Bass Guitar Amplifier

Group 26

Kris Edstrom Armon Eghbali James Howell Jeremy Nelson

Motivations

- Delving deeper into the world of music can be a daunting task both because of price and knowledge.
- One piece of equipment can cost from hundreds to thousands of dollars, and that's saying you know what you need to buy.
- To combat this, we are designing an all-in-one bass amp header, which will be intuitive to use, and affordable to beginners, while having enough features to appease a professional.

Project Objectives

- Building an affordable Bass Guitar Amplifier that doesn't have any unnecessary features that raise the price
- Designing and implementing several common and powerful analog and digital effects
- Touch Screen interface to control the digital effects
- The ability to output to a speaker via a Neutrik Connector

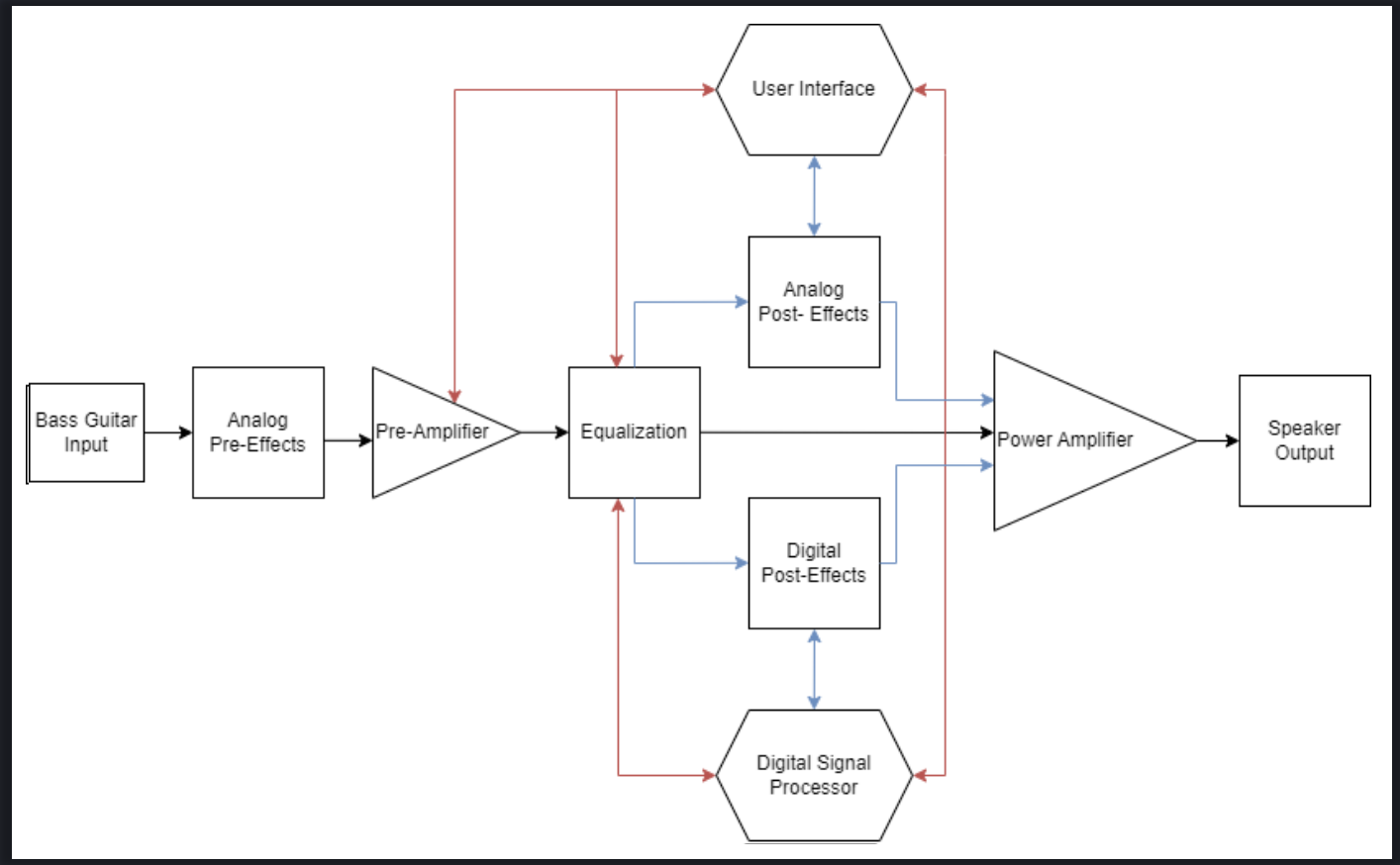
Target Specifications

Attribute	Description
Size	24" x 12" x 12" (W x H x D)
Weight	12lbs
Output Power Rating	70W @ 8Ω
Input Power Rating	120VAC 60Hz
Frequency Response	31Hz – 4.5kHz
THD (Total Harmonic Distortion)	2%
Input Impedance	1MΩ
Output Impedance	8Ω
SNR (Signal to Noise Ratio)	80dB
Analog Effects	4
Digital Effects	4
Inputs	¼" (6.35mm) Audio Input Jack ¼" (6.35mm) Effect Input Jack
Outputs	Neutrik Speaker Pass Through

Overall Block Diagram

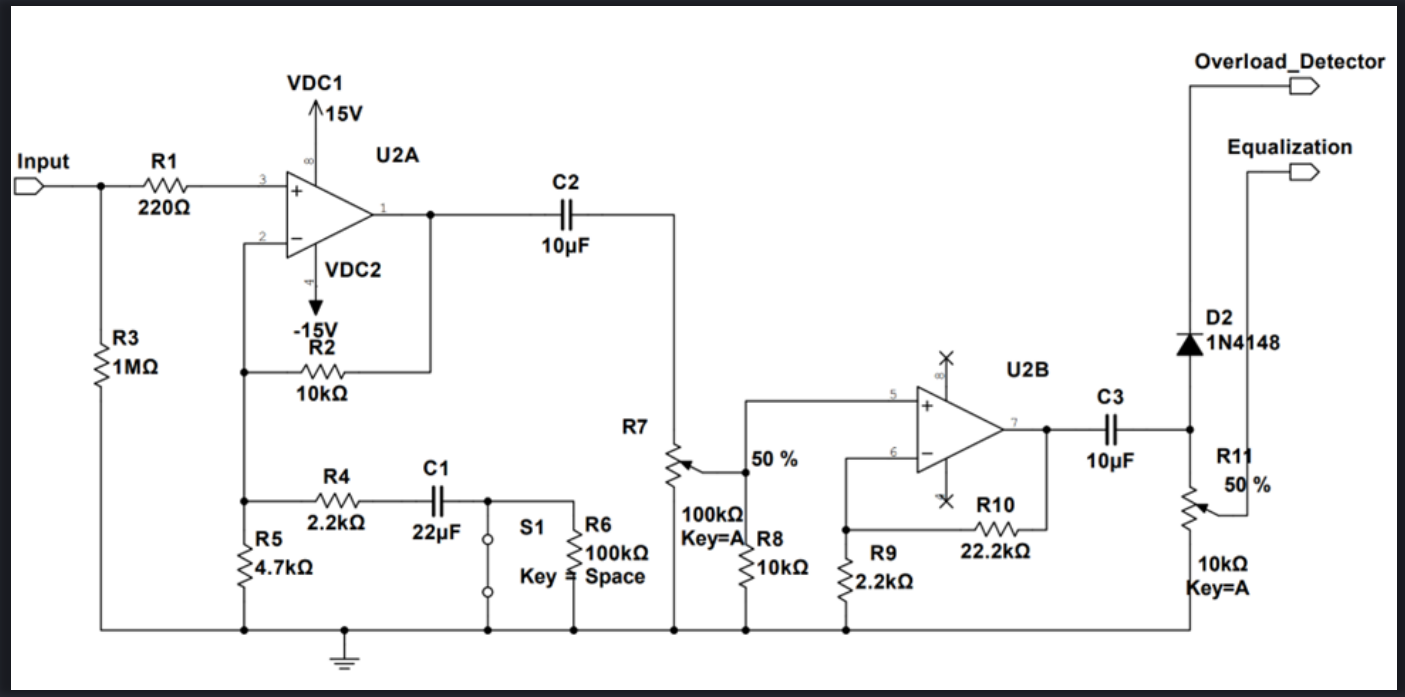
- Main Components:

1. Pre-Amplifier
2. Equalizer
3. Analog Effects
4. Digital Effects
5. Power Amplifier
6. User Interface



Pre-Amplifier

- Functions of a Pre-Amplifier:
  1. Raises the Input signal to Line Level (100mV to ~2V)
  2. No Current Gain
  3. Flat Frequency Response
  4. Low Noise
  5. High Input Impedance
  6. Low Output Impedance



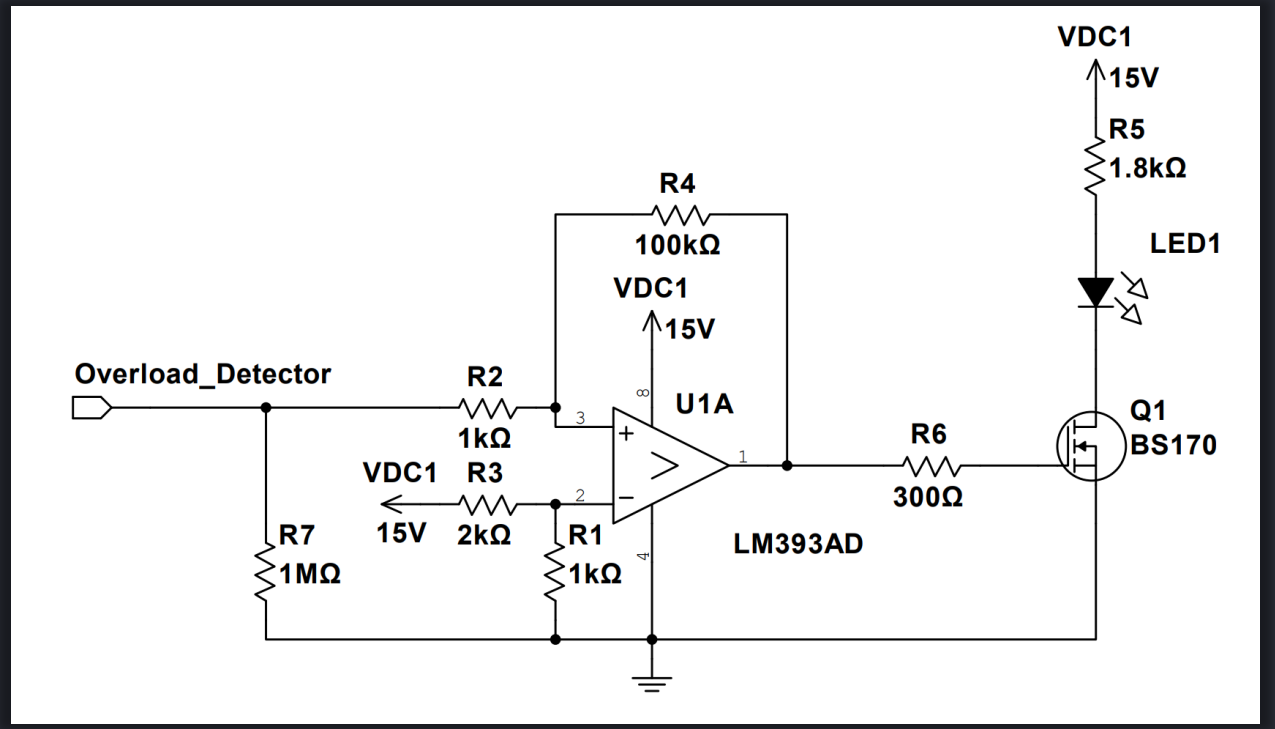
Significant Design Decisions

- Requirements for an Op Amp:
  - High CMRR
  - Low Noise
  - Low Power Consumption
  - Low Cost
- Decided on TI's OPA1642

Part	CMRR (dB)	GBP (MHz)	Slew Rate (V/us)	THD + N (%)	VNoise Density (nV/√Hz)	Cost
AD8510	100	8	20	0.00005	8	$3.85
LT1792	105	5.6	3.4	0.00005	8.3	$11.64
OPA1642	126	11	20	0.00005	5.1	$2.43
OPA1652	110	18	10	0.00005	3.8	$2.75
AD711	88	4	20	0.00005	45	$11.66

Overload Detector

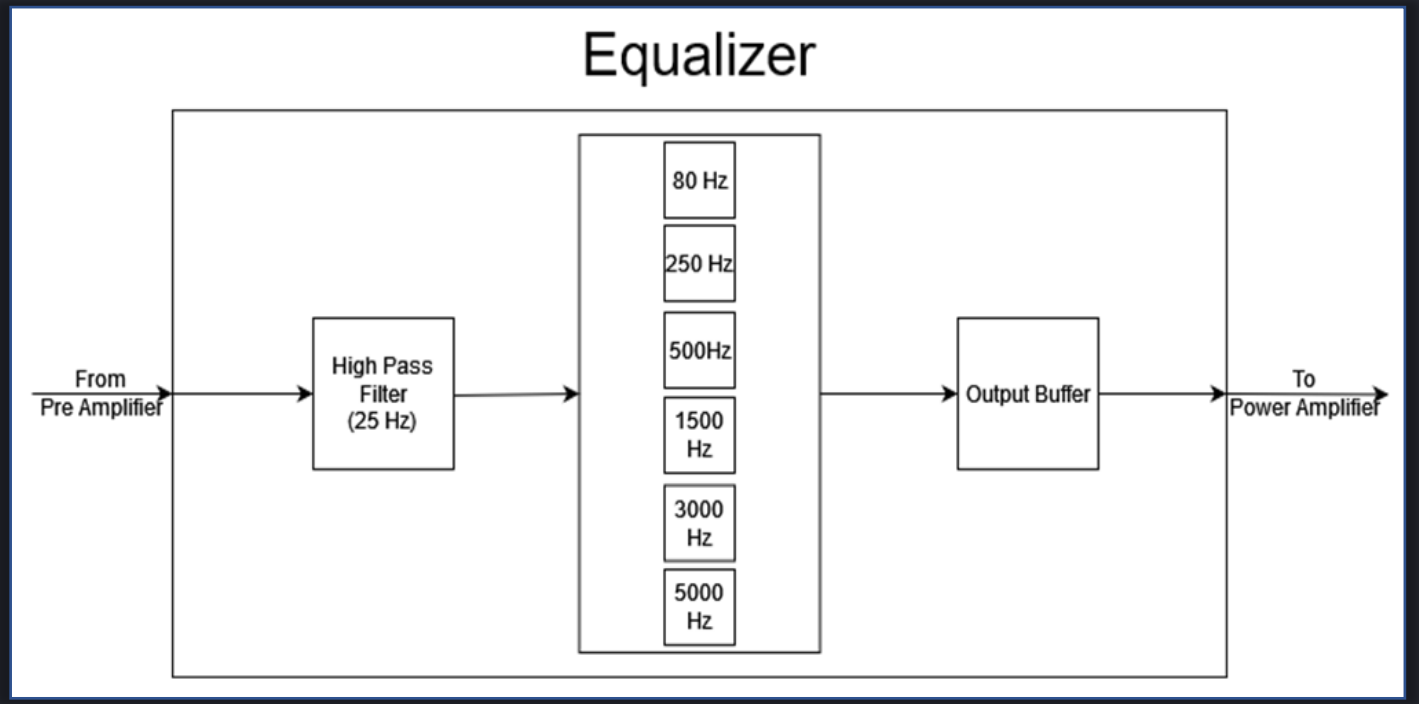
- Detects Voltage levels over 5V
- Alerts user to adjust the Pre-Amplifier Voltage Gain
- Requires a simple and modular design



