Senior Design: JAKS

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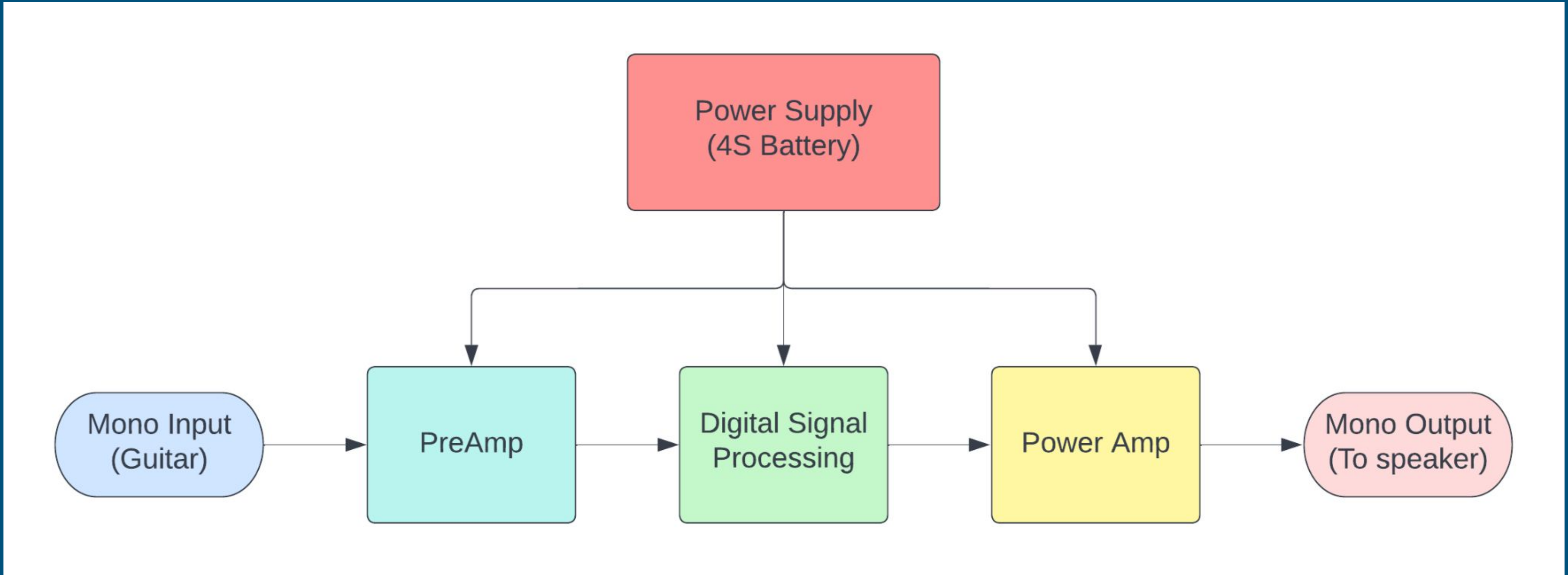
Introduction

- Goal: To create a portable guitar amplifier for a reasonable price
    - Preamp
    - DSP (Digital Sounds Processing)
    - Power Amplifier
    - Power supply with rechargeable batteries

Block Diagram

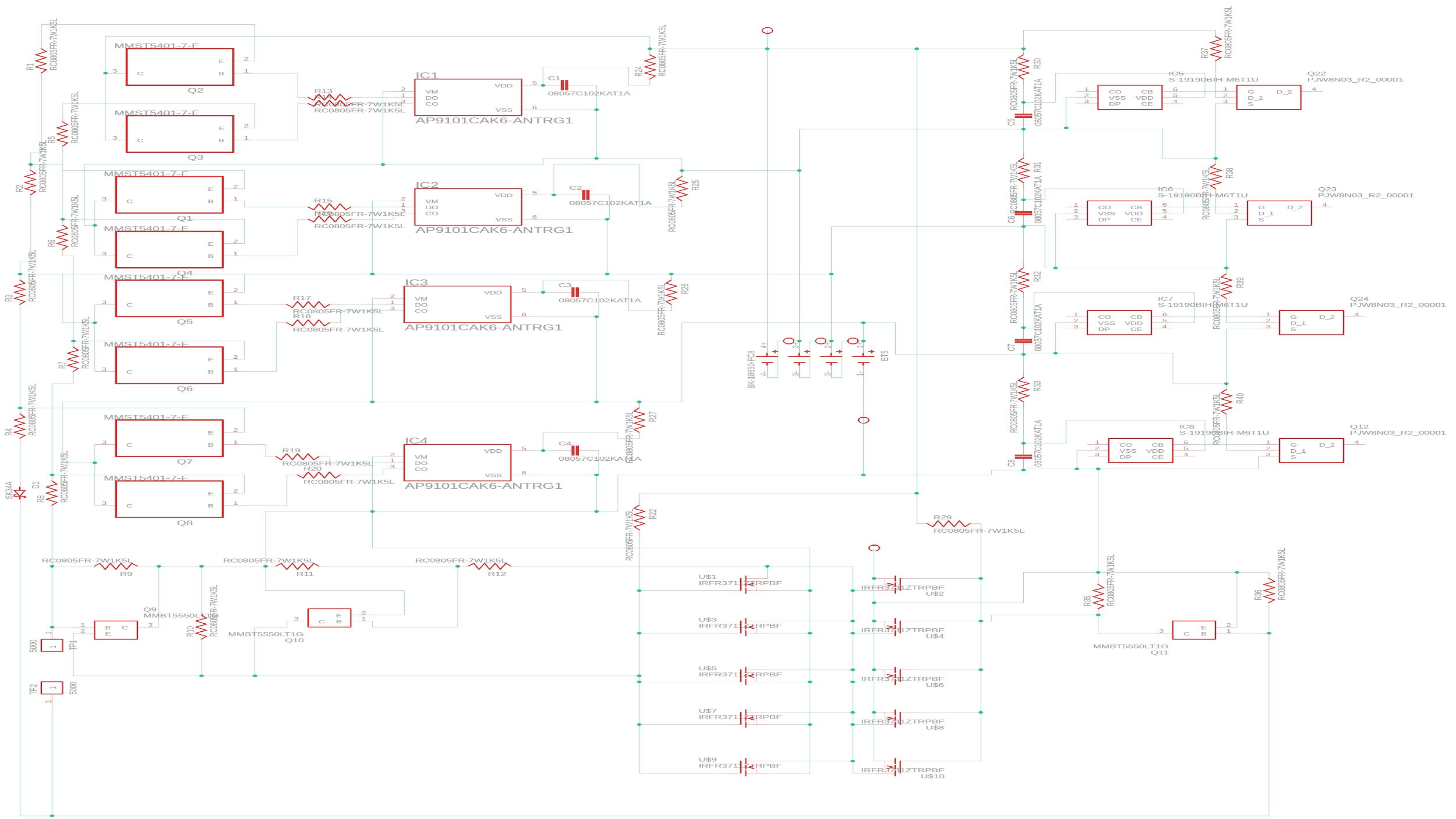


Battery Management System (BMS)

