Touchless Control:
Hand Motion Triggered Light Timer

6.101 Final Project Report

Justin Graves

Spring 2018

1 Introduction

Often times when you enter a new room you are troubled with finding the light switch or you may not be able to find it due to the room being too dark. Or on the flip side maybe you are in such a rush when you leave a room that you forget to turn the light off. The idea behind this final project is to eliminate both of these problems by making the light turn on and off without actually physically touching a light switch.

The plan for accomplishing this goal was to use an IR sensor to trigger turning on the light and as a trigger to start a timer as to when the light should turn off.

Gesture triggering is accomplished with a LED and a photodiode placed next to each other. The LED emits infrared radiation (IR) and when and a object blocks the path of radiation some of the radiation is reflected and detected by the photodiode (figure 1) and a current is produced from the photodiode.

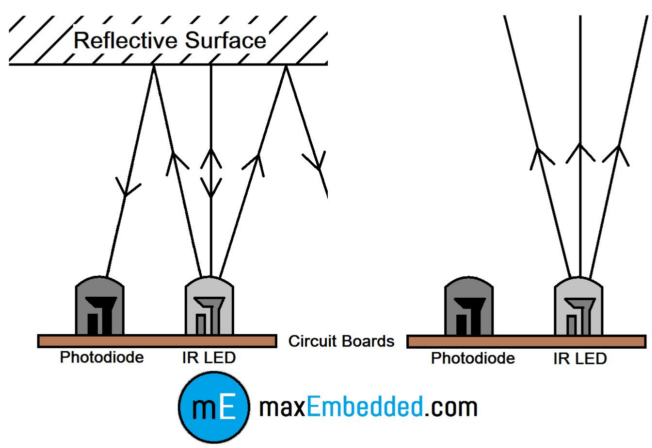


Figure 1. IR Sensors operation

The IR sensor chosen for this project was a Sharp IR Sensor GP2Y0A21YK0F that outputs analog voltage corresponding to the proximity of the object. The sensor had a minimum range of 4” (~10 cm) and a maximum range of 30” (~80 cm) and had a voltage output range from about 0.5 Volts when no object was present and peaking to about 3.2 Volts (figure 2).

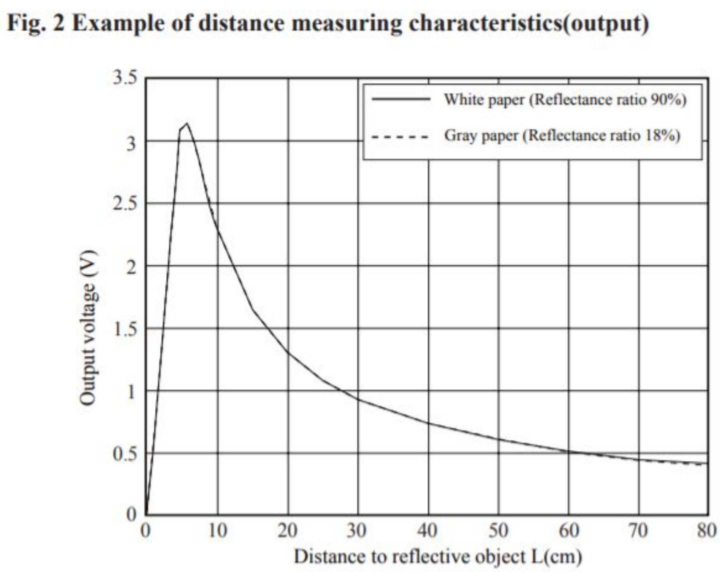


Figure 2. Output characteristics of Sharp IR sensor

The idea for this project came from the Professor Gim Hom during lecture when he talked about having a light in his closet turn on when he opened the door and turn off shortly afterwards.

1.1 Goals

The goals for this project were discussed with 6.101 staff and broken down into three sections. The commitment is defined as the minimum to achieve with the project and thus displaying an adequate understanding of analog electronics. The goal was defined as a fully functioning project displaying a superior understanding of circuits and implementing complex design. And lastly the stretch goal is defined as a top notch project that really stands out with complexity, innovation, and risk.