Equalization

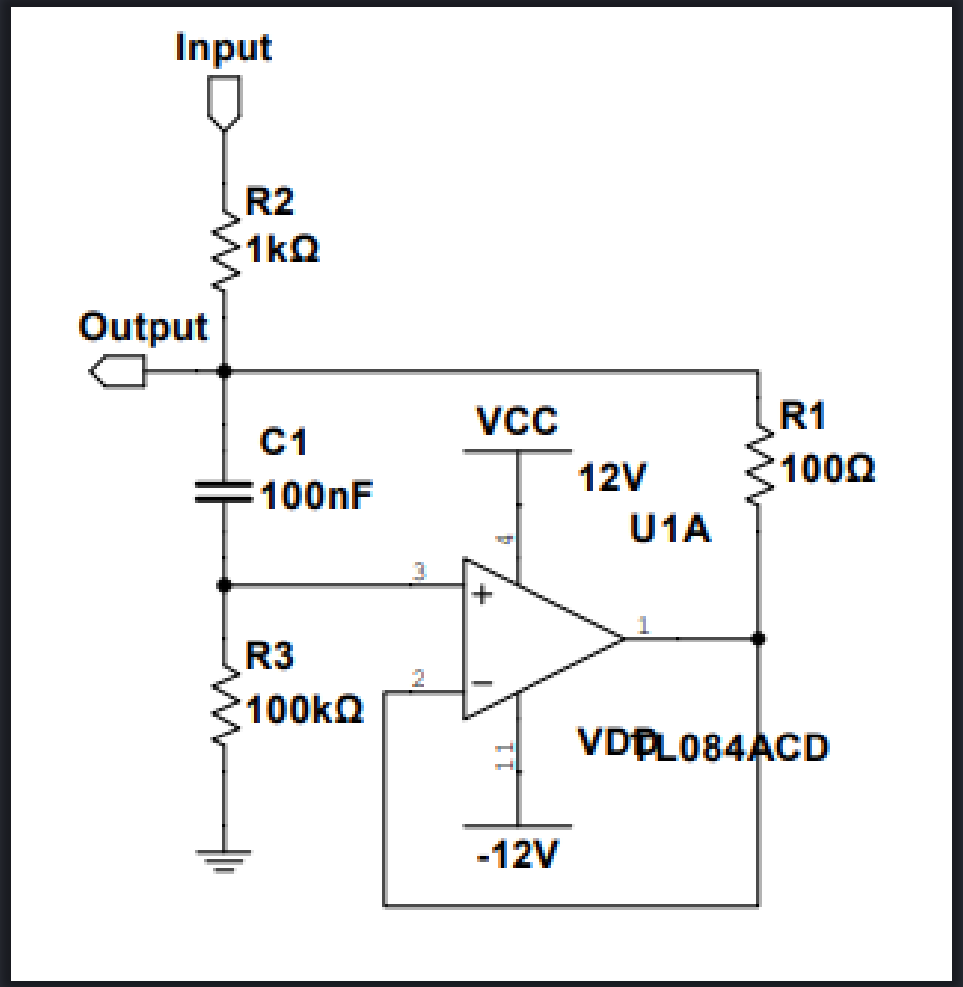
- 6 Band Graphic EQ
- Allows for ±12dB Boost or Cut
- High Pass Filter with a -3dB Frequency of 25Hz

- Adjustable Frequencies:
  - 80, 250, 500, 1500, 3000, and 5000Hz



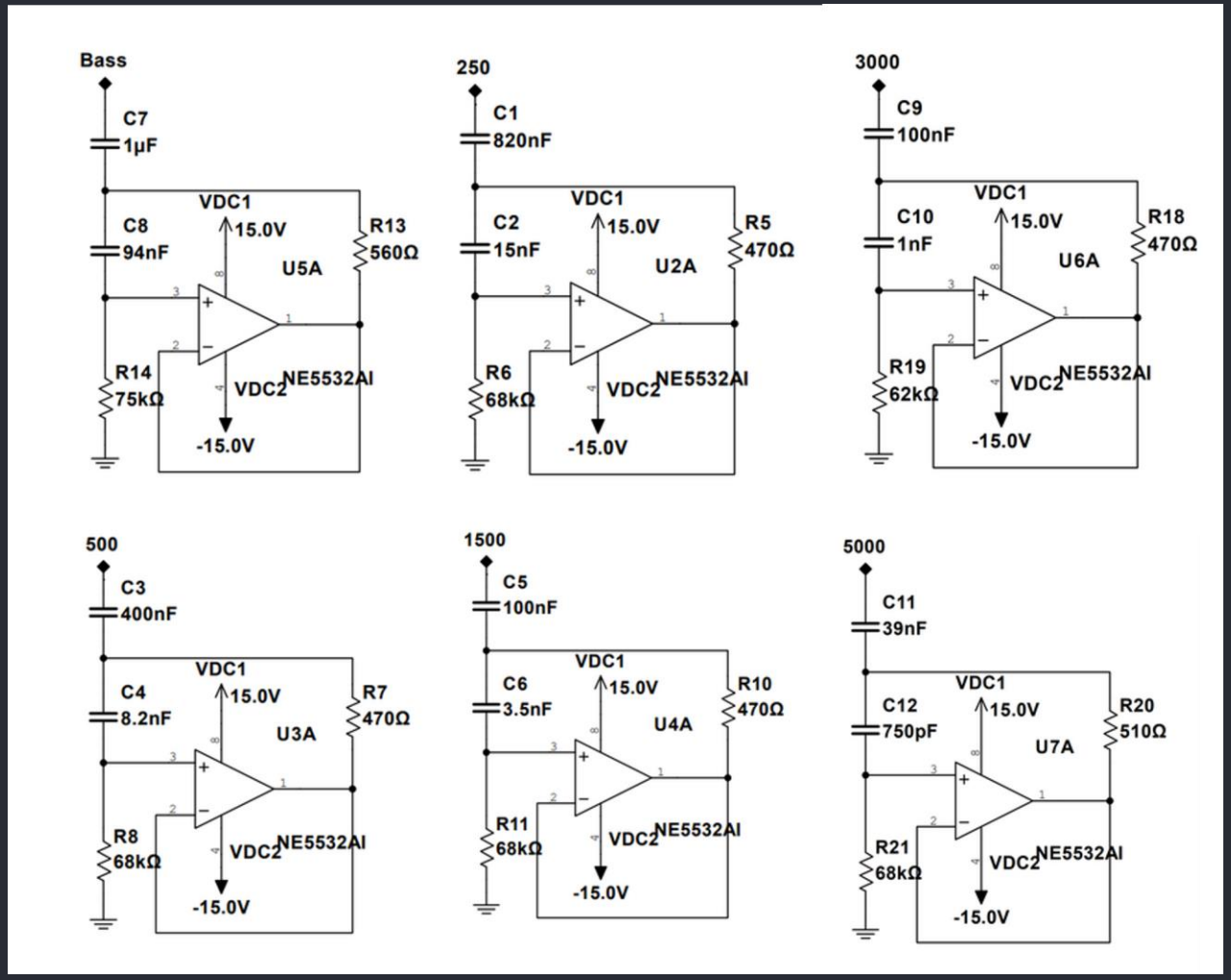
Equalizer Filter Topology

- Each of the 6 Bands are constructed with Gyrator Notch Filters
- Benefits of Gyrator Filters:
  - Able to target very specific frequencies for attenuation
  - Fewer needed components compared to other filter topologies
  - More cost effective than other topologies



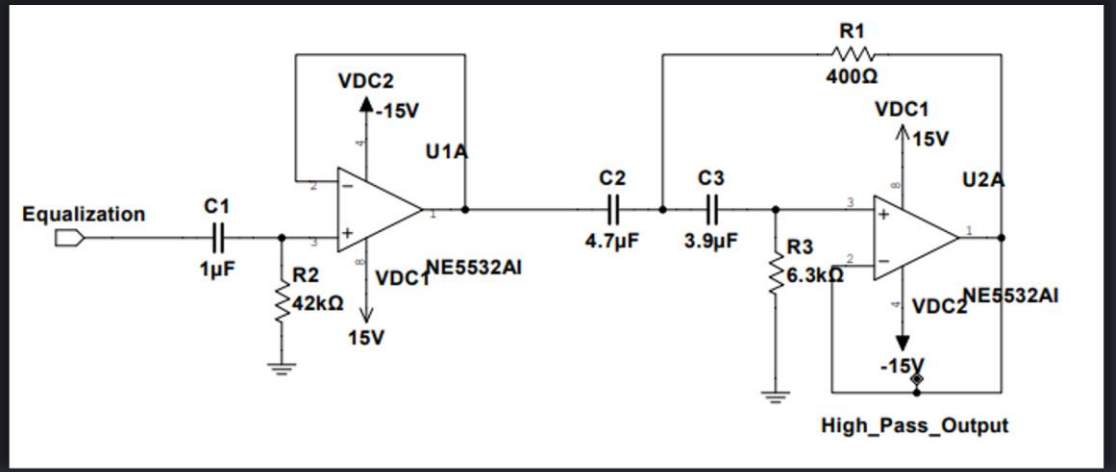
Filter Schematics

Name	Targeted Frequency (Hz)	Calculated Frequency (Hz)
Bass	80	80.09
Upper-Bass	250	253.84
Low-Mid	500	491.56
Mid	1500	1504.81
High-Mid	3000	2948.32
Treble	5000	4997.09

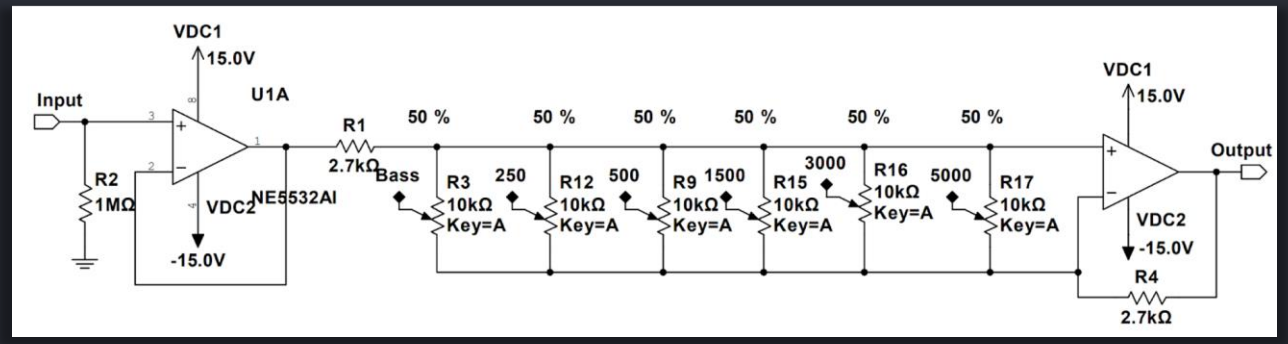


High Pass and Output Buffer Schematics

- High Pass Filter:
  1. Targeted Corner Frequency of 25Hz
  2. Filters out inaudible signals before the speaker output



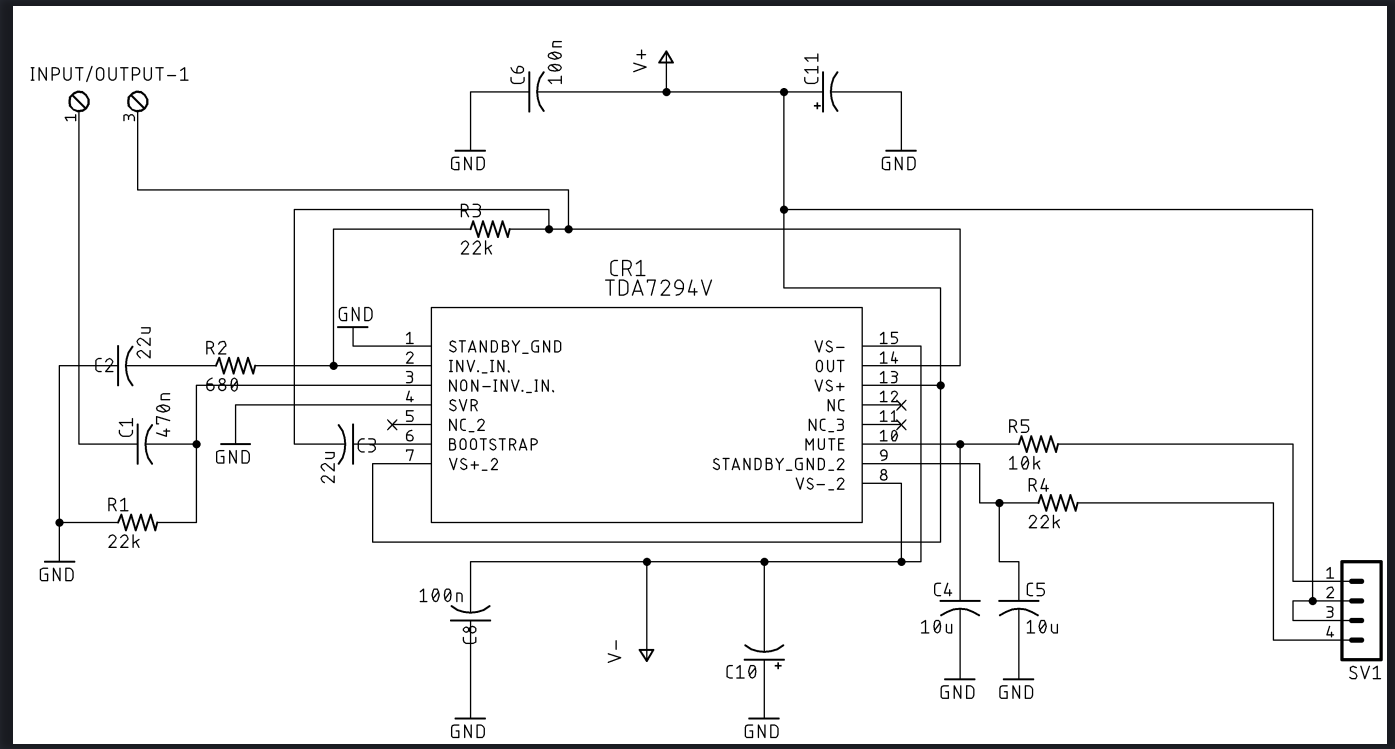
- Output Buffer:
  1. Recombines the Equalized components
  2. Applies a small voltage gain and buffers the output



