9/24/2025
Goal to have AB amplifier components determined by EOD 10/01, most likely will use standard AB amplifier topology, goal for PCB demo is to have amplifier powered by bench supply driving output coil oscillating a guitar string with signal from either microcontroller or signal generator.

9/25/2025

9/28/2025

[PMOD I2S Board]

This board will be connected to the nucleo board for initial DSP development. Currently this is the only thing that we can work on before we have multiple MCUs to test other protocols such as I2C with.

The ECE supply center contains 2 optocouplers; MIDI circuit prototyping could occur now as well.

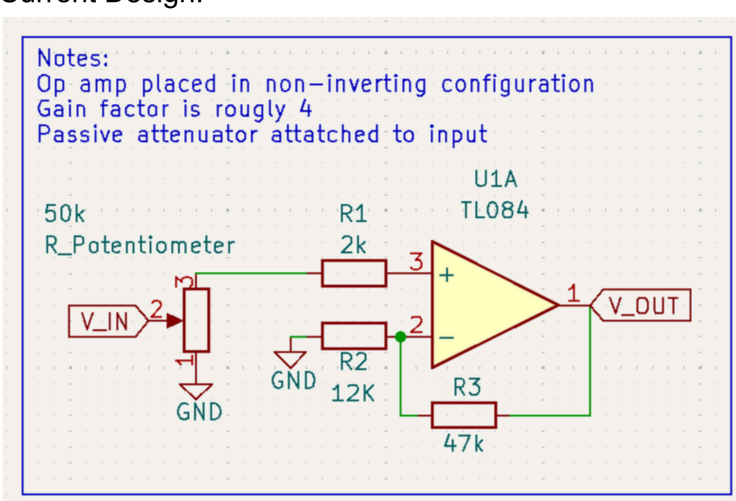
9/29/2025

Op Amp buffer will be used to amplify and decouple the pickup signal. Circuit should have the following features:

- Variable input attenuation
- Non-inverting configuration
- Negative feedback network for high frequencies (low pass filter for D/A)
- Voltage gain of ~4
- High slew rate (TL082, found in supply shop)

[Example Circuit]

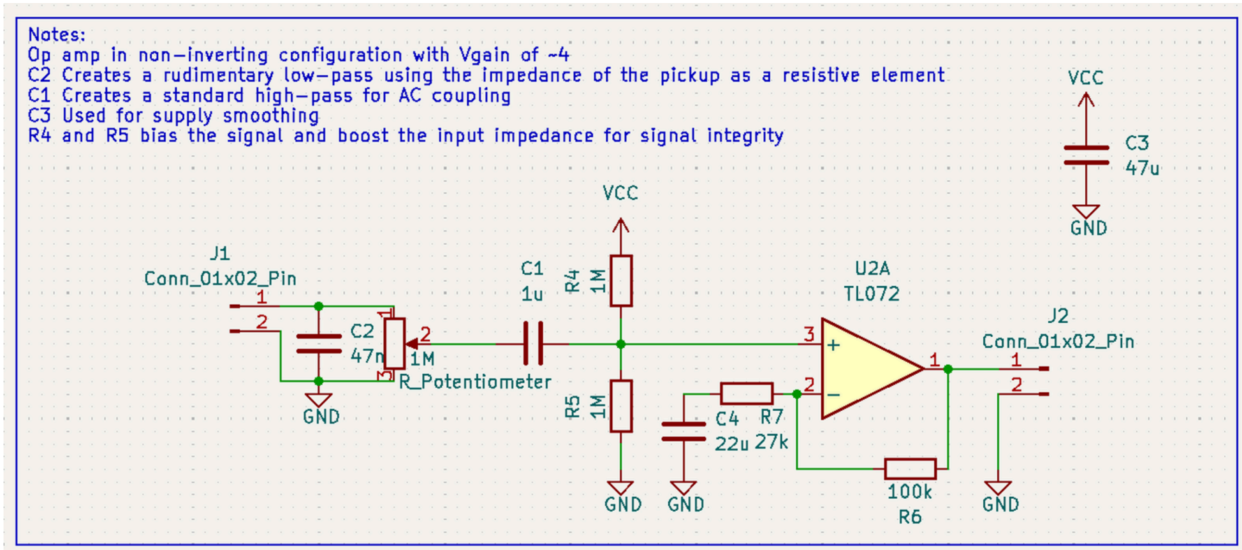
Current Design:



This will be tested in the upcoming week as all parts are sourceable from the ECE supply center Testing can be conducted with a guitar and an oscilloscope, ensuring the correct relationship between v_out and v_in from the signal of a guitar pickup.

10/2/2025

Finalized buffer circuit shown below:



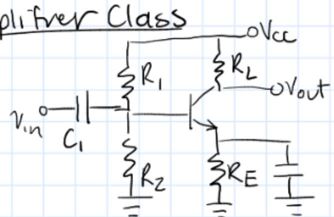
Parts needed from EShop:

Name	Quantity	Description	Cabinet	Drawer
TL072	2	Low-Noise JFET Amplifier IC	9	16
500k	2	Potentiometer	5	14
1M ohms 1/4W	3	Resistor 1/4 Watt	4	6
110K ohms 1/4W	2	Resistor 1/4 Watt	4	5
27K ohms 1/4W	2	Resistor 1/4 Watt	4	5
22μF	3	Electrolytic Capacitor	6	7
1 μF (105)	2	Capacitor	6	6
4700pF	2	Ceramic Disk Capacitor	6	5

10/4/2025 Ash Huang

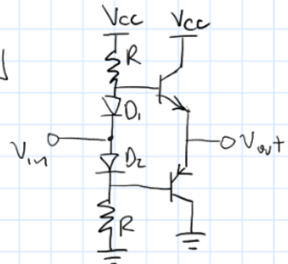
Amplifier Class

A)



- high linearity high gain
- always biased on
- conduction thru 360° of output wvf (I source)
- ~30% efficiency due to high idle current, power supply filtering to avoid hum/noise

AB)



- typical for audio power amps
  - + half cycle input, + biased ON
  - − half cycle, − biased ON
- each transistor on for half cycle
- small bias voltage @ ~5-10% of quiescent current to bias just above cut-off
  - ↳ for AB, each transistor is on for slightly more than 1 half cycle
  - ↳ overcomes crossover distortion of class B amp

input 1V_{pp} from DAC (should be audio, not 16 PCM)

output 2 Vrms, let's say this is $2\sqrt{2}$ Vpp @ 1 W for an 8Ω speaker coil (I cando basic math lmao)

$\frac{(2\sqrt{2})^2}{8} = 1$ W so current should be 250 mA rms?

