Modular Light Control System

ECE 445 Design Document

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2/27/2019

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1. Introduction

1.1 Objective

Modern home automation has been popular lately thanks to the internet, which wirelessly pulls the strings so we do not have to. People love convenience and simplicity, which the internet provides. However, with convenience comes a cost.

Smart light systems can take time, expertise, and much money to install. Our goal is to design an affordable, modular, wifi-capable sensor system solution in order to automatically control zonal lighting and help lessen power consumption. The system will be easy to install with minimum effort applied and little to no professional help required. It should be able to detect movement and human presence by sensor fusion between a passive infrared (PIR) sensor and an amplified microphone, and to change specified and grouped lights. Sensor fusion will be beneficial in reducing false negatives in a case where the room is occupied and the PIR sensor does not detect movement, the microphone may detect sounds made by the occupants. Having multiple sensors can also eliminate false sensor positives, in cases such as where the HVAC system might trigger the PIR, in order to improve accuracy. One potential reach goal would be having a user interface to easily control sensor and switch groupings and policies and to add new sensors.

1.2 Background

If you've ever been in a room with motion sensing lights, you may be familiar with how frustrating it can be when the lights turn off whilst you're still occupying the room. You have to periodically stand up, move around, possibly even wave your arms, and go back to where you were. What if the room is very large and you want to control a set of lights in a certain portion of the room where the switch is far away? Who would want to move across a large room every twenty to thirty minutes?

Other systems require a hefty initial investment since they require multiple pricey smart switches all around the house, the majority linked together with a required standalone smart hub for control. Each switch can cost upwards of $50 [1], and hub, potentially up to $100 [2]. Outfitting an entire house may run over one thousand dollars! [3] In some switches, they are limited by having the sensor mounted on the switch itself, which can be potentially far from the lights.

Our system will address these issues by being cost effective and not requiring any major rewiring other than replacement of switches. The modularity of the sensors and the ease of mounting (using 3m double sided tape) will allow for the sensors to be at any location. Our system will also be able to group multiple sensor units to one or more switches using an app based user interface. Once setup, the system will work in the background with no required human intervention, unless the user overrides the sensors by a manual toggle on the switch.

1.3 High-Level Requirements

- Modularity to add and adjust the switches and sensors without requiring any professional help or tools
- Zonal Lighting through easy grouping of sensors and switches, allowing you to control multiple switches with a single sensor or vice versa. Grouping can be done via API's
- Run the microcontrollers in the sensors using an interrupt driven approach in order to reduce power consumption

