COST EFFICIENT OCCUPANCY SENSOR

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By

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Approved:

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Abstract

The purpose of this project was to design a low-cost occupancy sensor. While many existing commercial systems perform this function, it is done so at a high cost to the consumer. This system prototype is capable of occupancy detection over a given time interval and can be manufactured at a low cost.
Acknowledgements

I would like to thank my advisor Professor Emanuel for assisting me during the course of this project and I would also like to thank the lab technician, Mr. Bob Brown for assistance in obtaining the several key components needed for this project.
Executive Summary

This paper provides an overview of the background and technology needed to design an occupancy sensing system. This paper shall first begin with the introduction which provides an overview about the project as a whole. This section goes into detail of explaining what the different occupancy sensing technologies are and how exactly they are applicable to the project at hand. The next section of this paper is the background theory and technologies. Within the background theory and technologies the essential background necessary to gain a better understanding of the system is outlined. This section goes in to detail be explaining the concepts of infrared technology, and pyro electricity and also giving an overview of current occupancy sensing technologies and their advantages and disadvantages.

The next two sections of the paper, Design and Methodology and Experimental Results go provide a detailed overview of the design and the results received in the building of the prototype. Within the Design and Methodology section the following subsystems are outlined: Sensing, Signal Conditioning, Inverter, and LED Output The sensing subsystem provided the details on how the input of the sensor is modeled. The signal conditioning subsystem describes how the input signal is transformed into an output signal that can be used to drive another section of the circuit. The inverting subsystem will prepare the signal for the next stage within the system. The LED output subsystem will provide verification that the entire system works.

The final section Conclusion and Future Works will provide an overview of the work that was done over the time frame of the project and if it met the project objectives.
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1. Introduction

With the advent of technology there has been a greater increase in the need of occupancy sensing. This need is driven by the fact that the use of occupancy sensing leads to the reduction of electrical costs which are associated with lighting\(^1\) and in turn provides a positive impact on our environment. As of today lighting use accounts for 30 to 50% of building use and 17% total annual energy consumption in the United States\(^2\). Energy waste created by lighting use be reduced by 30 to 70% with the addition of occupancy sensors\(^3\). Occupancy sensing systems are capable of detecting room occupancy through the use of motion sensing technologies. Occupancy sensing can be implemented in many larger systems such that a motion detection functionality can be used as an automatic switching control in order to control lighting systems as previously mentioned and/or as a trigger within a security alarm applications.

Occupancy sensor systems have the capability to detect occupancy within a room through the use of three different technologies: Ultrasonic, Passive Infrared, and Hybrid (Ultrasonic and Passive Infrared Technologies). Ultrasonic Technologies are capable of transmitting sound on the frequency of 20,000 to 40,000 Hz to a receiver. An ultrasonic sensor within an occupancy sensor module will detect any movement which disrupts the ultrasonic field. Passive Infrared sensors operate by detecting a change in infrared radiation in comparison to the radiation of the background environment. A passive infrared sensor can detect motion within the range of 430 THz to 300 GHZ. A hybrid technology will implement both of these technologies within an occupancy sensor\(^4\).

\(^1\) http://www.greenglobes.com/advancedbuildings/main_t_load_build_occupancy_sensors.htm
\(^2\) http://www.wbdg.org/ccb/GREEN/REPORTS/cgrsens.pdf
\(^3\) http://www.greenglobes.com/advancedbuildings/main_t_load_build_occupancy_sensors.htm
\(^4\) http://ecmweb.com/lighting-amp-control/occupancy-sensors-101
For this purposes of this project a cost efficient occupancy sensor which utilizes passive infrared sensing technology to detect room occupancy. This occupancy sensor was then interfaced with a simple LED control circuit in order to display a change in occupancy.
2. Background Theory and Technologies

Infrared Technology

Infrared technology can be used to describe technologies that utilize or are powered by the effects of infrared radiation.

