Mastering Electronics Extra Credit Project

12/15/2023

Zeyn Schweyk

3-Band Audio Equalizer Circuit Report

YouTube Demo

I created a 3-Band Audio Equalizer Circuit which is a network of three buffers, three passive filters, three variable resistors, and a summation amplifier, which all boost and/or cut bass, mid, and treble frequencies of an audio signal. As a musician myself, and by looking up the standard frequency ranges that are typically associated with low, mid, and high frequencies, I was able to choose my resistor and capacitor values accordingly by using the formula for a high/low pass filter: f = 1/(2*pi*R*C)

Low Frequencies: 0Hz – 312 Hz

Mid Frequencies: 312Hz – 3882Hz

High Frequencies: 3882Hz - infinity

Although the cutoff frequency formula for a low-pass and high-pass filter are the same, their meanings are slightly different. A low-pass filter passes signals below its cutoff frequency and attenuates all signals above it. A high-pass filter passes signals above its cutoff frequency and attenuates all signals below it. With these definitions, a low-pass filter would allow low frequencies to pass through, while a high-pass filter would allow high frequencies to pass through.

In order to filter the input signal for mid-range frequencies between 312Hz and 3882Hz, I used a band-pass filter, which is a low-pass and high-pass filter connected in series. To attenuate frequencies below 312Hz, I used a high-pass filter. To attenuate frequencies above 3882Hz, I used a low-pass filter.

Since I only had a handful of 0.1 micro-Farad capacitors, they were my limiting component, so I chose my resistors based off them. Re-arranging the equation above, R = 1/(2*pi*f*C), and with each filter using a 0.1 micro-Farad capacitor…

Filter	Cutoff Frequency	Resistance Necessary
Low-Pass	312Hz	1/(2*pi*312*(.1*10^-6)) = 5100 Ohms
High-Pass	3882Hz	1/(2*pi*3882*(.1*10^-6)) = 410 Ohms
Band-Pass (Low Pass Filter)	3882Hz	1/(2*pi*3882*(.1*10^-6)) = 410 Ohms
Band-Pass (High Pass Filter)	312Hz	1/(2*pi*312*(.1*10^-6)) = 5100 Ohms

I did not have 410 Ohm resistors available to me, so I instead placed two 820 Ohm resistors in parallel in place of each 410 Ohm resistor.

Next, as shown in the Block Diagram and Schematic below, the three variable resistors serve to diminish the amplitude of the output signals from the high, band, and low pass filters, while simultaneously adjusting the gain of the summation operational amplifier. What's interesting is that when turning the knob of one of the variable resistors to increase its resistance, the gain of the summation amplifier actually decreases. As the Schematic below shows, the three variable resistors are connected in parallel and the outputs of all three filters are connected to the summation amplifier. The output voltage of this amplifier is

$$-Vout = (R10 / R7) * V1 + (R10 / R8) * V2 + (R10 / R9) * V3$$

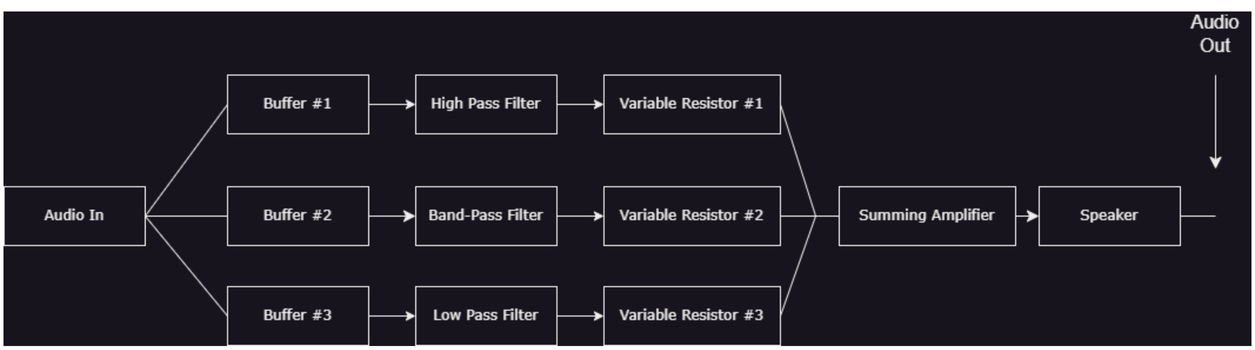
where R7, R8, and R9 are variable resistors, and V1, V2, and V3 are the voltages outputs from each of the filters. Assuming V1, V2, and V3 are held constant, if you increase one of the variable resistors, the gain decreases. If you decrease one of the variable resistors, the gain increases.

