UtahStateUniversity

Revision: 3
Effective Date: 12/13/17

# Design Baseline Document

# Breath Strummer


Steven Proctor

Rhett Ramsey

Randy Richards


Mechanical & Aerospace
ENGINEERING

# PROJECT ROLES AND RESPONSIBILITIES

| PROJECT ROLE | NAME | DOCUMENT ROLE: PAGES COVERED |
|---|---|---|
| LEAD ENGINEER | Randy Richards | Compiler & Reviewer: all<br>Coauthor: Section 2 |
| SYSTEM ENGINEER | Rhett Ramsey | Author: Section 1 |
| P-CARD SPECIALIST | Steven Proctor | Author: Sections 2-8 |
| FACULTY ADVISOR | Jackson Graham | Approval |
| CUSTOMER | Ruud van der Wel | Acceptance |

# CONTENTS

# APPENDICES

A. Bill of Materials
B. Drawing Package

# 1 PROBLEM DEFINITION

## 1.1 OVERVIEW

### 1.1.1 Objective

The objective of this project is to develop a breath-activated guitar strummer. The purpose of the Breath Strummer is to provide a means by which a person with an arm injury or disability can play the guitar. As such, the Breath Strummer is designed primarily for a person who wishes to play the guitar but has limited or no function of one of their arms. One fully functional arm is still required to finger the chords on the neck of the guitar, but the Breath Strummer eliminates the need of a second arm by providing a means of strumming through one's breath.

### 1.1.2 Customer

Ruud van der Wel of My Breath My Music Foundation, located in the Netherlands, has devoted his time to providing individuals with various disabilities the opportunity to play musical instruments that they would normally be unable to play. Some of the products developed by the My Breath My Music Foundation include a flute that can be played with no hands and keyboards that require the use of only one hand. As a respiratory therapist, Mr. van der Wel specializes in employing the use of one's breath to control these various products.

### 1.1.3 Target End User

The intended target end user of the Breath Strummer is somebody who wishes to play the guitar but has limited or no use of a single arm or hand. One functional arm is still required to finger the chords on the neck of the guitar. The strummer is controlled by the user's breath due to the concern that many would-be-users of the Breath Strummer may have other disabilities throughout their body. Additionally, the Breath Strummer will be developed an open-source product that is affordable and simple to assemble in an attempt to make it more available to those who wish to build and extend it.

### 1.1.4 Interfacing Systems and Users

The Breath Strummer interfaces directly with a standard acoustic guitar. The design will primarily accommodate the use of a hollow body, steel string, acoustic guitar. The Breath Strummer must not damage the guitar and should be of size and configuration that allows the user to hold the guitar in his or her lap while sitting.

This product will require a user to attach the strumming mechanism to the guitar. Rather than being installed and removed regularly, the strummer will likely be installed onto a guitar once and remain attached. Because of this, being able to install the instrument with only one arm will not be a requirement.

### 1.1.5 Issues of Primary Concern

To achieve results similar to those produced by a human arm, the Breath Strummer must incorporate the ability to strum guitar strings at varying speeds and intensities. The input device must sense pressure and position differences in the user's breath and head position, and respond accordingly. The customer has also specified that the user should be able to control the number of strings played at any time.

## 1.2 Engineering Requirements

The following requirements were specified by the customer in both the Project Description document and the Customer Kickoff Meeting held on January 22, 2017.

### 1.2.1 The device shall be able to selectively strum the top four, five, or six guitar strings.

Source: The Breath Strummer must allow the user to control which strings are played at any one time, as not all chords are composed using all six strings. This requirement was communicated through the Project Description document and verified during an initial kickoff meeting with the customer.

Fulfillment Strategy: To select the number of strings to be strummed, it is proposed that a control switch: such as a foot pedal, or a the breath input device: similar to the My Breath, My Music's magic flute, be used. This component will either mechanically or electrically adjust the strummer so that it only picks the specified number of strings.

### 1.2.2 The device shall be able vary the strum intensity from 70 dBs to 80 dBs measured 1 meter from the guitar.

Source: The Breath Strummer must create dynamics similar to those achieved by a human. For this to be achieved, the device must allow variance in volume output. This requirement was communicated through the Project Description document and verified during an initial kickoff meeting with the customer.

Fulfillment Strategy: A pressure sensor, such as the Honeywell ASDX Series Ultra-Low Silicon Pressure Sensor, will detect breath intensity of the user, which will signal the assembly to adjust the depth of the pick relative to the guitar strings to correspond to the appropriate volume.

### 1.2.3 The device shall be able to vary strum speed from 100 ms to 750 ms per sweep

Source: For the Breath Strummer to sound as close to human as possible, variance in strumming speed must be achieved. This requirement was communicated through the Project Description document and verified during an initial kickoff meeting with the customer.

Fulfillment Strategy: A ranged input device, like a potentiometer, will be used to adjust the desired strumming speed. The potentiometer output will control the speed at which the strummer picks the guitar strings.

#### 1.2.4 The device that mounts to the guitar shall not exceed a weight of 2.5 Kg, or be of a size to interfere with the user when playing

Source: The device must not weigh so much as to make the guitar difficult to manage with a single arm. Additionally, the device should not get in the way of the user while playing or make the guitar uncomfortable to hold. This requirement was communicated through the Project Description document and verified during an initial kickoff meeting with the customer.

Fulfillment Strategy: The bulk of the device will be located over the sound hole out of the way of the user, and be made using lightweight (i.e. plastic, aluminum, etc.) parts. The device will mount to the guitar such that it does not rest on the user during normal use of the guitar. If this isn't possible, additional design decisions will be made to increase comfortable for normal use.

## 1.3 GOALS

The following project goals were specified by the customer in both the Project Description document and the Customer Kickoff Meeting held on January 22, 2017.

#### 1.3.1 The device should be an open-source product that others can replicate and use.

Source: The My Breath My Music Foundation has specified that they wish for this product to be readily available to anybody who wishes to use it. To achieve this, the system should be an open-source design that others can easily duplicate. This goal was communicated through the Project Description document and verified during an initial kickoff meeting with the customer.

Fulfillment Strategy: To create a design that is simple to assemble and use, our team plans to use standard parts when possible. The use of custom parts will be limited to reduce the cost of the device. To further aid in the setup of the device, an installation and setup procedure will be documented and published.

#### 1.3.2 The device should have the ability to play individual strings

Source: While the requirement is to allow a single armed individual to strum basic chords on a guitar, the ability to play individual strings would further the user's ability to play and enjoy the instrument. This is an exciter that was discussed during a follow up meeting with the customer.

Fulfillment Strategy: Individual string selection would come from a user input such as a foot pedal, or the angular position of the breath input device. This would signal the device to only play the string corresponding the input position. This may require an additional button to allow the user to toggle between chord strumming and note picking.

## 1.4 FUNDAMENTAL ASSUMPTIONS

There are several fundamental assumptions regarding the use of the Breath Strummer. It is assumed that the user is able to inhale and exhale regularly. Because the device will be controlled with the user's breath, the user must be able to control the rate and intensity with which he or she breathes. It is also assumed that the user of the Breath Strummer has one fully functional arm available to finger the chords on the neck of the guitar. If a foot pedal is ultimately used as a control switch for the number of strings being played, it would be assumed that the user has functionality in at least one leg.

### 1.5 GOVERNING STANDARDS

Due to the device being open source and non-profit, there are no governing standards that apply. Regardless, measurements will still be taken to ensure electrical safety, as well as proper sanitation - as parts of the device will come into contact with the user's mouth.

### 1.6 DELIVERABLES

The following are considered items that our design team will deliver to the customer, along with dates that outline when the customer can expect each deliverable.

- System Requirements Report, 24-Jan-2017
- Conceptual Design Report, 21-Feb-2017
- Conceptual Design Review, 28-Feb-2017
- Preliminary Design Report, 21-Mar-2017
- Preliminary Design Review, 28-Mar-2017
- Critical Design Report, 1-Oct-2017
- Critical Design Review, 2-Oct-2017
- Final Design Report, 12-Dec-2017
- Final Design Review, 13-Dec-2017
- Engineering Prototype, 20-Dec-2017

## 2 CONCEPTUAL ANALYSIS

### 2.1 DESIGN SPACE

The design space consists of technical requirements or components that do not have a notable influence on the design itself. These are things that must happen regardless of the chosen final design, and as such, are not helpful in making design decisions. In the case of the Breath Strummer, there are four technical requirements that are considered design space.

The first is that the device be controlled via breath with an exhale resulting in a down stroke and inhale resulting in an upstroke. This is the fundamental concept behind the Breath Strummer, as the name implies.

The second design space requirement is that the device hold a standard guitar pick of any thickness. This will allow the user to adjust the timbre to achieve a more natural sound. It also allows for use of commercially available picks, reducing cost and complexity of the final design.

Third is that the device must mount to the guitar without damaging it. The device is intended to be removable, restoring the instrument to its original state when removed. A permanent device would imply a custom fit, essentially defeating the requirement that the device be open-source. Guitars come in a wide range of sizes, and the device should be able to adapt to fit most steel string, acoustic guitars.

The last technical requirement in the design space is that the device be powered by a commonly available source, such as standard size batteries or via USB. This will allow the device to be used by the global community.

Concepts that involved a free-standing strumming mechanism were quickly dismissed as the design space insisted that the strumming mechanism be mounted to the guitar. User inputs such as foot pedals were also dismissed as the strummer is to be controller by breath input, and no information is given regarding the user's ability to use their feet.

## 2.2 Concepts Considered

Many of the considerations made come from prior experience playing guitars and wind instruments. Two of the members of the design team play the guitar regularly and are familiar with the mechanics involved. In addition, extensive internet research was done to see if similar devices already existed. There were several designs that fully automated a guitar to be played by a computer but very few that only assisted the user. There was only one device found that allowed the user full control of the fret board and hands-free control of the strumming. In this instance the strummer was a mechanical device that was pulled back and forth across the strings with foot pedals and a cable system. It is similar in principle but quite different in how it interfaces with the user.

For general information about acoustic steel string guitars the team talked to a local guitar shop. Information about guitar sizes, string spacing, action height, etc., was obtained so the team could design a product that will accommodate a wide a range of guitars as possible.

Design decisions were broken down into four subsystems: the microcontroller, the strumming mechanism, the control for selecting the appropriate number of strings to be strummed, and the control for varying the strumming speed. Each system is integrated with the others but are essentially discrete in the sense that a design decision in one area does not affect the final design on another.

