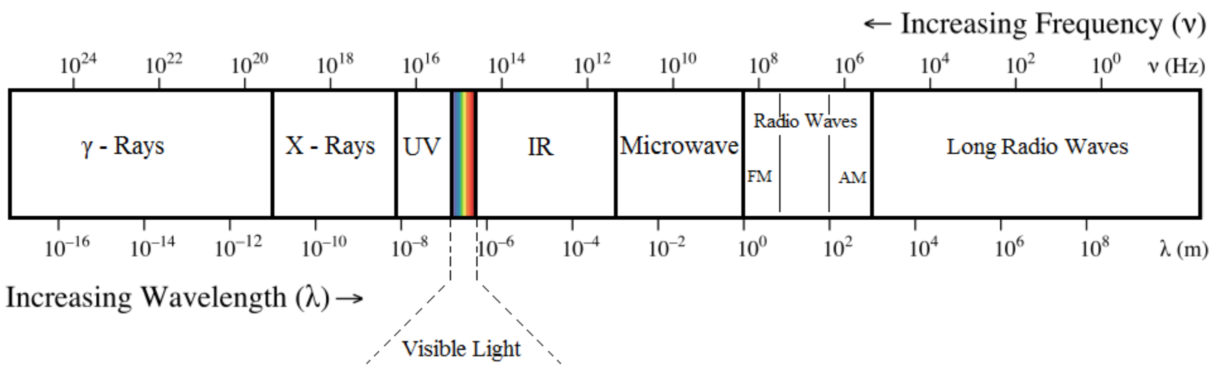
The Transmitter Circuit

The infrared transmitter circuit is made up of:

- NE555 Timer IC
- 3 Resistors
- 2 Ceramic Capacitors(Capacitor Code 102)
- An Infrared LED 3mm T-1 HIR205C/H0
- Switch
- Breadboard
- Connecting Wires
- Power Source
- Ground terminal

IR Led

IR LED is a special type of LED that emits Infrared rays of the Electromagnetic Spectrum. The wavelength of Infrared Rays (700nm – 1mm) is greater than that of Visible light and hence they are invisible to human eye.



A typical IR LED emits infrared rays in a wavelength range of 740 – 760 nm. There are many sources of infrared light like sun, light bulbs, all hot items and even human body.

So, in order to prevent interference and false triggering, we will modulate the infrared light. The modulated signal can only be demodulated by the appropriate IR Receiver.

Features of the IR LED

- High reliability
- 2.54mm lead spacing
- Low forward voltage
- Good spectral matching to Si photodetector
- High radiant intensity

Datasheet for the LED

Parameter	Symbol	Min.	Typ.	Max	Unit	Condition
Radiant Intensity	IE	11	-	48	mW/sr	I_f=20mA
Peak Wavelength	λ_P	-	850	-	nm	I_f=20mA
Spectral Bandwidth	Δλ	-	45	-	nm	I_f=20mA
Forward Voltage	V_F	-	1.45	1.65	V	I_f=20mA
		-	1.8	2.4		I_f=100mA
Reverse Current	IR	-	-	10	µA	VR=5V
View angle	2Ө1/2	-	40	-	Degree	If=20mA

555 TIMER IC

They are of two kinds:

- NE temp 0deg to 70deg Celsius
- SE temp -55deg to 125deg Celsius

The 555 IC is used to create a free running Astable oscillator to continuously produce square wave pulses.