Power Amplifier

- Functions of a Power Amplifier:
  1. High Current Gain
  2. Ability to Drive an 8Ω Load
  3. Maximum of 100W Output
  4. Low Noise

- Nice to Haves:
  1. Thermal and Short Circuit Protections
  2. Mute Switch
  3. Integrated Heatsink with Options to Add Additional Cooling

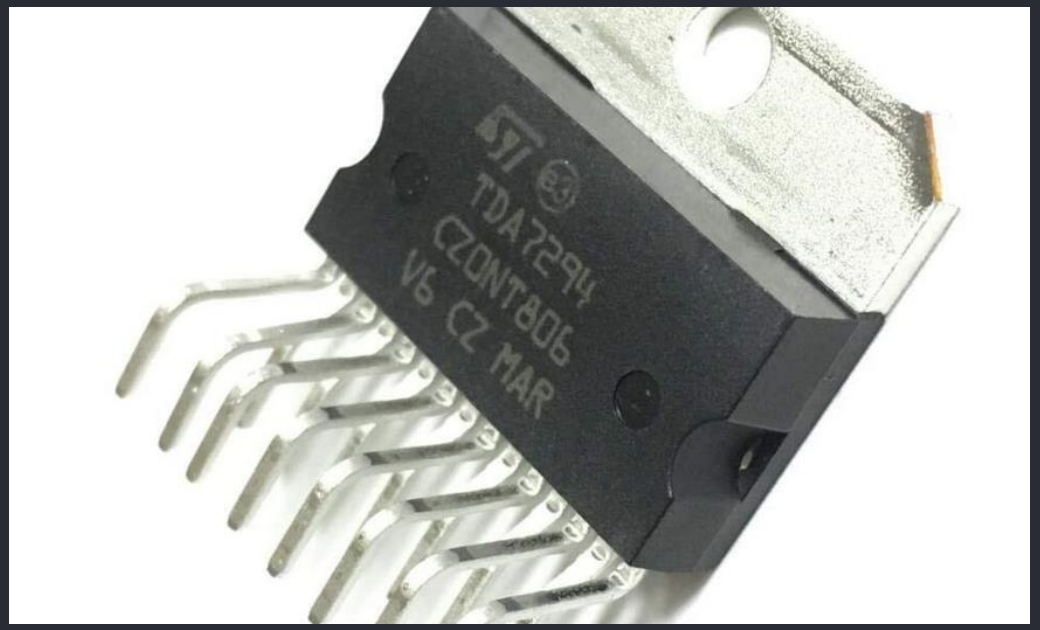


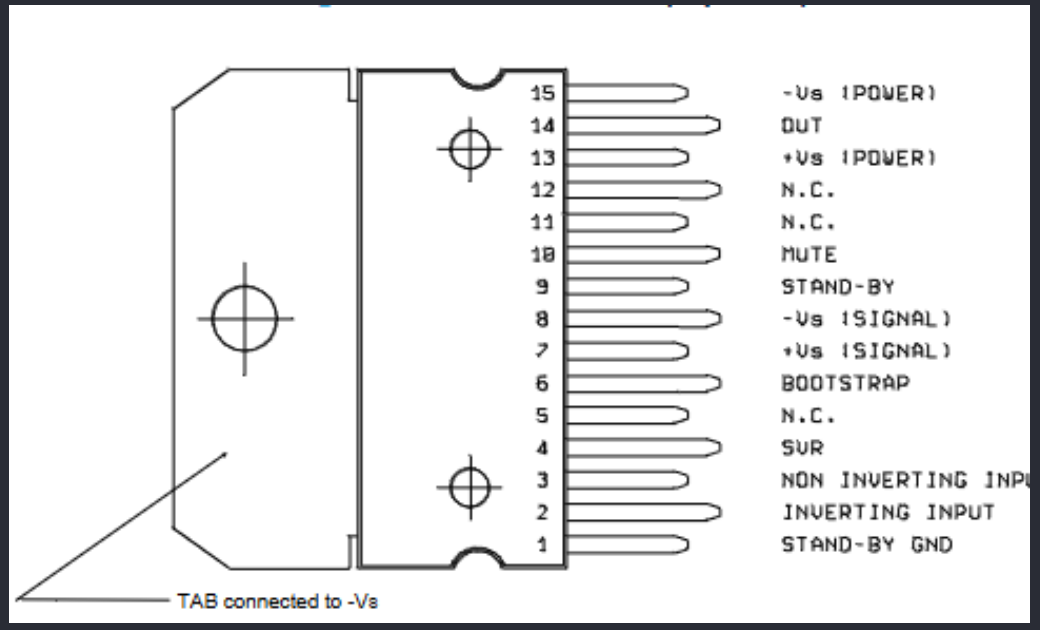
Power Amplifier Component Selection

Part	SlewRate (V/us)	Output Power	THD + N (%)	Cost
LM3875	11	56W @ 8Ω	0.06	$9.33
TDA7294	10	100W @ 8Ω	0.01	$10.45
TPA3156D2	10	50W @ 8Ω 70W @ 4Ω	0.1	$2.05
TPA3221	10	170W @ 2Ω	1	$2.11

TDA7294

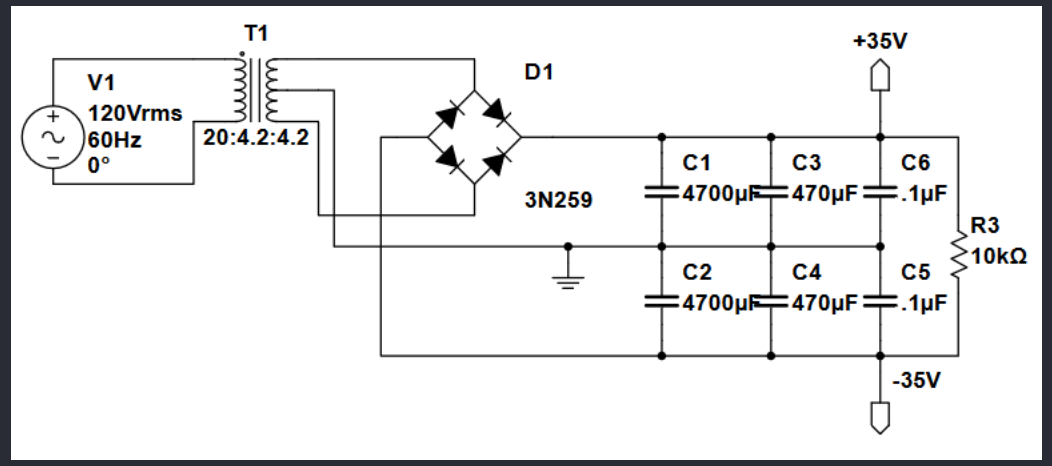
- High Output Power (up to 100W)
- Class AB amplifier
- Supports 4Ω and 8Ω loads
- Muting and Standby functions
- Short circuit and Thermal shutdown Protections

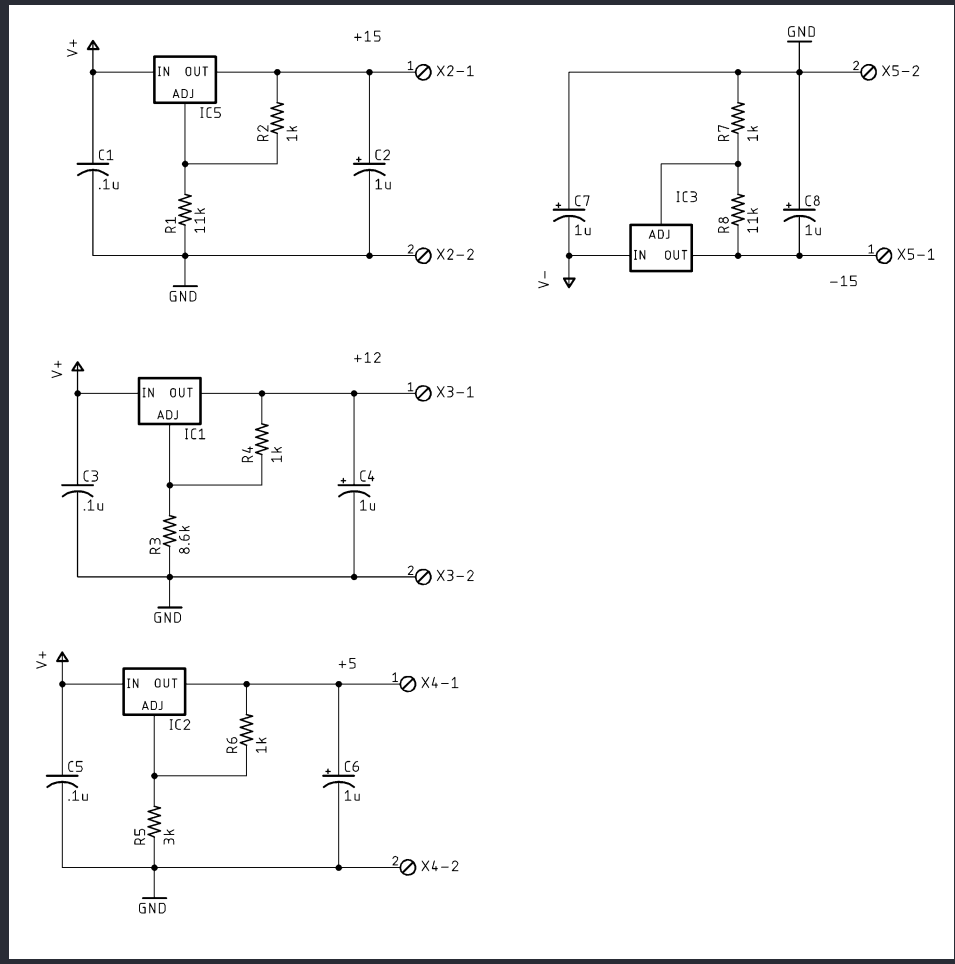




Power Supply

- Takes in standard 120v 60hz
- Filters the DC signal from the rectifier
- Outputs an unregulated ±35v
- Outputs a regulated ±15v, +12v, +5v