### 2.2.1 Microcontroller

The microcontroller is the brain of the Breath Strummer. It interprets the input from the various sensors and control systems and sends an output signal to the servos. The three microcontrollers under consideration are the Raspberry Pi, the Arduino, and the Adafruit Feather.

The Raspberry Pi is made primarily for computing and running an operating system based on the Linux kernel. As such, all operations have to go through the operating system, causing a higher latency between the input signal and hardware execution. The Pi is the most expensive but by far the most powerful in terms of processing. However, the Pi does not have pulse width modulation (PMW), which is needed to control the servos. There is a shield (attachment) for the Pi that will handle the PWM but stacks another processing center and adds to the cost.

The Arduino is a microcontroller built for small scale controls and robotics applications. It has native PWM, lacks an operating system, handles the computations and signal interpretation directly, and reduces latency to nearly real time. The Arduino will also require an attachment to handle the quantity of servos the Breath Strummer will have but is slightly cheaper than the Pi's shield. The Arduino is also built with applications similar to the Breath Strummer in mind and has a servo library available, greatly simplifying the task of programming the controller.

The Feather and Arduino are both Adafruit controllers, so like the Arduino, the Feather has the same programming advantages, as well as the native PWM. The Feather is less than half the size of the other two, but still has more than enough processing capabilities for the Breath Strummer. The Feather will also require a shield, or 'wing' as they are called in the Feather series, to handle the quantity of servos. The Feather also has proto space built into the controller, alleviating the need for a second board to handle the additional electrical components.

#### 2.2.2 Strummer

The strummer is the mechanism that will be holding the picks and engaging the guitar strings. Three setups were considered: a single pick sweeping across the strings, two picks sweeping in opposite directions, and six static picks that each pluck individual strings.

The single pick system uses the most human like movement and would be the smallest with the fewest parts. The single pick system would also reduce the number of servos and allow the controller to function without a shield. The largest issue with the single pick system is the delay between strums. The user must have the option to perform multiple strums in a single direction, meaning a single pick must return to a neutral position between strums.

The two-pick system eliminates the delay problem because it would have a pick ready to strum in either direction. However, this makes strumming specific strings very difficult as the pick performing the strum would have to drop down between strings during the strumming action to engage the appropriate strings. This design essentially doubles the parts needed by the single pick and will require a shield to handle the additional servo.

The six-pick option avoids the delay between strums and makes the action of strumming individual strings no different than strumming all six strings. This option would require the most parts and be the most expensive, but does offer the only reasonable solution for meeting the goal of playing individual strings. In addition, it provides a simple way to ensure that when chord combinations are selected the appropriate strings will be engaged without the risk of missing a string during a strum.

### 2.2.3 String Selection Control

The string selection control is the method by which the user will choose to strum the top four, five, or six strings. Each standard chord on the guitar uses a different number of strings to produce all the necessary notes. For example, an "E" chord uses all six strings, while a "D" chord uses only the top four strings. As such, the user needs to be able to select the number of strings associated with the chord they are trying to play. It is desirable that this input device can be expanded to allow more advanced players to play individual strings in order to reproduce melodies or "riffs" typical to guitar music.

A harmonica style input device would allow the user to easily switch the number of strings being played. The 'harmonica' would have three tubes through which the user could blow. Each tube would correspond to a different number of strings. One tube would tell the microcontroller to strum all six strings, while the other two would indicate that the user only wants five or four strings to be strummed. The harmonica input could be expanded to allow an advanced user to play individual strings.

A simple switch could change how the microcontroller interprets an input through each tube. With three tubes and the ability to exhale and inhale through each tube, the user would have six types of input – one for each string. An exhale into tubes 1, 2, and 3 would correspond to a strum across the $1^{st}$, $3^{rd}$, and $5^{th}$ string respectively. While an inhale into tubes 1, 2, and 3 would result in a strum across the $2^{nd}$, $4^{th}$, and $6^{th}$ string respectively. The biggest downside to this design is that it requires three pressure transducers, one for each tube. Not to mention the need for the user to learn how to play in a harmonica fashion.

A simpler input device could achieve the same results as the harmonica with less parts and cheaper cost. By adding a potentiometer to the input device, the microcontroller could track the angular position of the input device. This would allow the user to change the number of strings being strummed by tilting their head up and down. A higher position would cause four strings to be strummed, while a lower position would tell the microcontroller to strum all six strings.

Like the harmonica design, the potentiometer would also allow an adept user to play individual strings after activating a switch. The switch would tell the microcontroller to read the potentiometer inputs as individual strings instead of chords. Therefore, the highest position would result in the top string of the guitar being played while the lowest position would play the lowest string on the guitar. The six strings would be proportionally spaced between the limits of the potentiometer's range of motion, allowing for simple intuitive control of individual strings.

Lastly, a foot controlled string selection device was also considered. This would be controlled similar to the breath input potentiometer but with the user's foot. Again, a higher position would result in the top four strings being playing when in chord mode or the highest string after activating the individual string selection. However, major downsides include the need to build an additional device and the lack of precision control that can be achieve with the breath potentiometer.

### 2.2.4 Strum Speed Control

The project requires that the Breath Strummer be able to vary the speed at which it strums a chord. There is a strong correlation between playing slowly and quietly while playing fast tends to produce a louder sound. As such a speed control will also give the user some control over the dynamics of the song. A potentiometer is one of the easiest ways to smoothly transition through a range of inputs, and thus is the crux of all methods considered to control the speed of the strumming.

The first method would be almost identical to the breath input potentiometer mentioned in the previous section. However, where the previous potentiometer only allowed motion in the vertical plane and controlled the string selection, this potentiometer would allow motion in the horizontal plane and would control the speed of strumming. This potentiometer could also be implemented in the mouthpiece. Moving the input tube to the left would slow the speed while moving the tube to the right would increase the speed. This would couple with the string selection potentiometer to provide maximum control using the already required mouthpiece.

A foot control was also considered for controlling the speed. Using a potentiometer attached to a hinged pedal, the user would rock their foot up and down to vary the speed. While this design is more appropriate for speed control than string selection, it still involves creating an entirely new piece of hardware that would complicate the design and drive up cost.

Lastly, a slide potentiometer mounted to the guitar was also considered. This potentiometer would be attached on the back of the neck near the head of the guitar. This would allow for easy access while the user is playing basic chords. However, positioning the slide control at this location would be impractical if the user was playing individual strings, as many melodies are played higher on the neck, and thus far from the slide. The positioning may also prove to be a nuisance when switching between chords, as the user would likely bump the slide during chord transitions.

## 2.3 Options Analysis

To determine the best design option for each design considered above, the following decision matrices were used to rate each option. A higher number corresponds to a superior ability or feature. Blue colored numbers (3 or higher) indicate a beyond exceptional performance. Green colored numbers (2-2.9) indicates that the option meets the requirements. Yellow colored numbers (1-1.9) indicate that the design might meet the requirements, but is overall questionable. A zero means the design will not meet the requirement.

**Table 1. Microcontroller Decision Matrix**

| MICROCONTROLLER | Weight | | Raspberry Pi | Arduino | Adafruit Feather |
| --- | --- | --- | --- | --- | --- |
| Variable Speed | 4 | | 1 | 2 | 2 |
| Size and Weight | 2 | | 1 | 1 | 2 |
| Open Source | 1 | | 1 | 2 | 3 |
| Individual String play | 1 | | 1 | 2 | 2 |
| | | | | | |
| Total Score (Possible vs. Actual) | 24 | | 8 | 14 | 17 |

**Table 2. Strummer Decision Matrix**

| STRUMMER | Weight | | 1-Pick Sweep | 2-Pick Sweep | 6-Pick Static |
|---|---|---|---|---|---|
| Strum Select Strings | 5 | | 2 | 1 | 3 |
| Variable Speed | 4 | | 1 | 1 | 1.5 |
| Size and Weight | 3 | | 3 | 2 | 1 |
| Open Source | 1 | | 2 | 1 | 1 |
| Individual String play | 1 | | 1 | 0 | 3 |
| | | | | | |
| Total Score: Possible vs. Actual | 42 | | 26 | 16 | 28 |

**Table 3. String Selection Control Decision Matrix**

| STRING SELECTION CONTROL | Weight | | 3-Tube 'Harmonica' | Head Control Pot | Foot Pedal/Pot |
|---|---|---|---|---|---|
| Strum Select Strings (Accessibility) | 5 | | 3 | 3 | 1 |
| Open Source | 1 | | 1 | 2 | 1 |
| Individual String play (Access) | 1 | | 1 | 2 | 1 |
| | | | | | |
| Total Score (Possible vs. Actual) | 21 | | 17 | 19 | 7 |

**Table 4. Strum Speed Control Decision Matrix**

| STRUM SPEED CONTROL | Weight | | Head Control Pot | Foot Pedal/Pot | Thumb Switch/Dial |
|---|---|---|---|---|---|
| Variable Speed (Accessible) | 5 | | 2 | 2 | 1 |
| Size and Weight | 3 | | 2 | 1 | 2 |
| Open Source | 1 | | 1 | 1 | 1 |
| | | | | | |
| Total Score (Possible vs. Actual) | 27 | | 17 | 14 | 12 |

## 2.4 Proposed Concepts

In order to provide the most user friendly and open source experience, it is recommended that the Adafruit Feather be used as the microcontroller to control the strummer. The Adafruit provides the cheapest and lightest option while coming equipped with a library that is built to control servo motors.

2.4

2.4

This will make for ease of assembly and programming without adding significant size or weight to the final design.

Despite the fact that the six-pick strummer is considerably more complicated compared to a single pick sweep, it is recommended as the ideal solution due to its versatility. Attempting to control individual strings, altering the speed, and alternating up and down strokes with a single pick requires additional degrees of motion which greatly increases the likelihood of failure. Though the six-pick increases the number of motors, it simplifies the code that the single-pick would require. The six-pick also provides the user more room to expand their skills, with the potential to become just as proficient as two-handed guitarists.

Both the string selection and speed variation can be solved using the same method. By adding a two-dimensional potentiometer (or joystick potentiometer) to the breath input device, the user will be able to maximize control over the guitar while maintaining a simple and intuitive design. All other considerations required the creation of additional hardware that would complicate the design, drive up the cost, and lower the approachability of the device. By keeping all control in one location, the user will be able to intuitively learn and master the system.

# 3 SYSTEM OVERVIEW

The Breath Strummer will consist of three main subsystems: the mouthpiece, the controller, and the strummer.

