Softbal Swing Trainer Prototype

Ashley Reilly
Jeremy Rine
UC Berkeley Mechanical Engineering
ME102B: Fall 2020

1 Project Description

1.1 Inspiration

Product ideas can be motivated from passions in life. In order to balance the rigour of student life as an engineer, it is important to have hobbies. Ashley's hobby playing softball inspired our creation for a training device. In **figure 1** below two pictures taken during a single swing. The first picture represents the starting swing position and the second picture shows the position after the ball is hit. An ideal swing occurs when the batter maintains a horizontal plane position of their shoulders with the ground. When a ball is hit with this form chances are higher that the ball will follow what is called a line drive. A line drive will have the highest velocity making it difficult for the opposing team to field. As seen in the picture to the right the batter drops their back shoulder significantly. This drop will cause the ball to be hit upward, creating what is called a pop fly and is easily caught by the opposing team. Our idea is to create a haptic feedback device that will be used during training to correct a batter swinging form.

Figure 1: *Softball Action Shots.*

1.2 Brainstorming

We desired the device to trigger vibration motors when the batter's swing drops below a threshold angle. We used an accelerometer as our sensor to collect change in position data, and coded our microcontroller to power the vibrating motors. The threshold angle was optimized through testing. In order to read the change in angle most accurately we placed the accelerometer at the midpoint of the shoulders inline with the horizontal plane. Another aspect we considered was comfortability and versatility. We incorporated a wearable shoulder harness with the device so that it does not impede the batter's swing and is adjustable to fit different body types. We created a finite state diagram (**Figure 2**) to start the process of selecting electrical components of the device.

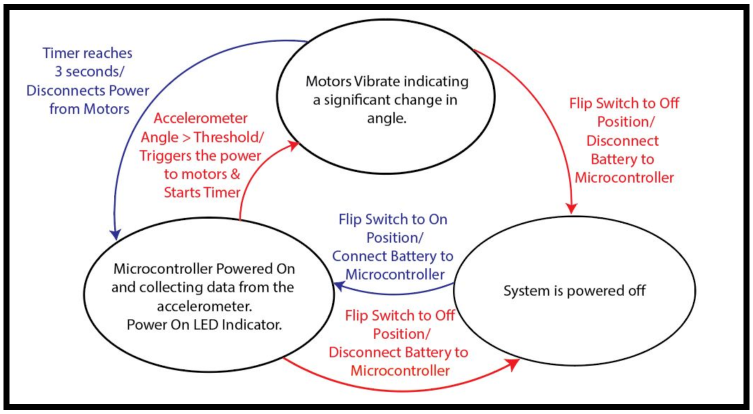


Figure 2: *Finite State Diagram. This diagram maps the functions desired from the device.*

2 Prototyping

We have access to a 3D printer, laser cutter, and soldering iron. With these tools we are able to create prototypes from materials such as PLA, plywood, acrylic, and create circuits beyond our breadboard.

2.1 Circuit Prototyping

We started prototyping by creating a breadboard circuit of the electro-mechanical components. This allowed us to test our electrical system and easily make changes to ensure proper function. **Figure 3** shows our first circuit prototype and **Figure 4** is a wiring diagram of the physical design. The following list were considerations in prototyping the circuit component of our project:

- Placing batteries in parallel to create more capacity to hold a charge, but limiting the voltage seen by the board when the switch is turned on.
- Illuminated LED indicating the system is on.
- Switched power to the board.
- 2 motors each with 80 mA current drive.
- Motor driver board controls the power to the motors.
- When the accelerometer reading passes a tested threshold a PWM signal is sent from the microcontroller to the motor board and then current is sent to the motors creating a vibration indicating to the user that they have dipped their shoulder past the limit.