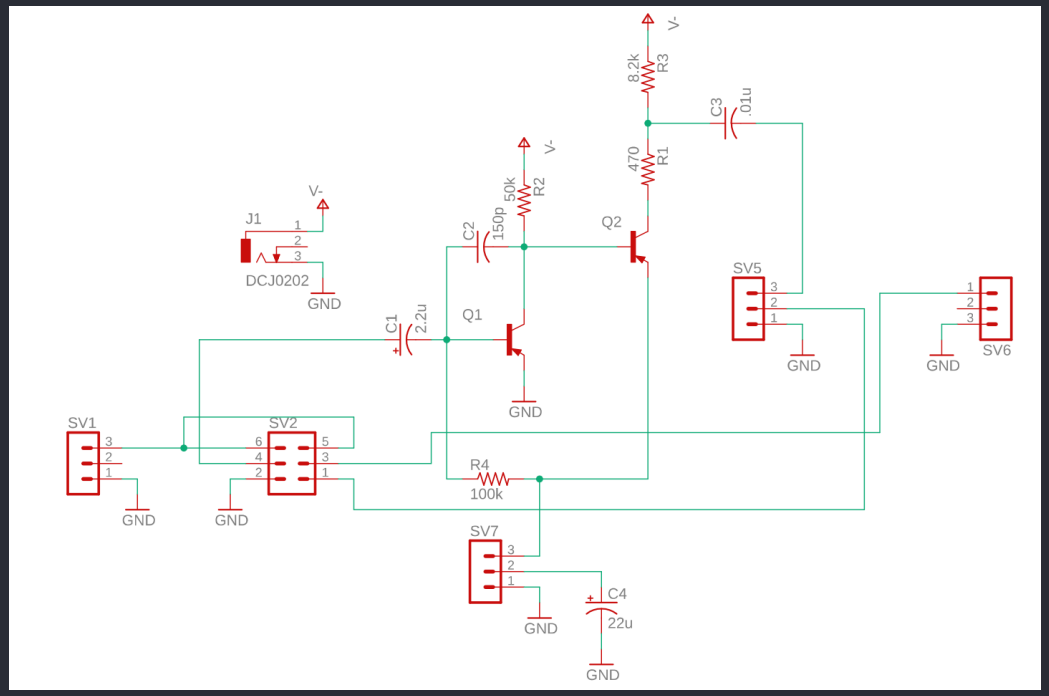


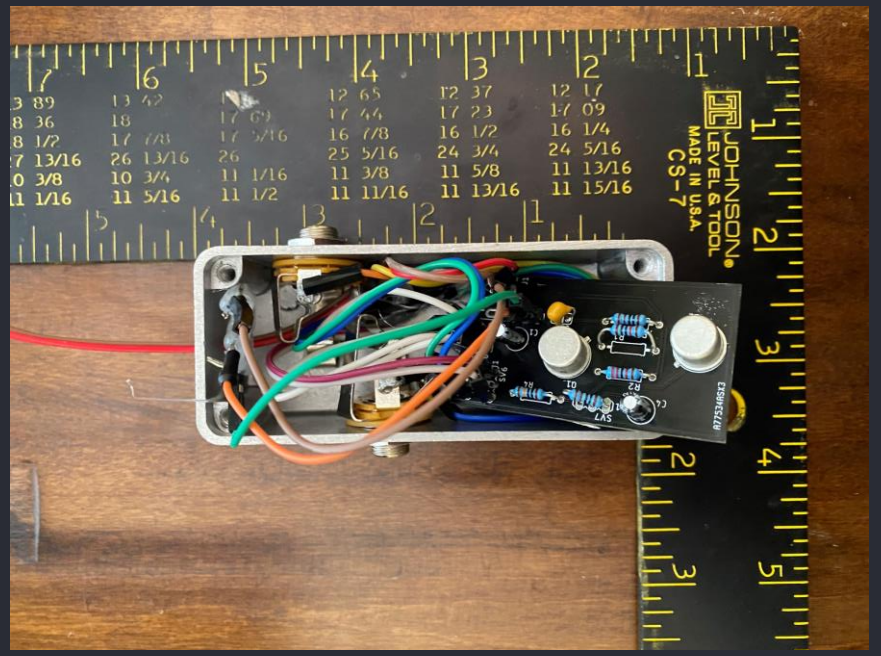


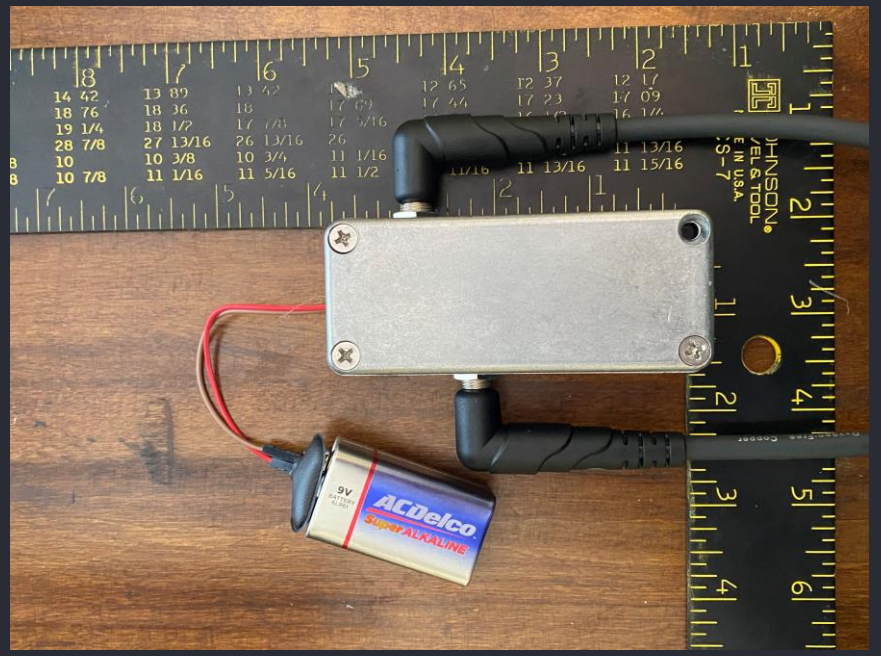
Analog Effects

- Fuzz
- Phasor
- Compression
- Distortion

Fuzz

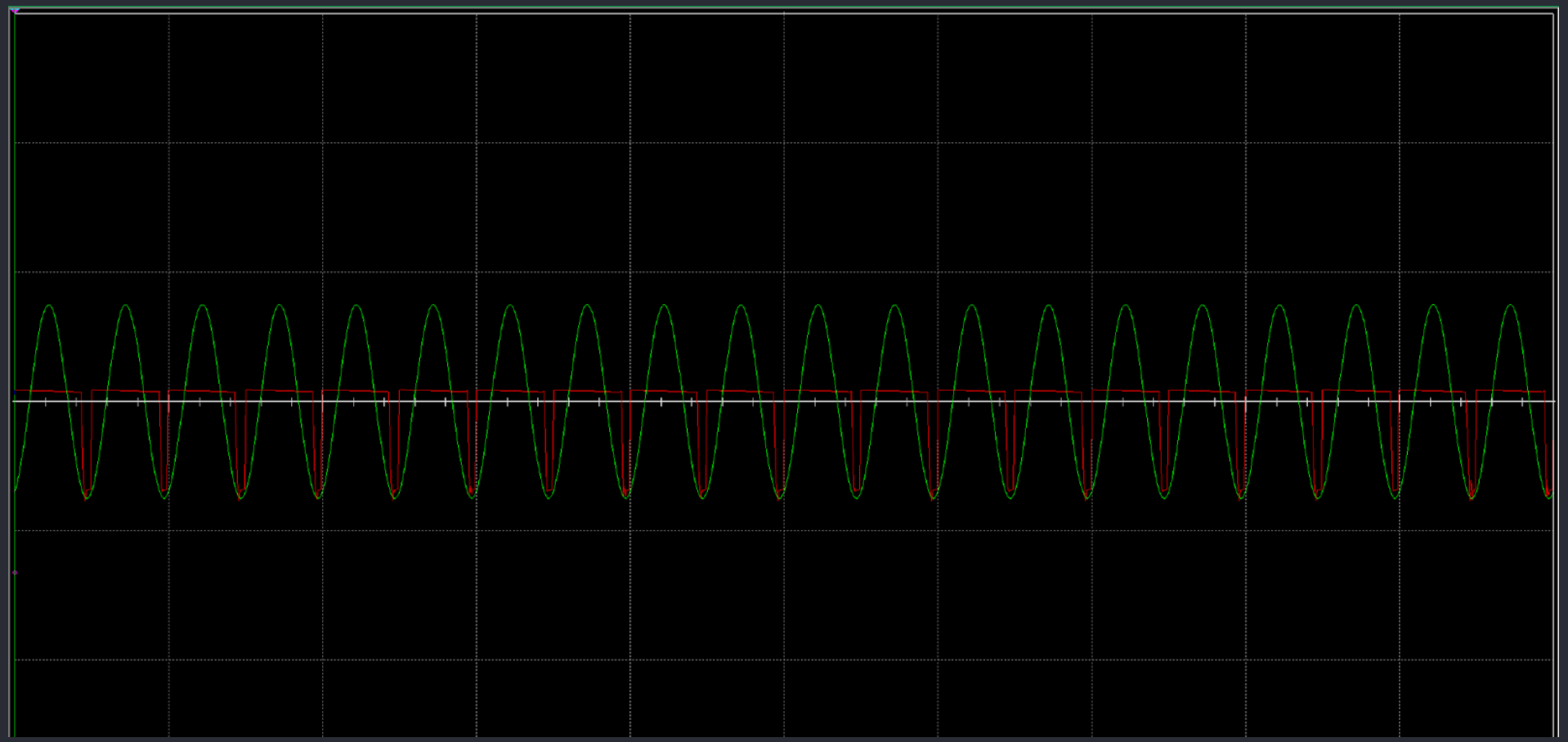

V-
8.2k
R3
C3
.01u
470
R1
V-
50k
R2
J1
C2
150p
Q2
DCJ0202
GND
C1
2.2u
Q1
SV5
SV6
GND
GND
GND
SV1
SV2
R4
100k
GND
GND
SV7
C4
22u
GND
GND