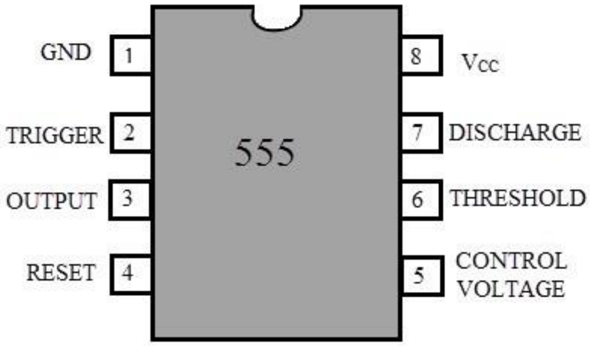
It can be connected in either:

- Monostable mode-producing a precision timer for a fixed time duration
- Bistable mode – to produce flip-flop type switching action
- Astable mode- to produce a very stable 555 oscillator circuit 4 generating highly accurate free running waveforms whose output frequency can be adjusted by means of an externally connected RC tank circuit consisting of just two resistors and a capacitor.

Features of the 555

- 3 modes of operation Astable Mode (for Oscillator Circuit or Pulse Generator), Monostable mode (as a timer) and Bistable mode (as a flip flop)
- Wide varieties of power supplies from 5V to 18V
- High output current
- Adjustable duty cycle

Pin out Diagram

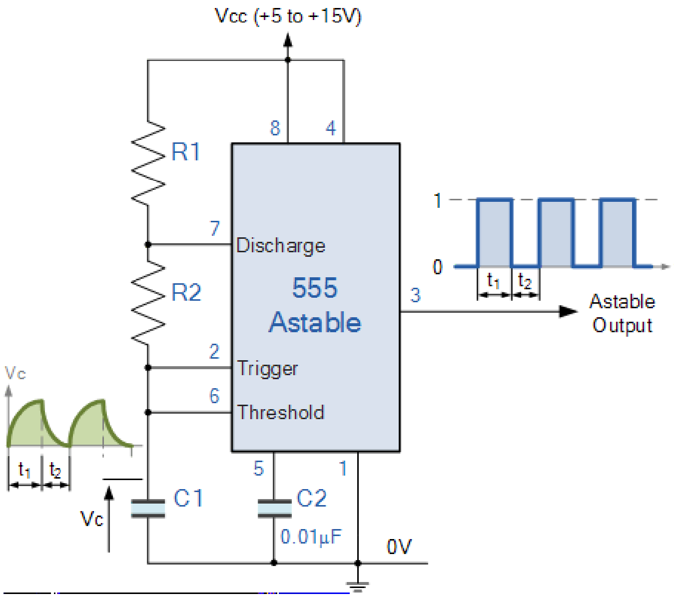


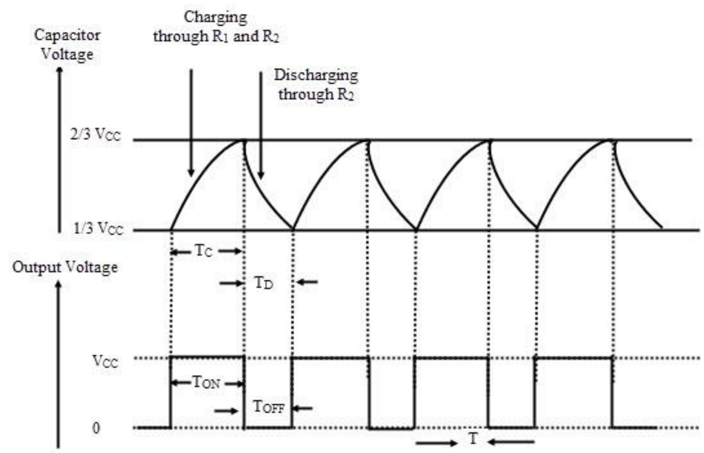
8-Pin DIP

Descriptions of the Pinout

PIN		IO	DESCRIPTION
NO	**NAME**		
1	GND	O	Ground Reference Voltage
2	Trigger	I	Responsible for the transition of SR flip-flop
3	Output	O	Output Driven Waveform
4	Reset	I	A negative pulse on reset will disable or reset the timer
5	Control Voltage	I	Controls the width of the output pulse by controlling the threshold and trigger levels
6	Threshold	I	Compares the voltage applied at the terminal with reference voltage of 2/3
7	Discharge	I	Connected to open collector of the transistor which discharges a capacitor between intervals
8	VCC Supply	I	Supply Voltage

The Astable Oscillator Circuit





In order to get the 555 oscillator to operate as an Astable multivibrator, it is necessary to continuously retrigger the 555 IC after each and every timing cycle.