2. Design

2.1 Block Diagram

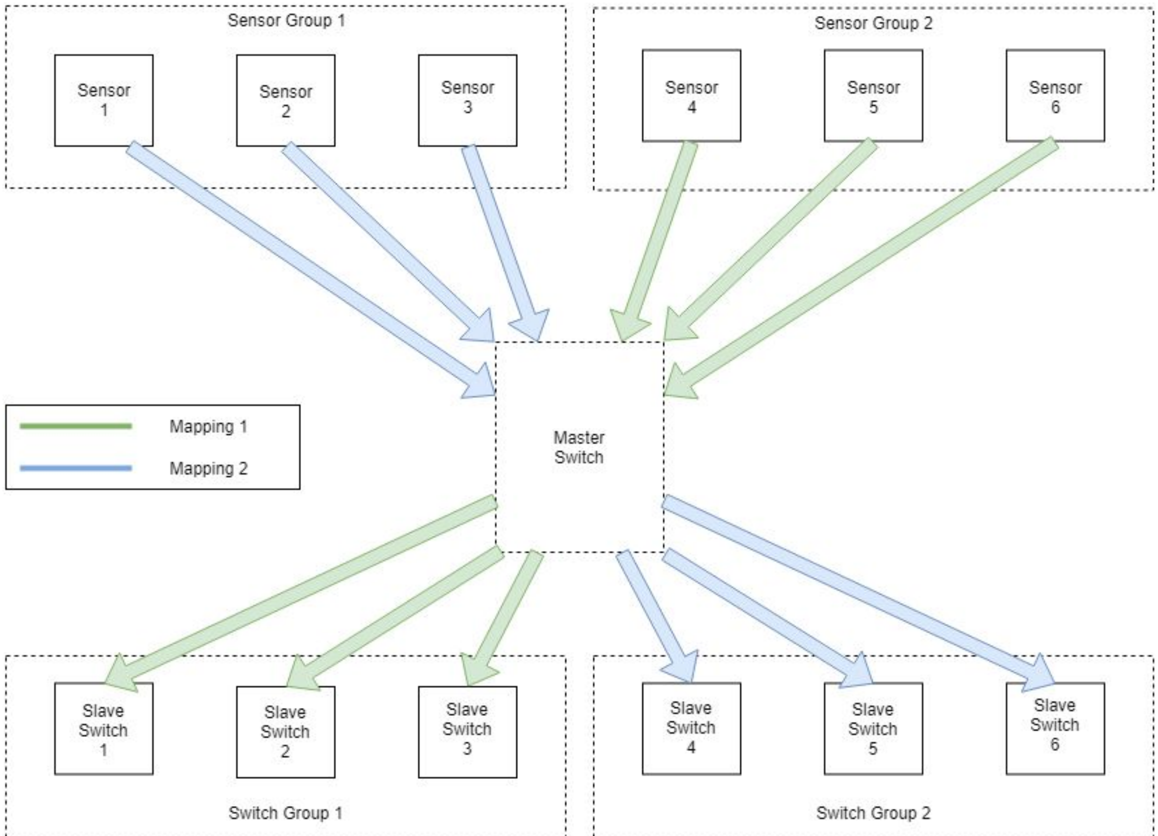

Figure 1: Functional Block Diagram

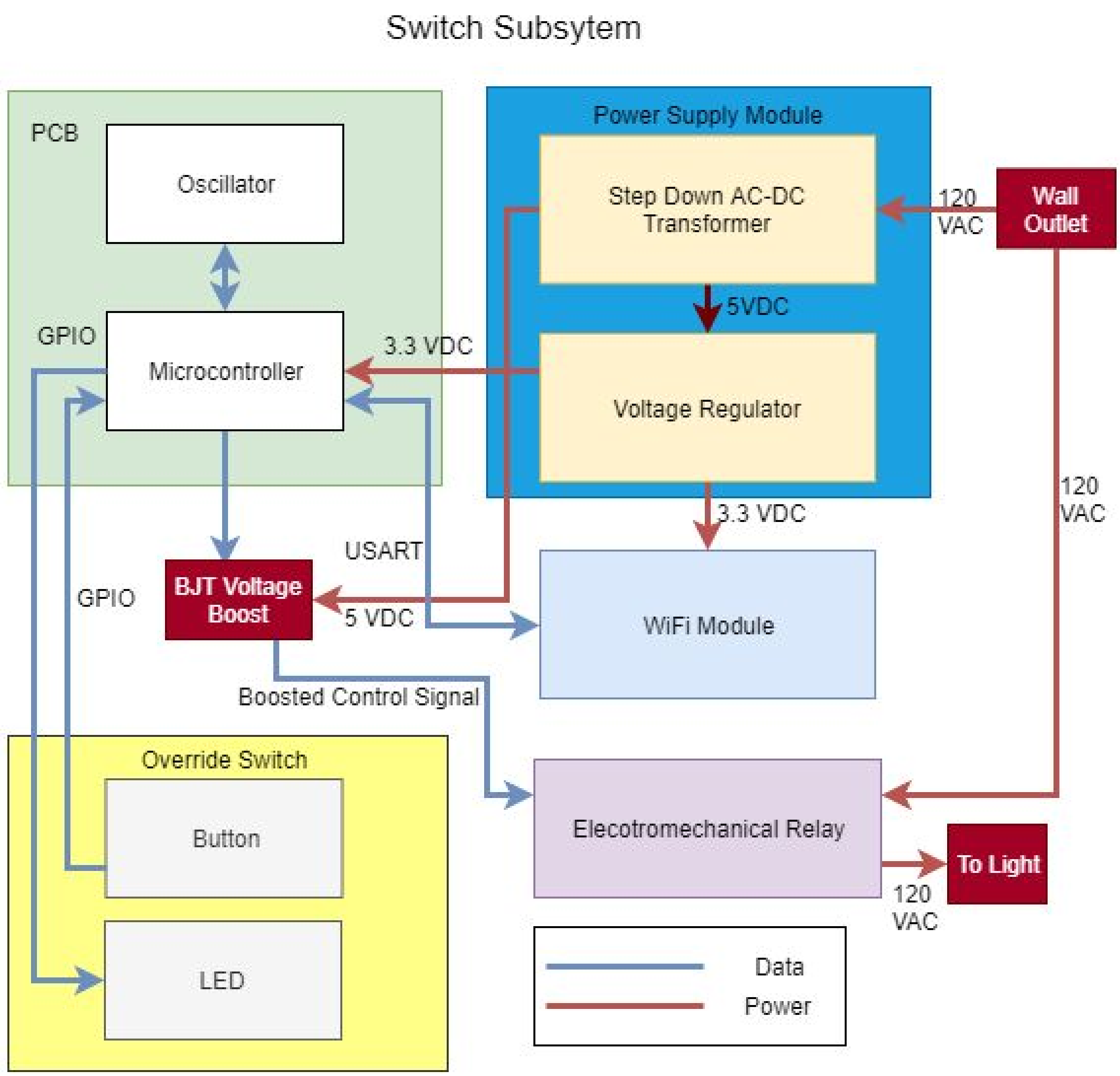

Figure 2: Switch Subsystem

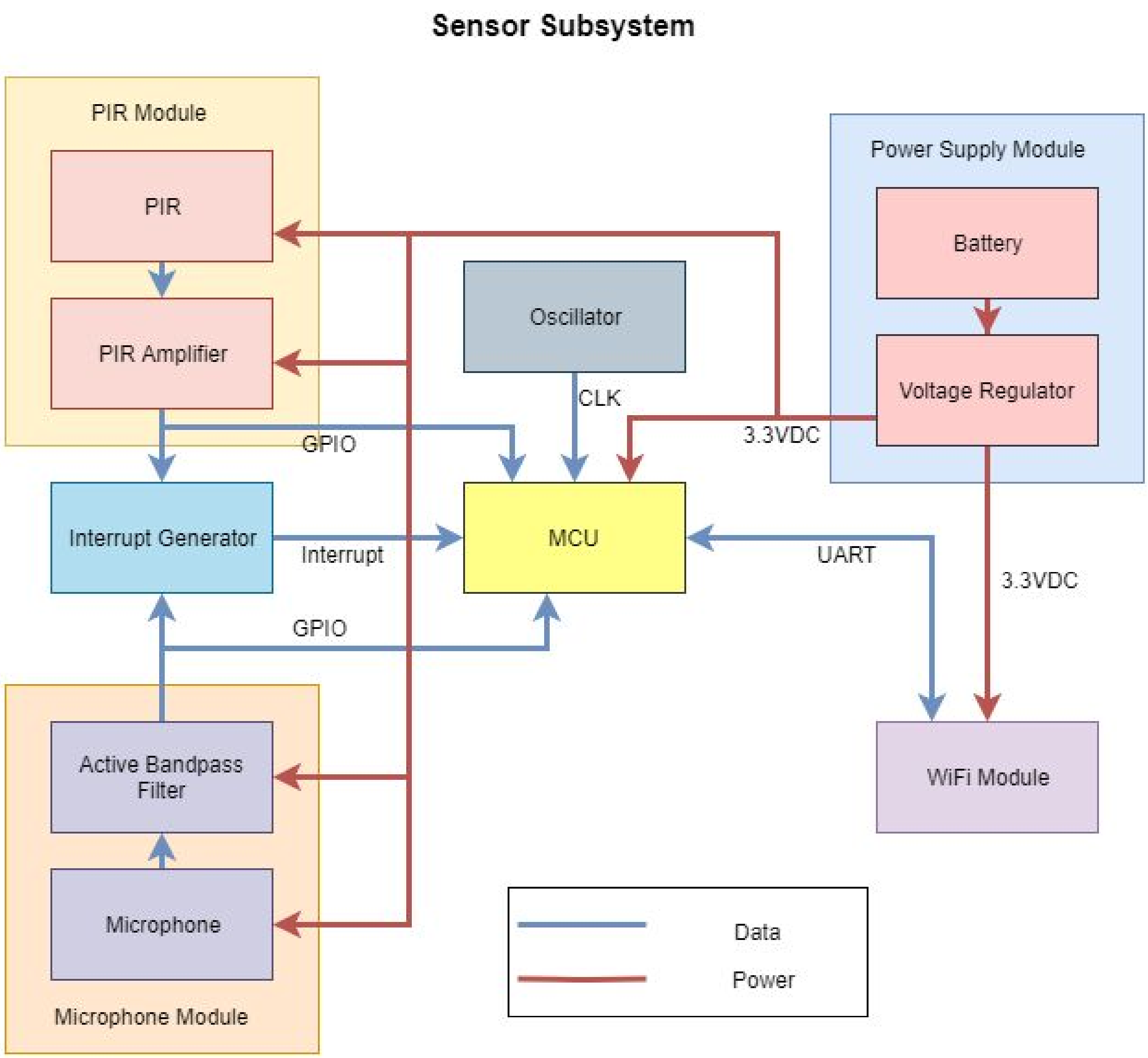

Figure 3: Sensor Subsystem

2.2 Physical Design

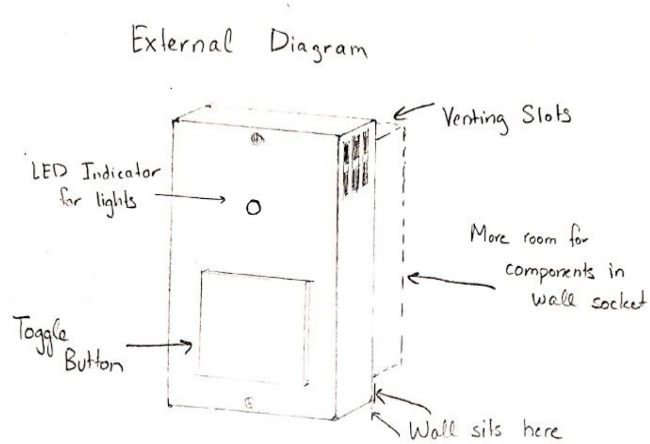

Figure 4: Switch External Diagram

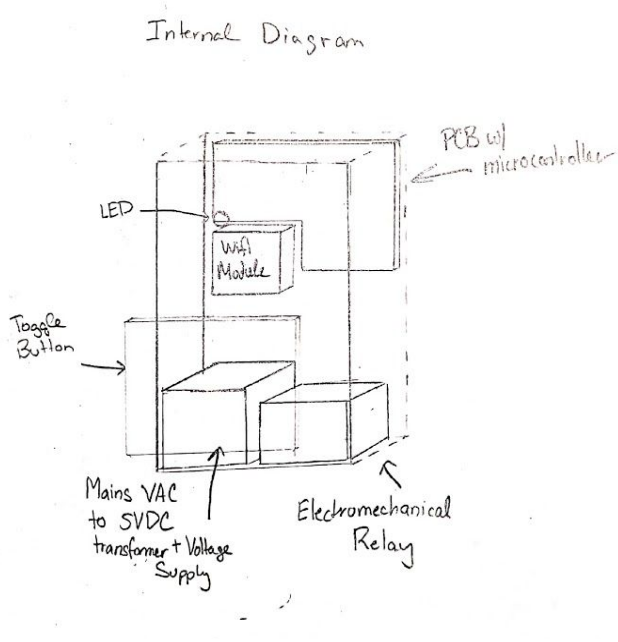

Figure 5: Switch Internal Diagram

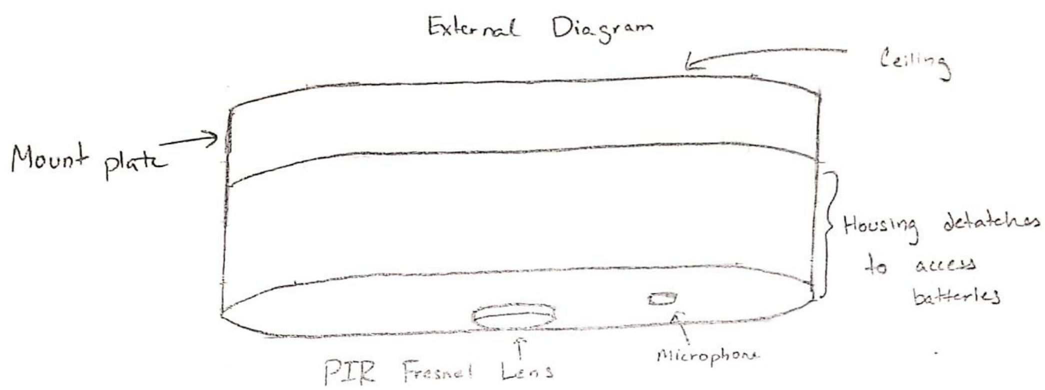

Figure 6: Sensor External Diagram

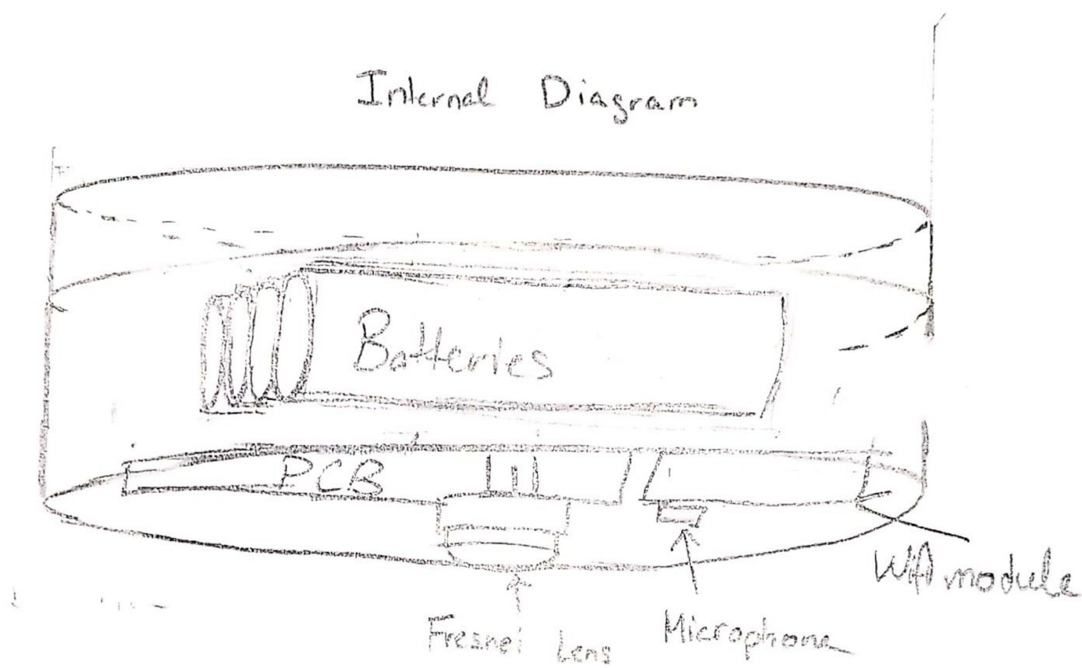

Figure 7: Sensor Internal Diagram

2.3 Block Design

2.3.1 Functional Overview and RV Table

The system has 3 major components:

- Sensors
- Master Switch
- Slave Switches

The sensors are the module responsible for human detection by using a PIR sensor and an acoustic microphone. They will be powered off batteries and will be easy to move, replace and add to an existing system.

The master switch will be the brains of the system and will contain the policies and groupings of the sensors and switches, thus allowing for control over zonal lighting. All sensors and slave switches will be directly communicating with only the master switch, which will be controlling the state of the lights via the slave switches. These groupings and policies will be user controllable via http requests sent to the master switch and as a reach goal we will try to build a an android application to handle the configurations and policies.

The slave switch will control the EMR and will perform the actions it receives from the master switch, such as turning off or turning on the lights. The slave switch will also offer the user the option to control the lights manually via a button installed on the faceplate of the switch module.

All communications between subsystems will be via WiFi. The range of the system will be constrained only by the range of the wifi network being used.

2.3.1.1 Sensor Subsystem

Active Bandpass Filter:

The microphone outputs an RMS voltage of 0.398 V [4] and will thus need to be amplified before feeding into the Microcontroller. As the microphone output will be used to detect human voice, we will pass it through an appropriate band pass filter because the microphone can detect frequencies ranging up to 20kHz [12]. The amplifier output must reach the peak to peak voltage of Vcc for maximum granularity in audio sensing. The filter must cut off at 4 kHz, which is the intelligibility frequency range of human voice.

Requirements	**Verification**
1. Must filter the input signal with a -3dB bandwidth of 4kHz ± 100 Hz (the frequency range of human voice intelligibility) 2. Amplifier must amplify desired signals by proper gain of 2.9315 ± 0.1	1. A voltage signal generated by a signal generator at 1.126V peak-to-peak (max output of the microphone) at the filter input must output 0.8 V ± 0.1 V at 4kHz 2. A voltage signal generated by a signal generator at 1.126V peak-to-peak with a frequency of 1kHz at the filter input must output 3.3V ± 0.113V as recorded by an oscilloscope

PIR:

We will use a IRA-S210ST01 Passive InfraRed (PIR) sensor to detect human movement. This sensor has a default broad viewing angle, which we will be correcting using a fresnel lens compatible with the PIR.

Requirements	**Verification**
1. Ensure the field of view is no more than a 9ft radius when elevated 10ft and with the IML-0688 fresnel lens attached	1. a) Hook up the 10ft high PIR + fresnel lens to a 3.3V voltage supply, and an oscilloscope to the outputs b) Determine and record the field of view using the oscilloscope

PIR Amp/Filter:

We need an amplifier and a filter attached to the PIR outputs so that we have a clean and isolated signal that is of the proper frequencies for human objects passing within the FOV. We will be using a Rohm BD9251FV amplifier, which is designed to be used with a PIR sensor. As the output of the PIR sensor is in mV, this process is essential for the functioning of the PIR module.

Requirements	**Verification**
1. Test the PIR Amp to ensure that the output voltage remains below 3.3±.1VDC	1. a) Hook up to a voltage supply, and the output to a DMM b) Test for 60 seconds to ensure voltage safe at 3.3±.1VDC to not blow the Atmega's input pins