JOHNSON
LEVEL & TOOL
MADE IN U.S.A.
CS-7

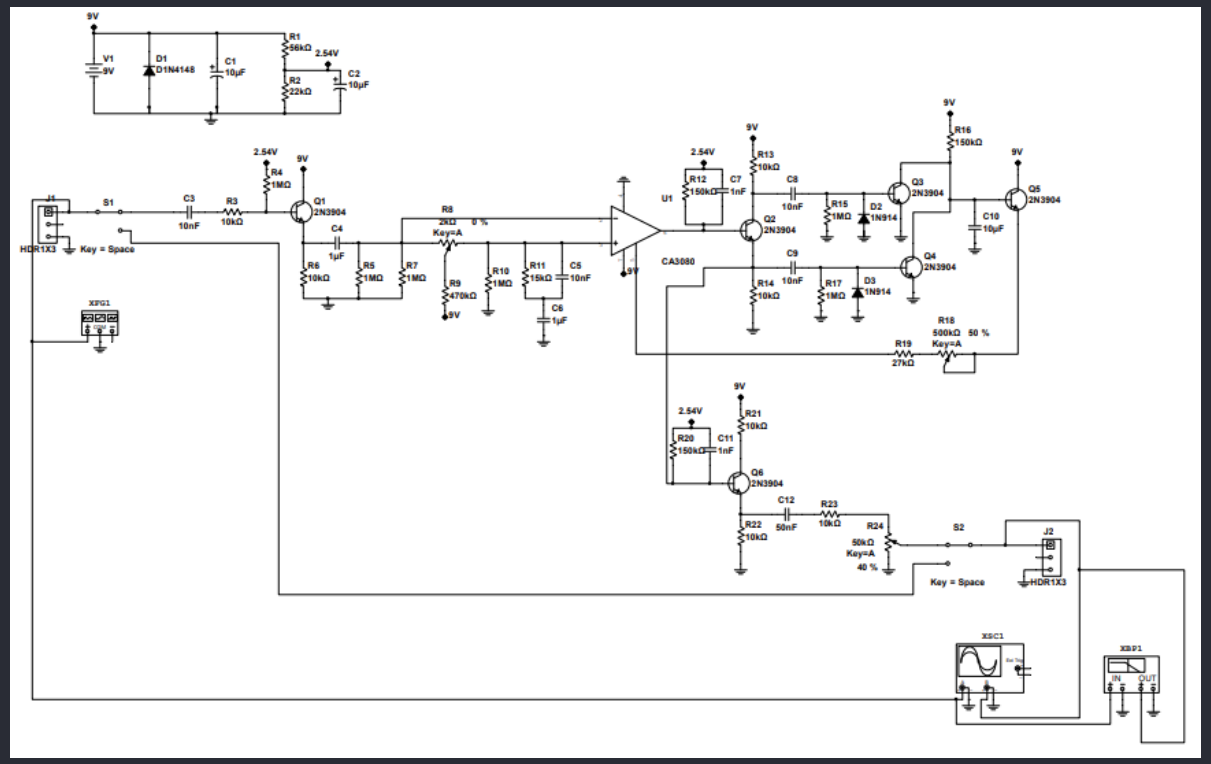

ACDelco
Super ALKALINE
9V

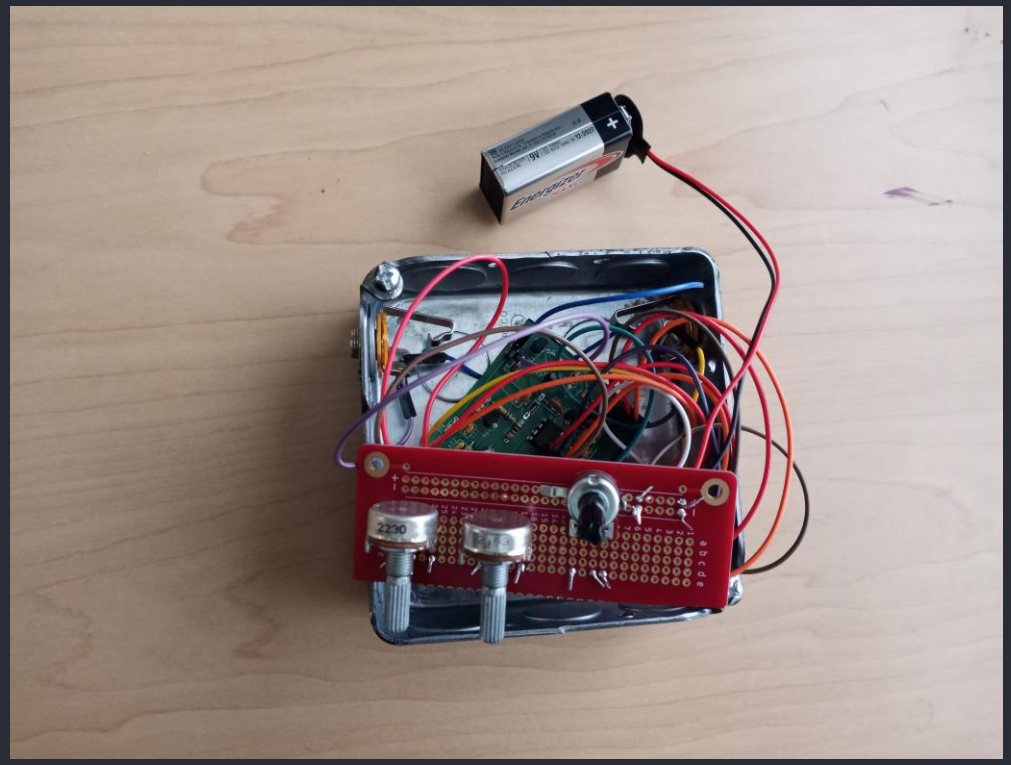
Fuzz

- Achieve the quintesessential "Fuzz Face" effect



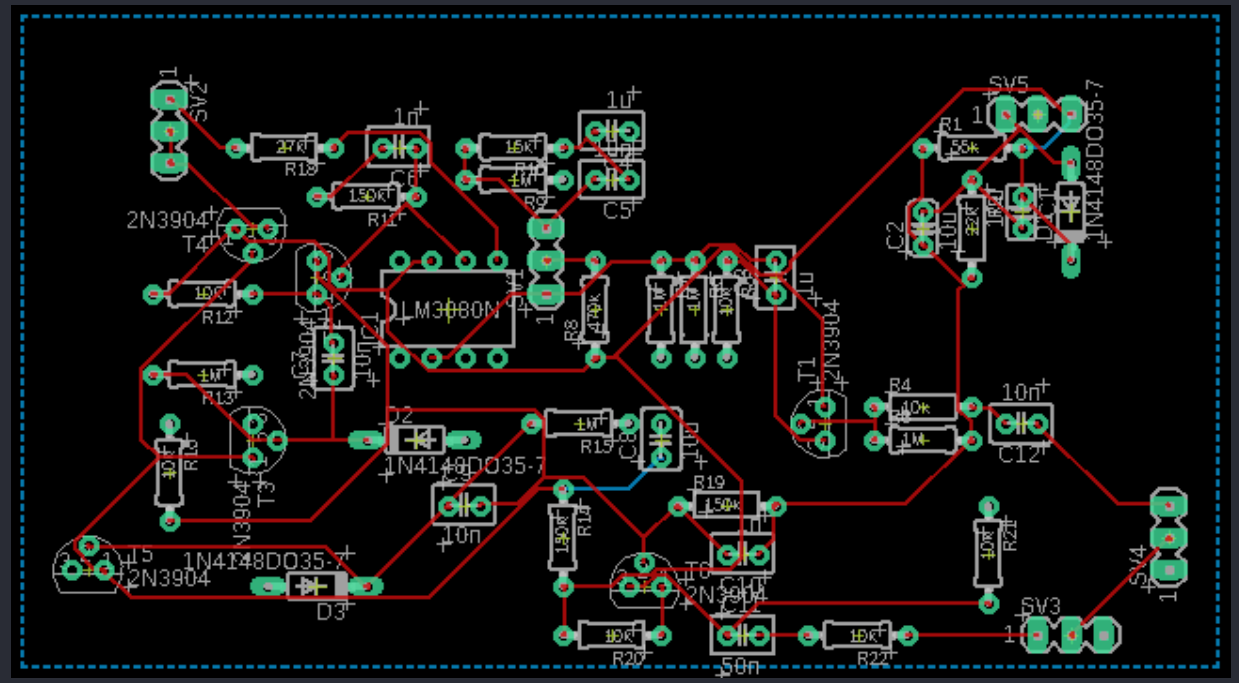
Compressor

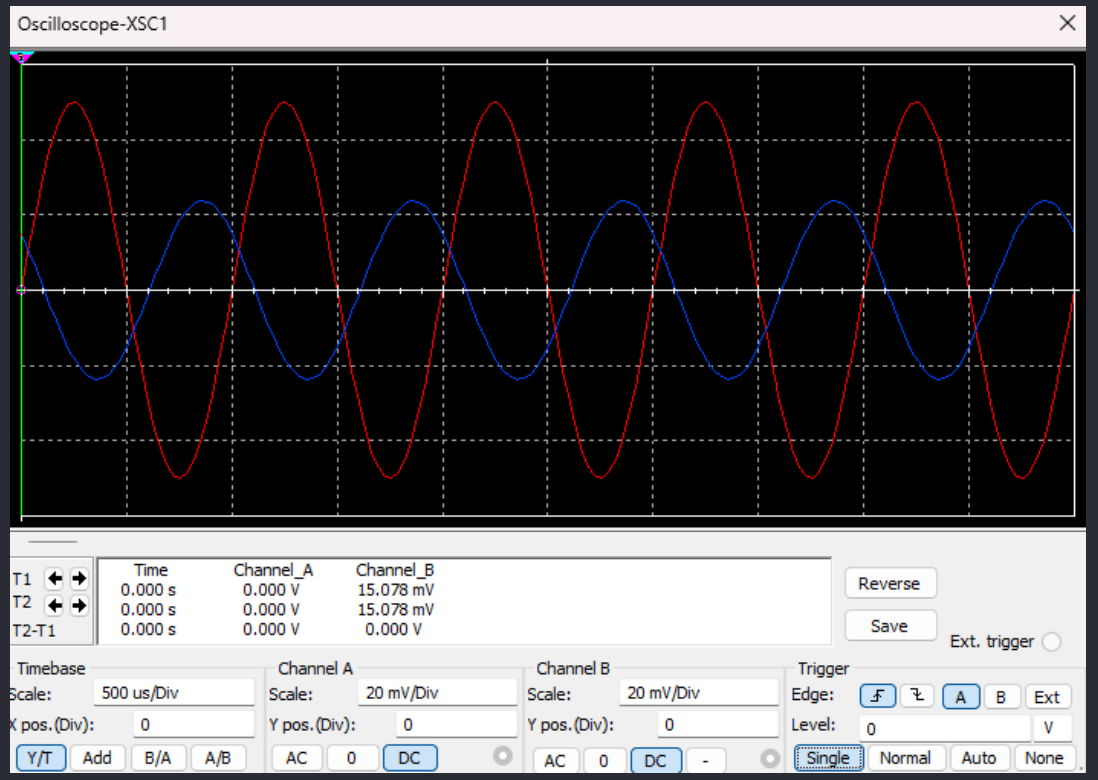

9V
V1
9V
D1
D1N4148
C1
10µF
R1
56kΩ
2.54V
R2
22kΩ
C2
10µF
J1
HDR1X3
Key = Space
S1
C3
10nF
R3
10kΩ
R4
1MΩ
Q1
2N3904
C4
1µF
R6
10kΩ
R5
1MΩ
R7
1MΩ
R8
2kΩ
Key=A
R9
470kΩ
R10
1MΩ
R11
15kΩ
C5
10nF
C6
1µF
XFG1
U1
CA3080
R12
150kΩ
C7
1nF
R13
10kΩ
C8
10nF
Q2
2N3904
R14
10kΩ
C9
10nF
R15
1MΩ
D2
1N914
Q3
2N3904
R16
150kΩ
Q4
2N3904
R17
1MΩ
D3
1N914
Q5
2N3904
C10
10µF
R18
500kΩ
50 %
Key=A
R19
27kΩ
R20
150kΩ
C11
1nF
R21
10kΩ
Q6
2N3904
R22
10kΩ
C12
50nF
R23
10kΩ
R24
50kΩ
Key=A
40 %
S2
J2
HDR1X3
Key = Space
XSC1
XBP1
IN
OUT


Energizer
2230

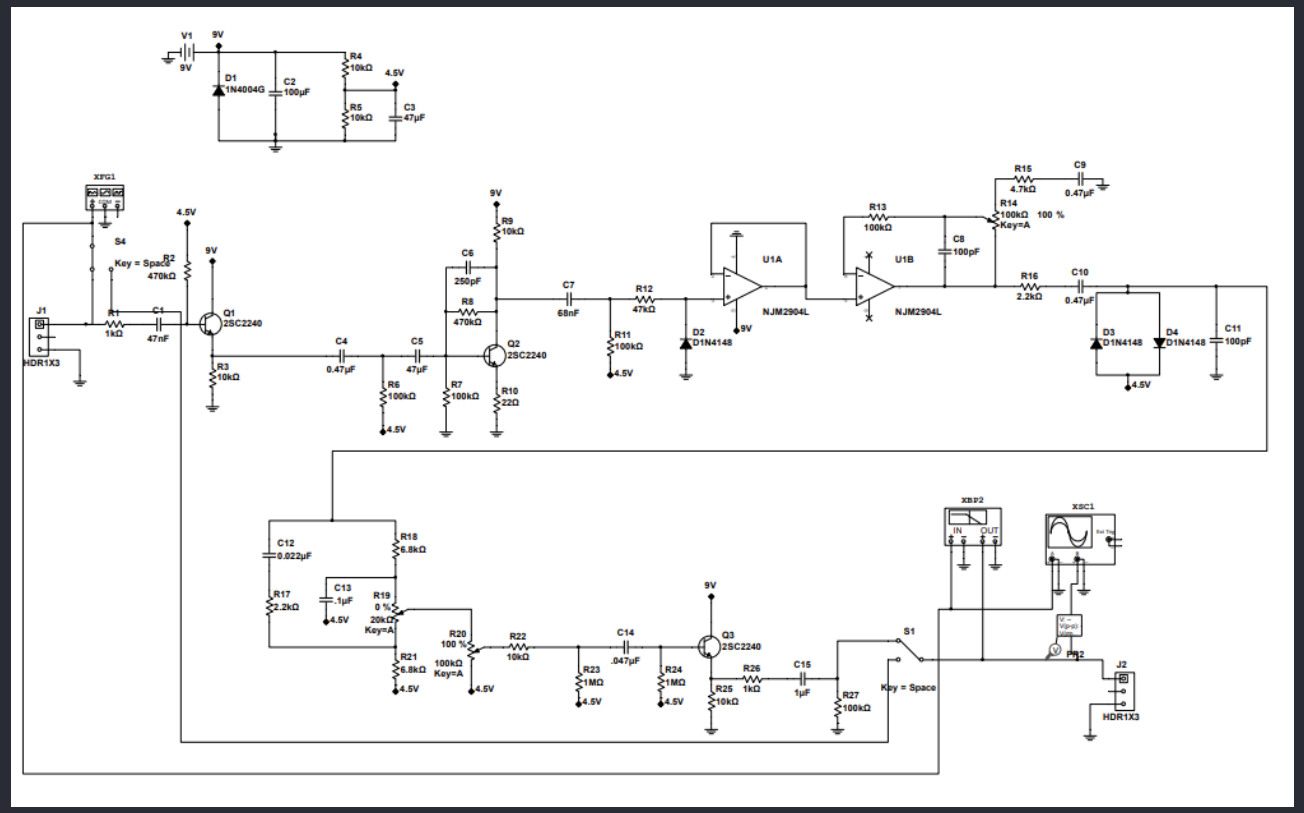
Compressor

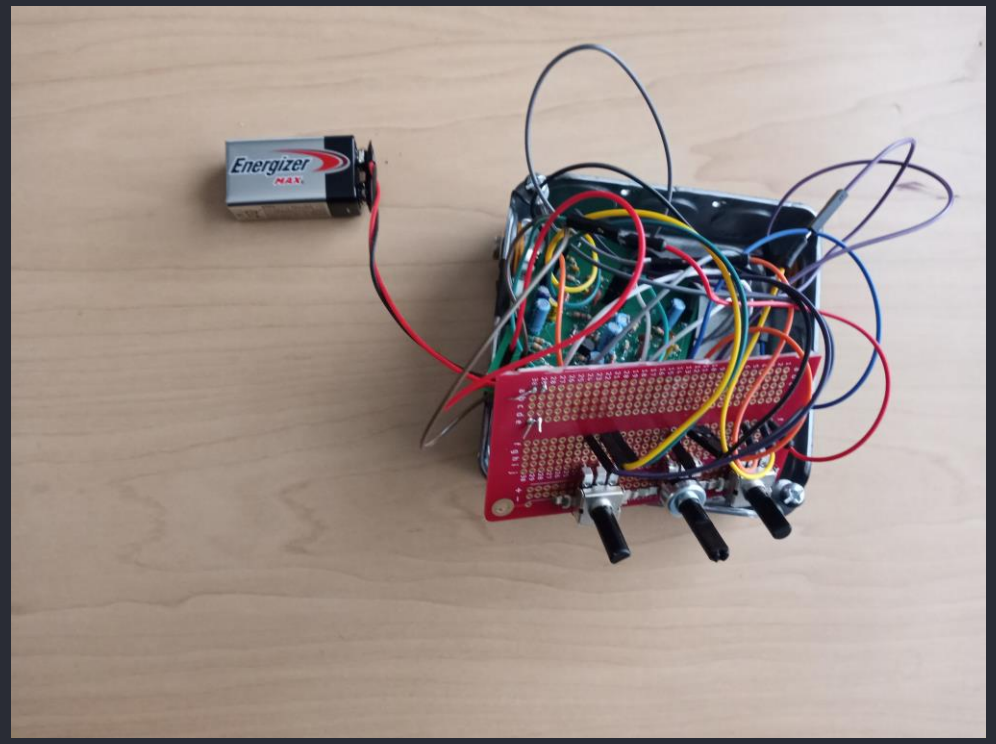
- Achieve the quintessential "compression" sound effect