Selecting Mouser BD135/136 BJT for audio amplifiers

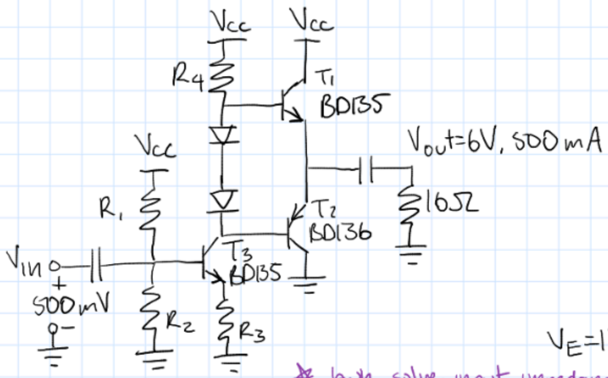
- V_{CE} sat @ 0.5V
- V_{BE} = 1V
- h_{FE} = 40 @ V_{CE}=2V I_C=150 mA
  - = 25 @ V_{CE}=2V I_C=0.5A

max. 250

V_{EBmax}=5V

I_{Cmax}=3A

low power



$V_{BE_{on}} = 1V$, select ≤0.7V diodes
for audio, can be slow-switching

diode kit is 1N4148, $P_{tot} = 500mW$
$t_r = 4ns$

$I_{CE_1} = 280mA$, assuming $\beta \approx 140$ $I_{B_1} = 1.8mA$

$V_{BC2} = V_{cc}/2 = 6V$ $I_D = 10mA$ for $V_D \approx 0.65V$

$I_{bias} \approx 14$ mA

so $R_4 = (12-6-0.7-0.7)/14 \approx 330\Omega$

$V_E = 1V$, $R_3 = 71.4\Omega$

let $\beta_3 = 25$ so $I_{B3} = 0.56$ mA

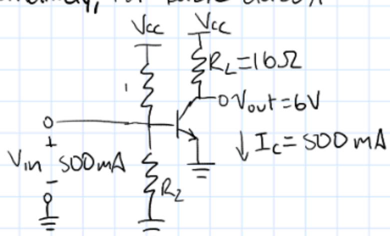
$I_{R1} = \beta_3 I_{B3}$

$R_2 = 2.5V/14mA = 178\Omega$

$R_1 = 9.5V/14mA = 679\Omega$

* bruh solve input impedance for those BJTs for I_{R4} these aren't MOSFETS

Alternatively, for basic class A



$\beta \approx 140$

$I_B = 3.6$ mA

$V_{BE_{on}} = 1V$

assuming $I_{R_1} = 100 I_B$

$R_1 =$

just use an opamp – drive coil w/square wave (more efficent)
harmonic garbage will filter out w/coil since it's inductive
you need all the help you get vibrating the string, drive that @ maxpwr