Commitment:

- Light up a LED with IR sensor
- Have the LED stay on for only fixed amount of time once triggered with sensor

Goal:

- Light up a light bulb with the IR sensor
- Connect light bulb to AC grid (wall socket) with opto-isolator and triac
- Once triggered, have the light bulb turn off after some delay

Stretch Goal:

- Have a Pulse Width Modulated (PWM) signal control the brightness of LED based on distance
- Have delay timer start once IR sensor no longer detects anything

1.2 Overview

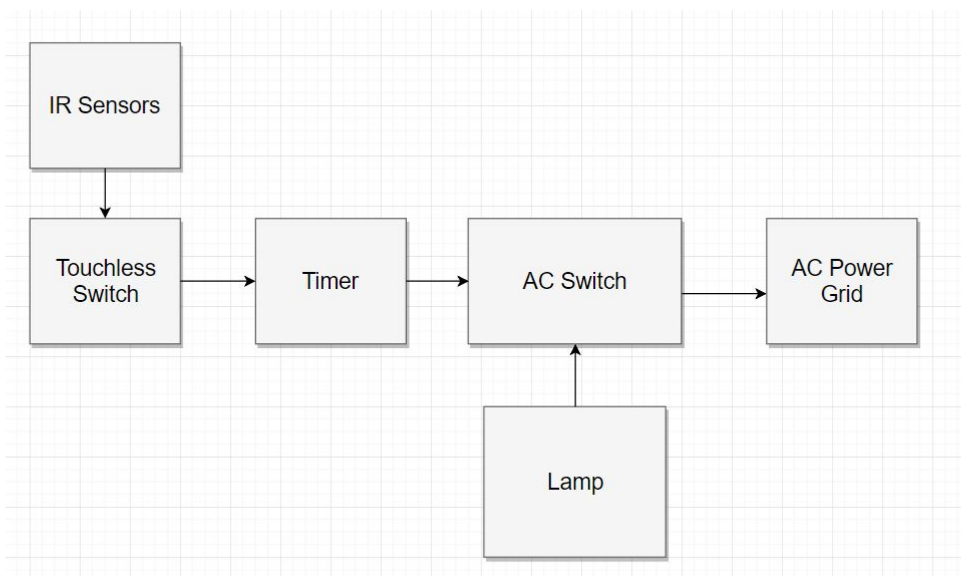


Figure 3. High Level Block Diagram of Project

The overall project can be divided into three main modules (figure 3): Touchless switch, Timer, and AC switch.

In the touchless switch module, the IR sensor outputs roughly 0.5 volts when no object in placed in front of the sensor and therefore could not be used directly to trigger the

555 timer or any other “switch” in the circuit. So instead the voltage output from the sensor is compared to a reference voltage and used to output +15V and -15V. This module also has memory sub module that stores the last voltage outputted from the sensor that is not equal to 0.5 Volts. This memory sub module is using as a reference voltage to create a Pulse Width Modulated signal used to control the brightness of the output led in the AC switch module.

The timer module is a 555 timer IC operating in the monostable mode and uses the -15V trigger from the touchless switch to start its cycle aka timer. In the monostable mode the 555 timer generates a one time pulse that has the pulse width equal to 1.1*R*C where R is the resistor used in the charge path of the capacitor. During this time the 555 timer output Vcc or in this case since its connected to 15V it outputs 15V during the pulse width. This pulse width of 1.1*R*C seconds is used to supply the power to the AC switch. The timer module also has a reset that uses the + 15V from the touchless switch to reset the time of the 555.