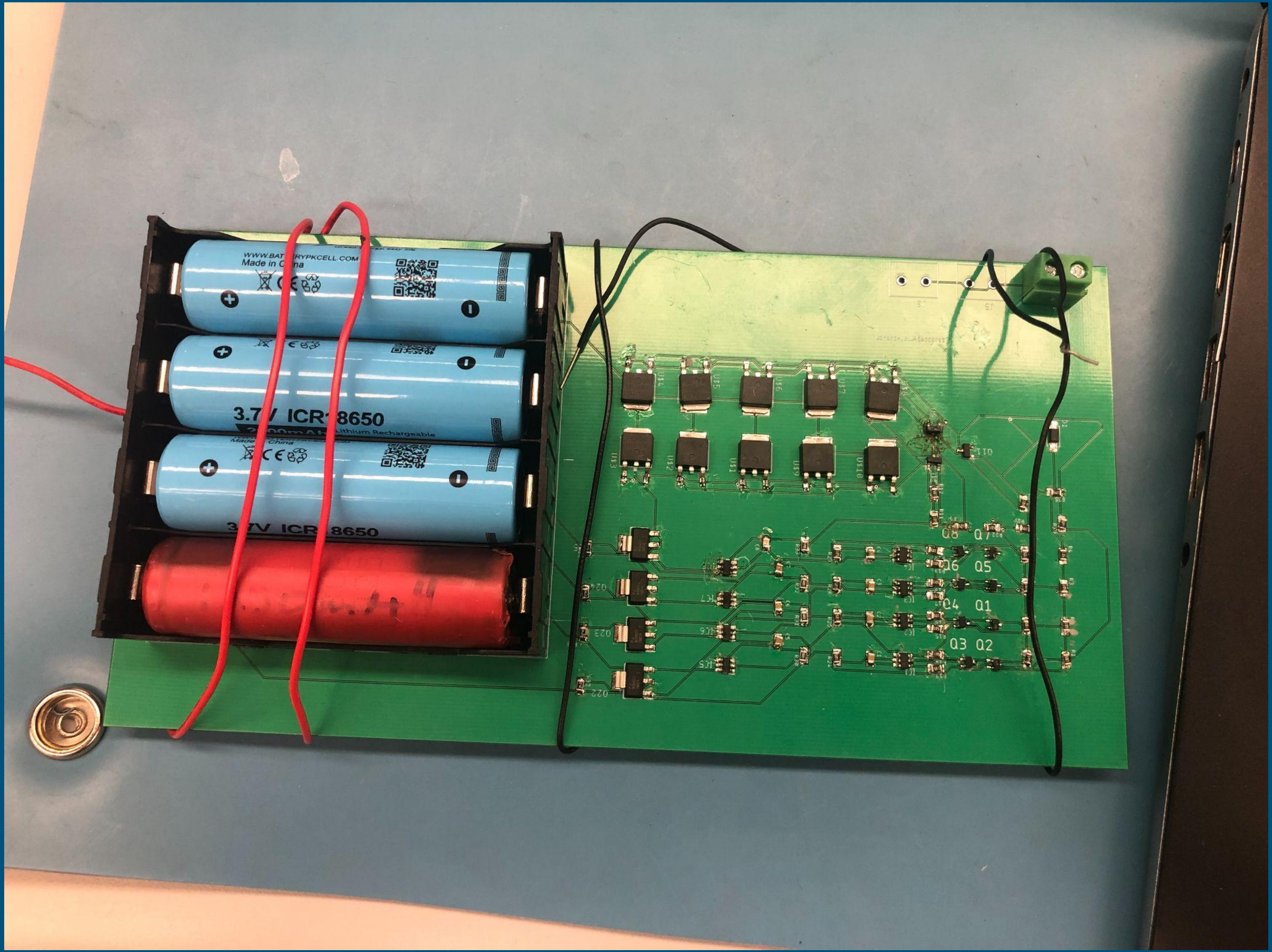
- The primary function of a BMS is to protect the battery cells from being damaged
- Can also calculate remaining charge, balance charge across cells, monitor temperature, health, and safety of the batteries
- The plan: design our own BMS to manage a bank of 4 lithium ion batteries which will be used to supply power to the amplifier

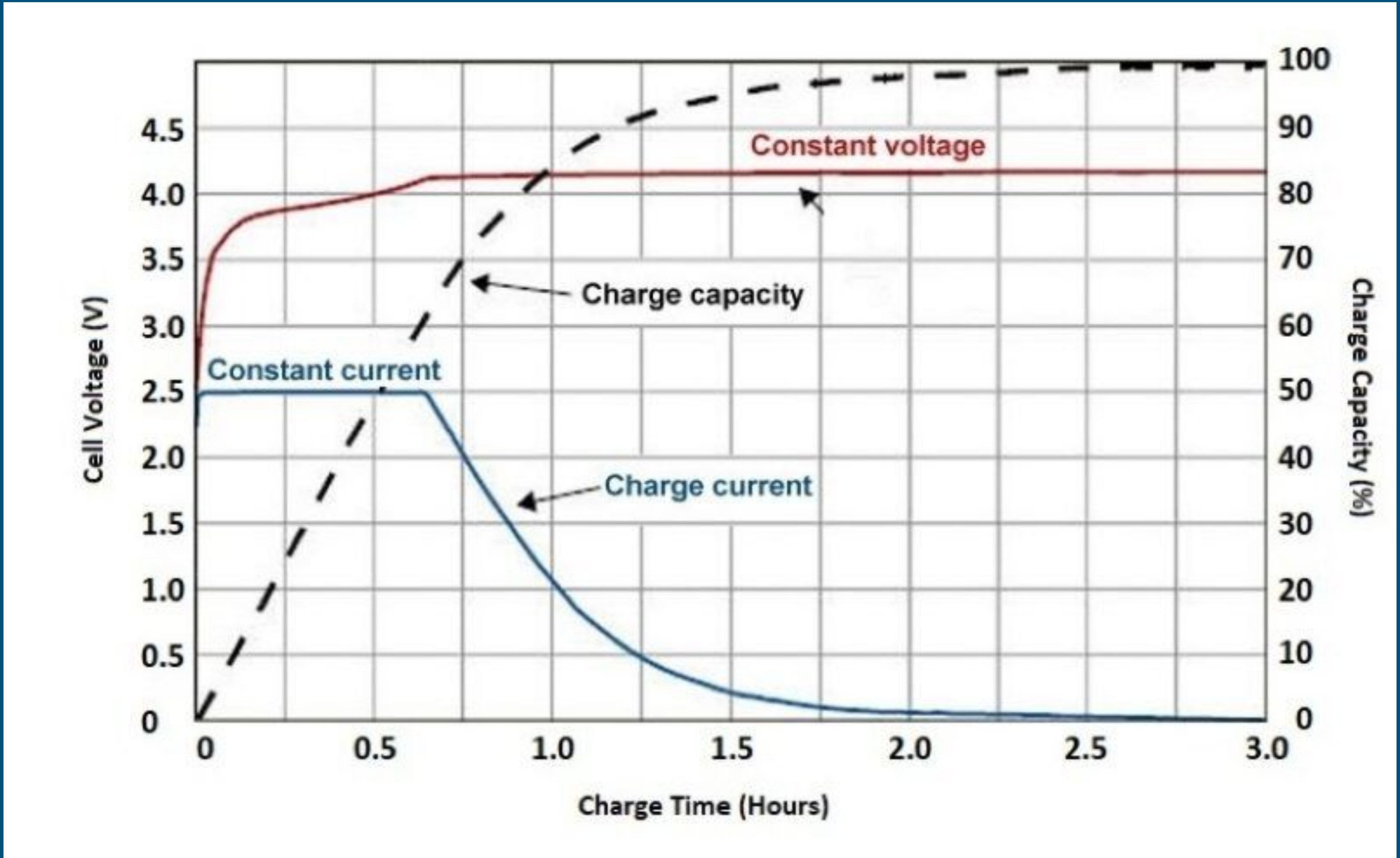
Parts Run-down

- AP9101CAK6 - Battery protection IC
- MMST5401 - Bipolar PNP transistor
- S-19190BIH - Cell balancing IC
- PJW8N03 - N-channel Enhancement Mode MOSFET
- 18650 - lithium batteries
- IRFR3711 - MOSFET
- SK34 Schottky diode



MMST5401-7-F
Q2
Q3
Q1
Q4
Q5
Q6
Q7
Q8
IC1
IC2
IC3
IC4
AP9101CAK6-ANTRG1
VM
DO
CO
VDD
VSS
C1
C2
C3
C4
08057C102KAT1A
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R15
R17
R18
R19
R20
R22
R24
R25
R26
R27
R29
R30
R31
R32
R33
R35
R36
R37
R38
R39
R40
RC0805FR-7W1K5L
D1
SK34A
TP1
TP2
5000
Q9
Q10
Q11
MMBT5550LT1G
BK-18650-PC8
BT5
U$1
U$2
U$3
U$4
U$5
U$6
U$7
U$8
U$9
U$10
IRFR3711ZTRPBF
IC5
IC6
IC7
IC8
S-19190BIH-M6T1U
CB
VSS
DP
CE
C5
C6
C7
C8
Q22
Q23
Q24
Q12
PJW8N03_R2_00001
G
D_1
D_2
S