2. The amp/filter chip must output a high voltage pulse at minimum Vcc-0.6V and maximum Vcc+0.1V for a person walking past the calculated distance range as necessary.	1. Position the PIR connected to the amp/filter chip and calculate the viewing range at a specific distance given the viewing angle. 2. Connect the PIR amp/filter output to an oscilloscope 3. Walk past the center of the viewing direction at the distance calculated earlier 4. Observe a logical pulse in the oscilloscope at at least Vcc-0.6V

Mic:

In order to reduce false positives and help determine human presence, an ICS-40180 SMD microphone will be used to capture audio. It is powered off the 3.3±4%VDC provided by the voltage regulator [12].

Requirements	**Verification**
1. The mic needs to be able to pick up frequencies ranging from 80Hz to 4kHz	1. a) Attach the ISC-40180 to a 3.3V voltage supply, and an oscilloscope to the output b) Test the frequency range of the microphone using natural and man-made noises

Sensor MCU:

The sensor microcontroller (MCU) will be the center for fine tuned evaluation of our detection model. It will receive analog inputs from the PIR and microphone modules and will convert them from analog to digital using the onboard A/D converters. The MCU will be responsible for communicating with the master switch as per need through the ESP8266 WiFi module. It will communicate with the WiFi module over UART.

Requirements	**Verification**
1. Able to communicate with the WiFi module over UART at a minimum baud rate of 9600 to communicate with external clients/ web servers	1. a. Establish UART connection at 9600 baud with WiFi module b. Send 100 packets to external web server c. Verify packets were received at external web server with a max error rate of 2.5%
2. Able to process incoming information from sensors and send trigger messages to slave switches with a maximum latency of 1 second	2. a. Connect microcontroller to PC via USB and development board b. Upload a Log Print Program (Provided by us) to the microcontroller which will then print out the log on the PC monitor which can be used to verify the latency

WiFi Module:

The WiFi module will be used to facilitate communication between the sensors and the switches. The part we are using for this is ESP8266. This module provides us with the necessary TCP/IP stack. It is low powered and allows for UART communication with the microcontroller along with the functionality to load our own firmware on it.

Requirements	**Verification**
1. Able to establish a stable connection with a pre defined external web server.	1. a. Establish a TCP connection between server on ESP8266 and web server on external computer. b. Send 100 packets/units of data from external computer to ESP8266 and record replies using the ping command c. Verify packet loss by computing total number of replies with a maximum packet loss of 2.5%

Interrupt driver:

In order to send an interrupt to the proper digital pin without wasting power through any ADCs on the atmega in its deep sleep state, we must use an analog interrupt system. We use the PIR and microphone module outputs to drive transistors that will pull a digital pin on the atmega to a high enough voltage to trigger an interrupt. The circuit also has a capacitance and a resistance in order to maintain that voltage for a proper amount of time and discharge as necessary.

Requirements	**Verification**
1. The interrupt driver circuit must pull the digital pin input to a minimum voltage of 2.0V given a signal of 1V ± 0.1V and keep the voltage at above 2.0V for a minimum of one clock cycle.	1. Connect the sensor module outputs to the gates of the MOSFETs 2. Trigger each sensor by either making noise or motion to trigger the corresponding sensor 3. With the digital pin output connected to an oscilloscope, observe the transient effect of the output voltage. Record the data onto an external memory. 4. Do an experiment once for each sensor. Record the data and observe that the output voltage stays above 2.0V for at least 1.001us for each sensor triggering the output.

Voltage Regulator:

Because the sensor will be wireless, we plan on using 4 1.5V AA lithium batteries for power and a total voltage of 6V. To not fry any components and to increase longevity, we will use a commercial SOT-233 package LD1117S33CTR voltage regulator as opposed to creating our own regulation circuit, since the manufactured ones have tighter specs and will integrate into the PCB splendidly. The regulator can operate with a input voltage of 4.75 to 10V and is able to output a very steady 3.3 ± 4% VDC at a maximum of 800mA [11], enough to satisfy the MCU and wifi module.

