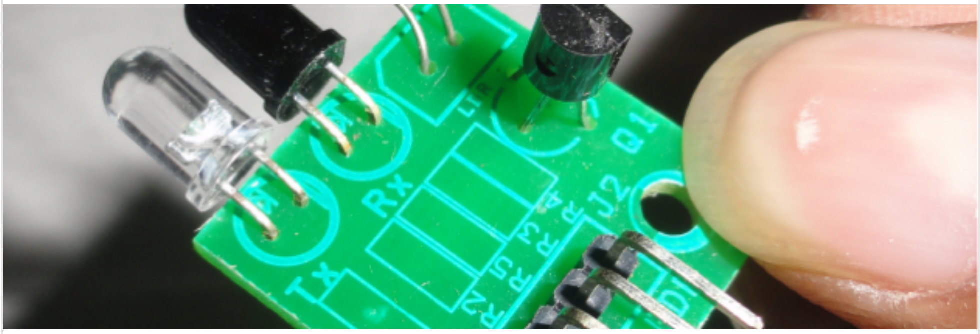
Vishwam Electronics Microcontrollers Robotics
134 comments



How to build an IR Sensor

What is an IR sensor?

An IR sensor is a device which detects IR radiation falling on it. There are numerous types of IR sensors that are built and can be built depending on the application. Proximity sensors (Used in Touch Screen phones and Edge Avoiding Robots), contrast sensors (Used in Line Following Robots) and obstruction counters/sensors (Used for counting goods and in Burglar Alarms) are some examples, which use IR sensors.

Before reading ahead, I would suggest you to go through this small post by Mayank on sensor fundamentals. It would help you in understanding the

Search maxEmbedded

Search

Popular Recent Random

MON 20 The ADC of the AVR

FRI 24 AVR Timers – TIMER0

TUE 06 RF Module Interfacing without Microcontrollers

THU 16 LCD Interfacing with AVR

FRI 10 I/O Port Operations in AVR

Browse maxE by Categories

concepts discussed in this post.

Working Mechanism

An IR sensor is basically a device which consists of a pair of an IR LED and a photodiode which are collectively called a photo-coupler or an opto-coupler. The IR LED emits IR radiation, reception and/or intensity of reception of which by the photodiode dictates the output of the sensor. Now, there are so many ways by which the radiation may or may not be able to reach the photodiode. Let's discuss a few.

Direct incidence

We may hold the IR LED directly in front of the photodiode, such that almost all the radiation emitted, reaches the photodiode. This creates an invisible line of IR radiation between the IR LED and the photodiode. Now, if an opaque object is placed obstructing this line, the radiation will not reach the photodiode and will get either reflected or absorbed by the obstructing object. This mechanism is used in object counters and burglar alarms.

Indirect Incidence

High school physics taught us that black color absorbs all radiation, and the color white reflects all radiation. We use this very knowledge to build our IR sensor. If we place the IR LED and the photodiode side by side, close together, the radiation from the IR LED will get emitted straight in the direction to which the IR LED is pointing towards, and so is the photodiode, and hence there will be no incidence of the radiation on the photodiode. Please refer to the right part of the illustration given below for better understanding. But, if we place an opaque object in front the two, two cases occur:

Reflective Surface

If the object is reflective, (White or some other light color), then most of the radiation will get reflected by it, and will get incident on the photodiode. For further understanding, please refer to the left part of the illustration below.

Non-reflective Surface

If the object is non-reflective, (Black or some other dark color), then most of the radiation will get absorbed by it, and will not become incident on the photodiode. It is similar to there being no surface (object) at all, for the sensor, as in both the cases, it does not receive any radiation.

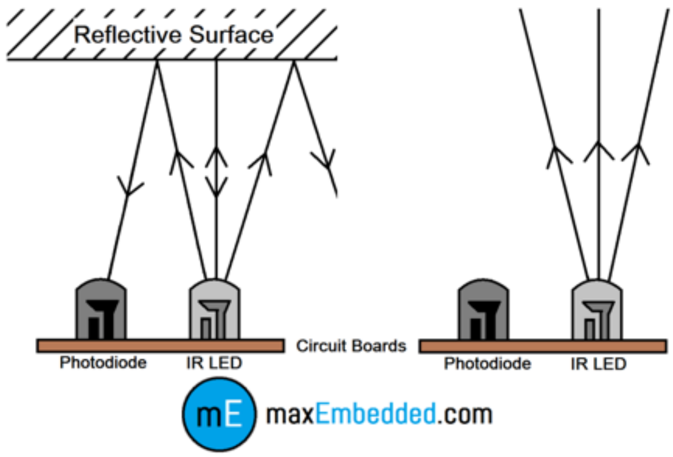


Illustration Indirect Incidence of IR radiation

Where do we use them?