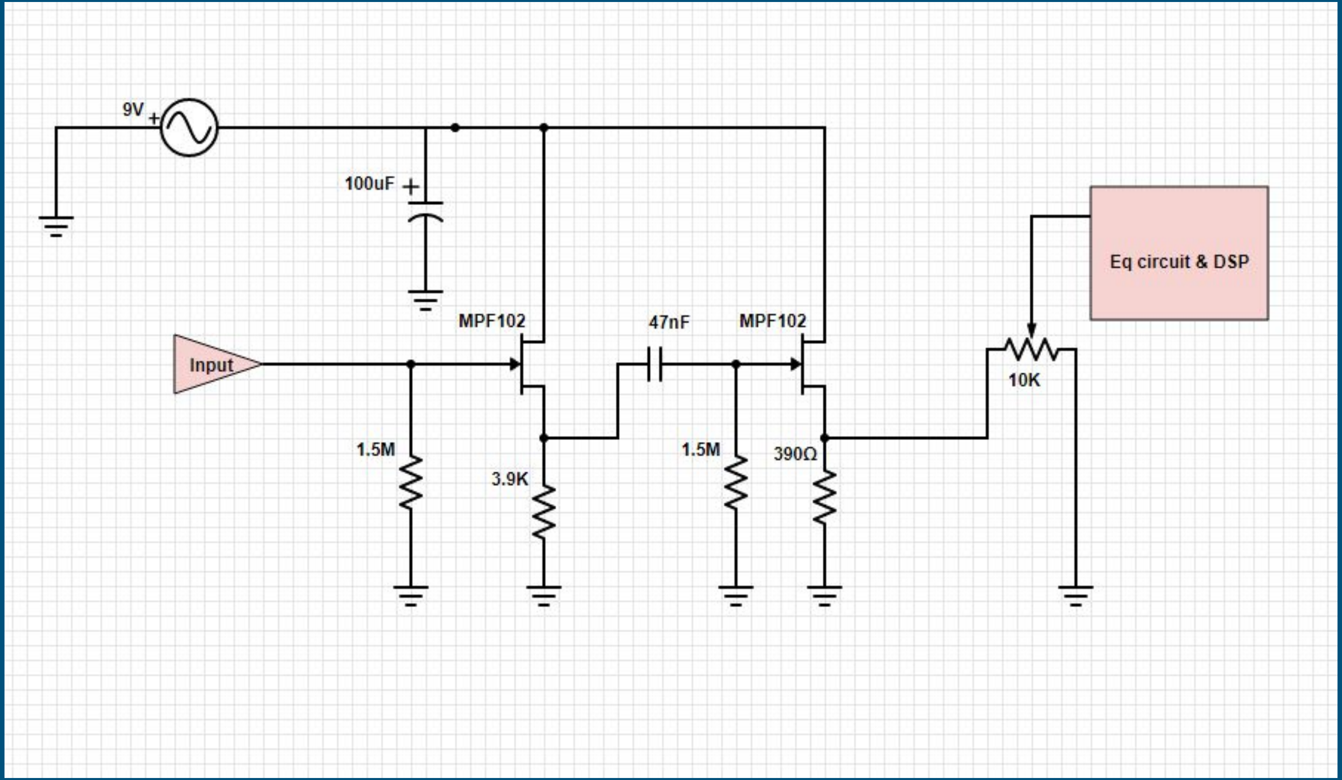

Lithium Rechargeable
Q8 Q7
Q6 Q5
Q4 Q1
Q3 Q2


Constant voltage
Charge capacity
Constant current
Charge current
Cell Voltage (V)
Charge Capacity (%)
Charge Time (Hours)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
100
90
80
70
60
50
40
30
20
10
0
0
0.5
1.0
1.5
2.0
2.5
3.0

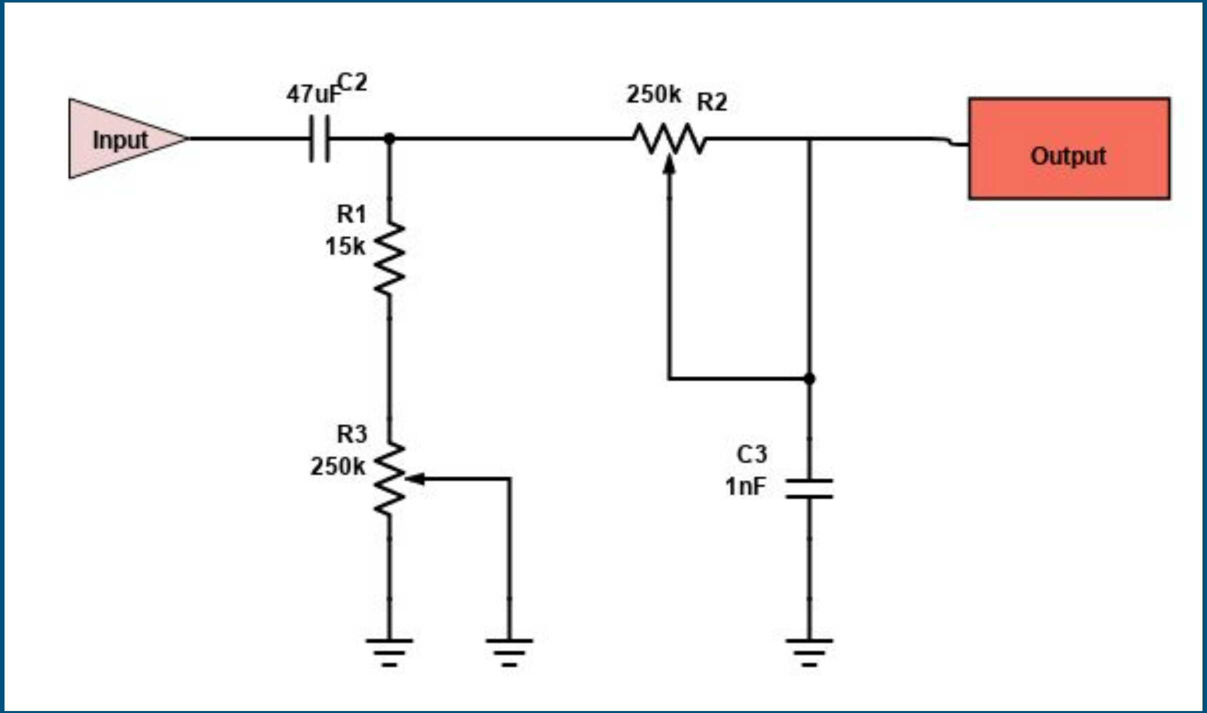
End Result and Key Takeaways

- After putting the BMS together and connecting it to the amp, the voltage would drop
- After backtracking and testing each component we could not identify the issue
- However, we can still power the amplifier using the lithium batteries directly
- In the long run, this could damage the health and performance of the batteries, is not a good safety practice, and can potentially affect their ability to become fully charged

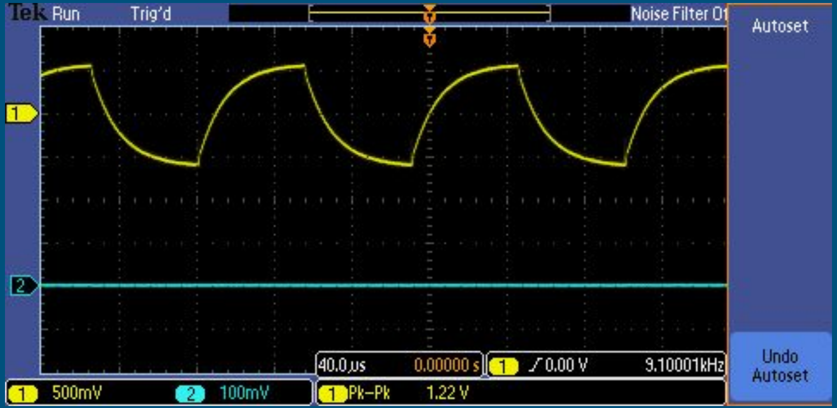
Preamp

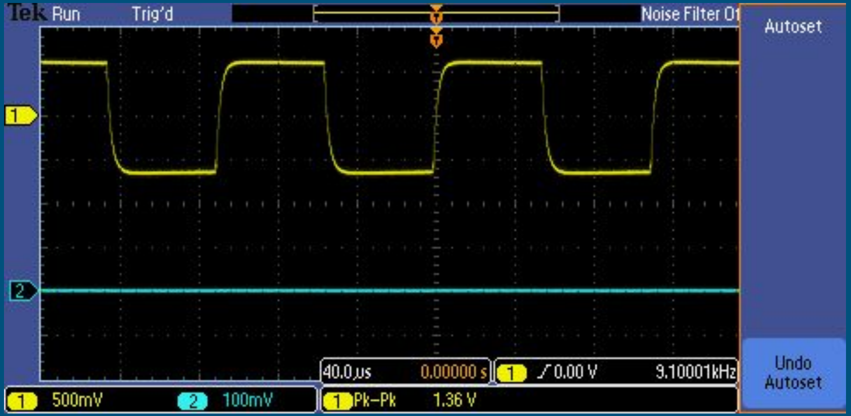

9V
+
100uF
+
MPF102
47nF
MPF102
Eq circuit & DSP
Input
10K
1.5M
3.9K
1.5M
390Ω

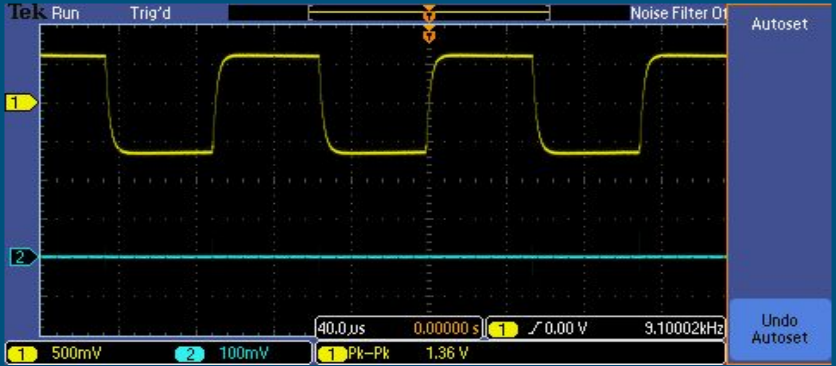
EQ Circuit



EQ Readings


Tek Run Trig'd
Noise Filter Of
Autoset
40.0µs 0.00000 s 1 0.00 V 9.10001kHz
1 500mV 2 100mV
1 Pk-Pk 1.22 V
Undo Autoset