![Electromagnetic Spectrum](image)

**FIGURE 1: ELECTROMAGNETIC SPECTRUM**

Infrared radiation can read wavelengths within the range of 430 THZ and 300 GHZ. Infrared radiation can be used to describe the region between microwaves and the visible light spectrum as shown in Figure 1. Infrared radiation can detect these wavelengths by detecting heat or thermal radiation. Each object with a temperature is capable of emitting a certain degree of infrared radiation. The hotter the object the more infrared radiation can be emitted. Infrared technology can be categorized into three different sub categories: Far Infrared, Thermal Infrared and Near Infrared. Far Infrared can be used to describe the region of infrared technology within the range of 0.7 to 1.3 microns. Mid-Infrared is used in

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6 [http://science.hq.nasa.gov/kids/imagers/ems/infrared.html](http://science.hq.nasa.gov/kids/imagers/ems/infrared.html)
the region that covers between 1.3 to 3 microns. Thermal Infrared can be used in order to describe the region of infrared radiation that ranges between 3 microns and 30 microns. The major difference between these regions is that while thermal radiation measures radiation that is emitted from an object near and mid infrared is used to describe systems in which energy is reflected\(^7\).

**Pyroelectricity**

Pyroelectricity is defined as a phenomenon in which a temporary voltage is excited due to pyroelectric material being either heated up or cooled down\(^8\). Pyroelectricity serves a very important purpose within the occupancy sensor unit as this is the material capable of detecting motion in within the passive infrared sensor itself.

**Current Occupancy Sensing Technologies**

There are several occupancy sensing technologies commercially available. A large manufacturer of occupancy sensing technologies is Leviton. Leviton is a major manufacturer of occupancy and vacancy sensor system. Occupancy sensing systems work as a lighting control with will turn the light on was someone walks into the room while vacancy sensor work very similar to an occupancy sensing system with the exception that if the room is not detected as occupant all of the lights in the room are turned off. The Leviton occupancy sensor lighting control system can range anywhere from $20.00 to $50.00. While occupancy sensors can range from $30.00 to 130.00 depending on manufacturer and sensor mount\(^9\). My goal for this project is to implement some of the same technology with much lower costs.

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\(^7\) [http://electronics.howstuffworks.com/gadgets/high-tech-gadgets/nightvision1.htm](http://electronics.howstuffworks.com/gadgets/high-tech-gadgets/nightvision1.htm)


3. Design and Methodology

3.1 Objectives

In the design of the occupancy sensor system I sought to meet the following objectives:

- Cost Efficient Design
- Detection of Occupancy
- Validation of Occupancy Sensing

Cost efficiency is a key point of this project; in order to meet this specification low cost components were chosen. This will be further detailed in the cost analysis provided in section 3.2. It was also necessary that this system performed room occupancy detection through the use of motion detection systems. Validation of occupancy sensing is achieved by using the output of this system in order to act as a switch to turn on an LED.

3.2 Cost Analysis

This cost analysis shall provide more insight into the cost associated in the development of this prototype. The two costs associated with this prototype are the costs of materials and the cost of labor.

3.2.1 Bill of Materials

The bill of materials provides a listing of all components used in the creation of the occupancy sensor system. The bill of materials for one prototype unit is shown below in Table 1.
Table 1: Bill of Materials of One Prototype Unit