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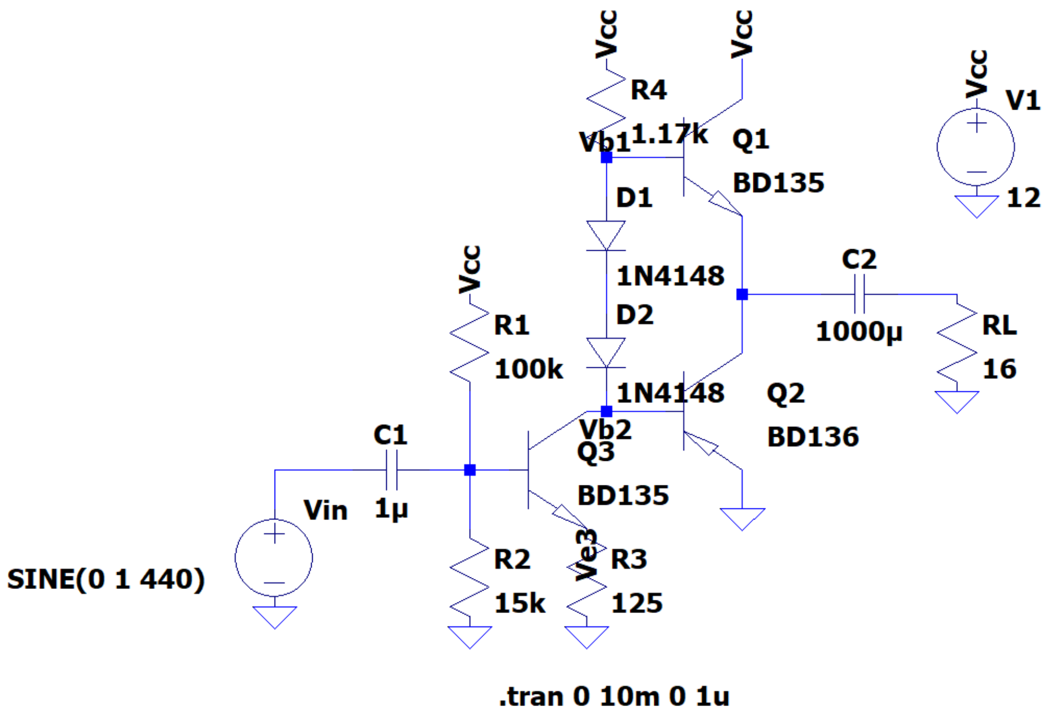
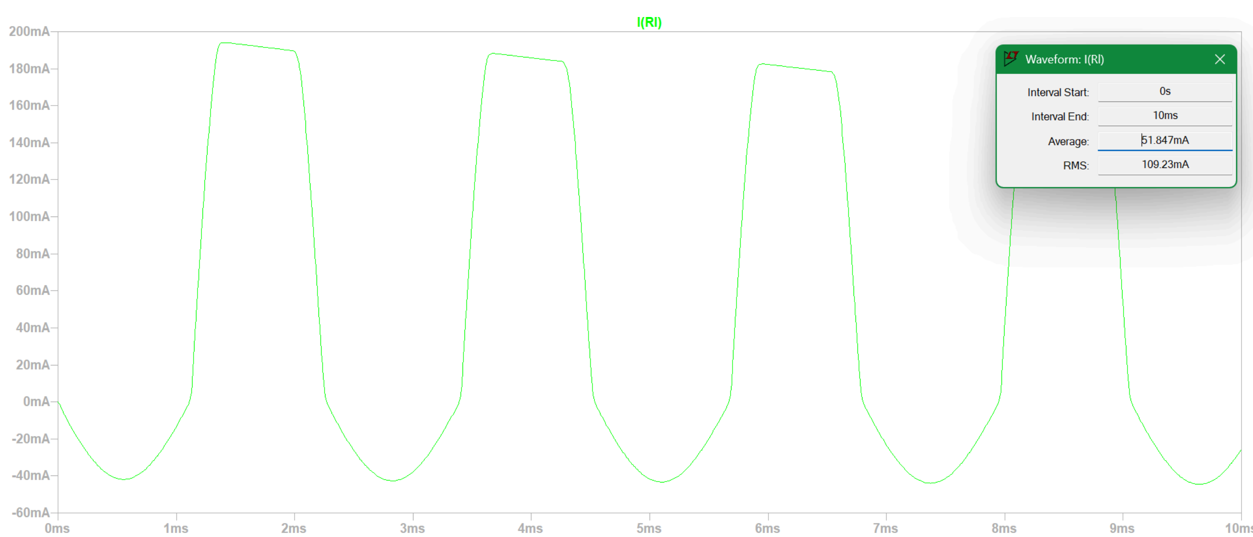
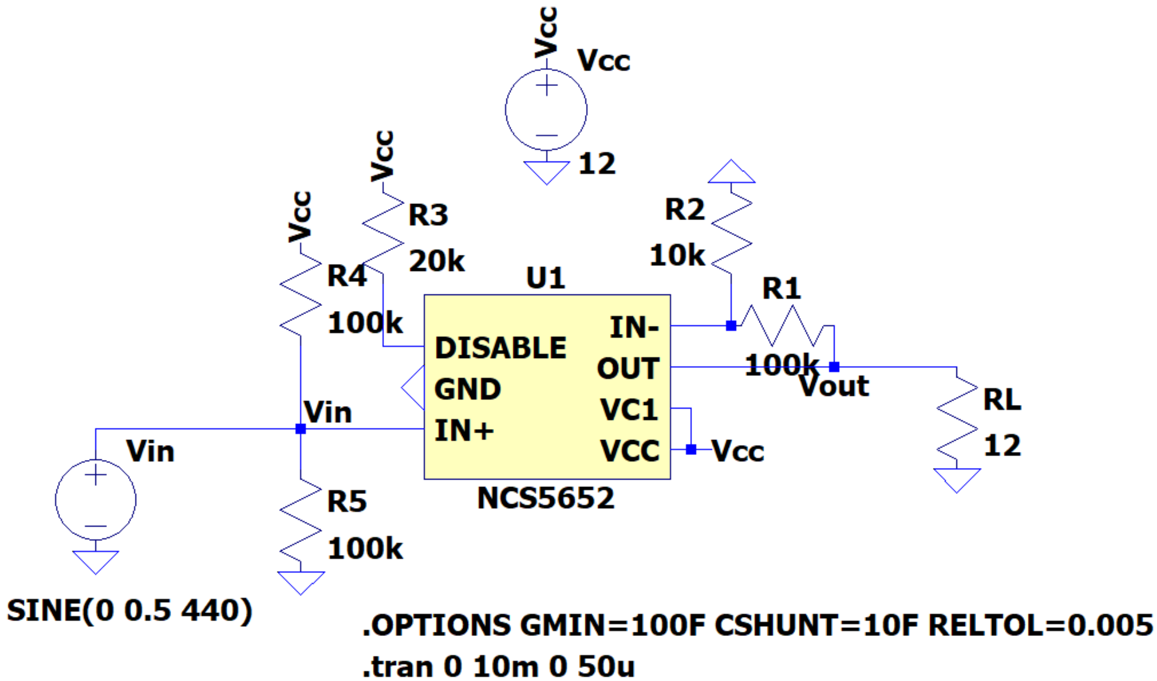


LTspice model



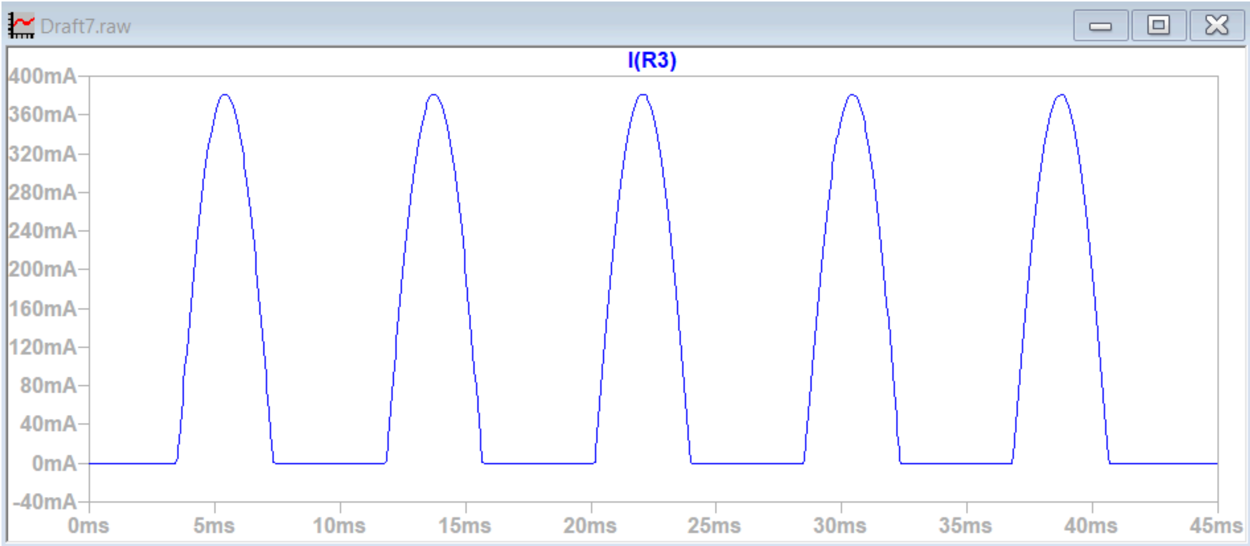
Try AB opamp instead? Output current needs to be ~500mA at 6V to deliver 3W to driver coil