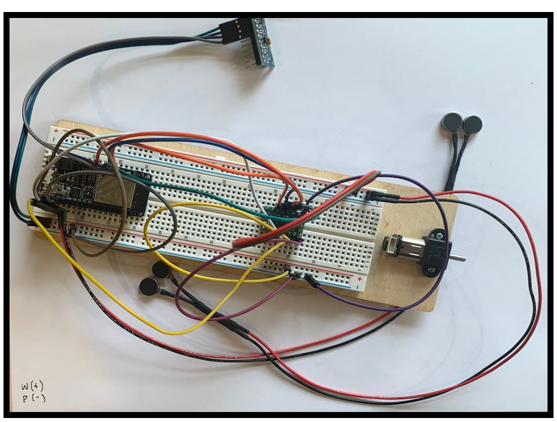


Figure 3: *Circuit Prototyping Breadboard*

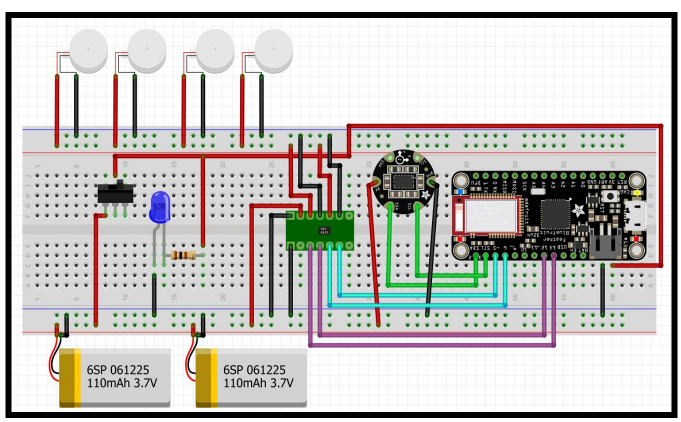


Figure 4: *Circuit diagram produced with Fritzing*

2.2 First Housing Prototype

After completing the circuit prototype we took measurements of the components and created a housing design (**Figure 5**). The following list contains points that we took into consideration for the first iteration:

- Threaded inserts for the attachment from the housing to the cover plate.
- 3D print the housing. Laser cut the cover plate.
- Create recessed hex nut holes to thread screws from the circuit board to the housing.
- Create easy access to the motors from the circuit.
- Place the usb port of the board at an easy access point for charging.
- Include space for two batteries to enhance capacity.
- Consider the mechanical attachment of the shoulder straps to the housing where there is little stress on the motor wires.

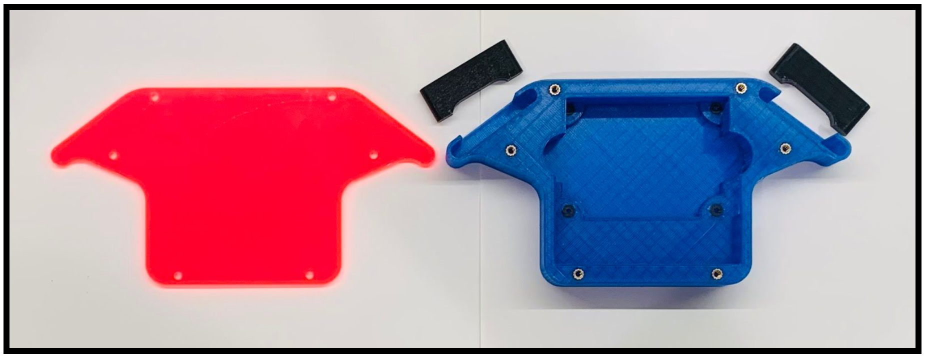


Figure 5: *First housing iteration. The component on the left is a cover plate that is laser cut acrylic, and the component on the right is 3D printed PLA. The black pieces are inserts that hold the shoulder straps in place and are made using 3D printed PLA.*

During the prototyping process and creating our first iteration we discovered changes that need to be made to optimize the functionality of our device. The follow list are those changes:

- Move the hole for the usb port, the alignment is slightly off.
- Create the holes for the screw inserts longer, possibly all the way through the housing to create a spot to connect the housing to the fabric.
- Need an on/off switch and create a place for that in the housing.

2.3 Shoulder Strap Prototyping

The vibration motors are placed along the shoulder straps of the device. We aligned the motors at the collar bone so that vibration is felt with the greatest magnitude. To minimize cyclic loading of the motor wires we created laser cut polymer sleeves to protect them. A future iteration of this would be to use a wiring loom instead.

3 Testing and Results

Using Arduino IDE and MatLab code found in Appendix 1 and 2 we were able to analyze the behavior of the accelerometer readings, and optimize the interrupt that controls the motor vibrations.

3.1 Swing Motion Analysis

In order to determine when criteria that would trigger the activation of the motors we recorded the pitch and roll values of two good posture swings and two bad posture swings. **Figure 6** shows these values plotted against each other.