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Description</th>
<th>Quantity</th>
<th>Unit Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHI 878</td>
<td>Passive Infrared Sensor</td>
<td>1</td>
<td>5.64</td>
<td>5.64</td>
</tr>
<tr>
<td>LM324N</td>
<td>Low Power Quad Operational Amplifier</td>
<td>1</td>
<td>0.48</td>
<td>0.48</td>
</tr>
<tr>
<td>74LS04N</td>
<td>Hex Inverter</td>
<td>1</td>
<td>0.74</td>
<td>0.74</td>
</tr>
<tr>
<td>LM555</td>
<td>555 Timer</td>
<td>1</td>
<td>0.43</td>
<td>0.43</td>
</tr>
<tr>
<td>WP7113ID</td>
<td>Red LED</td>
<td>1</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>445-4276-ND</td>
<td>33 nF Capacitor</td>
<td>2</td>
<td>0.45</td>
<td>0.90</td>
</tr>
<tr>
<td>445-8492-ND</td>
<td>26 uF Capacitor</td>
<td>1</td>
<td>0.45</td>
<td>0.45</td>
</tr>
<tr>
<td>P5539-N</td>
<td>46 uF Capacitor</td>
<td>1</td>
<td>0.23</td>
<td>0.23</td>
</tr>
<tr>
<td>P13478-N</td>
<td>10 uF Capacitor</td>
<td>1</td>
<td>0.30</td>
<td>0.30</td>
</tr>
<tr>
<td>SR215C103KAATR1</td>
<td>0.01 uF Capacitor</td>
<td>1</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>MF1/4CCT52R1004F</td>
<td>1 MOhm Resistor</td>
<td>2</td>
<td>0.18</td>
<td>0.36</td>
</tr>
<tr>
<td>270-10K-RC</td>
<td>10k Ohm Resistor</td>
<td>1</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td>CCF075K10GKE36</td>
<td>5.1 k Ohm Resistor</td>
<td>1</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>CCF60200KFKE36</td>
<td>200 k Ohm Resistor</td>
<td>1</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>CCF60200RFKE36</td>
<td>200 Ohm Resistor</td>
<td>1</td>
<td>0.10</td>
<td>0.10</td>
</tr>
</tbody>
</table>

As shown in the table above many low cost components were used in the creation of this system. The costs were contained by looking through the catalog of prices at Digikey and Mouser. The total costs of all the materials in one unit is $10.28.
In addition to showing the cost associated in the production of one prototype I also performed a Bill of Materials for a bulk order of 100 units to compare the difference in pricing. This Bill of Materials can be found below in Table 2.

<table>
<thead>
<tr>
<th>TABLE 2: BILL OF MATERIAL OF 100 PROTOTYPE UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part Number</td>
</tr>
<tr>
<td>LHI 878</td>
</tr>
<tr>
<td>LM324N</td>
</tr>
<tr>
<td>74LS04N</td>
</tr>
<tr>
<td>LM555</td>
</tr>
<tr>
<td>WP7113ID</td>
</tr>
<tr>
<td>445-4276-ND</td>
</tr>
<tr>
<td>445-8492-ND</td>
</tr>
<tr>
<td>P5539-ND</td>
</tr>
<tr>
<td>P13478-ND</td>
</tr>
<tr>
<td>SR215C103KAATR1</td>
</tr>
<tr>
<td>MF1/4CCT52R1004F</td>
</tr>
<tr>
<td>270-10K-RC</td>
</tr>
<tr>
<td>CCF075K10GKE36</td>
</tr>
<tr>
<td>CCF60200KFKE36</td>
</tr>
<tr>
<td>CCF60200RFKE36</td>
</tr>
</tbody>
</table>
The total cost associated with the materials necessary to complete 100 units is $610.39. When the materials for 100 units is ordered the cost per unit is approximately $6.10. The purchasing of materials in bulk allows for a $4.18 decrease in materials per unit.

3.2.2 Labor Costs

In the consideration of labor costs it is important to consider the costs necessary to fabricate a prototype board and assemble all of the components on the board. In order to receive a general idea of how much this prototype could cost to fabricate and produce I used an online price quote generator, Bittele Electronics, which provided an approximate cost to fabricate and assemble all the components onto a prototype board. The cost to fabricate 1 PCB board is $164.11 and the cost to assemble one unit is $94.78 within the time period of 4 to 5 days. The labor cost to fabricate 100 units $323.01 and the cost to assemble 100 units is $560.70.

3.2.3 Cost Comparison: Single vs. Hundred Units

Now that the individual costs associated with the creation of a prototype unit have been discussed calculations will be performed below in order to determine the cost per unit if this system is manufactured individually and if the system is manufactured in bulk.