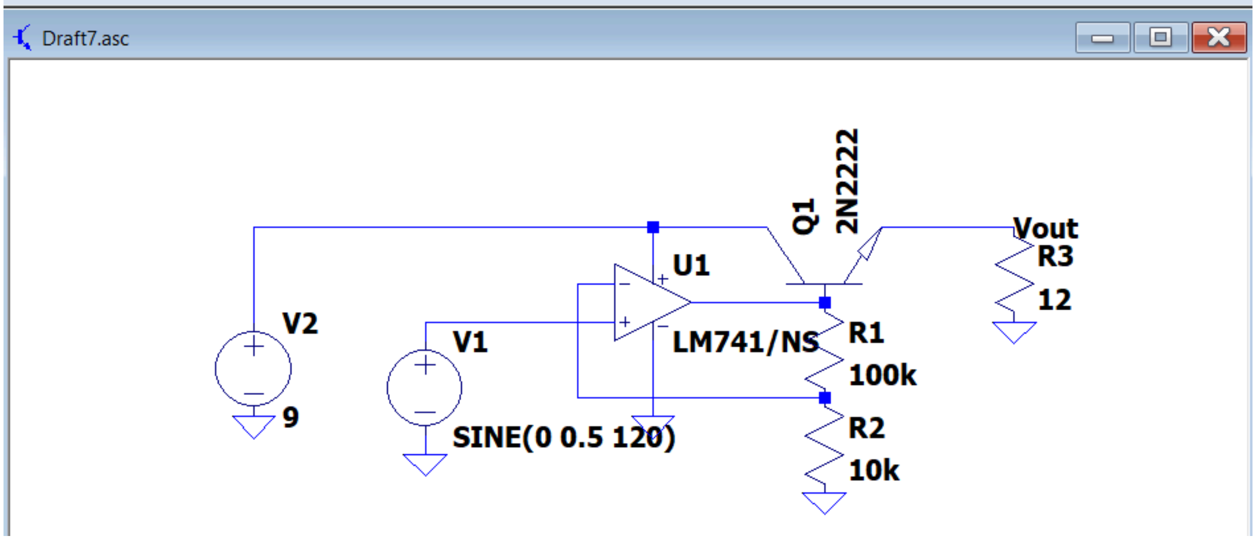
10/15/2025



Due to high sim time, ran simulation on both halves of waveform.

