Design Review

Group 29
Empty Seat Finder

Jaehyun Kang
Junsung Lee
Table of Contents

1. Introduction

2. Block Diagram and Descriptions
   2.1.Sensor Module
      2.1.1. PIR Sensor
      2.1.2. Pressure Sensor
   2.2.Power Module
   2.3.Control Module
      2.3.1. Microcontroller
      2.3.2. Multiplexer and Decoder Module
   2.4.Wifi Module
   2.5.Main Hub

3. Tolerance Analysis

4. Requirements and Verifications

5. Cost analysis
   5.1. Parts
   5.2.Labors
   5.3.Total Fees

6. Discussion of Ethics and safety
   6.1.Code of Ethics
   6.2.Safety

7. Citations
1. Introduction

In many social congregational meetings that take a long time such as listening to an extensive speech from Microsoft recruiters or a lecture from a favorite professor, it is ideal for the listeners to be in a comfortable position. The most important of which is to be sitting down in a chair. However, we have found through our own personnel experience and observation that it is not so easy to find seats in very crowded areas and places where there are very few seats left in a large crowd.

We wanted to find a way to shorten the search time for the people looking for a seat and provide an easy way to locate an empty spot. In order to achieve this, we gave each seat the ability to recognize a person sitting in the seat. This information will be relayed to an LED panel located at the aisle of the seats to provide information to the individuals looking for a seat about seat occupancy locations.
2. Block Diagram and Descriptions

Figure 1. Block Diagram of Empty Seat Finder
2.1 Sensor Module

Each seat in a row of seats will have one PIR sensor and one Pressure sensor attached. The PIR sensor will be located below the armrest and the pressure sensor will be located below the seat cushion cover in the middle area. The sensors will work together to distinguish an inanimate object from an actual person.

2.1.1 PIR Sensor

Input: 5V from the voltage adapter

Output: 3.3V to the Multiplexer Module

The sensor that will detect change in the amount of IR radiation due to a presence of a human body. We will use the HC-SR501 version for its ability to change the trigger selection so the sensor will remain active until the person leaves. The output from this sensor will be digital, so we will only be interested in whether the sensor is outputting high or low. The input voltage for the sensor is 5V and the output will be 3.3V. The PIR sensor’s output is sent to the Multiplexer module for multiplexing before being sent to the microcontroller to be processed.
2.1.2 Pressure Sensor

Input: 5V from the power module

Output: 1.4V to 3.8V depending on pressure to the Multiplexer Module
The pressure sensor will be a small piece of static dissipative foam with wires connected to it, dipped in a thin rubber coating. The dimensions for the piece of foam will be 1cmx1cmx0.5cm. This sensor will be placed on top of the seat of the chair to sense the presence of an object on the seat. It will work in conjunction with the PIR sensor to distinguish the presence of a human or an object. The pressure sensor will change its resistance value when pressure is applied to it. The pressure sensor will receive a constant 5V input and using the voltage divider, we will manipulate the amount of voltage output that the pressure sensor will send to the multiplexer module.

![Figure 3. Circuit Diagram of Pressure Sensor](image-url)
2.2 Power Module

2.2.1 Power Converter

Input: 110V from the outlet

Output: 5V to the PIR sensors, Pressure Sensors, microcontroller and voltage regulator

The power supply will draw its main power from a 110V power outlet. We will use an adapter that will bring this voltage down to around 5V to be used in the microcontroller, PIR and pressure sensors. The Wifi module and USB module will need a separate adapter that will bring the voltage down to around 3.3V. The main hub will be a computer so it will take direct 110V from an outlet.
2.2.2 Buck Boost Converter

Input: 5V from the Power Converter

Output: 3.3V to the Wifi Module and USB module

We will use buck booster converter (TPS63031DSKT) to change the voltage from the Power converter and make constant voltage. The buck boost converter will receive an input of 5Vs and output a current at 3.3V. This current will be used to power the USB module and the WiFi Module.