In order to calculate the total cost to create 1 unit I will use the Equation 1 below.

\[
\text{Total Cost for 1 Prototype Unit} = \text{Cost of Materials} + \text{Cost of PCB Fabrication} + \text{Cost of PCB Assembly}
\]

\textbf{Equation 1: Total Cost for 1 Unit}

Equation 1 will yield a total cost of 269.17 for the creation of one prototype if all the creation of this prototype is completely outsourced.

In order to calculate the total cost to create 100 units I will use the Equation 2 below.
Total Cost for 100 Prototype Units = Cost of Materials + Cost of PCB Fabrication + Cost of PCB Assembly

**EQUATION 2: TOTAL COST FOR 100 UNITS**

Equation 2 will yield a total cost of $1,494.1 for 100 units at an average cost of $14.94 per unit to manufacture. In the comparison of unit price of a single unit and a bulk order of 100 units it is true to say that this unit can be manufactured at a very low cost per unit and as such will be available to the consumer at a lower cost. This cost can be further minimized by receiving more exact quotes from various PCB companies by providing a larger degree or specifications as this cost analysis was built to give a generic quote on the cost to produce this prototype.
3.3 Preliminary Design

This section shall offer an overview of the preliminary design considerations considered in the design of the occupancy sensor system.

**FIGURE 2: PRELIMINARY SYSTEM BLOCK DIAGRAM**

3.3.1 Passive Infrared Sensor Input

In order to detect the occupancy within a room the use of passive infrared technology was utilized. As room occupancy is detected the passive infrared sensor will output a change in voltage of .1 mv. The sensor that will be used in the design of this module is the LHI 878 passive infrared sensor. The module chosen can be shown below in figure 3.

**FIGURE 3: LHI 878 DUAL ELEMENT PYROELECTRIC SENSOR**

Furthermore an internal view of this sensor can be shown below in figure 4.
Within the sensor itself are two sensor elements that operate similar to a pyroelectric capacitor. As human motion is detected across the plates of the pyroelectric sensor elements a charge is generated. The charge that the pyroelectric elements generate is then discharged through the use of the gate resistor. If charge is generated current will flow to the S, source terminal and provide a small voltage output. If human motion is not detected than the voltage output of the S, source terminal pin will not generate any output voltage.

This phenomenon can also be shown in the schematic diagram below in figure 5.
In figure 5 above the combination of the current source and capacitor act as the sensor elements. The current source denotes a change in charge which charges the capacitor C1 and is then discharged through the gate resistor R1. If motion is detected across the passive infrared sensor then current is sent through the source pin and a change in voltage can be detected across the load R2. The voltage V1 serves the purpose of powering the JFET transistor output of the sensor. The output of this system is shown in the simulation below.
The positive spike in voltage denotes when there is a change in voltage in hence human motion is detected.

3.3.2 Amplifier Sub-Module

The purpose of the amplifier sub module unit is to provide gain in order to read a larger voltage output. It has been decided to use a two stage amplifier that is capable of amplifying the output signal from .0001 V to 1 V in order to use this voltage to turn on an LED and provide proof that this system works. A diagram displaying the circuit is shown below.
Figure 7: Preliminary Multistage Amplifier

Shown in Figure 7 above is the complete amplification module. The sinusoidal source is used as a simulation of human motion as a human walks by the passive infrared sensor. Although the sinusoidal input used to model the sensor can be further explained in detail in section 3.4.1. The purpose of this module is to provide amplification of the output signal for the passive infrared signal. The amplification provided in the module above is done so with a Non-Inverting Amplifier. A non-inverting amplifier is defined as an operational amplifier in which the input is amplified in the same direction of the voltage input\textsuperscript{10}. The equation to determine the degree of voltage amplification is displayed in equation 3 below

\[
G = 1 + \frac{R_2}{R_1}
\]

Equation 3: Non Inverting Amplifier Gain Equation

\textsuperscript{10} http://www.williamson-labs.com/480_opam.htm
For a gain of 101 I have decided to use and R2 value of 100k Ohms and R1 value of 1.0 K Ohms. I will then amplify this voltage again with a gain of 101 V in order to achieve the amplification from .1mv to 1V.