Since it is known that audio signals operate at very low voltages, in the milli-Volt range, I experimentally chose my potentiometers to have max resistances of 10K Ohms, the smallest of all the potentiometers I had available to me. This luckily proved to work out nicely.

As the Bode plot shows in the Simulation, the band-pass filter attenuates frequencies within the valid range of 312Hz – 3882Hz by about -7db. This is not typical behavior, as frequencies within that range should not be attenuated at all. As the high-pass and low-pass attenuation functions show, the frequencies above and below their cutoffs respectively do not have diminished volume, which is expected. I was able to notice and verify these behaviors in my circuit as well.

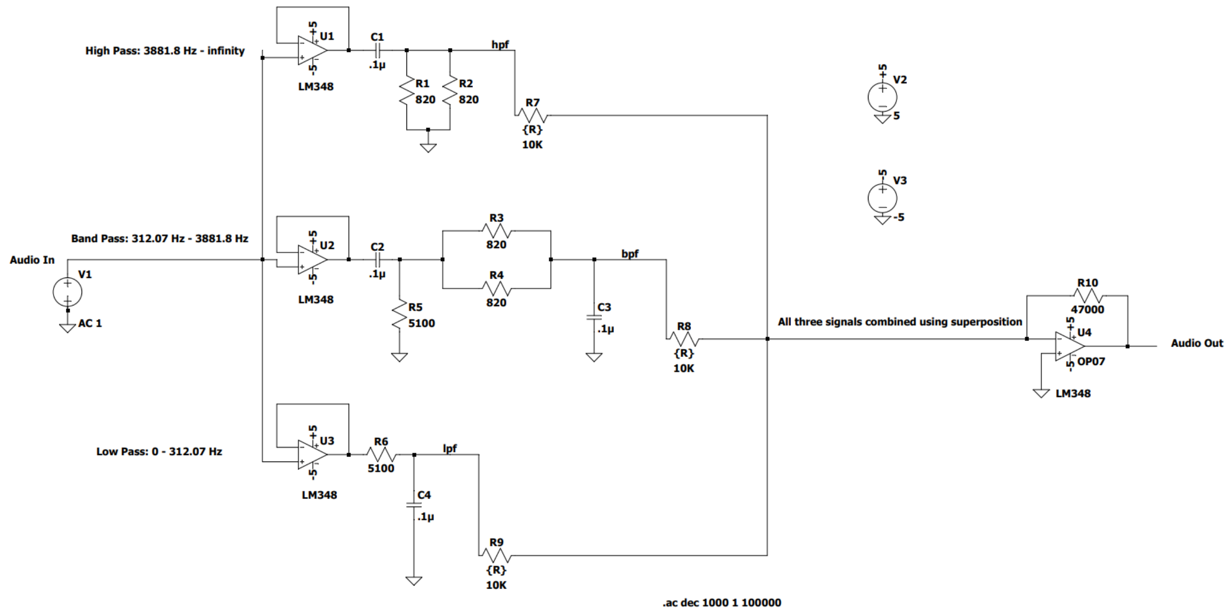
I noticed that my filters did not do a particularly good job at filtering frequencies immediately above or below a cutoff frequency. While testing my circuit's performance, I noticed how adjusting my band-pass variable resistor for a close enough low range frequency would slightly alter the amplitude of the signal. This is most likely due to the fact that I only used first-order filters, and had I connected multiple of the same filters together, I would have seen much sharper cutoffs in the Bode plots.

Block Diagram



Schematic

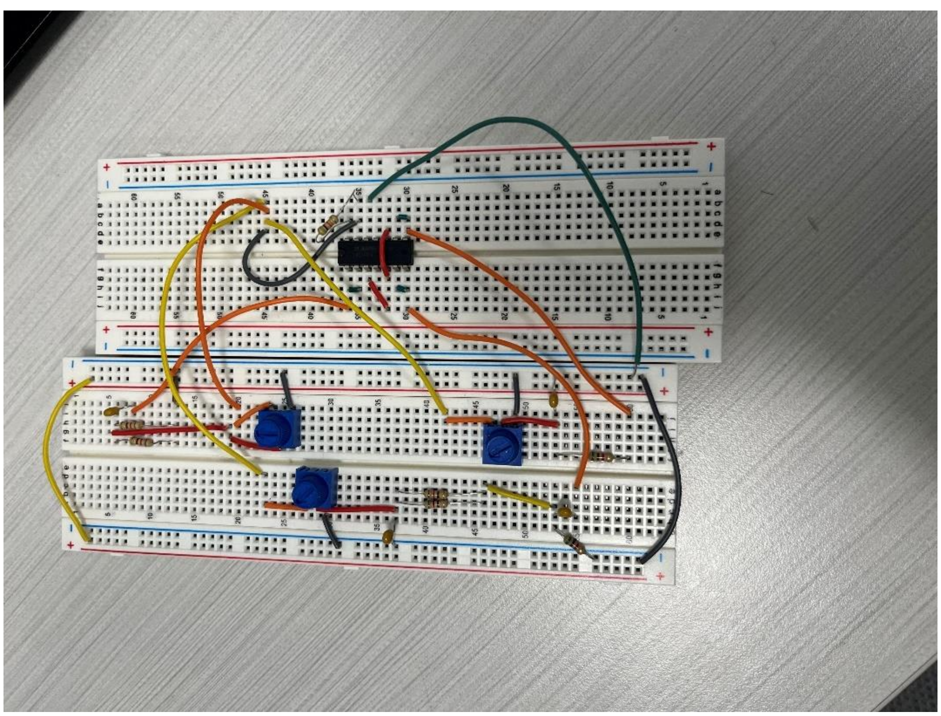
3-Band Audio Equalizer Schematic - Zeyn Schweyk

