**Final Report**

**ECE 458, Spring 2020**

**Group 9 - Acoustic Awareness Enabler**

University of Massachusetts Dartmouth

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# Project Overview

## 1.0 Background

The idea of the Acoustic Awareness Enabler is reported to have resulted from an incident in which the customer was watching a movie on her laptop with headphones. Her husband had called for her to respond, but she was unaware of this, her attention drawn to her computer. She thought then, what if there was a way for her headphones to let her know if someone was trying to get her attention? This was the apparent beginning of the Acoustic Awareness Enabler. Senior Design Project Group 9 seeks to realize this idea to a working device, capable of alerting a user wearing headphones to an external acoustic event.

## 1.1 Project objectives and Customer Requirements

The primary objective of the Group 9 Senior Design Project is to build a device known as the Acoustic Awareness Enabler, which is described as follows. The Acoustic Awareness Enabler is a device that is positioned between two auxiliary cables leading from an audio source to headphones. The device listens to outside noises and alerts the user (i.e. wearing headphones) to the unusually loud sound by turning off the audio throughput. The device uses three sensitivity settings, which provide the user with a selection of necessary threshold sound level (relative to surrounding environment) needed to pause the audio. The following were outlined as customer requirements for the Acoustic Awareness Enabler:

## Customer Requirements

The customer requirements for the Acoustic Awareness Enabler are given in Table 1. These were the required conditions set by the customer early in the project lifespan and have not changed. The seventh requirement was added to the project a few months into design. From these requirements, the engineering requirements are derived. The requirements shown in red were affected by COVID-19. Because of a lack of access to components, it was not possible to test the battery life of the device with all components in place, as evidenced by the test plans section. A 3.5mm audio jack for the input and output to the device was also not necessary as no device was constructed. Customer Requirement 7 was also not implemented.

Table 1 Customer Requirements

|  |  |
| --- | --- |
| **Cust. Req. #** | **Customer Requirements Description​** |
| 1 | Self-containment of power source (rechargeable) and battery life of 8 hours​ |
| 2 | 3.5mm audio jack for input and output​ |
| 3 | Must have 3 different levels of interruption noise sensitivity (High, Medium and Low sensitivity) ​ |
| 4 | When interruption is detected, the volume of the noise going through users’ headphones must be muted or lowered​ |
| 5 | Must be able to distinguish between ambient and interrupt with a 1% false interrupt detection rate​ |
| 6 | Must have a reset button to restart audio ​ |
| 7​ | Separate audio cable between device and audio source​ |

1. **Engineering Requirements, Constraints and Applicable Standards**

**3.1 Engineering Requirements**

The Engineering requirements are shown in Table 2 below. These requirements were also affected by the COVID-19 pandemic. As outlined in the customer requirements, requirements 1, 2 and 7 could not be fully demonstrated as no physical device could be completed. However, a theoretical approach was taken to meet the other requirements. Three levels of interruption noise sensitivity were demonstrated within the   
“AA\_Enabler” program in the appendix and in section 6.6.2. The processing in MATLAB done in the subsequent sections of 6.4 satisfy 3.1 and the requirements under Requirement 5. Requirements 3.2 and 4.1 are satisfied by the demonstration of the Acoustic Awareness Enabler prototype. This also satisfies all of the requirements under Requirement 6.

Table 2 Engineering Requirements

A screenshot of a cell phone

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## 3.2 Constraints

The following constraints have been imposed on the project. These have mostly remained constant throughout the course of the design project. A major area of concern for the physical device was portability factor, as the device was meant to be used at home as well as on the go. Another constraint was form factor or shape of the device. This would have been a necessary consideration when factoring in the device fitting into the enclosure. Another area of concern was how available components were for assembly. Due to COVID-19 many of these constraints were not constrictive. For example, the group was well under the original budget of $500 because no physical PCB was realized.

* Portability
* Form Factor (maximum size constraint of 3 x 2.5)
* Availability of Components
* Budget of $500 supplied by the customer
* Time: Project must be completed by Spring 2020

## 3.3 Standards

The list below is a compilation of ethical standards that the project adhered to. The IEEE code of ethics contains 10 ethical statements that must be adhered to for practicing engineers. For communicating with the microcontroller, the C programming language is used, which contains its own standards. The ports of the device are standard 3.5mm jacks. Sound levels must comply with a few standards listed below. I2C and SPI standards are relevant to hardware interfaces for seven bit addressing. The enclosure and battery were not used for the project, but the standards for these are listed.

* IEEE Code of Ethics
* Microcontroller Coding – ATMega328pb, C Programming AVR
* 3.5mm Auxiliary Port
* Sound Level – IEC 652 TYPE2 and ANSI S1.4 TYPE 2
* I2C and SPI Standards: 7 bit addressing
* IEC62133 – Battery Safety for Lithium Polymer Batteries
* Electrical Enclosures – IP40, NEMA 1

## 3.4 Ethical Issues

COVID-19 presents many new issues to the forefront which were not present before the pandemic occurred. The evacuation of on-campus students and faculty has effectively altered the expected outcome of the final design product. Due to a lack of availability of physical components, emphasis has shifted towards a more theoretical approach. Design tends to differ from manufacturing and therefore a necessarily accurate comparison between the two cannot be made. The situation also presented scheduling issues for the final few months of the project and require restructuring of previous plans. Zoom software was used to abide by campus and societal rules of social distancing.

## 3.5 Concept of Operations

In terms of user interaction with the Acoustic Awareness Enabler, there arise only the following situations: turning the device on or off, changing the sensitivity threshold and resetting the device to start a new cycle of data collection or to turn the audio back on after it was turned off as a result of an interrupt.

Behind the scenes, the Acoustic Awareness Enabler is taking in acoustic data and testing whether a recent level exceeds a threshold level calculated from the average and standard deviation of a longer period of data. If the device finds that the sound level has not been exceeded, it will replace the oldest data set with the most recent and calculate the average and standard deviation continuously and test if a yet more recent sound will exceed a new threshold. If the threshold is exceeded, the device will turn off the audio throughput to the headphones. The Software Diagram flowchart outlines how the device works “under the hood”. In attempt to outline how the Acoustic Awareness Enabler works functionally, a matrix was constructed to outline what events would be triggered at which time under all possible conditions. Finally, a high-level schematic was designed to give an overview of what hardware would be used to build the Acoustic Awareness Enabler.



Figure 1. AAE Comic Strip

# Functional Overview

The Acoustic Awareness Enabler’s function is to detect sudden increases in environment sound levels and mute audio throughput from one’s phone or computer to headphones when this sudden increase is detected. There are three sensitivity settings, which determine how loud a sound needs to be to pause one’s audio.

Six parts or subsystems make up the Acoustic Awareness Enabler. These subsystems are the Acoustic Information Subsystem, Processing Subsystem, Setting Information Subsystem, Auxiliary Switching Subsystem, Power Supply Subsystem and the Enclosure & Formfactor Subsystem.

A screenshot of a cell phone

Description automatically generated

Figure 2. Subsystems of the Acoustic Awareness Enabler

A microphone is used to collect environment sound levels. The sound level information is amplified and sent to the microprocessor, which analyzes this data to determine if an interrupt is achieved. The ON/OFF buttons RESET button and sensitivity setting buttons convey information to the microprocessor as to the current mode of operation. When an interrupt is detected, the microprocessor communicates this information to the digital switch, which will mute the audio throughput to the headphones. A battery power source is needed as well as an enclosure and a printed circuit board as a form factor apparatus to confine the components into the enclosure. Below is a high-level schematic that provides an overview of how these main subsystems interact.

A screenshot of a cell phone

Description automatically generated

Figure 3. High-Level Schematic

The following table outlines the various modes of operation that the Acoustic Awareness Enabler is found, as well as identifying which possible changes would be needed to alter the current mode of operation.

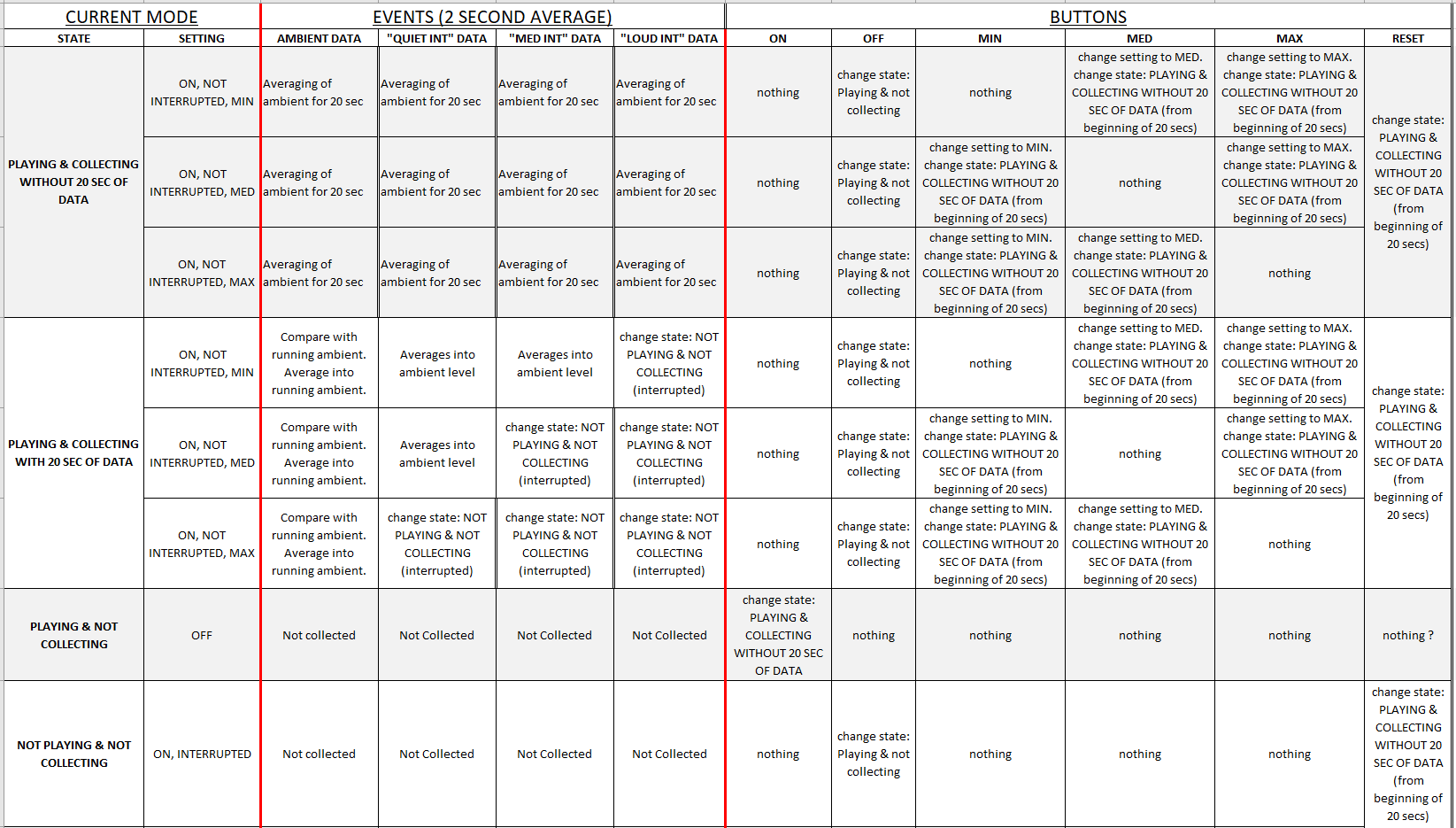


Figure 4. Functional Flowchart

# 5. Alternatives

Early in the design project, many alternatives were explored with options weighed based on specific criteria. The major factors considered were choice of microcontroller and method of threshold calculation. Towards the middle of the design process, several new factors were considered for both the microcontroller and the threshold method. These will be explored in the subsection below.

## 5.1 Alternative 1 – Microcontroller Selection

At the start of the project 3 different microcontrollers were examined and from there the best choice between the microprocessors were chosen from.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Microcontroller | ADC Resolution | Architecture | Cost\* | SRAM | Voltage Range |
| **ATmega328PB** | **10-bit** | **8-bit AVR** | **$1.41** | **2 kB** | **1.8 V** – **5.5 V** |
| ATmega2560 | 10-bit | 8-bit AVR | $12.35 | 8 kB | 4.5 V – 5.5 V |
| ATSAMD21G18 | 14-bit | 32-bit ARM | $3.22 | 32 kB | 1.62 V – 3.63 V |

\*Cost Information is based on the price of the device as of November 2019.

Alternative microcontrollers had their advantages to the ATmega328PB, mainly both devices had more RAM meaning the CPU could store more onto memory, which means that faster algorithms could be used to compute standard deviation and 2s Averages. Since adding 200x 10-bit integers can potentially leave a number that exceeds the highest 16-bit integer (65535), the ATSAMD21G18 having 32-bit registers and 32-bit operations means that we could add the average of all 200 samples instead of adding 50 samples and adding that to the 2s Average 4 times before actually averaging the number which is what was done in the program for the ATmega328PB. Another advantage is ADC resolution, higher resolution means being able to distinguish audio levels better, which the ATSAMD21G18 was best suited for among the three.

There are also multiple reasons for choosing the ATmega328PB, the main reason is familiarity, one of the team members has experience with using the CPU to write programs on. The other two CPUs that was not the case, especially with the ATSAMD21G18 which is also a different CPU architecture, which would have required additional time to learn to write programs for it. One additional reason is flexibility on voltage. The ATmega2560 needs at least 4.5V, the ATmega328PB could operate at 3.7V should the power savings be needed, giving this CPU the widest range of voltage levels to choose from.

The other reason is cost, it was much cheaper to get the ATmega328PB as a chip compared to getting the AT2SAMD21G18 or an ATmega2560 and it was also cheaper to purchase development boards (such as the ATmega328PB XPlained MINI) than it is to get development boards for other CPUs.

## 5.2 Alternative 2 – Threshold Calculation

When considering the method of interrupt threshold calculation, three methods were identified. These methods were the “Static dB Level”, “dB Interrupt-Factor Method” and “Data Analysis Method.”

The first method, the “Static dB Level” identifies a specific sound level which, when exceeded an interrupt is identified. For instance, one may select 80 dB to be the interrupt threshold. If a sound level is detected that exceeds 80 dB, then the audio throughput to one’s headphones is muted. This method was not selected for use in the Acoustic Awareness Enabler. The main issue identified with this method is that average sound levels vary for different environments. The average sound level in a lab is much quieter than in a car, for instance although both scenarios may be situations identified as candidates for the Acoustic Awareness Enabler. If this method were to be implemented, a way for the user to manually select the threshold level may be used, however this would invalidate the purpose for three threshold sensitivity settings.

The “dB Interrupt-Factor Method” identifies a ratio between an average environment level and the interrupt. For instance, one might say that an interrupt is approximately 1.4 times the level of the ambient. This method solves the issue with the first method with regards to the setting levels. The main issue with this method is that, given the level of fluctuation of environments, a dB-factor may be achieved regularly in some environments, while it may never be achieved in others. The issue about fluctuation of environments raises concerns about achieving a 1% false detection rate, which is an engineering requirement. For this reason, this method was not selected.

The “Data Analysis Method” analyzes data of an environment and compares it to a normal Gauβian distribution. The threshold is identified as a certain number of standard deviations from the average sound level. This method was found to be consistent with collected data on several environments. Further simulations suggested that a 1% false detection rate is best achieved using this method and for this reason, this method was selected for use in the Acoustic Awareness Enabler.

# 6. Technical Design Descriptions

## 6.1 Subsystem 1 – Analog Electronics

The Analog Electronics Subsystem can be divided into two parts, consisting of the microphone and the amplifier. These are two critical components of the Acoustic Awareness Enabler needed to get optimal results. The microphone takes in the ambient noise level and interrupts in the current environment where the user is located. These signals are fed into the amplifier subsystem so the signal can be amplified and analyzed by the microcontroller’s ADC. Considering that the project progress was restricted by COVID-19, the results below are mostly theoretical.

### 6.1.1 – Microphone Subsystem

A close up of a map

Description generated with high confidence

Figure 5- Microphone Subsystem

The microphone subsystem consists of a simple two pin microphone with the positive pin pulled high by a 2.2kohm resistor to a positive voltage rail of 5vdc. The value for the resistor was chosen based on the manufacturers specs to achieve nominal impedance within the microphone. A .1 microfarad capacitor was placed in parallel with the microphone and is known as a coupling capacitor. Its function in the circuit is too block the DC signal from the source voltage and only allow the AC component of the input signal to pass. Test conducted with this circuit yielded voltage outputs of 28-34mv. Below is an oscilloscope output viewed on an Analog Discovery 2 of the microphone taking in ambient noise and an interrupt represented by the spike in the middle of the graph.

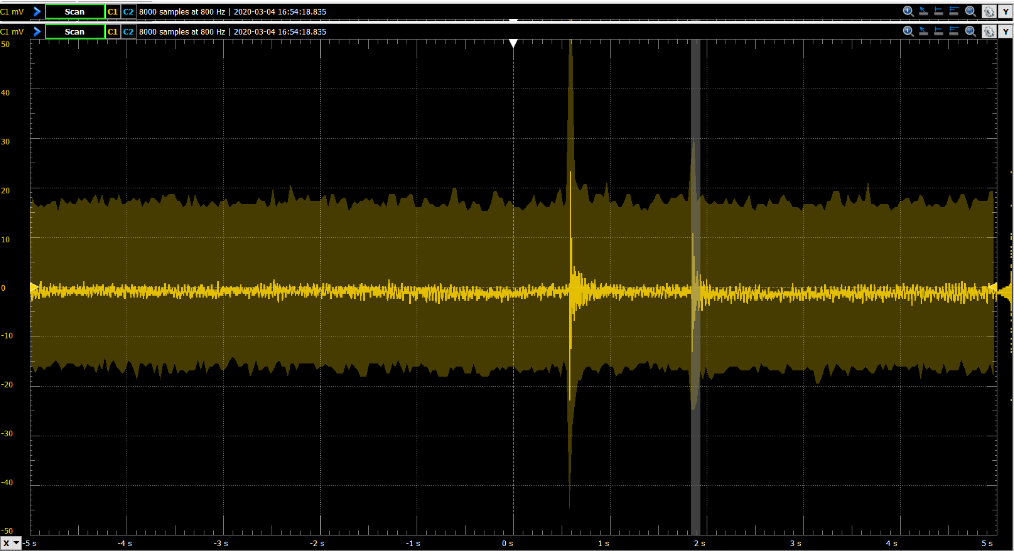


Figure 6 - Microphone Output

### 6.1.2 – Amplifier Subsystem

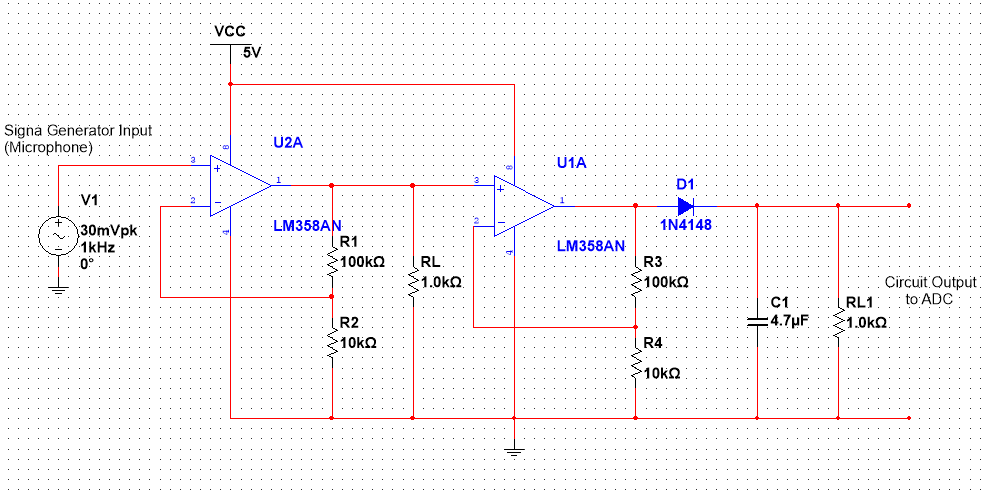


Figure 7 - Amplifier Subsystem

The amplifier subsystem consists of two operational amplifiers cascaded together, with the output of the second amplifier feeding into a rectifier circuit consisting of a diode and a capacitor. The amplifiers used are LM358 op-amps, which are in a non-inverting configuration. Luckily, two identical op-amps are housed within one IC chip allowing more flexible design of the PCB. The amplifiers are cascaded together to allow the proper gain needed of the signal coming from the output of the microphone. Due to their flexibility with voltage requirements, they utilize the same 5 vdc voltage rail as the microphone circuit. At the output of the second amplifier, amplified signal leads into a half-wave rectifier circuit consisting of a 1N4148 diode and a 470uF capacitor. The signal coming from the microphone is an AC signal and needs to be converted to DC to be processed by ADC within the microcontroller. Below is a simulation in Multisim where the output signal is probed before (yellow sine wave) and after (red dc output) the rectifier output to show how it works. Before the diode there was a voltage of 3.450vdc and after the diode the simulation showed 2.721vdc. The voltage drop is normal, and this proves that the amplification circuit is working considering that the input signal was only 30mvdc.

