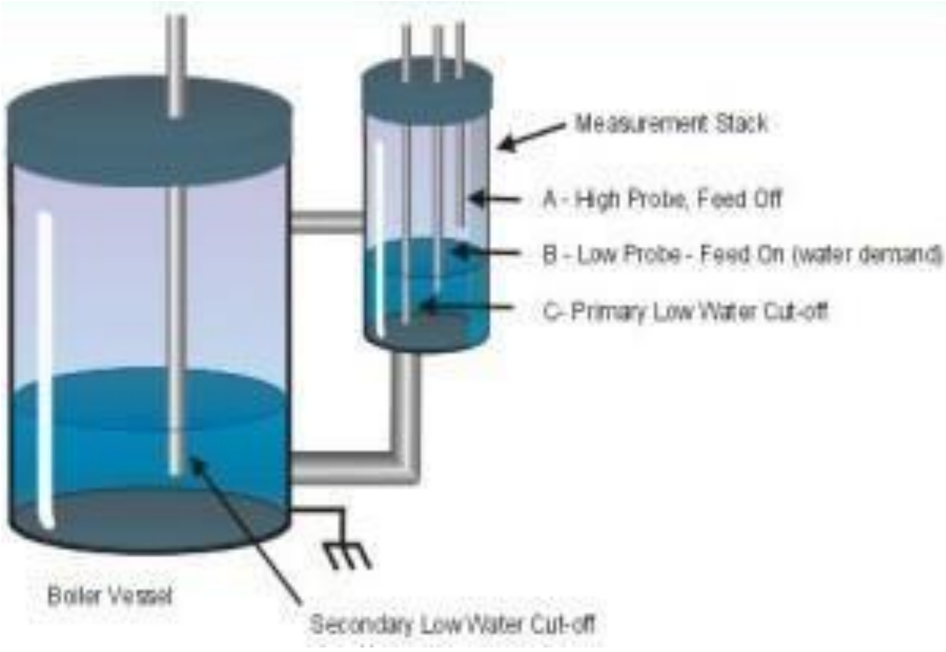
Principle of Operation: A liquid level control system by using a float sensor works on the principle of buoyancy, which states, “A float immersed in a liquid is buoyed towards upward direction by an applied equal force to the weight of the displaced liquid". As a result, the body drives partially and gets submerged upon the liquid surface and covers the same distance the liquid level moves.

Working: Level detection of liquids is often done with a float-type liquid level switch. The float transfers on a mechanical arm or sliding pole and activates a switch when the level moves towards upward direction. Sometimes the float itself contains a small magnet that varies the state of a switch when the liquid level gets moving up and moves into the original position. This type of level sensor comes with many advantages like it is very simple, highly accurate, and best suitable for various products.

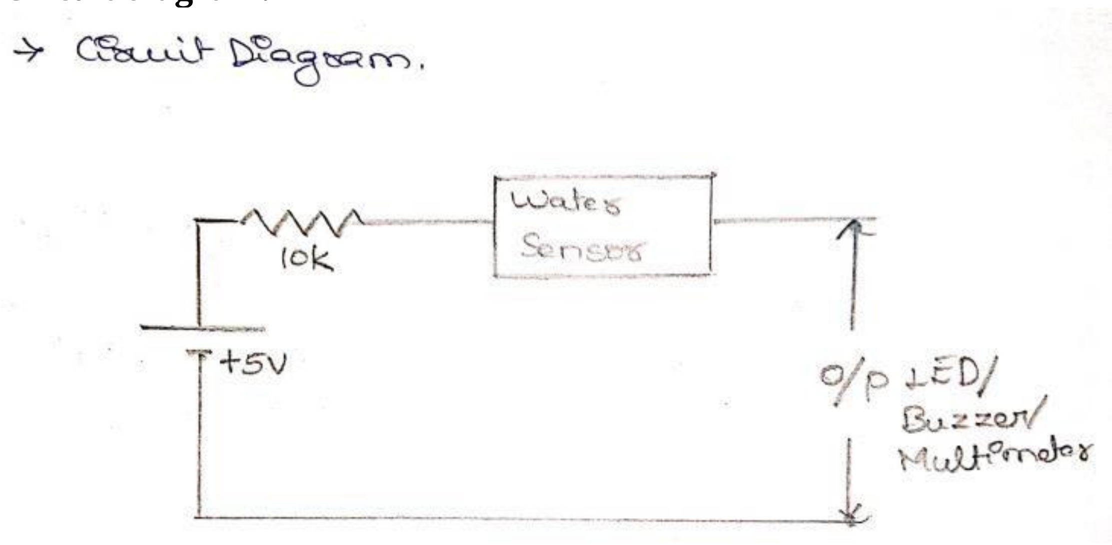
Level Detection and Measurement by Using Capacitance Sensor



Level Detection by Using Conductivity Probes



Circuit diagram:-



Observation:-

→ Observation.