Proximity Sensors

We use **reflective indirect incidence** for making proximity sensors. The radiation emitted by the IR LED is reflected back on the photodiode by an object. Closer the object, higher will be the intensity of the incident radiation on the photodiode. This intensity is made analogous to a voltage by a circuit, which is then used to determine the distance.

Proximity sensors find use in Touch Screen phones, apart from many other devices. In a Touch Screen Phone, the touch screen needs to disabled when it is held near the ear, while in use, so that even if the cheek makes contact with the tough screen, there is no effect.

Line Follower Robots

IR sensors are the main triggers of the whole line following robot's action mechanism. IR sensors are the ones which detect the color of the surface underneath it and send a signal to the microcontroller or the main circuit which then takes decisions according to the algorithm set by the creator of the bot. The sensors used in them are based on **reflective/non-reflective indirect incidence**. The IR LED emits IR radiation, which in normal state gets reflected back to the module from the white surface around the black line, which gets incident on the photodiode. But, as soon as the IR radiation falls on the black line, the IR radiation gets absorbed completely by the black color, and hence there is no reflection of the IR radiation going back to the sensor module.

Item Counter

This is based on **direct incidence** of radiation on the photodiode. Whenever an item obstructs the invisible line of IR radiation, we make an increment in the value of a stored variable in a computer/microcontroller which may be indicated by LEDs, Seven Segment Displays, LCDs etc.

These counters are often used in monitoring systems of large factories, where products on conveyor belts, that are loaded/unloaded are counted.

Burglar Alarm

This is also based on **direct incidence** of radiation on the photodiode. Here, the

IR LED is fitted on one side of the door frame, and the photodiode on the other, such that in normal condition, the IR radiation emitted by the IR LED falls on the photodiode directly. As soon as a person obstructs the IR path, the alarm goes off. This alarm can be switched on at night, and switched off in the day, during normal use of the door.

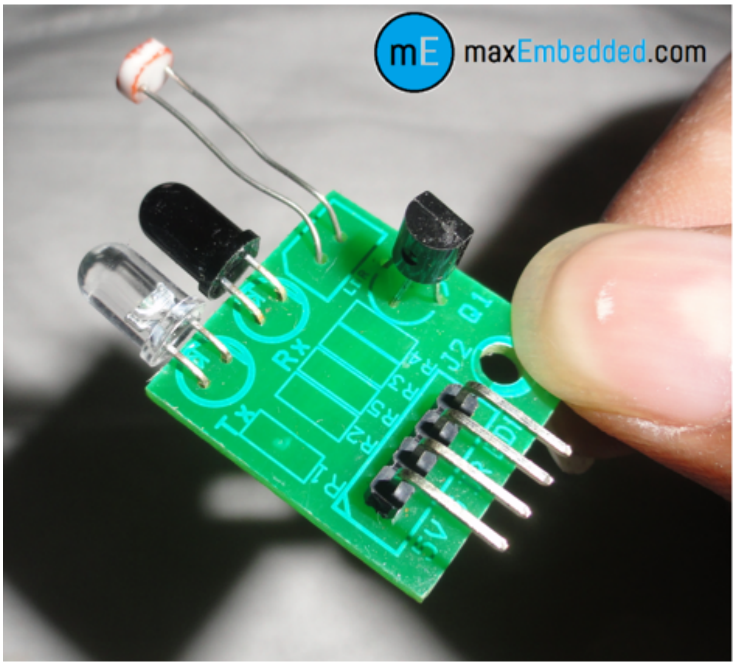
This mechanism is used extensively in security systems and is replicated on a smaller scale for smaller objects, such as exhibits in an exhibition, etc.

Analog vs Digital sensor

Now that you know all about IR sensors, their working mechanism and applications, it's a good time to talk about analog and digital sensors. But first let's talk about what analog and digital are.

Analog data

Analog data is basically a continuous stream of data, without discrete levels. It can be used to express anything, voltage, temperature, pressure etc. provided it is not in steps of discrete levels. What we see around us, or hear, or anything that is sensed by our sense organs is a continuous stream of input, and hence is analog. For example, let's a consider a stationery car. We are the driver of the car, and we want to attain a speed of 60 Km/hr. Obviously, we can't attain this speed instantly, we will have to move up from 0 to 60 Km/hr gradually, no matter how fast we accelerate. So, all the different values of speeds that we attain in this process are all analog data as they can be anything, and are not discrete. Music too, is analog, since each note that we hear is a sine wave, which we all know is continuous.