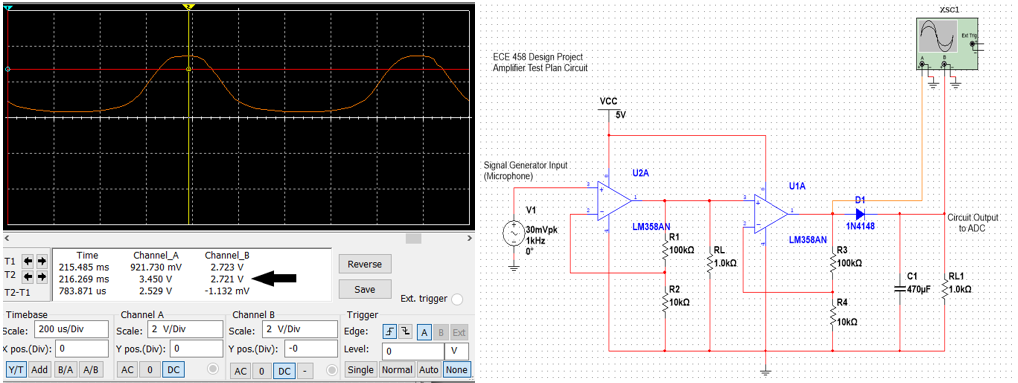


Figure 8 - Amplifier Circuit Output

## 6.2 Subsystem 2 – Auxiliary Switching

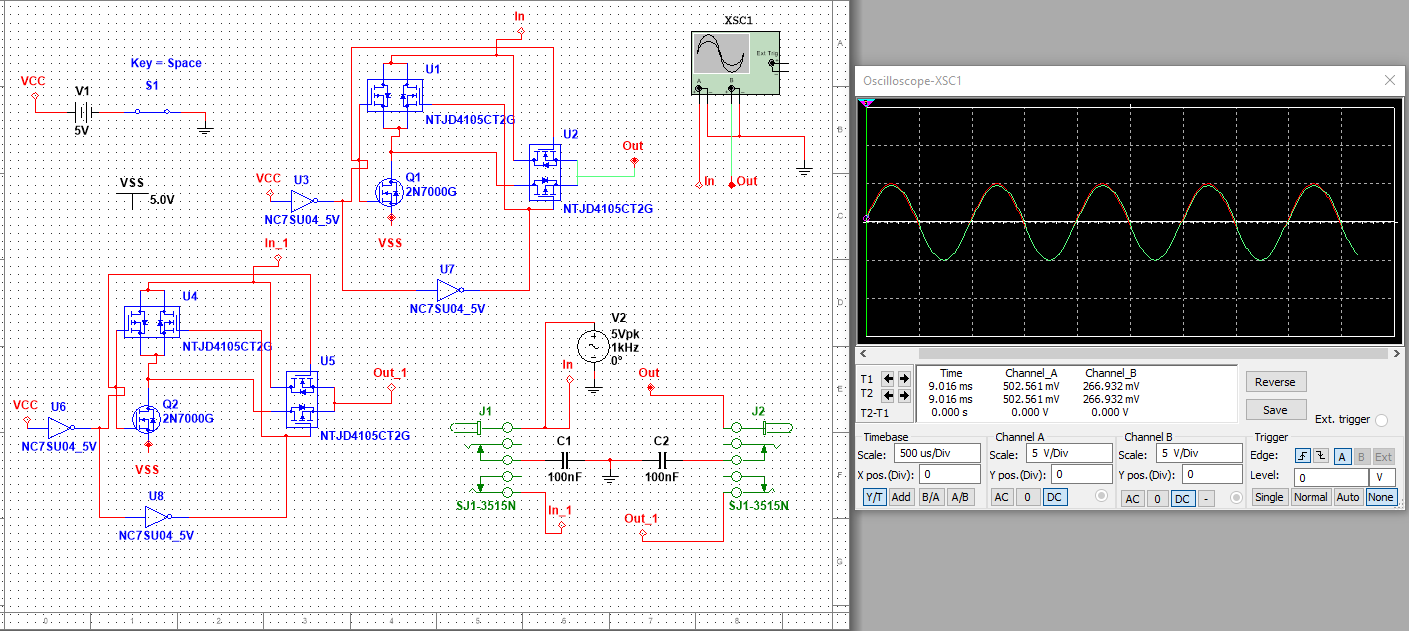


Figure 9. Aux w/ Digital Switch

By reading the digital switch data sheet, the team were able to emulate the inner circuit of one of the switches in the chip. The way the CD4066B CMOS Quad Bilateral Switch work is that inside the chip contains four switches that are each controlled by a controller pin that will close the switch when it receives a voltage signal and remains open when there is no signal connected to the pin. Now the idea is that the processor will send a signal to the controller pin to open the switch. When the processor uses the microphone to detect an interrupt in the environment, a signal will be sent to the controller pin to open the switch cause the flow of sound waves to not go through the aux port. While physically performing this circuitry in the lab, it turned out successful.

Initially the auxiliary ports had both grounds connected to each other instead of a common power rail as to reduce noise. However, this was revised as the noise wasn’t entirely cleared than if connected directly to the GND rail. The first revision includes connecting a capacitor to each auxiliary ground pin and connect them both together in parallel to the resistor and the resistor goes to ground, but the noise still retained. The second revision removes the resistor and just connects the capacitors straight to ground (*Figure 6*) and this solves the noise issue.

The Auxiliary Switch control pins are connected to PORTB1:0 on the ATmega328PB. One switch is used for each side of the headphone hence the need for two switches and two ports. To turn on both switches, pins PB1:0 are both on (sending current to the auxiliary port), and to turn both switches off, pins PB1:0 are both off. The Acoustic Awareness Enabler toggles both ports on and off depending on the standard deviation.

## 6.3 Subsystem 3 – Setting Information

What is important is creating a user interface that is simple to understand and get the jobs done. The main component is three buttons that set the threshold sensitivity, the three sensitivities are discussed further in detail in section 6.6.2. Aside from that is the power button, of course that turns the device off and on. Aux pot is included in both sides for input for headphones and output for device. Also, a reset button that will recalibrate the device for better calculation of the ambient noise.

Acoustic Awareness Enabler has 5 Buttons, an on/off button (connected to PORTC4), a reset button (connected to PORTC3) and three threshold sensitivity buttons (connected to PORTC2:0). PORTC2 sets the threshold sensitivity level to high, PORTC1 to medium and PORTC0 to low. On/Off Button sets the device into sleep mode and the auxiliary ports stay connected. When the button is pressed again while in sleep mode, the device restarts to initialization of the program. The Reset button restarts the program back to initialization.

Pin Layout for the Buttons:

|  |  |  |
| --- | --- | --- |
| **ATmega328PB I/O** | **Function** | **Description** |
| PORTC4 | On/Off Button | Turns the device Off and back On |
| PORTC3 | Reset Button | Resets the Program |
| PORTC2 | High Sensitivity Button | Sets Sensitivity Mode to High |
| PORTC1 | Medium Sensitivity Button | Sets Sensitivity Mode to Medium |
| PORTC0 | Low Sensitivity Button | Sets Sensitivity Mode to Low |

For debugging purposes (not incorporated into the PCB design), 3 LEDs were set to PORTD3 and PORTD1:0. LED lights indicate what sensitivity mode is activated.

Pin Layout for the LEDs:

|  |  |  |
| --- | --- | --- |
| **ATmega328PB I/O** | **Function** | **Description** |
| PORTD3 | High Sensitivity LED | If on, device is on High Sensitivity Mode |
| PORTD1 | Medium Sensitivity LED | If on, device is on Med. Sensitivity Mode |
| PORTD0 | Low Sensitivity LED | If on, device is on Low Sensitivity Mode |

## 6.4 Subsystem 4 – Processing Subsystem

The Processing Subsystem can be subdivided into four multiple subsections: The intake to the A/D converter data, threshold and standard deviation calculation, False Detection rates and environment data plots.

In the microcontroller, the whole processing subsystem takes place within a timer interrupt service routine that occurs once every 10ms. At the beginning of the ISR the program reads the ADC and stores a number into an array. After storing the first 50 numbers they are added to the 2s Average and the process continues until 200 numbers total are added to the 2s Average. From there the 2s Average is computed and stored into an array of 2s Averages and added to the 20s Average. The process repeats until there are ten 2s Averages and then the 20s Average is computed. With the 20s Average and 2s Average array the standard deviation is calculated. If the standard deviation exceeds the threshold (which varies depending on the sensitivity mode), the auxiliary ports are disabled, else the auxiliary ports are reenabled.

### 6.4.1 – ADC Intake

The Analog to Digital Converter was set to a reference voltage of 5V and input was set to a varying voltage in order to test the value presented by the 10-bit ADC. As shown in the table, as the input voltage on pin C5 increases towards the reference voltage, the ADC value increases up to the maximum 10-bit integer value (1023).

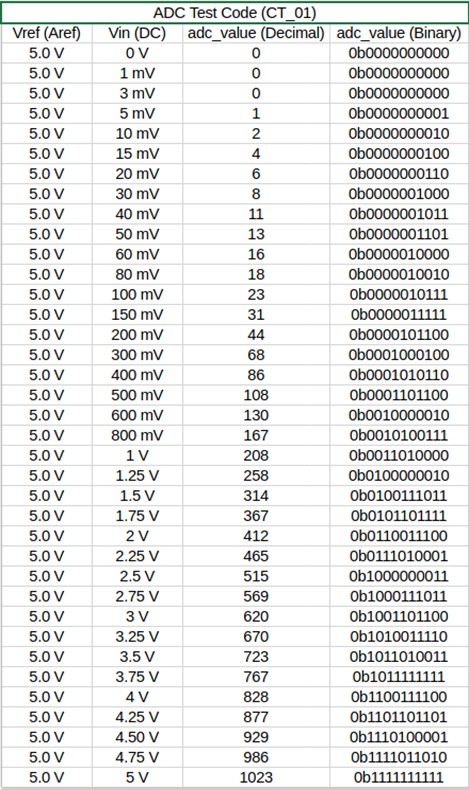


Figure 10 ADC Test Code

### 6.4.2 – Thresholds and Standard Deviations

The thresholds and standard deviations were the main area of concern for the processing subsystem of the project. Several program simulations and methods were used to generate accurate standard deviations for the various threshold levels. For the device, three user selected thresholds were needed, and these were all functions of the standard deviation and average ambient level of a particular environment. Environments were collected using a sound meter and plots were constructed in MATLAB demonstrating each data point along with overlapping curves for each threshold.

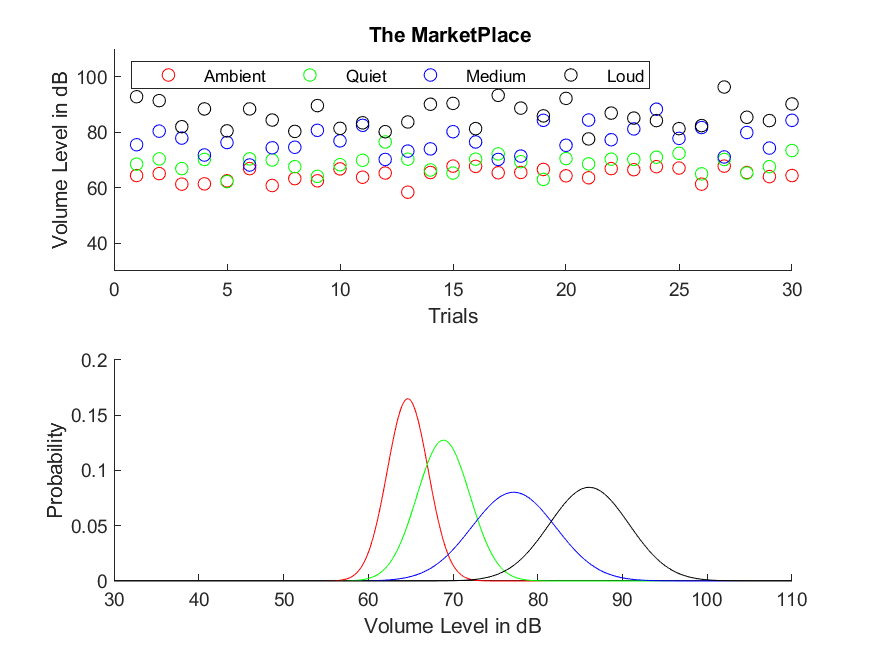


Figure 11 Marketplace

A screenshot of a cell phone

Description automatically generated

Figure 12 Senior Design Room

A picture containing screenshot

Description automatically generated

Figure 13 SENG

A picture containing screenshot

Description automatically generated

Figure 14 Wendy's

A picture containing screenshot

Description automatically generated

Figure 15 Campus Center

A picture containing screenshot

Description automatically generated

Figure 16 RF Photonics Lab

In each environment, thirty data points were collected for each category of ambient, low, medium and high interrupt levels. These are shown within each scatter plot as separate points. The full MATLAB code is included in the appendix. Gaussian or Normal Distribution functions are used for each threshold.

Additionally, a program in C# was constructed which utilized the samples collected with the sound meter to test out various standard deviation multiples for each threshold. The program used ClosedXML provided by NuGet to read the Excel files into a program and manipulate the data. The user could select which environment to read data from and then a threshold level was provided by the program depending on which level was inputted. A sample output is provided below, with the full program given in the appendix section.

A close up of a logo

Description automatically generated

Figure 17 Program Sample

### 6.4.3 – False Detection Rates

A false detection, with respect to the Acoustic Awareness Enabler is when an interrupt is detected when there is no physical reality that would suggest that an interrupt had occurred. A false detection may be frustrating for the user of the Acoustic Awareness Enabler as this means that their audio was turned off for no good reason. In order to assess the performance of the Acoustic Awareness Enabler, a demonstration of a sufficiently low (less than 1%) false detection rate is needed, as per engineering requirement (XYZ). The following information is needed to determine a false detection rate (FDR).

Table 3. Detection Rates Matrix

|  |  |  |
| --- | --- | --- |
| Variable | Name | Description |
| Environment Data (Ambient) | n/a | Collection of data points. Running intake information to the AAE. |
| 2 second average | 2secAve | The most recent 2 seconds of data (typically 200 data points) are averaged to determine an instantaneous sound level. |
| 20 Seconds Averages Array | Data20sec | The 20-second averages array is typically made of 10 numbers, which are 2-second averages of the most recent 20 seconds of data. |
| 20 Second Average | 20secAve | The average sound level from the last 20 seconds of data. |
| 20 second Standard Deviation | 20secStd | The standard deviation of the environment data is calculated. |
| Threshold Setting | Ț | The threshold setting is High, medium or low as selected by the user. The threshold setting is not a sound level, but a is the number of standard deviations from an ambient average that will theoretically trigger an interrupt. |
| Running Threshold | RT | The running threshold is the instantaneous sound level required for an interrupt to be detected. This value is updated after each new 2-second average.  The running threshold is calculated using the following formula: |
| Interrupt detected | ID | A detected interrupt means that the running threshold has been exceeded by the instantaneous 2 second average. |
| Real Interrupt | RI | A real interrupt is an event that may be detected. This is the case in which the source of an interrupt is worthy of being detected. The value of RI is determined by previous knowledge of the event, which was acquired through data collection. If the interrupt is real, RI=1. If the interrupt is not real, RI=0. |
| True Interrupt Detection | TID | A true interrupt detection, TID happens when an interrupt is detected that, through collected data is found to be a verified real interrupt. |
| False Detection | FD | False detection is an event where an interrupt is detected, while the interrupt is unfounded. |
| False Negative | FN | A false negative means that an interrupt was not detected, despite the existence of a real interrupt. |
| False Detection Rate | FDR | The false detection rate is the probability of the event , given that . |

In order to calculate a false detection rate, a data set is required that possesses both real interrupts and interrupt detection. Data samples were collected for six environments containing samples for all possible events. Using data from these environments, false detection rates may be calculated. One parameter that the designers of the Acoustic Awareness Enabler may easily manipulate is the Threshold setting (Ț) values. There exist three values that are used for the threshold setting, depending on the user-selected sensitivity setting of high, medium or low.

As shown next, the false detection rate (FDR) is a function of Ț. The false detection rate should be as low as possible, though it is an engineering requirement that it be below 1%. Since Ț is an array of three integers, there will also exist three different false detection rates.

The six environments were simulated in MATLAB using the following procedure. Ten random numbers from the collected data were allocated to the array signifying the previous 20 seconds. This data would be used to analyze how that collection of data will respond to other data points. The set of data is simulated against a controlled sequence of ambient-level sounds, then a series of quiet-level, medium-level and loud-level interrupts. Given knowledge of which levels are supposed to trigger interrupts, it was calculated whether and when an interrupt was detected. Using the definition of variables above, a false detection rate as well as a false negative rate was determined each time the program ran. The following figure is an example of the plotting of true interrupt detections (TID). The first 10 samples were the data points that supplied the basis for which the following were tested against. The following 15 were further ambient-level data points, where a true interrupt detection would be impossible (because real interrupt RI = 0). The remaining points were 25 each in the order of quiet interrupts, medium interrupts and loud interrupts.

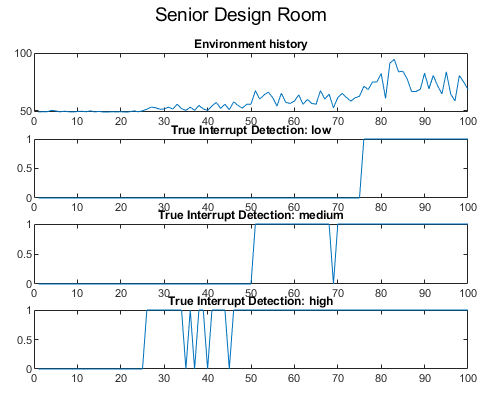


Figure 18. True Interrupt Detection in Senior Design Room

The number of standard deviations to threshold (Ț), as mentioned previously has significant influence on the rate of detection and therefore the rate of false detection and false negatives. In order to analyze which number of standard deviations to threshold (Ț) were suitable for various environments, a parameter sweep of Ț is performed in a new MATLAB program for many iterations of simulated environments to determine which values for Ț can result in the lowest false detection rate. The results are recorded in the table below.

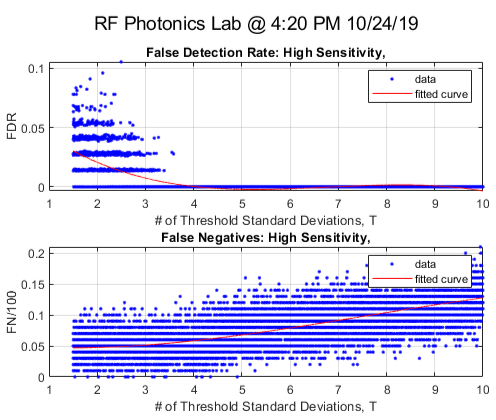


Figure 19. False Detection Rate vs. Threshold Ț

Table 4. Detection Rates from Environments

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Data Environment | Threshold Sensitivity Setting | Ț | Average False Detection Rate | Average False Negative Rate |
| RF Photonics Lab | High | 3.5 | 0.0018 | 0.052 |
| RF Photonics Lab | Medium | 24.5 | 0.0058 | 0.094 |
| RF Photonics Lab | Low | 40 | 0.041 | 0.064 |
| The Marketplace | High | 2 | 0.00 | 0.21 |
| The Marketplace | Medium | 5.75 | 0.00 | 0.12 |
| The Marketplace | Low | 11.5 | 0.01 | 0.22 |
| Campus Center | High | 4 | 0.00 | 0.39 |
| Campus Center | Medium | 5.5 | 0.00 | 0.39 |
| Campus Center | Low | 8 | 0.00 | 0.23 |
| Wendy’s | High | 3.75 | 0.00 | 0.63 |
| Wendy’s | Medium | 4.5 | 0.00 | 0.43 |
| Wendy’s | Low | 8.5 | 0.00 | 0.24 |
| SENG/On the Go | High | 3.25 | 0.00 | 0.25 |
| SENG/On the Go | Medium | 6 | 0.00 | 0.32 |
| SENG/On the Go | Low | 9 | 0.00 | 0.24 |
| Senior Design Lab | High | 4 | 0.006 | 0.03 |
| Senior Design Lab | Medium | 30 | 0.003 | 0.10 |
| Senior Design Lab | Low | 55 | 0.02 | 0.04 |

A challenge is posed then, since numbers of standard deviations to threshold Ț are at varying levels for optimization, how is the most appropriate number, Ț selected in order to produce the best performance? There is an inevitable tradeoff between performance in quieter areas with lower standard deviations and performance in areas with high volume levels and higher standard deviations. Once a threshold number is chosen for each setting, there will need to be a method of analyzing the system performance. While the False Positive Rate or False Detection Rate is more important than the False Negative Rate, it would not suffice for the False Detection Rate to be zero, but the False Negative Rate is 100%; this case would render the device useless. One method of analyzing both qualities is the receiver operator characteristic plot.

### 6.4.4 – Receiver Operator Characteristic

A receiver operating characteristic describes how a system behaves with respect to its false positive (or false detection) rate and true positive (or true interrupt detection) rate. Depending on the type of system, a false negative may be more desirable than a false positive. In a choice between a false negative and a false positive, the Acoustic Awareness Enabler prefers a higher false negative rate over a higher false positive rate. This means that it is preferred that it is preferable that the AAE will not stop audio throughput even when it should have, as opposed to the case where it stops audio throughput when it shouldn’t have. The receiver operator characteristic may be shown as a scatter plot with the false detection rate on the x-axis and the true positive rate on the y-axis. Each point indicates a trial in which both the false positive and true positive rates were calculated. As demonstrated previously, it is possible to perform a simulation of the process of the AAE and identify the false positive and false negative rates. Therefore, the operator characteristic can be known.

As discussed previously, the false detection rate and false negative rate are a function of the number of standard deviations to each threshold level (Ț). This figure can be altered to produce a more desirable receiver operator characteristic. There are two approaches of accomplishing this, however.