The retriggering is achieved by connecting the trigger input (pin 2) and the threshold input (pin 6) together. Thus allowing the device to re-trigger itself on each and every cycle allowing it to operate as a free running oscillator, therefore it has no stable states as it continuously switched from one state to another.

Also the single timing resistor of the Monostable circuit should be split into two separate resistors R1 and R2 with their discharge connected to *discharge* input (pin 7) as shown above.

During each cycle capacitor, C1 charges up through both timing resistors, R1 and R2, but discharges itself only through resistor, R2 as the other side of R2 is connected to the *discharge* terminal, pin 7. Then the capacitor charges up to 2/3Vcc (the upper comparator limit) which is determined by the 0.693(R1+R2) C1 combination and discharges itself down to 1/3Vcc (the lower comparator limit) determined by the 0.693(R2*C1) combination. This results in an output waveform whose voltage level is approximately equal to VCC – 1.5V and whose output “ON” and “OFF” time periods are determined by the capacitor and resistors combinations. The individual times required to complete one charge (and discharge cycle of the output is therefore given as:

Astable 555 oscillator charge and discharge times:

$t1=0.693(R_1+R_2).C1$ ~ High

And

$t2=0.693*R_2*C1$ ~ Low

Where R is in Ohms

C is in Farads

NB: Vdiode=0.693V, which can be determined from datasheet or by testing

Therefore When connected as an Astable multivibrator, the output from the **555 Oscillator** will continue indefinitely charging and discharging between 2/3Vcc and 1/3Vcc until the power supply is removed.
The duration of one full timing cycle is therefore equal to the sum of the two individual times that the capacitor charges and discharges added together and is given as:

555 Oscillator cycle time
$T=t1+t2=0.693(R_1+2R_2)*C$

The output frequency of oscillations can be found by inverting the equation above for the total cycle time giving a final equation for the output frequency of an Astable 555 Oscillator as:

555 Oscillator Frequency Equation:

$$F = \frac{1}{T} = \frac{1.44}{(R1 + 2R2) * C}$$

By altering the time constant of just one of the RC combinations, the **Duty Cycle** (Mark-to-Space) ratio of the output waveform can be accurately set and is given as the ratio of resistor R2 to resistor R1. The Duty Cycle for the 555 Oscillator, which is the ratio of the “ON” time divided by the “OFF” time is given by:

555 Oscillator Duty Cycle

$$Duty\ Cycle = \frac{TON}{TOFF + TON} = \frac{R1 + R2}{R1 + 2R2}\%$$

If both timing resistors, R1 and R2 are equal in value, then the output duty cycle will be 2:1 that is, 66% ON time and 33% OFF time with respect to the period.
As the timing capacitor, C charges through resistors R1 and R2 but only discharges through resistor R2 the output duty cycle can be varied between 50 and 100% by changing the value of resistor R2. By decreasing the value of R2 the duty cycle increases towards 100% and by increasing R2 the duty cycle reduces towards 50%. If resistor, R2 is very large relative to resistor R1 the output frequency of the 555 Astable circuit will determined by R2 x C only.
The problem with this basic Astable 555 oscillator configuration is that the duty cycle, the “mark to-space” ratio will never go below 50% as the presence of resistor R2 prevents this. In other words we cannot make the outputs “ON” time shorter than the “OFF” time, as (R1 + R2)C will always be greater than the value of R1 x C. But one way to overcome this problem is to connect a signal bypassing diode in parallel with resistor R2, which we will not do in this project.

Lastly, a 50% duty cycle means the high time is equal to the low time. If an LED is placed at the output of this Astable circuit, it will turn on at the same span of time as it is turned off. But getting an exact 50% duty cycle is impossible with this circuit.