10/26/2025



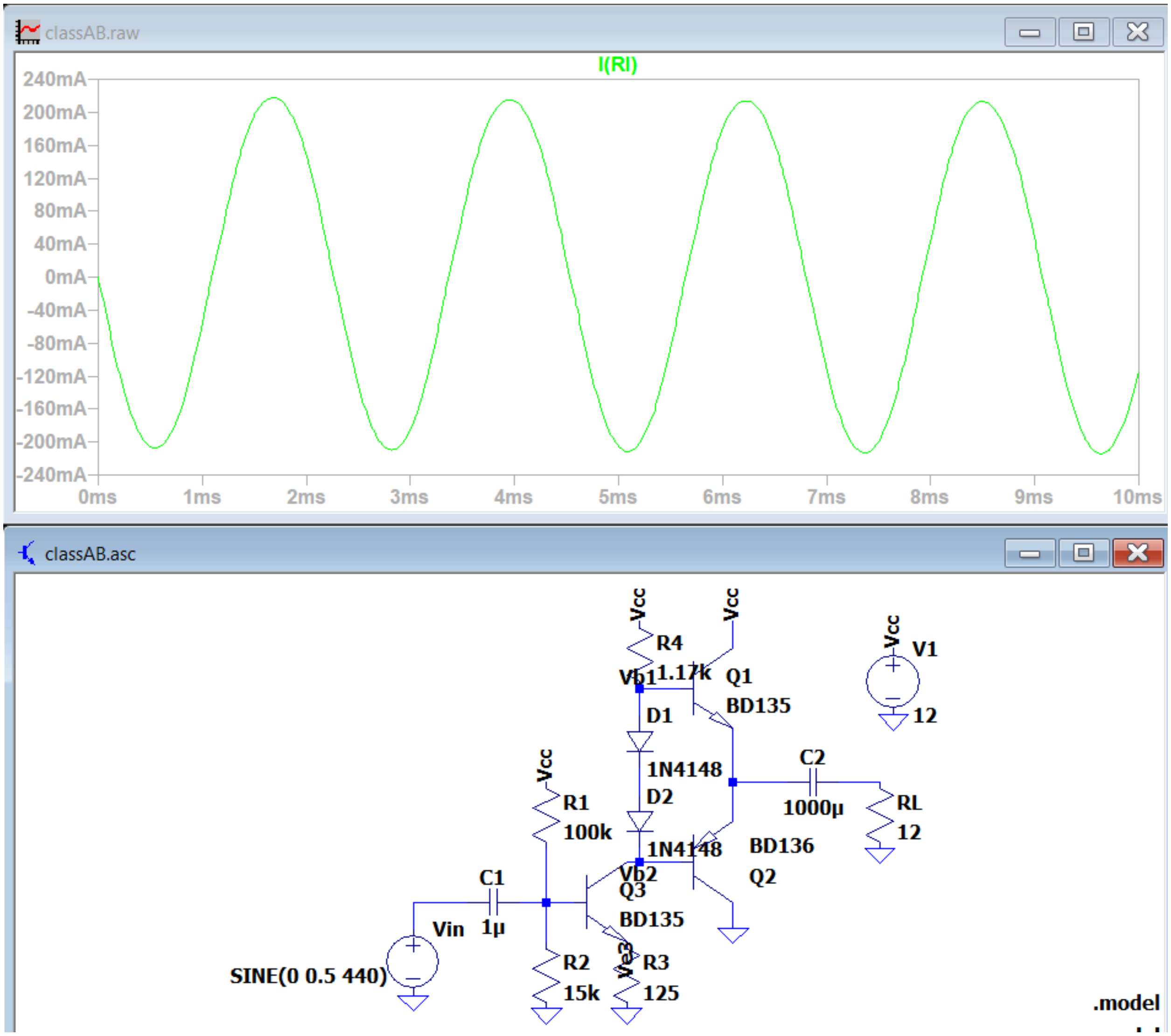


Power amplifier design using BJT at output to drive higher current- should use a complementary pnp to pull some current as well on negative half cycle

10/27/2025
LTspice keeps crashing
Works fine with a 500mV DC offset on sine; accomplished with voltage divider from power supply and DC blocking cap on input sine wave
Has some clipping on scope

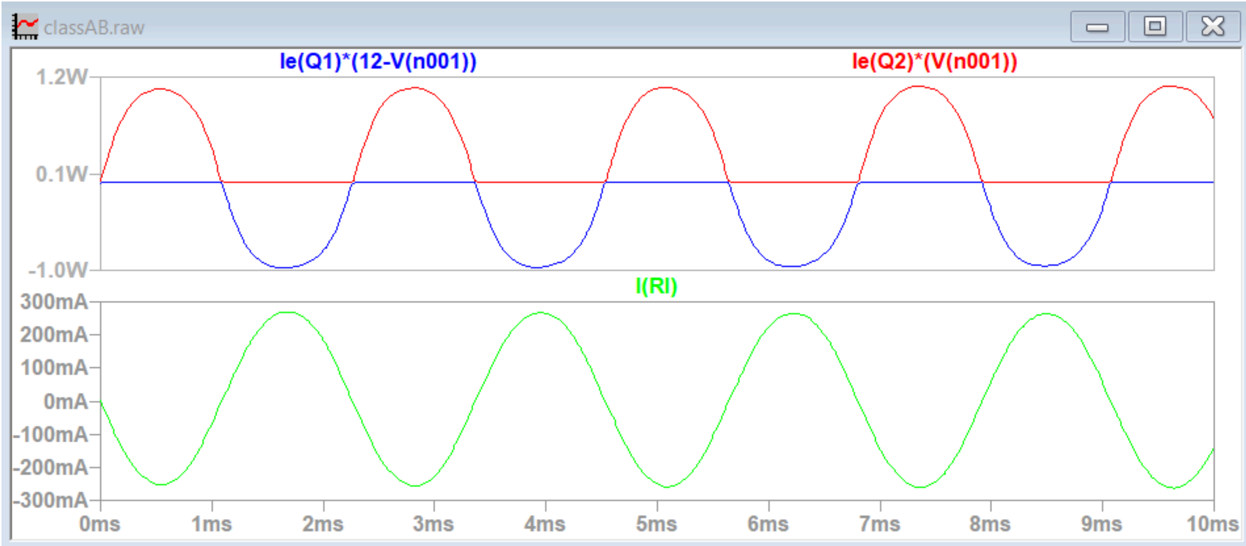
10/29/2025
Class A amplifier produces too much heat on the npn and causes some runaway currents that pull the supply voltage way down if on for too long - should use AB topology to reduce power losses to heat and use larger BJTs that allow for more power dissipation and have space for heatsinking on PCB

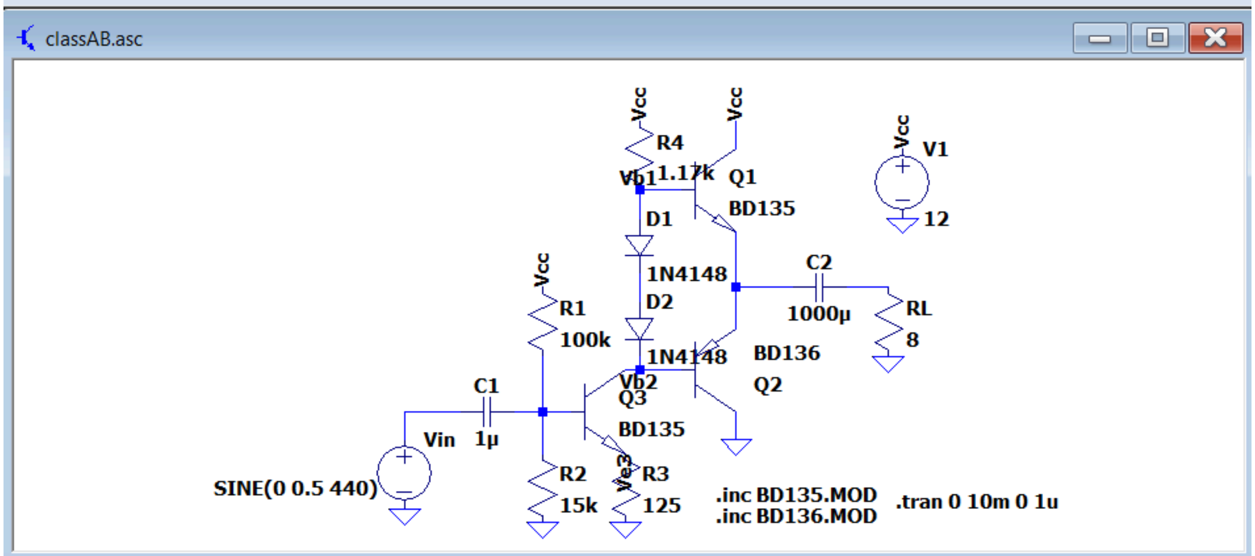
Also the AB amplifier from 10/6 works fine I just didn’t flip the emitter and collector on the pnp