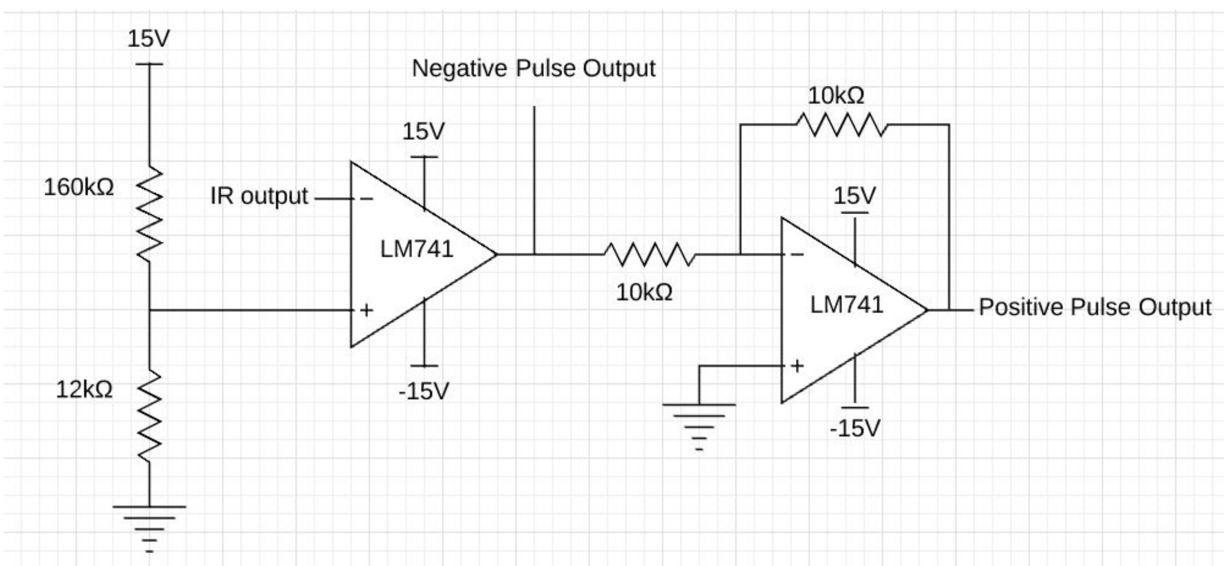
The AC switch module uses an opto-isolator and a triac to turn on the light bulb. The opto-isolator along with the triac acts as a switch that separates the low voltage side and the high voltage side from the AC grid. Essentially inside of the opto-isolator is a LED and a phototransistor. The LED is hooked up to the low voltage side and when it emits radiation that turns on the phototransistor which is hooked up via a triac to the AC grid or high voltage side. In short, when the LED is on the light bulb is also on. Since it is not safe to work straight from the AC grid, for this project the setup was wired with an external LED on the low voltage side and the light bulb was left disconnected. The idea behind this is that it would allow for a safe environment and that if the LED was on, that was a direct indicator that the light bulb would be on. This AC switch was first verified with Professor Gim Hom with the light bulb attached and plugged into a 120VAC wall socket that it indeed was on when the LED was on before being disconnected.

2 Design/Implementation

2.1 Touchless Switch

The touchless switch module consisted of making two short pulses, one negative and one positive. As mentioned above, the IR sensor outputs roughly 0.5 volts when no object in placed in front of the sensor. In order to not have false positive with triggering the light on, we send the output of the IR sensor to a comparator where the reference voltage is 1 volt. The reference voltage was chosen at 1 volt because the data sheet of the sensor indicates that would correspond to a distance of 12" and thus meaning that you need to be within 1 foot of the sensor in order to turn on the light. This module is also responsible for controlling the brightness for the LED.