For one, the number of standard deviations to the threshold levels (Ț) can be optimized separately for the environments available. This approach was considered less in the early development stage, as it was considered complicated to accomplish and the potential benefits were not explored for this reason. Simulations at the later stages of development also demonstrated how particular the system may be and how much of an impact the number of standard deviations to threshold (Ț) may have on the false detection rate, which should be 1% or less. Although it may complicate the problem, the results may be improved as it would allow the AAE to have better performance in each environment. One method of allowing this type of optimization for each environment would be to allow the number of standard deviations to the threshold (Ț) to be a function of the ambient average volume level and standard deviation, since these are the main differentiating qualities of the environments. A piecewise function or if-then statement implementation could be problematic, as it would require testing of scenarios where the environment is categorized on the boundary of each if-then statement and prone to fluctuating between identified environments. Therefore, it would be proposed that the number of standard deviations to the threshold (Ț) would have to be continuous and either a linear, quadratic or higher-order equation. Also note that, T being three separate solutions for each threshold settings, there would be three equations for each sensitivity setting. Further, it may require a larger selection of environment samplings to produce an accurate quadratic or higher order Ț function.

The other approach is a compromise, to select a static value for Ț that will benefit some environments in terms of the Receiver Operator Characteristic and produce sub-optimal results in others. It is also the case that some environments are expected to be more likely scenarios for the use of the Acoustic Awareness Enabler. A weighting system can be used to determine a preferable performance for the more important locations. The weighting factor multiplies the thresholds and is then divided to produce a weighted result:

Table 5. Weighted Calculation for Threshold

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Location | Importance Weighting Factor | High Sensitivity threshold | Medium Sens. Threshold | Low Sensitivity Threshold |
| Senior Design Lab | 5 | 4 | 30 | 35 |
| RF Photonics Lab | 5 | 3.5 | 24.5 | 40 |
| Campus Center | 3 | 4 | 5.5 | 8 |
| Wendy’s | 3 | 3.75 | 4.5 | 8.5 |
| The Marketplace | 2 | 2 | 5.75 | 11.5 |
| SENG/On the Go | 1 | 3.25 | 6 | 9 |
| Total | 19 | **3.57** | **16.84** | **24.02** |

Receiver Operator Characteristics are now plotted for all environments to assess their performance. This approach is to be implemented with a final product Acoustic Awareness Enabler to assess its performance in a variety of scenarios. The program in Appendix 1234567789 may be used to analyze further data collected using a final product Acoustic Awareness Enabler. The theoretical performance using the weighted sums is summarized as follows.

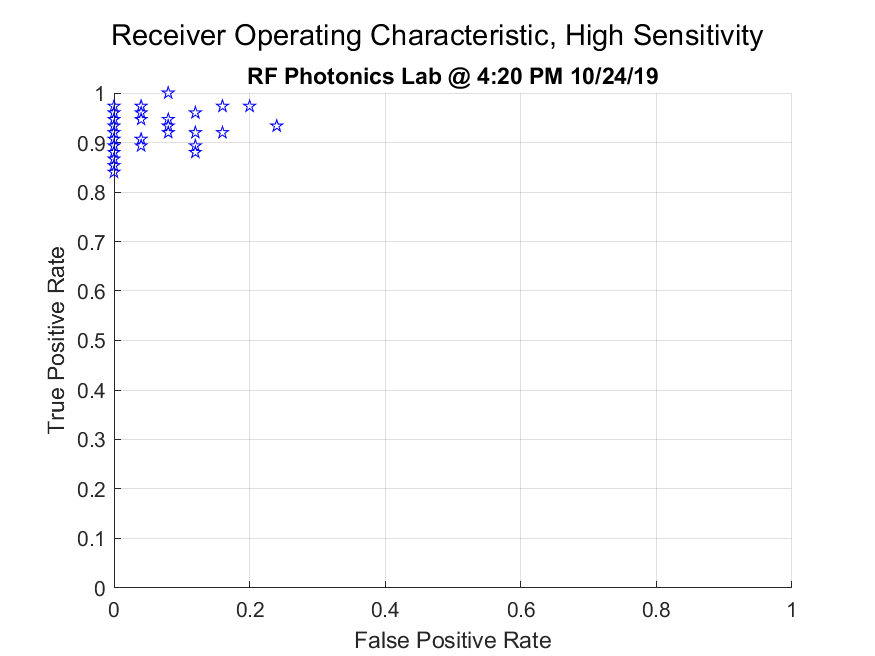


Figure 20. Receiver Operating Characteristic - RF Photonics Lab

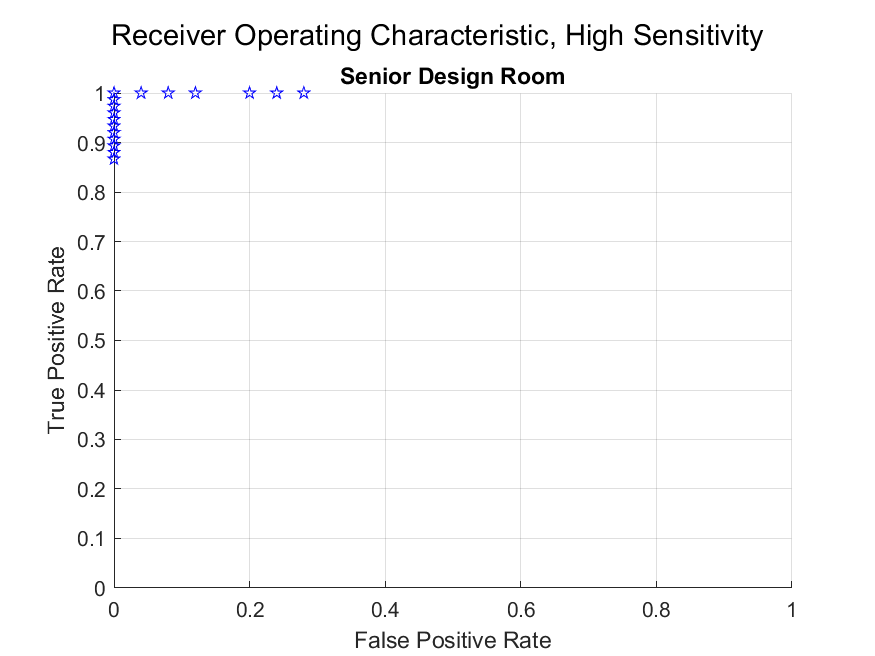


Figure 21. Receiver Operating Characteristic - Senior Design Room

The Senior Design Room and the RF Photonics Lab locations were deemed as more likely scenarios where a user is expected to employ the Acoustic Awareness Enabler, since they are more like a quiet home or office environment. Performance in these locations was reasonably good, with a great majority of false detection rates over many iterations of the program below 1%. If it was found that even better device performance is sought in these locations, increasing the thresholds (Ț) would be a simple way to achieve that performance increase in quieter, low fluctuating environments. The values are set lower for the consideration of device performance in other environments.

We propose that these tests be performed using an integrated. It would be important to ensure that the microphone we are using behaves as the sound meter, for instance. Also, worth mentioning is how the number of data point and averaging of the microcontroller may influence accuracy. The data collected currently is comprised of data points taken at random times. This contrasts with a simulation of a continuous stream of data collected from an environment, which is what the microcontroller can do. We also propose that improvement of performance be focused on a few likely environments of use, simulating office and home environments. Following the same procedure of identifying what levels a true interrupt may be in an environment will be key in determining the false detection rate of the device.

## 6.5 Subsystem 5 – Enclosure and Form Factor

### 6.5.1 – Enclosure

Due to constraints brought upon by the COVID-19 pandemic, the project did not make it to the point of utilizing an actual enclosure to house the final circuit board and all the peripherals. Instead a mock enclosure was made to show how components were planned to be placed if the project ever reached that point. Side A and B both have a panel mount 3.5mm jack installed for the audio input and output, respectively. As a note, the red square on Side A is where a micro-usb port would have been located to charge the internal battery. Side C consists of a SPST push-button switch to turn the Acoustic Awareness Enabler on or off and a momentary push-button switch to reset the device. Side D has three momentary pushbuttons to select the appropriate sensitivity level for the environment that the user is in.

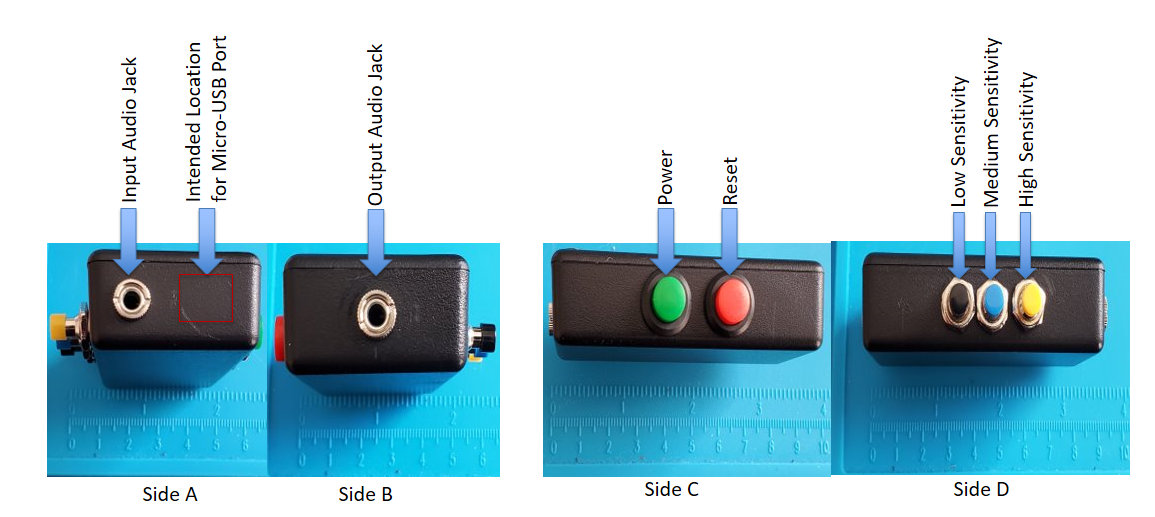


Figure 22 - Mock Enclosure Design

### 6.5.2 – Printed Circuit Board

As a result of the constraints which resulted from the COVID-19 pandemic, less emphasis was made on the final product integration. Furthermore, access to lab equipment, essential to producing a final approved printed circuit board layout was largely restricted. Electronics testing that would be necessary for a timely printed circuit board was delayed. Despite the issues that prevented the team from developing a printed circuit board, we have demonstrated that the printed circuit board is manufacturable in the constraint size of 3”x2.5”. A test layout (figure below) was developed on a board layout of the maximum size constraint to prove that this constraint is not an issue for the printed circuit board.

A circuit board

Description automatically generated

Figure 23. Initial PCB for Size Constraint Test

For a final printed circuit board, the following schematic should be used, were a printed circuit board to be manufactured. This schematic which includes pin payouts is proposed based on computer simulation and limited electronics testing. It is advisable that the schematic be tested before building a printed circuit board.

**A close up of a map

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Figure 24. Proposed Schematic Layout for PCB

## 6.6 Subsystem 6 Power Supply

The power supply design has not been finalized and that would depend on two factors, the physical size of the device and how much current the whole system requires total. Early in the project the PRT-13854 battery was selected (3.7V 850 mAH) although it takes two of them in series to reach or exceed 5V. One alternative there would be to run the ATmega328PB at 3.7V this way two batteries could be set up in parallel. In series, two batteries amount to 7.4V 850 mAH and in parallel it’s 3.7V 1700 mAh, the latter giving the system double the battery life.

To determine the power supply needed for the device the total current of the whole system must be measured. The whole system’s total current can be measured by connecting a multimeter between the power supply and the high voltage rail that components such sa the CD4066BE and the buttons. Due to unavailability of lab equipment the total current of the system could not be measured which puts a hold on choosing the power supply.

# 7. Test Plan and Results

## 7.1 VCRM (Verification Cross Reference Matrix)

The Verification Cross Reference Matrix (VCRM) illustrates the specific test plans which satisfy the Customer and Engineering Requirements. The table categorizes each requirement as an inspection, analysis, demonstration or test. As stated in the Customer Requirements and Engineering Requirements section, some of the requirements were not demonstrable.

Table 6. Verification Cross Reference Matrix

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Cus.Req. #** | **Eng. Req. #** | **Engineering Requirement Description** | **Related Test Plan Codes** | **Verification** | | | | **Where met in design** |
| **I** | **A** | **D** | **T** |
| 1​ | 1.1 | 8 hours of power supplied to device​. | ET\_09, ET\_13, ET\_15 |  |  | X | X | Power supplied by battery. |
| 2​ | 2.1 | Audio Source Input 3.5mm ​ | ET\_04, NT\_02 | X |  | X |  | Interface of enclosure and electronics. |
| 2.2 | Audio Source Output 3.5mm​ | ET\_04, NT\_02 | X |  | X |  |
| 2.3 | I/O interface – digital switch​ | ET\_03, ET\_07, | X |  |  | X | Digital Switch found in electronics and controlled by µC. |
| 3​ | 3.1 | Processing includes average and standard deviation calculations to determine threshold | PT\_01, PT\_02, PT\_04 |  | X | X |  | Process first validated in external software then programmed in µC. |
| 3.2 | Three separate sensitivity buttons | ET\_05, PT\_01 |  | X |  | X | Interface of enclosure and electronics. |
| 4​ | 4.1 | Digital switches turn off audio throughput when interruption threshold is exceeded. | ET\_10, ET\_11, ET\_12 |  |  |  | X | µC reads acoustic signals and alerts when threshold exceeding, sending a signal to the digital switch. |
| 5​ | 5.1 | Digital signal processing is invoked to determine the presence of an outlier in a set of acoustic level readings. ​ | PT\_04, CT\_01, CT\_04, CT\_05 |  |  | X |  | Process first validated in external software then programmed in µC. |
| 5.2 | Lowest Ambient Noise of 30 dB based on ANSI standards | ET\_01, PT\_01 |  | X |  | X | Microphone meeting requirement is selected, signal processing design in accordance. |
| 5.3 | Must have 100 Hz Sampling frequency to detect averages in sound (not reconstructing signal) ​ | CT\_05 |  |  | X |  | At the interface of the ADC on µC and analog input from microphone and analog electronics. |
| 5.4 ​ | Need a sound level detector | ET\_01 |  |  |  | X | Microphone is used. |
| 6​ | 6.1 | Physical reset button will be present on Acoustic Awareness Enabler to reset acoustic environment data. ​ | ET\_05, NT\_02 |  |  | X | X | Button pressed sends signal to µC to turn switch on after being off. If switch is on, clear processing data. |
| 6.2 | Use of switches to resume audio after reset button has been pressed. ​ | ET\_10 |  |  |  | X | Button pressed sends signal to µC to turn switch on after being off. |
| 6.3 | Button will recalibrate device and will delay further interrupts for 20 seconds while gathering data​ | ET\_11, PT\_04 |  |  | X | X | If switch is on, clear processing data. Set 20 second pause on interrupts. |
| 7​ | 7.0 | Audio (auxiliary) Cable Included with Enclosure | ET\_04 | X |  |  |  | Include test auxiliary cable. |

## 7.2 Test Cases and Test Results

The flowchart below outlines all test plans that were proposed at the beginning of the semester. The arrows indicate prerequisite plans for subsequent test plans. The test plans in this flow chart are color-coded by subsystem. These test plans have mostly remained the same since the test plan and test report, although some test plans were performed under less than ideal conditions as a result of lab availability. A few test plan prerequisites were forgone as a result of the pandemic constraints, which resulted in a “partial completion” condition. For instance, although a test plan such as PT\_07 technically required the completion of ET\_13, certain aspects of the test plan were attempted and in some cases partially completed. The next flowchart is color coded according to the level of completion. Solid green boxes indicate test plans that were considered a “Pass.” Light green boxes indicate that the test plan was partially completed, meaning that either only some parts of the test were attempted or they were performed without first completing prerequisites, which were unable to complete due to the pandemic constraints. Finally, test boxes colored black were not completed or were unable to be attempted.

![A picture containing text, clock

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generated](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4RCKRXhpZgAATU0AKgAAAAgABAE7AAIAAAAIAAAISodpAAQAAAABAAAIUpydAAEAAAAQAAAQcuocAAcAAAgMAAAAPgAAAAAc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAE1pY2hhZWwAAAHqHAAHAAAIDAAACGQAAAAAHOoAAAAIAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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0f8JIf+gNq/wD4Cf8A16n2chcrNuisT/hJD/0BtX/8BP8A69H/AAkh/wCgNq//AICf/Xo9nIOVm3WF4l/4+dD/AOwpH/6BJTv+EkP/AEBtX/8AAT/69Zms6pPfzaY0Gjari1vUnkza4+UK4459WFXTpyUtSoxdzrf4fwrmbb/kBeJv+vm6/wDQBVz/AISM4x/Y2r/+An/16rafb3M3h/Wy1rNC95NcPFFKu1yGUAcduaIxcU7+QJNLU1dGH/Ejsf8Ar2j/APQBVGYf8V9Z/wDYMuP/AEbDUGna49rplrbyaNq2+KFEbFrnkKAe/tVaTVZm8U2+oDRtV8iOylgb/RedzPGw4z6KapQlzN+ocruzrap6rp41PTZLXzDEWKsrgZ2srBlOO/IHFUP+EkP/AEBtX/8AAT/69H/CSH/oDav/AOAn/wBes1TmndE8rRPNp93epaG8lhV7e6Wb90hwQARjk9eaj1RRq1pPpnlXUJk+VZzDlVIOQevIyBTP+EkP/QG1f/wE/wDr0f8ACSf9QbVv/AT/AOvVKM73sO0ivdaBf3Ec5Nzb5vZg93HsYK6KgURg5yAcZJ78jiuhQEIoYAHHO3pWN/wkh/6A2r/+An/16P8AhJD/ANAbV/8AwE/+vSlGclZg1Jm3WHov/IxeIv8Ar7i/9Jo6X/hJD/0BtX/8BP8A69ZunarNa6tq1zLo2q7LyeOSLFrngQohzzxyppxpys/66oai7M0vGH/Iq3n0T/0NaW7/AOR30z/sH3f/AKHBWdrmpzato81lbaPqglmKhTJbbVHzA8nPHSrusSTWfiXT75bK6uoUtLiJjbR7yrM0JGRnuFb8qqMWkk/P8gS0t6m5isTwV/yJOk/9eqU7/hJP+oNq/wD4Cf8A16zfDmqzaX4bsLG50bVfOt4FR9trkZHvmpUJcjXp+ouV2OtrLOm3EGsTXllLEFulQTJKhOCmQCpBHUHGD6CoP+EkP/QG1f8A8BP/AK9H/CSH/oDav/4Cf/XqVCaDlkizBAdJF5KRJcfabkyhYo8lcqBj/wAd6+9ULjR5NVnuJkdoILxYkuI5oiHAjYkFee4OOfrU3/CSf9QbVv8AwE/+vR/wkn/UG1b/AMBP/r1SU1qtx2kSWOkzW+tT6hK8KmVCjJCrDzPmyGbJPI5Ax/eNa9Yn/CSH/oDav/4Cf/Xo/wCEkP8A0BtX/wDAT/69S4Tk7sTjJjfGX/IsTf8AXaD/ANHJW6K5HxDqk2p6LJa22jar5jSRMN1rgYWRWPf0BrT/AOEk/wCoNq//AICf/XqnTlyJev6D5XYXTP8Aka9b/wBy2/8AQWrarC0JprjWtVvZLS4tophCsYuI9jNtUg8Z963aip8X3fkTLcKRvun6UtI3Kn6VmSYvhAf8UXov/XhD/wCgCmagP+K30X/r1u//AGjVLQNVuNN8N6bZXGiar51vaxxSYtwRuVQDg7vWmXep3E3iXTr5NF1TybaCdH/0cZy/l4/i/wBk1z8y5EvT9D2fYz+tVJdHz9V1TsddVfULU3um3NqG2GeF4wxGcbgRn9azP+Ejf/oC6t/4DD/4qj/hI3/6Aurf+Aw/+KrXnizgjh60Wmlt5obb6FKml2tozQRfZriKYGJWIYIR6ngnFTaoF1WzudLaG6i89TF54hyqns2e4qP/AISN/wDoC6t/4DD/AOKo/wCEib/oCat/4DD/AOKqLwtY6OXEOXO1qtVqtyCfw/c3UV21y1pLLesvmq0b7FCptXGGz3J59faty0ha2s4YZJWmaONUaR+rkDGT7nrWV/wkb/8AQF1b/wABh/8AFUf8JG//AEBdW/8AAYf/ABVNOCd0TUhiakVGS0Xp6fkbdYOjf8jR4h/67Qf+iFp//CRv/wBAXVv/AAGH/wAVWXp2p3NrrerXUmi6p5d3JE0eLcdFjVTn5vUGlKabX9dCqOHqKFRNbruv5omr4v8A+RXu/ov/AKGtbVcprmp3GqaPNZ2+jamJJdoUvAAB8wPJ3e1dXVRacm15fqY1YOnQhGW95flEKKKK0OMKKKKAEP3T9KxPCI/4ozR/+vKL/wBBFbZ+6fpXPeEtQso/B2kK93ArCziBBlXj5R71DaU18/0OuEXLDysvtR/KQ/UR/wAVpon/AFwu/wCUVb+K5nUdQs28ZaK4u4CqwXWT5q8Z8v3rc/tSw/5/Lf8A7+r/AI0otXl6/oiq9Ofs6Wn2f/bpFo1xdnpN2fBN1p0tnIbnyiFjeFFGdx4DD731NdV/adh/z+W//f1f8aP7TsP+fy3/AO/q/wCNElGXUKNSrRTUY9U/u/4cSeWGOF7dJ4oZCpCjcBtJHHFcraaJqMkMUcNqtoFsYbS6WV9nnFWy+Cuc5GRux/Ga6V7jSJZPMklsnf8AvMyE/nU39p2H/P5b/wDf1f8AGlKKk9WVSq1KMWoR37oqeGbW4svDVjbXcC28sMIQxI2QuOgrVqr/AGnYf8/lv/39X/Gj+1LD/n8t/wDv6v8AjVxsla5z1FUqTc3Hd3MvRv8AkaPEP/XaD/0QtSeL/wDkV7v6L/6GtU9H1CzXxNr7NdwBWmgwTKvP7lfepPFd/Zy+GbpI7qBmIXAEqkn5196xuvZv5/qd/JP65Sdv+ff5ROioooroPJCiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigAooooAKKKKACiiigArPOgaOeuk2P/AIDJ/hWhRSaT3LjUnD4XYz/7A0f/AKBNj/4DJ/hR/YGj/wDQJsf/AAGT/CtCilyx7F+3q/zP72Z/9gaP/wBAmx/8Bk/wo/sDR/8AoE2P/gMn+FaFFHLHsHt6v8z+9mf/AGBo/wD0CbH/AMBk/wAKP7A0f/oE2P8A4DJ/hWhRRyx7B7er/M/vZn/2Bo//AECbH/wGT/Cj+wNH/wCgTY/+Ayf4VoUUcsewe3q/zP72Z/8AYGj/APQJsf8AwGT/AApV0LSEYMulWSsDkEW6ZB/Kr9FHLHsHt6v8z+8KKKKoxCiiigD/2Q==)

Figure 25. Original Test Plan Flowchart

A picture containing clock

Description automatically generated

Figure 26. Test Plan Flowchart with Completion Status

## 7.3 Test Summary

The following table outlines test plans and their corresponding completion status; pass, partial completion, not performed (fail). Test plans that were impacted by constraints of lab equipment are noted.