Choosing Timing Components for RC circuit in Timer

Choosing the right values for resistors and capacitors is necessary as the 555 timer can provide delays from microsecond to g depending on the values of R and C in the charging circuit.

When the 555 timer is operating in Astable mode, then it requires an RC circuit consisting of two resistors and a capacitor. R1 & R2 should be in the range of 1 Kilo Ohms to 1 Mega Ohms, as discussed below:

Timing Capacitor

- Choosing capacitors with large capacitances will be a problem. This is because electrolyte capacitors with large capacitances often tend to have wider tolerance limits. So the actual values and the marked values may have a significant difference.
- Large capacitance electrolyte capacitors will have high leakage currents which can affect the timing accuracy as the capacitor charges.
- It is better to avoid electrolyte capacitors that have a high working voltage rating as they do not work efficiently when operated at a voltage 10% less than their rated voltage.
- Hence, capacitors with working voltage greater than the VCC of the 555 timer should be chosen.
- Timing capacitors with capacitance less than 100pF in order to produce short output pulses may also cause problems.
- For capacitors with such low values, stray capacitance around the circuit might affect the capacitance of the timing capacitor.

Timing Resistor

- When operating the 555 timer as an Astable multivibrator, the value of the timing resistor should be at least 1 Kilo Ohms. If the idea is to build a low power consumption circuit, then it is better to have higher values for the timing resistors.
- The disadvantage in choosing resistors with higher resistances as they lead to inaccuracies in timing. In order to minimize these inaccuracies, the value of the timing resistor shouldn’t be more than 1 Mega Ohms.
- Using high values of resistance > 1 Mega Ohms can increase the error between calculated and actual frequency. So a maximum of 1 Mega Ohms is recommended.
- If the value of R1 is less than 1 Kilo Ohms, there is a danger that the trigger input (pin2) may not be able to reach a low enough voltage to trigger the comparator in the 555 and so oscillations cannot take place.

Trigger Pulses

- The Pin 2 in the 555 timer is a trigger input. When the trigger input goes below the reference voltage i.e. 1/3 VCC, the output of the timer is high and the timing interval begins.
- The trigger pulse should momentarily go below the reference voltage and the duration is important as it should not be longer than the output pulse.
- Trigger pulses are generally identified by a narrow negative going spike. A differentiator circuit made from a capacitor and a resistor will produce two symmetrical spikes but a diode is used to eliminate the positive going spike.
- The duration of the pulse is determined by the differentiator circuit (i.e. it depends on the capacitor and resistor).

<u>Project Transmitter Calculations</u>

Taking the value:

- C1=1nF
- C2=10nF
- R1=1kOhms
- And we want it to generate a frequency of approximately 38kHz

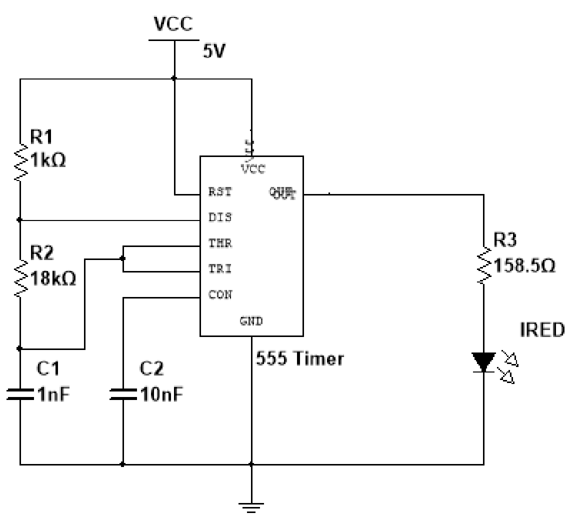
Thus finding the value of R2, from the formula:

$$f = \frac{1}{T} = \frac{1.44}{(R1 + 2R2) * C}$$

$$R2 = \frac{1.44}{FC} - R1 * \frac{1}{2}$$

Thus, $R2 = \frac{1.44}{38kHZ * 1nF} - 1k\Omega * \frac{1}{2}$

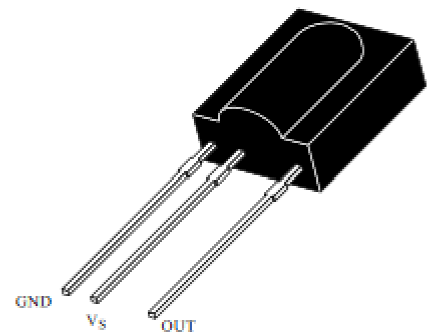
$$R2 = 18 \; approx \; 18k\Omega$$



The Receiver Circuit

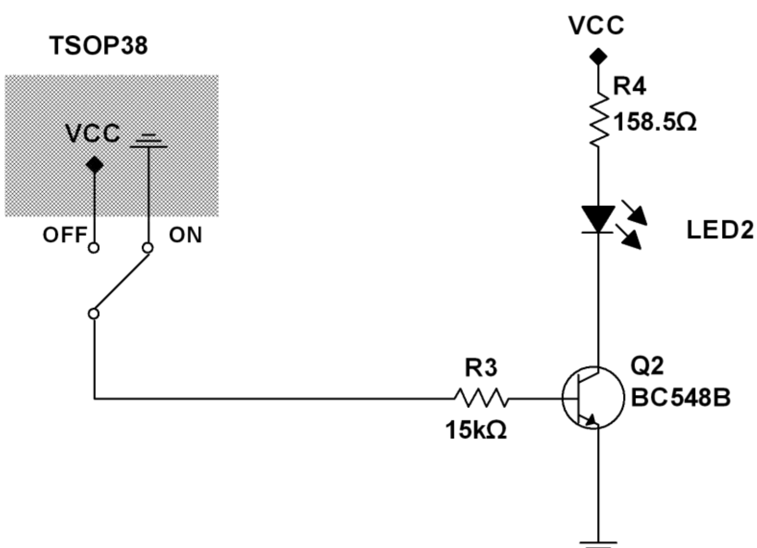
It consists of an IR phototransistor, a diode, a MOSFET, a potentiometer and an LED. When the phototransistor receives any infrared radiation, current flows through it and MOSFET turns on. This in turn lights up the LED which acts as a load. The potentiometer is used to control the sensitivity of the phototransistor.
TSOP1738 Features:

- Photo detector and preamplifier in one package
- Output active low
- Internal filter for PCM frequency
- High immunity against ambient light
- Improved shielding against electric field disturbance
- 5 Volt supply voltage, low power consumption
- TTL and CMOS compatibility
- Continuous transmission possible



Circuit Components

- TSOP 1738
- LED
- 2 Resistors
- BC548B Transistor
- Breadboard



- For a RED Led:
  - Vf=1.83V &
  - I=20mA
- Vcc, supply Voltage=5V
- $R = \frac{Vs-Vf}{I}$
- $\frac{5-1.83}{0.02} = 158.5\Omega$

From the BC548 Datasheet,

Hfe(max)	150
Hfe(Min)	90
IC(Max)	0.1
Vbe(Sat)	0.7
Vce(Sat)	0.09

Geometric Average of hfe is given by:

$$hfe = \beta = \sqrt{hfe(\mathrm{max}\quad) * \mathrm{hfe}(\mathrm{min}\quad)} = \sqrt{90 * 150} = 116.19$$

When Saturated,

$$Vbe = 0.7V$$

$Collector\ Curent\ is$:

$$IC = \frac{Vcc}{Rc} = \frac{5}{158.5} = 0.0315A$$

And Since:

$$hfe = \frac{IC}{IB} \quad then\ \ IB = \frac{0.0315}{116.19} = 0.0002715A$$

And $IBRB = VCC - VBE$

$RB = \frac{VCC-VBE}{IB} = \frac{5-0.7}{0.0002715} = 15k\Omega$, value of the base resistor of the transistor.