Requirement	**Verification**
1. Voltage Regulator will maintain a 3.3 ± .1VDC to power the MCU	1. a. Wire input to 9 ± .1 VDC power supply, and digital oscilloscope to output b. Measure for 1 minute and plot voltage to ensure durability, proper voltage and levels of noise c. Sweep voltage from 9V to 3V to ensure 3.3 ± .1V to mimic battery degradation
2. Voltage regulator will provide enough current to power the Wifi Module	2. a. Wire input to 5 ± .5VDC power supply, and digital oscilloscope to output voltage b. Use multimeter to check output current exceeds 225 ± 25mA for powering Wifi Module.

2.3.1.2 Switch subsystem

Switch MCU:

Master- The master MCU will be continuously communicating with the slave switches and sensors over TCP/HTTPS networks using the wifi module. The MCU will also have the system profiles stored for the sensor and switch groupings according to which it will trigger the appropriate switches based on the sensor outputs.

Requirements	**Verification**
1. Able to communicate with the WiFi module over UART at a minimum baud rate of 9600 to communicate with external clients/ web servers	1. a. Establish UART connection with WiFi module at 9600 baud b. Send 100 packets to external web server c. Verify packets were received at external web server with a max error rate of 2.5%
2. Able to process incoming information from sensors and send trigger messages to slave switches with a maximum latency of 1 second	2. a. Connect microcontroller to PC via USB and development board b. Upload a Log Print Program (Provided by us) to the microcontroller which will then print out the log on the PC monitor which can be used to verify the latency

Slave- The slave MCU will be continuously communicating with the Master MCU to receive trigger commands to switch the lights On and Off. The MCU will be powering the LED on the override switch, and also outputting a control signal to the electromechanical relay.

Requirements	**Verification**
1. Able to communicate with the WiFi module over UART at a minimum baud rate of 9600 to communicate with external clients/ web servers	1. a. Establish UART connection with WiFi module at 9600 baud b. Send 100 packets to external web server c. Verify packets were received at external web server with a max error rate of 2.5%
2. Able to process incoming information from master switch and trigger lights with a maximum delay of 1 second	2. a. Connect microcontroller to PC via USB and development board b. Upload a Log Print Program (Provided by us) to the microcontroller which will then print out the log on the PC monitor which can be used to verify the latency

WiFi Module:

The WiFi module will be used to facilitate communication between the sensors and the switches. The part we are using for this is ESP8266. This module provides us with the necessary TCP/IP stack. It is a low powered chip and allows for UART communication with the microcontroller along with the functionality to load our own firmware on it.

Requirements	**Verification**
1. Able to establish a stable connection with a pre defined external web server.	1. a. Establish a TCP connection between server on ESP8266 and web server on external computer. b. Send 100 packets/units of data from external computer to ESP8266 and record replies c. Verify packet loss by computing total number of replies with a maximum packet loss of 2.5%

Override Toggle:

A button on the outside of the switch that when triggered, sends a signal to the MCU to override the PIR sensor signal to toggle the lights.

LED:

The LED acts as an indicator of the light's current state, and will mimic the status.

Electromechanical Relay:

An electromechanical relay (EMR) will be used so that a low-voltage control signal can trigger and close a separate high-voltage circuit. The MCU will provide a 3.3V control signal which will be boosted to 5VDC by a BJT, and the lights will run off the 104-127VAC line. Because line voltage is extremely dangerous, we will be using a commercial EMR module. It contains a SRD-05VDC-SL-C 10A 240VAC EMR attached to a breakout board with accompanying protective circuitry; it is designed for safe use of relays. This EMR module can be controlled by a 5VDC signal [10].

AC-DC Power Supply:

The entire switch assembly and its components will ultimately source power from the wall mains line, which can vary from RMS 104-127VAC [8]. The maximum requirement amongst the switch components is 5VDC, so a CUI Inc. PSK-S5B-5-L will be used to step down the mains voltage. It is a single-output AC to DC converter which can take a voltage input ranging from 85VAC to 264VAC, well encapsulating mains standards, and can safely output 5 ± .1 VDC at 1A and 75% efficiency [9], provided a filtering capacitor is tied to ground to limit unwanted high frequencies. It comes in a package of 37x24.5x18mm, enough to fit inside the switch housing, and will feed a voltage regulator before powering the components.

Requirement	**Verification**
1. Is able to achieve 5±.1VDC using 1 and 10uF filtering capacitors since the voltage regulator and EMR require 5VDC input	1. a. Wire input to power supply, and digital oscilloscope to output voltage b. Sweep voltage supply from 104-127VAC and ensure 5VDC output c. Measure for 1 minute and plot voltage to ensure proper and acceptable voltage and levels of noise

Voltage Regulator:

We will use a commercial SOT-233 package LD1117S33CTR voltage regulator to take the 5 ± .1VDC output from the ADC(AC to DC converter) and further throttle it down to power the MCU and the Wifi Module with 3.3VDC. We want a voltage regulator so we can try to further reduce the voltage noise from the ADC and ensure a stable output voltage of 3.3 ± 4% VDC at a maximum of 800mA [11], enough to satisfy the MCU and wifi module.

Requirement	**Verification**
1. Voltage regulator will maintain 3.3 ± .1VDC to power the Wifi Module	1. a. Wire input to 5 ± .5VDC power supply, and digital oscilloscope to output b. Measure for 1 minute and plot voltage to ensure durability, proper voltage and levels of noise
2. Voltage regulator will provide enough current to power the Wifi Module	2. a. Wire input to 5 ± .5VDC power supply, and digital oscilloscope to output voltage b. Use multimeter to check output current exceeds 225 ± 25mA for powering Wifi Module