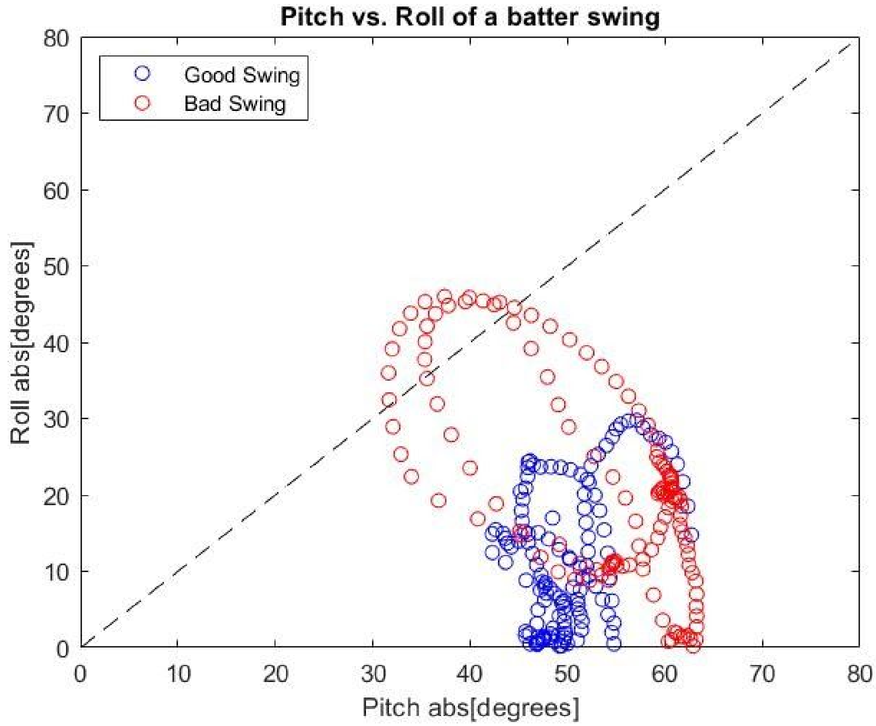


Figure 6: *Data points of pitch and roll collected from good and bad swing postures. The dashed line indicates the threshold where roll exceeds pitch.*

3.2 Calibration Selection

By examining the data collected through Matlab, we determined that a bad swing posture had the unique condition that the roll value exceeded the pitch value. This condition was used as our interrupt trigger for turning on the vibration motors.

4 Final Assembly

1	HiLetgo MPU9250/6500 Accelerometer
2	DRV8833 Motor Driver
3	Huzzah 32 Microcontroller
4	3.7V LiPo Batteries
5	LED
6	SPDT Switch
7	3.3V Coin Vibration Motor
8	Clear Polymer Wire Housing
9	Acrylic Cover Plate
10	M3x8 Button Head Machine Screws
11	Brass Heat-Set Thread Inserts
12	Nylon M2.5 Screws
13	PLA Housing

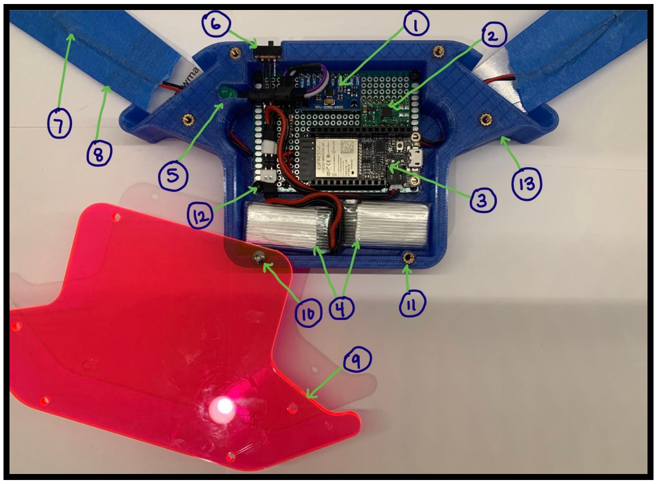


Figure 7: *Final assembly including all parts. The list to the left names the components of the system pictured to the right*

4.1 Part Functions

The Huzzah 32 microcontroller (3) runs the arduino code found in Appendix 1. The switch (6) controls the power from the batteries (4) to the microcontroller. The function of the code is to detect changes in pitch and roll from the accelerometer (1). Rotating acceleration causes discrepancies in the pitch and roll of the sensor readings, and in order to correct this we measure the output of the roll and compare to the output of the pitch. When the roll exceeds the pitch the interrupt is triggered and the microcontroller sends a PWM signal to the motor driver (2). The motor driver board controls the current given to the 3.3V motors (7) and drives vibration for 2 seconds. Once the motor stops a 5 second delay is triggered so that the accelerometer can stabilize from the vibration of the motors. The max current of the motors is 80 mA and according to the microcontroller data sheet we are able to run 2 motors simultaneously. The motors are secured in a polymer lining (8) to protect the wires from damage. We included an LED (5) to indicate when the power is on. The housing (13) is 3D printed with PLA, and threads (11) are inserted to connect the cover plate (9) with machine screws (10). The circuit board is connected to the housing using nylon screws (12)