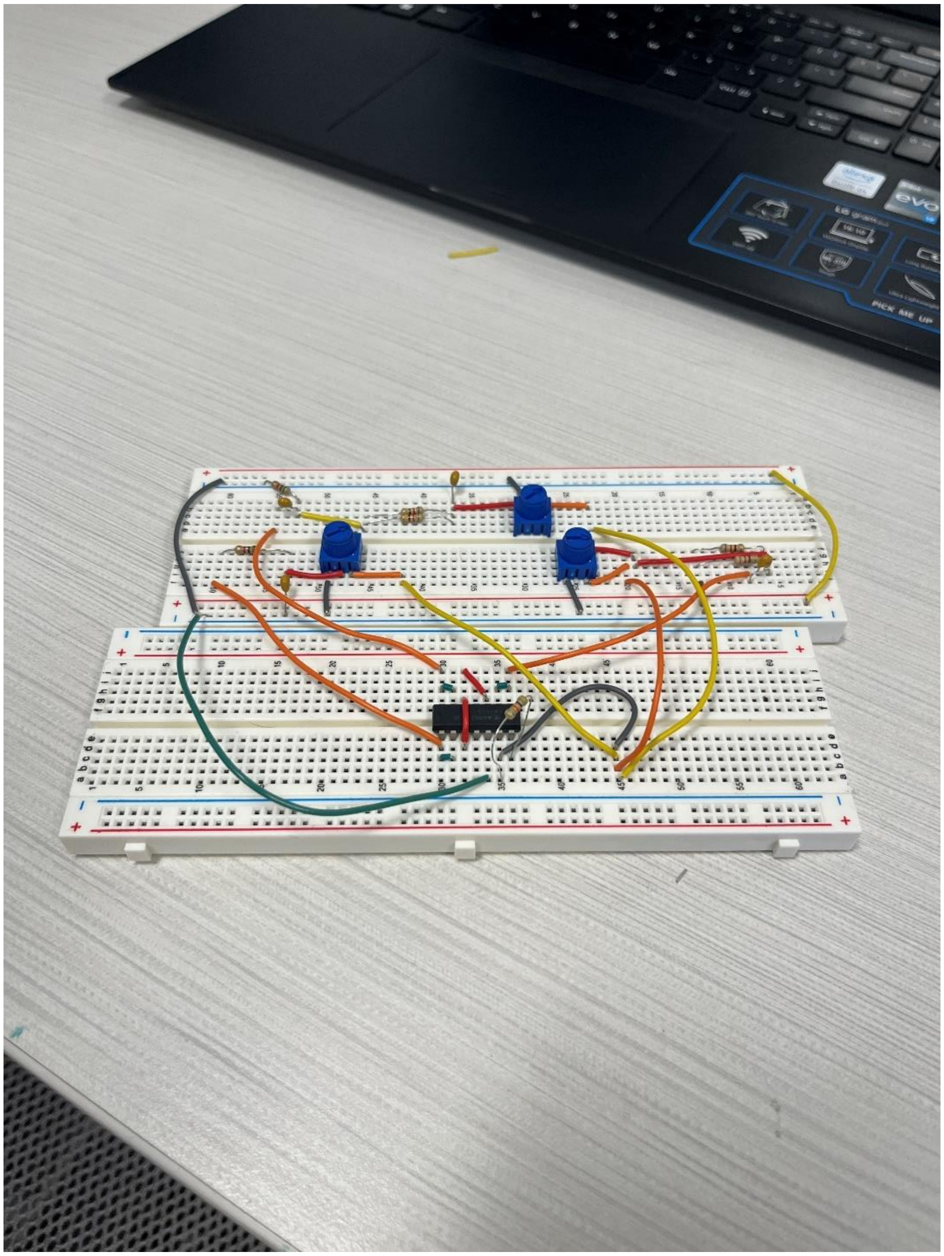


C1, C2, C3, C4; Cermamic Capacitor Multilayer Monolithic .1 uF 50V 125C 10% X7R 5mm; ELCAP-MLC-50V-.1U-03
R1, R2, R3, R4; Resistor Carbon Film 820 Ohm 1/4W, 5%; RES-010-00450-EH
R5, R6; Resistor Carbon Film 5.1K Ohm 1/4W, 5%; ELRES-CF1/4W-5%-5.1K-03
R7, R8, R9**; 3386P - Trimmer Resistor - Through Hole 3/8" 10K Ohms Single Turn 10% Top Knob; 3386P-1-103TLF-EL