2.3.2 Circuit Schematics

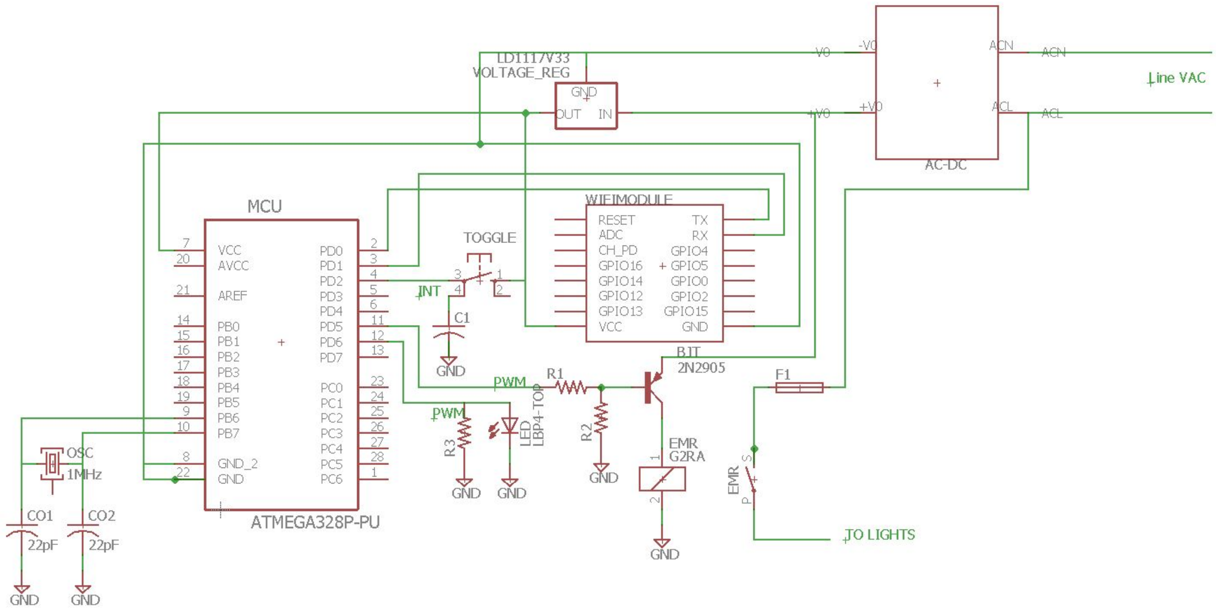

Figure 8 (above): Schematic for Switch Subsystem

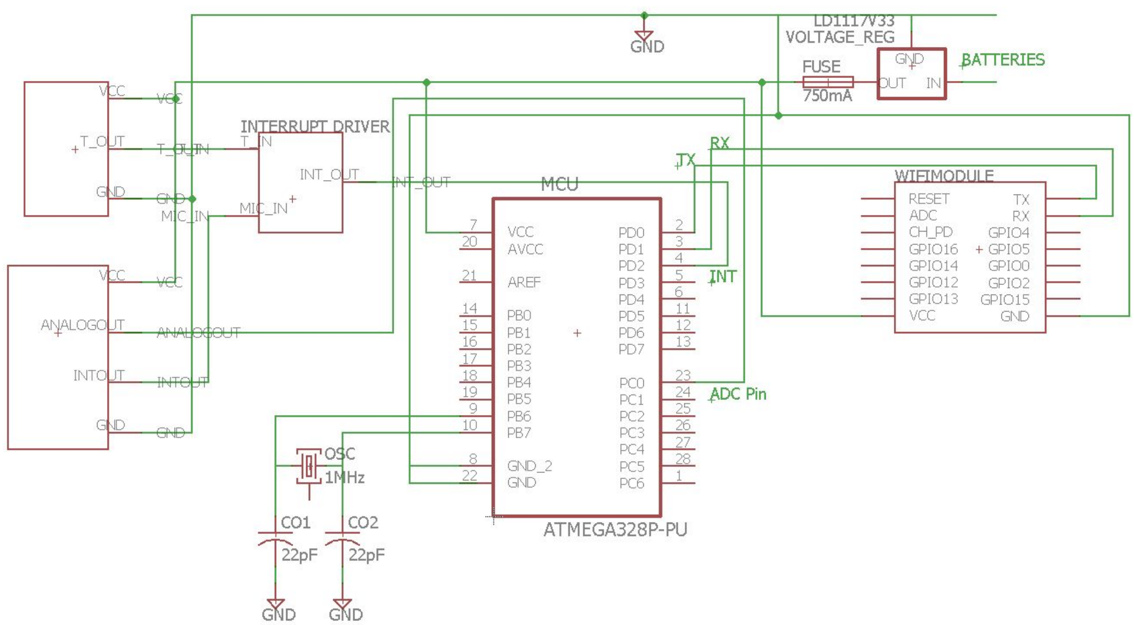

Figure 9: Schematic for Sensor Subsystem

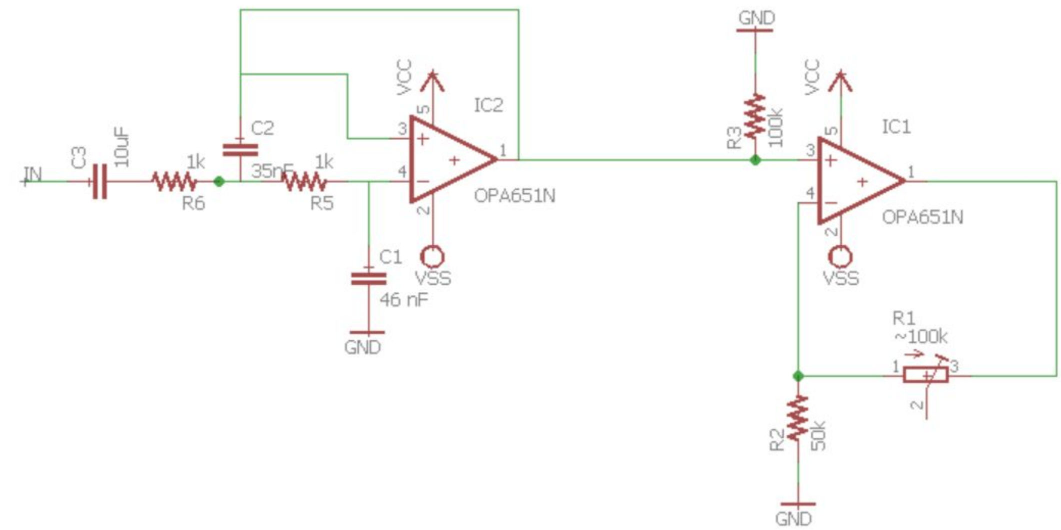

Figure 10: Schematic for audio active band pass filter

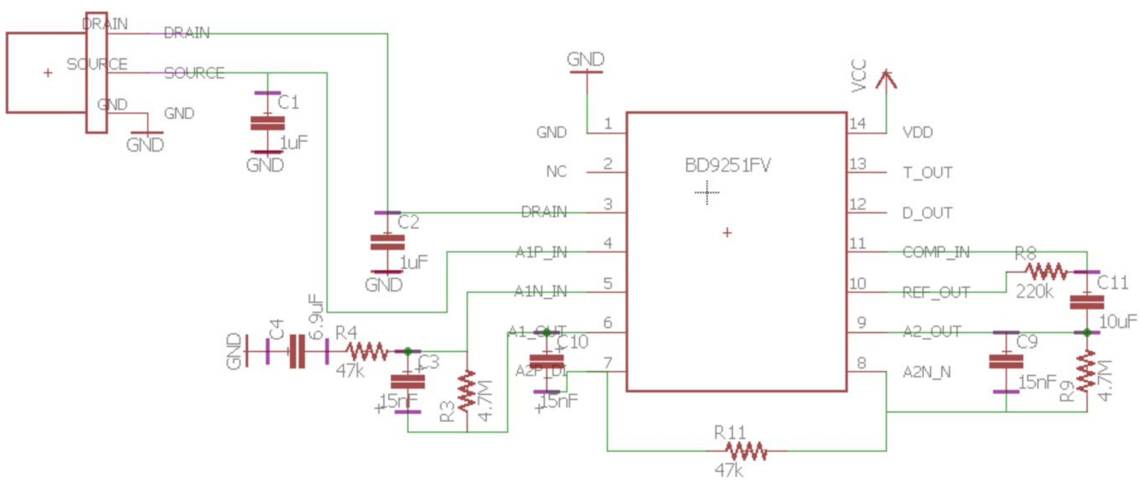

Figure 11: Schematic for PIR module

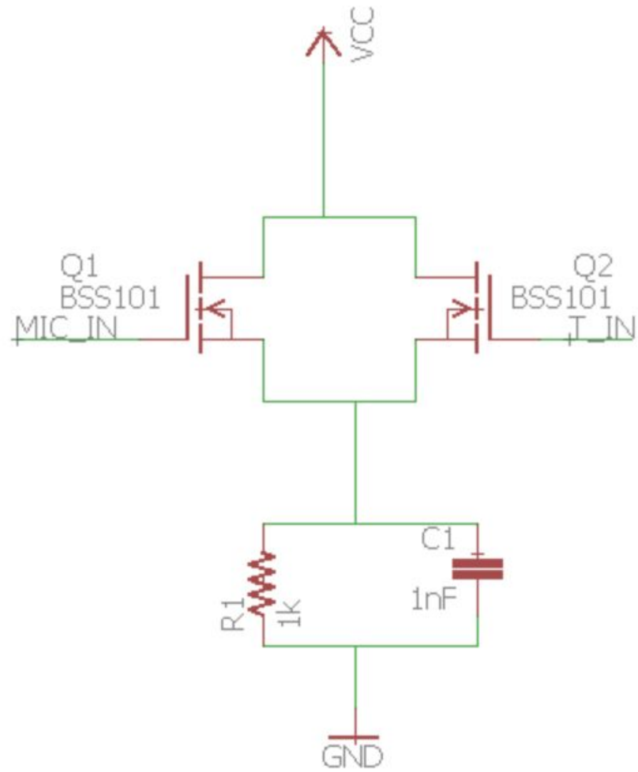

Figure 12: Schematic for interrupt module

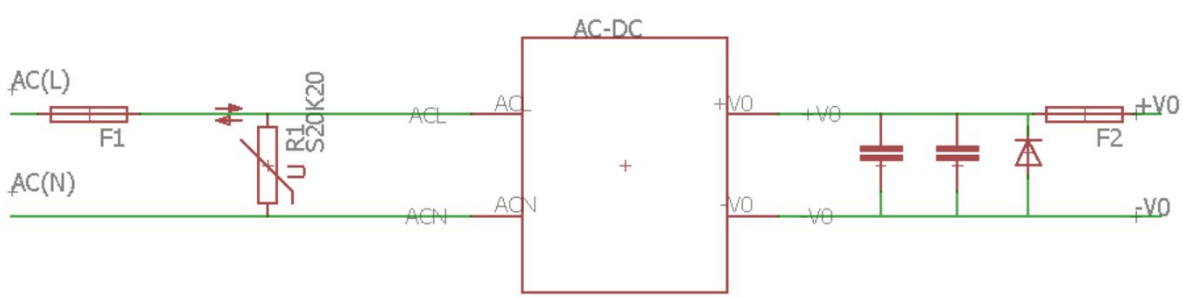

Figure 13: Schematic for the AC-DC peripherals

2.3.5 Plots

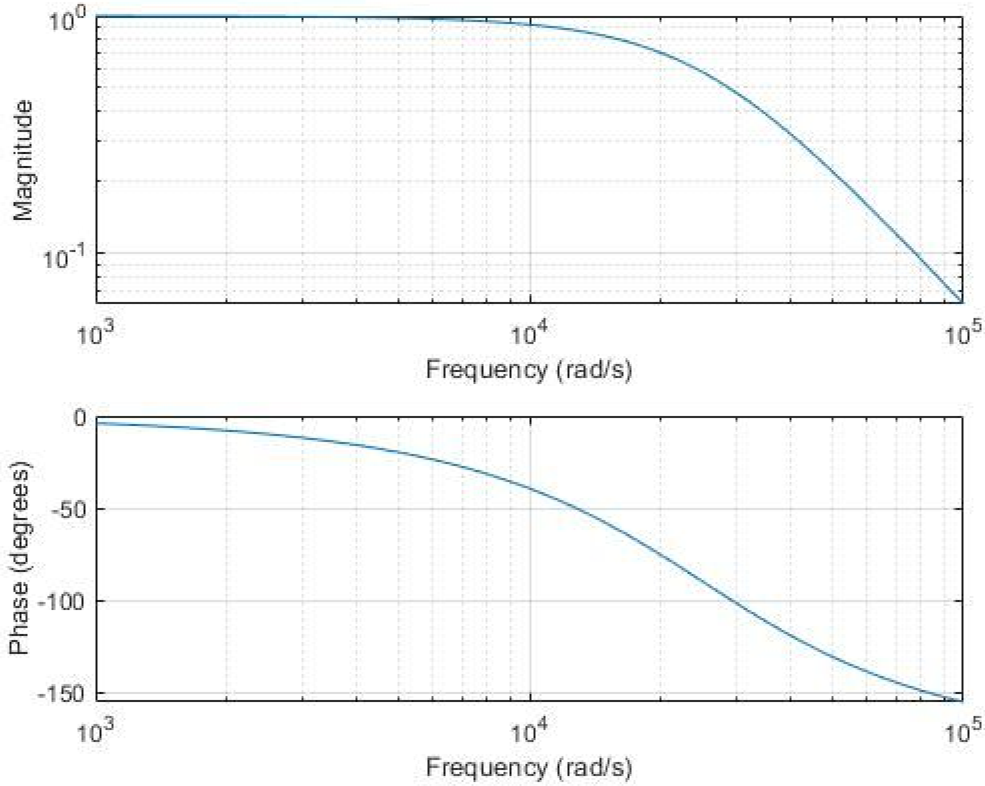

Figure 14: Bode plots for active band pass filter

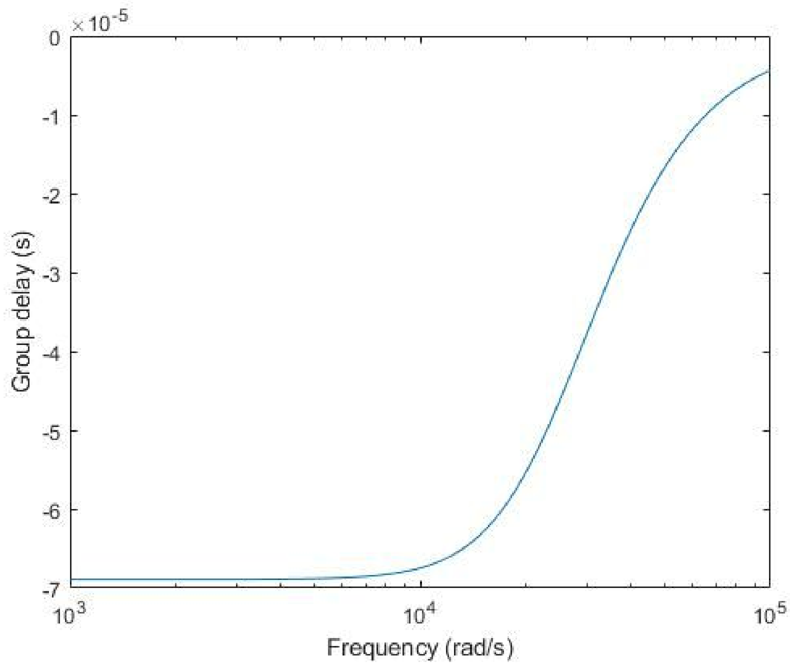

Figure 15: Group delay for active band pass filter

2.3.4 Calculations

2.3.4.1 Amplifier

Our microphone outputs a maximum RMS voltage of 0.398 V [4]. Our voltage into the atmega must have a peak value of $\frac{V_{cc}}{2}$ with a $\frac{V_{cc}}{2}$ in order for the analog pin to have its maximum possible input granularity while still maintaining the tolerances of the input. We calculate these values with a supply voltage of 3.3V. Our gain must be as follows.

$$A_v \equiv \frac{V_{out,peak}}{V_{in,peak}} = \frac{V_{cc}/2}{V_{in,peak}} = \frac{V_{cc}/2}{\sqrt{2}V_{rms}} = \frac{1.65V}{\sqrt{2}*0.398V}$$

$$A_v = 2.9315\ \frac{V}{V}$$

Therefore, our amplifier must have a gain of 2.9315. The feedback amplifier shown in figure 5 has a generalized gain of

$$A_v = 1 + \frac{R_1}{R_2}\ .$$

Therefore, our amplifier must have

$$\frac{R_1}{R_2} = 1.9315\ .$$

We will use an R2 value of 50k and a potentiometer for R1 for the sake of fine tuning.

2.3.4.2 Viewing Angle