Analog sensor

If we make an analog IR sensor, then we will get an analog output in terms of voltage which can hold any value between 0 volts and the voltage that we have provided as Vcc. Higher the intensity of the radiation falling on the photodiode, higher will be the output voltage. One such sensor is the one in the photograph above. It is a sensor I found in a very expensive Robotics Kit. It also has an LDR (Light Dependent Resistor) on board with a transistor amplifier to amplify the output of the LDR which is used to detect ambient light.

We can use analog sensors to estimate the distance of an object from the sensor, where distance will be inversely proportional to the output voltage. We can do so by interfacing our sensor with a microcontroller which is capable of receiving analog data and program it to calculate the distance. Analog sensors are used, and can be used in many other applications.

Making an Analog IR sensor is relatively easier than making a digital one. All we need is an IR LED and a photodiode, both with series resistors with them. To make one, just remove everything on the right (starting from the IC) of the circuit diagram given below in the "How Does It Work" section. That means you will only need 4 components, namely, the 150 and 10K resistors, and the IR LED and the Photodiode. The output of this sensor will have to be taken from the junction of the photodiode and the 10K resistor, which in the circuit diagram given below, is connected to the 3rd pin of the IC.

Digital Data

Digital Data is expressed in terms of two discrete values, 0 and 1. The smallest unit of digital data is called a 'bit'. One bit of digital data can only be one of two values, 0 and 1, unlike analog data, where one unit of analog data can hold any value possible. For example, there is a toy car designed such that the remote control has only 2 buttons. Both of them will make the car move forward, one with a speed of 30 Km/hr and the other with 60Km/hr. We see here that we don't have an option to move the car at any other speed other than the ones defined above, there are only two discrete levels of speed. This is how digital data is in nature.

Analog data can be converted into digital data using Analog to Digital Converters (ADC). Our Music CD players at home are nothing but highly sophisticated Analog to Digital Converters, since they convert Analog data (Music) on a CD to digital data, process the data, amplify it, reconvert the processed data to analog data and output the music via speakers. In hardware, digital information can be expressed as voltages, i.e, 0 Volts and 5 Volts. They are also known as digital logic high (represented by '1') for 5 V and digital logic low (represented by '0') for 0 Volts.

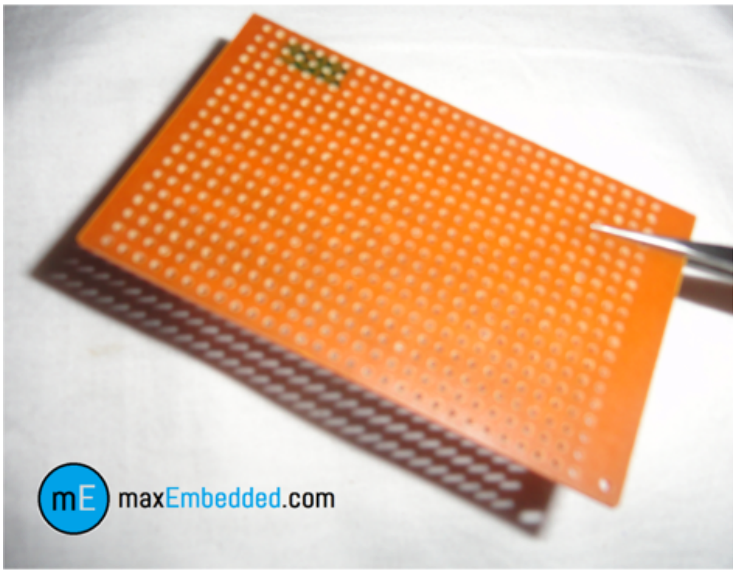
If we want to make a digital sensor, we will have to use a device which creates discrete levels and only gives out 0 and 5 volts as output. This device in the design that we are using is the LM358M, which a Dual Op-Amp. Any General Purpose Op-amp with similar gain and operating voltages can be used, like the LM324M. This digital output of the sensor, can be fed into the GPIO (General Purpose Input/Output) pins of any microcontroller. To learn how to use AVR microcontollers to convert and process analog data, please refer to this post on the ADC of the AVR.

In this post, we are primarily making a digital IR sensor.

What do we need?