Tek Run Trig'd
Noise Filter Of
Autoset
40.0µs 0.00000 s 1 0.00 V 9.10001kHz
1 500mV 2 100mV
1 Pk-Pk 1.36 V
Undo Autoset


Tek Run Trig'd
Noise Filter Of
Autoset
40.0µs 0.00000 s 1 0.00 V 9.10002kHz
1 500mV 2 100mV
1 Pk-Pk 1.36 V
Undo Autoset


Tek Run Trig'd
Noise Filter Of
Autoset
40.0µs 0.00000 s 1 0.00 V 9.10002kHz
1 500mV 2 100mV
1 Pk-Pk 1.02 V
Undo Autoset

Preamp Readings

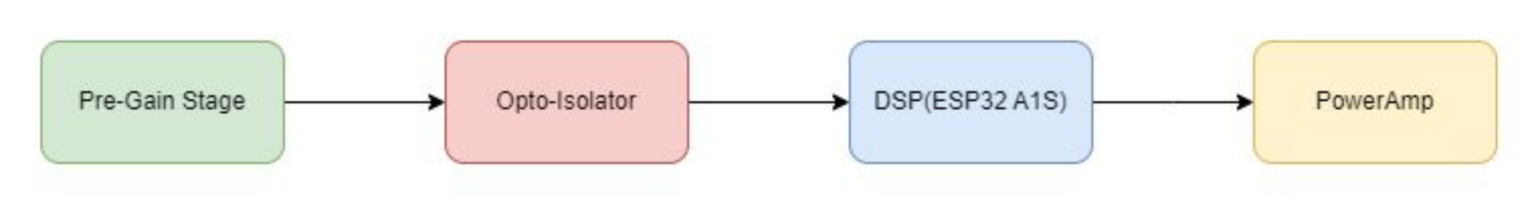
- Used gain of max voltages since this better reflected the output voltage of the wave generator
- Gain: 6.2dB
- Eq section failed to cut or operate at any frequency

Bill of Materials

Part Number	Component	Value	Cost
1	RESISTOR	1.5M	0.01
2	RESISTOR	3.9k	0.01
3	RESISTOR	1.5M	0.01
4	RESISTOR	390Ω	0.01
5	RESISTOR	15k	0.01
6	POLARIZED CAP	100uF	0.25
7	NON POLARIZED	1nF	0.45
8	NON POLARIZED	47μF	0.45
9	NON POLARIZED	47μF	0.45
10	POTENTIOMETER	250k	2.07
11	POTENTIOMETER	250k	2.07
12	POTENTIOMETER	10k	2.07
13	JFET	MPF102	2.14
14	JFET	MPF103	2.14

Block Diagram

- Pre-Gain
  - To increase signal
- Opto-isolator
  - To protect inputs of microcontroller
- DSP(ESP32-A1S)
  - To modulate signal using Digital Signal Processing



Pre Gain stage and Opto-Isolation Circuit

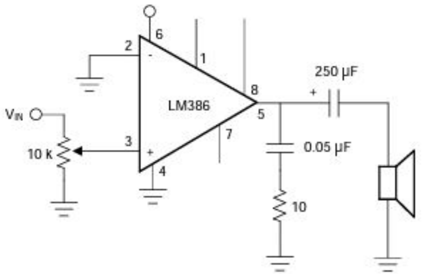


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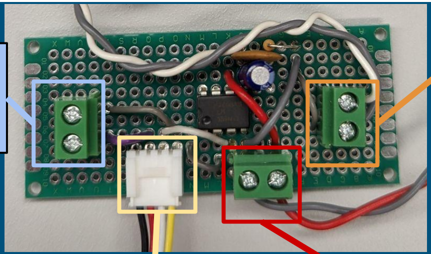
Figure 10. LM386 with Gain = 20

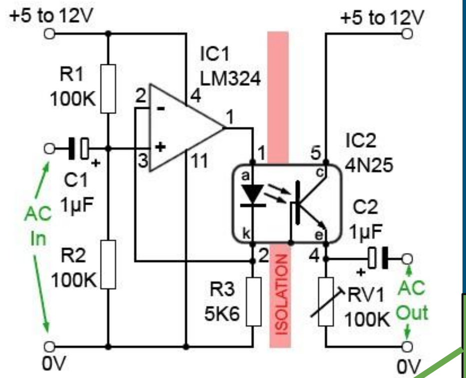


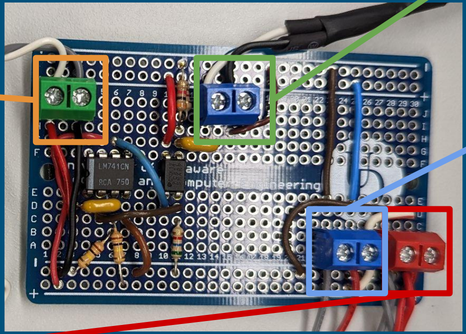
GTR Input

To Vol Pot

Signal Out/In

Vin/GND





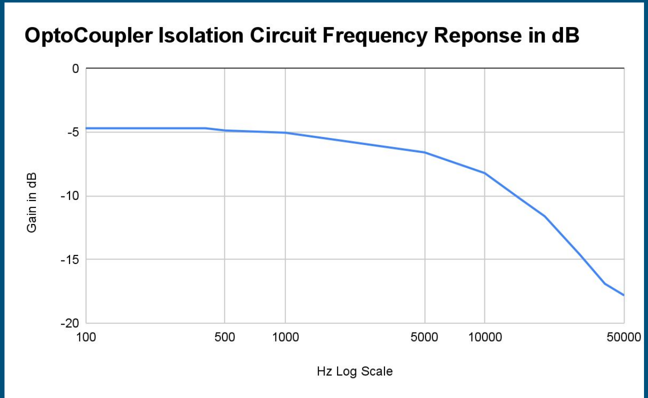
Opto Signal Out to Micro In

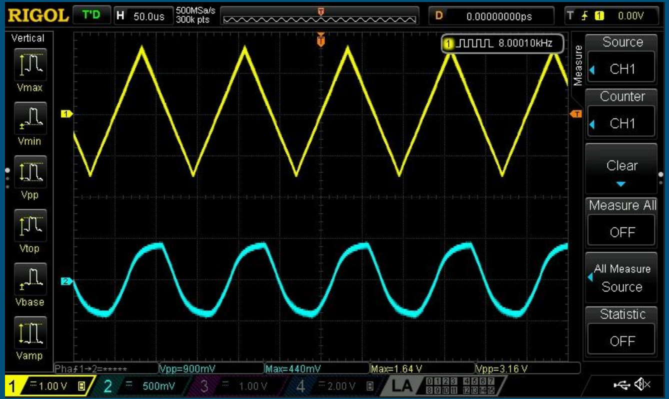
Vin2/GND

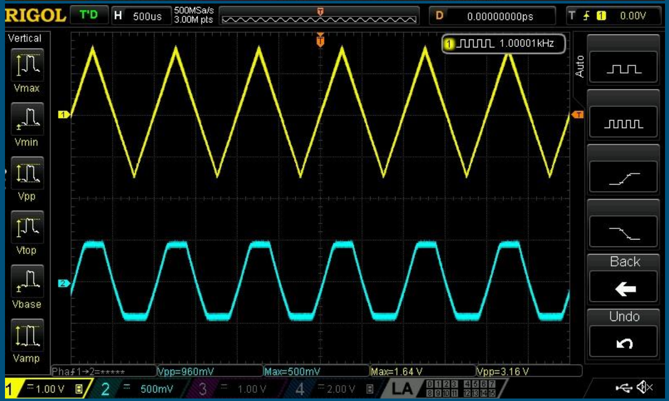
Opto-Isolation Frequency Response

What I Found

- Frequency Response is comparable to example.
- Saturation = Sounds Like Distortion (Can be good)







DSP (ESP32 A1S)/Last Year

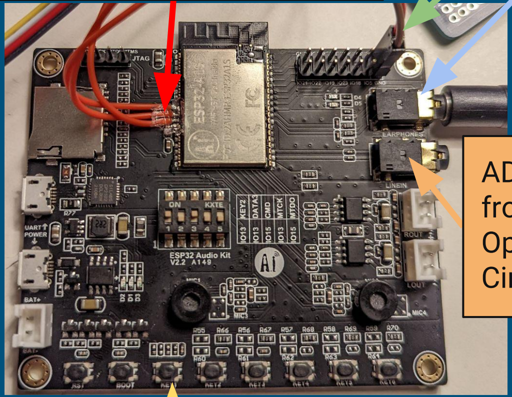
Why ESP32 A1S ?