To calculate the viewing range of our sensors, we take into account the viewing angle of the sensors and the height of the ceiling.

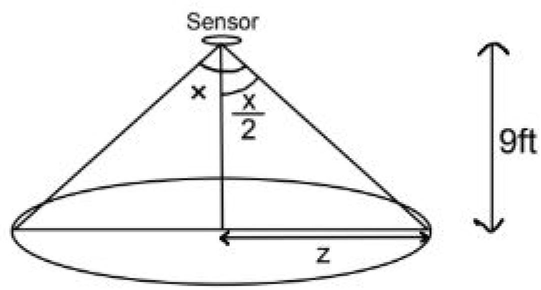

Figure 16: Viewing range diagram

Observing figure 6, x is the total viewing angle of the sensor, z is the radius of the detection zone, and we assume an average ceiling height of 9 feet. Given these values, we can calculate the z value as

$$z = 9 * tan(\frac{x}{2}) .$$

2.3.4.3 Filter

The audio filter is designed as a bessel filter in order to maintain a nearly constant propagation delay across the frequency spectrum within the passband, thus minimizing distortion of the signal. A second order active low-pass filter (which has a roll-off of -40dB per decade in the stopband) has the generalized form shown in figure 17 **[**15]**.**

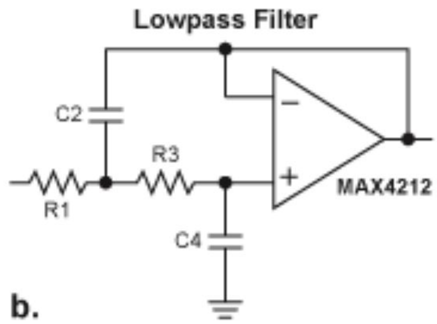

Figure 17: Active lowpass filter

The transfer function for the low-pass filter in figure 17 has a transfer function given by

$$H(s) = \frac{G_1 G_3}{s^2(C_2 C_4) + sC_4(G_1 + G3_3) + G_1 G_3}$$

where G_1 and G_2 are the conductances of R_1 and R_2. We use the Matlab *besself* function to calculate the transfer function coefficients for an analog second order bessel filter with a cutoff frequency of f=4kHz. After scaling the numerator and denominator equally to maintain the TF characteristics while calibrating the coefficients such that they correspond to realistic component values, we equate these coefficients to those of H(s) for the generalized active bessel LPF and find the following circuit parameters.

$$R_1 = R_2 = 1k\Omega$$
$$C_2 = 45.94\ nF$$
$$C_4 = 34.46\ nF$$

The corresponding circuit schematic can be found in figure 8. The bode plots and group delay plot can be found in figures 11 and 12 respectively.