So when TSOP 38 is LOW (**IR Signal Detected**) the transistor will be functional and it will drag the transistors output to 0V that is logic 0. Otherwise when TSOP1738 is HIGH (**No IR Signal in Range**) the output will be at 5V which is logic 1. Here is a mini table of the states:

State(IR Signal)	TSOP	Output LED	TRANSISTOR
Present	0	off	off
Absent	1	On	on

The Microcontroller will take action upon receiving a logic 0 from the receivers output.

Expected Transmission Range for the IR sensor

The maximum transmission distance for the IR, depends on several factors (primary factors) are:

- Radiant Intensity of the Emitter (I.e.=11Mw/sr)
- Sensitivity of the Receiver (Ee=0.5Mw/M^2)

The relation between intensity of a source and the resulting irradiance in the distance r is given by the basic square root rule law. An emitted intensity I.e. generates in a distance r the irradiance Ee = Ie/r2. This relationship is not valid under near field conditions and should be used not below a distance d smaller than 5 times the emitter source diameter.

Using a single radiation point source, one gets the following relation between the parameter E_e, ϕ_e, and r

$$Ee = \frac{d\phi_e}{dA}\left[\frac{W}{m^2}\right]$$

$$use$$

$$I_e = \frac{d\phi_e}{d\Omega}, \Omega = \frac{A}{r^2} and\ get$$

$$E_e = \frac{d\phi_e}{dA} = I_e\left(\frac{d\Omega}{dA}\right) = \frac{I_e}{r^2}\left[\frac{W}{m^2}\right]$$

$$The\ distance\ r\ resulting\ as$$

$$r = \sqrt{\frac{I_e}{E_e}} = \sqrt{\frac{Intensity}{senstivity}}$$

And since our transmitter's 3mm LED has $I_e\ of\ 11Mw/sr$ and our receivers TSOP1738 has an $E_e\ of\ 0.5mW/m^2$ at a frequency of 30-40 kHz, these were obtained from their respective datasheet, thus

$$r = \sqrt{\frac{11}{0.5}} = 4.69Meters$$

Transmission distance increases as the intensity increases and as the receiver becomes more sensitive.

Where Ie is the IR-LED radiant intensity in W-sr^1 and d is the source-to-eye distance in meters.