Appendix 1: Arduino Code

```
#include "MPU9250.h"

MPU9250 mpu;

// PWM declarations
const int MotorA1 = 14;
const int MotorA2 = 42;
const int MotorB1 = 15;
const int MotorB2 = 33;
const int resolution = 8;
const int channel1 = 1;
const int channel2 = 2;
const int freq = 20000;
int lastbuzz = 0;
float pitchval;
float rollval;

void IRAM_ATTR onDip(){
	ledcWrite(1,230);	// Turn on motors at 90% max speed.
	delay(2000);
	ledcWrite(1,0);		// Turn motors off.
	delay(2000);
}

void setup()
{
	Serial.begin(115200);
	Wire.begin();
	delay(2000);

	// Accelerometer setup
	mpu.setup();

	// PWM setup
	ledcAttachPin(MotorA1, channel1);
	ledcAttachPin(MotorA2, channel2);
	ledcAttachPin(MotorB1, channel1);
	ledcAttachPin(MotorB2, channel2);
	ledcSetup(channel1, freq, resolution);
	ledcSetup(channel2, freq, resolution);
}

void loop()
{
	static uint32_t prev_ms = millis();
```

```
    if ((millis() - prev_ms) > 16)
    {
    mpu.update();
    mpu.print();
    Serial.print("roll  (x-forward (north)) : ");
    Serial.println(mpu.getRoll());
    Serial.print("pitch (y-right (east))    : ");
    Serial.println(mpu.getPitch());
    Serial.print("yaw   (z-down (down))     : ");
    Serial.println(mpu.getYaw());

    prev_ms = millis();

    pitchval = abs(mpu.getPitch());
    rollval = abs(mpu.getRoll());

    }
    if (rollval > pitchval)
    {
    if (millis() > 10000)          // 10 second delay at startup for accelerometer
    {                              // to calibrate.
    if (millis() - lastbuzz > 5000) // 5 second delay to let the accelerometer
    {                               //  stabilize.
    onDip();
    lastbuzz = millis();
    }
    }
    }
}
```

Appendix 2: Matlab Code

```
%% MATLAB FROM ARDUINO SERIAL COMMUNICATION
clf;
close(1);
clc;
clear;
pause on

FilePath = './good_swing.csv';    % define your output file path
SerialPort = 'COM3';              % change to an active serial port


RecordTime = 5;          % define the overall record time in sec

BaudRate = 115200;

if ~ismember(SerialPort,serialportlist)
        disp('Serial not activated. Pause program.')
        pause;
end

f = fopen(FilePath, 'w');

sd = serialport(SerialPort, BaudRate, 'Timeout', 2);

pause(1);

flush(sd);
readline(sd);

disp('Data logging starts...')

init = tic; refresh = tic;
while toc(init) < RecordTime
        try
        if sd.NumBytesAvailable
        data = readline(sd);
        disp(data);
        fprintf(f,data);
        fprintf(f,'\n');
        end

        catch ME
        fclose('all');
        clear sd;
        error('Error occurred. Stop logging...')
        end
end
```

```
disp('Data logging finished. Good bye!')
```

```
%% Plot Pitch Vs. Roll

data1 = readtable('good_swing.csv');
data1 = data1([100:227],:);

g_pitch = table2array(data1(:,1));
g_roll = table2array(data1(:,2));

data2 = readtable('bad_swing.csv');
data2 = data2([100:227],:);

b_pitch = table2array(data2(:,1));
b_roll = table2array(data2(:,2));

pitchscale = (0:1:79);
rollscale = (0:1:79);

plot(g_pitch, g_roll,'bo',b_pitch, b_roll,'ro', pitchscale, rollscale, 'k--')
title('Pitch vs. Roll of a batter swing')
xlabel('Pitch abs[degrees]')
ylabel('Roll abs[degrees]')
xlim([0 80])
ylim([0 80])
legend('Good Swing', 'Bad Swing', 'Location', 'northwest')
```

Softball Swing Trainer

Ashley Reilly
Jeremy Rine
UC Berkeley Mechanical Engineering
ME102B: Fall 2020

1 Electrical Design

1.1 Current Limitations

In order to bring our ideas to a physical reality we used the technical specifications of each component to make sure that we could connect them without exceeding electrical current limitations on any component. We did these calculations assuming each component was being run at full draw.

Component	Maximum electrical draw (mA)
Huzzah 32 microcontroller	200
MPU-9250	3.5
3.3V Coin vibration motors (2)	160
LED	20
Pololu DRV8833 (logic)	0.033
Total	383.533

1.2 Runtime Calculation

After calculating the total current draw of the system we checked the capacity of our intended battery setup (two parallel 350mAh LiPo batteries) compared to the total draw possible from our system.

$$runtime = \frac{battery\ capacity\ [mAh]}{system\ draw\ [mA]}$$

$$runtime = \frac{700\ [mAh]}{383\ [mA]}$$

$$runtime = 1.82\ hours$$

An average batting practice lasts roughly one hour, so by this calculation the on-board power supply is more than adequate under constant maximum electrical draw conditions.

1.3 Pin Current

After determining the current requirements of the system as a whole, we checked the current limitations of each component to make sure that no individual part is overloaded.

Component	Current limit [mA]	Desired current [mA]
Huzzah 32 3.3V output pin	250 (reserving 250 for processor)	80*2 + 3.5 = 163.5
Pololu DRV8833 (motor)	1200	160

All other current requirements were well below any limitations or compounded through any single point.