2.1.1 Positive and negative Pulse generator

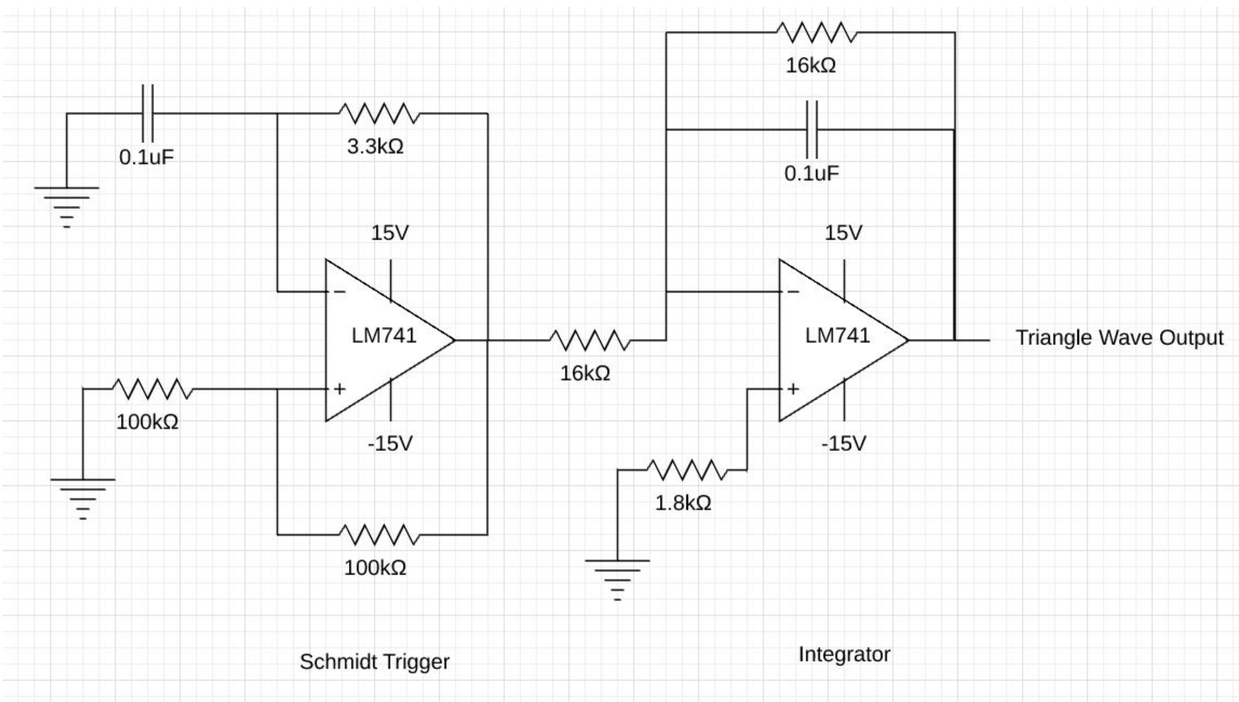


In the negative pulse generator, the circuit uses a resistor divider to make the voltage at the positive terminal $\frac{12k}{12k+160k} * 15V \approx 1.04\ V$. The positive pulse is created from the output of the negative pulse generator by using it as input to an inverting amplifier with a gain of $-\frac{R_f}{R_{in}} = -1$.

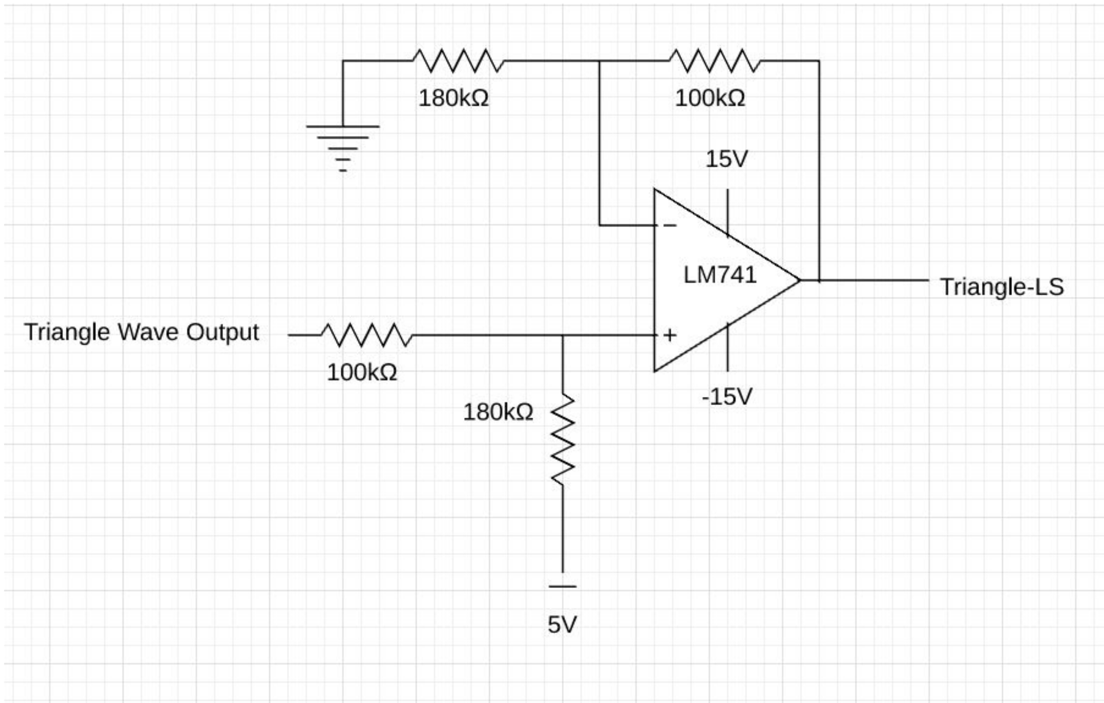
2.1.2 Brightness Controller

To control the brightness of the output LED, the circuit used a PWM signal generated by comparing a level shifted triangle wave to the last stored voltage corresponding the sensors last distance measured. Or in other words, depending on how closer you are to the sensor determines the duty cycle of the PWM signal which correlates to how bright the output LED will be.