- ESP32 can operate at 240MHz
- Built in ES8388 audio codec
  - Communicates via I2S protocol
  - ADC/DAC 24 bit 8kHz to 96kHz sample rate
- Why make a Dev-Board?
  - Breadboard Friendly
  - Smaller package
  - Eliminate unused components (SD card, Mic, Buttons)

3.3V and GND for Potentiometers

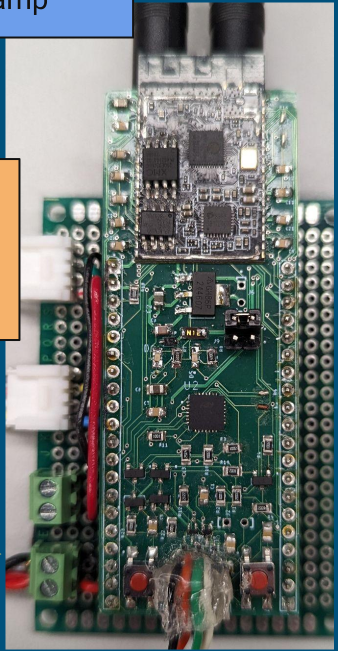
Three Potentiometers connected to ADC for Pots (Hard to breadboard)

DAC output to Poweramp

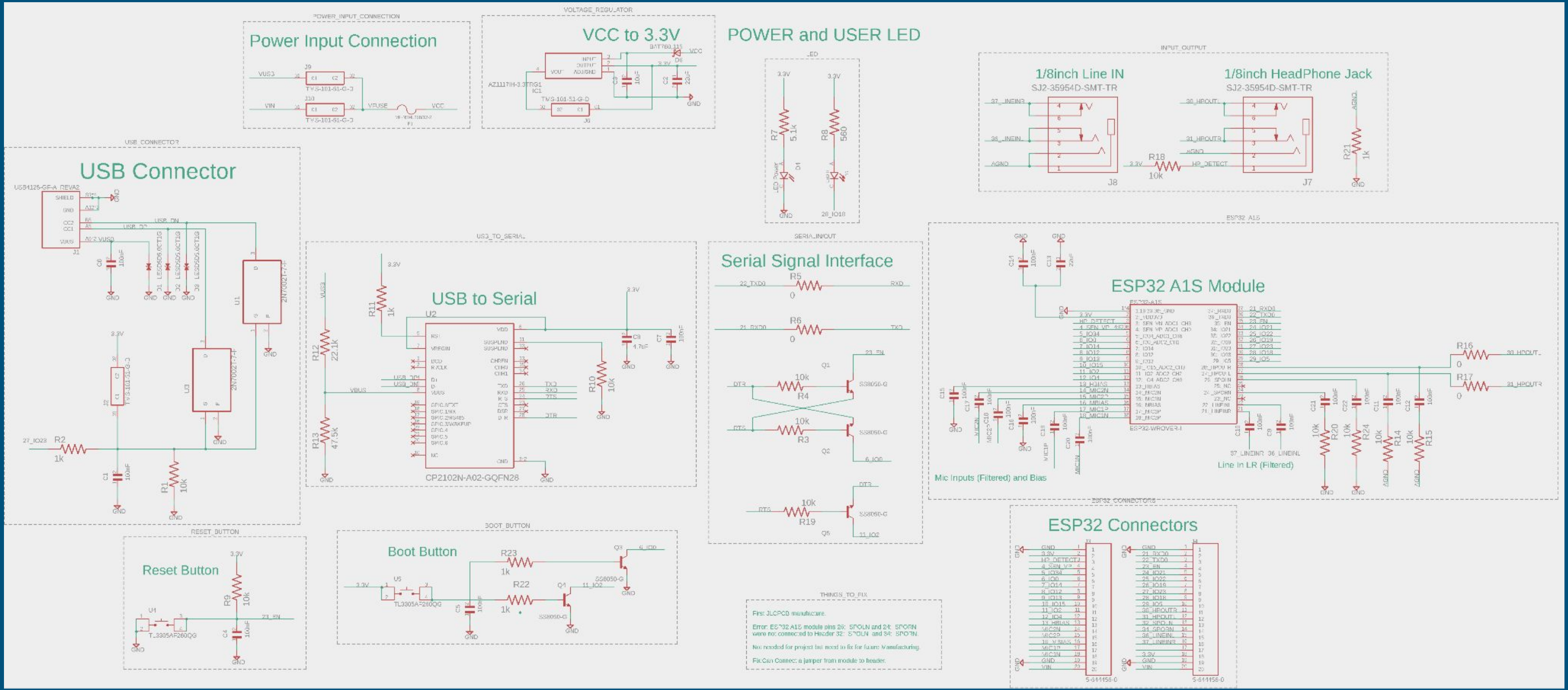


ADC input from Opto-Isolator Circuit

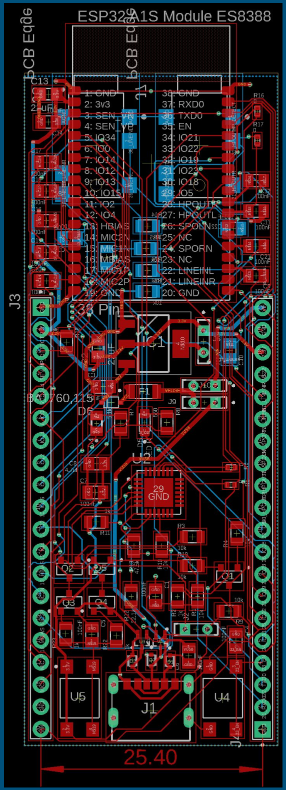
From This -To This

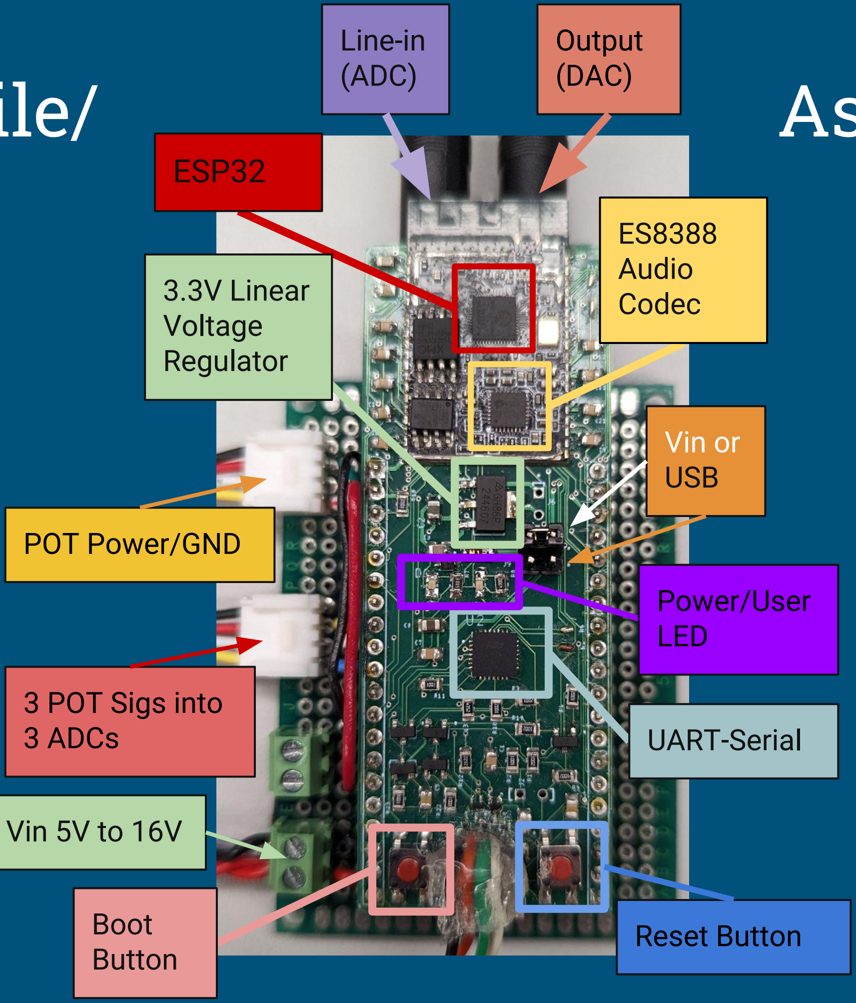


Dev-Board Schematic



Board file/ Assembly / Part List





Qty	Value	Parts	Description	Price
2	22uF	C2, C13	Capacitor	0.33
1	10uF	C3	Capacitor	0.72
1	4.7uF	C8	Capacitor	0.44
18	100nF	C1, C4, C5, C6,	Capacitor	0.32
1	47.5k	R13	Resistor	0.1
1	22.1k	R12	Resistor	0.1
11	10k	R1, R3, R4, R9,	Resistor	0.1
1	5.1k	R7	Resistor	0.1
5	1k	R2, R11, R21,	Resistor	0.1
1	560	R8	Resistor	0.1
4	0	R5, R6, R16, R17	Resistor	0.1
1	LED R	D5	LED	0.27
1	LED G Power	D4	LED	0.3
3	LESD5D5.0CT1G	TVS	Transient Voltage Suppressor	0.31
1	Schottky barrier	D6	Medium power Schottky	0.43
2	2N7002T-7-F	U1, U3	N-Channel Transistor	0.42
5	Bipolar (BJT) Transist	Q1, Q2, Q3, Q4,	Bipolar (BJT) Transistor NPN	0.29
1	Voltage Regulators	IC1	Linear Voltage Regulators	0.4
1	CP2102N-A02-GQF	U2	UART to Serial	6.8
2	Switch Tactile	U4, U5	Switch Tactile	0.21
1	USBC	J1	USBC	0.81
2	Audio Jack w/ 2 Swit	J7, J8	4 conductors, 3.5mm, SMT	1.41
1	Fuse 12V 2.6A	F1	Polymeric PTC Resettable	0.94
4	2 pin Jumper	J2, J6, J9, J10	2 pin header Jumper	0.1
2	20 Pin Header	J3, J4	20 Pin Header	0.5
1	ESP32-A1S	A1	ESP32 with es8388	6.4
Total Qty	74		Total Price	35.7