The mouthpiece is the system that will interface with the user and will house most of the input instrumentation. This includes the pressure transducer that will detect the breath input, a joystick potentiometer that will be used to select strings and vary the strum intensity, and a RJ45 port to interface the instrumentation with the controller.

The controller consists of an Adafruit Feather microcontroller, a Feather Wing (shield) for handling the quantity of servos, a USB power supply for all the components, and a RJ45 jack to interface with the instrumentation.

The strumming mechanism is the system that physically interfaces with the guitar. The strummer consists of six servos, a housing for the servos, and the mounting system. The controller subsystem will be attached to this system. The mouthpiece will interface with the controller via Ethernet cable and the afore mentioned RJ45 jacks.

# 4 MOUTHPIECE

## 4.1 PHYSICAL DESCRIPTION

The breath input device is a small rectangular box mounted to a standard microphone stand, which implement a joystick potentiometer as the hinge, as shown in Figure 1. The box is approximately 4” x 2” x 1” with the tube protruding roughly 1” from the box. The tube is a 3/8” rigid tube that connects directly to the Honeywell pressure transducer. The pressure transducer is mounted to a small electrical breadboard inside the housing. The joystick potentiometer and the pressure transducer feed into a RJ45 jack mounted on the breadboard on the side of the housing. This port allows the connection of an Ethernet cable which will convey electrical signals from the mouthpiece to the microcontroller.

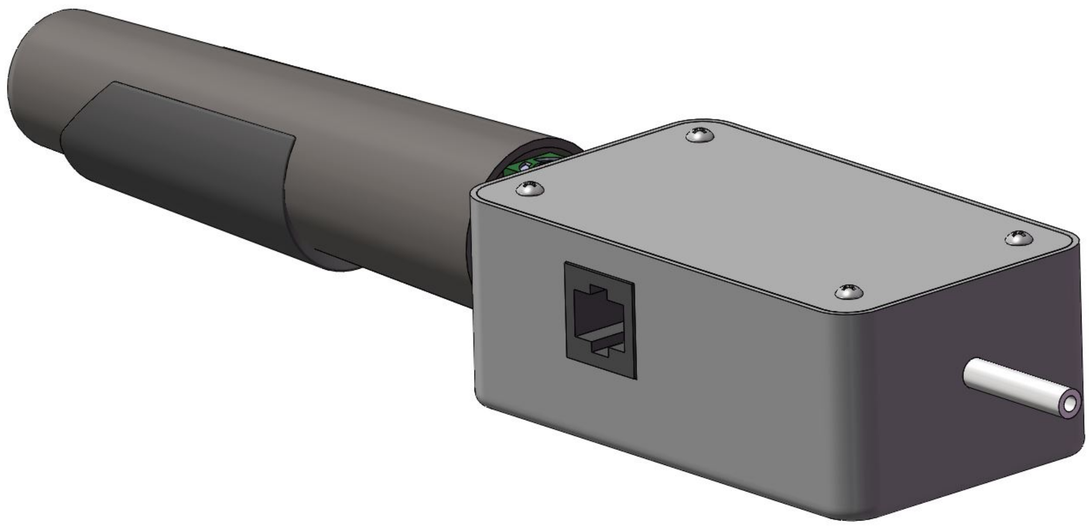


**Figure 1: Mouthpiece**

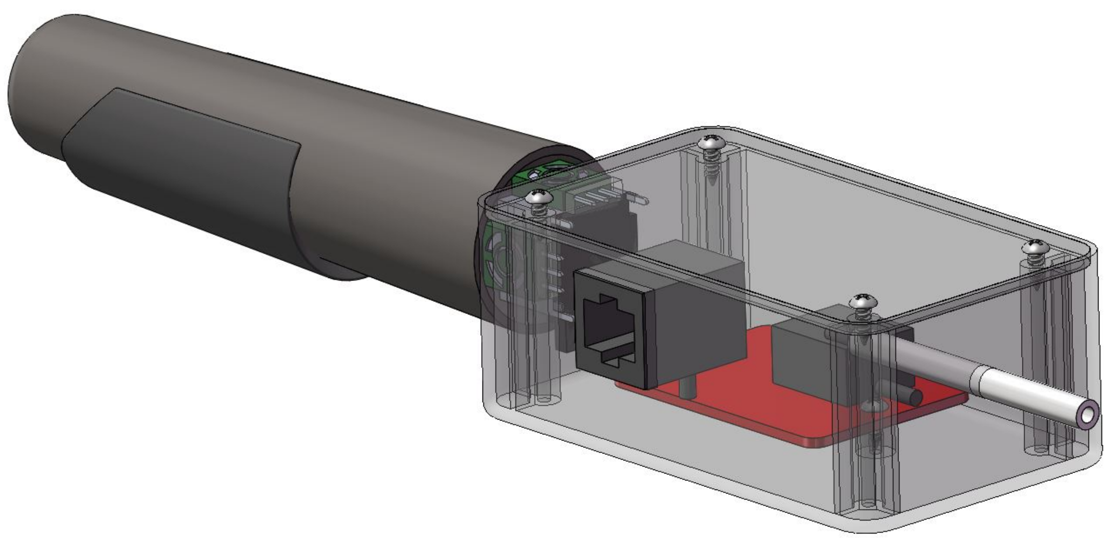


**Figure 2: Mouthpiece (Transparent)**

## 4.2 FUNCTIONAL DESCRIPTION

The mouthpiece has three main functions: string/chord selection, speed control, and converting breath input into electrical signals which will control the volume and direction of the strum. As the user blows into the tube the pressure transducer sends a positive voltage to the processor, and as the user inhales the transducer will send a negative voltage. The harder the user inhales or exhales, the larger the voltage magnitude will be. The greater the magnitude of the voltage, the deeper the picks will dig into the strings. This satisfies the design requirement outlined in section 1.2.2.

The joystick potentiometer give the user control of the string/chord selection and speed control. As the user pivots the input tube in a horizontal plane, the resistance of the potentiometer will increase or decrease. The farther left the tube is positioned the slower the strummer plays, and the further right it is positioned, the faster the strummer plays; satisfying requirement 1.2.3. The vertical pan of the tube changes the number of strings the strummer will play. The highest position in the vertical plane will play the top four strings, the middle position will play the top five strings, and the lowest position will play all six strings. After the user activates a toggle switch, the vertical pan will play individual strings; playing the top string when in the highest position, and playing the bottom string at the lowest position. This fulfills the requirement and goal described in sections 1.2.1. and 1.3.2. respectively.

# 5 STRUMMER

## 5.1 PHYSICAL DESCRIPTION

The strumming mechanism, shown in Figure 3, will mount directly onto the face of the guitar over the sound hole. GoPro instrument mounts will be used to attach the feet of the frame to the guitar. This will allow the user to easily attach and remove the frame for transportation and storage. The legs of the strummer will be 3D printed from acrylonitrile butadiene styrene (ABS) plastic and sized at approximately 5” x 2” x 0.5” with protrusions that allow the attachment of four 3/8” aluminum rods. Each pair of rods will be coupled with a servo motor via a 3D printed coupler. These servos will rotate the pick arrays so the picks reach further into the sound hole, allowing the user to change the dynamic at which the string is played.

Each set of aluminum rods will support a small box which contains an array of three servos each, otherwise known as the pick array. The box is dimensioned at 3” x 1.5” x 1” and includes a hollow cutout where the servos are mounted. The pick array is designed so that the servos can slide horizontally and lock in custom locations to allow for the use of guitars that have differently spaced strings.

3D printed pick holders are used to hold standard guitar picks, and are attached to each servo. Small pieces of 1/32” rubber are attached to the inside of the pick holder to prevent the pick from falling out. Each pick holder is .75” x .5” x .25” with a thru hole that press fits to the gears on the servos.

The processor will mount on the outside face of one of the legs mentioned previously, and the battery pack will mount to the guitar itself. One of the legs will contain a switch that allows the user to switch between play mode and calibration mode. Calibration mode allows the user to adjust the starting depth of the picks to account for variance in string action. Wires that run from the controller to the servos will be secured to the aluminum rods via zip ties, such that they stay clear of the strings and picks, and do not snag when the pick arrays rotate.