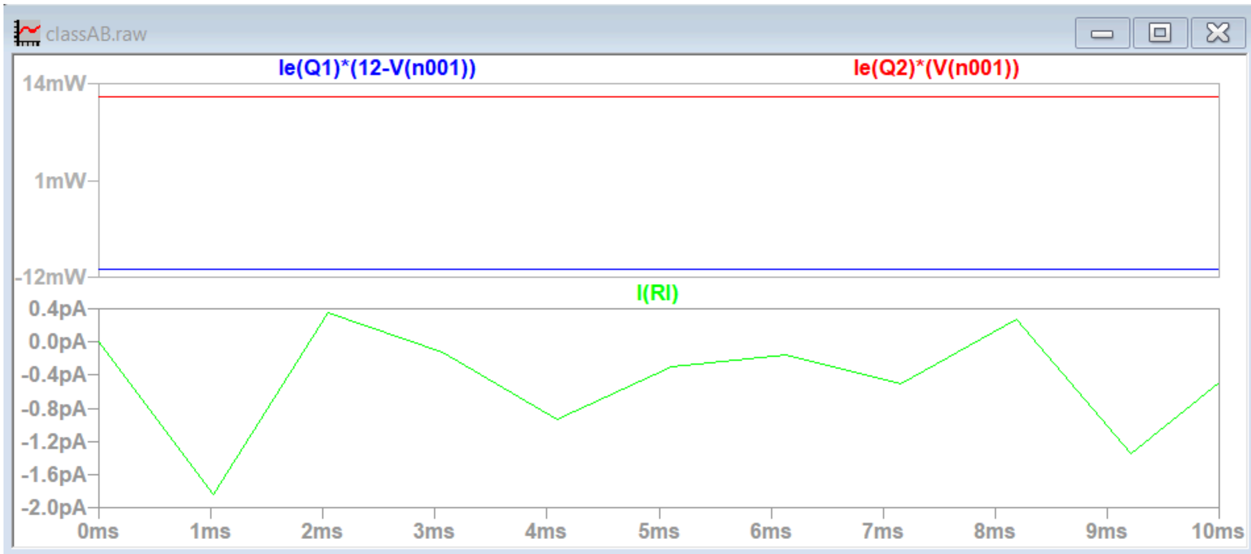


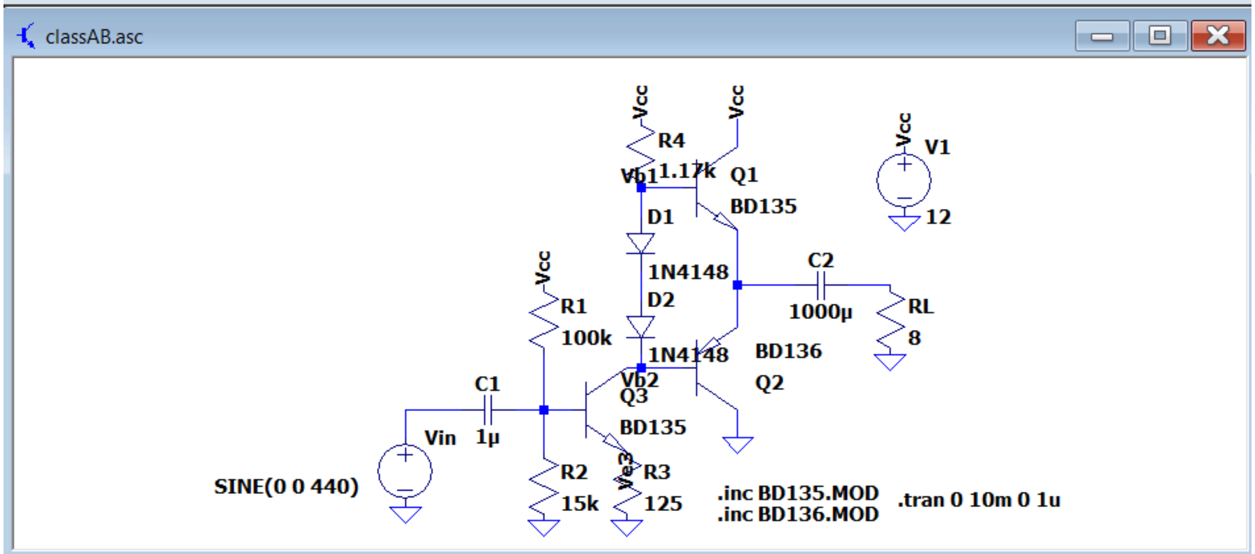
Im going to cry

Comparing power losses to BJTs for different topologies:


classAB.raw
Ie(Q1)*(12-V(n001))
Ie(Q2)*(V(n001))
1.2W
0.1W
-1.0W
I(Rl)
300mA
200mA
100mA
0mA
-100mA
-200mA
-300mA
0ms
1ms
2ms
3ms
4ms
5ms
6ms
7ms
8ms
9ms
10ms