Potentiometer Configuration

- 3 Potentiometers
  - Vol
  - Tremolo Depth (ON/OFF)
  - Tremolo Frequency
- Potentiometer Filter (noise)
  - Read Analog Values
  - Map from 0-4096 to 0-33 (ES8388 built in volume depth)
  - Implement Running Average (readings change slower but more accurate)
  - Very Stable Values (No Fluctuation)

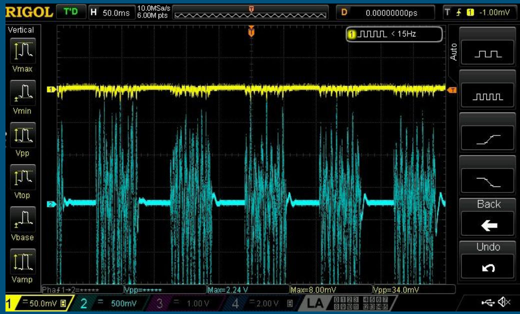

```
float EMA_a = 0.25;
int EMA_S = 0;

//Filtering by using a mass average calculation
EMA_S = (EMA_a*pot1) + ((1-EMA_a)*EMA_S);
```

DSP (ESP32 A1S) Tremolo Effect implementation

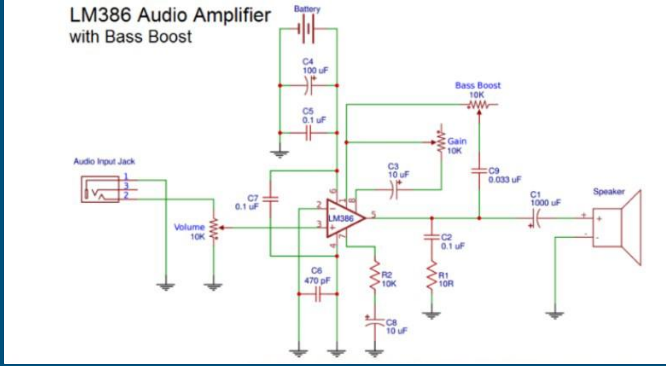
Main library used called Yummy DSP

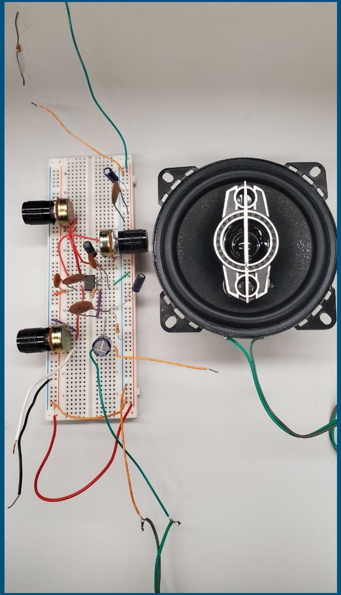
- I2S stores them
- Tremolo Effect

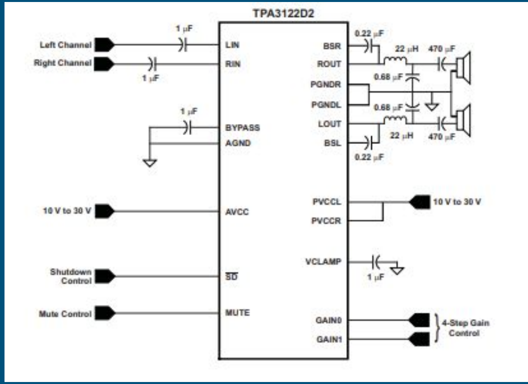


Power Amplifier Fall Semester

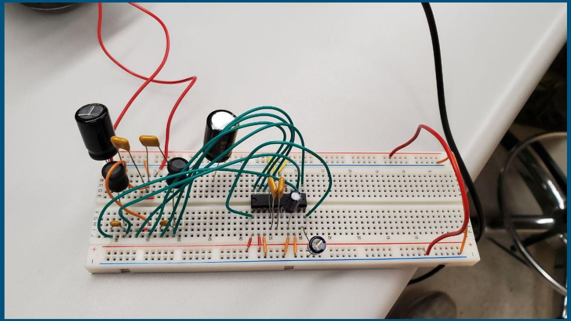
- LM386N-3
- Class AB Mono low voltage
- Operates from 4V- 12V
- Loads impedance
  - 4Ω to 32Ω
- Gain
  - 26 - 46 dB





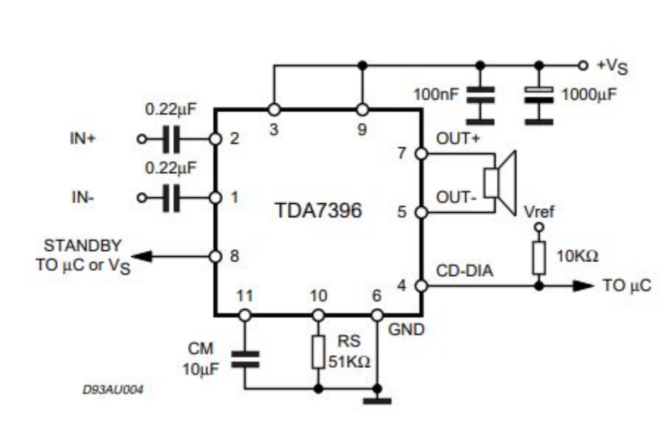


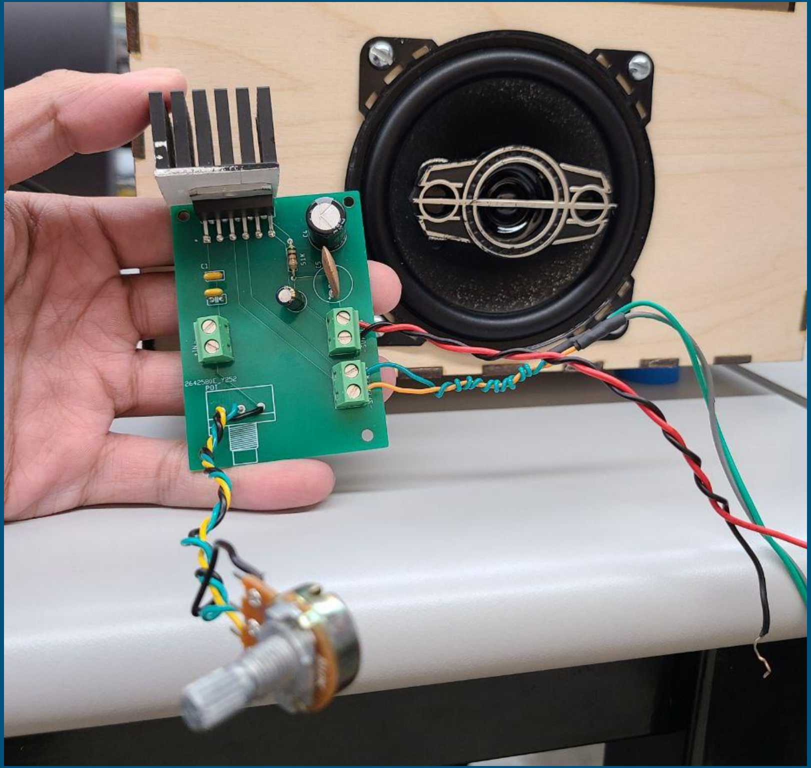
- TPA3122D2
- 15W (per channel) Stereo
- Class D
- Operates from 10V- 30V
- 4 Selectable Fixed Gain Settings
  - 20db, 26db, 32db, 38db
- At 12V: Gain = 20dB
  - Max = 38dB (need 24V)