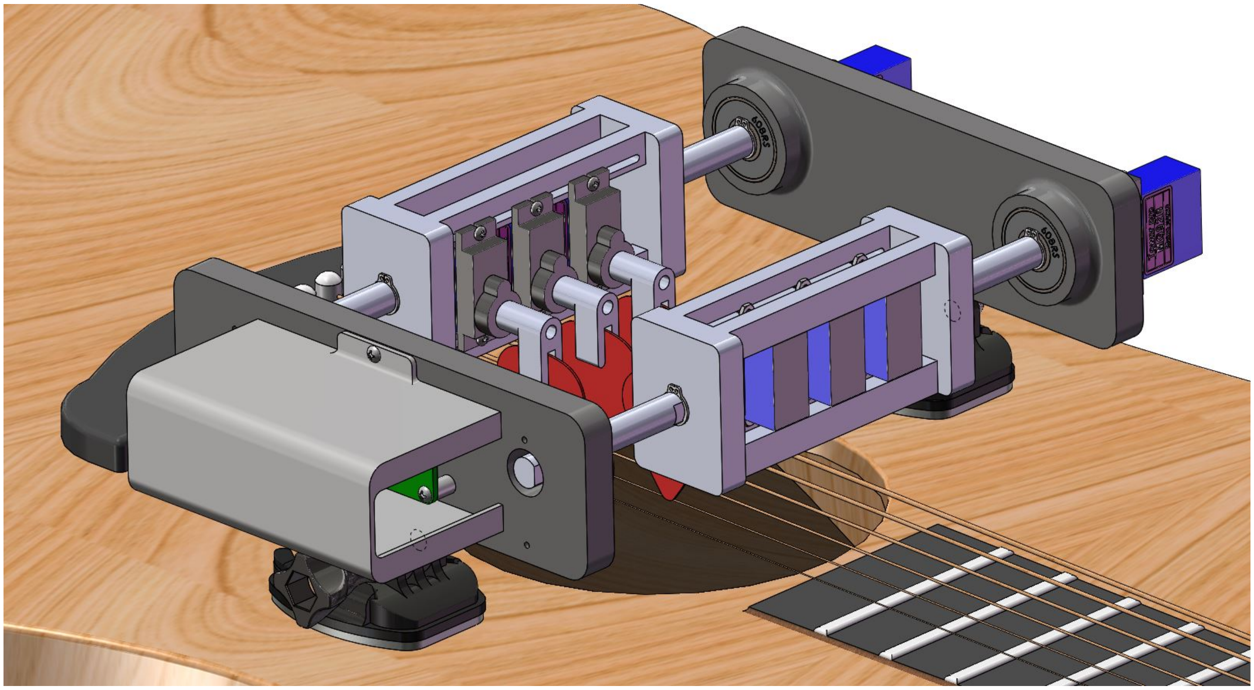


**Figure 3: Strummer Assembly Mounted To Guitar**

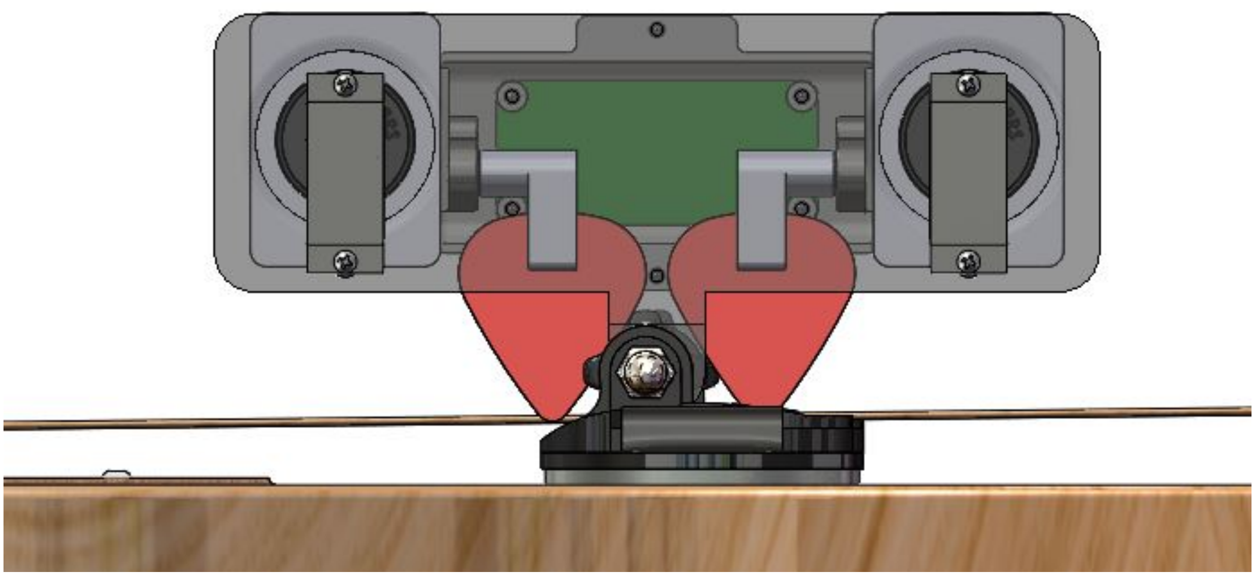


**Figure 4: Side View of Strummer (Transparent)**

### 5.2 Functional Description

When the user blows harder the processor will activate the servos coupled to the aluminum rods. As the pressure is increased the pick arrays will rotate towards the sound hole, lowering the picks deeper into the sound hole. The potentiometer mounted to the side of the strummer frame will also allow the user to select an initial depth for the picks before they begin playing. This accomplishes the requirement that the strummer must be able to vary the volume, or intensity of the strumming described in section 1.2.2.

Because each string has its own pick, the system does not have to return to a neutral position in order to alternate strumming up and down. The direction of an individual pick's rotation won't change the sound of the strum, but the order in which the strings are picked will. Therefore, the controller will activate the servos in the order that reproduces the user's desired strumming motion. An exhale will activate the servo on the low "E" string first, followed in rapid succession by the other five servos up to the high "e." An inhale will produce a similar result starting with the high "e" servo and finishing with the low "E."

## 6 Controller

### 6.1 Physical Description

The microcontroller consists of an Adafruit Feather and a shield attachment to drive the servo motors. An Ethernet port will be mounted to the microcontroller to connect the mouthpiece to the processor. The dimensions of the processor are about 4" x 3" x 1". The controller will mount directly to the frame of the strummer assembly. A small, toggle switch will connect to the processor that will allow the user to toggle input functionality between calibration mode and play mode.

### 6.2 Functional Description

The microcontroller will accept the signals from the potentiometers, transducer, and calibration toggle switch. Calibration mode will tell the program to process the rotation of the mouthpiece in either the vertical or horizontal plane as the degree to which the user wishes to rotate the pick arrays in and out of the sound hole.

The brain of the controller is the program that interprets the transducer voltages and conditions them before sending signals to the servo motors. The controller will ask each servo to rotate in a sequence, either up or down depending on the sign of the input voltage. A time delay between each signal makes the strum sound more human. When a user moves the mouthpiece to the right, the delay will be shortened resulting in a faster strum. Whereas a moving the mouthpiece to the left will result in a larger delay between servos, causing a slower strum

# 7 MANUFACTURING STRATEGY

## 7.1 MOUTHPIECE SUB-ASSEMBLY

The custom parts of the mouthpiece assembly 120 will be printed using a 3D printer and ABS plastic on USU's campus according to the CAD models for parts 121, 122, 123. The electronic components of the assembly with be soldered and prepared by the design team according to drawing 130D. Assembly of the mouthpiece will also be completed by the design team, as per drawing 120D. The printing and assembly of the mouthpiece is expected to take 2-3 weeks after the drawings are submitted to the shop.

## 7.2 STRUMMER SUB-ASSEMBLY

Similar to the mouthpiece, the custom parts of assembly 110 will be printed on USU's campus using a 3D printer and ABS plastic according to the CAD models for parts 111-114, 116, and 117. The shafts holding the pick arrays above the sound hole will be modified by USU's machine shop according to drawing 115D. The strummer will be assembled by the design team according to drawing 110D. Lead time for this assembly is estimated to be 2-3 weeks after drawing are submitted.

## 7.3 CONTROLLER SUB-ASSEMBLY

The controller will be assembled according to drawing 130D by the design team. No custom parts were designed for the controller sub-assembly and a list of commercial parts that compose the assembly is included in drawing 130D. The code used by the controller is a custom code written by Randy Richards, and is documented in Appendix C. The time expected to assemble this component is 1-2 weeks; however, testing, troubleshooting, and calibrating the program is expected to take 3-4 weeks after completing the assembly.

# 8 SPECIAL TOPICS

## 8.1 ENVIRONMENTAL AND SOCIETAL IMPACT

The Breath Strummer will have a negligible impact on the environment. Any impact it does have will be due to processes already in place that are used to manufacture the parts used in the design. Because this is an open source product that is designed for a small specific group of individuals, it is unlikely that it will ever be produced on a scale that would have a measureable impact on the environment. However, it will have a positive societal impact in the sense that it grants a group of individuals who would normally be unable to play the guitar the ability to do so. Again, while this impact is positive, it is considered mostly negligible.

The lifespan of the Breath Strummer is expected to be long, and therefore have minimal impact on the environment when parts need to be replaced. The most susceptible parts to fail are the servos used to strum the strings and rotate the pick arrays. No definitive lifespan is giving for the servos used in the design, but previous users have indicated that they can last anywhere from 1-20 years depending on the load they are put under. All mechanical parts should withstand normal wear and tear without need of replacement. All other electrical components may need to be replaced every 5-20 years.

## 8.2 SAFETY

The Breath Strummer does not pose any major safety concerns. Mild safety concerns include sharp edges, weight, common electrical hazards, and overexertion in breathing. To mitigate these hazards any sharp corners will be rounded, and lightweight material such as plastic and aluminum will be used for any custom parts. Special consideration will go into calibrating the input device to ensure that user will not have to exert more air flow than is typical for a simple wind instrument. As long as the user adheres to the safety practices outlined by the manufactures of the commercially available electrical components used in this design, electrical hazards should not be of concern.

## 8.3 BILL OF MATERIAL (BOM) OVERVIEW

As one of the goals of the Breath Strummer is to be an open source design, many commercially available parts were used in the final design of the strummer. The strummer assembly required several custom designed parts. These were printed in ABS plastic to minimize the cost of manufacturing. The only component that required manufacturing work was part 115. Part 115 is the D-shaft rod used to support pick arrays over the sound hole and had to be manufactured as per drawing 115D for this purpose.

The total expected cost of the Breath Strummer varies depending on the tools and parts already available. Table 5, in Appendix A, contains the Bill of Materials and lists the parts used in the final design of the Breath Strummer. As mentioned previously, all custom parts were printed using ABS plastic and USU's in house 3D printers. The prices associated with these parts are estimates, and may vary depending on location.

The cost of a guitar, guitar strings, guitar picks, and microphone stand were not included in the cost of building a Breath Strummer. It is assumed that an individual who wishes to build a Breath Strummer already owns these components. With this stipulation, it is estimated that the cost to build a Breath Strummer will be between $400-$500. A margin of $100 is added to account for potential need to buy tools and to account for variations in shipping and manufacturing costs.

## 8.4 BUDGET

Because the Breath Strummer is composed of many commercially available products, the majority of the budget was set aside for purchase of materials. Manufacturing costs were expected to be very small. This project was allotted a budget of $2500.

Table 6 lists the expected vs. actual costs of materials and manufacturing. $1600 of the budget was set aside for the cost of materials, and $400 for the cost of manufacturing. That left a margin of $500 for unexpected expenses, in whatever category it may fall under. Table 7 shows the list of all items purchased during the project's lifetime and which category they fell under.