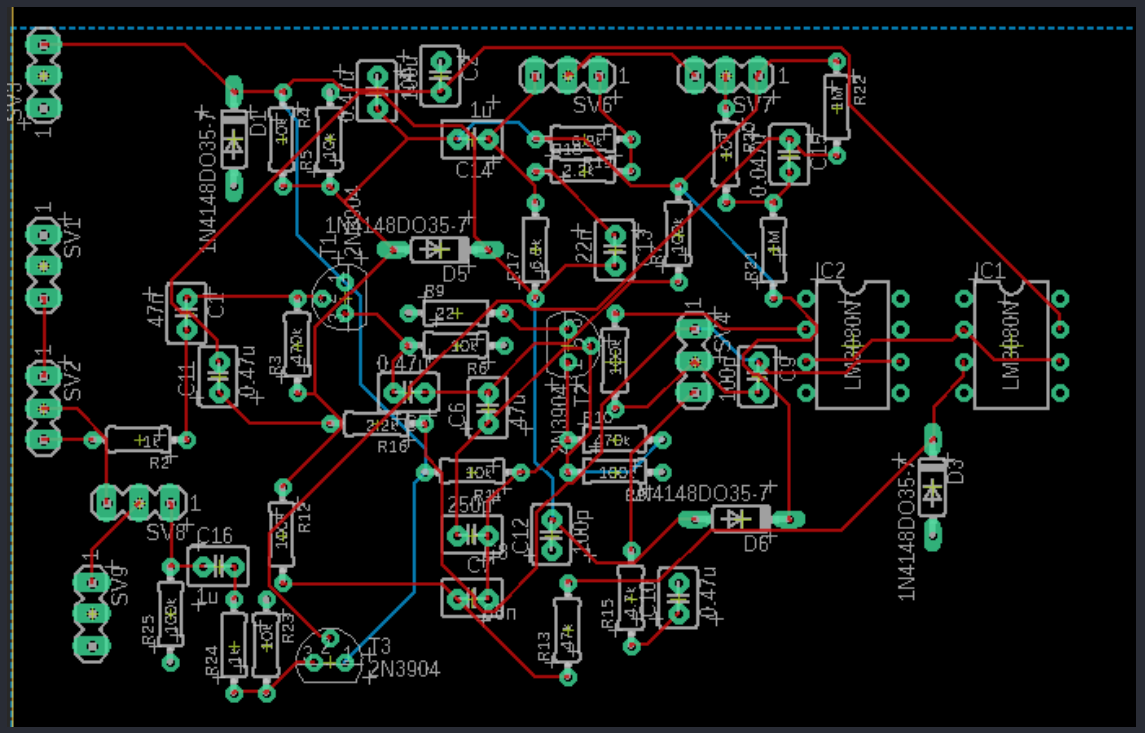
Distortion

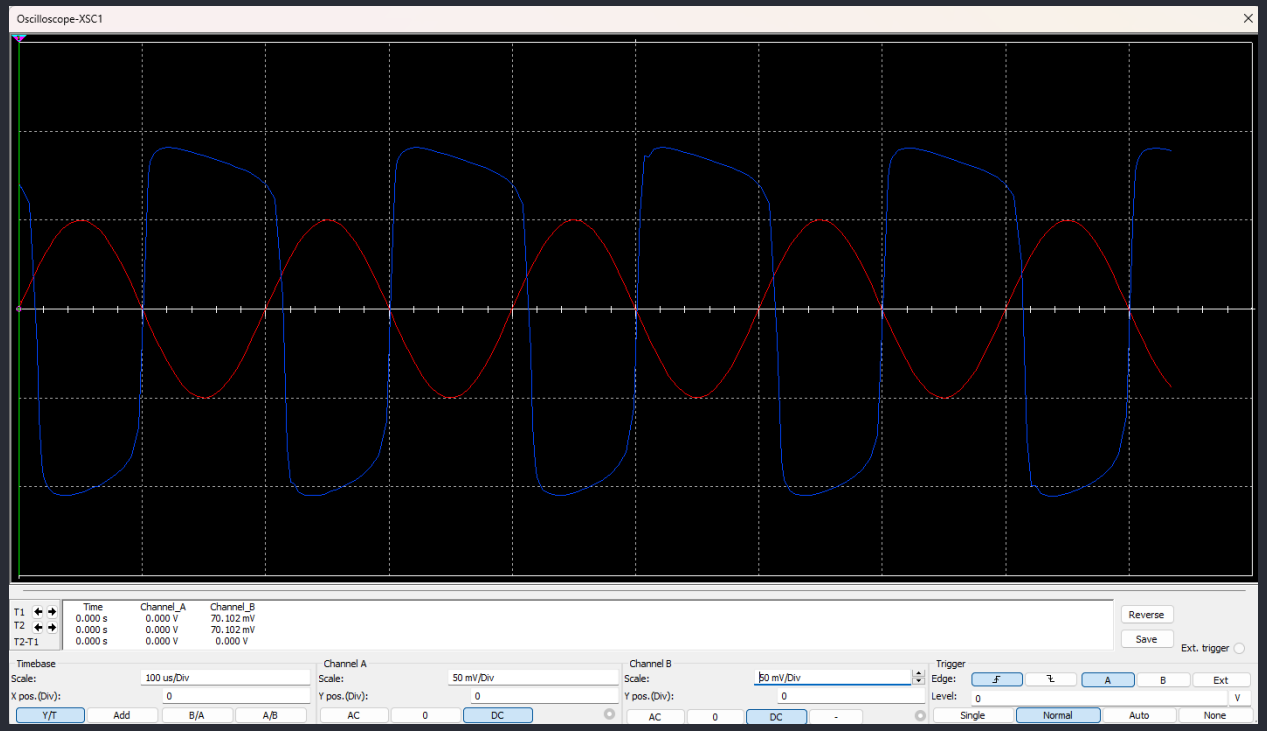

V1
9V
D1
1N4004G
C2
100µF
R4
10kΩ
R5
10kΩ
C3
47µF
4.5V
XPG1
S4
Key = Space
R2
470kΩ
J1
HDR1X3
R1
1kΩ
C1
47nF
Q1
2SC2240
R3
10kΩ
C4
0.47µF
C5
47µF
R6
100kΩ
C6
250pF
R8
470kΩ
R9
10kΩ
R7
100kΩ
R10
22Ω
Q2
2SC2240
C7
68nF
R12
47kΩ
R11
100kΩ
D2
D1N4148
U1A
NJM2904L
U1B
R13
100kΩ
C8
100pF
R14
100kΩ
100 %
Key=A
R15
4.7kΩ
C9
0.47µF
R16
2.2kΩ
C10
0.47µF
D3
D1N4148
D4
D1N4148
C11
100pF
C12
0.022µF
R18
6.8kΩ
R17
2.2kΩ
C13
.1µF
R19
0 %
20kΩ
Key=A
R21
6.8kΩ
R20
100 %
100kΩ
Key=A
R22
10kΩ
C14
.047µF
R23
1MΩ
R24
1MΩ
Q3
2SC2240
R25
10kΩ
R26
1kΩ
C15
1µF
R27
100kΩ
S1
Key = Space
XBP2
IN
OUT
XSC1
J2
HDR1X3


Energizer
MAX

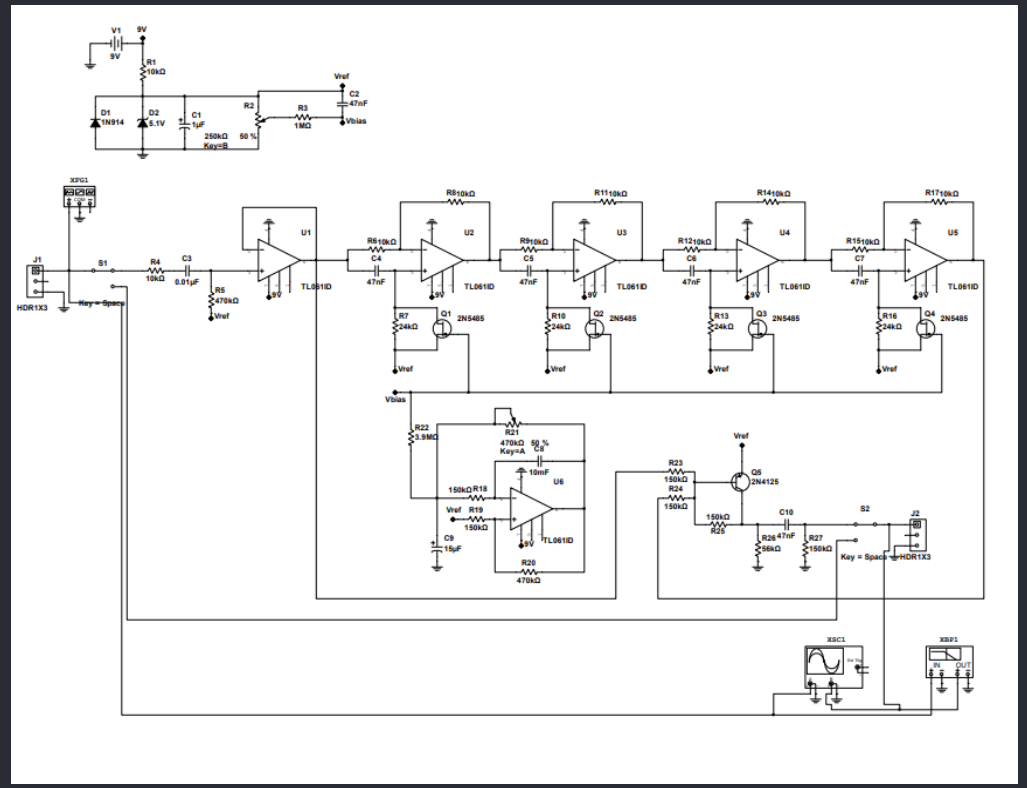
Distortion

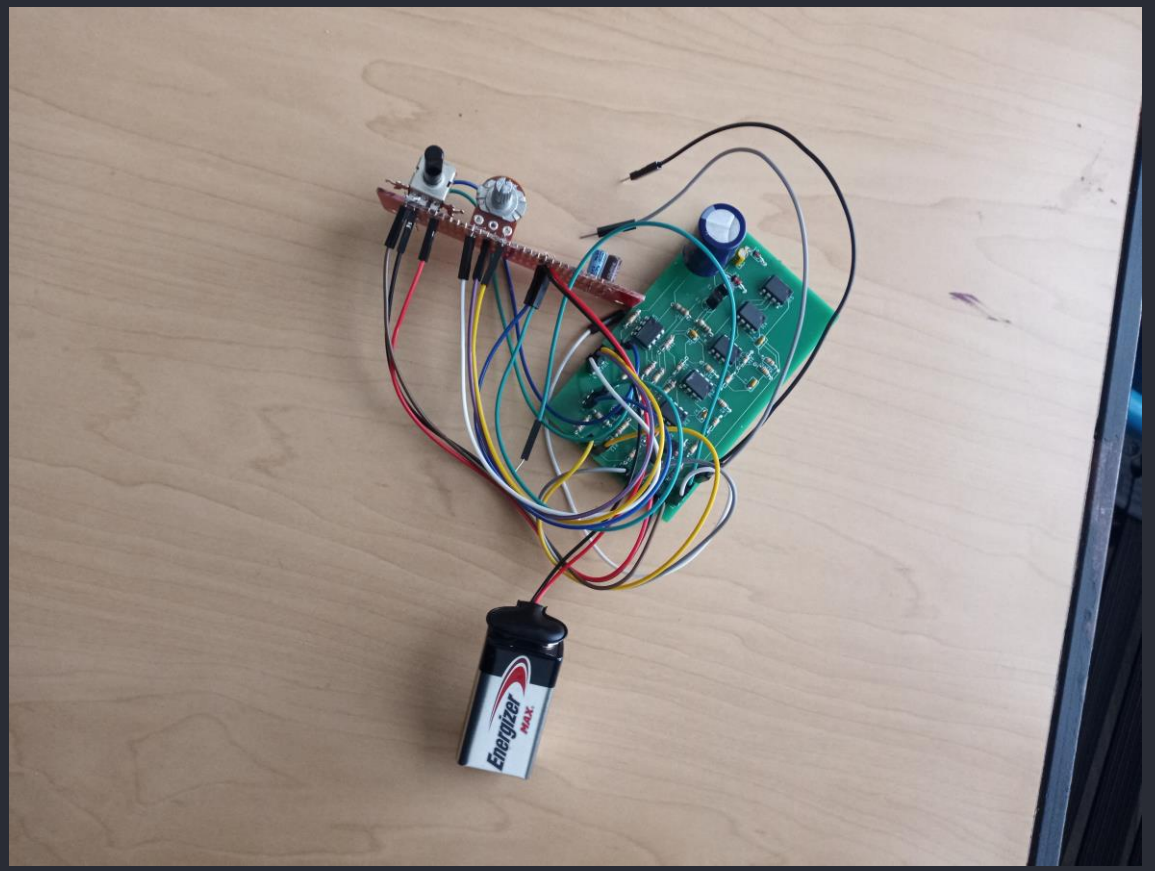
- Achieve the quintessential "distortion" effect.





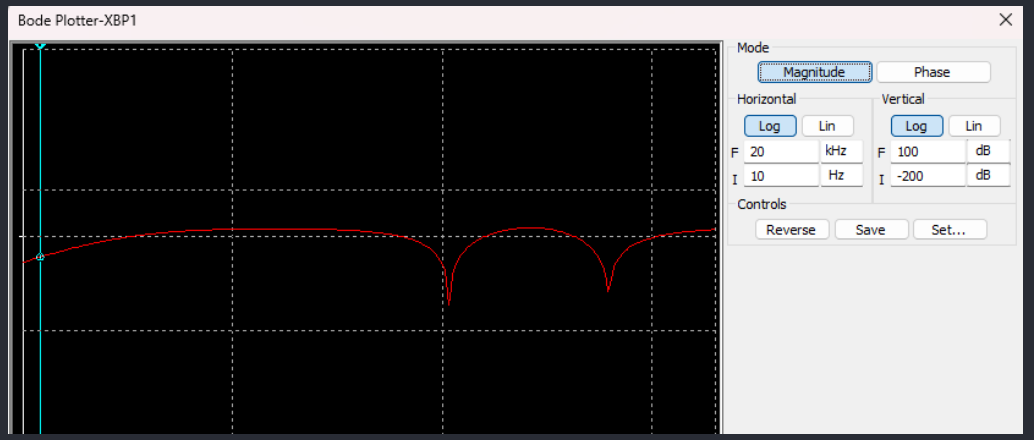
Phasor

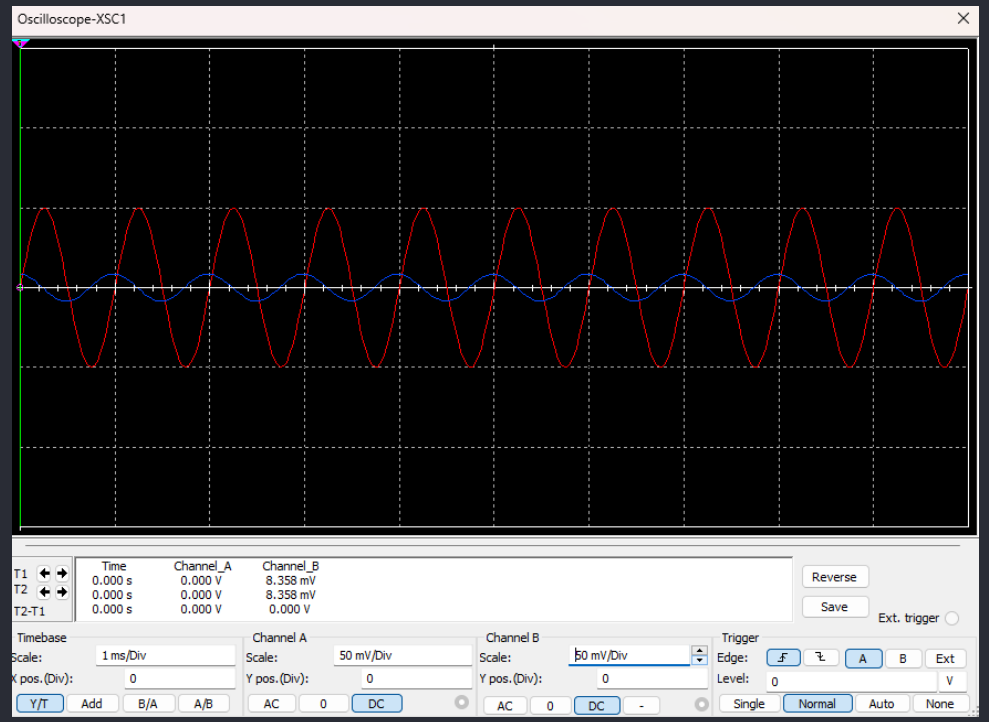

V1 9V
R1 10kΩ
D1 1N914
D2 5.1V
C1 1µF
R2 250kΩ Key=B 50 %
R3 1MΩ
C2 47nF
Vref
Vbias
XPC1
J1
HDR1X3
S1
Key = Space
R4 10kΩ
C3 0.01µF
R5 470kΩ
U1
TL061ID
R6 10kΩ
C4 47nF
U2
R9 10kΩ
C5 47nF
U3
R11 10kΩ
C6 47nF
U4
R14 10kΩ
C7 47nF
U5
R7 24kΩ
Q1 2N5485
R10 24kΩ
Q2 2N5485
R13 24kΩ
Q3 2N5485
R16 24kΩ
Q4 2N5485
R22 3.9MΩ
R21 470kΩ Key=A 50 %
C8 10nF
U6
R18 150kΩ
R19 150kΩ
C9 15µF
R20 470kΩ
TL061ID
R23 150kΩ
R24 150kΩ
R25 150kΩ
Q5 2N4125
C10 47nF
R26 56kΩ
R27 150kΩ
S2
J2
Key = Space
HDR1X3
XSC1
XBP1
IN
OUT