Depth (in cm)	Observed Voltage (V)	Strip Emerged in Water.
0	0	Initial (Dry)
0.5	4.43	
1.0	4.6	
2.0	4.65	Half
3.0	4.75	
3.5	4.8	Full
4.0	5	

Result:-

Sensitivity of the Liquid sensor was determined and observed successfully.

Experiment 9
Digital Sensor

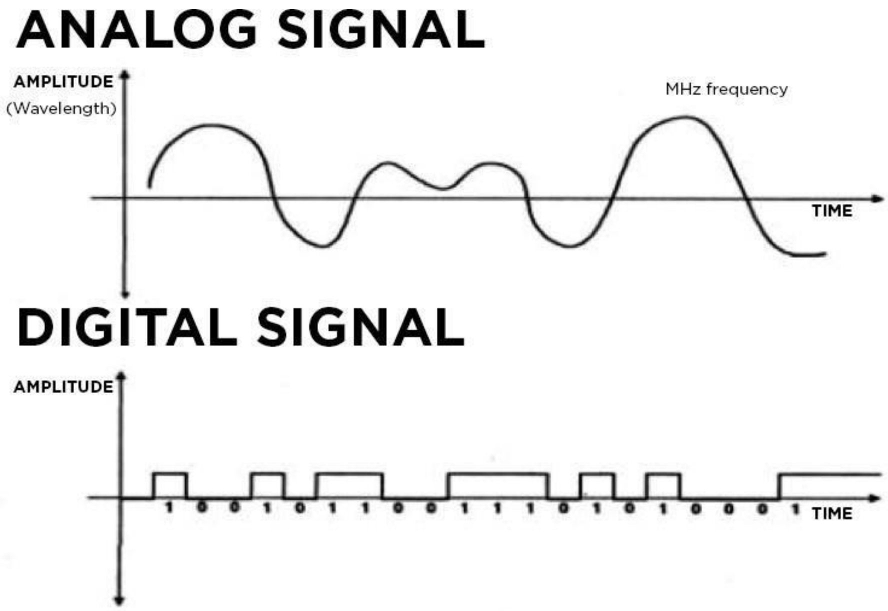
AIM:-

a. Conduct an experiment to understand the PIR and door sensors.

b. Analyze the application of digital sensors.