2.3 Control Module

2.3.1 Microcontroller

Input: 5V from the power module

Output: 3.3V from the I/O pins to the Wifi module, Multiplexer Module and Decoder Module

The microcontroller will be the main component that tracks all the inputs from the sensors that decides whether the seats are occupied or not. We will be using Atmega328p PU for the main operations. The power consumption of the atmega328p small, but the power consumption of the crystal oscillator depends on the frequency. If we use a battery, we would use a 8MHz xtal oscillator instead of 16MHz because 16MHz frequency takes more power consumption than 8MHz frequency. But since we are using the power outlet, so we don’t need to care power consumption and we applied 16MHz crystal oscillator. Like upper, because of very little power of atmega328 chipset, so it is not yet able to run 16MHz clock cycle. We want both these functions because we do not want to use too much electricity and yet still be able to cycle through the seats very quickly while obtaining information from the sensors. Due to the low number of I/O pins on the Atmega328p, we will be implementing multiplexing to increase the number of inputs that a single Atmega328p microcontroller can handle. While a single Atmega328p has 23 I/O pins to be used, we need 2 to be used as a clock input, 2 as a USB/Wifi input so the number of I/O pins left to use would be 19. However, this is not enough to connect all the PIR and
Pressure sensors and status LEDs. Since we are working on a bases that there could be at most 16 seats per row, we would need 32 I/O pins if we do not use multiplexing.

![Circuit Diagram of the Microcontroller](image)

**Figure 5. Circuit Diagram of the Microcontroller**

### 2.3.2 Multiplexer and Decoder

**Multiplexer**

*Input:* 3.3V input from PIR and Pressure Sensors  
*Output:* 3.3V output to Microcontroller

**Decoder**

*Input:* 3.3V input from the microcontroller  
*Output:* 3.3V output to the Status LED Module
The multiplexer and Decoder will help with the large number of inputs and outputs that the microcontroller needs. With only 23 pins for I/O, the microcontroller does not have enough pins for all the sensors and LEDs. By multiplexing the input and output data, we can save the number of I/O pins required for such a large number of inputs and outputs.

2.3.3 Status LED

Input: 3.3V from the Decoder Module

This row of LEDs will provide information to the users of the availability of seats. For a seat that is occupied, the LED will be turned on to indicate that the seat has been taken, otherwise the LED will be off to indicate that there is an empty seat.

![Figure 6. Circuit Diagram of Decoder and Status LED](image)

2.4 Wifi Module

Input: Input 3.3v from the power module

Output: Wireless signal to the Main hub

Enables Wifi connection to the main hub and sends information about the seats to the main hub. We will be using ESP 8266 Serial Wifi wireless module for Arduino. We picked this module because of its low power consumption (<1.0W
for standby), but still has a good enough processing and storage functions that will meet our needs of 1Mb/s data transfer speed.

2.5 USB Module

Input: 3.3V from the Voltage Regulator

Output: Data sent to the PC

The USB Module will be the central way in which we will program our microcontroller. The USB module will allow us to change the programming on the microcontroller so that we can adjust the number of sensors and LEDs that we will use depending on the number of seats in a row. It will have a bidirectional data flow because we want to give information about the seating arrangements to the microcontroller, but also want feedback from the microcontroller about its operation status.

2.6 Personal Computer

The Personal Computer will be a labtop that will be able to gather the information from many intermediate hubs and display all the information onto a single screen. It will be connected via Wifi to the intermediate hubs because the exit to the room can be a long way away from the actual seats.
Figure 7. High Level Circuit Diagram
3. Tolerance Analysis

A key part of this project is to be able to distinguish the presence of a human from an inanimate object. In order to distinguish between a person and an object, the microcontroller will take both the inputs of the PIR sensor and Pressure sensor to determine whether the object in the seat is a person or just a backpack. A simple truth table (Table 1) will be used for this procedure.

<table>
<thead>
<tr>
<th>PIR sensor output</th>
<th>Pressure Sensor output</th>
<th>Human Presence</th>
</tr>
</thead>
<tbody>
<tr>
<td>HIGH</td>
<td>HIGH</td>
<td>YES</td>
</tr>
<tr>
<td>HIGH</td>
<td>LOW</td>
<td>NO</td>
</tr>
<tr>
<td>LOW</td>
<td>HIGH</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>(YES if the PIR sensor output or the Human Presence output had been HIGH the previous clock cycle)</td>
<td></td>
</tr>
<tr>
<td>LOW</td>
<td>LOW</td>
<td>NO</td>
</tr>
</tbody>
</table>