2 Software

Using the Arduino IDE we wrote our code to check the roll pitch and yaw readings from the accelerometer every 16 milliseconds. We specifically selected a high sample frequency due to improve the response of the device and to also prevent the microcontroller running at maximum frequency which would have been unnecessary and determentral to battery life. Using the roll and pitch values we set an interrupt to trigger when the roll value exceeded the pitch value from any sample. When this happens the vibratory motors are powered and run for two seconds. Due to the short nature of swinging a softball bat, we only need to trigger the motors once to let the user know that their posture was out of specification. By the time the user sets up for a second swing, the code has already reset and is ready to monitor swing posture again.

3 Parts list

After working through the theoretical electrical design, the following components were used for the prototype development.

Name	Part #	Price	Source	Qty.
Adafruit Huzzah 32	3405	$19.95	Adafruit	1
HiLetgo MPU9250/6500	3-01-0876	$14.95	Amazon	1
3.3V Coin Vibration Motor	E-1027-MOTOR-12	$8.99	Amazon	12
SPDT Switch	805	$0.95	Adafruit	1
LED	n/a	n/a	Spare parts	1
Pololu DRV8833 Dual Motor Driver	2130	$4.95	Pololu	1
CheerWing 3.7V LiPo battery packs (4) and charging system	n/a	$14.99	Amazon	2

Lucent clear polymer sheet (12”x24”x0.025”)	LC101025-QTR	$7.73	JP Plus	1
Acrylic Sheet (Pink) (12”x24”x0.125”)	CH341690-QTR	$17.81	JP Plus	1
PLA Spool (Translucent Blue)	n/a	$29.99	Atomic Filament	1
Brass Heat-Set Inserts for Plastic	94459A130	$9.57	McMaster	50
M3x8 Button head machine screws	92095A181	$9.37	McMaster	100
Nylon M2.5 Screws & Nuts	3229	$16.95	Adafruit	Kit

4 Fabrication

4.1 3D Printing

The main housing, **Figure 1**, was 3D printed due to the complexity of the geometry to house all desired components, routing channels for wires, and protection for field testing. If mass scale production is considered injection molding would be a desirable manufacturing method. We used heat-set brass inserts to take advantage of standard hardware without requiring high precision 3D printing. The motor wing retaining inserts, **Figure 2**, were also 3D printed due to their small size and geometric considerations.

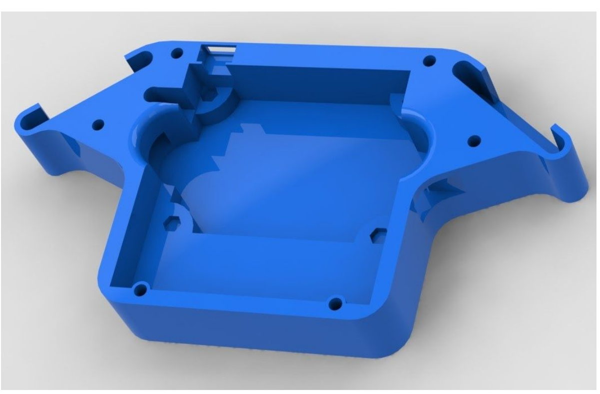


Figure 1: Main housing CAD rendering

Figure 2: Motor wing retaining insert CAD rendering

4.2 Laser Cutting

The cover plate, **Figure 3**, was laser-cut out of ⅛" acrylic sheet due to the two-dimensional nature of the design. This process took seconds to complete vs. the hours that 3D printing typically takes.
The motor wings, **Figure 4**, were laser-cut from 1mm polymer to provide a flexible platform for mounting the vibration motors and to keep them located properly on the shoulder straps. Not only was this process much faster than 3D printing, it avoids the cost of specialty flexible filament.

Figure 4: Cover plate CAD rendering

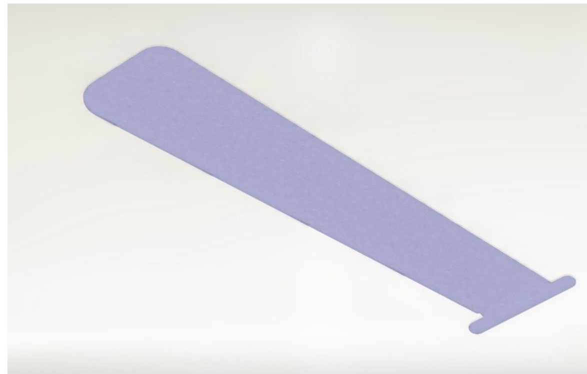


Figure 5: Motor mount wing CAD rendering

4.3 Engineering Drawings

All engineering drawings are included in Appendix 1. These documents are intended to be provided as production blueprints.

5 Assembly

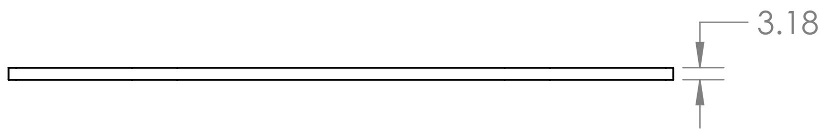
5.1 Electrical

All components are to be soldered together using a semi-permanent breadboard to reduce the overall size and provide durable soldered connections. Connectors will be used for the batteries, LED, power switch, and motors to improve ease of installation and component replacement if necessary.