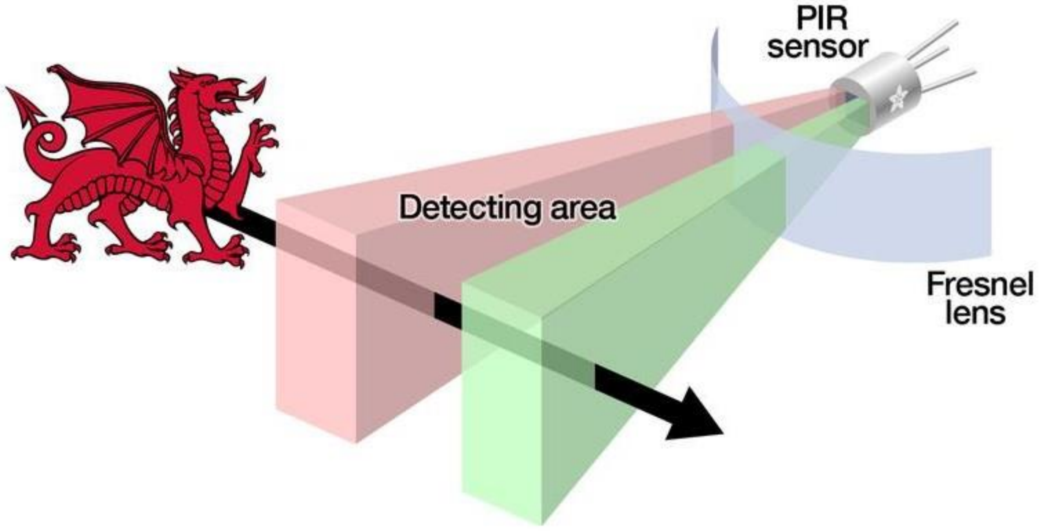
Components required:-

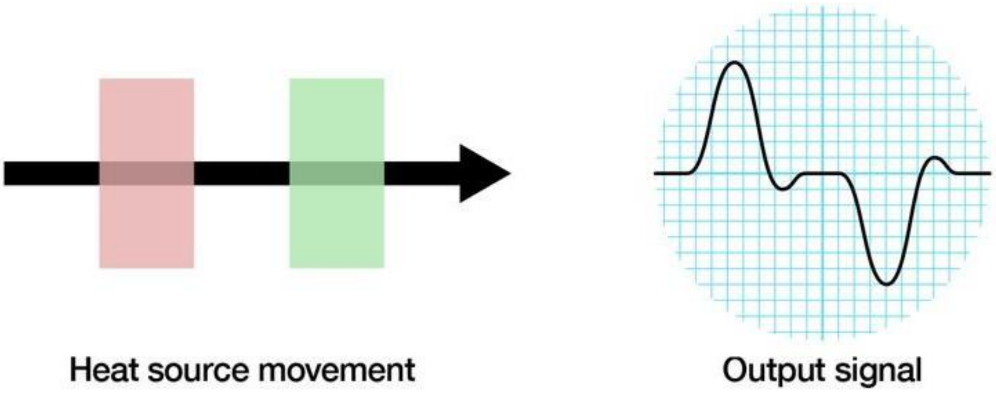
Theory:-



Working:-

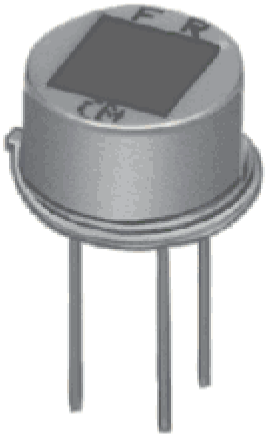
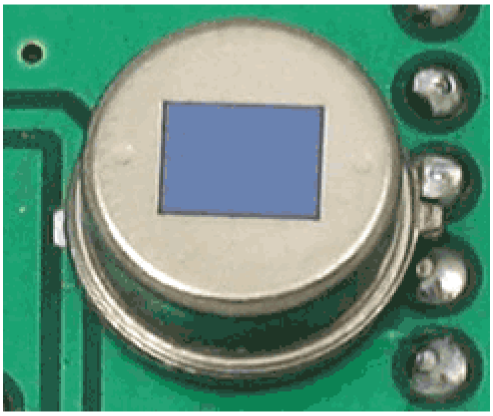
The PIR sensor itself has two slots in it, each slot is made of a special material that is sensitive to IR. The lens used here is not really doing much and so we see that the two slots can 'see' out past some distance (basically the sensitivity of the sensor). When the sensor is idle, both slots detect the same amount of IR, the ambient amount radiated from the room or walls or outdoors. When a warm body like a human or animal passes by, it first intercepts one half of the PIR sensor, which causes a *positive differential* change between the two halves. When the warm body leaves the sensing area, the reverse happens, whereby the sensor generates a negative differential change. These change pulses are what is detected.