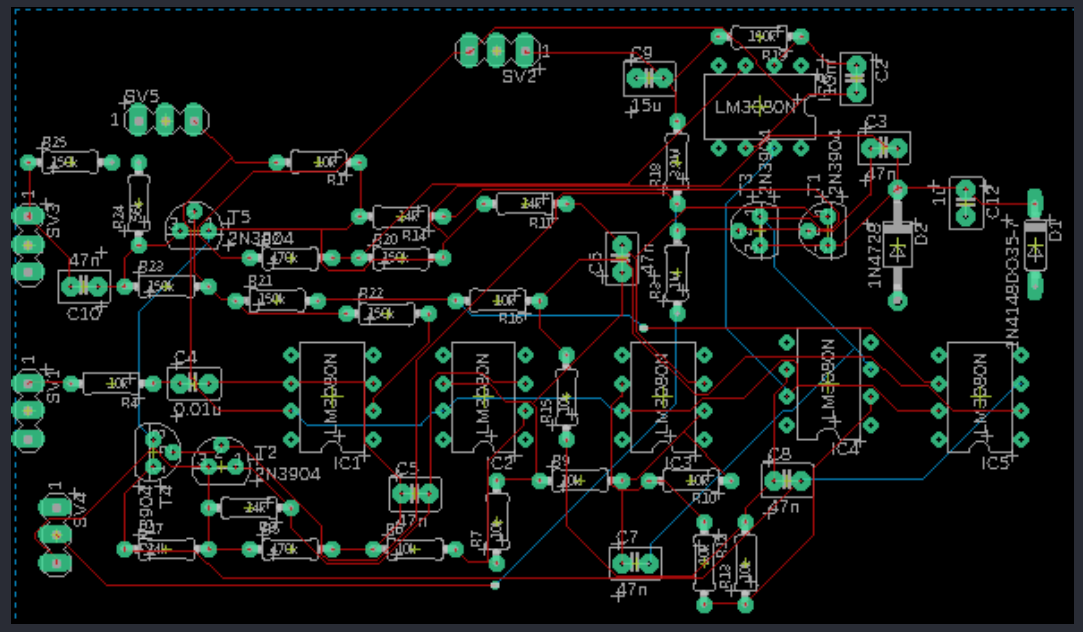

Energizer
MAX

Phasor

- Achieve the "Phase 90" sound effect







Digital Effects

- Digital effects will include echo, flanger, reverb, and wah-wah
- Echo, flanger, and reverb fall under time-based delays while wah-wah is a time varying delay
- Can have cleaner sound than analog effects and more customizeable, but feel less organic

Microcontroller for DFX

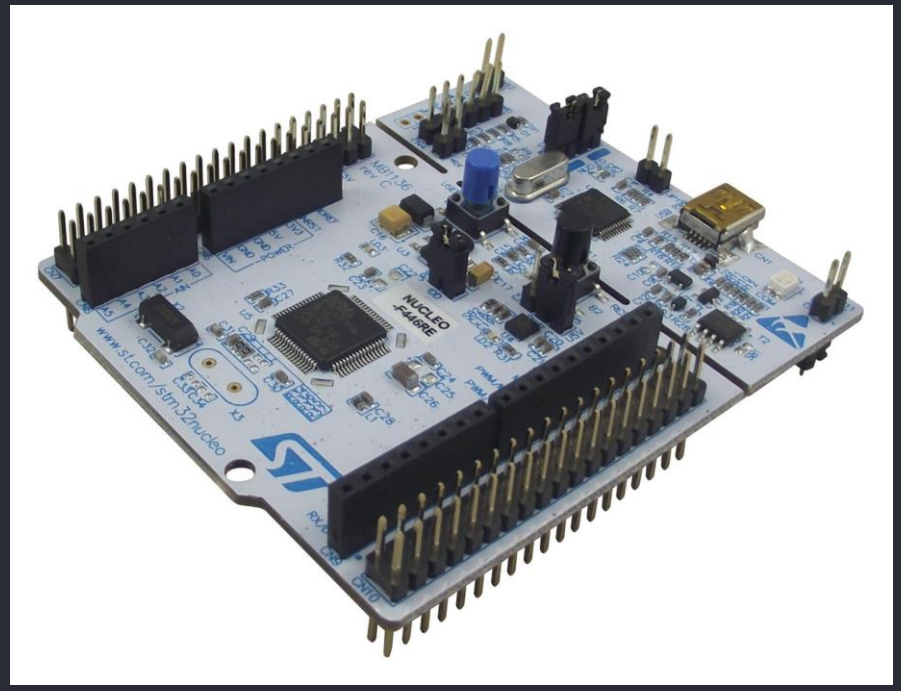
Part	Core size	Ram	#I/O	Cost
STM32F446RE	32-bit	512KB	114	$15.00
TAS2505EVM				$238.00
TMS320F28377DPTPS	32-bit	204KB	97	$27.00

Considerations:

- Cost
- Peripherals
- Memory size and clock rate

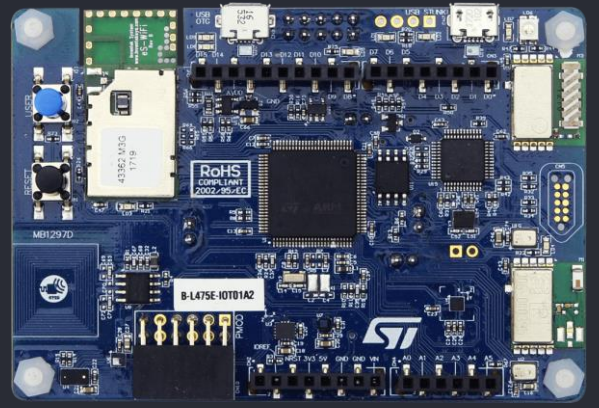
Selection

- Selection- STM32F446RE
- Fair price which aligns with project goal
- Necessary peripherals such as ADC and DAC
- Highly portable code, will allow for use of L series board after development and testing
- May need external SRAM module

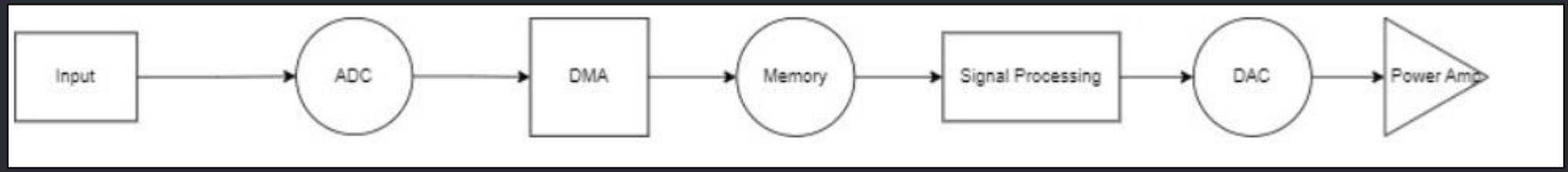


Microcontroller Change

- Current plan is to externally supply power to mcu via regulated 5V supply
- If power consumption becomes a problem, can change to stm32 L series. Such as STM32L475RCT3
- If physical size of the board is an issue, change to Sparkfun's MicroMod STM32 processor



Design



- ADC will have 10-bit resolution and sample at 44.1kHZ to meet memory constraints
- DMA used to access memory without CPU, especially helpful with real-time processing applications
- Sampled audio will go through the desired audio processing
- Modified digital signal sent to DAC and outputted to power amplifier

Echo

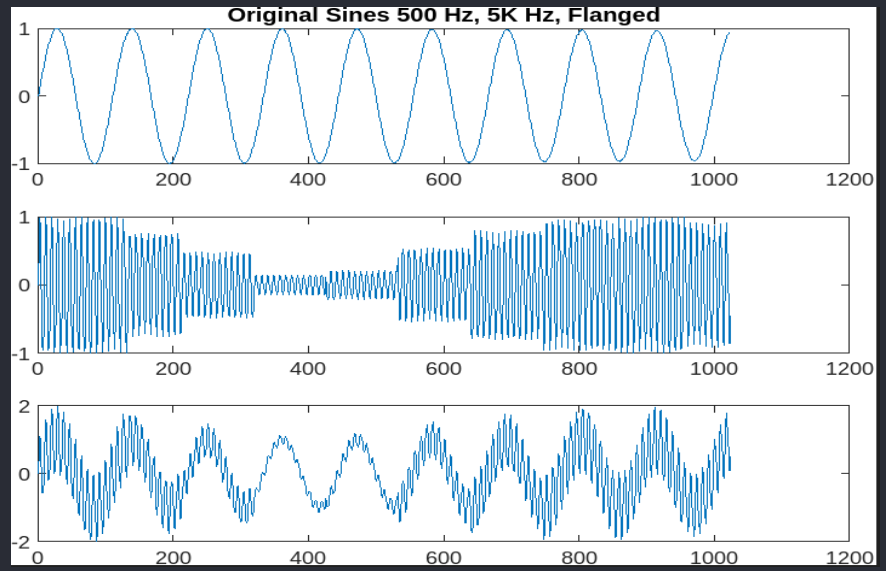
- Echo is produced by creating delays of 50ms or greater
- Does not distort the signal, only produces a fading effect
- Can be realized with the following difference equation

$$y(n) = x(n) + \alpha y(n - N)$$

Flanger

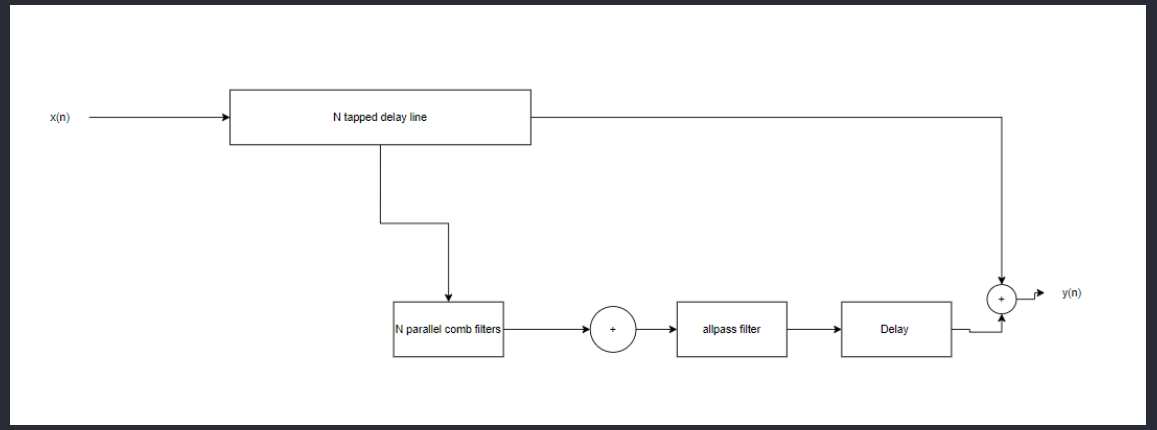
- Flanger produces a delay up to 15ms
- Signal is modulated with an LFO of around 1Hz
- Creates comb filter moving up and down the frequency spectrum

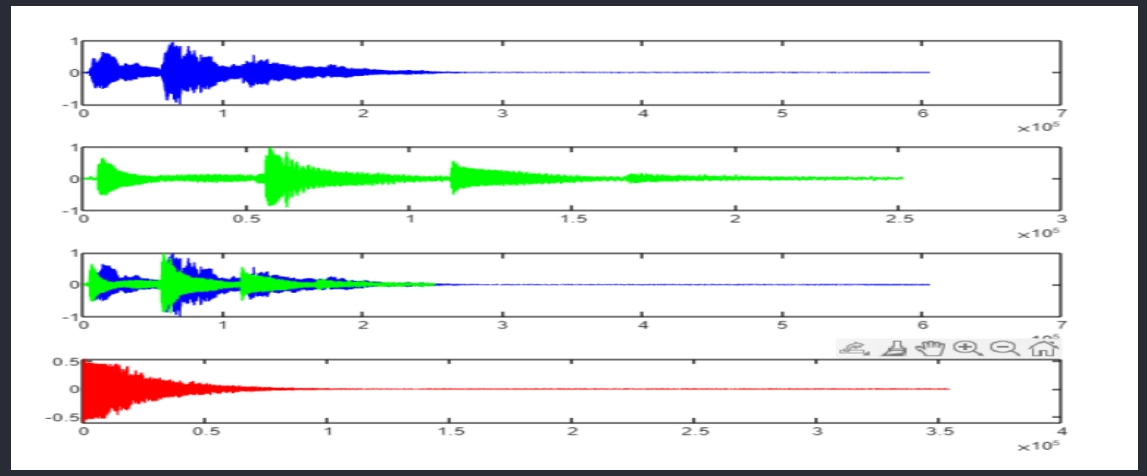
```
function [y] = flanger(x,Fs)
    delay=0.003; % sine wave delay
    lfofreq=.5; %frequency of 1Hz sine wave for modulation
    gain=0.5; % gain for forward feed and blend

    sampdel=(delay*Fs);
    sampledelay=(round(sampdel)); % number of samples neeed for delay

    y=zeros(length(x),1); % empty output array
    y(1:sampledelay)=x(1:sampledelay);
    for i= (sampledelay+1):length(x) % modulate for the number of samples needed for delay
        lfowave=(sin(2*pi*i*(lfofreq/Fs))); % create array for sine wave modulation
        abs_sin=abs(lfowave);
        sin_delay=ceil(abs_sin*sampledelay); %% creates delay

        y(i)=gain*x(i)+gain*(x(i-sin_delay)); %% feedforward and blend
        %x(i)=x(i)+gain*(x(i-sin_delay)); %% create feedback
    end
end
```



Reverberation

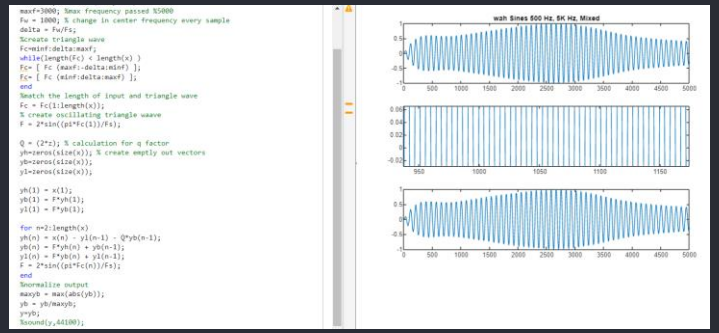
- Occurs due to the reflection and buildup of sound , which eventually fades as it is absorbed by objects
- Convolution reverb is the most authentic sounding, but needs impulse response
- Alternatively, use filter banks and delay lines