The two stage amplification system was created through the use of the LM324N quad operational amplifier.

3.3.3 LED Module

The final stage was to prove that the system designed was capable of detecting motion by turning on and LED. In order to do so the output of the last stage of the operational amplifier will be used as an input to turn on the LED. This system can be seen in figure 9 below.

Figure 8: LM324N Operational Amplifier

Figure 9: LED Module
3.4 Final Design

As the system was further developed and tested many modifications were made in order to still meet the original objectives. In order to still meet the original objectives of this project a top level block diagram was created and each section was further defined.

![Top Level Block Diagram](image)

**Figure 10: Top Level Block Diagram**

3.4.1 Sensing Subsystem

The sensing subsystem is composed of a passive infrared sensor. As an individual walks within the detection zone of the passive infrared sensor a .1 mv voltage difference is created. This voltage change is of a very small magnitude. To more directly read this voltage it is necessary to amplify the signal into the 1-5 V range.
Figure 11 shows the modeling of a passive infrared sensor. The current source represents a source of infrared radiation. This source of infrared radiation then goes through the gate of the JFET transistor and switch on the transistor. This transistor works as the switching element of the passive infrared sensor that may turn the entire system on with the detection of infrared radiation. To model this sensor in the upcoming circuit designs I will be using a varying current source.

3.4.2 Signal Conditioning Subsystem

Figure 12: Signal Conditioning Subsystem 1 Block Diagram
3.4.2.1 Signal Conditioning Subsystem 1

The block diagram in figure 12 demonstrates the first part of the amplification process of the initial .1 mV input. The first stage of this block diagram is to the passive infrared signal input which is provided from the sensing in subsystem. The second stage of the block diagram involves a non-inverting amplifier. A non-inverting amplifier allows for the signal phase to remain the same and amplifies the peak voltage of the input signal. As mentioned in Equation 3: Non Inverting Amplifier Gain Equation the gain can be adjusted through the use of the resistors used in the formation of the Non-Inverting Amplifier. While originally it was decided to use a 100k resistor and a 1k resistor to provide a gain of approximately 100 as shown in Figure 7: Preliminary Multistage Amplifier, for the final design resistances of 1M Ohms and 10k Ohms were utilized. This will allow the voltage to increase by 10 mV.

The third stage of the block diagram is the signal output filter. Although the use of a non-inverting amplifier allows for an amplification of the input signal this also allows for the amplification of noise or small disturbances in the system. This cause a signal output with a lot of interference and as a result it became very difficult to read an output voltage change in respect to the detection of human motion from the passive infrared sensor. As a result a band pass filter was created in order to allow frequencies within the range of 0.6 – 5 Hz. This range was chosen as it is the range of frequencies necessary to detect human motion.11 The signal output filter was designed with two RC filters around R2 which is the 1MOhm resistor and R1 which is the 10K Ohm resistor. To attain the values of the capacitances needed to sample signals between 0.6 and 5Hz the equation for cutoff frequency was used, this is shown below.

\[ f_c = \frac{1}{2\pi RC} \]

**EQUATION 4: CUTOFF FREQUENCY EQUATION**

Equation 4 yielded the capacitance of 33nF for the 1Mohm resistor which has a cutoff frequency of 5 Hz and 26uF for the 10kOhm resistor which has a cutoff frequency of 0.6HZ. In addition to serving as a component in the RC filter, the capacitors will also serve as a DC block allowing on the changes in voltage to pass through. The entire system can be seen below.