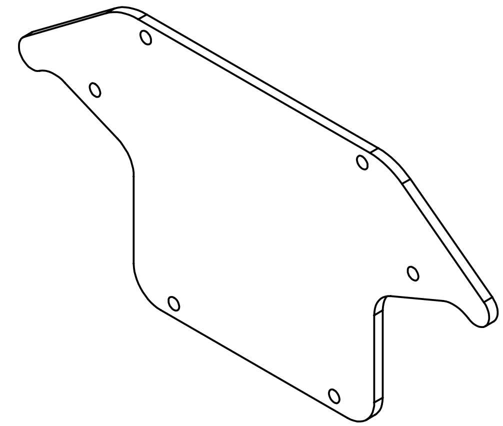
5.2 Mechanical

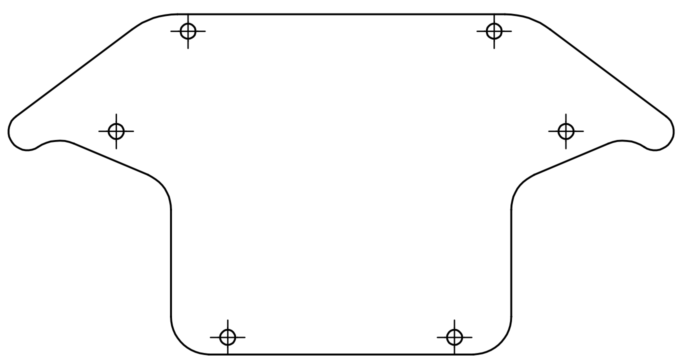
The housing and top cover will be attached with stainless steel machine screws and will provide ease of disassembly/reassembly. The motor wings will be affixed to the main housing using a tab and grove system which provides a mechanical attachment without the need of hardware or adhesive.

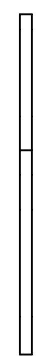
APPENDIX 1



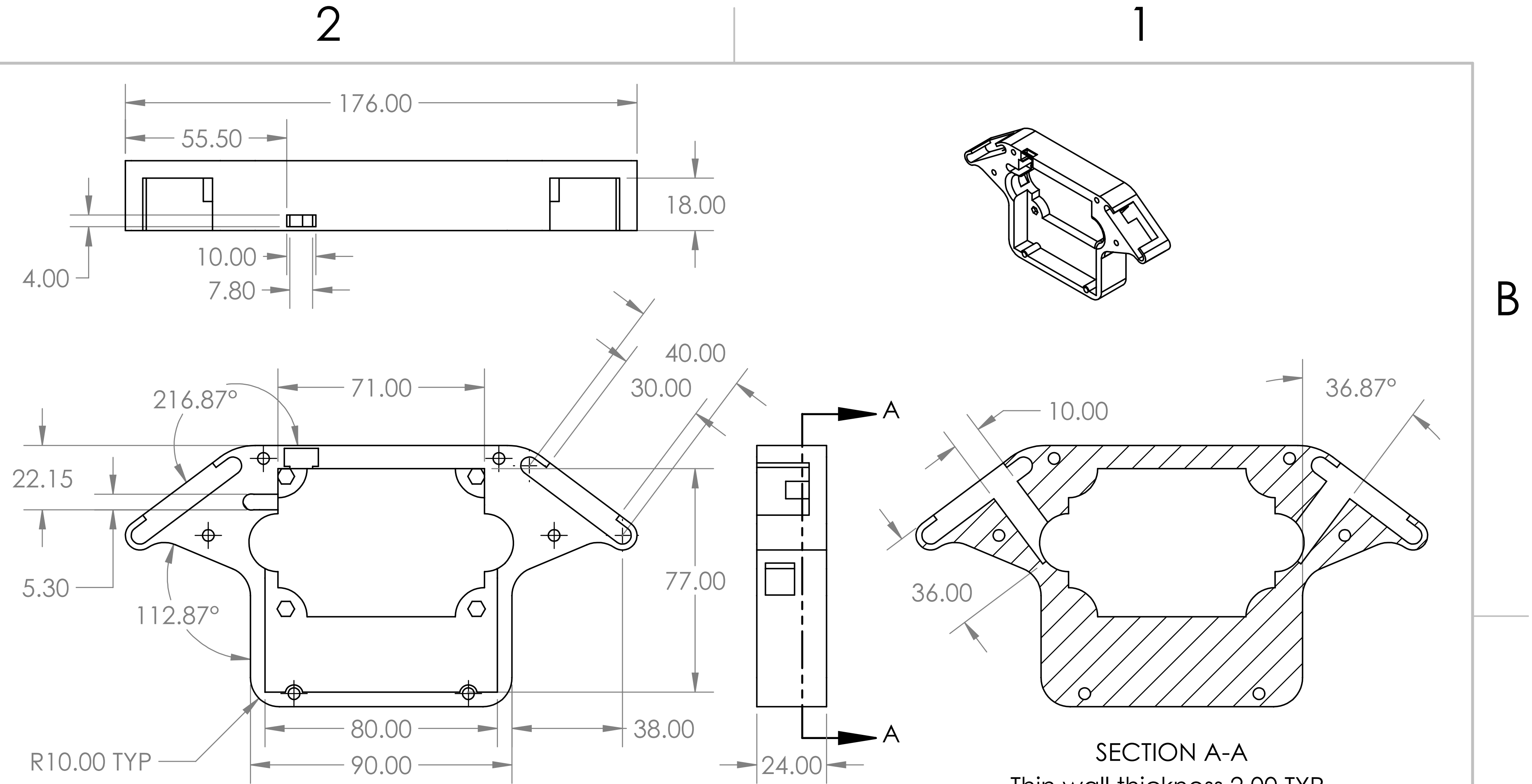
All dimensions the same from the housing drawing