**Table 6. Budget**

| Catagory | Budgeted | | Actual | | Remaining | |
|---|---|---|---|---|---|---|
| **Materials** | **$** | **1,600.00** | **$** | **1,229.66** | **$** | **370.34** |
| *Guitar* | *$* | *400.00* | *$* | *364.93* | *$* | *35.07* |
| Acoustic Guitars | $ | 350.00 | $ | 329.98 | $ | 20.02 |
| Guitar Picks | $ | 25.00 | $ | 14.97 | $ | 10.03 |
| Guitar Strings | $ | 25.00 | $ | 19.98 | $ | 5.02 |
| *Microcontroller* | *$* | *250.00* | *$* | *129.15* | *$* | *120.85* |
| Adafruit Feather | $ | 75.00 | $ | 39.90 | $ | 35.10 |
| FeatherWing | $ | 50.00 | $ | 19.90 | $ | 30.10 |
| Adafruit Attachments | $ | 25.00 | $ | 8.90 | $ | 16.10 |
| Power Pack | $ | 60.00 | $ | 29.99 | $ | 30.01 |
| Wiring | $ | 40.00 | $ | 30.46 | $ | 9.54 |
| *Strummer* | *$* | *450.00* | *$* | *367.13* | *$* | *82.87* |
| Servos | $ | 200.00 | $ | 124.80 | $ | 75.20 |
| Fasteners | $ | 50.00 | $ | 46.16 | $ | 3.84 |
| Hardware | $ | 200.00 | $ | 196.17 | $ | 3.83 |
| *Mouthpiece* | *$* | *400.00* | *$* | *317.71* | *$* | *82.29* |
| Pressure Transducer | $ | 200.00 | $ | 196.08 | $ | 3.92 |
| Potentioemters | $ | 50.00 | $ | 30.42 | $ | 19.58 |
| Microphone Stand | $ | 75.00 | $ | 54.84 | $ | 20.16 |
| Tubing | $ | 25.00 | $ | 11.02 | $ | 13.98 |
| Wiring | $ | 50.00 | $ | 25.35 | $ | 24.65 |
| *Tools* | *$* | *100.00* | *$* | *50.74* | *$* | *49.26* |
| Hand Tools | $ | 50.00 | $ | 32.99 | $ | 17.01 |
| Decibel Meter | $ | 50.00 | $ | 17.75 | $ | 32.25 |
| **Manufacturing** | **$** | **400.00** | **$** | **15.07** | **$** | **384.93** |
| 3D Printing | $ | 200.00 | $ | 15.07 | $ | 184.93 |
| Machine Shop | $ | 200.00 | $ | - | $ | 200.00 |
| **Margin** | **$** | **500.00** | **$** | **61.82** | **$** | **438.18** |
| Shipping | $ | 100.00 | $ | 55.22 | $ | 44.78 |
| Unexpected Expenses | $ | 400.00 | $ | 6.60 | $ | 393.40 |
| **TOTAL** | **$** | **2,500.00** | **$** | **1,306.55** | **$** | **1,193.45** |

**Table 7. Purchasing List**

| Quantity | Category | Title | Company | ID | Price |
|---|---|---|---|---|---|
| 2 | Microcontroller - Feather | Adafruit Feather 32u4 Basic Proto | Adafruit Industries | 2771 | $ 39.90 |
| 2 | Microcontroller - Wing | 8-Channel PWM or Servo FeatherWing Add-on For All Feather Boards | Adafruit Industries | 2928 | $ 19.90 |
| 2 | Microcontroller - Attachments | Short Feather Headers Kit - 12-pin and 16-pin Female Header Set | Adafruit Industries | 2940 | $ 3.00 |
| 2 | Microcontroller - Attachments | Right Angle Male Header - 4 pack | Adafruit Industries | 816 | $ 5.90 |
| 6 | Mouthpiece - Pressure Transducer | Honeywell 8-Pin DIP Differential Pressure Sensor -1 to 1 psi | Onlinecomponents.com | ASDXRRX001PDAA5 | $ 196.08 |
| 1 | Tools - Decibel | Decibel Meter | BAFX Products | BAFX3370 | $ 17.75 |
| 1 | Tools - Hand Tools | Electirc Soldering Iron Kit | Sywon Online | SFS-1 | $ 32.99 |
| 12 | Strummer - Servos | Metal Geared Micro Servo | RioRand | MG90S | $ 49.80 |
| 10 | Strummer - Servos | A-537 Towerpro 14g Digital Metal Gear High Torque SubMicro Servo | Heads Up RC Hobby Shop | MG92B | $ 75.00 |
| 1 | Strummer - Hardware | Gooseneck | GoPro | ACMFN-001 | $ 19.99 |
| 2 | Strummer - Hardware | Removable Instrument Mounts | GoPro | AMRAD-001 | $ 39.98 |
| 1 | Strummer - Hardware | Suction Cup | GoPro | AUCMT-302 | $ 39.99 |
| 1 | Microcontroller - Power | PowerCore 13000mAh Portable Charger | AnkerDirect | AK-A1215011 | $ 29.99 |
| 1 | Strummer - Hardware | Neoprene Sheet, 70A, Adhesive Backing, .032" thick, 12" x 12" | Amazon LLC | NEO-A-032I12I12I70A | $ 17.69 |
| 1 | Strummer - Hardware | SBR Sheet, 70 Shore A, No Backing, Smooth, .25" thick, 12" x 12" | Amazon LLC | 33-007-250-012-012 | $ 9.10 |
| 5 | Mouthpiece - Potentiometers | Top Adjustment Single Turn Knurled Shaft 10K Potentiometer | Uxcell | 43093 | $ 5.60 |
| 5 | Mouthpiece - Potentiometers | 1K Linear Taper Rotary Potentiometer | Uxcell | a15011600ux0213 | $ 6.10 |
| 6 | Mouthpiece - Potentiometers | Knurled Shaft Linear Rotary Taper Potentiometer for Arduino Pack | Third Eye Sunglasses | B01HW3G9JI | $ 8.02 |
| 2 | Mouthpiece - Tubing | Rigid Tubing for Aquarium Pumps, 3/16" Dia, 3' Length | Lee's Pet Products | ALE16005 | $ 11.02 |
| 8 | Strummer - Hardware | Skateboard Bearings, 8 x 22 x 7 | WeCrafter | 608ZZ | $ 6.99 |
| 5 | Strummer - Hardware | HSS Straight Machine Boring Tool Round Lathe Bar Rod 8mm x 100mm | Uxcell | a14080700ux0403 | $ 9.98 |
| 100 | Strummer - Fasteners | SS Machine Screw, Pan Head, Phillips, 1/2" Length, #1-72 Thread | Amazon LLC | B000FN1UCE | $ 18.37 |
| 100 | Strummer - Fasteners | Zinc Plated Steel Machine Screw Hex Nut, #1-72, 3/64" w, 5/32" t | Amazon LLC | B000N2TK88 | $ 2.92 |
| 1 | Mouthpiece - Mount | Hohner 154 Harmonica Neck Holder | Amazon LLC | 154 | $ 21.99 |
| 2 | Mouthpiece - Mount | Universal Microphone Clip Holder w/ 5/8" Male to 3/8" Female Adapter | Wymic Stands | WM-A11 | $ 7.90 |
| 1 | Mouthpiece - Mount | On Stage Stands Tripod Boom Microphone Stand | Amazon LLC | MS7701B | $ 24.95 |
| 2 | Microcontroller - Wiring | CAT 6 Ethernet Cable LAN 10' | Ultra Clarity Cables | UCP610 | $ 7.99 |
| 2 | Microcontroller - Wiring | CAT 6 Ethernet Cable LAN 6' | Ultra Clarity Cables | UCP66 | $ 7.49 |
| 2 | Microcontroller - Wiring | CAT 6 Ethernet Cable LAN 3' | Ultra Clarity Cables | UCP63 | $ 5.99 |
| 3 | Mouthpiece - Wiring | Breadboard Mini Solderable | Digi-Key | 1568-1083-ND | $ 8.85 |
| 10 | Mouthpiece - Wiring | SparkFun RJ45 Breakout | SparkFun | BOB-00716 | $ 9.00 |
| 5 | Mouthpiece - Wiring | RJ45 8-Pin Connector | SparkFun | PRT-00643 | $ 7.50 |
| 10 | Guitar - Pick | Planet Waves Standard Pick - Medium | KSM Music | 1CBKP410 | $ 4.99 |
| 10 | Guitar - Pick | Planet Waves Standard Pick - Light | KSM Music | 1CRP210 | $ 4.99 |
| 10 | Guitar - Pick | Planet Waves Standard Pick - Heavy | KSM Music | 1CBUP610 | $ 4.99 |
| 1 | Guitar - Strings | D'Addario PB Acoustic Strings - Lite | KSM Music | EJ26 | $ 9.99 |
| 1 | Guitar - Strings | D'Addario PB Acoustic Strings - Medium | KSM Music | EJ17 | $ 9.99 |
| 1 | Guitar - Acoustic | Ibanez Jampack Solid Top, Natural - Acoustic Guitar | KSM Music | IJD100S | $ 199.99 |
| 1 | Guitar - Acoustic | Ibanez Quick Start Jampack Grand Concert Acoustic Guitar | KSM Music | IJVC50 | $ 129.99 |
| 2 | Strummer - Hardware | GoPro Grab Bag | GoPro | AGBAG-002 | $ 39.98 |
| 1 | Microcontroller - Wiring | 15cm Male to Femalse Servo Extension Lead Wire Cable | Dnhobby | B01FLHLKZ0 | $ 8.99 |
| 2 | Mouthpiece - Potentiometers | Joystick Potenentiometer 10KOhm | Digi-Key | 254TA103B50A | $ 10.70 |
| 1 | Strummer - Hardware | 6061 Aluminum 8mm Diameter Rod 3 feet | McMaster | 4634T34 | $ 3.03 |
| 100 | Strummer - Fasteners | 18-8 Stainless Steel Hex Nut, 1-72 | McMaster | 91841A125 | $ 8.16 |
| 50 | Strummer - Fasteners | 18-8 Stainless Steel Phillips Rounded Head Screw for Sheet Metal, #1 3/4" | McMaster | 92470A065 | $ 8.10 |
| 100 | Strummer - Fasteners | Zinc Yellow-Chromate-Plated Steel External Retaining Ring, 5/16" OD | McMaster | 98410A115 | $ 9.44 |
| 100 | Strummer - Fasteners | Nylon Unthreaded Spacer, 3/16" OD, 1/2" for #2 screws | McMaster | 4639A713 | $ 8.61 |
| N/A | Shipping | Total Shipping Costs | N/A | N/A | $ 55.22 |
| N/A | Unexpected Expenses | Tax | GoPro | N/A | $ 6.60 |
| 2 | Manufacturing | 3D Printed Pick Holder | USU EED Lab | 114 | $ 15.07 |
| | | | | **Total** | **$ 1,306.55** |

### 8.4.1 Margin Management

To account for unexpected expenses, $500 of the $2,500 budget was set aside for margin. This project was intended to have rapid prototyping to refine the design, and the number of prototypes needed is unknown. These iterations may result in larger expenses than originally planned for. This margin may also be used for parts that may need to be replaced due to failure or inability to fulfill the desired objective.