Table 1. Truth Table for distinguishing the Presence of Humans

For when both the PIR and Pressure sensors are triggered, we can be sure that there is an actual human sitting in the seat. When the PIR sensor is triggered, but the Pressure Sensor is not, it would most likely mean that someone had walked past the seat and had not taken the seat itself. When only the Pressure sensor is triggered, we know that there is something in the seat, but we want to make sure that the thing occupying the seat is a human. If a person sitting in a seat were to sit very still, the PIR sensor would eventually fail to acknowledge the presence of a person due to the lack of change in heat radiation. Thereby we will implement a special case where if the output of the PIR sensor output or the human presence output was HIGH in the previous clock cycle, it would remain high until the pressure sensor is released. When both the PIR sensor and the pressure sensor is not picking up anything, there is no human presence.
Another key component is the pressure sensor. In order to find the amount of fixed resistance that we would need, we ran the equation for the voltage divider.

\[
Vin \left( \frac{R_1}{R_1 + R_2} \right) = V_{out}
\]

Figure 8. Circuit Diagram of the Pressure Sensor
The following plot shows the outcome for Vout when different resistor values were used for the R1 resistor for a range of R2 being 400Ohms to 2600Ohms while Vin was 5V.

![Graph of Voltage vs Resistance for Pressure Sensor](image)

**Figure 9. Plot for Voltage vs Resistor for Pressure Sensor**

Since the I/O pins for the Atmega328p could interpret a digital high from 1.5V we decided to use a 1k Ohm resistor as the fixed resistor as with this value we could derive both a digital low and a digital high from our pressure sensor.
To figure out the resistors that we needed for the LED controller transistors, we did the following calculations.

![Circuit Diagram of a single Transistor](image)

When we use NPN BJT transistor we need to calculate the value of Va from the decoder output. When setting an input voltage, we need to reduce the input voltage because the maximum rating base emitter voltage ($V_{BE} \approx 0.7V$) is 5V. In order to do this, we applied a resistance R1 between base and Va.

The equation for this is

$$\frac{V_a - V_b}{I_b} = R1 \quad \text{where} \quad V_A = 5V, \ V_B = 3.3V, \ I_B = 5mA.$$  

Thus, R1 is $\frac{5V - 3.3V}{5mA} = 340\Omega$. 
We also want the base emitter junction to be in forward biased mode.

And between VCC and Vc, there needs to be another resistance.

\[ R2 = \frac{VCC-Vc}{Ic} \]

where \( Ic = 0.8 \text{ mA} \), \( VCC = 5V \), \( Vc = 3.3V \).

Thus, \( R2 = \frac{5V-3.3V}{0.8mA} = 2.12K\Omega \).

We thought we needed a resistor between ground and emitter because some current might flow in reverse from ground to the transistor. Therefore, we used huge value resistor for R3 to try and remove that reverse current.

And the I-V characteristic of the MOSFET is

![I-V characteristic of MOSFET](image)

Figure 11. Plot of I vs V for Transistor

So the saturation happened when \( V_{DS} = 2V \), \( I_D = 100 \text{ mA} \).
<table>
<thead>
<tr>
<th>Devices</th>
<th>Power Consumption(mW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status LED</td>
<td>1680</td>
</tr>
<tr>
<td>PIR Sensors</td>
<td>5200</td>
</tr>
<tr>
<td>Pressure Sensors</td>
<td>224</td>
</tr>
<tr>
<td>Decoder</td>
<td>100</td>
</tr>
<tr>
<td>Multiplexer</td>
<td>100</td>
</tr>
<tr>
<td>Microcontroller</td>
<td>82</td>
</tr>
<tr>
<td>USB Module</td>
<td>330</td>
</tr>
<tr>
<td>Wifi Module</td>
<td>561</td>
</tr>
<tr>
<td>Total</td>
<td>8277</td>
</tr>
</tbody>
</table>