2.3.5 Software

2.3.5.1 Software Flowcharts

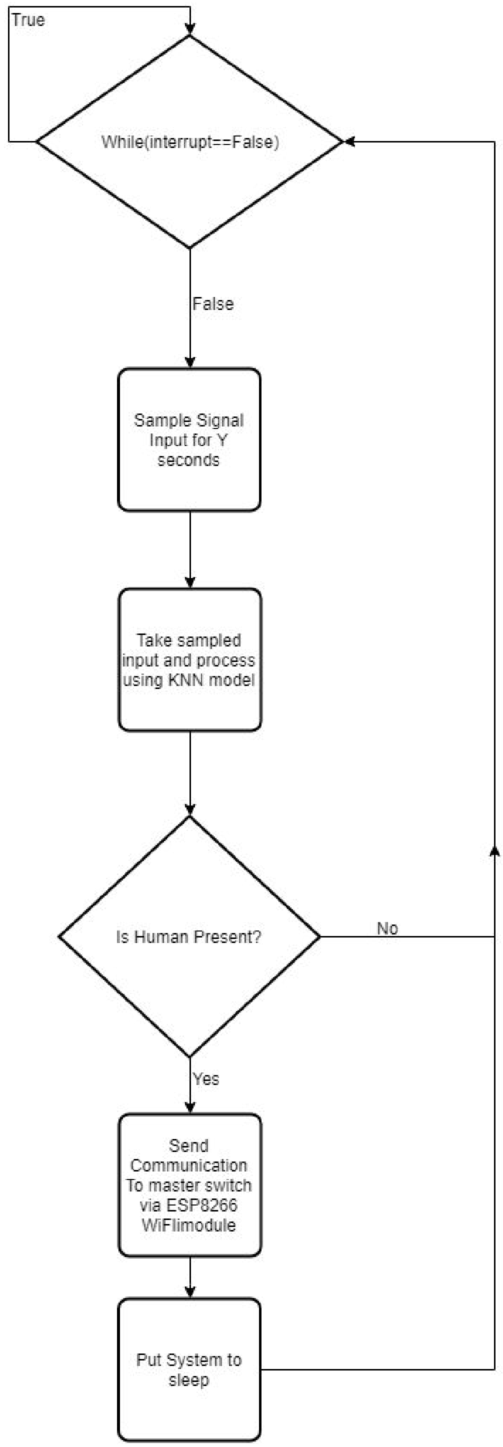

Figure 18: Sensor flowchart

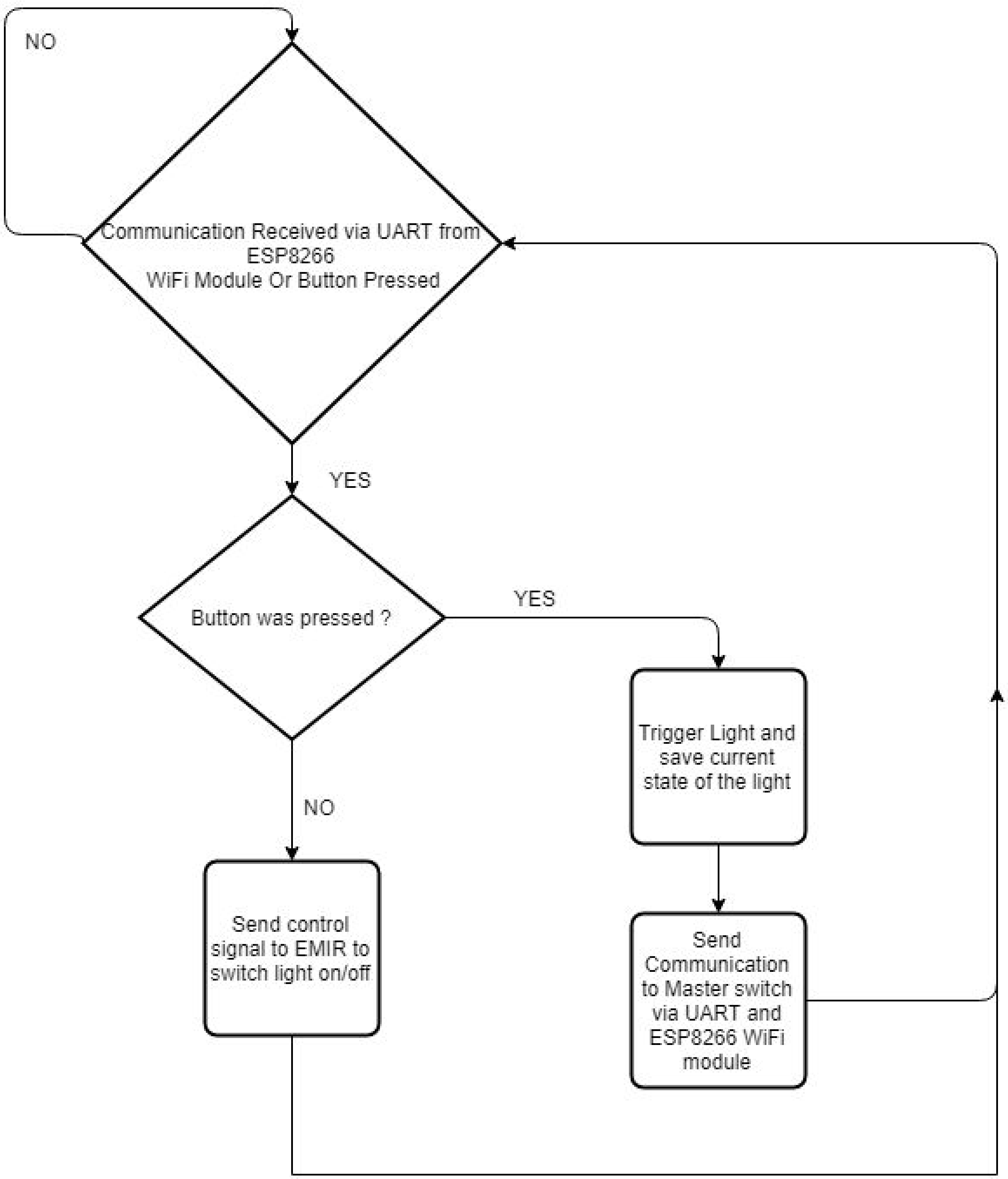

Figure 19: Slave switch flowchart

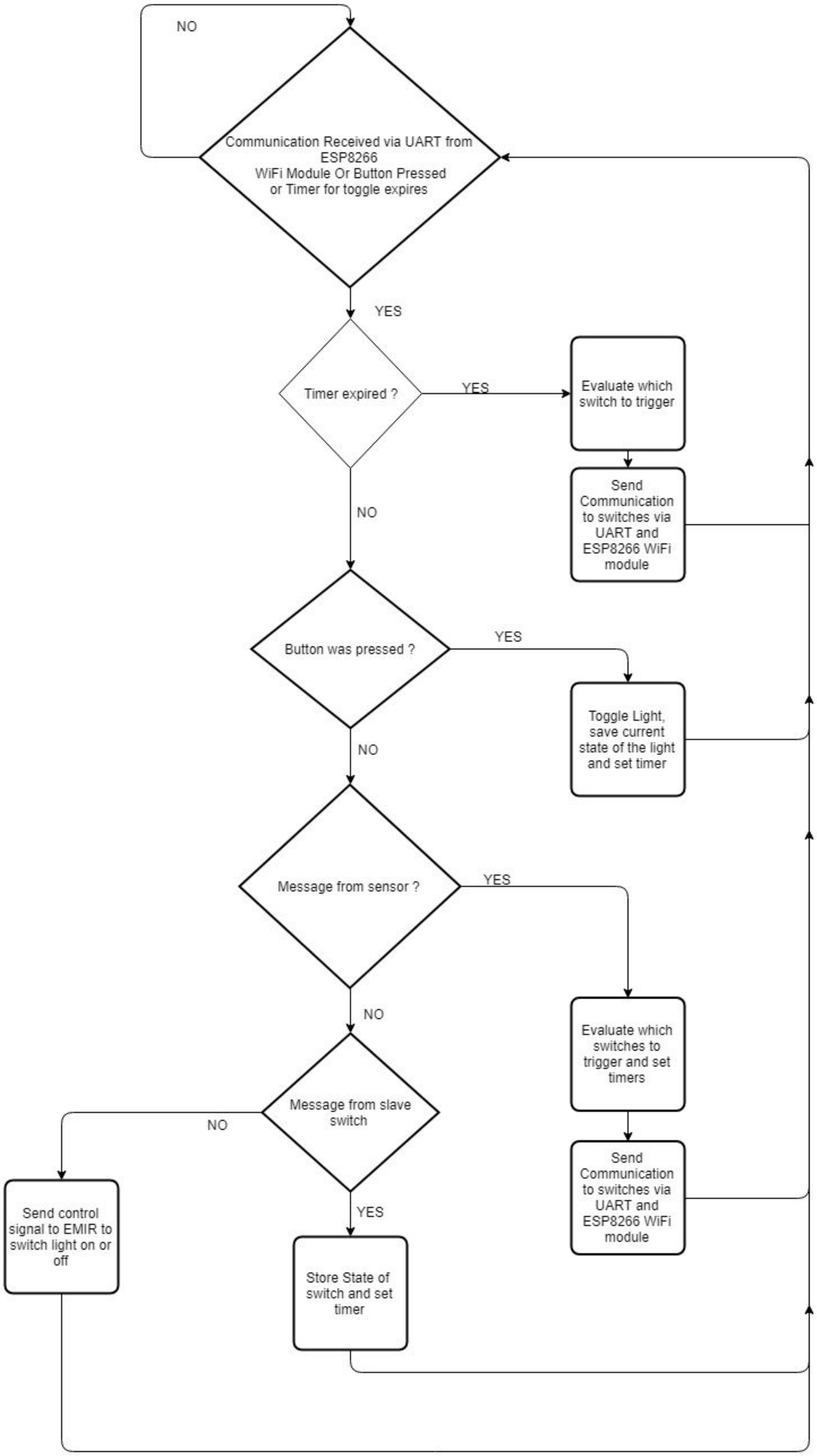

Figure 20: Master switch flowchart

2.3.5.2 Detection algorithm

The algorithm we are going to use for our base implementation will be the K-Nearest-Neighbor (KNN) algorithm; the K for the algorithm will be chosen based on the training data we collect. The AtMega will be using this model only when an interrupt is raised via the thresholding module in hardware, thus reducing power consumption. Once the AtMega windows the signal for a time period, which will be determined by testing, it will use this windowed signal on a trained KNN model to evaluate the presence of a human. We have chosen this algorithm for the versatility it provides in any situation and for its low compute cost, resulting in lower power consumption, during the classification phase.