		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			
			CHECKED			TITLE: Laser cut 1/8" acrylic
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE A	DWG. NO. Cover	REV 1
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:2	WEIGHT:	SHEET 1 OF 1



SECTION A-A
Thin wall thickness 2.00 TYP

PROPRIETARY AND CONFIDENTIAL

THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF <INSERT COMPANY NAME HERE>. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN MM
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:
PLA 3D Printed Housing

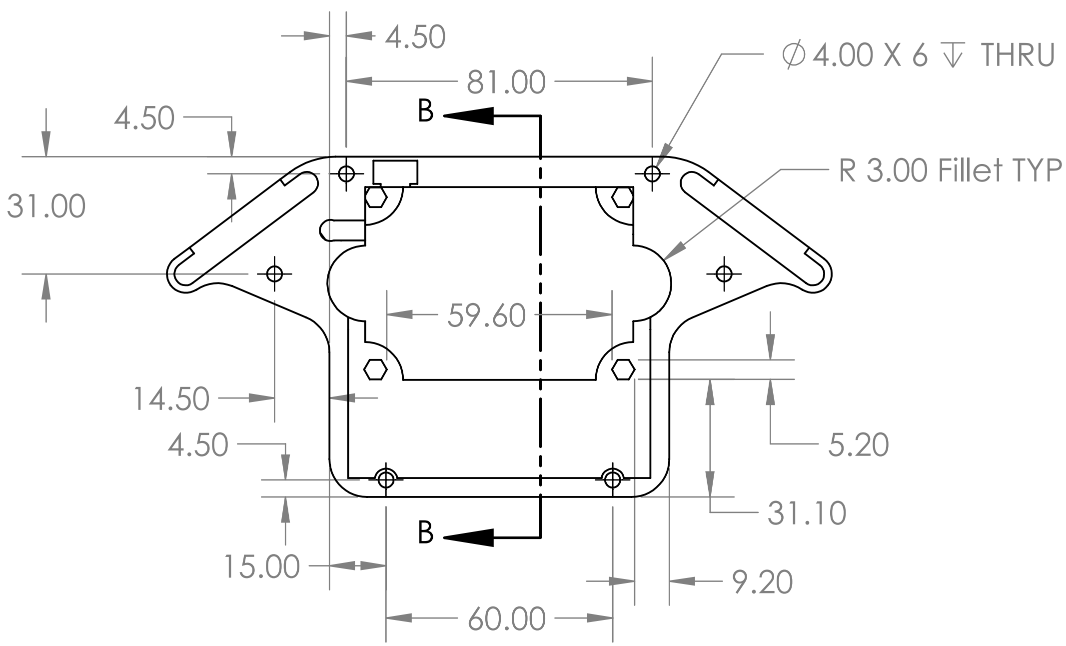
SIZE **A** | DWG. NO. Housing | REV 2

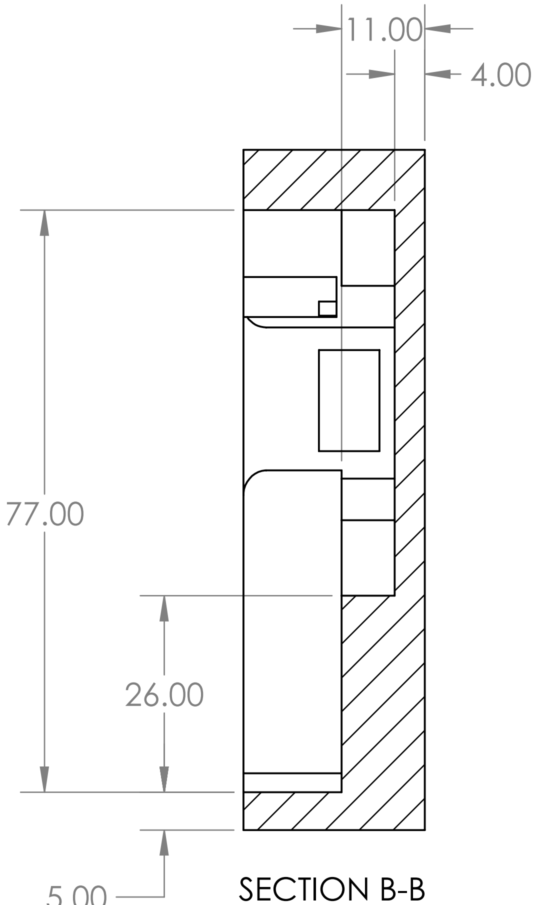
SCALE: 1:2 | WEIGHT: | SHEET 1 OF 2

A

B A

Hole Information