FIGURE 8: RADIANT INTENSITY VS. FORWARD CURRENT

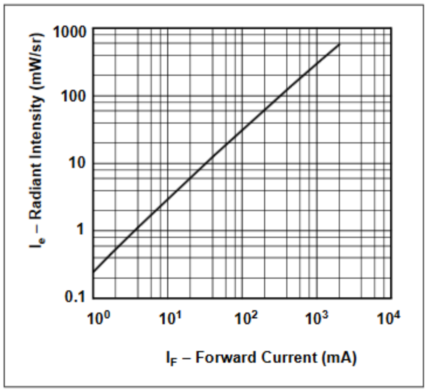
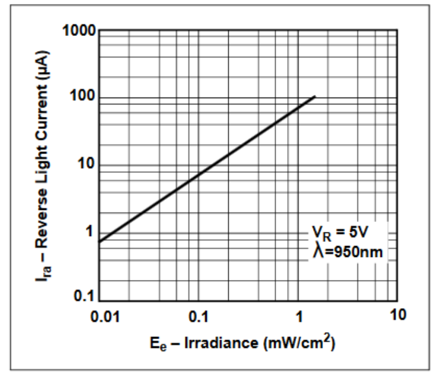
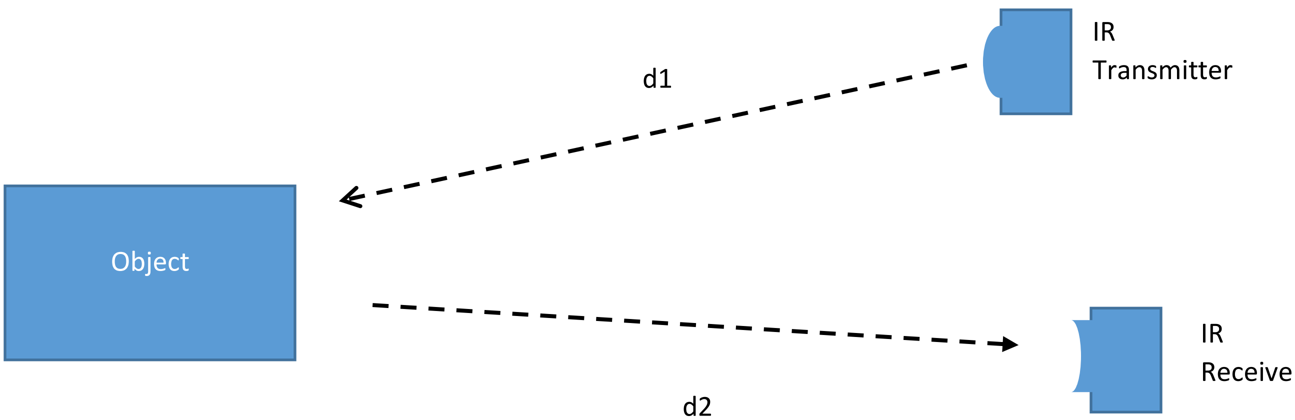


FIGURE 12: IRRADIANCE VS. CURRENT



The total irradiance, Ee, can be determined from IR-LED datasheet specifications.



<u>Sensitivity Analysis of The Infrared Sensor (i.e. between the Transmitter and the Receiver)</u>

<u>Limitation of the IR sensor performance</u>

- Performance of IR sensors has been limited by their poor tolerance to light reflections such as ambient light or bright object colors.
- No object recognition at the dead zone area, for example our IR sensor dead zone was limited to a minimum of 4m.
- IR sensors also give inaccurate detection result with transparent or bright color materials.
- Detection results also depend on the weather conditions and the sensing reliability of IR sensors decreases with moisture and humidity.

- Furthermore, IR sensors can sense IR radiation from the sunlight, which can cause correctable or non-correctable errors at output.
- Besides that, if analogue IR sensor is used, signal losses will occur at the amplifier circuit.

Improvements

Use of IR and PIR Sensors for Object Detection

Infrared sensors detect the object's distance with infrared radiation. When the beam detects an object, the light beam returns to the receiver with an angle after reflection. The method of triangulation is as shown in Figure 4 below.

PIR sensors are also known as Pyroelectric Infrared sensor, Passive Infrared sensor or IR motion sensor, which detect the difference in temperature, thermal radiation, human body or an animal. PIR sensor operates with the radiation of body heat as shown in Figure 5 below. The hotter the detected object, there will be more emission occurs in PIR sensor.

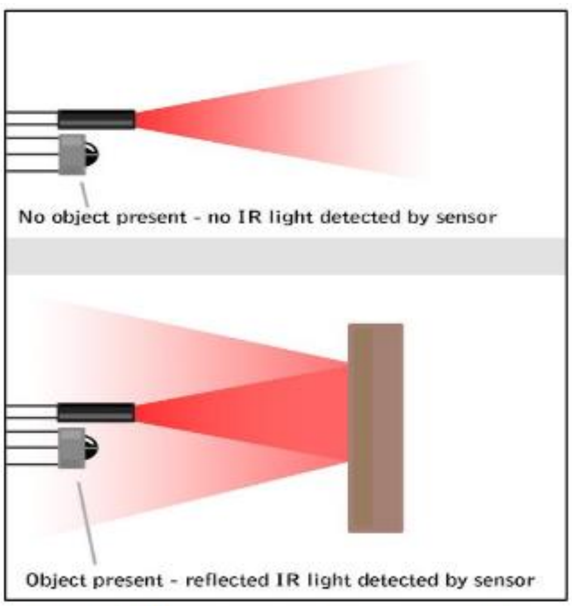


Figure 4. IR sensor working principle [15]