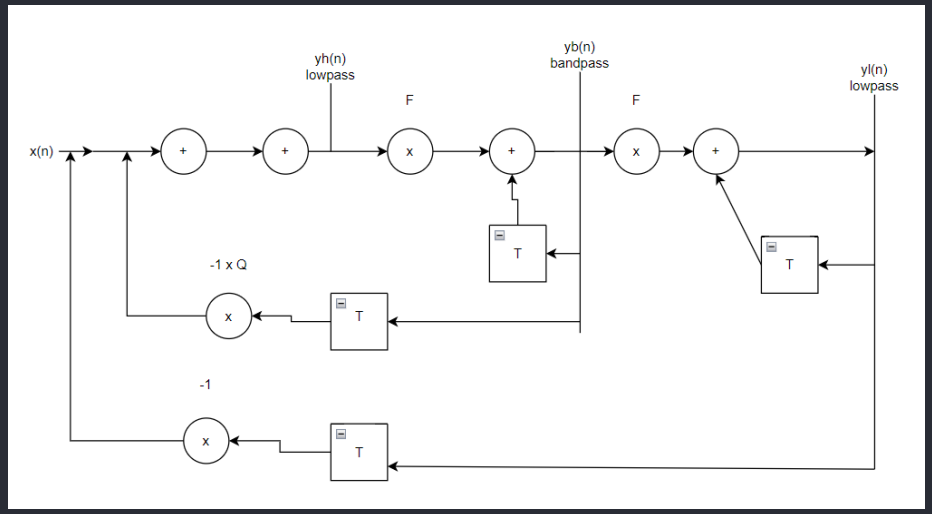




Wah-Wah

- Created by applying a narrow bandpass filter with varying center frequency
- The following block diagram and difference equations help make the effect realizable





$$yh(n) = x(n) - yl(n-1) - Q1 * yb(n-1);$$

$$yb(n) = F1 * yh(n) + yb(n-1);$$

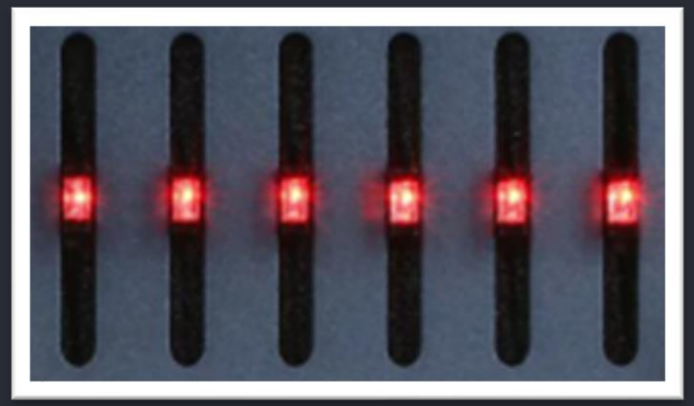
$$yl(n) = F1 * yb(n) + yl(n-1);$$

User Interface

- Amp Header
- Digital Effects
- Analog Effects

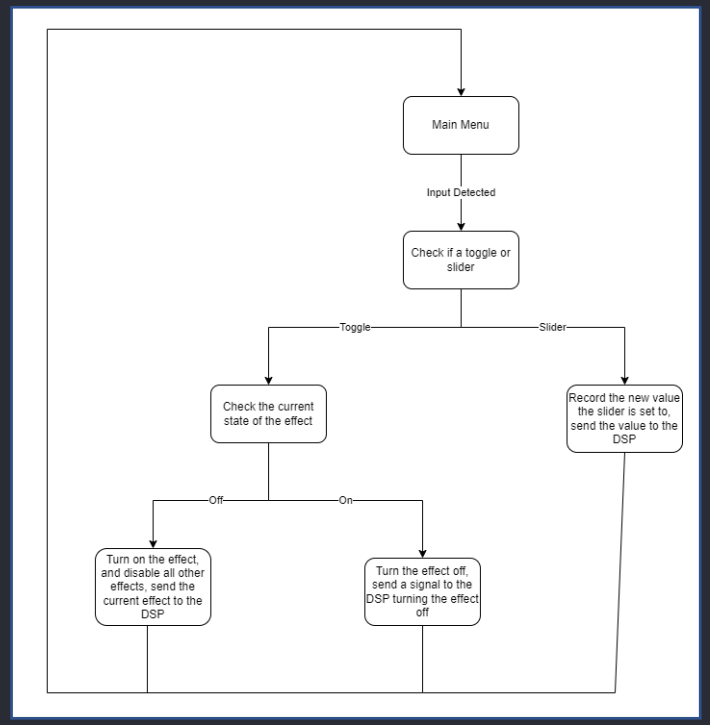
Amp Header Controls

- User will interface with the amp header controls using potentiometers



Digital Effects - Interface

- The digital effects will be interfaced with through a touch screen, handled by a microcontroller, which will pass the user inputs to the digital signal processor



Touchscreen

Part	Diagonal Size	Resolution	Screen/Overlay	Cost
ER-TP070-1	7 inch	N/A	Overlay	$9.39
2544-AFK800480A0-7.0N12NTM-R-ND	7 inch	800x480	Both	$36.04
AFY800480B0-5.0N12NTM-R	5 inch	800x480	Both	$31.62
ATM0500D27-T	5 inch	800x480	Both	$36.39
ER-TFT070-2	7 inch	800x480	Screen	$17.09
ER-TP050-2	5 inch	N/A	Overlay	$2.96
ER-TFT050-3	5 inch	800x480	Screen	$16.52
MSP4022	4 inch	480x320	Both	$11.83

Microcontroller

Part	Core Size	RAM	# of I/O	Cost
MSP430G2553IPW28R	16-bit	512 B	24	$3.18
ATSAM4LC4AA-MUR	32-bit	32 KB	27	$6.36
PIC24FJ256DA210T-I/PT	16-bit	96 KB	84	$11.35
MK70FN1M0VMJ15	32-bit	128 KB	128	$30.94
MSP430FR6989IPZR	16-bit	2 KB	83	$12.12
ESP-WROOM-32	32-bit	520 kB	39	$5.99

Analog Effects - Interface

- The analog effects will be interfaced with through pedal boxes which are equipped with switches and potentiometers

Housing

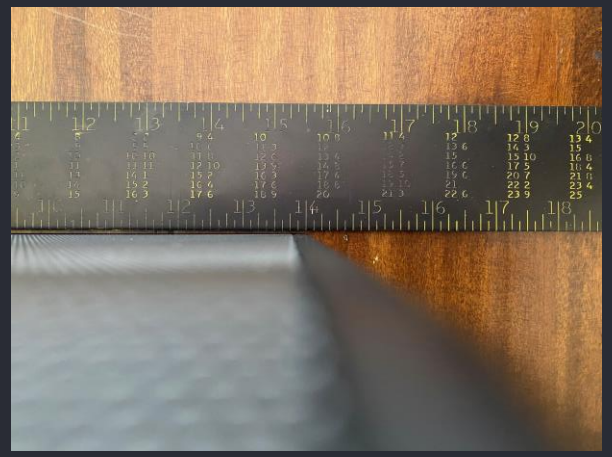
- Chose CoolerMaster NR200
- Modified to accommodate amp interface controls and I/O

Engineering Specification Testing

1. Physical Features
2. Output Power Rating
3. Frequency Response
4. Total Harmonic Distortion
5. Signal to Noise Ratio

Physical Features

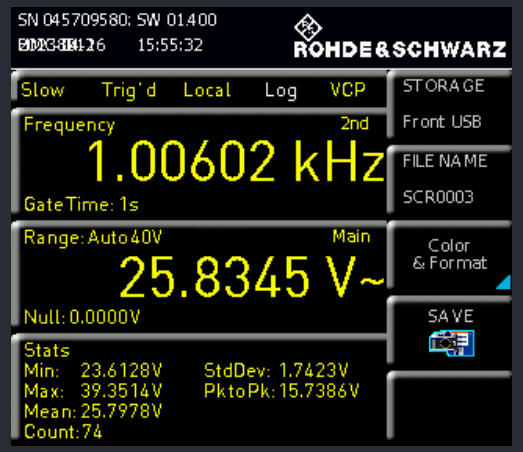
- Size : 14" x 7" x 11.5"
- Weight : 9.8lb*

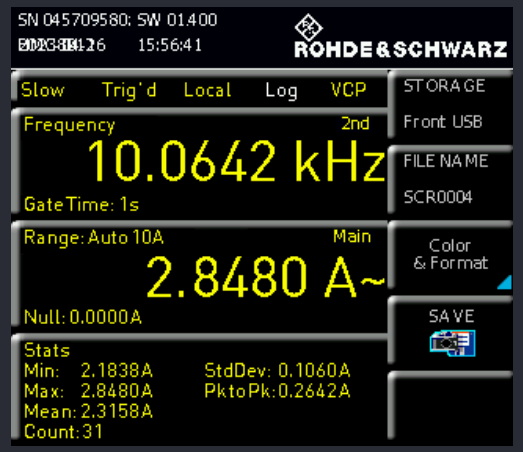


- * Average value after 5 runs

Output Power Rating

- Targeted Output Power Rating of 70w @ 8Ω
- Measured Output Power Rating of 73.576w @ 8Ω





*Average values after 5 runs

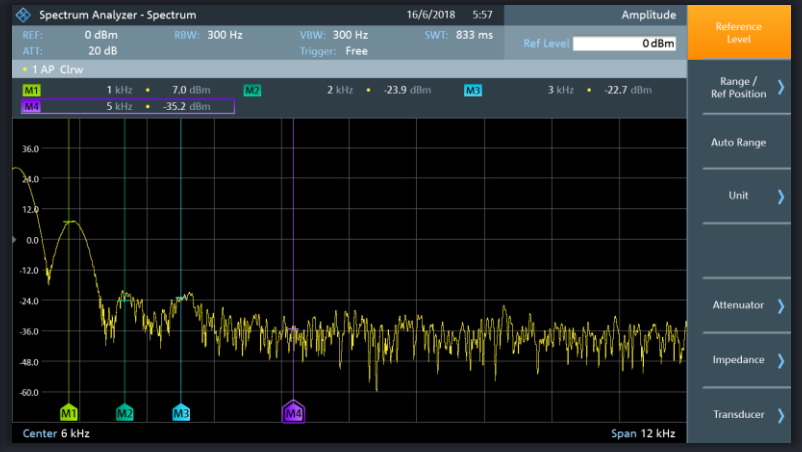
Frequency Response

- Targeted Frequency Response: 31Hz – 4.5kHz

Total Harmonic Distortion

- Targeted THD of 2% @ 1kHz
- Measured THD of 1.499% @ 1kHz

Frequency (kHz)	Measured dBm		
1	7.7	0.005888437	
2	-30	0.000001	
3	-38	1.58489E-07	
4	-40	0.0000001	
5	-43	5.01187E-08	
6	-50	0.00000001	
7	-53	5.01187E-09	
			1.32362E-06
			0.000224783
			0.014992762
		Total Harmonic Distortion	1.499276198



Signal to Noise Ratio

- Targeted SNR of 80db
- Measured SNR of 87.036

Noise Power (W)	0.0512
Signal Power (W)	4.456254691
SNR (dB)	87.03622443

* Average values after 5 runs

Work Distribution

	Pre-Amplifier	Equalizer	Power Amplifier	Power Supply	Analog Effects	Digital Effects	User Interface
Kris			X		X		X
Armon						X	
James	X	X	X	X			
Jeremy				X	X		

Budget

Item	Supplier	Price/Unit	# of Units	Total Cost
Pre-Amplifier				
Resistors	Mouser	$10.02	1	$10.02
Capacitors	Mouser	$8.95	1	$8.95
LM393	Mouser	$0.53	1	$0.53
OPA1642	Mouser	$2.98	1	$2.98
BS170	Mouser	$0.43	1	$0.43
NE5532	Mouser	$1.78	6	$10.68
Pots	Mouser	$10.00	1	$10.00
Misc		$10	1	$10.00
PCB	JLCPCB	$9.50	1	$9.50
Assembly	JLCPCB	$32.67	1	$32.67
Total Cost				$95.76

Item	Supplier	Price/Unit	# of Units	Total Cost
Power Amplifier				
Resistors	Mouser	$2.20	1	$2.20
Capacitors	Mouser	$10.81	1	$10.81
TDA7294	Mouser	$10.46	1	$10.46
Misc		$5	1	$5.00
PCB	JLCPCB	$2	1	$2.00
Assembly	JLCPCB	$10.24	1	$10.24
Total Cost				$40.71

Item	Supplier	Price/Unit	# of Units	Total Cost
Power Supply				
Component	Mouser	$48.23	1	$48.23
LM317	Mouser	$1.48	4	$5.92
LM337	Mouser	$0.96	1	$0.96
Misc		$10	1	$10.00
PCB	JLCPCB	$4.00	1	$4.00
Total Cost				$69.11

Item	Supplier	Price/Unit	# of Units	Total Cost
User Interface				
ESP-32-WRC	Amazon	$6.99	1	$6.99
TFT Touchsc	AliExpress	$12.00	1	$12.00
Misc	Mouser	$15.00	1	$15.00
				$0.00
				$0.00
				$0.00
				$0.00
Total Cost				$33.99

Item	Supplier	Price/Unit	# of Units	Total Cost
Effect Pedals				
PCB	JLCPCB	$4.00	3	$12.00
Resistors	Mouser	$11.23	1	$11.23
Capacitors	Mouser	$15.43	1	$15.43
Transistors	Ebay	$19.00	1	$19.00
Op Amps	Mouser	$10.00	1	$10.00
MCU	STM	$15.00	1	$15.00
				$0.00
Total Cost				$82.66

Item	Supplier	Price/Unit	# of Units	Total Cost
Other				
Case	Amazon	$52.00	1	$52.00
Connectors	Amazon	$10	1	$10.00
Wire	Amazon	$10.00	1	$10.00
Switches	Amazon	$20	1	$20.00
Misc		$30.00	1	$30.00
Shipping		$50.00	1	$50.00
Total Cost				$172.00

Total Cost: $494.23

Conclusions

- We succeeded in building an affordable all-in-one bass guitar amplifier
- Working amplification, equalizer, and interface fully integrated.
- Partially working digital and analog effects

Future Work:

- Bluetooth compatibility
- Additional effects
- Improve overall functionality of individual components integration