1. IR LED
2. Photodiode
3. LM-358M (Op-Amp)
4. 2 x 150 Ω Resistance

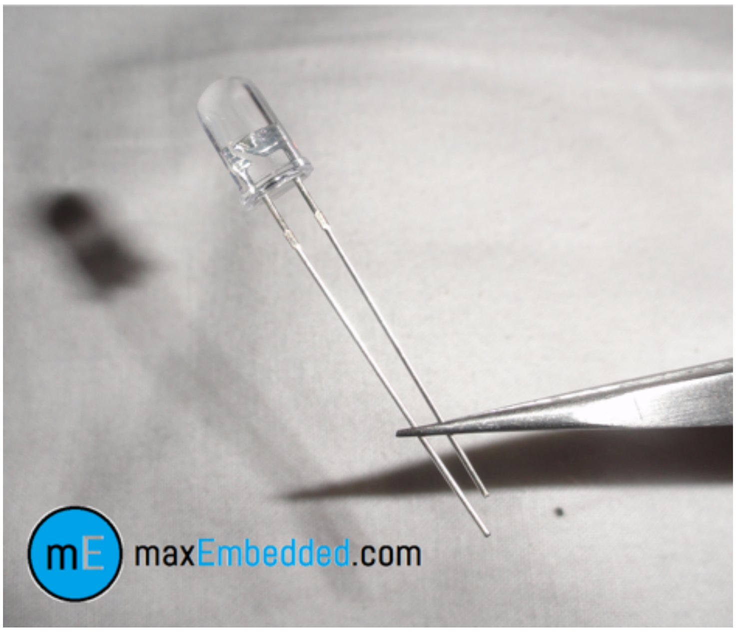
5. 1 x 10 kΩ Resistance
6. 1 x 10 kΩ Variable Resistance (Potentiometer/Preset)
7. 5 Volt power source
8. Wires
9. General purpose PCB or bread board (Picture Below)



PCB

Some things you need to know

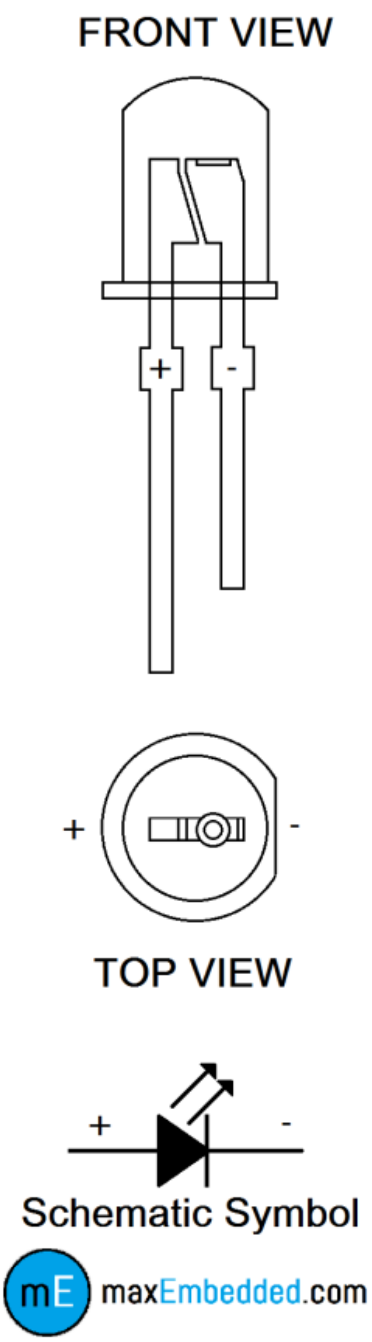
IR LED



IR LED

An IR LED is a type of LED which emits light in the frequency range of Infra-Red, hence the name 'IR' LED. Please note that Infra-Red radiation is invisible to the human eye, and hence we cannot see an IR LED emit it when it actually is. But there is a way to see IR radiations, if you want to. If you look at IR radiation through the lens of a camera, you will be able to see it. Apart from this, in every other sense an IR LED works exactly like an ordinary LED (Look at the picture above), consumes a current of about 20mA and operates on around 3V

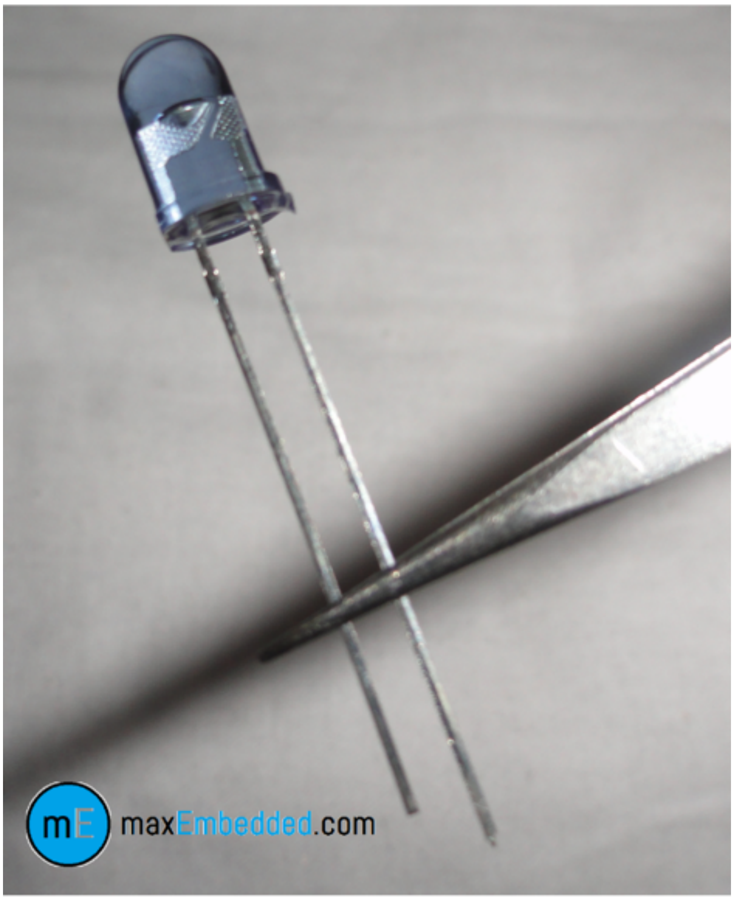
DC. please refer to the diagram given below for details on connections of the IR LED, as well as the ordinary LED, if you choose to use one.