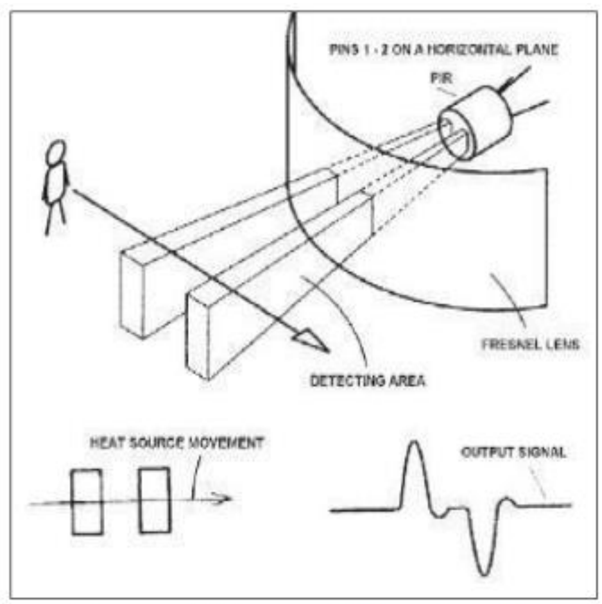


Figure 5. PIR sensor object detection

Object temperature calculation is based on Stefan-Boltzmann Law.

$$Te = \sqrt{T_S^4 + \frac{\Phi}{A\sigma\varepsilon\varepsilon_S}}$$

$Ts = Sensor's\ surface\ temperature\ Tc = objects\ temperature\ in\ Kelvin,$

$\Phi = magnitude\ of\ net\ thermal\ radiation\ flux\ \phi, \varepsilon = emissivity\ of\ the\ object$

PIR sensor relatively has a lower power consumption compared to IR sensor. PIR sensor also senses accurate detection in narrow areas and is compatible to work in microcontrollers. The IR and PIR sensors can act as a transducer since they use infra-red signal as the input and convert it to analogue electrical output signal

The traffic light has been successful in controlling the traffic but it also has certain limitations as well. Further improvement can be achieved by adding more sensors along the road intersection. Besides that, ______ can be implemented for monitoring applications.

Glossary

An ampere

SI unit of electrical current

C capacitance

Unit: F (farad) = C/V

Ee, **E irradiance** (at a point of a surface)

F **frequency**

Unit: s^{-1}, Hz (Hertz)

I.e., I **radiant intensity** (of a source, in a given direction

M **meter**
SI unit of length

IC **collector current**

LED and IRLED
Light Emitting Diode LED:
Solid state device embodying a p-n junction, emitting optical radiation when excited by an electric current.
IR Abbreviation for infrared

T **period of tim**e (duration)

SI unit of length

λ **Wavelength**, general

Sr **steradian** (sr)

SI unit of solid angle : Solid angle that Ω, having its vertex at the center of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere.

Radiation and Light
Visible radiation
Any optical radiation capable of causing a visual sensation directly.

Radiation and Light
IR infrared radiation
Optical radiation for which the wavelengths are longer than those for visible radiation.
Note: The range between 780 nm and 1 mm

VCC supply voltage (positive)

V **volt**

VCE_{sat} **collector-emitter saturation voltage**

The saturation voltage is the dc voltage between collector and emitter for specified (saturation) conditions, i.e., IC and EV (Ee or IB), whereas the operating point is within the saturation region

V_F **forward voltage**

The voltage across the diode terminals which results from the flow of current in the forward direction

VS **supply voltage**

$\phi_e; \phi, P$

Radiant flux; radiant power

Power emitted, transmitted or received in the form of radiation. Unit: W = Watt