**Figure 13: Signal Condition Subsystem 1**
3.4.2.2 Signal Conditioning Subsystem 2

The signal conditioning subsystem 2 while similar to the first signal conditioning subsystem does provide some differences. The signal conditioning subsystem 2 is cascaded with the first subsystem as such the output for the first signal conditioning subsystem is the input to the second stage amplifier. In the preliminary design it was decided that the output voltage of the amplification system must be within 1-5 V. In the final design it was decided to output a voltage of 2V. It was decided to keep the higher resistance of R2 at 1MOhms. In order to calculate the resistance of R1 the equation for the voltage output of a non-inverting amplifier was used, shown below.

\[ V_o = \left(1 + \frac{R_2}{R_1}\right) \times V_i \]

**Equation 5: Voltage Output for Non Inverting Amplifier**

Equation 5 was used to calculate a R1 value of 5K Ohms. For the purposes of this project a resistor of 5.1k Ohms will be used for R1. This will create a gain of approximately 200 which is what is necessary in order to amplify the voltage to 2V.

After the signal is amplified it must then be filtered again to only read frequencies of 0.6 to 5Hz. This is done through the use or RC filters on the 1M and 5.1k Ohm resistors. The values for the capacitances
are attained with the equation to determine frequency cutoffs, Equation. The capacitance values attained are 33nF for the 1MOhm resistor, and 52uF for the 5.1k Ohm resistor.

3.4.3 Inverting Subsystem

The inverting subsystem is an intermediary step from the output of the signal conditioning system to the LED Output subsystem. The input needed to drive the LED output system must be a negative pulse, the output of the signal condition subsystem will provide a peak value every time a human is detected. In order to reverse this I employed the use of a digital inverter. The digital inverter that I used was the 74LS04N. The output of this subsystem shall provide the input of the LED Output subsystem.

3.4.4 LED Output Subsystem

The purpose of the LED output system is to provide verification that the conditioned output of the passive infrared sensor can by driven to perform a function as it is common in an occupancy sensor that the output serves as a switch control for a larger system such as a lighting control or alert system. The block diagram outlining the LED Output Subsystem is outlined below.

![Figure 15: LED Output Subsystem](image-url)
Show in Figure 16 above is the 555 Timer circuit. The 555 Timer is utilized in order to provide a timed output. For this application the input into the 555 Timer should be able to turn on the LED for a set amount of time and act as a lighting control switch. The 555 Timer above is implemented in Monostable operation. In Monostable operation the output will provide a pulse for duration of the set delay time. The set delay time is determined by the following time constant equation.

\[ \tau = 1.1 \times R \times C \]

**Equation 6: Time Constant equation**
The R value was set to 200k Ohms and C value was set to 10uF in order to yield a delay time of two seconds. This allows the LED to turn on for 2 seconds when a human is detected by the occupancy sensor system.
4. Experimental Results

In order to verify that the entire system was operating it was necessary to test the following.

- A change in voltage is detected when human motion occurs across the sensor. (This is indicated by Channel 2 in Blue).
- Voltage may be amplified by a gain of 100 for the first stage of the non-inverting amplifier. (This is indicated by Channel 3 in Purple).
- Voltage may be amplified by a gain of 200 for the second stage of the non-inverting amplifier. (This is indicated by Channel 4 in Green).
- The output of the LED connected to the timer can hold a charge for a given time interval.

4.1 Passive Infrared Sensor Functionality Test

In order to test the functionality of the passive infrared sensor I used an oscilloscope in order to measure the voltage level when no motion was detected and the voltage level when motion is detected.

![Figure 17: Passive Infrared Sensor Output (No Motion)]
In Figure 17 above when no motion is detected across the Sensor this yields an output of 1.99mV.

![Figure 18: Passive Infrared Sensor Output (Motion)](image)

In figure 18 above the average voltage when motion is detected is 3.61 mV. This yields to a difference of about 1.62 mV when measured. This was different than the initial expected voltage difference of .1mV which was measured. This voltage difference could also be accounted to the external disturbance such as slight temperature changes that the LHI 878 sensor could be measuring such as the difference in the air from a window being open or the overhead lights in the testing environment.