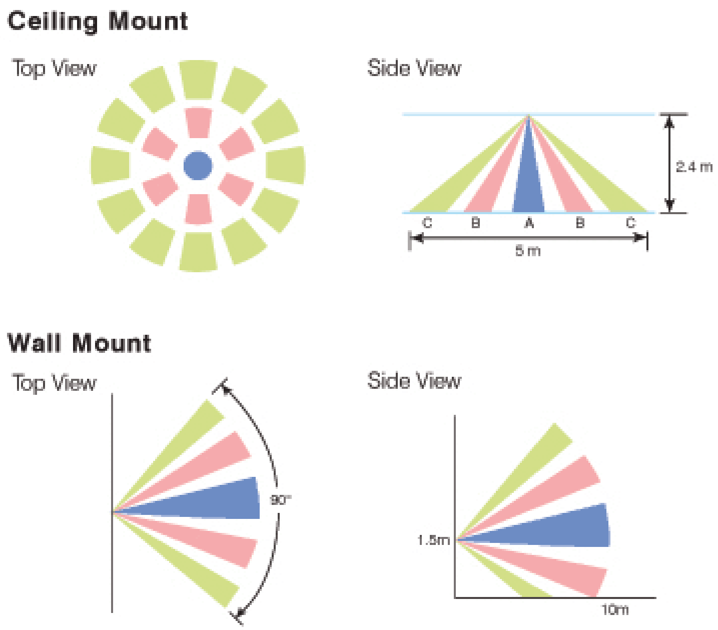




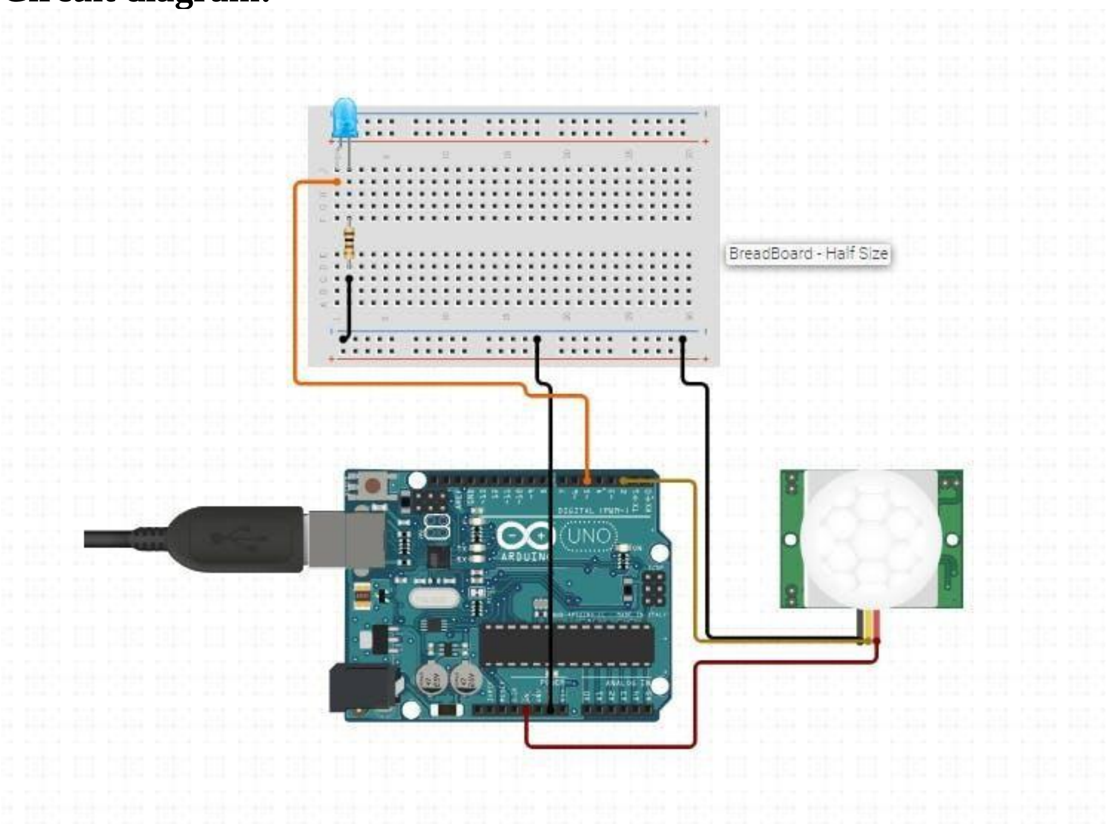
The PIR Sensor

The IR sensor itself is housed in a hermetically sealed metal can to improve noise/temperature/humidity immunity. There is a window made of IR-transmissive material (typically coated silicon since that is very easy to come by) that protects the sensing element. Behind the window are the two balanced sensors.

Circuit diagram:-



Program:-

int calibrationTime = 30;

```
long unsigned int lowIn;
long unsigned int pause = 5000;
boolean lockLow = true;
boolean takeLowTime;
int pirPin = 2;
int RELAY = 12;
void setup(){
  Serial.begin(9600);
  pinMode(pirPin, INPUT);
  pinMode(RELAY, OUTPUT);
  digitalWrite(pirPin, LOW);
 Serial.print("calibrating sensor ");
    for(int i = 0; i < calibrationTime; i++){
      Serial.print(".");
      delay(1000);
      }
    Serial.println(" done");
    Serial.println("SENSOR ACTIVE");
    delay(50);
  }
void loop(){

     if(digitalRead(pirPin) == HIGH){
       digitalWrite(RELAY, HIGH);
       if(lockLow){

         lockLow = false;
         Serial.println("---");
         Serial.print("motion detected at ");
         Serial.print(millis()/1000);
         Serial.println(" sec");
         delay(50);
         }
         takeLowTime = true;
       }

     if(digitalRead(pirPin) == LOW){
       digitalWrite(RELAY, LOW);

       if(takeLowTime){
        lowIn = millis();
        takeLowTime = false;
        }
```

```
    if(!lockLow && millis() - lowIn > pause){
        lockLow = true;
        Serial.print("motion ended at ");      //output
        Serial.print((millis() - pause)/1000);
        Serial.println(" sec");
        delay(50);
        }
     }
 }
```

Observation:-

Sl no	Object	Led(on/off)
01	Yes/passing	On
02	No/empty	Off

Result:-

Sensitivity of the PIR sensor was determined and observed successfully.