Detailed Diagram of an LED

Photodiode

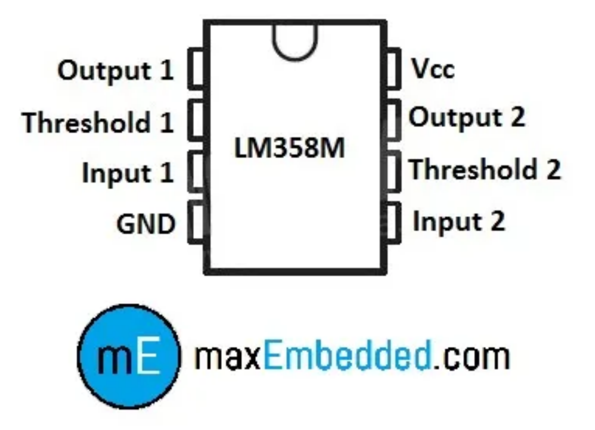
A photodiode is a type of diode which detects light. We can think of it as having a very high resistance when no light is falling on it. As we increase the intensity of light incident on it, the current through it gradually increases too. So, by increasing the incident light on a photodiode, we convert it into a normal low value resistor, which conducts current. We should note here that a photodiode looks exactly like an LED, sometimes, with a dark blue or black film on the outer casing (Please look at the picture below), but we make use of it in reverse bias, that means opposite in configuration as in the case of an LED. You can refer to the diagram above for the connections of the photodiode, but remember to connect it in reverse bias as shown in the circuit diagram given in the "How does it work?" section below.



Photodiode

IC Op-Amp LM358M (as a voltage comparator)

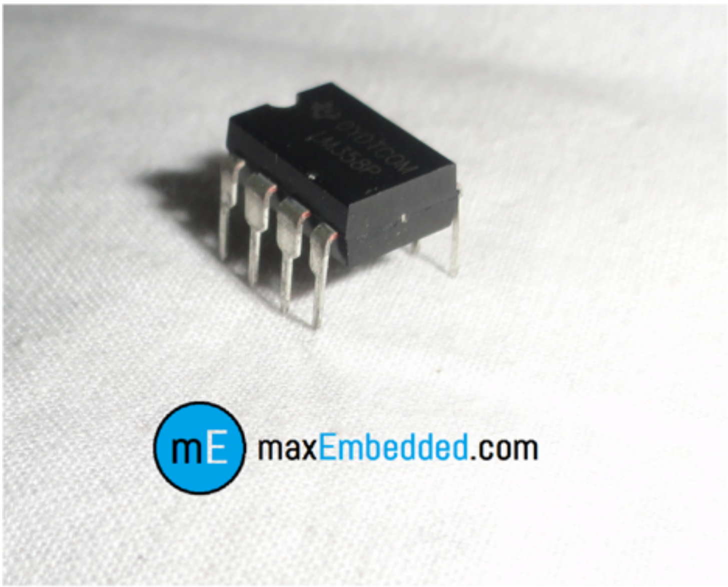
LM358M is a general purpose Dual Operational Amplifier (Op-Amp). Knowing the working of an Op-amp here is really of no use to us, as we are not using it as an amplifier as such, so we will only be talking about how we use it here in the IR sensor circuit, what it does, but not much about how it does it. So basically, we use it to compare two voltages, one is fixed and the other varies with an environmental parameter. If the parameter controlled voltage is higher than the fixed the voltage, then the IC should give one output, and if it is lower than the fixed voltage, then it should give another output. So, we see that the IC gives only two types of outputs, which we design to be 5 Volts and 0 Volts. This makes our sensor digital.