## 8.5 Lessons Learned

As will be discussed in the next section, calibrating the Breath Strummer has proved to be one of the more tedious aspects of installing and playing the device. It would have been beneficial to spend more time performing detailed measurements and tests early in the design process. Measurement of the vertical distance the strings traveled when pressed should have been taken. These measurements would have helped design a more robust pick holder earlier in the design process.

Some tests, such as measuring the torque required to strum each string, should have been performed earlier in the design process as well. This was limited both by personal time management, and a restriction that prevented us from manufacturing any parts until the critical design review (CDR) had been completed. A crude mockup of the strummer assembly would have been required to obtain accurate measurements of the torque needed to strum a guitar string. These measurements would have helped determine whether or not the servos initially selected were capable of doing picking the strings. As such, earlier prototyping would have benefited the final design.

The budget for this project was limited to the first six months of the project's year lifespan. This resulted in an unbalanced design process where many unnecessary parts were purchased before the design was finalized. Once the design was complete and the manufacturing process began, it became necessary to purchase additional parts. This was complicated by the need to purchase through people outside of the design team, as the initial budget was gone. This slowed down the purchasing and manufacturing process, and in turn limited the number of iterations that could be performed before the end of the project's life. A budget that lasted the entire length of the project would have allowed for a quicker manufacturing and iteration changes.

Finally, stricter deadlines for accomplishing certain aspects of the design and manufacturing would have helped resolve many of the issues listed above. While more detailed measurements and tests would have increased the early design time, completing milestones such as the preliminary design review (PDR) and CDR earlier would have enabled for a more thorough iteration process. Additionally, if permission had been granted to manufacture parts earlier, initial tests would have been more informative and precise.

## 8.6 Recommended Future Work

Most recommendations for future work are centered around ways to improve the calibration of the Breath Strummer. Currently the user must recalibrate the locations of the picks each time the device is powered on. This is because the Adafruit Feather being used to control the strummer does not come with any memory, and therefore cannot save the position set by the user after being powered down. The 32u4 Adalogger is recommended as a replacement to the Adafruit Feather, as it will allow the calibration to be saved between sessions via a micro SD card. Otherwise, this new processor is functionally identically to the current Adafruit Feather.

Due to the different string sizes, aligning the depth of each individual pick with the corresponding guitar string can be difficult. The picks lie on a horizontal plane, while the strings lie on a slanted plane because of the various sizes. Each pick must be manually adjusted by pulling the pick further out of the pick holder until it lines up with the bottom of the string. Repeating this process for each string is tedious and difficult. As such, it is recommended that the pick holders be redesigned so that each string has a custom pick holder that holds the pick at the appropriate height when the pick is fully inserting into the holder. Unfortunately, variations between guitars may result in a need to adjust the design based on the user's guitar. However, in the long run custom pick holders will save the user a lot of time and energy.

A slight problem occurs when the Breath Strummer is attached to a guitar with high action. Action is the distance between the face of the guitar and the strings. When the distance between the strings and the guitar is large, the guitar is said to have a high action. When the strings on a high action guitar are pressed, they moved down far enough that the Breath Strummer will be unable to reach them. For this reason, it is recommended that the action of any guitar to be used with the Breath Strummer be lowered as much as possible to minimize the vertical distance traveled by the string. This is a common practice in the guitar community that will greatly improve the performance of the Breath Strummer.

Another common guitar tweak that will improve the performance of the Breath Strummer is to change the gage of the guitar strings. Gage refers to the diameter of the strings. A heavy gage string has a large diameter, where a lighter gage string has a smaller diameter. A heavy gage string has the potential to stall the servo motors. Therefore, it is recommended that any guitar that is coupled with the Breath Strummer be fit with light gage strings. Additionally, light gage strings will help the user lower the action and minimize the distance traveled by each string.

The current mouthpiece design allows the user to switch between chord mode and note mode by moving the mouthpiece all the way the way to one side. This method proved to be awkward for the user to both transition and control the system in note mode. Therefore, it is recommended that a foot switch be used to toggle between chord mode and note mode, as this should provide a better user experience.

Similarly, the current method for switching between calibration mode and play mode involves switching wires manually. Time restrictions prevented the installation of a toggle switch originally proposed to control the transition. It is recommended that the toggle switch be installed in the next iteration.

During testing, some participants complained about the level of noise produced by the servo motors. One possible solution is to purchase plastic gear servos which are slightly quieter than the metal gear servos currently being used. This may require the pick array size to be increased, but shouldn't alter the remainder of the design. Another solution is to redesign the pick array to completely encase the servos and add some sort of sound dampening material inside the encasing. It is recommended that these two options be investigated further to determine their effectiveness in dampening the noise from the servos.

# Appendix A

# Bill of Materials

**Table 5. Bill of Materials**

**Assembly 110: Strummer Assembly**

| Item # | Qty. | Part/Assembly Name | Company | ID | Price |
|---|---|---|---|---|---|
| 1 | 2 | Removable Instrument Mounts | GoPro | AMRAD-001 | $ 19.99 |
| 2 | 2 | GoPro Buckle Mount | GoPro | N/A | $ 6.99 |
| 3 | 2 | GoPro Thumbscrew | GoPro | N/A | $ 4.95 |
| 4 | 8 | A-537 Towerpro 14g Digital Metal Gear High Torque SubMicro Servo | Heads Up RC Hobby Shop | MG92B | $ 45.00 |
| 5 | 6 | Pick Holder | USU | 114 | $ 3.24 |
| 6 | 1 | Leg Support | USU | 111 | $ 20.91 |
| 7 | 1 | Leg Support | USU | 112 | $ 20.91 |
| 8 | 2 | Servo Array | USU | 113 | $ 29.06 |
| 9 | 4 | Aluminum D-Shaft | USU | 115 | $ 20.00 |
| 10 | 12 | 18-8 Stainless Steel Phillips Rounded Head Screw, 1-72, 1/2" | McMaster | 91772A070 | $ 13.81 |
| 11 | 12 | 18-8 Stainless Steel Hex Nut, 1-72 | McMaster | 91841A125 | $ 8.16 |
| 12 | 4 | Skateboard Bearings, 8 x 22 x 7 | WeCrafter | 608ZZ | $ 3.49 |
| 13 | 2 | Rod Adapter | USU | 117 | $ 1.32 |
| 14 | 1 | MicroController Assembly | USU | 130 | $ - |
| 15 | 1 | Microprocessor Cover | USU | 116 | $ 10.93 |
| 16 | 4 | Nylon Unthreaded Spacer, 3/16" OD, 1/14" for #2 screws | McMaster | 94639A705 | $ 7.74 |
| 17 | 4 | 18-8 Stainless Steel Phillips Rounded Head Screw for Sheet Metal, #2 1/2" | McMaster | 92470A098 | $ 4.34 |
| 18 | 4 | 18-8 Stainless Steel Phillips Rounded Head Screw for Sheet Metal, #1 3/4" | McMaster | 92470A065 | $ 8.10 |
| 19 | 4 | Nylon Unthreaded Spacer, 3/16" OD, 1/2" for #2 screws | McMaster | 4639A713 | $ 8.61 |
| 20 | 8 | Zinc Yellow-Chromate-Plated Steel External Retaining Ring, 5/16" OD | McMaster | 98410A115 | $ 9.44 |
| 21 | 2 | 18-8 Stainless Steel Phillips Rounded Head Screw for Sheet Metal, #2 1/4" | McMaster | 92470A095 | $ 4.00 |
| 22 | 1 | Neoprene Sheet, 70A, Adhesive Backing, .032" thick, 12" x 12" | Amazon LLC | NEO-A-032I12I12I70A | $ 17.69 |
| 23 | 1 | Self Locking Zip Ties | Walmart | N/A | $ 3.98 |
| | | | | **Total** | **$ 272.66** |

**Assembly 120: Mouthpiece Assembly**

| Item # | Qty. | Part/Assembly Name | Company | ID | Price |
|---|---|---|---|---|---|
| 1 | 1 | Housing Base | USU | 121 | $ 16.36 |
| 2 | 1 | Breadboard Mini Solderable | Digi-Key | 1568-1083-ND | $ 2.95 |
| 3 | 1 | Honeywell 8-Pin DIP Differential Pressure Sensor -1 to 1 psi | Onlinecomponents.com | ASDXRRX001PDAA5 | $ 32.68 |
| 4 | 1 | RJ45 8-Pin Connector | SparkFun | PRT-00643 | $ 1.50 |
| 5 | 6 | 18-8 Stainless Steel Phillips Rounded Head Screw for Sheet Metal, #2 1/4" | McMaster | 92470A095 | $ 4.00 |
| 6 | 1 | Housing Lid | USU | 122 | $ 5.16 |
| 7 | 1 | Rigid Tubing for Aquarium Pumps, 3/16" Dia, 3' Length | Lee's Pet Products | ALE16005 | $ 5.51 |
| 8 | 1 | Thumb Joystick 10k Joystick Potentiometer | SparkFun | COM-09032 | $ 3.95 |
| 9 | 1 | Microphone Mount | USU | 123 | $ 15.48 |
| | | | | **Total** | **$ 87.59** |