Experiment 10
Temperature Sensor

AIM:-

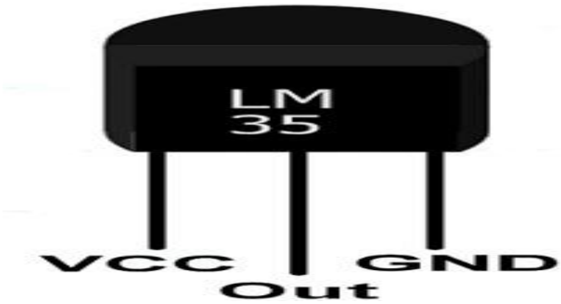
a.Conduct an experiment to determine the sensitivity of the temperature sensor.
b.Design a system to display the temperature in the location

Theory:-

- LM35 is a temperature measuring device having an analog output voltage proportional to the temperature.
- It provides output voltage in Centigrade (Celsius). It does not require any external calibration circuitry.
- The sensitivity of LM35 is 10 mV/degree Celsius. As temperature increases, output voltage also increases.

  E.g. 250 mV means 25°C.

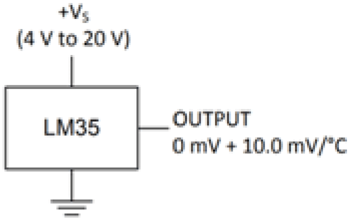
- It is a 3-terminal sensor used to measure surrounding temperature ranging from -55 °C to 150 °C.
- LM35 gives temperature output which is more precise than thermistor output.



tfow 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} = 10 mv/°C × T

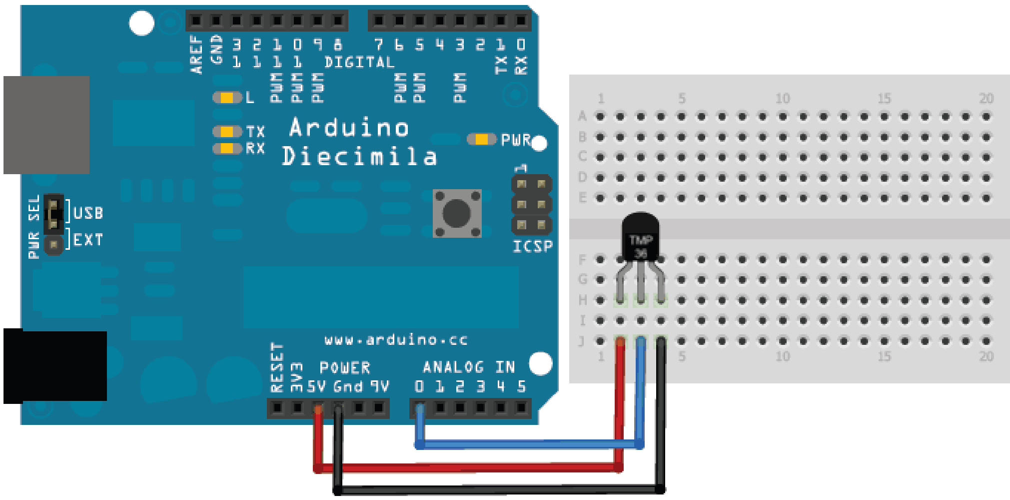
where

- V_{OUT} is the LM35 output voltage
- T is the temperature in °C

LM35 Temperature Sensor Applications:

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

Circuit Diagram:-



Program:-

```
int val;
int tempPin = 1;

void setup()
{ Serial.begin(9600);
}
void loop()
{
val = analogRead(tempPin); float
mv = ( val/1024.0)*5000; float cel
= mv/10;
float farh = (cel*9)/5 + 32; float
kel=273+cel;
Serial.print("TEMPRATURE in Celsius= ");
Serial.print(cel);
Serial.print("*C");
Serial.println();
delay(1000);
Serial.print("TEMPRATURE in Fahrenheit = ");
Serial.print(farh);
Serial.print("*F");
Serial.println();
Serial.print("TEMPRATURE in Kelvin = "); Serial.print(kel);
Serial.print("*k");
```

```
Serial.println();
delay(1000);

}
```

Observation:-

Slno.	Temp in Cel(*c)	Fahrenheit(F)	Kelvin(k)

Result:-

Sensitivity of the Temperature sensor was determined and output in various scales were verified.