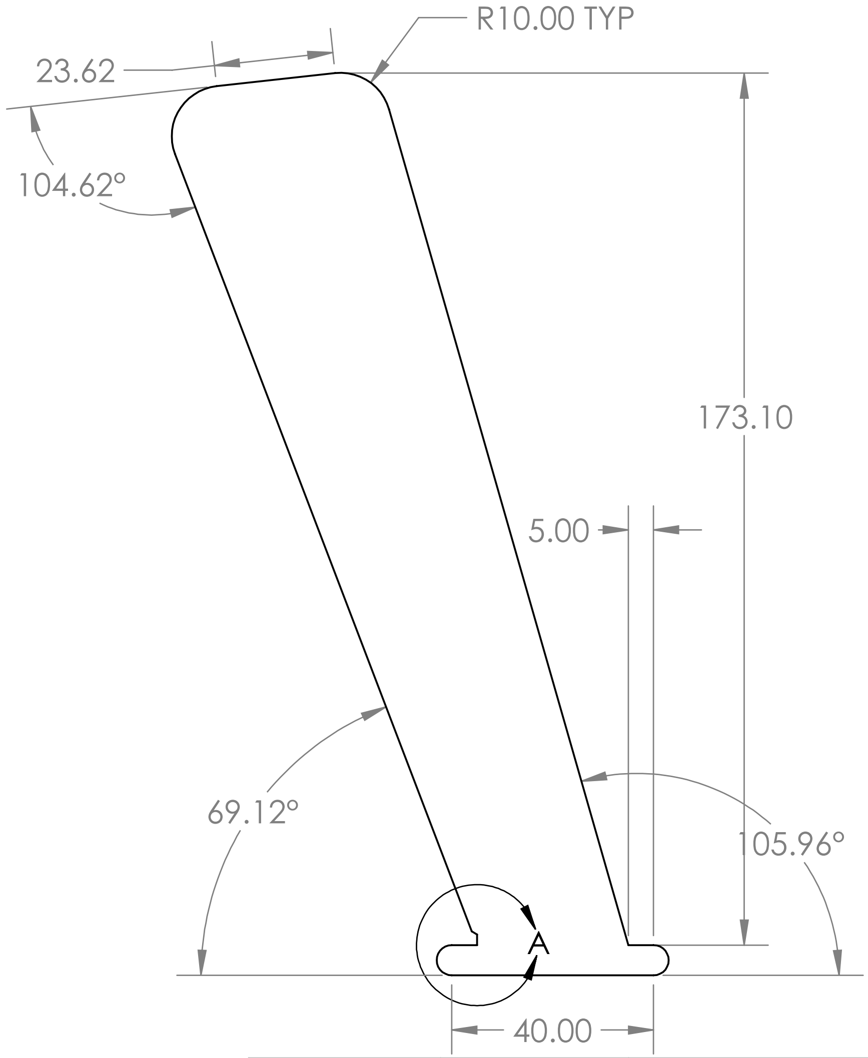




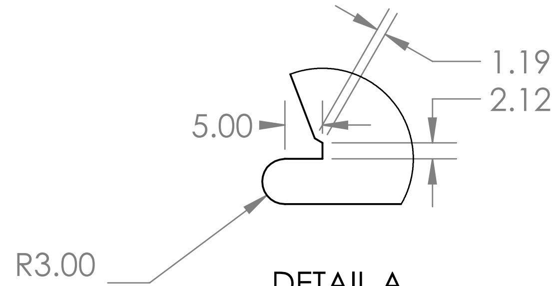
SECTION B-B
SCALE 1 : 1

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN MM TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN			
			CHECKED			TITLE:
			ENG APPR.			PLA 3D Printed Housing
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE A; DWG. NO. Housing; REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:2; WEIGHT:; SHEET 2 OF 2

B A



Laser cut 1mm thick plastic sheet
x2 units



DETAIL A
SCALE 1 : 1

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN MM
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

NEXT ASSY	USED ON
APPLICATION	

TITLE:

Shoulder wings for motor support

SIZE	DWG. NO.	REV
A	Wing	1

SCALE: 1:1.5 WEIGHT: SHEET 1 OF 1