Table 7. Test Summary

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Eng. Req. ID** | **Test Code** | **Test Name** | **Pass/ Fail** | **Comments** |
| 5.2/5.4 | ET\_01 | Microphone Test | Pass | The microphone used about 28-35mV of electricity depending on Decibels of noise heard. |
| 5.4 | ET\_02 | Amplifier Circuit Test | Pass | The amplifier successfully amplified a signal that was at peak 17.6 mV to 197 mV. |
| 4.1 | ET\_03 | Digital Switch Test | Pass | Disconnecting the switch from vdd still left the switch on until it was connected to ground. |
| 2.1,2.2,5.1,6.3,7.0 | ET\_04 | Auxiliary Port and Cable Test | Pass | The headphone jack fit in the Aux port and successfully was able to send audio from one aux to the other. |
| 3.2, 6.1 | ET\_05 | Testing of Buttons and Switch | Pass | The buttons and switch worked perfectly. |
| 5.4 | ET\_06 | Analog Input Electronics Test | Pass | Combining the microphone and amp allowed for a increase in the voltage being read. |
| 2.1, 2.2, 2.3, 4.1 | ET\_07 | Audio Switch Test | Pass | \*Due to COVID-19, a DC power source was inaccessible, the workaround was to add 2x 3.7V batteries in series and a voltage divider to create a 5V DC source. |
| 3.1, 5.1, 5.2, 5.3, 5.4 | ET\_08 | Analog Integration w ADC Test and Debug | Partial Completion | Constricted by lab availability due to COVID-19 |
| 1.1 | ET\_09 | Power Consumption Test | Not Performed | Constricted by lab availability due to COVID-19 |
| 3.2 | ET\_10 | Audio Switching Function | Partial Completion | Constricted by lab availability due to COVID-19 |
| 3.1, 4.1, 5.1, 5.4 | ET\_11 | Interrupt Detection Device | Not Performed | Constricted by lab availability due to COVID-19 |
|  | ET\_12 | Acoustic Awareness Device | Not Performed | Test prerequisites incomplete. |
| 1.1 | ET\_13 | Battery Power Consumption | Not Performed | Test prerequisites incomplete. |
| All | ET\_14 | Acoustic Awareness Enabler 1.0 Debug Test | Not Performed | Test prerequisites incomplete. |
| 1.1 | ET\_15 | Device Lifetime Test | Not Performed | Test prerequisites incomplete. |
|  | ET\_16 | Device Improvement Methods | Not Performed | Test prerequisites incomplete. |
| 5.1 | PT\_01 | Threshold Setting as f(σ) Concept Validation | Pass | This data validates the concept of threshold as a function of standard deviation. Further tests improve accuracy of standard deviation. |
| 5.1,5.2 | PT\_02 | Standard Deviation Calculation | Pass | The plot shows that there is a general positive correlation between ambient level and standard deviation. |
| 5.1,5.2,5.3 | PT\_03 | Interrupt Calculation Process | Pass |  |
| 5.1,5.2,5.3 | PT\_04 | 20 Second Averaging, Interrupt Process | Pass | The program “interrupt.cs” only provides a simple initial test, since loud instantaneous noises tend to trigger the interrupt to occur, which is undesirable. This is because the program takes a two second average by taking only a minimum and maximum sound level and averaging those two discrete levels. Highest threshold is difficult to trigger, especially when standard deviation is high (>1). |
| 5.1 | PT\_05 | Processing Debug Test | Pass | Within the program at least, implementing a 30 second average vs a 3 second average did not improve the averaging process. An accurate standard deviation or average could not be obtained (See Figure 19). Recursive averaging does not change average calculation in a noticeable way. The iterative averaging method will be used. The timing yields a wide variance of ticks (between 4000 and 6000 ticks but can be as low as 500). This is done using the Stopwatch class in C# |
| 5.1 | PT\_06 | Standard Deviation Debugging | Partial Completion | Constricted by lab availability due to COVID-19 |
| 5.1,5.4 | PT\_07 | Device Accuracy Test & Debug | Partial Completion | Constricted by lab availability due to COVID-19 |
| 5.1 | CT\_01 | ADC Test Code | Pass | See Figure 32 |
| 2.3, 4.1, 6.2 | CT\_02 | Audio Switch Test Code | Pass | The Auxiliary Ports (Input and Output) both needed a 1kΩ resistor to GND. |
| 3.2, 6.1, 6.3 | CT\_03 | Setting Button Test Code | Pass | The code was tweaked in order to get the on/off button operating. |
| 2.3, 3.2, 4.1, 6.1, 6.2, 6.3 | CT\_04 | Main µC Test Code | Pass | No Comment |
| 6.2, 6.3 | CT\_05 | Process Implement in µC | Partial Completion | Partial Completion |
| Constraint of maximum size: 3.5” x 2” | BT\_01 | PCB Test Layout | Pass | Test proves that electronics and PCB can be fabricated under maximum constraint size. |
| 6.1,6.2,6.3, Constraint of maximum size: 3.5” x 2” | BT\_02 | Initial PCB | Partial Completion | Partial Completion: PCB not being ordered. Schematic for layout completed. |
| 6.1,6.2,6.3, Constraint of maximum size: 3.5” x 2” | BT\_03 | PCB Review | Not Performed | Test prerequisites incomplete. |
| 7.0, Constraint size | BT\_04 | PCB Manufacture Summary | Not Performed | Test prerequisites incomplete. |
| 6.1, 6.2, 6.3 | BT\_05 | PCB Function Test and Comparison | Not Performed | Test prerequisites incomplete. |
| 7.0, customer req. 1 | NT\_01 | Enclosure Selection | Pass with Failure criteria | Partial Completion with both Pass and Fail designations. Enclosure has been ordered despite test prerequisite completions. |
| 1.1 | NT\_02 | Enclosure Outfit for Components, I/O | Partial Completion | Test prerequisites incomplete. |
| 1.1 | NT\_03 | Enclosure Integration with Battery and PCB | Not performed | Test prerequisites incomplete. |

# 8. Risk Discussion

Present Risks within the Project:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Risk** | **Eng. Req.** | **Likelihood** | **Consequence** | **Risk Score** | **Possible Method to Mitigtae Risk** |
| Complications with accuracy of microphone communication with ADC (resolution issue). | 5.1 | Possible | Major | High | Proper amplification of mic signal testing mic/ADC. |
| Complications or inconsistency in achieving <1% false alarm rate. | 5.1 | Unlikely | Major | High | Troubleshooting of both hardware and software. |
| Complications in manufacture of PCB. | Not Req. | Possible | Moderate | High | Have professionals review PCB design and get it out for manufacture early. |
| Battery Life is Insufficient (< 8 Hours) | 1.1 | Possible | Moderate | High | Pre-calculations, Actual battery life tests. |
| Complications in creating a proper plastic/physical enclosure. | Not Req. | Unlikely | Moderate | Med. | Use pre-made case and modify. |
| Interruption Threshold will never be exceeded in an environment with high fluctuation (high standard deviation). | 5.1 | Possible | Minor | Med. | Possible limitations of device applications may alter threshold setting to operate differently in these settings (e.g. max ambient standard deviation). |
| Failure to get components in a timely manner. | All | Rare | Insignificant | Low | Most parts in possession, no rare parts. |

Due to COVID-19, none of these risks have been fully solved, although there are plans to mitigate these risks that would theoretically work.

|  |  |  |
| --- | --- | --- |
| **Risks** | **Possible Method to Mitigate Risk** | **Methods taken to Mitigate Risk** |
| Complications with accuracy of microphone communication with ADC (resolution issue). | Proper amplification of mic signal testing mic/ADC. | Test Plans for constructing an accurate ADC reading and microphone measuring (incomplete). |
| Complications or inconsistency in achieving <1% false alarm rate. | Troubleshooting of both hardware and software. | Signal processing of recorded data performed, and receiver operating characteristic plotted for environments. Lab constraints hampered ability to test signal processing theory with fully integrated design. |
| Complications in manufacture of PCB. | Have professionals review PCB design and get it out for manufacture early. | PCB layout not sent to manufacture due to pandemic constraints. |
| Battery Life is Insufficient (< 8 Hours) | Pre-calculations, Actual battery life tests. | Battery life tests not performed due to lack of lab availability. |
| Complications in creating a proper plastic/physical enclosure. | Use pre-made case and modify. | Pre-made case ordered and modified. |
| Interruption Threshold will never be exceeded in an environment with high fluctuation (high standard deviation). | Possible limitations of device applications may alter threshold setting to operate differently in these settings (e.g. max ambient standard deviation). | Concluded to be a non-issue in a trade off between interrupt detection accuracy and false detection rates as demonstrated by signal processing. |
| Failure to get components in a timely manner. | Most parts in possession, no rare parts. | Not proven to have been an issue. |

# 9. Plan, Schedule, and Costs

## 9.1 Plan and Schedule – Final Update

The schedule is outlined below. The dark gray represents actual time spent on tasks whereas the light gray represents what was planned throughout the semester. The actual and planned hours are outlined in the right- and left-hand columns respectively.





Figure 27 Plan and Schedule

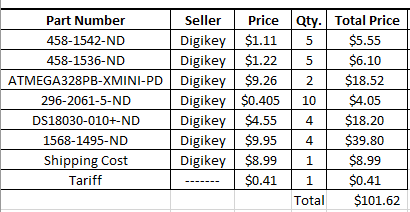
## 9.2 Actual Hours vs Planned Hours

The Plan and schedule section demonstrates that several processes took for less time than what was expected. This was partially because many activities were interrupted by the COVID-19 pandemic. Most of the electronics and enclosure related tasks were discontinued due to lacking access to university facilities. It was also due to inaccurate planning in some instances. Some sections were not attempted because the prior tests could not be completed. This is outlined in the Test Summary. The necessity of scheduling throughout both last semester and the present semester provided insight into the importance of keeping a schedule as well as discrepancies that can occur as a result of doing so.

## 9.3 Cost Summary

The cost summary is outlined below. The budget of $500 was not exceeded. Costs such as the printed circuit board were not done, which reduced the total cost of the project.

Table 8. Cost Summary



# 10. Summary

The Acoustic Awareness Enabler is a device equipped to provide a user with a customizable filter for background noise when listening to continuous audio. Although many parts of the project could not be completed due to circumstance, the project will likely be resumed by a future group. Suggestions for future work would include the physical construction of a printed circuit board and device. It would also be helpful for subsequent teams to adjust threshold levels if necessary. Threshold levels could be tailored to specific types of environments or could possibly cater to environments that are more realistic or expected for users of the device. Another area that could be expanded on would be doing spectral analysis on potential interrupts to filter based on frequencies. Certain characteristic sounds could be filtered out, such as unnecessary background noises which differ from human voices in terms of frequency spectrum. If a physical device could be completed, the customer could greatly benefit from having a convenient device with realistic sensitivity settings for attenuating outside audio. The device would be beneficial mostly on a personal level, for people who often use media devices on the go or around the home and would appreciate automatic interruptions when these are convenient.

**11. Lessons Learned / Impacts due to COVID-19**

COVID-19 presented many random variables into the equation which prevented the proper completion of the project. A physical device could not be obtained due to the circumstances. The final few months of the project proved to be quite a challenge. However once the team grew accustomed to remote meetings, it became second nature and a theoretical approach was taken.

Aside from COVID-19, many lessons were learned about teamwork and project planning. For many members of the team, this was the first time for completely independent group work. In the past, many group projects or assignments were highly structured and clear answers were obtained upon completion. The Senior Design project presented new challenges by forcing students to come up with answers independently, which provided appropriate preparation for the future workforce endeavors. It was also the first time that keeping a project schedule was required, which is very important for real world projects as well.

**12. Documentation**

## Appendix A. C# Threshold Program based on Physically Collected Data

using System;

using System.Data;

using Excel = Microsoft.Office.Interop.Excel;

using ClosedXML.Excel;

using System.Linq;

//In order to use ClosedXML namespace, you must download nuget from nuget website

//To enable it, go to Tools -> Nuget package manager -> Manage nuget packages for solution

namespace AA\_Enabler

{

class Program

{

/\*

\* Select environment from the environments that we have data for.

\* Loads selected environment. Choose 10 random numbers from the list of 30 numbers from the column for Ambient data.

\* Display the 10 random numbers. We currently do this, but instead of typing in 10 numbers, we want the environment to be simulated in some level as though the last 20 seconds were in that environment.

\* Calculate average and standard deviation for the environment and display threshold

\* Ask user to submit a new 2 second average for the environment.

\* Calculate if that new 2 second average is an interrupt for each threshold setting

\*

\* average of each environments - real interrupt level

\*

\*

\*\*/

static void Main(string[] args)

{

Console.WriteLine("Select Environment by Environment No (1-6):");

string selection = Console.ReadLine();

int select = int.Parse(selection);

DataTable \_dt = new DataTable(); //DataTable Stores values

DataSet \_ds = new DataSet(); //DataSet is used to display values

string Book1 = @"C:\Users\Jared\source\repos\AA\_Enabler\Book1.xlsx";

string Book2 = @"C:\Users\Jared\source\repos\AA\_Enabler\Book2.xlsx"; //Load file from computer location, change as necessary based on where the file is

string Book3 = @"C:\Users\Jared\source\repos\AA\_Enabler\Book3.xlsx";

string Book4 = @"C:\Users\Jared\source\repos\AA\_Enabler\Book4.xlsx";

string Book5 = @"C:\Users\Jared\source\repos\AA\_Enabler\Book5.xlsx";

string Book6 = @"C:\Users\Jared\source\repos\AA\_Enabler\Book6.xlsx";

switch (select) //scan user input and select appropriate file

{

case 1:

\_dt = ImportSheet(Book1);

break;

case 2:

\_dt = ImportSheet(Book2);

break;

case 3:

\_dt = ImportSheet(Book3);

break;

case 4:

\_dt = ImportSheet(Book4);

break;

case 5:

\_dt = ImportSheet(Book5);

break;

case 6:

\_dt = ImportSheet(Book6);

break;

}

DataTableReader reader = \_ds.CreateDataReader(\_dt);

Console.WriteLine("\nData for the set (Ambient, Low, Med, High):\n");

PrintColumns(reader);

//string[] str\_col = new string[\_dt.Rows.Count];

double[] d\_col\_Ambient = new double[30];

double[] d\_col\_Low = new double[30];

double[] d\_col\_Med = new double[30];

double[] d\_col\_High = new double[30];

for (int index\_r = 0; index\_r < \_dt.Rows.Count; index\_r++)

{

int index\_c = 0;

d\_col\_Ambient[index\_r] = double.Parse(\_dt.Rows[index\_r][index\_c].ToString());

}

for (int index\_r = 0; index\_r < \_dt.Rows.Count; index\_r++)

{

int index\_c = 1;

d\_col\_Low[index\_r] = double.Parse(\_dt.Rows[index\_r][index\_c].ToString());

}

for (int index\_r = 0; index\_r < \_dt.Rows.Count; index\_r++)

{

int index\_c = 2;

d\_col\_Med[index\_r] = double.Parse(\_dt.Rows[index\_r][index\_c].ToString());

}

for (int index\_r = 0; index\_r < \_dt.Rows.Count; index\_r++)

{

int index\_c = 3;

d\_col\_High[index\_r] = double.Parse(\_dt.Rows[index\_r][index\_c].ToString());

}

//foreach (double q in d\_col\_Ambient) //Test ambient double array

//{

// Console.WriteLine(q);

//}

Console.WriteLine();

double[] ten\_rand\_ambient = new double[10];

ten\_rand\_ambient = ten\_Random(d\_col\_Ambient);

Console.WriteLine("Ten Random Numbers from Ambient Data Set");

foreach (double i in ten\_rand\_ambient) //Test random integer array of 10

{

Console.WriteLine(i);

}

Console.WriteLine();

double ten\_avg\_ambient = ten\_rand\_ambient.Average();

double std;

Console.WriteLine("Select a Sensitivity Level (Low [1], Medium [2], High [3])");

string x = Console.ReadLine();

int t = Int32.Parse(x);

double sumOfSquaresOfDifferences = d\_col\_Ambient.Select(val => (val - ten\_avg\_ambient) \* (val - ten\_avg\_ambient)).Sum();

std = Math.Sqrt(sumOfSquaresOfDifferences / d\_col\_Ambient.Length);

if (std < 1)

{

ten\_avg\_ambient = ten\_avg\_ambient + 2;

}

double t1 = ten\_avg\_ambient + 1.5 \* std;

double t2 = ten\_avg\_ambient + 4 \* std;

double t3 = ten\_avg\_ambient + 7 \* std;

Console.WriteLine("The standard deviation is {0}\n", std);

if (t == 3)

{

Console.WriteLine("The Instantaneous Threshold Level is: {0}", t1 );

}

else if (t == 2)

{

Console.WriteLine("The Instantaneous Threshold Level is: {0}", t2);

}

else

{

Console.WriteLine("The Instantaneous Threshold Level is: {0}", t3);

}

Console.WriteLine();

while (true)

{

Console.WriteLine("Enter a two second average:");

string str = Console.ReadLine();

double two\_avg = double.Parse(str);

if (t == 3)

{

if (two\_avg >= t1)

{

Console.WriteLine("Interrupt has occurred");

}

else

{

Console.WriteLine("No interrupt");

}

}

if (t == 2)

{

if (two\_avg >= t2)

{

Console.WriteLine("Interrupt has occurred");

}

else

{

Console.WriteLine("No interrupt");

}

}

if (t == 1)

{

if (two\_avg >= t3)

{

Console.WriteLine("Interrupt has occurred");

}

else

{

Console.WriteLine("No interrupt");

}

}

}

}

public static DataTable ImportSheet(string fileName)

{

var datatable = new DataTable();

var workbook = new XLWorkbook(fileName);

var xlWorksheet = workbook.Worksheet(1);

var range = xlWorksheet.Range(xlWorksheet.FirstCellUsed(), xlWorksheet.LastCellUsed());

var col = range.ColumnCount();

var row = range.RowCount();

//if a datatable already exists, clear the existing table

datatable.Clear();

for (var i = 1; i <= col; i++)

{

var column = xlWorksheet.Cell(1, i);

datatable.Columns.Add(column.Value.ToString());

}

var firstHeadRow = 0;

foreach (var item in range.Rows())

{

if (firstHeadRow != 0)

{

var array = new object[col];

for (var y = 1; y <= col; y++)

{

array[y - 1] = item.Cell(y).Value;

}

datatable.Rows.Add(array);

}

firstHeadRow++;

}

return datatable;

}

static void PrintColumns(DataTableReader reader)

{

// Loop through all the rows in the DataTableReader

while (reader.Read())

{

for (int i = 0; i < reader.FieldCount; i++)

{

Console.Write(reader[i] + " ");

}

Console.WriteLine();

}

}

static double[] ten\_Random(double[] array)

{

//Gets 10 random integers from an integer array

Random rand = new Random();

double[] ten\_array = new double[10];

for (int i = 0; i < 10; i++)

{

int r = rand.Next(array.Length - 1);

ten\_array[i] = array[r];

}

return ten\_array;

}

}

}

## Appendix B. False Detection Rate & Receiver Operating Characteristic MATLAB Program

%ECE458 - Senior Design

%Michael Benker

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%% FALSE DETECTION RATES %%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

clf;clear all; clc; close all;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

samples=100;

%Threshold Levels. Begin and End for sweeping capabilities

T\_h\_begin = 3.57;

T\_h\_end = 3.57;

T\_m\_begin = 16.84;

T\_m\_end = 16.84;

T\_l\_begin = 24.02;

T\_l\_end = 24.02;

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%VARIABLES

Ave2sec = 0; %2-second average

Data20sec = zeros(10,1);

history = zeros(100,1);

RI\_med = zeros(100,1); %1 if real interrupt, 0 if false interrupt

RI\_high = zeros(100,1);

RI\_low = zeros(100,1);

ID\_low = zeros(100,1); %1 if interrupt detected, 0 if interrupt not detected

ID\_med = zeros(100,1);

ID\_high = zeros(100,1);

TID\_low = zeros(100,1); %1 if ID = RI = 1, 0 otherwise

TID\_med = zeros(100,1);

TID\_high = zeros(100,1);

FD\_low = zeros(100,1); %1 if ID = 1 & RI = 0, 0 otherwise

FD\_med = zeros(100,1);