Experiment 11
Heart beat Sensor

AIM:-

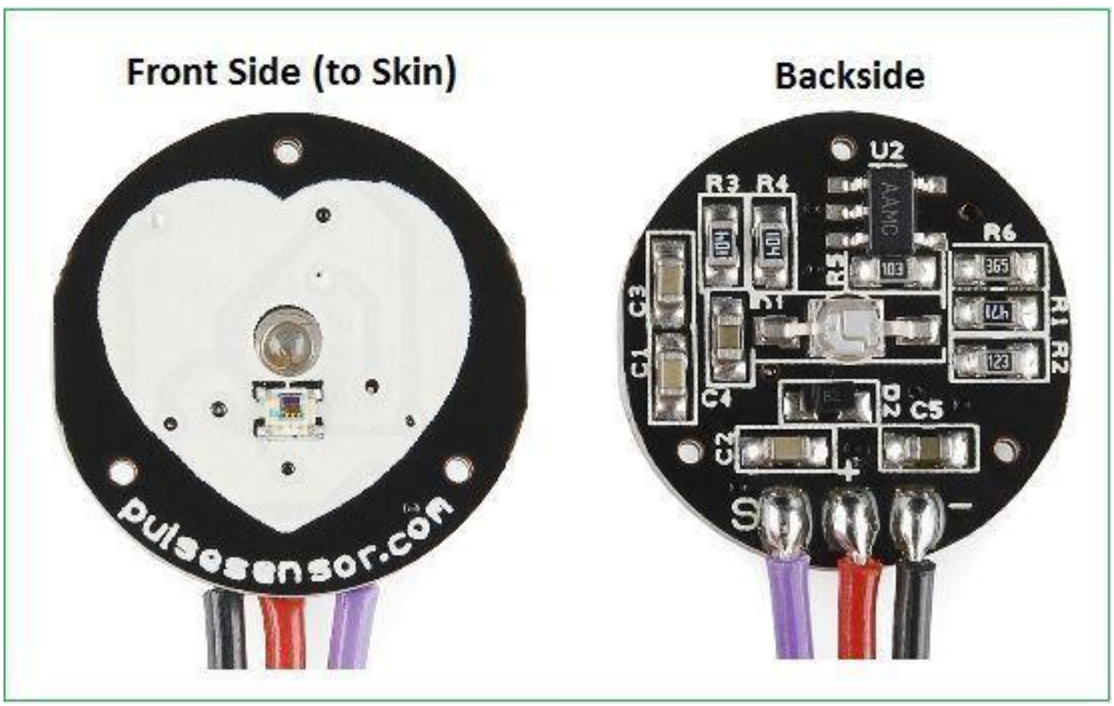
a. Conduct an experiment to determine the sensitivity of the heart beat sensor.

b. Analyze the application of heart beat sensor to determine the pulse rate.

Components required:-

Theory:-

Heartbeat Sensor is an electronic device that is used to measure the heart rate i.e. speed of the heartbeat. Monitoring body temperature. Heart Rate can be monitored in two ways: one way is to manually check the pulse either at wrists or neck and the other way is to use a Heartbeat Sensor.

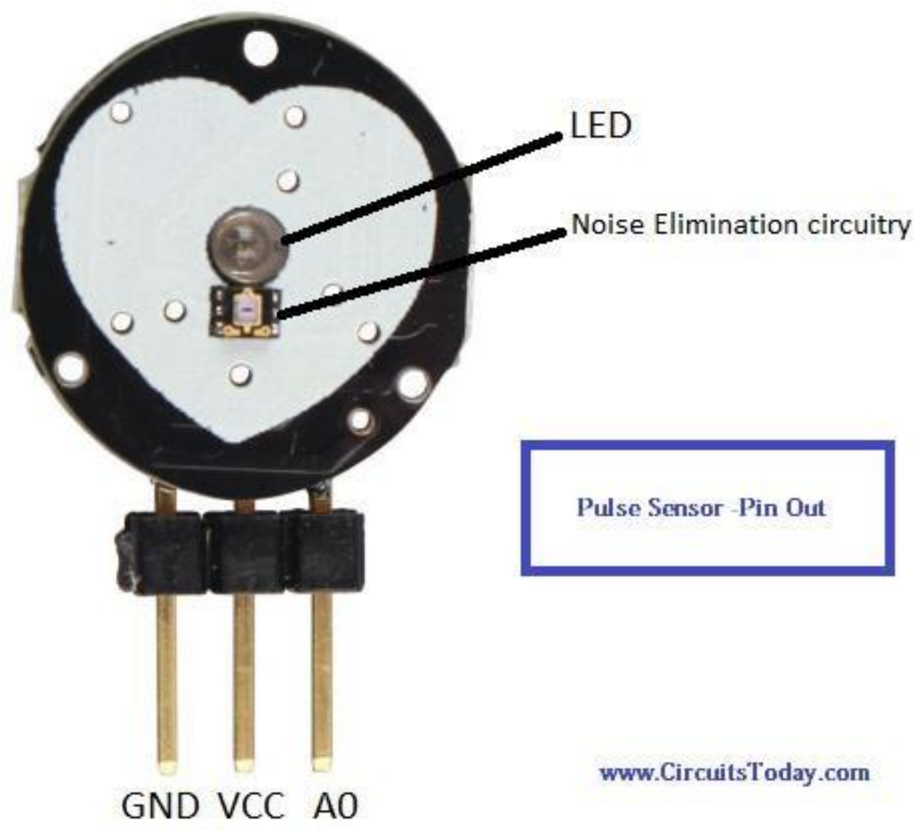


Pin Out – Pulse Sensor

The pulse sensor has three pins which are as described below:

- **GND:** Ground Pin
- **VCC:** 5V or 3V Pin
- **A0:** Analog Pin

There is also a LED in the center of this sensor module which helps in detecting the heartbeat. Below the LED, there is a noise elimination circuitry which is supposed to keep away the noise from affecting the readings.

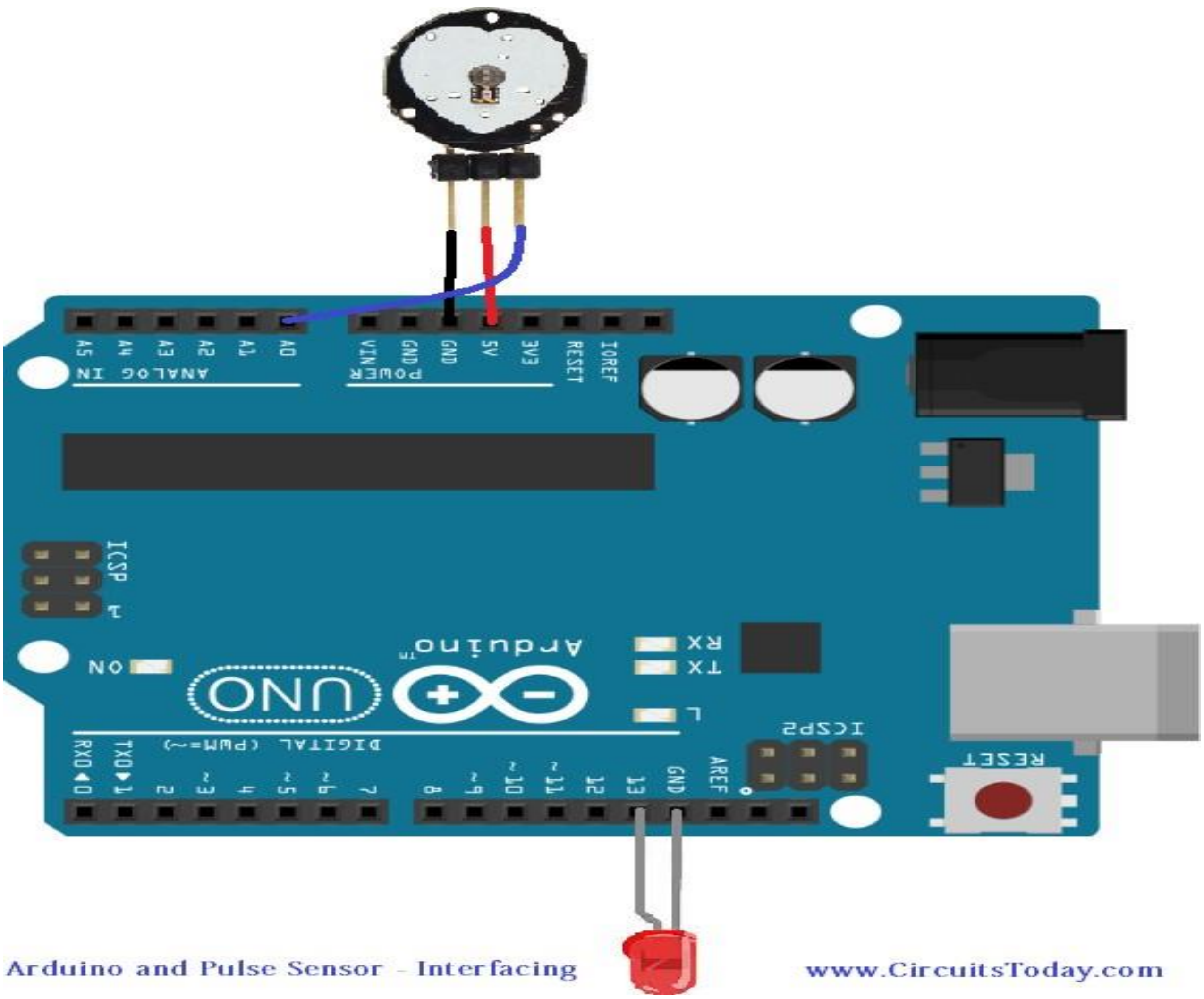


Working – Pulse Sensor

When a heartbeat occurs blood is pumped through the human body and gets squeezed into the capillary tissues. The volume of these capillary tissues increases as a result of the heartbeat. But in between the heartbeats (the time between two consecutive heartbeats,) this volume inside capillary tissues decreases. This change in volume between the heartbeats affects the amount of light that will transmit through these tissues. This change is very small but we can measure it with the help of Arduino.