Table 2. Power Consumption Calculations

4. Requirements and Verifications

<table>
<thead>
<tr>
<th>Component</th>
<th>Requirement</th>
<th>Verification</th>
<th>Points</th>
</tr>
</thead>
</table>
| PIR Sensor     | • The sensor will give a high output of 3.25~3.35 when sensing an object with a heat radiation higher than 30°C. Heat radiation below 30°C will give a 0.05~0.1V low output.  
• The sensor will output 3.25V~3.35V when an object with heat radiation of 35°C | • Connect the PIR sensor to a power supply of 5V. Take a voltmeter and measure the output voltage from the PIR sensor when a human hand (heat radiation of around 36.5°C) is waved in front of the sensor 20cm away. The output voltage should fall into the boundaries of the requirement voltage for when the hand is there and when the hand is not there | 10     |
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure Sensor</td>
<td>• The pressure sensor will provide around 2400<del>2800 Ohms of resistance when 0N of force is applied, but when a force of 40N is applied, the resistance will be lowered to around 400</del>800 Ohms.</td>
</tr>
<tr>
<td></td>
<td>• Connect the input and output wires of a Pressure Sensor with an Ohmmeter to see that the resistor values of the requirements are met for when it is left alone and when force is applied.</td>
</tr>
<tr>
<td>Power Converter</td>
<td>• The power supply will take a 110V<del>240V AC input and be able to provide a 4.95V</del>5.05V DC output.</td>
</tr>
<tr>
<td></td>
<td>• Connect a multimeter to the output of the converter while it is connected to a standard 120V AC outlet and verify that it meets the requirement voltage.</td>
</tr>
</tbody>
</table>
Buck Boost Converter
- The Voltage Converter should take a 4.95V~5.05V input and able to output a constant supply of 3.25~3.35V current
- Connect the input of the voltage regulator to a power supply set to 5V and connect the output of the regulator to a multimeter to see if the output voltage matches the requirements

Microcontroller
- The microcontroller should be able to take a 3.1~3.5V input as high and 0.0~0.3V input as a low
- Be able to distinguish the presence of a human or an object in each seat. The accuracy should be at least 95%
- Program the microcontroller to send a 3.3V output to pin 4 when it reads 3.1~3.5V on pin 14. Then connect a 5mm LED to pin 4 and connect a voltage supply set to 3.3V to pin 14. The LED should light up when the power supply is on.
- Give random inputs of 1 and 0 to pins 14~17 on the microcontroller, then run the distinguishing algorithm and check the outputs of pins 23~28 to see if the truth table for the algorithm is correct
<table>
<thead>
<tr>
<th>Component</th>
<th>Requirements and Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status LED</td>
<td>- The LED should be able to be tuned on for 10 hours straight without burning out.</td>
</tr>
<tr>
<td></td>
<td>- The LED with an input voltage of 3.3V will be bright enough to be distinguishable under standard fluorescent light from a distance of 10m</td>
</tr>
<tr>
<td></td>
<td>Connect a LED to a voltage source and 300Ohm resistor and provide a 3.3 volt current. Then keep it on for 10 hours straight and check the temperature of the LED to make sure that it does not go over 50C.</td>
</tr>
<tr>
<td></td>
<td>Connect a LED to a voltage source and 300Ohm resistor and provide a 3.3 voltage current. Then check if the LED can be easily distinguishable from a 10m distance with an accuracy of 90% against an LED that is not on.</td>
</tr>
<tr>
<td>Wifi Module</td>
<td>- The Wifi module must be able to accurately send information to the main hub at least a distance from 50m.</td>
</tr>
<tr>
<td></td>
<td>Establish connection between the Wifi module and the main hub from a 5m distance and slowly increase that distance to 50m and make sure that the connect remains unbroken.</td>
</tr>
<tr>
<td></td>
<td>Test the speed of the wifi connection with sample packets of</td>
</tr>
</tbody>
</table>

5
5. Cost analysis

5.1 Parts

<table>
<thead>
<tr>
<th>Parts</th>
<th>Serial number</th>
<th>Unit Price</th>
<th>Quantity</th>
<th>Total Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED</td>
<td>L1-1-W5TH15-1</td>
<td>$0.5</td>
<td>30</td>
<td>$15</td>
</tr>
<tr>
<td>PIR(Pyroelectric Infrared) sensors</td>
<td>10 pack HC-SR501</td>
<td>$17</td>
<td>2(20)</td>
<td>$34</td>
</tr>
<tr>
<td>WI-FI module</td>
<td>MOD-WIFI-ESP8266-DEV</td>
<td>$6.95</td>
<td>1</td>
<td>$6.95</td>
</tr>
<tr>
<td>Microcontrollers</td>
<td>Atmega328P-PU</td>
<td>$3.70</td>
<td>1</td>
<td>$3.70</td>
</tr>
</tbody>
</table>

- The speed of the data rate should be stable at 1Mbps.
- The computer will be able to receive the collective data from all the intermediate hubs.
- The information should be updated every second.
- We will test to see if the computer can receive information from one intermediate hub and proceed from there to increase the number of connected hubs.
- Check the update speed with a time stamp and measure the time it takes to get a correct reading from a sensor to displaying the information on the computer.