FD\_high = zeros(100,1);

FN\_low = zeros(100,1); %1 if ID = 0 & RI = 1, 0 otherwise

FN\_med = zeros(100,1);

FN\_high = zeros(100,1);

FDR\_low = 0; %probability of false interrupt given interrupt detection

FDR\_med = 0;

FDR\_high = 0;

FDR\_low\_array = zeros(samples,1);

FDR\_med\_array = zeros(samples,1);

FDR\_high\_array = zeros(samples,1);

T\_high\_array = zeros(samples,1); %standard deviations for high sensitivity setting

T\_med\_array = zeros(samples,1); %standard deviations for medium sensitivity setting

T\_low\_array = zeros(samples,1); %standard deviations for low sensitivity setting

FN\_low\_array = zeros(samples,1);

FN\_med\_array = zeros(samples,1);

FN\_high\_array = zeros(samples,1);

Opti\_low = zeros(samples,1);

Opti\_med = zeros(samples,1);

Opti\_high = zeros(samples,1);

TID\_low\_Array = zeros(samples,1);

TID\_med\_Array = zeros(samples,1);

TID\_high\_Array = zeros(samples,1);

TPR\_low\_Array = zeros(samples,1);

TPR\_med\_Array = zeros(samples,1);

TPR\_high\_Array = zeros(samples,1);

%IMPORT DATA

SoundData1 = 'Book3.xlsx'; %Read excel file in folder

DataMat = zeros(30,4); %Predefine Data Matrix

Ambients = xlsread(SoundData1, 'A2:A31'); %Ambient 1st col

Quiets = xlsread(SoundData1, 'B2:B31'); %Quiet is 2nd col

Mediums = xlsread(SoundData1, 'C2:C31'); %Medium is 3rd col

Louds = xlsread(SoundData1, 'D2:D31'); %Loud is 4th col

[k,DataLoc] = xlsread(SoundData1, 'E1:E1');

%Define past 20 seconds (ambients)

for s=1:samples

T\_high=T\_h\_begin+s\*(T\_h\_end-T\_h\_begin)/samples;

T\_med=T\_m\_begin+s\*(T\_m\_end-T\_m\_begin)/samples;

T\_low=T\_l\_begin+s\*(T\_l\_end-T\_l\_begin)/samples;

T\_high\_array(s,1)=T\_high;

T\_med\_array(s,1)=T\_med;

T\_low\_array(s,1)=T\_low;

RI\_med = zeros(100,1); %1 if real interrupt, 0 if false interrupt

RI\_high = zeros(100,1);

RI\_low = zeros(100,1);

ID\_low = zeros(100,1); %1 if interrupt detected, 0 if interrupt not detected

ID\_med = zeros(100,1);

ID\_high = zeros(100,1);

TID\_low = zeros(100,1); %1 if ID = RI = 1, 0 otherwise

TID\_med = zeros(100,1);

TID\_high = zeros(100,1);

FD\_low = zeros(100,1); %1 if ID = 1 & RI = 0, 0 otherwise

FD\_med = zeros(100,1);

FD\_high = zeros(100,1);

FN\_low = zeros(100,1); %1 if ID = 0 & RI = 1, 0 otherwise

FN\_med = zeros(100,1);

FN\_high = zeros(100,1);

for c =1:100

Data20sec(c,1) = Ambients(randi([1 30],1,1),1);

end

Ave20sec = mean(Data20sec);

Std20sec = std(Data20sec);

RT\_high = Ave20sec+Std20sec\*T\_high; %Running threshold level (high sens)

RT\_med = Ave20sec+Std20sec\*T\_med; %Running threshold level (med sens)

RT\_low = Ave20sec+Std20sec\*T\_low; %Running threshold level (low sens)

for c=1:25

new = Ambients(randi([1 30],1,1),1);

history(c,1)=new;

if new>RT\_high

ID\_high(c,1)=1;

FD\_high(c,1)=1;

end

if new>RT\_med

ID\_med(c,1)=1;

FD\_med(c,1)=1;

end

if new>RT\_low

ID\_low(c,1)=1;

FD\_low(c,1)=1;

end

end

%Quiet interrupts

%Only high sensitivity should activate interrupt

for c=26:50

new = Quiets(randi([1 30],1,1),1);

history(c,1)=new;

RI\_high(c,1)=1;

if new>RT\_high

ID\_high(c,1)=1;

TID\_high(c,1)=1;

else

FN\_high(c,1)=1;

end

if new>RT\_med

ID\_med(c,1)=1;

FD\_med(c,1)=1;

end

if new>RT\_low

ID\_low(c,1)=1;

FD\_low(c,1)=1;

end

end

%medium interrupts

%Only high and medium sensitivity should activate interrupt

for c=51:75

new = Mediums(randi([1 30],1,1),1);

history(c,1)=new;

RI\_high(c,1)=1;

RI\_med(c,1)=1;

if new>RT\_high

ID\_high(c,1)=1;

TID\_high(c,1)=1;

else

FN\_high(c,1)=1;

end

if new>RT\_med

ID\_med(c,1)=1;

TID\_med(c,1)=1;

else

FN\_med(c,1)=1;

end

if new>RT\_low

ID\_low(c,1)=1;

FD\_low(c,1)=1;

end

end

%loud interrupts

%all activate interrupt

for c=76:100

new = Louds(randi([1 30],1,1),1);

history(c,1)=new;

RI\_high(c,1)=1;

RI\_med(c,1)=1;

RI\_low(c,1)=1;

if new>RT\_high

ID\_high(c,1)=1;

TID\_high(c,1)=1;

else

FN\_high(c,1)=1;

end

if new>RT\_med

ID\_med(c,1)=1;

TID\_med(c,1)=1;

else

FN\_med(c,1)=1;

end

if new>RT\_low

ID\_low(c,1)=1;

TID\_low(c,1)=1;

else

FN\_low(c,1)=1;

end

end

%False Interrupt Detection Rate - Print all

%probability of false interrupt given interrupt detection

FDR\_low\_array(s,1) = sum(FD\_low, 'all')/(100-sum(RI\_low, 'all'));

FDR\_med\_array(s,1) = sum(FD\_med, 'all')/(100-sum(RI\_med, 'all'));

FDR\_high\_array(s,1) = sum(FD\_high, 'all')/(100-sum(RI\_high, 'all'));

TID\_low\_Array(s,1) = sum(TID\_low,'all')/sum(ID\_low, 'all');

TID\_med\_Array(s,1) = sum(TID\_med,'all')/sum(ID\_med, 'all');

TID\_high\_Array(s,1) = sum(TID\_high,'all')/sum(ID\_high, 'all');

FN\_low\_array(s,1)=sum(FN\_low,'all')/25;

FN\_med\_array(s,1)=sum(FN\_med,'all')/50;

FN\_high\_array(s,1)=sum(FN\_high,'all')/75;

TPR\_low\_Array(s,1) = sum(TID\_low, 'all')/(sum(RI\_low, 'all'));

TPR\_med\_Array(s,1) = sum(TID\_med, 'all')/(sum(RI\_med, 'all'));

TPR\_high\_Array(s,1) = sum(TID\_high, 'all')/(sum(RI\_high, 'all'));

end

%!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

DataLoc = char(DataLoc);

figure(1)

scatter(FDR\_low\_array,TPR\_low\_Array,'p','b')

xlabel('False Positive Rate')

ylabel('True Positive Rate')

suptitle('Receiver Operating Characteristic, Low Sensitivity')

title(DataLoc)

xlim([0 1])

ylim([0 1])

grid on

filenamelow = ['ROC\_lowsens\_standard' DataLoc '.png'];%

saveas(gcf,filenamelow);

figure(2)

scatter(FDR\_med\_array,TPR\_med\_Array,'p','b')

xlabel('False Positive Rate')

ylabel('True Positive Rate')

suptitle('Receiver Operating Characteristic, Medium Sensitivity')

title(DataLoc)

xlim([0 1])

ylim([0 1])

grid on

filenamemed = ['ROC\_medsens\_standard' DataLoc '.png'];

saveas(gcf,filenamemed);

figure(3)

scatter(FDR\_high\_array,TPR\_high\_Array,'p','b')

xlabel('False Positive Rate')

ylabel('True Positive Rate')

suptitle('Receiver Operating Characteristic, High Sensitivity')

title(DataLoc)

xlim([0 1])

ylim([0 1])

grid on

filenamehigh = ['ROC\_highsens\_standard' DataLoc '.png'];

saveas(gcf,filenamehigh);

# Appendix C. Main Microcontroller Program (main.c)

#include <avr/io.h>

#include <avr/interrupt.h>

#include <avr/wdt.h>

#include <avr/sleep.h>

#include <math.h>

volatile uint16\_t adc\_num \_\_attribute\_\_((address(0x800100))); // Takes the number from the ADCH:ADCL register

volatile uint16\_t adc\_2sAvg \_\_attribute\_\_((address(0x800102))); // The 2 Second Average (average of 4x adc\_num\_arr\_avg)

volatile uint16\_t adc\_20sAvg \_\_attribute\_\_((address(0x800104))); // The 20 Second Average (average of 10x adc\_2sAvg)

volatile uint16\_t adc\_num\_arr[50] \_\_attribute\_\_((address(0x800106))); // The adc\_num\_arr is an array of ADC values

volatile uint16\_t adc\_num\_arr\_avg \_\_attribute\_\_((address(0x80016A))); // Average of the adc\_num\_arr

volatile uint16\_t adc\_2sAvg\_arr[10] \_\_attribute\_\_((address(0x80016C))); // Array of 2 Second Averages

volatile uint8\_t adc\_num\_idx \_\_attribute\_\_((address(0x800180))); // Index of adc\_num\_arr (ADC array)

volatile uint8\_t adc\_2sAvg\_idx \_\_attribute\_\_((address(0x800181))); // Index of adc\_2sAvg (2s Avg array)

volatile uint16\_t adc\_sum\_squared \_\_attribute\_\_((address(0x800182))); // The sum squared of the adc\_2sAvg\_arr

volatile uint16\_t adc\_std\_dev \_\_attribute\_\_((address(0x800184))); // The square root of the adc\_sum\_squared divided by number of 2sAvgs (10)

volatile uint8\_t thresh\_sensitivity \_\_attribute\_\_((address(0x800190)));

// If thresh\_sensitivity = 0, then Sensitivity is Low

// If thresh\_sensitivity = 1, then Sensitivity is Medium

// If thresh\_sensitivity = 2, then Sensitivity is High

volatile uint16\_t thresh\_high \_\_attribute\_\_((address(0x800191)));

volatile uint16\_t thresh\_medium \_\_attribute\_\_((address(0x800193)));

volatile uint16\_t thresh\_low \_\_attribute\_\_((address(0x800195)));

volatile uint8\_t aux\_switch \_\_attribute\_\_((address(0x8001A0)));

// If aux\_switch == 3, Auxillary Ports are ON

// If aux\_switch == 0, Auxillary Ports are OFF

volatile uint8\_t sleep\_code \_\_attribute\_\_((address(0x8001A1)));

// If sleep\_mode = 0x00, then the device is powered on

// If sleep\_mode = 0x0F, then the device restarts

// If sleep\_mode = 0xFF, then the device is powered off

void WDT\_init() \_\_attribute\_\_((naked)) \_\_attribute\_\_((section(".init3")));

void WDT\_init()

{

MCUSR = 0;

wdt\_disable();

return;

}

int main()

{

/\* Initialization of Variables \*/

aux\_switch = 3;

adc\_num = 0;

adc\_2sAvg = 0;

adc\_20sAvg = 0;

adc\_num\_idx = 0;

adc\_2sAvg\_idx = 0;

adc\_sum\_squared = 0;

adc\_std\_dev = 0;

sleep\_code = 0x00;

for(adc\_num\_idx = 0; adc\_num\_idx < 50; adc\_num\_idx++)

{

adc\_num\_arr[adc\_num\_idx] = 0;

}

adc\_num\_idx = 0;

adc\_num\_arr\_avg = 0;

adc\_num\_idx = 0;

for(adc\_2sAvg\_idx = 0; adc\_2sAvg\_idx < 10; adc\_2sAvg\_idx++)

{

adc\_2sAvg\_arr[adc\_2sAvg\_idx] = 0;

}

adc\_2sAvg\_idx = 0;

thresh\_sensitivity = 0; // Set sensitivity to High

thresh\_high = 44; // High Sensitivity

thresh\_medium = 132; // Medium Sensitivity

thresh\_low = 220; // Low Sensitivity

/\* Initialization of I/O \*/

DDRC &=~ 0x3F; // Set PINC4:0 as Button Inputs and PINC5 as Input for ADC

DDRB |= 0x03; // Set PINB1:0 as Outputs for CD4066BE Switches

DDRD |= 0x0B; // The Output showing the Threshold Sensitivity Mode.

PORTD = 0x01;

PORTB = 0x03;

/\* Initialization of ADC \*/

ADMUX = (1 << REFS0)|(1 << MUX2)|(1 << MUX0);

ADCSRA |= (0b111 << ADPS0);

ADCSRA |= (1 << ADEN);

/\* Initialization of I/O Interrupt \*/

PCICR = (1 << PCIE1);

PCMSK1 = (1 << PCINT12)|(1 << PCINT11)|(1 << PCINT10)|(1 << PCINT9)|(1 << PCINT8);

/\* Initialization of Timer1 Interrupt\*/

TCNT1 = 12499; // Sets the timer to go off every 10 milliseconds.

TCCR1A = (0b00<<COM1A0)|(0b00<<COM1B0)|(0b00<<WGM10);

TCCR1B = (0b00<<WGM12)|(0b010<<CS10); // Set the Prescaler to 8

TIMSK1 = (0b1<<TOIE1); // Enables interrupts for TOV1

sei(); // Enable Interrupts

/\* Program Starts \*/

while(1)

{

asm("NOP");

}

}

ISR (PCINT1\_vect) /\* I/O Interrupt Routine \*/

{

cli();

if(PINC & (1 << PINC4)) // Power Off Button

{

if(sleep\_code == 0x00)

{

sleep\_code = 0xFF;

} else if (sleep\_code == 0xFF) {

sleep\_code = 0x0F;

}

}

if(PINC & (1 << PINC3)) // Restart Button

{

wdt\_enable(WDTO\_250MS);

// Perform a Soft Reset on the System

}

if(PINC & (1 << PINC2)) // High Sensitivity Button

{

thresh\_sensitivity = 2;

// High Sensitivity On

}

if(PINC & (1 << PINC1)) // Medium Sensitivity Button

{

thresh\_sensitivity = 1;

// Medium Sensitivity On

}

if(PINC & (1 << PINC0)) // Low Sensitivity Button

{

thresh\_sensitivity = 0;

// Low Sensitivity On

}

switch(thresh\_sensitivity)

{

case 0:

PORTD = 0x01; // Low Sensitivity

break;

case 1:

PORTD = 0x02; // Medium Sensitivity

break;

case 2:

PORTD = 0x08; // High Sensitivity

break;

default:

PORTD = 0x0B; // Default (Error)

break;

}

if(sleep\_code == 0xFF) // If the device is powered down and the button is pressed again, the device restarts

{

sei();

PORTD = 0x00;

PORTB = 0x03;

set\_sleep\_mode(2);

sleep\_mode();

} else if(sleep\_code == 0x0F) {

sleep\_disable();

wdt\_enable(WDTO\_250MS);

}

sei();

}

ISR (TIMER1\_OVF\_vect)

{

// This interrupt service routine is non-atomic

TCNT1 = 12499;

/\* Measure and Store ADC value at this point in time \*/

ADCSRA |= (1 << ADSC);

while(ADCSRA & (1 << ADSC));

adc\_num = ADC;

adc\_num\_arr[adc\_num\_idx % 50] = adc\_num; // Adds Element to the Array

adc\_num\_arr\_avg += adc\_num\_arr[adc\_num\_idx % 50];

adc\_num\_idx++;

/\* Compute 2s Average \*/

if((adc\_num\_idx > 0) && (adc\_num\_idx % 50 == 0))

{

adc\_num\_arr\_avg /= 50;

adc\_2sAvg += adc\_num\_arr\_avg;

adc\_num\_arr\_avg = 0;

}

if(adc\_num\_idx == 200)

{

adc\_num\_idx = 0;

adc\_2sAvg /= 4;

adc\_2sAvg\_arr[adc\_2sAvg\_idx] = adc\_2sAvg;

adc\_2sAvg = 0;

adc\_20sAvg += adc\_2sAvg\_arr[adc\_2sAvg\_idx];

adc\_2sAvg\_idx++;

}

/\* 20 Second Average and Standard Deviation Calculation \*/

if(adc\_2sAvg\_idx == 10)

{

adc\_std\_dev = 0;

adc\_2sAvg\_idx = 0;

adc\_20sAvg /= 10;

for(adc\_2sAvg\_idx = 0; adc\_2sAvg\_idx < 10; adc\_2sAvg\_idx++)

{

adc\_sum\_squared = adc\_2sAvg\_arr[adc\_2sAvg\_idx] - adc\_20sAvg;

adc\_sum\_squared \*= adc\_sum\_squared;

adc\_std\_dev += adc\_sum\_squared;

}

adc\_std\_dev = (uint16\_t)sqrt(adc\_std\_dev / 10);

adc\_sum\_squared = 0;

}

if(adc\_20sAvg + (adc\_std\_dev \* thresh\_high) > adc\_2sAvg\_arr[adc\_2sAvg\_idx] && thresh\_sensitivity == 0) // Above the High Sensitivity Threshold

{

aux\_switch = 0;

// Disable Audio

} else if(adc\_20sAvg + (adc\_std\_dev \* thresh\_medium) > adc\_2sAvg && thresh\_sensitivity == 1) // Above the Medium Sensitivity Threshold

{

aux\_switch = 0;

// Disable Audio

} else if(adc\_20sAvg + (adc\_std\_dev \* thresh\_low) > adc\_2sAvg && thresh\_sensitivity >= 2) // Above the Low Sensitivity Threshold

{

aux\_switch = 0;

// Disable Audio

}

if(adc\_20sAvg + (adc\_std\_dev \* thresh\_high) <= adc\_2sAvg && thresh\_sensitivity == 0) // Below or Equal to the High Sensitivity Threshold

{

aux\_switch = 3;

// Enable Audio

} else if(adc\_20sAvg + (adc\_std\_dev \* thresh\_medium) <= adc\_2sAvg && thresh\_sensitivity == 1) // Below or Equal to the Medium Sensitivity Threshold

{

aux\_switch = 3;

// Enable Audio

} else if(adc\_20sAvg + (adc\_std\_dev \* thresh\_low) <= adc\_2sAvg && thresh\_sensitivity >= 2) // Below or Equal to Low Sensitivity Threshold

{

aux\_switch = 3;

// Enable Audio

}

if(adc\_2sAvg\_idx == 10)

{

adc\_2sAvg\_idx = 0;

adc\_20sAvg = 0;

}

PORTB = aux\_switch; // Set Auxiliary Switch to 0

}

# Test Plans: Electronics

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Microphone Test | | Test Number | ET\_01 | | | |
| Requirement(s) Tested | | 5.4, 5.2 | Verification Method | I | A | D | T |
| Test Setup | | Fig. 6, 8  Oscilloscope  Variable DC Power Supply  Microphone Part Number: PM0F-6050P-36UQ | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Build Microphone Circuit as shown in Fig. 6 | See Fig. 6 | Circuit ready for testing | Pass |
| 2 | Turn on and set power supply to 5VDC and connect to Vcc on circuit diagram; connect ground. | 5VDC on Vcc, verifiable with volt meter | Voltmeter displayed 5VDC | Pass |
| 3 | Turn on oscilloscope, probe output of microphone and connect your ground wire. | Voltage output should be in the microvolt to millivolt range. | Voltage reading:-645uV@52.3dB | Pass |
| 4 | Simulate a loud noise, such as banging your hand on the table. | dB level between 30 and 90 dB; appropriate for volume level | 66.2dB | Pass |
| 5 | Record voltage output from microphone. | Between 1 and 500 mV | 28.8mV | Pass |
| 6 | Simulate the same noise but try to make it louder | Voltage output should be between 10 and 500 mV and voltage output increases with volume level increase. | 33.6mV@77.5dB | Pass |

|  |
| --- |
| Comments  The microphone used about 28-35mV of electricity depending on Decibels of noise heard. |

Date 3/07/2020 Test Engineer Ryan Dumont Witness Jared Alves

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Amplifier Circuit Test | | Test Number | ET\_02 | | | |
| Requirement(s) Tested | | 5.4 | Verification Method | I | A | D | T |
| Test Setup | | See Figure 7  Variable DC Power Supply  Oscilloscope | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Build Amplifier Circuit as shown in Fig. 7 | See Fig. 7 | Circuit ready for testing. | Pass |
| 2 | Turn on Power Supply and connect 5V DC to Amplifier supply rails (see Fig 7). | Voltage output verifiable with Volt Meter | Multimeter reads 5Vdc. | Pass |
| 3 | Turn on Function Generator and select (any) waveform with voltage range 0-500mV. Turn on Oscilloscope and connect probes to function generator output. | Oscilloscope window displays waveform. | Input set to 17.6mV peak. | Pass |
| 4 | Connect function generator output to input of amplifier circuit (see Fig. 7). Probe Channel 1 oscilloscope probes to amplifier input. Connect oscilloscope Channel 2 probes to amplifier output (see Fig 7). | Expected gain ~11. | Output measured at 197mv. | Pass |

|  |
| --- |
| Comments  The amplifier successfully amplified a signal that was at peak 17.6 mV to 197 mV. |