The pulse sensor module has a light which helps in measuring the pulse rate. When we place the finger on the pulse sensor, the light reflected will change based on the volume of blood inside the capillary blood vessels. During a heartbeat, the volume inside the capillary blood vessels will be high. This affects the reflection of light and the light reflected at the time of a heartbeat will be less compared to that of the time during which there is no heartbeat (during the period of time when there is no heartbeat or the time period in between heartbeats, the volume inside the capillary vessels will be lesser. This will lead higher reflection of light). This variation in light transmission and reflection can be obtained as a pulse from the ouptput of pulse sensor. This pulse can be then coditioned to measure heartbeat and then programmed accordingly to read as heartbeat count.

Circuit diagram:-



Program:

```
int sensor_pin = 0;

int led_pin = 13;

volatile int heart_rate;

volatile int analog_data;

volatile int time_between_beats = 600;

volatile boolean pulse_signal = false;

volatile int beat[10];         //heartbeat values will be sotred in this array

volatile int peak_value = 512;
```

```
volatile int trough_value = 512;

volatile int thresh = 525;

volatile int amplitude = 100;

volatile boolean first_heartpulse = true;

volatile boolean second_heartpulse = false;

volatile unsigned long samplecounter = 0;   //This counter will tell us the pulse timing

volatile unsigned long lastBeatTime = 0;

void setup(){

pinMode(led_pin,OUTPUT);

Serial.begin(115200);

interruptSetup();                  }

void loop()

{

  Serial.print("BPM: ");

Serial.println(heart_rate);

delay(200); // take a break

}

void interruptSetup()

{

TCCR2A = 0x02; // This will disable the PWM on pin 3 and 11

OCR2A = 0X7C; // This will set the top of count to 124 for the 500Hz sample rate

TCCR2B = 0x06; // DON'T FORCE COMPARE, 256 PRESCALER

 TIMSK2 = 0x02; // This will enable interrupt on match between OCR2A and Timer

sei();          // This will make sure that the global interrupts are enable

}
```

```
ISR(TIMER2_COMPA_vect){

 cli();

 analog_data = analogRead(sensor_pin);

 samplecounter += 2;

int N = samplecounter - lastBeatTime;

 if(analog_data < thresh && N > (time_between_beats/5)*3)

  {

  if (analog_data < trough_value)

{

trough_value = analog_data;

 }

 }

 if(analog_data > thresh && analog_data > peak_value)

{

 peak_value = analog_data;

}

 if (N > 250)

{

 if ( (analog_data > thresh) && (pulse_signal == false) && (N >
(time_between_beats/5)*3) )

{

pulse_signal = true;

 digitalWrite(led_pin,HIGH);

 time_between_beats = samplecounter - lastBeatTime;

lastBeatTime = samplecounter;
```

```
if(second_heartpulse) {
second_heartpulse = false;
for(int i=0; i<=9; i++)    {
 beat[i] = time_between_beats; //Filling the array with the heart beat values
}
 }
  if(first_heartpulse)
 {
 first_heartpulse = false;
second_heartpulse = true;
sei();
return;
 }
word runningTotal = 0;
for(int i=0; i<=8; i++)
{
beat[i] = beat[i+1];
runningTotal += beat[i]; }
beat[9] = time_between_beats;
runningTotal += beat[9];
runningTotal /= 10;
heart_rate = 60000/runningTotal;
 }                        }
```

```
if (analog_data < thresh && pulse_signal == true)

{

digitalWrite(led_pin,LOW);

  pulse_signal = false;

amplitude = peak_value - trough_value;

thresh = amplitude/2 + trough_value;

peak_value = thresh;

trough_value = thresh; }

 if (N > 2500)

 {

thresh = 512;

 peak_value = 512;

trough_value = 512;

lastBeatTime = samplecounter;

first_heartpulse = true;

second_heartpulse = false;

 }

 sei();                              }
```

Observation:-

Sl no	Person	Pulse
01	Person1 name	
02	Person2 name	

Result:-

Sensitivity of the sensor was determined and output was verified.

Experiment 12
Mini Project

Aim:

Design an application using various sensors.

Instructions for mini project: -

- Use any sensors from the list of sensors in the Sensors lab.
- The projects should be submitted to the teacher before semester end.
- The project should show a real time application of iot.
- The projects will be evaluated based on the idea, working and application of the projects.