500kb size and find the speed of the connection by measuring the time at which it takes to transfer that data.
<table>
<thead>
<tr>
<th>Description</th>
<th>Specifications</th>
<th>Price</th>
<th>Quantity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>120VAC-5VDC converter</td>
<td>5V 1A switching power supply adapter 1.2m input 110V to 240V</td>
<td>$3.60</td>
<td>1</td>
<td>$3.60</td>
</tr>
<tr>
<td>Register</td>
<td>CF1/4C122J</td>
<td>$0.14</td>
<td>34</td>
<td>$4.76</td>
</tr>
<tr>
<td>Capacitor</td>
<td>F380J106MMA</td>
<td>$0.19</td>
<td>4</td>
<td>$0.76</td>
</tr>
<tr>
<td>DC-DC Boost-Buck adjustable converter</td>
<td>TPS63031DSKT</td>
<td>$2.4</td>
<td>1</td>
<td>$2.4</td>
</tr>
<tr>
<td>NPN BJT transistor</td>
<td>2N3704</td>
<td>$0.6</td>
<td>16</td>
<td>$9.6</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>$80.77</td>
</tr>
</tbody>
</table>

### 5.2 Labors

<table>
<thead>
<tr>
<th>Name</th>
<th>Hourly Rate</th>
<th>Total Hours Invested</th>
<th>Total = Hourly Rate<em>2.5</em>Total Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jae Hyun Kang</td>
<td>$30/hr</td>
<td>160</td>
<td>$12000</td>
</tr>
<tr>
<td>Jun Sung Lee</td>
<td>$30/hr</td>
<td>160</td>
<td>$12000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$30/hr</strong></td>
<td><strong>320</strong></td>
<td><strong>$24000</strong></td>
</tr>
</tbody>
</table>

### 5.3 Total fees

<table>
<thead>
<tr>
<th>Sector</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor</td>
<td>$24000</td>
</tr>
<tr>
<td>Parts</td>
<td>$80.77</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$24080.77</strong></td>
</tr>
</tbody>
</table>
6. Discussion of Ethics and Safety

6.1 IEEE Code of Ethics

The following are the IEEE code of Ethics that we will most want to adhere to during the construction of our project.

[1] to accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment

[3] to be honest and realistic in stating claims or estimates based on available data;

[5] to improve the understanding of technology; its appropriate application, and potential consequences;

[7] to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;

[8] to assist colleagues and co-workers in their professional development and to support them in following this code of ethics

6.2 Safety

Most of our devices run on a low voltage around 3.3 to 5 and a low current at around 0.5mA. However, the only thing that could be dangerous is when the intermediate hub is connected to the outlet. Since the outlet is putting out current at 120Vs it is wise to take caution. Basic rules of handling an outlet will apply such as not touching it with a wet hand or sticking something into the hole of the outlet.
7 Citations

[1] Low-Cost Pyroelectric Sensor Networks for Bayesian Crowded Scene Analysis
http://ieeexplore.ieee.org/xpls/icp.jsp?arnumber=7051755

[2] Datasheet for the 74HC151D Multiplexer

[3] Datasheet for the 74HC238N Decoder

[4] Datasheet for the Atmega328p

https://easyeda.com/GerryChen/HC_SR501Human_Body_Infared_Sensor_Module-oO10UCSL3

[6] How to make a cheap Analog Pressure Sensor

[7] Atmega 328p-PU Power Consumption Experiment
http://gadgetmakersblog.com/power-consumption-arduinos-atmega328-microcontroller/

[8] Datasheet for the FT232RL USB Driver

[9] HC-SR501 PIR Motion Detector Product Discription
https://www.mpja.com/download/31227sc.pdf