Date 3/07/2020 Test Engineer Ryan Witness Stephen

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Digital Circuit Switch Test | | Test Number | ET\_03 | | | |
| Requirement(s) Tested | | 4.1 | Verification Method | I | A | D | T |
| Test Setup | | Figure 9  Digital Switch Part Number: CD4066BE  DC Power Supply (For Switch’s CTRL input and power source)  Function Generator (For the input signal, an AC power source)  Oscilloscope (Measuring the input and output signal of the Switch) | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Build Digital Switch Circuit as shown in Figure 9 | See Figure 9 |  |  |
| 2 | Turn on power Supply and connect 5V DC to the VDD of the Digital Switch Circuit. | Voltage output verifiable with Volt Meter | The 5v did activate the chip | pass |
| 3 | Use the Function Generator to send out a 5V AC Sine Signal and then test with a 5V AC Noise Signal. The signal will go to the input of one of the Digital Switches on the chip. | Voltage output verifiable with oscilloscope. | Instead of using a AC generator we connected the aux cable and used a actuall sound signal. | Pass |
| 4 | Set the CTRL pins of a switch between 5V and GND. Then compare the results on Step 5. | Voltage output verifiable with Volt Meter. | While connecting it to 5V the sound went through the circuit and connecting it to ground stopped it. | Pass |
| 5 | Connect an Oscilloscope (1x) Probe to the input signal (Vin) and output signal (Vout) and compare the two signals. Connect the grounds as well. | Verifiable through Oscilloscope:  If CTRL = 5V  Vout = Vin  If CTRL = GND  Vout = 0V DC | Sound signal is very noisy but we did see a signal input and output and heard it as well | pass |

|  |
| --- |
| Comments:  Disconnecting the switch from vdd still left the switch on until it was connected to ground. |

Date 3/7/20 Test Engineer Stephen Witness\_Ryan, Michael

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Auxiliary Port & Cable Test | | Test Number | ET\_04 | | | |
| Requirement(s) Tested | | 2.1,2.2,5.1,6.3,7.0 | Verification Method | I | A | D | T |
| Test Setup | | Audio Source (computer or phone)  3.5mm headphone jack(x2)  Male-to-Male Auxiliary Cable  Headphones | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1. | Attach the 3.5mm headphone jack to the input and output to make sure it fits. | The Auxiliary jack should fit any standard 3.5mm audio device. | The headphones did fit in the jack inputs and outputs | Pass |
| 2 | Connect Auxiliary ports together in series. |  |  |  |
| 3 | Connect the M-M auxiliary cable from an audio source to the auxiliary ports and connect headphones to the output of the other auxiliary port. Observe audio output to headphones. | The audio signal would travel through the device with little delay and drop of signal. | The audio signal did travel through the device. | Pass |

|  |
| --- |
| Comments  The headphone jack fit in the Aux port and successfully was able to send audio from one aux to the other. |

Date 3/07/2019 Test Engineer Stephen Witness Ryan

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Testing of Buttons and Setting Switch | | Test Number | ET\_05 | | | |
| Requirement(s) Tested | | 3.2, 6.1 | Verification Method | I | A | D | T |
| Test Setup | | Signal Detector (Multimeter or Oscilloscope)  Voltage Signal | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Connect one pin of each button to a voltage signal (5VDC). Measure input and output voltage with multimeter. | When Button is pressed the open circuit should become closed and the voltage signal should go through. | The Voltage is approx. 5V when the button is pressed and 0V when not pressed | Pass |
| 2 | Connect the Switch to a voltage signal and ground. Measure input and output voltage with multimeter. | Just like the buttons, when the switch is pressed check if current flows. | The audio signal from input and output mat | Pass |

|  |
| --- |
| Comments  The buttons and switch worked as expected. |

Date 3/4/2020 Test Engineer Drew Martins Witness Ryan Dumont

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Analog Input Electronics Test | | Test Number | ET\_06 | | | |
| Requirement(s) Tested | | 5.4 | Verification Method | I | A | D | T |
| Test Setup | | Fig. 6 7, 8  Sound meter Voltmeter  Variable DC Power Supply  Oscilloscope | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Verify Tests ET\_01, ET\_02. Build Microphone Test Circuit and Amplifier Test Circuit (see Fig. 6 and 7) | See Fig. 6 and 7 |  | Pass |
| 2 | Connect output of Microphone Circuit to input of Amplifier Circuit. | See Fig. 8 | Analog integration circuit ready for testing. | Pass |
| 3 | Turn on Power Supply and connect 5VDC to Amplifier supply rails (see Fig 8). | Voltage output verifiable with Volt Meter | Meter read 5Vdc | Pass |
| 4 | Turn on Oscilloscope and connect Channel 1 probe to Microphone output (e.g. Amplifier Input) and Channel 2 probe to amplifier output. | Observable amplification (A=11) of ambient. | Channel 1 read 13.073mV and Channel 2 read 138.11mV. | Pass |
| 5 | Simulate a loud noise, such as banging your hand on the table. |  |  | Pass |
| 6 | Record voltage output from microphone and from amplifier. | Expected gain ~11 | Channel 1 read 63.947mVdc and Channel 2 read 1.1004Vdc | Pass |
| 7 | Simulate the same noise but louder. | Voltage increases linearly with sound level reading (dB). | Channel 1 read 61.27mVdc .687Vdc and Channel 2 read .687Vdc . | Pass |

|  |
| --- |
| Comments:  Combining the microphone and amp allowed for an increase in the voltage being read. |

Date 3/07/2020 Test Engineer Ryan Witness Stephen

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Audio Switch Circuit | | Test Number | ET\_07 | | | |
| Requirement(s) Tested | | 2.1, 2.2, 2.3, 4.1 | Verification Method | I | A | D | T |
| Test Setup | | Fig. 9  Digital Switch Part Number: CD4066BE)  DC Power Supply (For Switch’s CTRL input and power source)  A Male-to-Male Auxiliary Cable from a device to the circuit & a pair of headphones or speakers.  Two Auxiliary Ports (One Aux-Input and One Aux-Output) | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Verify tests ET\_03 and ET\_04 | See ET\_03 and ET\_04 | Tests complete. | Pass |
| 2 | Connect a 5V DC power source to the VDD on the Switches | Voltage output verifiable with Voltmeter | Voltmeter gives an output of 5V\* | Pass |
| 3 | Set up two 5V DC inputs for the CTRL pins, one for each switch | Voltage output verifiable with Voltmeter | The switches are activated when CTRL Pin set to 5V and deactivated when CTRL Pin is set to 0V/GND | Pass |
| 4 | Connect an audio source (auxiliary cable – male-male) to the Aux-Input port | Auxiliary cable inserted | Auxiliary cable is connected | Pass |
| 5 | Connect headphones or speaker to Aux-Output and begin any mp3 file. | Audio can be heard if switch is on. | Audio can be heard when the switch is activated. | Pass |
| 6 | Set the CTRL pins of each switch between 5V and GND and determine if the audio is getting through to the other side, | If CTRL = 5V  Audio is enabled  If CTRL = GND  Audio is muted | Audio is enabled on 5V  Audio is disabled on GND | Pass |

|  |
| --- |
| Comments:  \*Due to COVID-19, a DC power source was inaccessible, the workaround was to add 2x 3.7V batteries in series and a voltage divider to create a 5V DC source. |

Date Test Engineer Witness

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Analog Integration with ADC Test & Debug | | Test Number | ET\_08 | | | |
| Requirement(s) Tested | | 3.1, 5.1, 5.2, 5.3, 5.4 | Verification Method | I | A | D | T |
| Test Setup | | Integration of ET\_06 and CT\_01  ATmega328PB  Variable DC Power Supply  Atmel Studio | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Verify functionality of ET\_06. | Complete ET\_06 | Complete ET\_06 | Pass |
| 2 | Connect the output of the op- amp to pin C5 on the microcontroller. | ET\_06 will be able to communicate with microcontrollers’ ADC. | ET\_06 can communicate with the microcontroller’s ADC | Pass |
| 3 | Run CT\_01. | See CT\_01 |  |  |
| 4 | Open the Atmel Studio software on your computer and use the debug function. |  |  |  |
| 5 | View the values that are seen by the ADC as ET\_06 is taking in the ambient noise. | The ADC number depends on the volume of the incoming audio to the microphone. | WIP | WIP\* |

|  |
| --- |
| Comments:  \*Test Step 5 is currently a work in progress.  Due to COVID-19, the equipment and teamwork required to finish this test plan was inaccessible. |

Date Test Engineer Witness

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Power Consumption Test | | Test Number | ET\_09 | | | |
| Requirement(s) Tested | | 1.1 | Verification Method | I | A | D | T |
| Test Setup | | Integration of ET\_08 and ET\_05  ATmega328PB  Power Supply  Digital Multimeter | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Build ET\_08 and load CT\_05 in microcontroller. | Program successfully loaded. See ET\_08. |  |  |
| 2 | Set power supply to 5 Vdc and connect the positive lead to Vcc and negative lead to ground. | Verifiable with voltage meter |  |  |
| 3 | Take digital multimeter and set it to read current. | Multimeter should switch to amperage mode. |  |  |
| 4 | Disconnect positive lead of power supply and connect one end of meter to that wire and the other lead of meter to Vcc on the circuit. | This will complete the circuit and allow you to measure current draw. |  |  |
| 5 | Run circuit for an hour and log the amperage output on multimeter for five-minute intervals | Current values should be roughly in the same range of each other. |  |  |
| 6 | Take average of those numbers and that is roughly the current draw of circuit per hour. Multiply this number times 8 (# of hours device needs to run for) and record the number. This is the current rating you will need on your battery. | An average of the current levels will be obtained to help with battery selection. |  |  |

|  |
| --- |
| Comments:  Due to COVID-19, ET\_08 remained incomplete which is a prerequisite of ET\_09. |

Date Test Engineer Witness

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Audio Switching Function Test | | Test Number | ET\_10 | | | |
| Requirement(s) Tested | | 3.2 | Verification Method | I | A | D | T |
| Test Setup | | Variable DC Power Supply  ATmega328PB  Integration of CT\_04 and ET\_08 | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Have ET\_08 already built and CT\_04 running on the microcontroller. | See ET\_08 and CT\_04. |  |  |
| 2 | Implement the code from CT\_04 with the circuit, testing the switch with the various sensitivity levels | Switch circuit functions with sensitivity levels accurately |  |  |

|  |
| --- |
| Comments:  Due to COVID-19, ET\_08 remained incomplete which is a prerequisite of ET\_10. |

Date Test Engineer Witness

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Interrupt Detection Device Test | | Test Number | ET\_11 | | | |
| Requirement(s) Tested | | 3.1, 4.1, 5.1, 5.4 | Verification Method | I | A | D | T |
| Test Setup | | Integration of ET\_07 and CT\_04  ATmega328PB  Variable Power Supply  Digital Multimeter  Oscilloscope | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Make sure ET\_07 is built and functioning correctly and CT\_04 is running on the microcontroller. | See ET\_07 and CT\_04. |  |  |
| 2 | Power up the variable DC power supply and set the output voltage to 5 VDC. | Verifiable with voltmeter. |  |  |
| 3 | Connect the positive lead to the +5 VDC voltage rail and the negative lead to the ground rail of the circuit. | Circuit should have power at this point. |  |  |
| 4 | Power on oscilloscope and connect test probes to channel one and channel 2. | Oscilloscope will be ready to view ambient noise. |  |  |
| 5 | Probe the input and output with channel 1 and channel 2 respectively to make sure microphone and amplifier are reading the ambient noise in the environment. | Original and amplified signal should be in view on screen. |  |  |
| 6 | Create a loud noise of your choosing for about 2 seconds to trigger an interrupt. | Loud noise audible. |  |  |
| 7 | Verify that an interrupt is achieved, examining the output pin of the microphone designated for the interrupt. | Interrupt is achieved. |  |  |

|  |
| --- |
| Comments:  Due to COVID-19, the equipment and teamwork required to finish this test plan was inaccessible. |

Date Test Engineer Witness

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Acoustic Awareness Device Test | | Test Number | ET\_12 | | | |
| Requirement(s) Tested | |  | Verification Method | I | A | D | T |
| Test Setup | | Integration of ET\_09, ET\_10 and ET\_11  Website: noises.online  Sound Meter | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Complete Tests ET\_09, ET\_10 and ET\_11. | Verify ET\_09, ET\_10 and ET\_11 are functioning. |  |  |
| 2 | Connect the interrupt output pin on the microcontroller from ET\_12 to the input of ET\_11. Monitor the output pin using a voltmeter or oscilloscope probe. | Follow circuit diagram for ET\_13. |  |  |
| 3 | Begin audio throughput through the auxiliary cables from the device source to the switching circuit and out to the headphones. | Sound coming from device source is on. |  |  |
| 4 | Select an ambient noise level from website: noises.online as was done in ET\_06. Allow device to maintain a constant ambient reading for 20 seconds. | Sound selection is audible for 20 seconds. |  |  |
| 5 | After 20 seconds, rapidly increase the volume of the output of the sound to start an interrupt. Monitor the audio output to the headphones. | Audio to the headphones should turn off when an interrupt is started. Ambient sound selection is much louder than the previous step to trigger and interrupt. |  |  |
| 6 | Repeat step 5 and record ambient levels before and after the interrupt while taking record of whether the audio was turned off at the time of the ambient volume increase. | Audio should turn off at volume increase IF the threshold has been exceeded. |  |  |
| 7 | Repeat steps 5 and 6 for all threshold level settings (high, medium, low). | Record under which cases the audio was turned off and the setting, ambient and interrupting sound level. |  |  |

|  |
| --- |
| Comments  Due to COVID-19, ET\_09, ET\_10 and ET\_11 remained incomplete which is a prerequisite of ET\_12. |

Date Test Engineer Witness

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Battery Power Consumption Test | | Test Number | ET\_13 | | | |
| Requirement(s) Tested | | 1.1 | Verification Method | I | A | D | T |
| Test Setup | | Integration of ET\_11 and ET\_09  ATmega328PB  Selected Lithium Ion Battery  Stopwatch | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Using calculated current consumption in ET\_09, choose a lithium ion battery pack from an online retailer that has at least that much or more capacity. | Battery has enough capacity for 8 hours. |  |  |
| 2 | Connect battery to ET\_11 and run CT\_05 for 8 hours. | The device should run on battery power for at least 8 hours. |  |  |

|  |
| --- |
| Comments:  Due to COVID-19, ET\_09 and ET\_11 remained incomplete which is a prerequisite of ET\_13. |

Date Test Engineer Witness

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| --- | --- | --- | --- | --- | --- | --- |
| Test Name | Acoustic Awareness Enabler 1.0 Debug Test | Test Number | ET\_14 | | | |
| Requirement(s) Tested | All | Verification Method | I | A | D | T |
| Test Setup | Integration of BT\_05, ET\_12, PT\_07 and NT\_03 | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Ensure that all components are housed and properly mounted in the modified enclosure. | A “completed” device will be built. |  |  |
| 2 | Turn on the Acoustic Awareness Enabler. | Device powers up. |  |  |
| 3 | Use one aux cord to connect your computer to the input jack of the A.A.E | This is where the music input will come from |  |  |
| 4 | Connect your headphones from the output of the A.A.E to your ears. | This will allow you to hear the audio signal. |  |  |
| 5 | Test each sensitivity level individually by pressing the panel mounted button associated with it. | Threshold setting changes to desired threshold setting. |  |  |
| 6 | Create various “interrupts” for each sensitivity level test. | Sound traveling through headphones should stop. Depending how well it stops may mean software adjustments for thresholds. |  |  |
| 7 | Log the behavior of the device and see if fine tuning in software is needed. | Results will tell you what work still needs to be done. |  |  |

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| Comments:  ET\_14 could not be satisfied since ET\_12 is a prerequisite of ET\_14 and remains incomplete. |

Date Test Engineer Witness

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| Test Name | Device Lifetime Test | | Test Number | ET\_15 | | | |
| Requirement(s) Tested | | 1.1 | Verification Method | I | A | D | T |
| Test Setup | | Completed Circuit Board  Chosen Battery Pack | | | | | |

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| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Verify that BT\_05 is satisfied | Circuit board should be populated and ready to test. |  |  |
| 2 | Take chosen battery and wire the positive terminal to Vcc on the final circuit board and the negative terminal to ground. Keep battery attached for 8 hours and turn on circuit. Do various tests during the 8-hour interval. | Battery should not die for the full length of time. |  |  |

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| Comments: |

Date Test Engineer Witness

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Device Improvement Methods | | Test Number | ET\_16 | | | |
| Requirement(s) Tested | | All | Verification Method | I | A | D | T |
| Test Setup | |  | | | | | |

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| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Confirm NT\_03, BT\_05, ET\_15, ET\_14, PT\_07 | See NT\_03, BT\_05, ET\_15, ET\_14, PT\_07. |  |  |
| 2 | Verify each category for possible improvements: Enclosure, PCB and electronics | Final product |  |  |

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| Comments:  ET\_16 could not be satisfied as ET\_14 is a prerequisite of ET\_16 and remains incomplete. |

Date Test Engineer Witness

# Test Plans: Processing

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| Test Name | Threshold Setting as f(σ) concept validation | | Test Number | PT\_01 | | | |
| Requirement(s) Tested | | 5.1 | Verification Method | I | A | D | T |
| Test Setup | | MATLAB, Sound Meter | | | | | |

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| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Obtain data set from environment X with sound meter, collecting 30 samples from “quiet environment”. Collect ambient samples, simulate “Low”, “Med” and “High” Interrupts and check sound levels. | Ambient levels (dB) and sound levels of low, medium and high interrupts | Data collected using sound meter. Example: Figure 11. | P |
| 2 | Repeat step 1 for “Medium” environment and “Loud” Environment | New data sets with same value categories | Data collected for several environments. | P |
| 3 | Compare and compute standard deviations in MATLAB of various data sets | Standard deviations of data sets | Standard deviation and averages calculated (Figure 12). | P |
| 4 | Verify that threshold from experimental data is based on standard deviation | Threshold Setting as a function of the standard deviation | Average standard deviation from the ambient average is calculate over all environments for each threshold setting (Figure 14). | P |

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| Comments:  This data validates the concept of threshold as a function of standard deviation. Further tests improve accuracy of standard deviation. |

Date 3/4/2020 Test Engineer Michael Witness Jared

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Standard Deviation Calculation | | Test Number | PT\_02 | | | |
| Requirement(s) Tested | | 5.1,5.2 | Verification Method | I | A | D | T |
| Test Setup | | MATLAB  In conjunction with PT\_01 | | | | | |

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| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Generate a plot of ambient level vs standard deviation in MATLAB by comparing measured data and standard deviations for data sets | Determine the relationship between the standard deviation and the ambient level of the environment | Plot of ambient vs standard deviation (Figure 15) | P |
| 2 | Derive a formula for threshold levels based on ambient and standard deviation | Find relationship between threshold setting and standard deviation | Threshold Formula (Figure 16) | P |

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| Comments:  The plot shows that there is a general positive correlation between ambient level and standard deviation. |

Date 3/7/2020 Test Engineer Jared Alves Witness Michael Benker

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | 20 second averaging, interrupt process | | Test Number | PT\_03 | | | |
| Requirement(s) Tested | | 5.1,5.2,5.3 | Verification Method | I | A | D | T |
| Test Setup | | Microsoft Visual Studio, C#  See attachment Code (Interrupt.cs) | | | | | |

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| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Write and compile code in C# that simulates the collection of 20 seconds or more of data at a rate of 100 samples per second. | Stores 20 seconds of data. | 2-second averages are recorded and saved in the program. When 20 of data is present, newest data set replaces oldest. | Pass |
| 2 | Implement standard deviation calculation to determine if a 2 second interval after 20 seconds of data is within a number of standard deviations. If the most recent 2 seconds is above a number of standard deviations, the program should indicate it. | Standard deviation calculation of interrupt is verifiable through calculation. | After 20 seconds of data present, standard deviation is calculated for newest data set. | Pass |
| 3 | If not present in the test code thus far, modify the code so that the oldest number in the data set is replaced by the newest average if the newest average is within a number of standard deviations. | After 20 seconds, data stored should always be from the most recent 20 seconds if there were no interrupts. See attachment code for final example of implementation. | Present in program. | Pass |
| 4 | Program says when newest data set falls out of threshold range [number of standard deviations], which is set in the program. | “Interrupt” is displayed when number of Threshold standard deviations \* sigma + average is equal to newest 2 sec average. | Program displays when interrupt is achieved and was found to be accurate in testing with #std=4, average = 56dB, sigma = 1.0 and newest 2 sec average is 63dB. | Pass |

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| Comments |

Date 3/7/2020 Test Engineer Michael Witness Jared

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| Test Name | Interrupt Environment Test | | Test Number | PT\_04 | | | |
| Requirement(s) Tested | | 5.1,5.2,5.3 | Verification Method | I | A | D | T |
| Test Setup | | Sound level meter  Visual Studio (C# language) - “interrupt.cs” (see attached code)  See Figure 18 | | | | | |

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| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Load “interrupt.cs” on Visual Studio | See PT\_03. |  | Pass |
| 2 | Measure ambient sound levels for 20 seconds using the sound meter and record the values in the program “interrupt.cs”. | Program displays recorded values after entering. |  | Pass |
| 3 | Generate interrupts and monitor with sound meter | Various interrupt dB levels from meter |  | Pass |
| 4 | Load measured interrupt values into program and test if an interrupt is triggered within program | Program will display whether an interrupt should occur in software | Interrupt is triggered with loud instantaneous noises (Figure 18) | Pass |
| 5 | If discrepancies occur, program must be edited | Optimized program | Possible changes to be made to highest threshold (T3) | Pass |

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| Comments  The program “interrupt.cs” only provides a simple initial test, since loud instantaneous noises tend to trigger the interrupt to occur, which is undesirable. This is because the program takes a two second average by taking only a minimum and maximum sound level and averaging those two discrete levels. Highest threshold is difficult to trigger, especially when standard deviation is high (>1). |