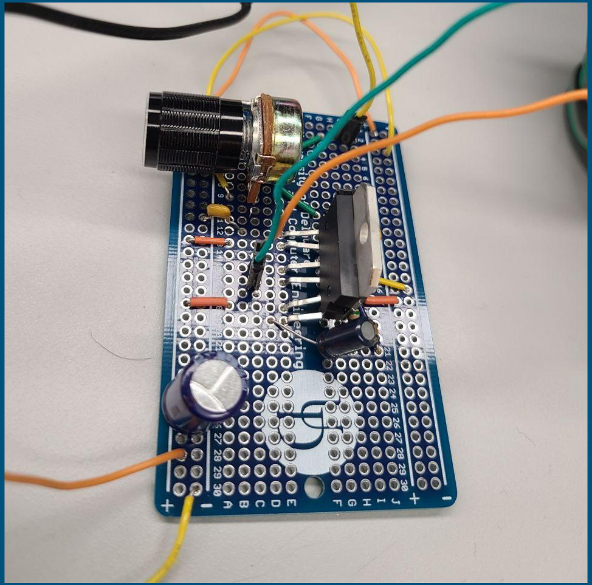
Power Amplifier Spring Semester

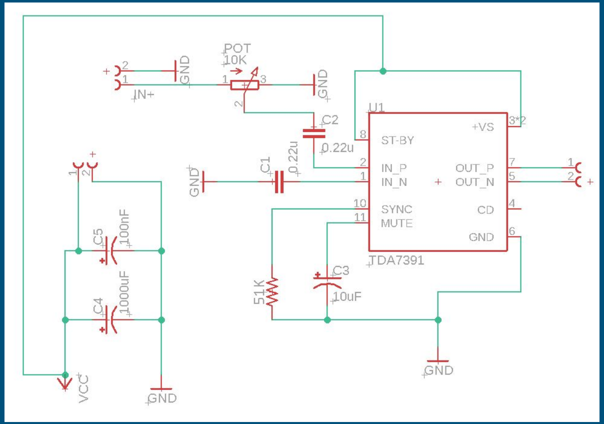
- TDA7396
- Class AB Mono
- Operates from 8V- 18V
- Loads impedance
    - 2Ω to 8Ω
- Gain: 26dB fixed