Our data collection method for training the model will be performed by connecting our sensors to an arduino uno and placing it in different rooms and locations for a day each. The arduino will log the input from the sensors. We will then go back and label the data for the the target variable as to whether a human was present or not.

As a reach goal, we will also experiment with other unsupervised and supervised algorithms such as GMM’s and SVM’s, as since there is a lot of uncertainty in the data, the performance of these algorithms are more in question than that of KNN. These algorithms, if successfully implemented, will allow for better data scaling and better accuracy, and in the case for GMM’s, will cut down the time spent on labelling the data.

2.4 Tolerance Analysis

Our system uses an interrupt-based approach to trigger the atmega out of a sleep state to begin parsing the given data. We designed our system such that this trigger was done in analog circuitry without using the internal ADC of the atmega as the ADC consumes too much power for our design to last an extended period of time. Therefore, it is crucial that our system responds properly to given analog inputs above a certain threshold in order to be activated. The digital input pins must be pulled to near Vcc in order to trip the interrupt signal, and this pulse must be high for one clock cycle in order to ensure that the atmega senses this signal.

We use the circuit as shown in figure 10 with a mosfet of ideal threshold voltage of 0.7V with a range of 0.3V to 1V [13]. We use an amplifier to create a 2V max peak-to-peak output from the microphone filter output in order to activate the mosfet in saturation mode at the half power point of the microphone.

We use the direct pulse from the PIR sensor to power a second transistor for the sake of a second interrupt. If either interrupt is tripped, the atmega must wake. As the pulse may not last long enough for a full clock cycle, we place an RC circuit at the drain in order to keep the voltage high for long enough. We define an RC time constant that corresponds to the period of the 1MHz clock, T = 1µs. The oscillator will have a variance of about ±0.1% [14]. This error gives us a period that will range from 0.999µs to 1.001µs.

Our resistors will have a tolerance of 10% and our capacitors have a tolerance of 20%, which means our time constant will have a possible variance of 32%. We design our RC parallel circuit in such a way that it will hold the proper voltage for longer than the maximum possible cycle given the minimum possible capacitance of 1nF - 10pF and a minimum possible resistance of 1kΩ - 50Ω. These possible R and C values will still hold a high voltage for a full cycle. The TTL input high to the atmega for a voltage high is a minimum of 2.0V [16], so we must have a time constant such that the voltage at the output of the mosfet stays above 2V for a full cycle.

We must also take into account the amplifier as a source of error. Each amplifier has a gain that is a product of two resistors that we have chosen to have 10% tolerances. The gain of each amplifier is

$$A = 1 + \frac{R_1}{R_2}.$$

These amplifiers thus have a maximum possible error of

$$\left|1 - \frac{2.75}{2.9315}\right| = 6.2\%$$

These gain variances will simply provide slightly varying thresholds for the mic to trigger the interrupt, which at 6.2% is not much of a concern to trigger the charging mosfet. The PIR amplifier chip chosen outputs logical high pulses at a minimum of Vdd-0.6V[17], which is still within tolerances required for the atmega.

Given these potential variances, our interrupt trigger system can still effectively charge up the given capacitor to within the proper voltage range for at least one full clock cycle.

3. Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor Costs

Assuming labor cost of $40/hour;

Person	**Total Hours = Hours/Week * Weeks**	**Total Cost = 40 * Hours * 2.5**
Ibrahim	12 * 16 = 192 Hours	$19,200
Rohan	12 * 16 = 192 Hours	$19,200
Konrad	12 * 16 = 192 Hours	$19,200
Total	**576 Hours**	**$57,600**

3.1.2 Parts Cost

For The Switch Module

Part	**#Units**	**Cost**	**Bulk cost/unit (500 num)**
LD1117S33CTR (digiKey)	1	$0.44	$0.23
ESP8266(digiKey)	1	$6.95	$2.00
PSK-S5B-5-L(digiKey)	1	$11.22	$9.10
Assorted RLC+(Misc)	1	$2.00	$0.50
SRD-05VDC-SL-C(Amazon)	1	$5.99	$1.50
ATMega328P	1	$1.46	$0.50
Total		$28.06	$13.83

For the sensor Module

Part	#Units	Cost	Bulk cost/unit (500 num)
ICS-40180(digiKey)	1	$1.52	$0.813
IRA-S210ST01(digiKey)	1	$3.12	$1.42576
BD9251FV-E2(digiKey)	1	$1.6	$0.919
IML-0688(digiKey)	1	$3.30	$1.595
LD1117S33CTR (digiKey)	1	$0.44	$0.23
ESP8266(digiKey)	1	$6.95	$2.00
Assorted RLC+(Misc)	-	$4.00	$0.50
LR6XWA/B Battery (DigiKey)	4	4*0.35 = $1.40	4*0.18 = $0.72
ATMega328P	1	$1.46	$0.50
LM27761DSGT(digiKey)	1	$1.88	$1.35
Total		$25.67	$10.04

3.1.3 Total Cost

The total cost , considering 3 each of the sensor and switch modules is:

Labor Cost	Parts Cost	Total Cost
$57600	$161.19	$57761.19

3.2 Schedule

Week	Ibrahim	Rohan	Konrad
2-17-19	Design Document	Design Document	Design Document
2-24-19	Parts, Data Collection, Design required PCB's, Prototype amplifier and filter microphone module.	Set up wifi module with UART comms, test detection models, data collection, decide on final model for detection	Parts, Data Collection, Design required PCB's, Begin Housing CAD, Oscillator
3-3-19	Tune Amplifier and filter module, test PIR and PIR amplification Chip. Verify PCB, Prototype Interrupt	Setup communication protocol between subsystems and verify speeds. Verify PCB	Test Power Systems, PIR Field of View, and Breadboard Mockup
3-10-19	PCB #1 Finalization & Order	PCB #1 Finalization & Order	PCB #1 Finalization & Order, 3D Print Housings
3-17-19	Spring Break	Spring Break	Spring Break
3-24-19	Individual Progress Reports, PCB #2 Finalization & Order	Individual Progress Reports, PCB #2 Finalization & Order	Individual Progress Reports, PCB #2 Finalization & Order
3-31-19	Fine tune circuit and final product	Fine tune circuit and final product	Fine tune circuit and final product
4-7-19	Test and Debugging	Test and Debugging	Test and Debugging
4-14-19	Debugging & Mock Demo	Debugging & Mock Demo	Debugging & Mock Demo
4-21-19	Final Debugging, Demo	Final Debugging, Demo	Final Debugging, Demo
4-28-19	Presentation, Final Paper, Lab Checkout	Presentation, Final Paper, Lab Checkout	Presentation, Final Paper, Lab Checkout

4. Safety & Ethics

The Modular Light Control can expose the user to high voltages, which can be extremely dangerous and can be fatal. To mitigate this, we are taking precautions to make the device as safe as possible for the installer and the user.

The electromechanical relay in our device will be connected to wall outlet power through one of its pins and will be conducting this wall power in its active state. This will pose a safety risk during our own testing procedures and during installation by any consumer. We would like to market this device as easy to install, but we will make the shock hazards abundantly apparent and will encourage support by others more familiar with the dangers for those who are entirely unfamiliar with rewiring electronics in order to maintain #1 of the IEEE code of ethics - “to disclose promptly factors that might endanger the public” [5]. We intend to include descriptions of proper safety practices regarding mains power with our product, and we will approach our design and test using the same safety practices. We will be following the OSHA standards for power safety [6]. Our ground and power rails on our device will be clearly marked so that polarities are not switched. When rewiring the circuitry, the power to the device will be off. In testing, we will use a ground-fault circuit-interrupter and insulating gloves to ensure no significant electric shock. We will use the “one hand rule” with one hand in pocket when working with the relays and transformers [7].

We are utilizing commercial manufactured parts like the step down transformer and pre-fabricated voltage regulator ICs when dealing with specific voltages. These commercial parts contain peripheral components and are designed to be safe compared to prototyped designs.

Physically isolating high VAC from the rest of the components and keeping them off PCB traces can not only help with EMF, but also with durability. The reasoning behind this is that if we were to design our own AC to DC converter, step down transformer and diode rectifier, the tolerances and design may be awry which could lead to the destruction of components and even physical harm. This is why we figured commercial voltage components are safer and more foolproof.

Fuses will be added near the inputs and outputs of the voltage supplies. This is a preventative measure to break the circuit before too much power can run through other components, potentially frying them. There will also be transient voltage suppressors, which act as surge protection if, for example, a lightning strike were to occur.

Since our device connects the modules through wifi, an ethical and safety concern arises with the possibility of unauthorized users who would be able to gain access to the network and control the lights manually and/or retrieve the sensor data to detect a person's presence in the building in order to use this information for malicious intent, directly infringing upon #9 of the IEEE code of ethics - "to avoid injuring others, their property, reputation, or employment by false or malicious action"[5]. In order to prevent this, we will have identifying data associated with the sensor boards that will be encrypted along with the data read from the sensors, and this ID will be required for the switches to act upon the given command. We strive to take advantage of the utility of wifi while also accounting for the associated safety concerns.

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