Date 3/7/2020 Test Engineer Jared Alves Witness Michael Benker

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Process Debug Test | | Test Number | PT\_05 | | | |
| Requirement(s) Tested | | 5.1 | Verification Method | I | A | D | T |
| Test Setup | | Microsoft Visual Studio, C# “interrupt.cs” program | | | | | |

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| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Test different averaging times (30 second average vs 3 second average) within C# by updating program | Data on 30 second average and 3 second average | Figure 19 – 20 vs 2 second average is best choice | Pass |
| 2 | Implement recursive averaging in software (C#) | Comparison of recursion to multi-averaging method | Figures 20 through 24 – No discernible difference between built in C# averaging and recursion methods | Pass |
| 3 | Test averaging to see if a time delay occurs when taking the average using Visual studio due to instruction timing | Time delay confirmation | Figure 25 – Iterative averaging yields wide variance in ticks | Pass |

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| Comments  Within the program at least, implementing a 30 second average vs a 3 second average did not improve the averaging process. An accurate standard deviation or average could not be obtained (See Figure 19). Recursive averaging does not change average calculation in a noticeable way. The iterative averaging method will be used. The timing yields a wide variance of ticks (between 4000 and 6000 ticks but can be as low as 500). This is done using the Stopwatch class in C# |

Date 3/22/2020 Test Engineer Jared Alves Witness Michael Benker

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Standard Deviation Debugging | | Test Number | PT\_06 | | | |
| Requirement(s) Tested | | 5.1 | Verification Method | I | A | D | T |
| Test Setup | | Microsoft Visual Studio, C#, program: “interrupt.cs”, “environment\_interrupt.cs” | | | | | |

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| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | After ET\_11, see if number of standard deviations must be fine-tuned (bypassed due to COVID-19) | Result of ET\_11 |  |  |
| 2 | Use environmental-based interrupt program to test sound meter data if interrupts occur correctly | Determination of whether the standard deviations should be altered | High standard deviation environments are way off |  |
| 3 | Test various standard deviation multiples close to the values originally chosen to see if different multiples of the standard deviation give more accurate threshold based on environmental data | Fine-tuned standard deviation multiples |  |  |

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| Comments:  Due to COVID-19, ET\_11 remained incomplete which is a prerequisite of ET\_12. |

Date Test Engineer Witness

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| Test Name | Device Accuracy Test & Debug | | Test Number | PT\_07 | | | |
| Requirement(s) Tested | | 5.1,5.4 | Verification Method | I | A | D | T |
| Test Setup | | Integration of BT\_05, PT\_05 and PT\_06 | | | | | |

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| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Confirm that Customer Requirement 5 is met by checking that the device is accurate 99% of the time through repetitive testing of device | Requirement 5 |  |  |
| 2 | Repeat testing of device as many times until 99% accuracy is achieved, fine tuning PT\_05 and PT\_06 as necessary | 99% efficiency and Customer Requirement 5 met |  |  |
| 3 | Change to new environment with a wider variance of ambient values and repeat process | Accurate device in varying environments |  |  |

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| Comments |

Date Test Engineer Witness

# Test Plans: Coding

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | ADC Test Code | | Test Number | CT\_01 | | | |
| Requirement(s) Tested | | 5.1 | Verification Method | I | A | D | T |
| Test Setup | | Microsoft Visual Studio, C  See Appendix Code (ADC Test Code) | | | | | |

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| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Begin Microsoft Visual Studio and select C as language | N/A |  | Pass |
| 2 | Initialize the I/O and interrupt header files | Allows for I/O and interrupt libraries to be used |  | Pass |
| 3 | Write a function to clear two ports (ex. B and D) | Function is usable in main |  | Pass |
| 4 | Within main function, set Data Direction registers B, C and D as necessary | Data Direction Registers configured | PINB1:0 = ADC High  PIND7:0 = ADC Low | Pass |
| 5 | Initialize ADMUX and ADC Status and Control Registers (reserved voltage and ADC channel) | Correct ADC channel and voltage configuration |  | Pass |
| 6 | Enable global interrupts and set timer1 using TCNT1 and TMSK1 as well as control registers | Interrupts enabled to be used for step 7 | Timer1 is activated once every second | Pass |
| 7 | Write Interrupt Service Routine to display highest two digits and lowest 8 digits of ADC | Tested ADC | The ADC is read from PINC5 and sent to PB1:0 and PD7:0  (See Figure 32) | Pass |

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| Comments  See Figure 32. |

Date Test Engineer Witness

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| --- | --- | --- | --- | --- | --- | --- |
| Test Name | Audio Switch Test Code | Test Number | CT\_02 | | | |
| Requirement(s) Tested | 2.3, 4.1, 6.2 | Verification Method | I | A | D | T |
| Test Setup | Processor: ATmega328PB  Program: Test Code for Buttons  References: ATmega328PB Datasheet  Hardware: CD4066BE Quad Bilateral Switch (14-DIP) Chip | | | | | |

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| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Write C code that tests the CPU and Switches |  |  | Pass |
| 2 | Set PINB1:0 as outputs to each Switch (PB1 for Aux-Left and PB0 for Aux-Right). | PINB1 -> Aux Left  PINB0 -> Aux Right | PINB1:0 controls the CD4066BE Bilateral Switch | Pass |
| 3 | Run a loop that counts PINB1:0 from 0 to 3, increment by 1 per second. | t = 0s, PB1:0 = 0  t = 1s, PB1:0 = 1  t = 2s, PB1:0 = 2  t = 3s, PB1:0 = 3  t = 4s, PB1:0 = 0 | t=0,PB1=0,PB0=0  t=1,PB1=0,PB0=1  t=2,PB1=1,PB0=0  t=3,PB1=1,PB0=1  t=4,PB1=0,PB0=0 | Pass |
| 4 | Test Circuit and Code | The sound should turn on each side of Aux depending on the state of PB1 and PB0. | The sound turns on each end of the headphone | Pass |

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| Comments:  The Auxillary Ports (Input and Output) both needed a 1kΩ resistor to GND. |

Date Test Engineer Witness

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| Test Name | | Setting Button Test Code | | Test Number | CT\_03 | | | |
| Requirement(s) Tested | | 3.2, 6.1, 6.3 | Verification Method | I | A | D | T |
| Test Setup | | | Processor: ATmega328PB  Program: Test Code for Buttons  References: ATmega328PB Datasheet  Hardware:   * 5x Push Buttons w/4.7kΩ Pull-up Resistor. * 3x LED lights w/330Ω Resistor. | | | | | |

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| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Write C code that tests the CPU and Buttons |  |  | Pass |
| 2 | Set PIND2:0 as output for the LED, each LED represents different threshold levels | PD2:0 is the output | PD2:0 is set as the output | Pass |
| 3 | Initialize PINC4:0 as the pull-up input for each button. | PINC4:0 are now pull-up inputs for the buttons to use | PC4:0 are set as button inputs | Pass |
| 4 | Implement button PINC3 as the RESET button. | PINC3 restarts the device. | PC3 button restarts the device | Pass |
| 5 | Implement button PINC2:0  as Threshold Sensitivity buttons. Sets the Sensitivity levels. | PINC2 = High  PINC1 = Medium  PINC0 = Low | PC2 is High Thresh.  PC1 is Med Thresh.  PC0 is Low Thresh. | Pass |
| 6 | Implement button PINC4 to set the device to sleep mode and restart the program if the button is pressed again. | Sleeps on 1 button press and restarts the device on the next press. | PC4 Button toggles the device on and off | Pass |
| 7 | Test Circuit and Code | PC4 Button turns the power on/off  PC3 resets the program  PC2:0 changes threshold levels | PC4 – On/Off  PC3 – Reset  PC2:0 – Threshold Buttons | Pass |

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| Comments:  The code was tweaked in order to get the on/off button operating. |

Date Test Engineer Witness \_

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Main Microcontroller Test Code | | Test Number | CT\_04 | | | |
| Requirement(s) Tested | | 2.3, 3.2, 4.1, 6.1, 6.2, 6.3 | Verification Method | I | A | D | T |
| Test Setup | | Processor: ATmega328PB  Program: Integration of CT\_02 and CT\_03  References: ATmega328PB Datasheet | | | | |  |

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| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Verify Tests CT\_02 and CT\_03 | See Tests CT\_02 and CT\_03 | CT\_03 Works  CT\_02 Works | Pass |
| 2 | Initialize PIND2:0 as outputs (for the LED lights) | PIND2:0 are outputs | LED Outputs Represents Threshold Levels | Pass |
| 3 | Initialize PINC4:0 as the pull-up input for each button | PINC4:0 are now pull-up inputs for the buttons to use | PC4:0 are buttons set as an input | Pass |
| 4 | Initialize PINB1:0 as inputs (for the Bilateral Switches) | PINB1 and PINB0 controls each switch | PB1:0 are audio control switches | Pass |
| 5 | Run a loop that counts PINB1:0 from 0 to 3, increment by 1 per second. | t = 0s, PB1:0 = 0  t = 1s, PB1:0 = 1  t = 2s, PB1:0 = 2  t = 3s, PB1:0 = 3  t = 4s, PB1:0 = 0 | t= 0s, PB1:0 = 0  t= 1s, PB1:0 = 1  t= 2s, PB1:0 = 2  t= 3s, PB1:0 = 3  t= 4s, PB1:0 = 0 | Pass |
| 6 | Test Circuit and Code (Switches) | The sound should turn on each side of Aux depending on the state of PB1 and PB0. | The sound turns on and off Aux Left and Right (see test Step 5) | Pass |
| 7 | Test Circuit and Code (Buttons) | PC4 Button turns the power on/off  PC3 resets the program  PC2:0 changes threshold levels | PC4 – On/Off  PC3 – Reset  PC2:0 – Threshold Buttons | Pass |

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| Comments |

Date 3/4/2020 Test Engineer Drew Martins Witness Ryan Dumont

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| Test Name | | | Process Implement in Microcontroller | | Test Number | | | | CT\_05 | | | | |
| Requirement(s) Tested | | | 6.2, 6.3 | | Verification Method | | | I | A | | | D | T | |
| Test Setup | | | Atmel Studio, Microsoft Visual Studio, AVR programming, C#, Oscilloscope and probes | | | | | | | | | | |
| Test Step | | Action (Attach test data, diagrams, etc. as appropriate) | | | | | Expected Result | | | | Observed Result | | | Pass  Fail | |
| 1 | | Perform demonstration PT\_04. | | | | | See PT\_04 Test Plan. | | | |  | | | Pass | |
| 2 | | To implement process PT\_04 in microcontroller, match variables that are defined using I/O such as analog input and threshold setting to microcontroller memory. | | | | | All variables from PT\_04 should be accounted for, including cascaded averages, 20 second standard deviations. | | | | See Main Microcontroller Code | | | Pass | |
| 3 | | Without connecting any I/O such as microphone and analog circuitry, digital switch and threshold switches, use the microcontroller to step through the process using user-defined 2 second ambient level averages. | | | | | Monitor 2 second averages saved to microcontroller. | | | | Each 2s Avg is saved into an array. | | | Pass | |
| 4 | | Verify that after 20 seconds, the oldest 2-second average gets replaced by the newest if the newest is below the interruption threshold. | | | | | Verification complete. | | | | The oldest 2s Avg is replaced every 20s. | | | Pass | |
| 5 | | Verify that after 20 seconds, if the newest 2-second average is above the threshold standard deviation, averaging stops and a high signal voltage is output to the digital switch output pin (not connected) using oscilloscope and probe. | | | | | Verification complete. | | | |  | | | WIP\* | |
| 6 | | Verify that the RESET variable resets the 20 seconds of averaging data when activated and no interrupt is allowed for 20 more seconds. | | | | | Verification complete. | | | | The reset button restarts the program from the beginning. | | | Pass | |
| 7 | | Verify that the OFF button will tell the microcontroller to manually shut down, as opposed to cutting the voltage supply. | | | | | Verification complete. | | | | The off button shuts down the microprocessor | | | Pass | |

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| Comments:  \*Due to COVID-19, the lab equipment required for this part of the test plan was not present. |

Date Test Engineer Witness \_\_\_\_\_\_\_\_

# Test Plans: Printed Circuit Board

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | PCB Test Layout | | Test Number | BT\_01 | | | |
| Requirement(s) Tested | | Constraint of maximum size: 3.5” x 2” | Verification Method | I | A | D | T |
| Test Setup | | Cadence OrCAD Suite  Eagle Autodesk PCB Designer Tools | | | | | |

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| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Run Cadence OrCAD: Capture CIS and construct a circuit with estimated components necessary for the PCB, including Microcontroller, Digital Switch, approximate analog electronics selections, OP-AMP and connections. | Circuit Layout | Schematic generated. | Pass |
| 2 | Import necessary library and padstack files (website: ultralibrarian.com) for components that are not standard in the program. | All components accounted for. | All expected components available with necessary libraries. | Pass |
| 3 | Export the schematic layout to a netlist file and load the netlist into OrCAD PCB Editor with a board layout size at the maximum constraint size 3.5” x 2” | Netlist file generated without errors or warnings. Board size in the Editor is 3.5” x 2”. Verify that components can be placed using the netlist. | All components successfully imported into OrCAD PCB Editor. Board size chosen to be maximum constraint size. | Pass |
| 4 | Place components on the board in the software and connect wires to demonstrate that all components fit in the maximum constraint size. | All components fit on the 3.5” x 2” layout. | All components with possible trace schemes fit on maximum constraint. | Pass |

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| Comments  *Figure 22. PCB Layout: Maximum Size Constraint.* Purpose of test: to see that electronics will fit in max constraint size. Figure depicts rectangle of max size on top of pcb to show that board size is the max constraint size. |

Date 3/20/2020 Test Engineer: Michael Benker Witness: Stephen Felix

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Initial PCB | | Test Number | BT\_02 | | | |
| Requirement(s) Tested | | 6.1, 6.2, 6.3, Constraint of maximum size: 3.5” x 2” | Verification Method | I | A | D | T |
| Test Setup | | Cadence OrCAD Suite  Eagle Autodesk PCB Designer Tools  Serpac Enclosures Website | | | | | |

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| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Verify Exact component selections and circuit layouts in ET\_06 and ET\_08. | See ET\_06 and ET\_08 | Circuit layouts for ET\_06 and ET\_08 have not been verified completely. | Fail |
| 2 | Create new schematic or modify layout from BT\_01 to include final component selections. Verify that all components and wire paths are correct. | Schematic components and wire pathways are correct. | In progress as of 3/26/2020. |  |
| 3 | Run Cadence OrCAD: Capture CIS or Eagle Autodesk PCB designer tools and construct a circuit with final components choices and correct wire pathways. | Circuit layout is in accordance with schematic. |  |  |
| 4 | If using Capture CIS, import necessary library and padstack files (website: ultralibrarian.com) for components that are not standard in the program. If using Eagle, ensure that all layout components are available. | All components accounted for. |  |  |
| 5 | Export the schematic layout to a netlist file and load the netlist into OrCAD PCB Editor or import the schematic to Eagle PCB Designer and ensure all layout components are available. | Netlist file generated without errors or warnings or all layout components available. |  |  |
| 6 | Reduce size of board as much as possible while preserving circuit layout on the board. | Board size is reduced from maximum constraint size. |  |  |
| 7 | Increase the board size to fit snug in the next largest available enclosure from Serpac enclosures website. Maintain equal margin sizes at each edge of the board. | Layout size fits in chosen enclosure. |  |  |

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| Comments  Due to Lab restrictions (COVID-19), a decision is being made to produce rough-estimate PCB boards that may be edited using solder, component insertions, etc. |

Date Test Engineer Witness

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | PCB Review | | Test Number | BT\_03 | | | |
| Requirement(s) Tested | | 6.1, 6.2, 6.3, Constraint of maximum size: 3.5” x 2” | Verification Method | I | A | D | T |
| Test Setup | | Cadence OrCAD Suite  Eagle Autodesk PCB Designer Tools | | | | | |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Complete BT\_02 Initial PCB | See BT\_02 |  |  |
| 2 | Review component choices and pathways on PCB layout with teammates. | Component choices and pathways match schematic layouts. |  |  |
| 3 | Seek brief consultation with University sources including students, technicians and professors to confirm that PCB is acceptable and that parameters such as linewidth are appropriate for manufacture. | PCB is satisfactory or adjustments must be conducted. |  |  |
| 4 | If PCB design is less than satisfactory, adjust as necessary according to advice sought for PCB. | PCB is satisfactory for manufacture. |  |  |
| 5 | Seek methods of PCB manufacture and place order. | PCB ordered for manufacture. |  |  |

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| Comments |

Date Test Engineer Witness

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| Test Name | PCB Manufacture Summary | | Test Number | BT\_04 | | | |
| Requirement(s) Tested | | 7.0, constraint size. | Verification Method | I | A | D | T |
| Test Setup | | PCB(s) | | | | | |

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| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Complete BT\_03, send PCB out for manufacture and receive manufactured PCB(s). | PCB(s) is mailed out and in possession of the team. |  |  |
| 2 | Inspect all components on PCB to verify that the components are as expected. | Components are as expected. |  |  |
| 3 | Inspect all pathways on PCB to verify that they are as expected. | Pathways as expected. |  |  |
| 4 | Inspect all input and outputs paths on the PCB. | Inputs and outputs as expected. |  |  |
| 5 | Verify that PCB fits in selected enclosure. | PCB fits in enclosure with selected battery source(s). |  |  |

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| Comments |

Date Test Engineer Witness

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| Test Name | PCB Function Test and Comparison | | Test Number | BT\_05 | | | |
| Requirement(s) Tested | | 6.1, 6.2, 6.3 | Verification Method | I | A | D | T |
| Test Setup | | PCB  Power Supply  Oscilloscope and probes  Website: noises.online  Sound meter | | | | | |

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| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Complete tests ET\_12 and BT\_04. | See ET\_12 and BT\_04. |  |  |
| 2 | Install program code to the ATmega328PB on the PCB. | ATmega328PB on PCB is responsive and code is loaded. |  |  |
| 3 | Connect wires to the connection ports on the PCB for each connector and connect power supply, ground and probes to respective ports on the PCB as per schematics used in ET\_12. | PCB function is comparable to ET\_12 function. |  |  |
| 4 | Conduct test ET\_12 but for PCB and record experimental results. | PCB function is comparable to ET\_12 function. |  |  |
| 5 | Compare results of PCB function test with ET\_12. | PCB function is comparable to ET\_12 function. |  |  |

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| Comments |

Date Test Engineer Witness

# Test Plans: Enclosure

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Enclosure Selection | | Test Number | NT\_01 | | | |
| Requirement(s) Tested | | 7.0, Customer Req. 1 | Verification Method | I | A | D | T |
| Test Setup | | ~~OrCAD Design~~  ~~Battery/Circuit Board Dimensions~~  Jameco.com | | | | | |

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| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Determine possible enclosure sizes from enclosures website. | Several enclosure sizes that meet size constraint. | Enclosure chosen and ordered: Hammond 2138222 (see datasheet figure) | Pass |
| 2 | Verify Battery Selection following battery consumption test ET\_09. | Battery is chosen and ready. | Due to lab availability constraints due to COVID-19, the decision has been made to choose the enclosure without completing this test. | Fail |
| 3 | Verify size of PCB initial layout | Size should be within customer’s constraints. | PCB layout will be built under the constraint of enclosure choice. | Pass |
| 4 | Once length and width measurements of PCB are verified, pick an enclosure with correct length and width to house the board. | Length/Width of PCB and battery should be smaller than enclosure. | PCB layout will be built under the constraint of enclosure choice. | Pass |
| 5 | Make sure enclosure has enough height space within to allow battery and PCB to be placed on top of one another. | Enclosure should be high enough to hold battery and circuit board when stacked on top of each other. | Under consideration. Battery may be selected given form factor constraint. | Pass |

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| Comments |

Date 3/25/2020 Test Engineer Ryan Dumont Witness Michael Benker

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Enclosure Outfit for Component, Holes, I/O | | Test Number | NT\_02 | | | |
| Requirement(s) Tested | | 1.1 | Verification Method | I | A | D | T |
| Test Setup | | Drill  Various Drill Bit Sizes  Enclosure  All Switches and Exterior Components | | | | | |

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| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Refer to figure 10 for tentative component placement. | A visual of proper placement will be obtained. |  |  |
| 2 | Drill the Proper size holes for each component in their appropriate place designated in figure 10. | Proper mounting locations will be created. |  |  |
| 3 | Mount all the components and make sure none interfere with each other. | All exterior components will be placed on enclosure. |  |  |

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| Comments |

Date Test Engineer Witness

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| --- | --- | --- | --- | --- | --- | --- | --- |
| Test Name | Enclosure Meets PCB and Battery Test | | Test Number | NT\_03 | | | |
| Requirement(s) Tested | | 1.1 | Verification Method | I | A | D | T |
| Test Setup | | Finalized Circuit Board  Battery  Enclosure | | | | | |

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| --- | --- | --- | --- | --- |
| Test Step | Action (Attach test data, diagrams, etc. as appropriate) | Expected Result | Observed Result | Pass  Fail |
| 1 | Place and secure battery in enclosure laying it flat on the bottom. | Battery should fit |  |  |
| 2 | Place and secure circuit board on top of battery. | Battery and circuit board should fit together |  |  |