**Assembly 130: Microcontroller Assembly**

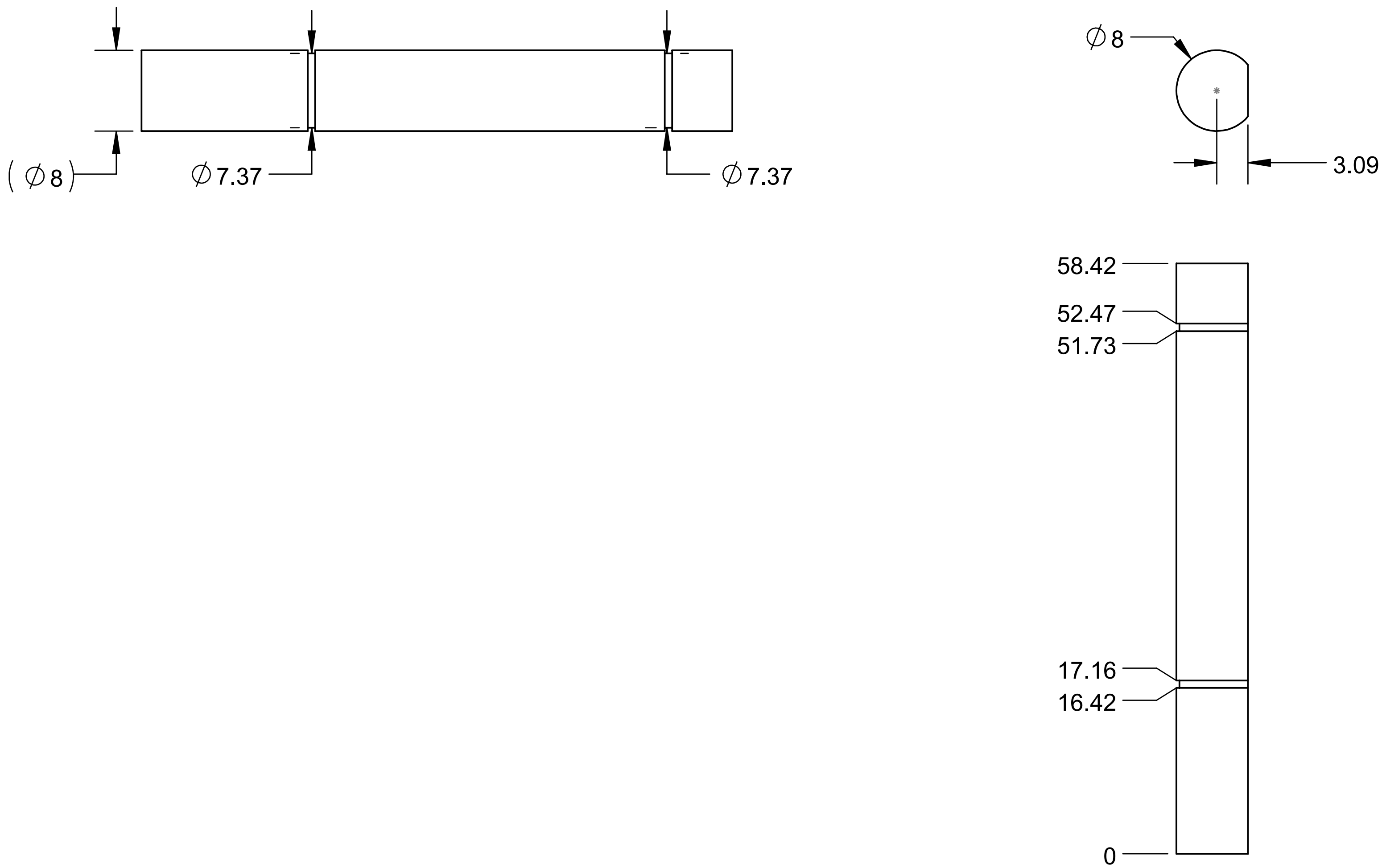
| Item # | Qty. | Part/Assembly Name | Company | ID | Price |
|---|---|---|---|---|---|
| 1 | 1 | Adafruit Feather 32u4 Basic Proto | Adafruit Industries | 2771 | $ 39.90 |
| 2 | 1 | 8-Channel PWM or Servo FeatherWing Add-on For All Feather Boards | Adafruit Industries | 2928 | $ 19.90 |
| 3 | 6 | 15cm Male to Femalse Servo Extension Lead Wire Cable | Dnhobby | B01FLHLKZ0 | $ 8.99 |
| 4 | 1 | RJ45 8-Pin Connector | SparkFun | PRT-00643 | $ 1.50 |
| 5 | 1 | SparkFun RJ45 Breakout | SparkFun | BOB-00716 | $ 0.90 |
| 6 | 1 | CAT 6 Ethernet Cable LAN 6' | Ultra Clarity Cables | UCP66 | $ 7.49 |
| 7 | 1 | PowerCore 13000mAh Portable Charger | AnkerDirect | AK-A1215011 | $ 29.99 |
| | | | | **Total** | **$ 108.67** |

**Custom Part 115: D-Shaft**

| Item # | Qty. | Part/Assembly Name | Company | ID | Price |
|---|---|---|---|---|---|
| 1 | 1 | 6061 Aluminum 8mm Diameter Rod 3 feet | McMaster | 4634T34 | $ 3.03 |
| | | | | **Total** | **$ 3.03** |
| | | | | **Grand Total** | **$ 471.95** |

# Appendix B

# Drawing Package




Mechanical & Aerospace ENGINEERING
Utah State University

**PROJECT**
BREATH STRUMMER

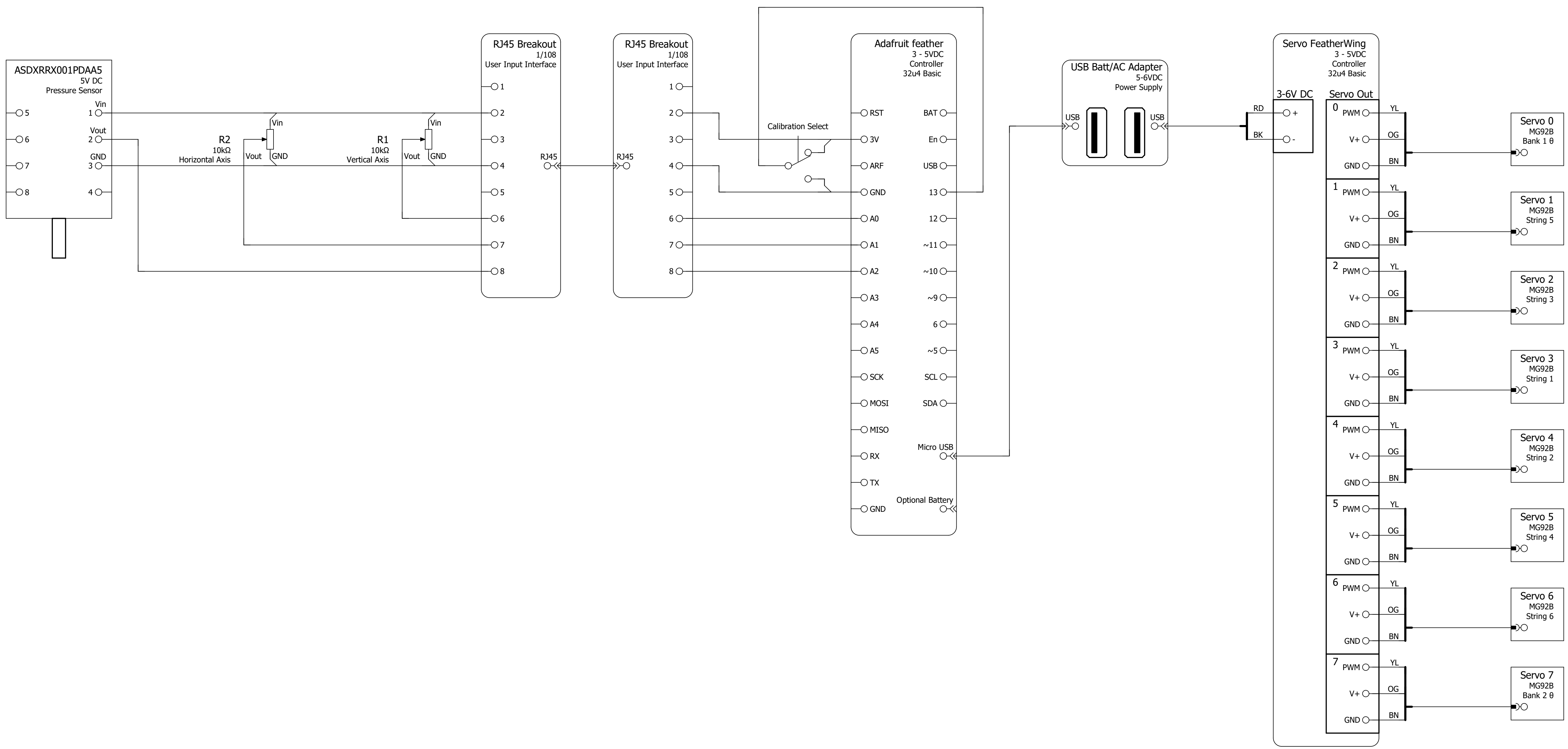
DRAFTED BY: RHETT RAMSEY

**SPECIFICATIONS AND TOLERANCES**

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [mm]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 25 micrometers

| | |
|---|---|
| PART/ASSEM NAME: 115_D_SHAFT | CHECKED BY: R. RAMSEY, R. RICHARDS, S. PROCTOR |
| PART/ASSEM NUMBER: 115 | APPROVED BY: R. RAMSEY, R. RICHARDS, S. PROCTOR |
| MATERIAL: 6061 ALUMINUM | DATE APPROVED: 9/30/2017 |
| FINISH: N/A | SHEET SCALE: 3:2 / SHEET NUMBER: 1 of 1 |