2.1.2.1 Triangle Wave Generator & Level Shifter

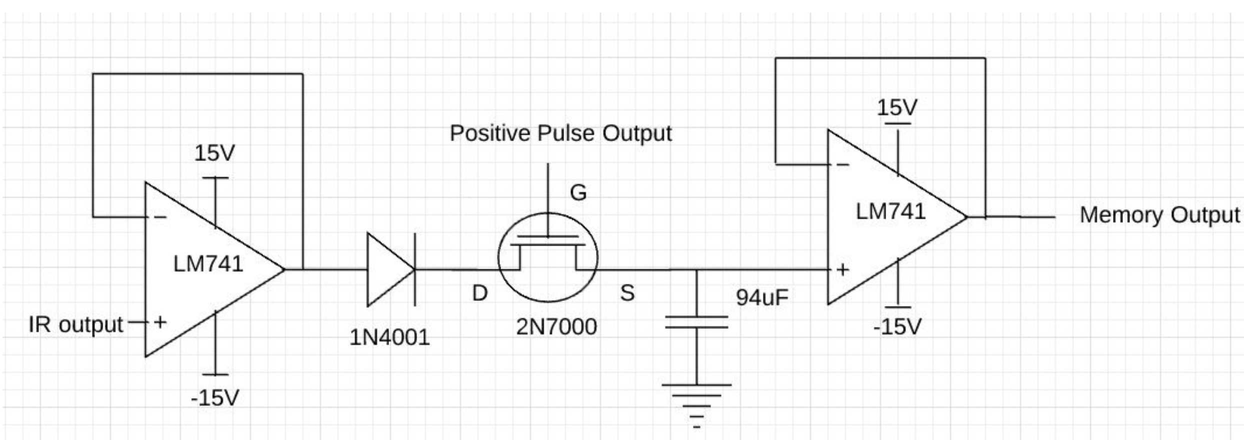


The triangle wave is generated by using a schmitt trigger oscillator that has an output of a square wave of about 1 kHz and sending this output through an integrator. Once the triangle wave is generated this waveform is shifted so that it lowest point is at 0.5 volts. In the circuit below the resistor of 180k and 100k were chosen to add the correct amount to the incoming triangle wave output to make it lowest point 0.5 volts and also preserving its amplitude. The resistors connected to the inverting input of the op amp provide the gain to restore the incoming triangle waves amplitude. For this circuit the amplitude of the triangle wave was about 2.5 Volts and therefore once it was level shifted we have a signal that was a triangle wave the was bounded by 0.5 volts and 3 volts. The reason behind choosing these lower and upper bounds was due to the fact that