Pin Configuration for LM358M

Now, we know how to use our Op-Amp, so let's talk about how to connect components to it. This IC is an 8 pin IC. Check the illustration above for the pin layout. Output (pin 1) is where we get the 5/0 Volts, Threshold (pin 2) is the fixed voltage, Input (pin 3) is where we supply our environment controlled voltage, and pin 4 & 8 are used to power up the IC. The best part about this IC is that it is a **Dual Op-Amp**, so you can make two completely separate IR sensors using the same IC! All you need to do is mirror all the connections on the lower three terminals of the other half of the IC (Refer to the pin diagram of the IC).

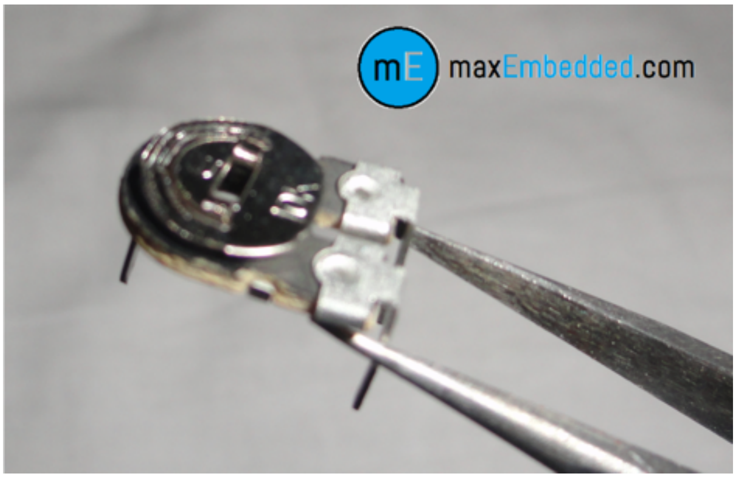
NOTE: The way we are using this IC here and the pin configuration I have shown here is not how an Op-Amp is used traditionally, we are actually manipulating the IC to work as a voltage comparator. Please do not use the above explanation as your guide to studying Operational amplifiers.



LM358M

Variable Resistor

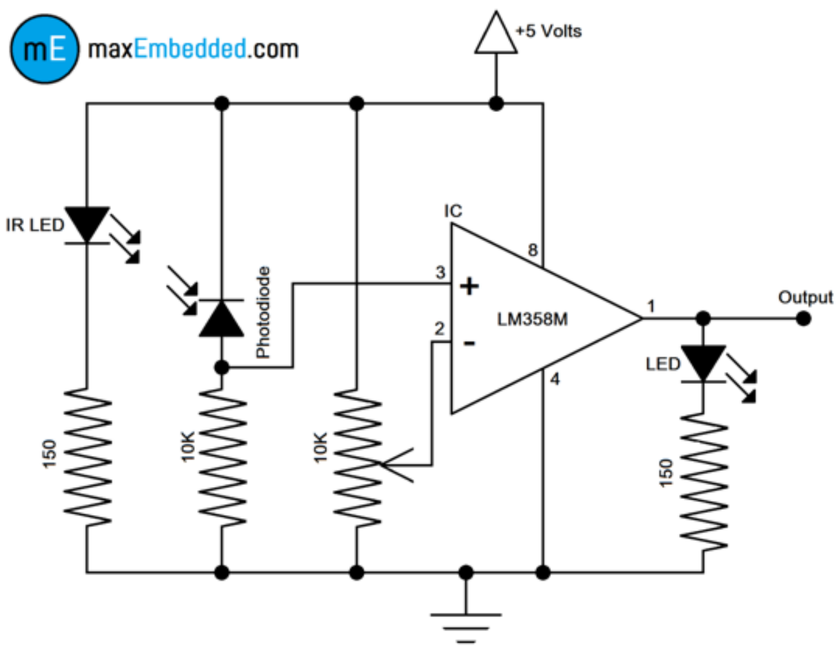
A variable resistor is a 3 pin device which is used to vary resistance. In this circuit, we use it to calibrate the IR sensor according to the environment. We give Vcc and GND to the terminals which are close together and connect the center terminal to the threshold of the IC (Assuming you are using the small triangular PCB mountable package like the one shown below).