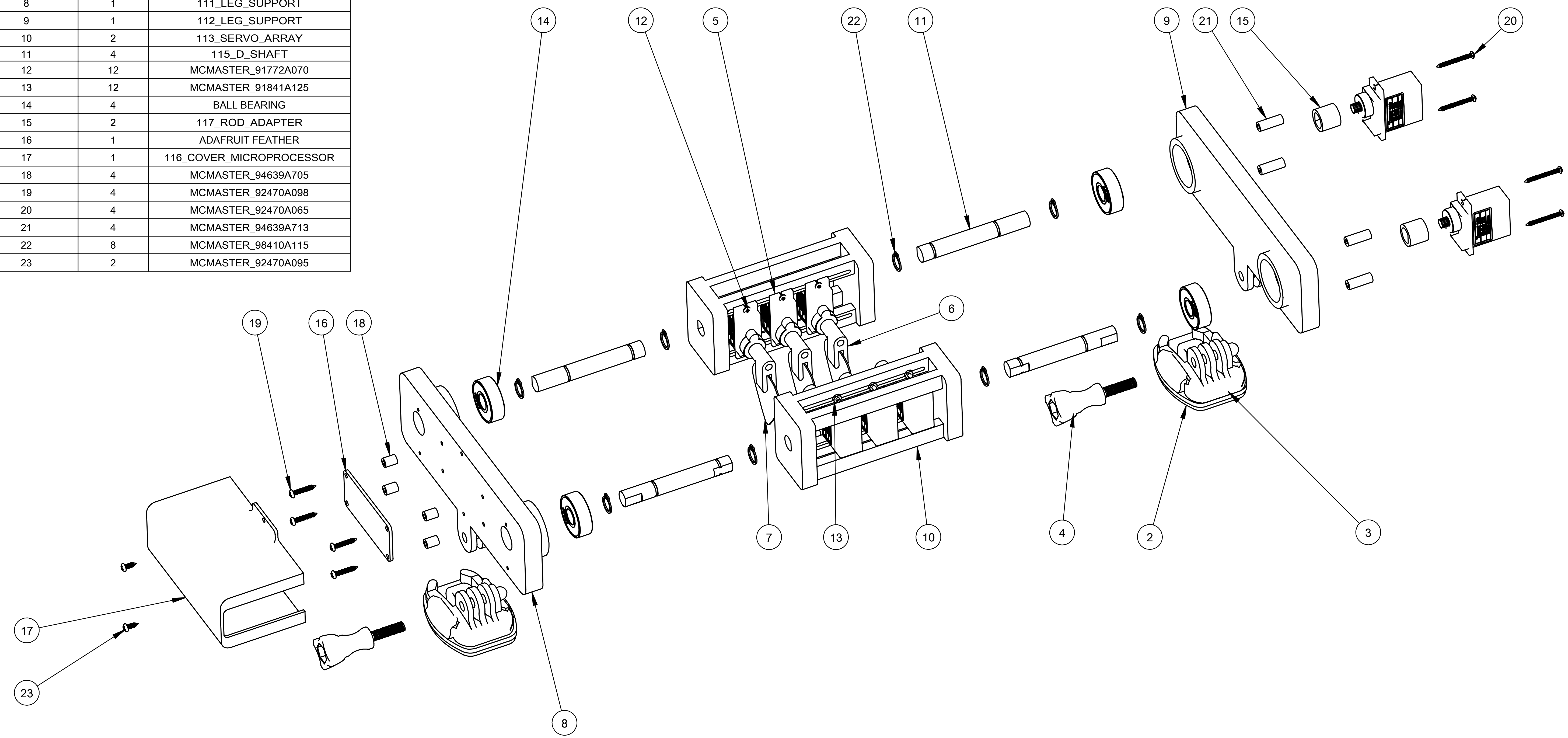

NOTE: SERVO FEATHERWING BOARD AND 32U4 CONTROLLER ARE STACKED WITH CONTROLLER TERMINALS REPEATED ON SERVO BOARD. REPEAT TERMINALS NOT SHOWN ON SERVO BOARD TO AVOID CONFUSION. THERE IS FUNCTIONALLY NO DIFFERENCE IN CONNECTING TO ONE TERMINAL SET VS THE OTHER.



RINGDIJK 84
3054 KV ROTTERDAM
NETHERLANDS

| | | | |
|---|---|---|---|
| ENGINEER: Randy Richards | 28Aug2017 | SIZE D | TITLE Breath Strummer |
| DRAWN: Randy Richards | 28Sep2017 | | |
| CHECKED: Steven Proctor | 28Sep2017 | SCALE N/A | |
| APPROVER: Ruud van der Wal | | | SHEET: 1 OF 1 |

| ITEM NO. | QTY. | PART/ASSEMBLY NAME |
|---|---|---|
| 1 | 1 | GUITAR (NOT SHOWN) |
| 2 | 2 | GOPRO ADHESIVE BASE |
| 3 | 2 | GOPRO BUCKLE MOUNT |
| 4 | 2 | GOPRO THUMBSCREW |
| 5 | 8 | MG92B_SERVO |
| 6 | 6 | 114_PICK_HOLDER |
| 7 | 6 | GUITAR PICK |
| 8 | 1 | 111_LEG_SUPPORT |
| 9 | 1 | 112_LEG_SUPPORT |
| 10 | 2 | 113_SERVO_ARRAY |
| 11 | 4 | 115_D_SHAFT |
| 12 | 12 | MCMASTER_91772A070 |
| 13 | 12 | MCMASTER_91841A125 |
| 14 | 4 | BALL BEARING |
| 15 | 2 | 117_ROD_ADAPTER |
| 16 | 1 | ADAFRUIT FEATHER |
| 17 | 1 | 116_COVER_MICROPROCESSOR |
| 18 | 4 | MCMASTER_94639A705 |
| 19 | 4 | MCMASTER_92470A098 |
| 20 | 4 | MCMASTER_92470A065 |
| 21 | 4 | MCMASTER_94639A713 |
| 22 | 8 | MCMASTER_98410A115 |
| 23 | 2 | MCMASTER_92470A095 |




Mechanical & Aerospace ENGINEERING
UtahState University

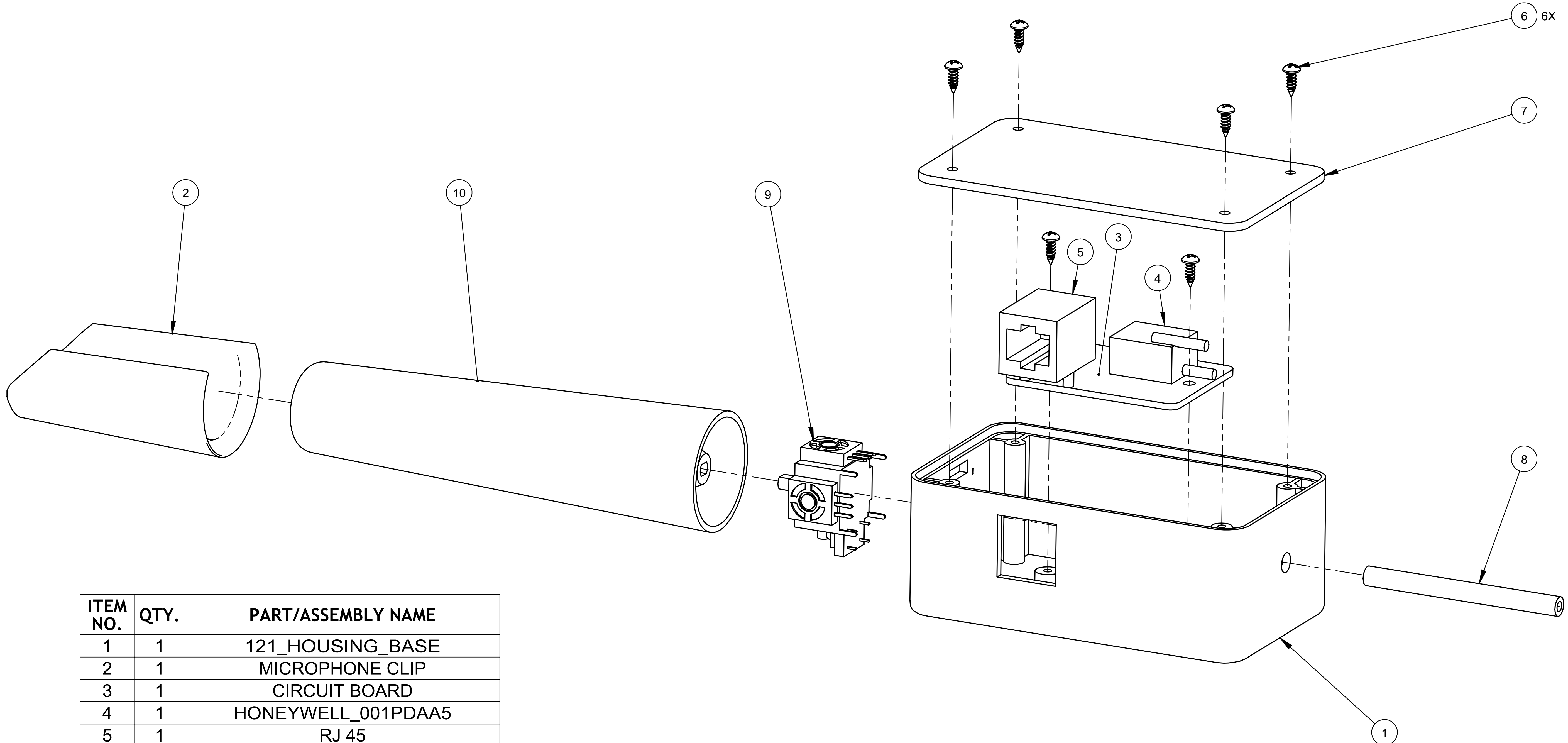
**PROJECT:** BREATH STRUMMER

| | |
|---|---|
| DRAFTED BY: | RHETT RAMSEY |
| PART/ASSEM NAME: 110_STRUMMER | CHECKED BY: R. RAMSEY, R. RICHARDS, S. PROCTOR |
| PART/ASSEM NUMBER: 110 | APPROVED BY: R. RAMSEY, R. RICHARDS, S. PROCTOR |
| MATERIAL: N/A | DATE APPROVED: 12/4/2017 |
| FINISH: N/A | SHEET SCALE: 1:2 — SHEET NUMBER: 1 of 1 |

**SPECIFICATIONS AND TOLERANCES**

UNLESS OTHERWISE NOTED
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches




| ITEM NO. | QTY. | PART/ASSEMBLY NAME |
|---|---|---|
| 1 | 1 | 121_HOUSING_BASE |
| 2 | 1 | MICROPHONE CLIP |
| 3 | 1 | CIRCUIT BOARD |
| 4 | 1 | HONEYWELL_001PDAA5 |
| 5 | 1 | RJ 45 |
| 6 | 6 | MCMASTER_92470A095 |
| 7 | 1 | 122_HOUSING_LID |
| 8 | 1 | TUBE |
| 9 | 1 | JOYSTICK POTENTIOMETER |
| 10 | 1 | 123 MICROPHONE MOUNT |

Mechanical & Aerospace ENGINEERING
UtahState University

**PROJECT:** BREATH STRUMMER

DRAFTED BY: RHETT RAMSEY

**SPECIFICATIONS AND TOLERANCES**

**UNLESS OTHERWISE NOTED**
DRAWING ARE CREATED IN ACCORDANCE TO ASME Y14.5-2009

DEFAULT DIMENSIONAL TOLERANCES:
LINEAR DIMENSIONS [inches]: X±.5, X.X±.1, X.XX±.03, X.XXX±.005
ANGULAR DIMENSIONS [degrees]: X±3, X.X±.5, X.XX±.1
MINIMUM SURFACE FINISH: 1000 microinches

| | |
|---|---|
| PART/ASSEM NAME: 120_MOUTHPIECE | CHECKED BY: R. RAMSEY, R. RICHARDS, S. PROCTOR |
| PART/ASSEM NUMBER: 120 | APPROVED BY: R. RAMSEY, R. RICHARDS, S. PROCTOR |
| MATERIAL: N/A | DATE APPROVED: 12/4/2017 |
| FINISH: N/A | SHEET SCALE: 1:1 SHEET NUMBER: 1 of 1 |