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| Comments |

Date Test Engineer Witness

## Figures: Electronics Testing

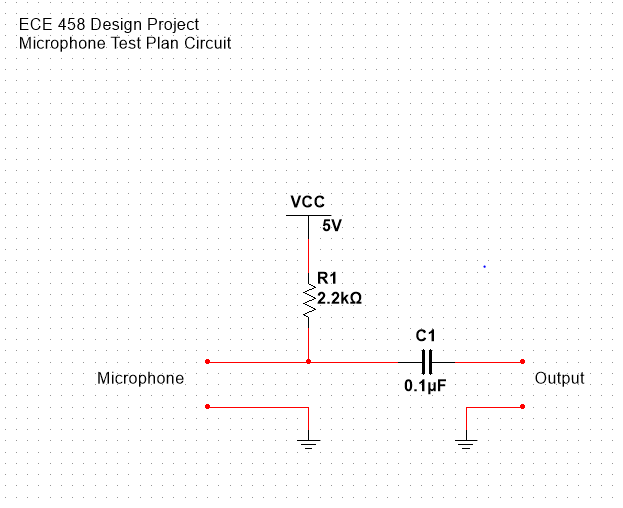


Figure 28 Microphone Circuit



Figure 29 Microphone Test

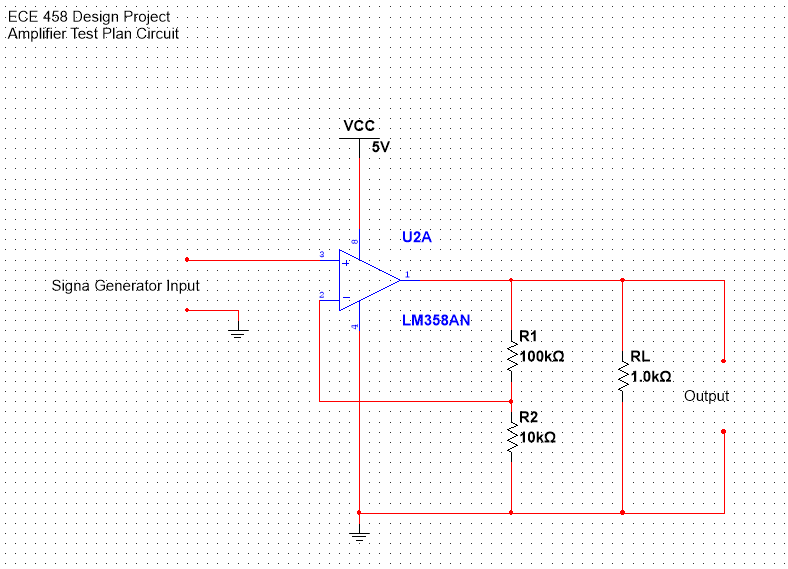


Figure 30 Amplifier Test Plan Circuit

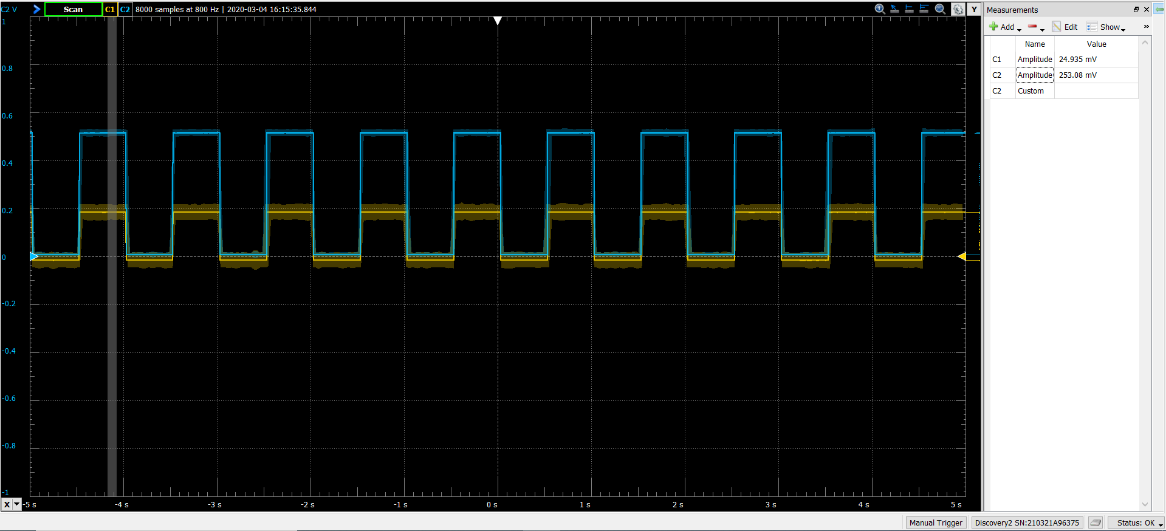


Figure 31 Amplifier 50mV Input

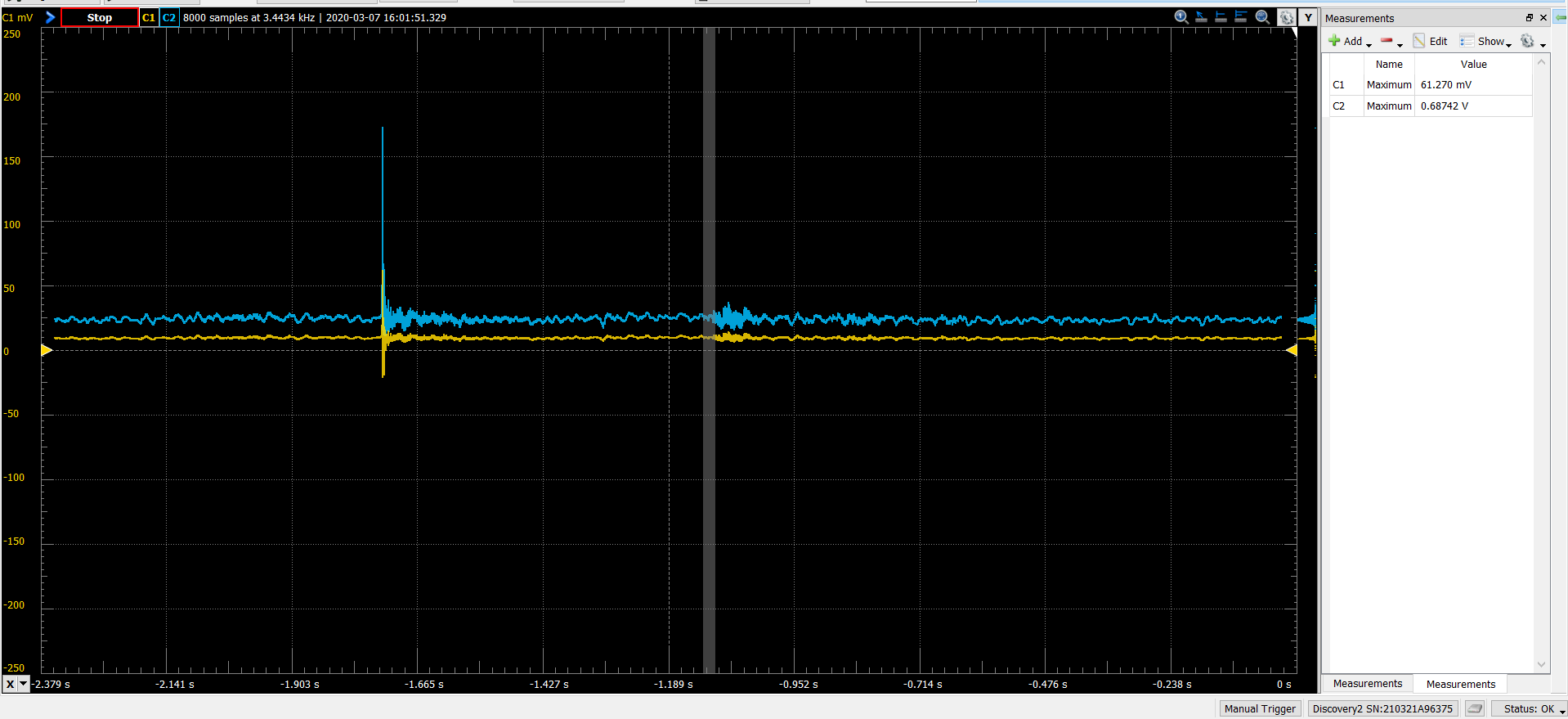


Figure 32 Microphone & Amp Integration

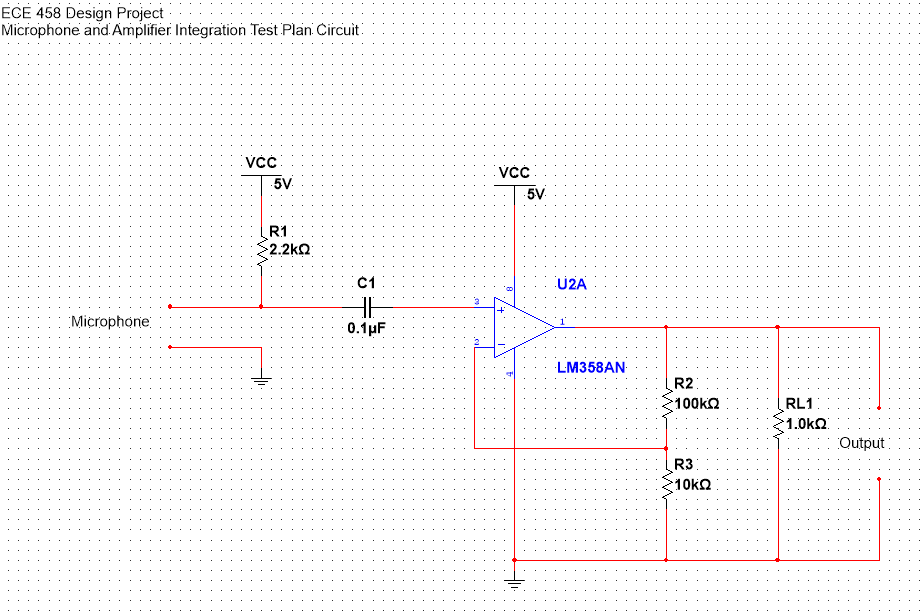
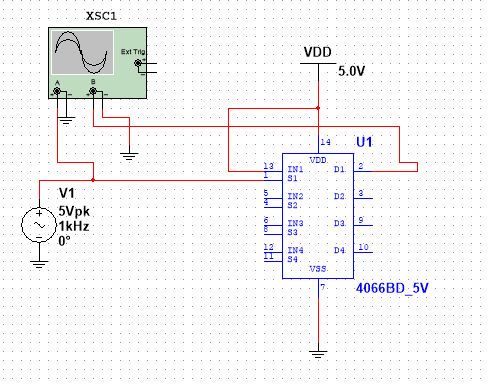


Figure 33 Microphone and Amplifier Integration Circuit



A picture containing game, basketball

Description automatically generatedFigure 34 Digital Switch Testing Circuit

Figure 35 Auxillary Switch Test

## Figures: Processing Testing

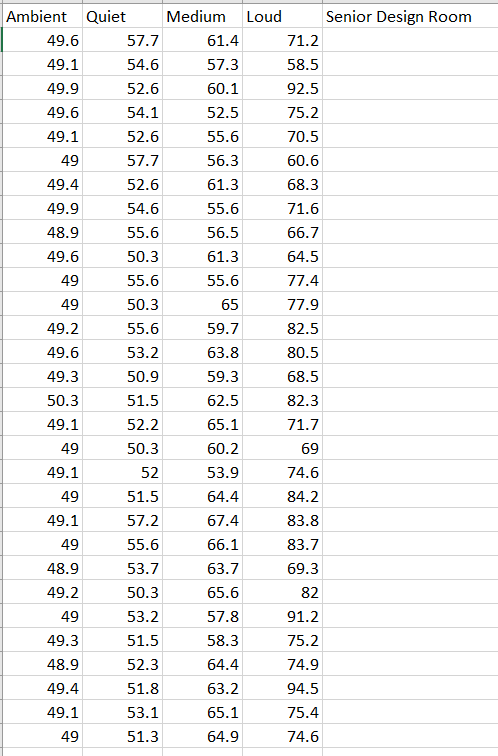


Figure 36. Data Collected using Sound Meter in One Environment

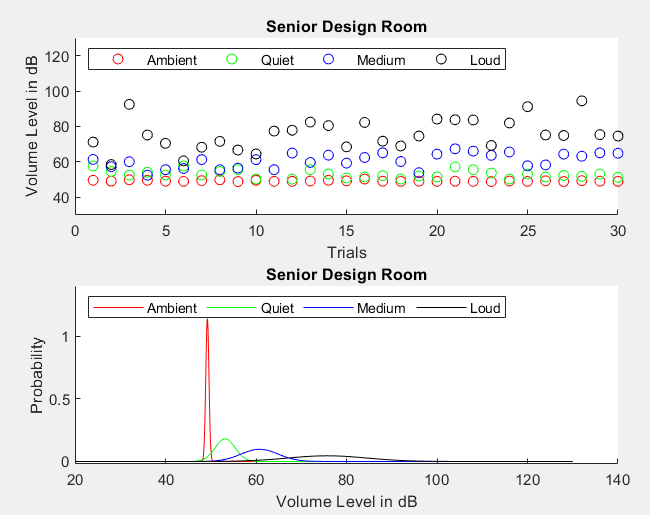


Figure 37. Data Plot with Sound Meter

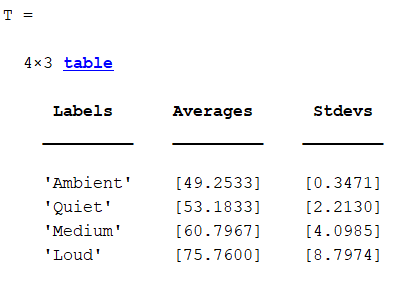


Figure 38. Standard Deviations of Environment



Figure 39. Multiple Environments

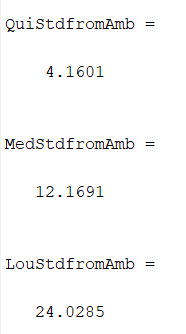


Figure 40. Average Standard Deviations of Each Threshold Level

A screenshot of a social media post

Description automatically generated

Figure 41 Standard Deviation vs Ambient

A screenshot of a cell phone

Description automatically generated

Figure 42 Threshold based on Standard Deviation

A screenshot of a cell phone

Description automatically generated

Figure 43 PT\_04 Successful Interrupt

A screenshot of a cell phone

Description automatically generated

Figure 44 30 second average vs 3 second average

A screen shot of a person

Description automatically generated

Figure 20 Call Recursion

Figure 45 Iterative Averaging

A close up of a screen

Description automatically generated

Figure 46 Call Iterative

A screenshot of a computer

Description automatically generated

Figure 47 Recursive Average Result

A screenshot of a computer

Description automatically generated

Figure 48 Iterative Averaging Result

A screenshot of a cell phone

Description automatically generated

Figure 49 Recursive Methods

A black sign with white text

Description automatically generatedA black sign with white text

Description automatically generatedA black sign with white text

Description automatically generated

Figure 50 Average Timing

## Figures: Coding Testing



Figure 51 ADC Test Code

## Figures: Printed Circuit Board Testing

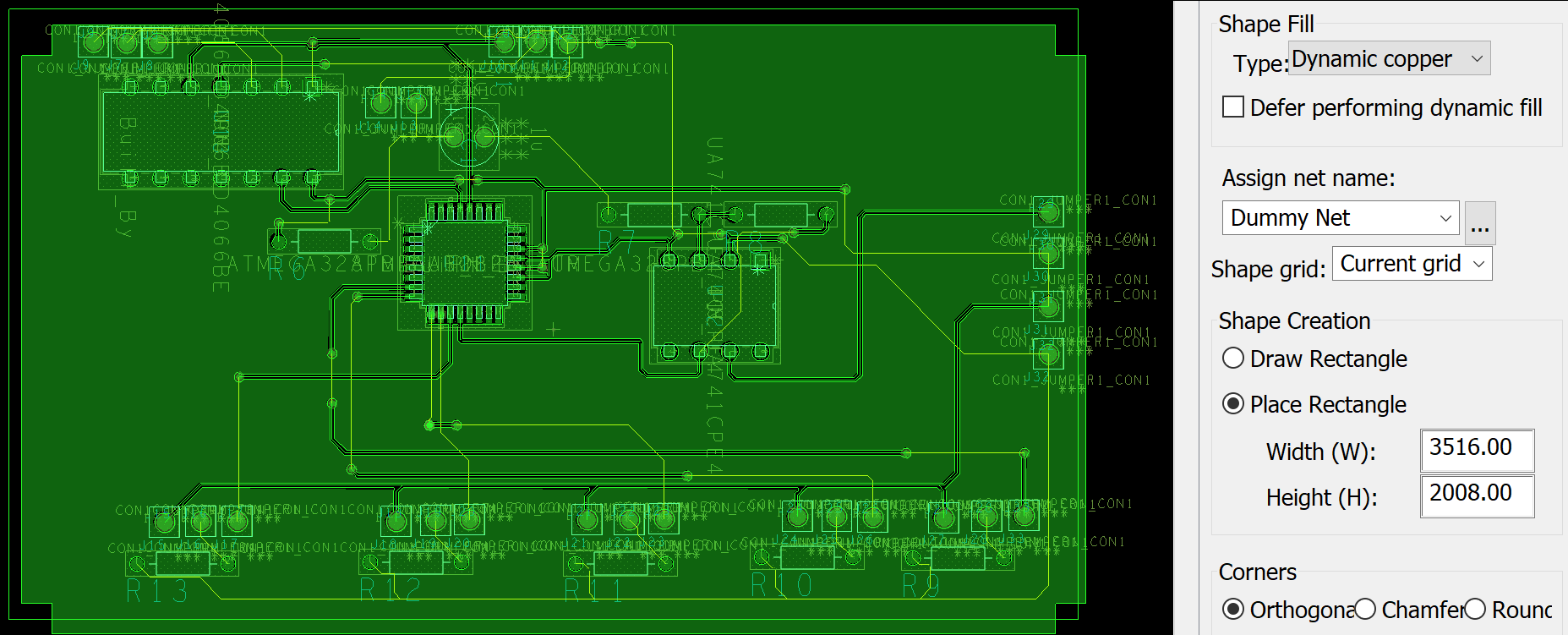


Figure 52. PCB Test Layout for Maximum Constraint Size (3500mil x 2000mil

## Figures: Enclosure Testing

A close up of text on a white background

Description generated with high confidence

Figure 53 Enclosure Outline

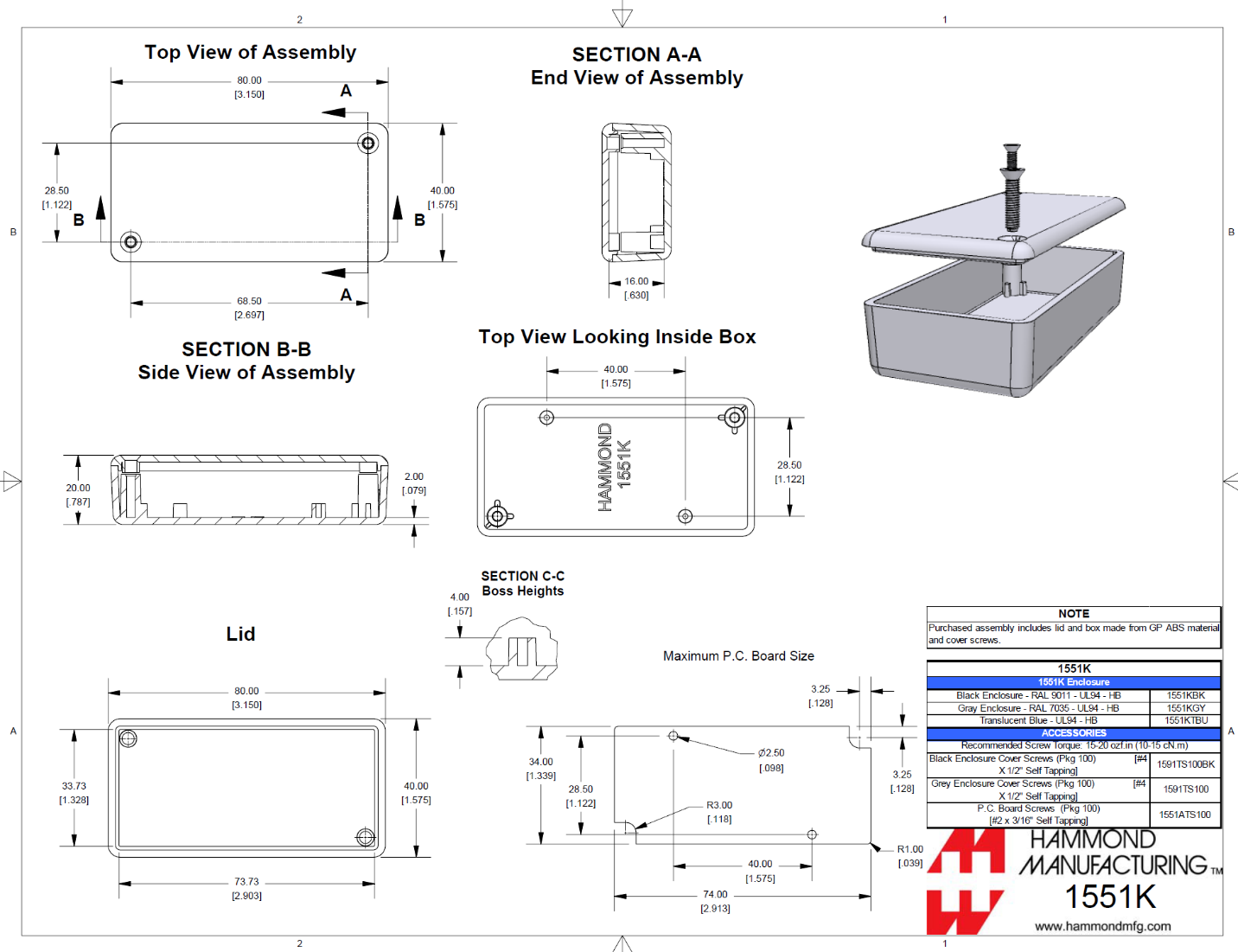


Figure 54. Selected Enclosure: Hammond 2138222