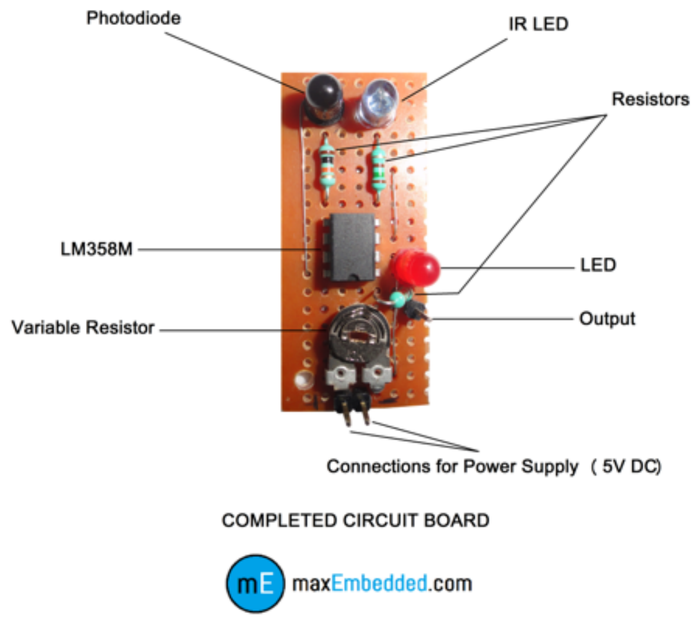
Variable Resistor

How does it work?

If the IR LED emissions become incident on the photodiode, the photodiode's resistance comes down to a finite value. The drop across the 10K series resistor is what we use as the input, which is compared with the threshold. The point to be noted here is that more the incident radiation on the photodiode, less will be the drop across it, and hence more will be the drop across the series resistor. If the voltage developed across the resistor is greater than the threshold set by us, the output of the IC will be high, else it will be low. Hence, if our reflected radiation is never strong enough to be greater than the threshold and we have a constant low as output, we can reduce the threshold voltage by turning the "minus shaped" slit in the variable resistance towards its terminal where we connected Gnd. In case our threshold is very low and the output is always high in spite of no radiation or if it is just too sensitive, then you can increase the threshold by turning the slit the other way. When the emissions are absorbed by a black surface, the resistance of the photodiode becomes very high due to no incidence of IR emissions on it, and the output remains low. I like to use an LED to indicate the output, even if I have the output going to the main circuit, but it is totally up to you when you make it.