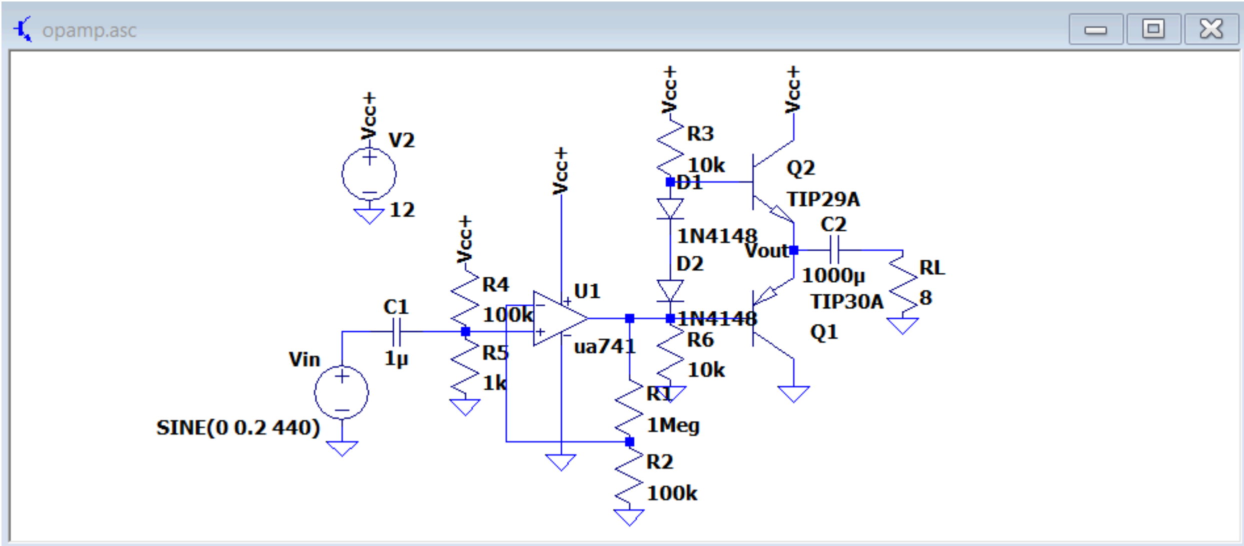

classAB.asc
Vcc
Vcc
R4
1.17k
Vb1
Q1
BD135
V1
Vcc
12
D1
1N4148
D2
1N4148
C2
1000µ
RL
8
Vcc
R1
100k
BD136
Q2
Vb2
Q3
BD135
C1
1µ
Vin
SINE(0 0.5 440)
R2
15k
Ve3
R3
125
.inc BD135.MOD
.inc BD136.MOD
.tran 0 10m 0 1u