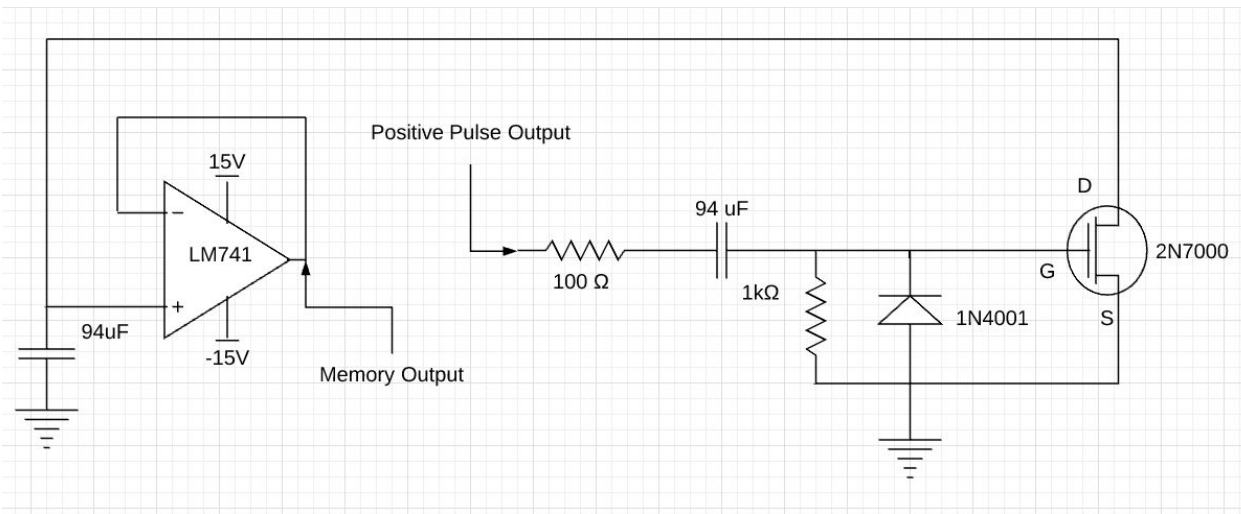
the IR sensor max output is roughly 3.2 volts and the lowest input is roughly 0.5 volts.

2.1.2.2 Sample and Hold



The purpose of this circuit is to store a voltage on the capacitor that correlates to the last distance the sensor detected. The mosfet is present to close the circuit once we have a value stored. The value will store on the capacitor ideally forever since no current flows through the op-amp and when the mosfet when it is closed. However due to leakage current through the capacitor the voltage does decay over time. Within a minute the voltage remains pretty steady. The diode is present so that we don't set the voltage to a lower voltage i.e. the 0.5 voltage after the object is moved away from the sensor.