4.2 Stage 1 Amplification Test

The first stage of the non-inverting amplifier is to amplify the voltage by a gain of 100. The two figures below show the voltage output of the first stage of the non-inverting amplifier.
Figure 19 shows an oscillogram where no human emotion is detected. The voltage of no motion detected is in this case is 9.12 mV.
Figure 20: STAGE 1 AMPLIFICATION (MOTION)

Figure 20 shows an oscillogram in which human motion is detected across the sensor. The voltage of human motion detection is 66.6mV. The difference in voltage is 66.6mV - 9.12 mV or 57.48 mV. This does demonstrate an amplification in the change of voltage from section 4.1 although this is not the exact gain of 100 which I had expected. I believe this is due to the fact of how the motion was sensed. I tested the ability to detect human detection by waving my hand within the focal range of the passive infrared sensor. I do believe if these measurements were taken at a farther distance an within a more temperature controlled environment the measurements would have been more exact
4.3 Stage 2 of Non-Inverting Amplifier Test

The second stage of the non-inverting amplifier is to amplify the voltage by a gain of 200. The two figures below show the voltage output of the second stage of the non-inverting amplifier.

Figure 21 shows the output of the second stage amplifier with no motion detected. The voltage level of the output of the second stage amplifier is 357mV.
In comparison to the figures in section 4.2 figure 22 shows a more noticeable peak and voltage and has a much greater change in voltage, 3.50V. This show that the voltage output is being amplified by a greater factor each time.

4.4 Comparison of different Amplifications
In the oscillogram above the different stages of amplification are shown without the LED timer delay circuit. Within this oscillogram Channel2 (represents the signal without amplification). As can be seen the signal is responds to an input by moving up slightly and provides an output of 15.2 mV when motion is detected. The Chanel 3 output represents the system after first stage amplification. It can be observed here that the rise in input is more clearly seen and the system has making it much easier to detect a peak voltage of 125 mV. The Channel 4 output represent the occupancy sensor system after second stage amplification. It can be seen here that the peak when movement is detected is very filtered allowing a clear readout signal and also that it has a much greater amplitude than the other two channels. This oscillogram has shown the successful readout of a peak voltage detected after the signal was amplified and filtered.
4.5 One Pulse Output from LED

This oscillogram shows the final output of the system. As can be seen this system creates a pulse for a period of time which keeps the LED continuously on for the time constant previously defined in this case for two seconds. In order to create a wider pulse the value of the resistor could be increased in order to allow the LED to remain on for a large amount of time.
5. Conclusions and Future Work

In conclusion I was able to build a system which met my original parameters. My first goal was to ensure that I was able to build a system that was cost efficient. I was able to achieve this goal through the use of low cost components and as such bringing down the cost necessary for the consumer. My second goal was to ensure that this system could detect occupancy sensing, I was able to do this through the use of passive infrared sensing technology. My third goal was to ensure that I could use the output of the sensor in order to act as a switching control for another element. This was achieved as my output for my sensor was capable to turn in an LED for an exact period of time. This gave validation for the entire system and provided a prototype very applicable toward the current models in industry.

Although the design was capable of meeting the standard specifications there are some suggestions for improvement to be addressed. If time had allowed I would have preferred to perform more testing in a variety of environments to test whether the changes in voltage gain were due to the fact of the filter design or testing conditions. Another possible improvement to the system is the addition Fresnel lens. Fresnel lens allow for a greater area of detection of the passive infrared sensor, this would have allowed for an amplification of detection within several meters. In addition the design of an outer case would have also served to make this design more commercially available.

Overall I do feel that this system in addition to meeting all of the necessary system requirements did provide a well-rounded experience in the integration of analog and digital circuit design. I expanded upon the areas of signal conditioning, sensor technologies, and digital logic. As such it provided a well worth experience that I do believe is necessary of any engineer in the completion of this project I do feel very satisfied with the outcome and look forward to what future teams can do to improve upon this design.
References


Appendices

FIGURE 25: FINAL SYSTEM DESIGN