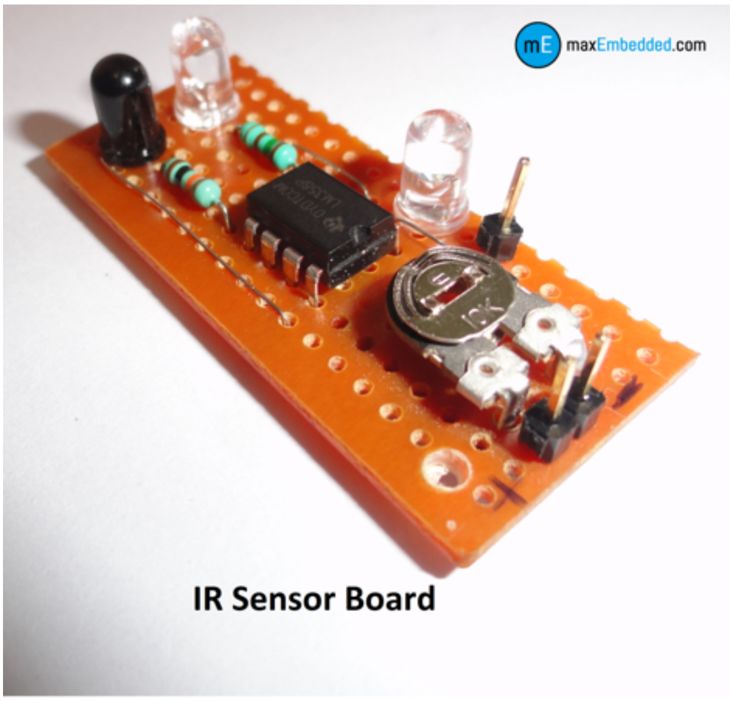
Circuit Diagram



Circuit Discription

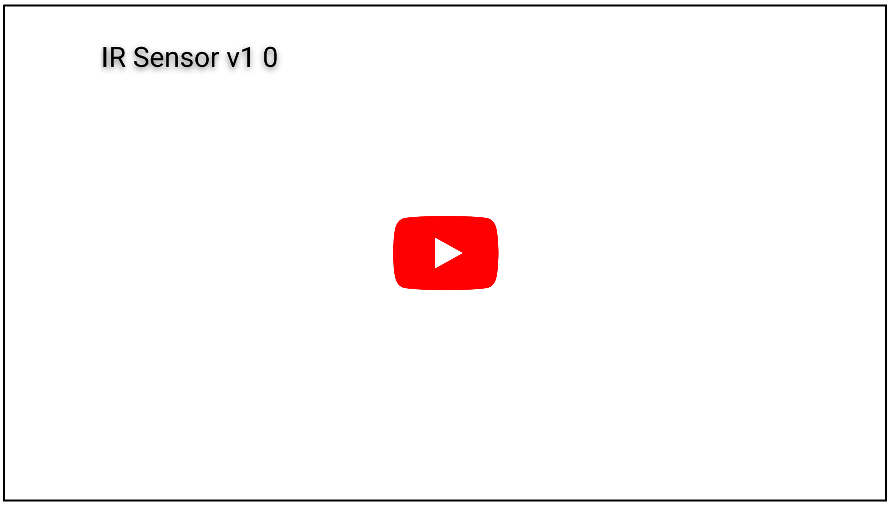
Completed IR Sensor

The sensor board that you see in the pictures is the one I made. It's pretty small, not as small as the ones available in the market which are pre-made on fabricated PCBs, but very close. I have designed it in such a way that I will need to supply it 5 Volts DC via the two male header pins in the bottom of the board. The output will have to be taken from the male header pin on the right side of the board and routed to the main circuit using a connecting cable. The LED above this output male header is the one that indicates a reflective surface in front of the board by glowing, I chose the color of the LED to be red. You may choose to make a breakout board (like I did), that can be used in any IR sensing application, or you may want to make one on the same PCB as your main circuit. You may want to add multiple sensors to the same board by just repeating the circuit over and over again, as many times as you want. (Remember, with one LM358M, you can make two independent IR Sensors).



Final Board

Sample Video



This is a sample video of me testing the IR sensor that i made. I test it by differentiating the colors black and white. I count the number of black lines, and if the count value is a prime number, i make an LED glow. The code for the same is given below. It is for the AVR Atmega16 Microcontroller in Embedded C/C++.

Sample Code

This is a sample code written by me for the AVR Atmega16 Microcontroller. I first check if the sensor has detected a non-reflective surface/obstacle. Then I increment the value of a variable at every detection. If the number of times the sensor has detected something is prime, then an LED glows, and if it is composite, the LED turns off. The code was written in and compiled using Atmel Studio 6. The code is pretty simple and straightforward if you are familiar with the AVR I/O operations. The code is right below, and can also be found in the AVR code gallery and on Pastebin.

```
#define F_CPU 1000000UL

#include <avr/io.h>

int ch_prime(int); //Prototyping the function for testir

int main(void)
{
		uint8_t num=0, res; //Creating variables 'num'
		DDRA &= ~(1<<0); //Setting 0th pin of Port A a
		DDRD |= (1<<0); //Setting 0th pin of Port D as

		while(1)
		{
			if (bit_is_set(PINA, 0)) //Checking i
			{
				while (bit_is_set(PINA, 0));
				res = ch_prime(++num); //Inc

				if (res==1)
				PORTD |= (1<<PIND0); //If re
				else
				PORTD &= ~(1<<PIND0); //If r
			}
			else
			continue; //If sensor has nothing in
		}
}

int ch_prime(int num)
{
		int i; //Declaring variable 'i' to use in the
		for (i=2;i<num;i++) //Run the loop for the val
		{
			if (num%i==0) //Check and compare to
			return(0); //If Number is composite,
		}
		if (i==num) //Compare the value of i to num, i
		return(1); //If number is prime, return 1
}
```

So this was it for this post. Don't forget to share your views, responses and queries in the comment box below. You can subscribe via email to stay updated and get feeds right into your inbox as well!

Written by-
Vishwam Aggarwal
vishwam@maxEmbedded.com

134 Comments

← Older Comments

Atharva

If the resistor below photodiode is removed and then if more light falls on photodiode voltage across photodiode will be less so output will be low right?

REPLY

← Older Comments

Trackbacks/Pingbacks

IR LED | Infrared Sensors | Pin Diagram & Working - SMPS Troubleshooting - […] Step by step details to build an IR sensor are available at: DIY- IR Sensor […]

Leave a Reply

Enter your comment here...

This site uses Akismet to reduce spam. Learn how your comment data is processed.

Copyright

Tags

accelerometer adapter adc assembly avr adc avr basics avr eeprom avr interrupts avr serial avr timers basics code gallery code optimization color spaces counters cv basics development server filter circuit i2c iot basics ir sensor matlab msp430 basics msp430 launchpad opencv pcb design pic basics power supply printed circuit boards pwm raspberry pi rf communication rf module robotics robot locomotion rs232 sbc basics sensors Serial spi timers uart usart web development wireless

Top Posts & Pages

- The USART of the AVR
- AVR Timers - CTC Mode
- AVR Timers - TIMER0
- I/O Port Operations in AVR
- Setting up AVR-GCC Toolchain on Linux and Mac OS X
- AVR Timers - TIMER1
- How to build an IR Sensor

Home Copyright Privacy Policy Credits Sitemap Contact

maxEmbedded is a free and open source platform to share knowledge and learn about the concepts of robotics, embedded systems and computer vision. People from around the world who are enthusiastic about these topics and willing to support the open source community are invited to share their information, knowledge and expertise by means of written tutorials and videos on the website.