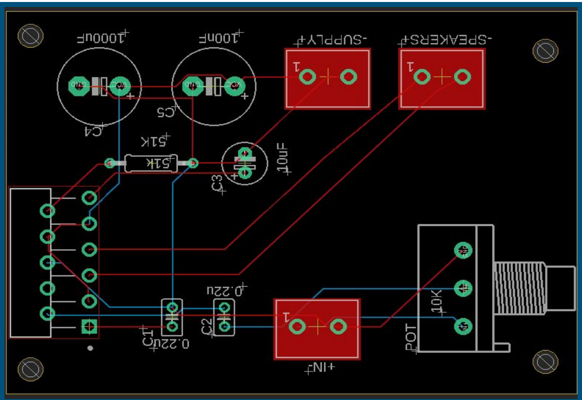


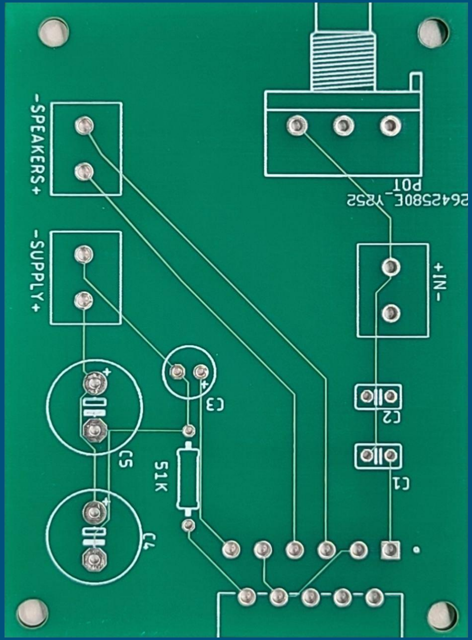


Power Amplifier PCB

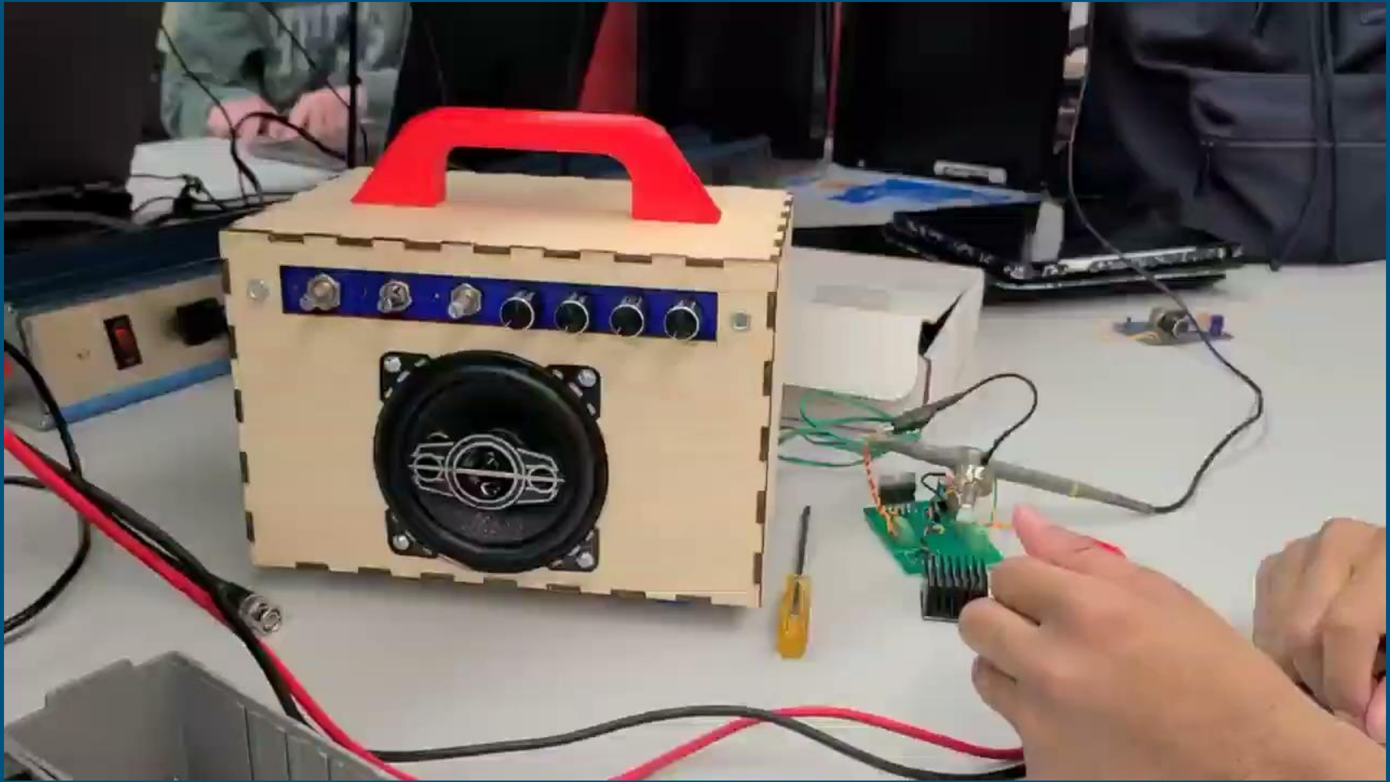






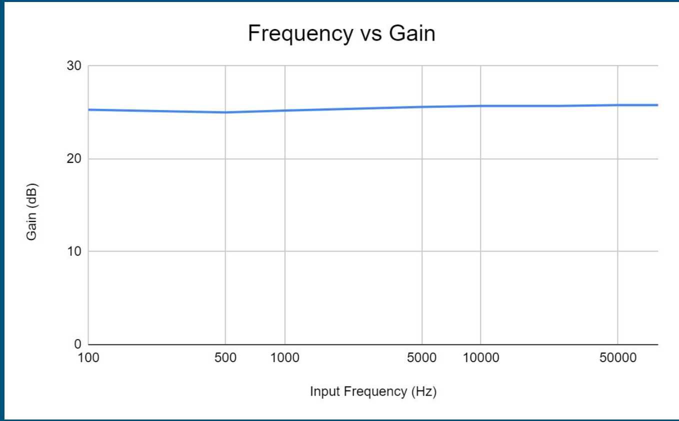


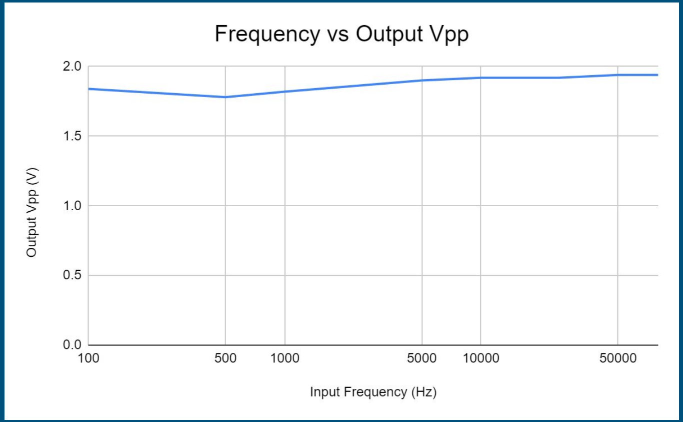
Power Amplifier Demo



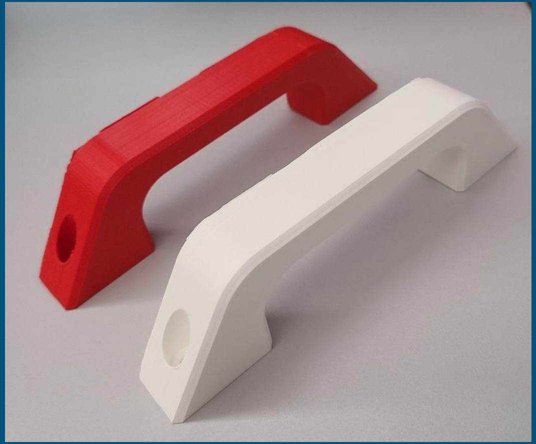
Frequency Response

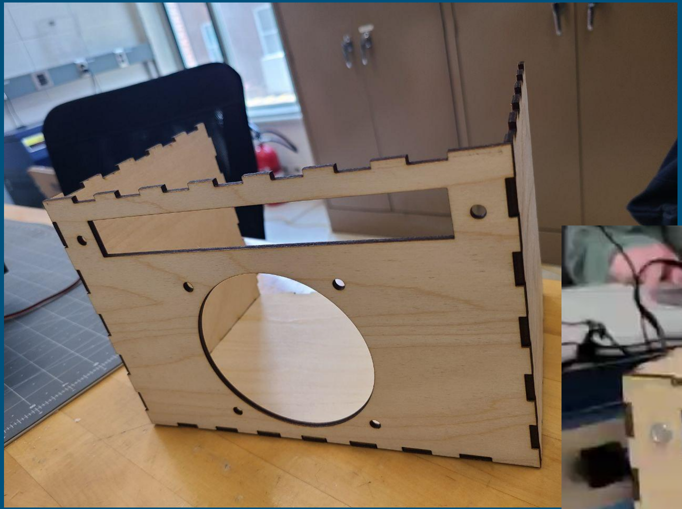
Input (Hz)	Input Vpp (mV)	Output Vpp (V)	Gain	Gain (dB)
100	100	1.84	18.4	25.3
500	100	1.78	17.8	25
1000	100	1.82	18.2	25.2
5000	100	1.9	19	25.6
10000	100	1.92	19.2	25.7
25000	100	1.92	19.2	25.7
50000	100	1.94	19.4	25.8
80000	100	1.94	19.4	25.8





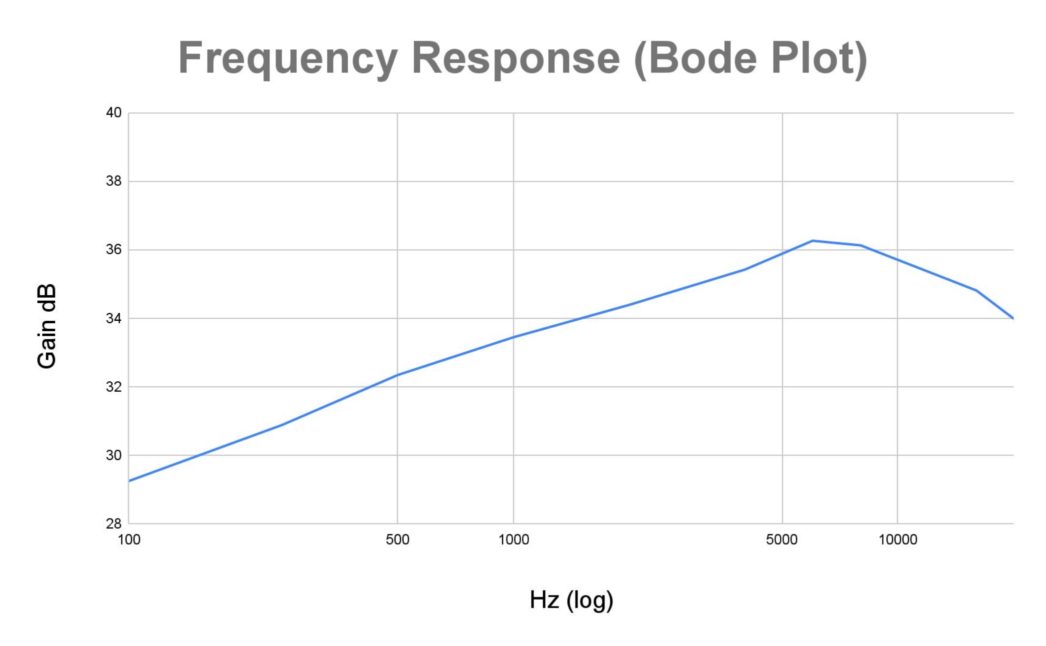
Enclosure (3D Print & Laser Cutting)



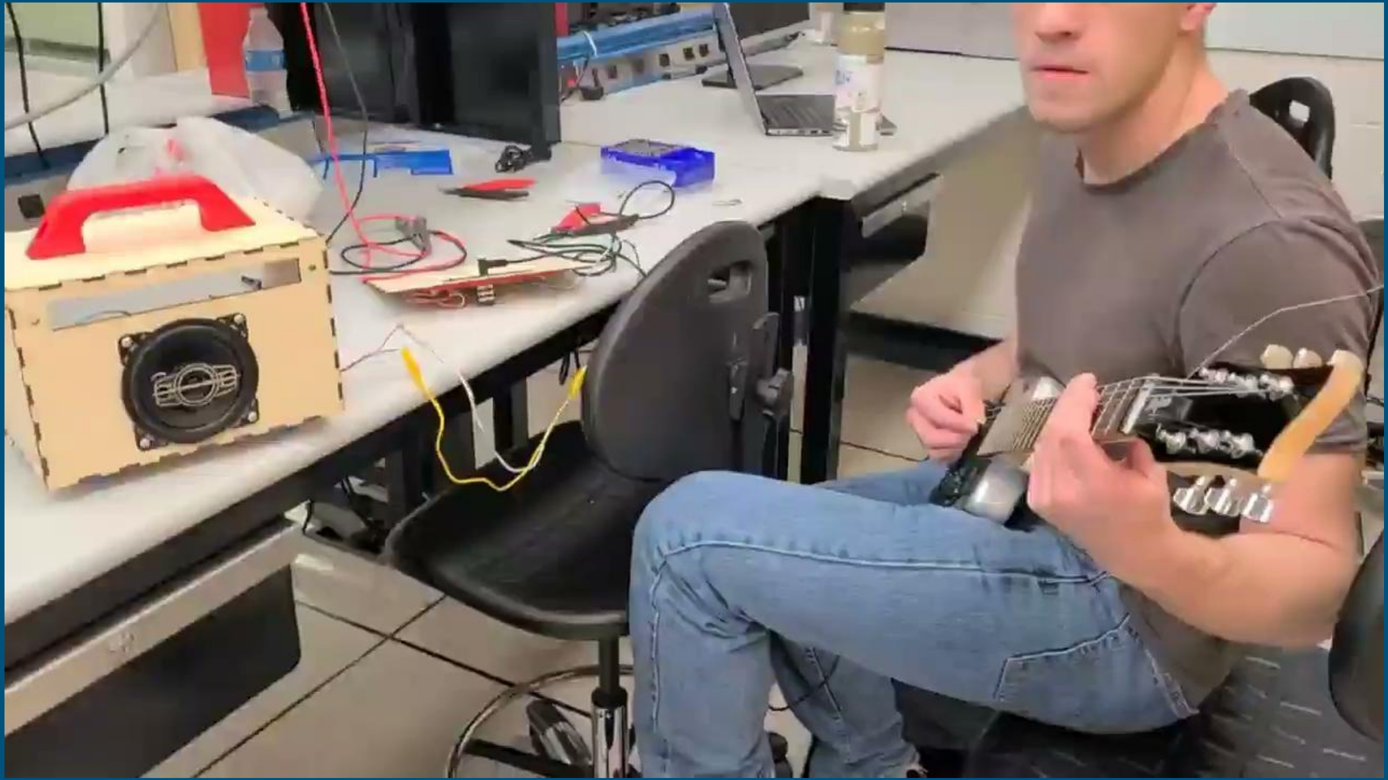


All Stages Connected

- All in series
  - Preamp
  - Opto-Isolation
  - DSP
  - Poweramp
- Conclusion
  - Signal prominent between
    - 1k to 10k (delta = 3dB)
  - Larger db drop before 1k
  - Less bass less current draw
    - Max Volume current draw 250mA (8hr play time)



Video Demo (Grunge Box)



Tremolo Effect

Future Improvements

- More effects
- An additional function to go wireless
- Increase low frequency response