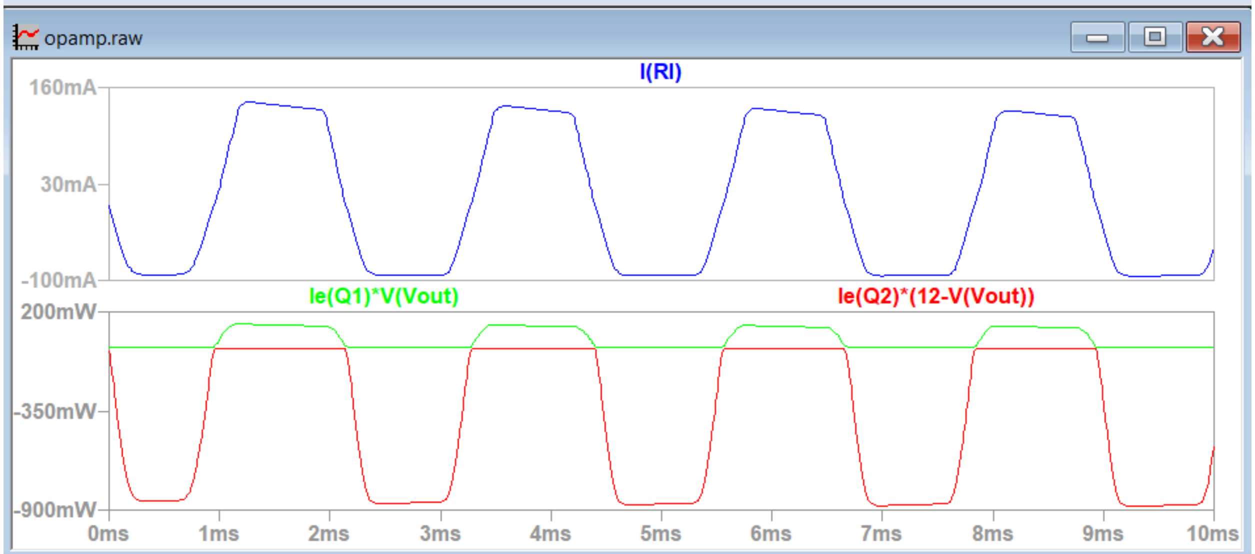


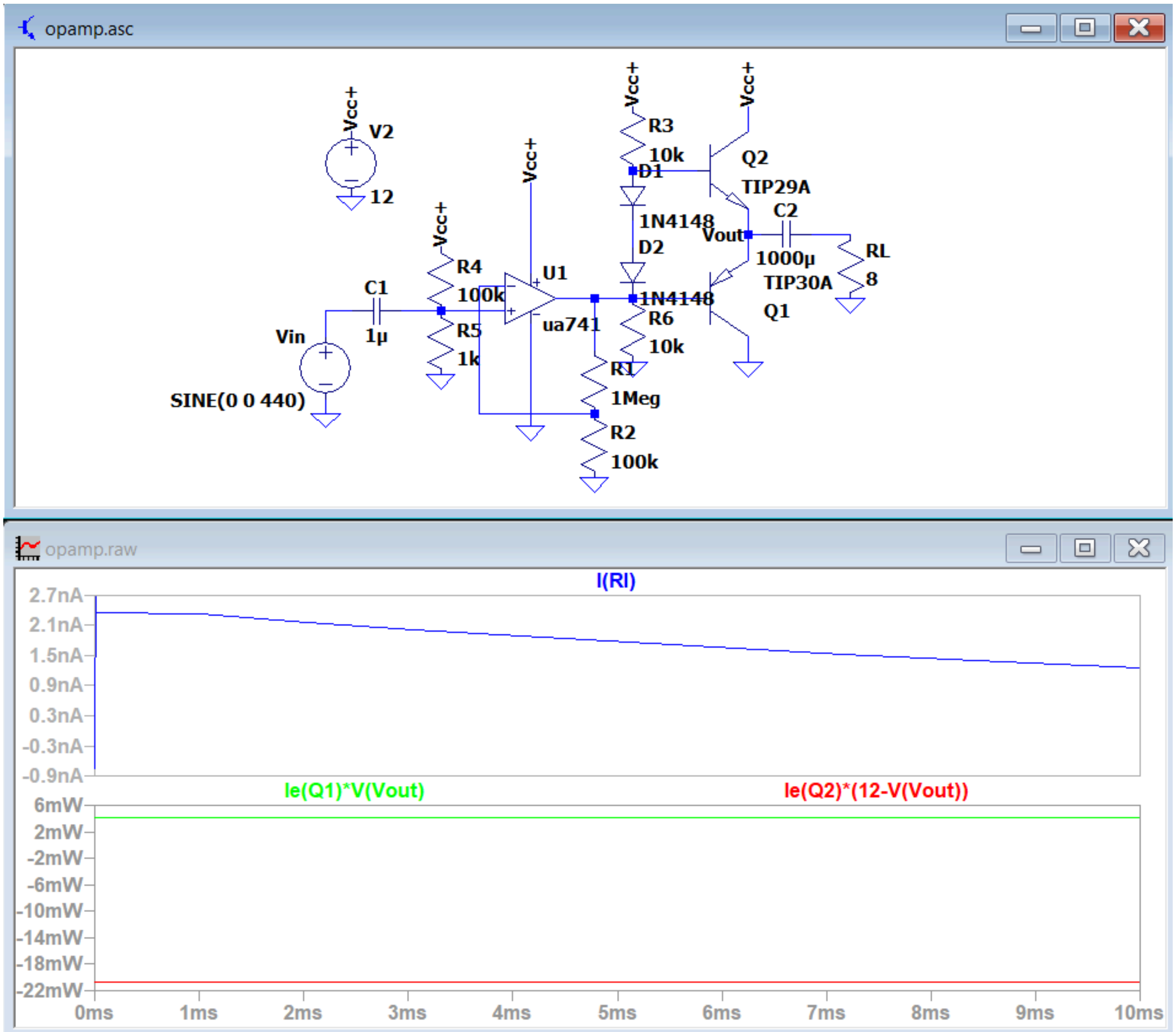


Max loss at ~350mW for both BJTs, this shouldn't be too much heat, when both off power consumption is <20mW

Opamp ckt max power loss at ~400mW


opamp.asc
Vcc+
V2
12
Vcc+
R4
100k
R5
1k
C1
1µ
Vin
SINE(0 0.2 440)
Vcc+
U1
ua741
Vcc+
R3
10k
D1
1N4148
D2
1N4148
R6
10k
R1
1Meg
R2
100k
Vcc+
Q2
TIP29A
Vout
C2
1000µ
TIP30A
Q1
RL
8


opamp.raw
I(Rl)
160mA
30mA
-100mA
Ie(Q1)*V(Vout)
Ie(Q2)*(12-V(Vout))
200mW
-350mW
-900mW
0ms
1ms
2ms
3ms
4ms
5ms
6ms
7ms
8ms
9ms
10ms



DC power consumption at 22mW

10/31/2025
Testing class AB amplifier and LM386 amplifier in lab and measuring waveforms, output heat
Class AB amplifier pulls more quiescent current than expected at about 500mA - may need to use LM386 instead

11/2/2025
Testing class AB amplifier and LM386 amplifier with guitar and coil - both work, but LM386 has lower quiescent current at ~14mA vs 500mA. While the class AB amplifier works, the LM386 should consume less power and output less heat while the string is off, so we will use the LM386.

Hardware for mechanical assembly:

Tuning Machines

  Will need two sets

M5 Wood Inserts

  Need a total of 36

  Drilled into top face

M5 35mm Screws

  Need a total of 36

  Fasten to Inserts, will protrude about an inch (25mm)

Countersunk Magnets

  #4 screw, slightly oversized hole

Audio Jack

MIDI DIN Jack

https://www.steppeschool.com/pages/blog/stm32-dac

Additional part numbers in master schematic:
74438356022
3386S-1-105LF
TL071HIDCKR
PJ-063AH

Master board BOM:

Description	Quantity	Dist	PN	Cost	Total Cost
2.2uH	1	Mouser	74438356022	$1.93	
1M Trim Pot	1	Mouser	3386S-1-105LF	$1.86	
TL071 OpAmp	15	Mouser	TL071HIDCKR	$0.173	
DC Barrel Jack	1	Mouser	PJ-063AH	$1.40	
STM32	15	Mouser	STM32L431CBT6	$3.02	
DC/DC	2	Mouser	TPS62913RPUR	$2.40	
Optocoupler	2	Mouser	4N25	$0.67	
2.2nF 0402	3	Mouser	GRM155R71H222JA01J	$0.10	
10nF 0805	1 * 15 = 15	Replace with eShop	C0805Y104K1RACAUTO	$0.20	0
100nF 0805	4 * 15 = 60	Replace with eShop	C0805Y104K1RACAUTO	$0.20	0
470nF 0402	3	Mouser	04023D474KAT2A	$0.31	
1uF 0805	2 * 15 = 30	Replace with eShop	VJ0805Y105KXQTW1BC	$0.084	0
4.7uF 0805	1 * 15 = 15	Replace with eShop	VJ0805G475KXQTW1BC	$0.21	0
10uF 0805	2 * 15 = 30	Replace with eShop	KAM21AR71A106MU	$0.28	0
22uF 0805	7 * 15 = 105	Replace with eShop	CC0805MFX5R5BB226	$0.122	0
220Ω 0805	3	Mouser	RG2012P-221-B-T5	$0.10	

2kΩ 0805	3	Mouser	TNPW08052K00FEEA	$0.12	
4.87kΩ 0402	3	Mouser	MCS04020C4871FE000	$0.16	
15.4kΩ 0402	3	Mouser	TNPW040215K4BEED	$0.23	
22kΩ 0805	1 * 15 + 2 = 32	Mouser	CR0805-JW-223ELF	$0.019	
100kΩ 0805	1 * 15 + 2 = 32	Replace with eShop	CHV0805-JW-104ELF	$0.146	0
180kΩ 0805	1 * 15 = 15	Mouser	CR0805-JW-184ELF	$0.015	
500kΩ 0805	2 * 15 = 30	Replace with eShop - 1M	RNCF0805BTE500K	$0.077	0
Ferrite Bead	3	Mouser	MPZ1005S100CT000	$0.10	
Diode	3	Mouser	SD0805S020S1R0	$0.34	