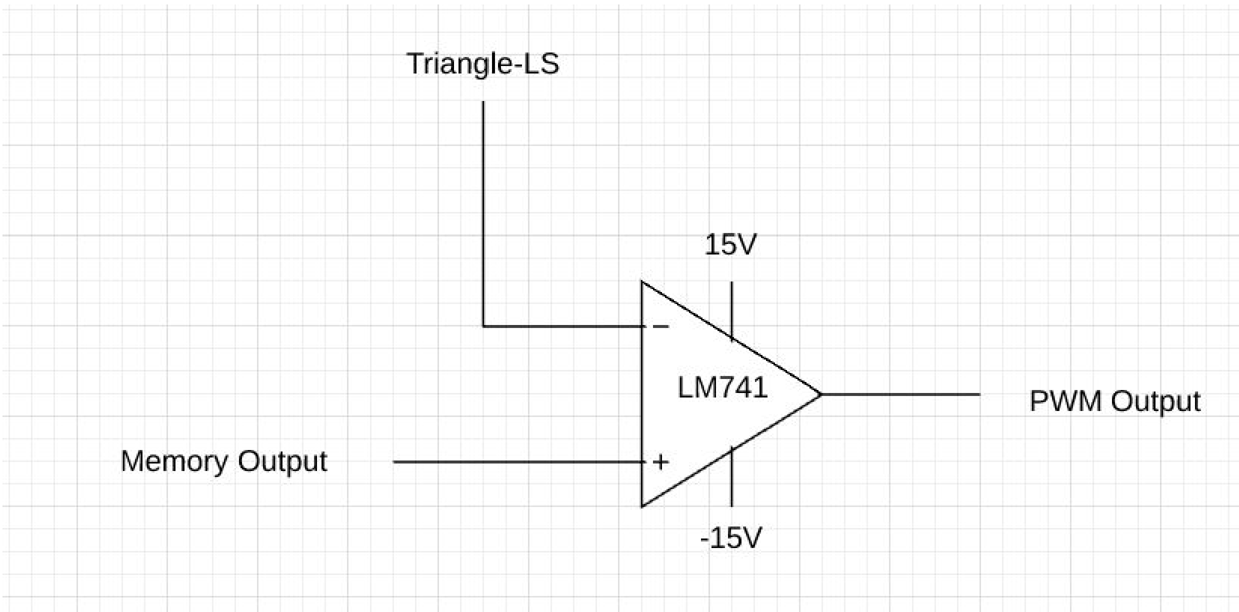
2.1.2.2.1 Positive Edge Detector



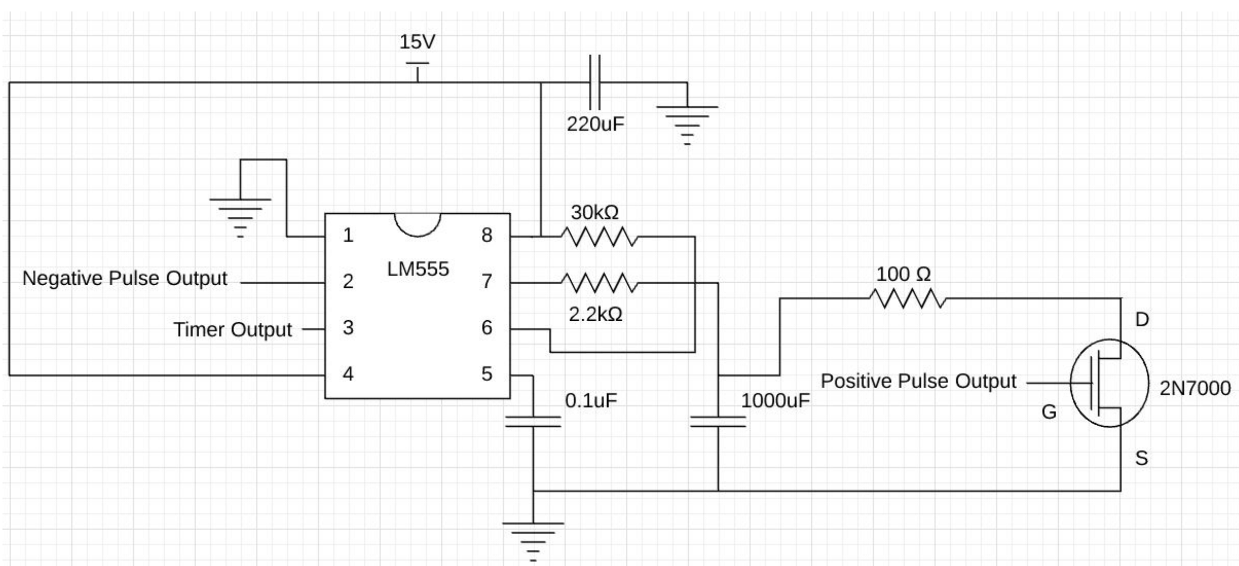
The purpose of this circuit is to deal with the diode in the sample and hold circuit. With the diode present you are not able to set the storage voltage to a lesser value once the capacitor has a voltage on it. So to deal with deal, this detector produces a high impulse like signal when it detects a transistor for low to high from its input, which causes the mosfet to conduct and short the memory capacitor. Since the voltage on the capacitor will never be more than 3 V the internal resistance of the mosfet is enough to ensure the mosfet will not burn out.

2.1.2.3 PWM Generator

This circuit is nothing more than a comparator that used the stored memory output voltage and compares it to the level shifted triangle wave to create a square with a duty cycle dependent upon the memory voltage. The higher the memory voltage the high the duty cycle and thus brighter the output LED will be. The frequency of the PWM output will also by 1 kHz since the level shifted triangle wave is the input. The frequency of 1 kHz was chosen since the eye would not detect the flicker in the LED at that frequency.



2.2 Timer

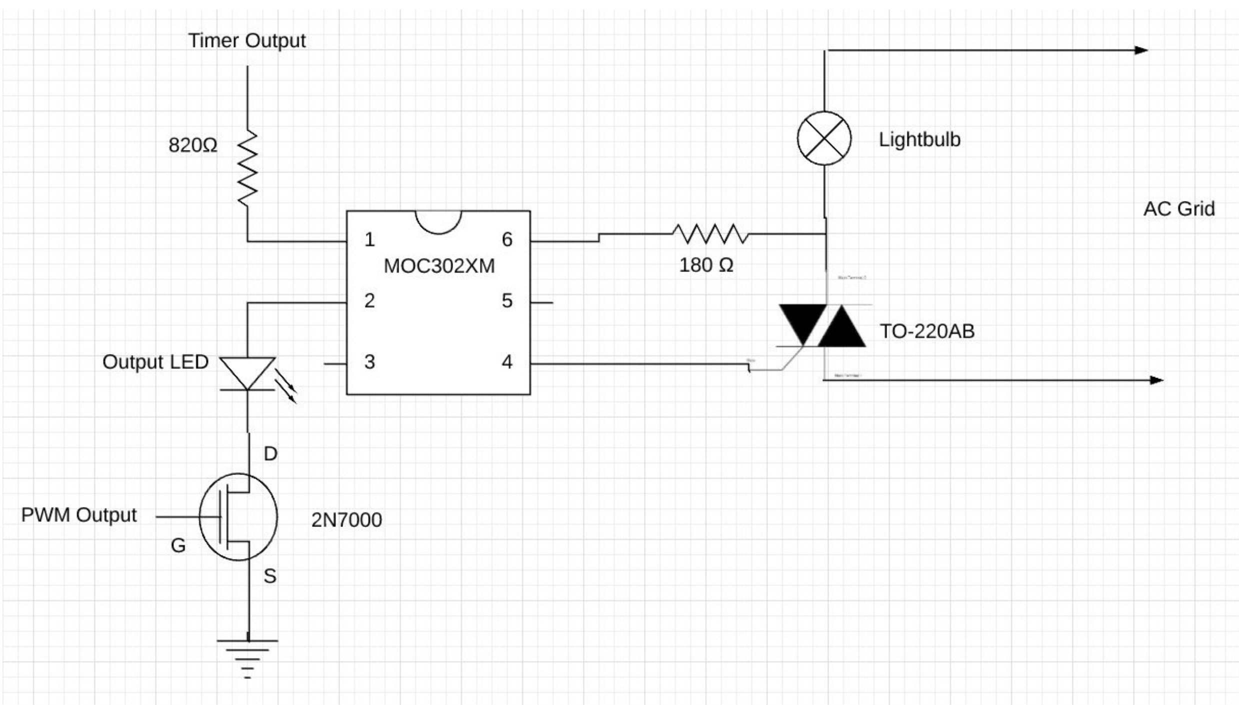


The 555 timer is being operated in the one-shot/monostable mode. What this means is that once the trigger (pin 2) of the timer detects a low voltage the capacitor at the control (pin 6) will begin to charge to V_cc. During this charging period the Timer Output will be 15V (high) and will remain high until the capacitor charges to 10 Volts. The resulting output signal will be a pulse that has a width equal to 1.1*R*C, where R and C refer to the charging path of the capacitor. In this circuit a R = 30k and C = 1000 uF which gives the circuit a pulse width of approximately 30 seconds. This means that are Timer Output will supply 15 V for only 30 seconds and the circuit uses this pulse to trigger the AC switch on and thus turn on the light bulb.

2.2.1 Timer Reset

Since the 555 timer is non-retriggerable once its cycle starts, a separate discharge path had to be implemented to reset the timer if you set off the sensor again or if the object in front of the sensor never leaves. With the idea being that the output of the 555 timer stops being high once the capacitor charges to ⅔ of Vcc and we will short out the capacitor every time an object is within one foot of the sensor. For the switch the circuit uses a mosfet to short out the capacitor. The 100 ohm resistance is there to limit the current through the mosfet but allow a small RC time constant to discharge the capacitor rapidly.

2.3 AC Switch



This circuit's main purpose is to interface the light bulb to the wall socket or AC grid safely and provide a means to turn the light on and off despite it always being plugged into the wall. The mosfet is present to control to current through the output LED by switching on and off based on the duty cycle from the PWM output. The resistor values were chosen to meet the specs of the data sheet of the MOC302XM (opto-isolator) for maximum current and was chosen because it has a maximum reverse blocking voltage of 400V. As mentioned previously the Timer output will supply 15V for thirty seconds once the sensor no longer detects anything and will reset if the sensor is triggered again by something within a foot of the sensor.

3 Results/Conclusion

The most challenging part of this circuit was the design. Putting the individuals pieces together was not that difficult but coming up with the ways to reset the 555 timer and to trigger the sample and hold circuit took the bulk of the time. Before the diode and positive edge detector where added the memory voltage would always get reset to 0.5 volts once the sensor no longer detected anything.

The overall goal of this project was to provide a light that turns itself on and off without the user having to physically do anything except walk closer or away from the sensor. All of the goals above were meet and thus the overall goal was achieved.