R10; Resistor Carbon Film 47K Ohm 1/4W, 5%; RES-010-00660-EH
LM348N; Quad general purpose 36V operational amplifier PDIP 14

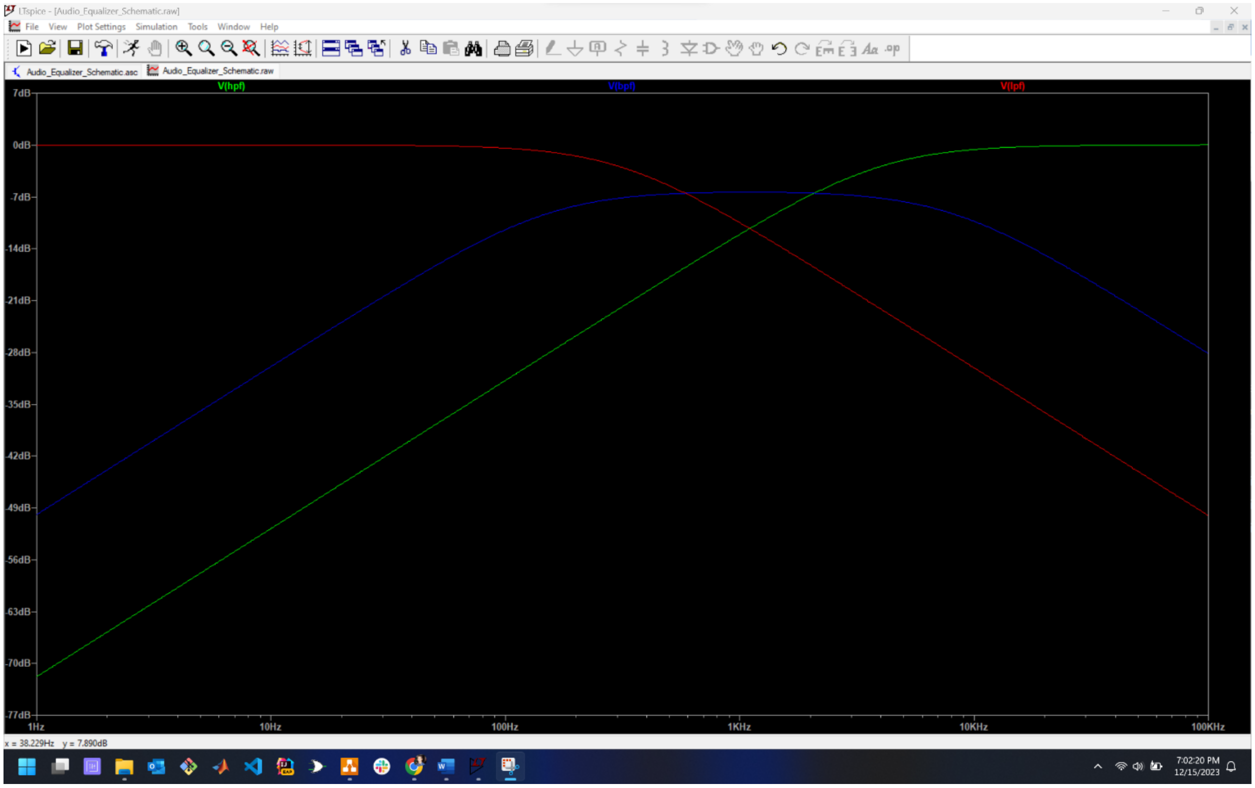
** R7, R8, R9 are actually 3-terminal components connected to GND, INPUT, and OUTPUT. Only 2 terminals (INPUT and OUTPUT) are shown in the circuit for simplicity

Photos of Circuit



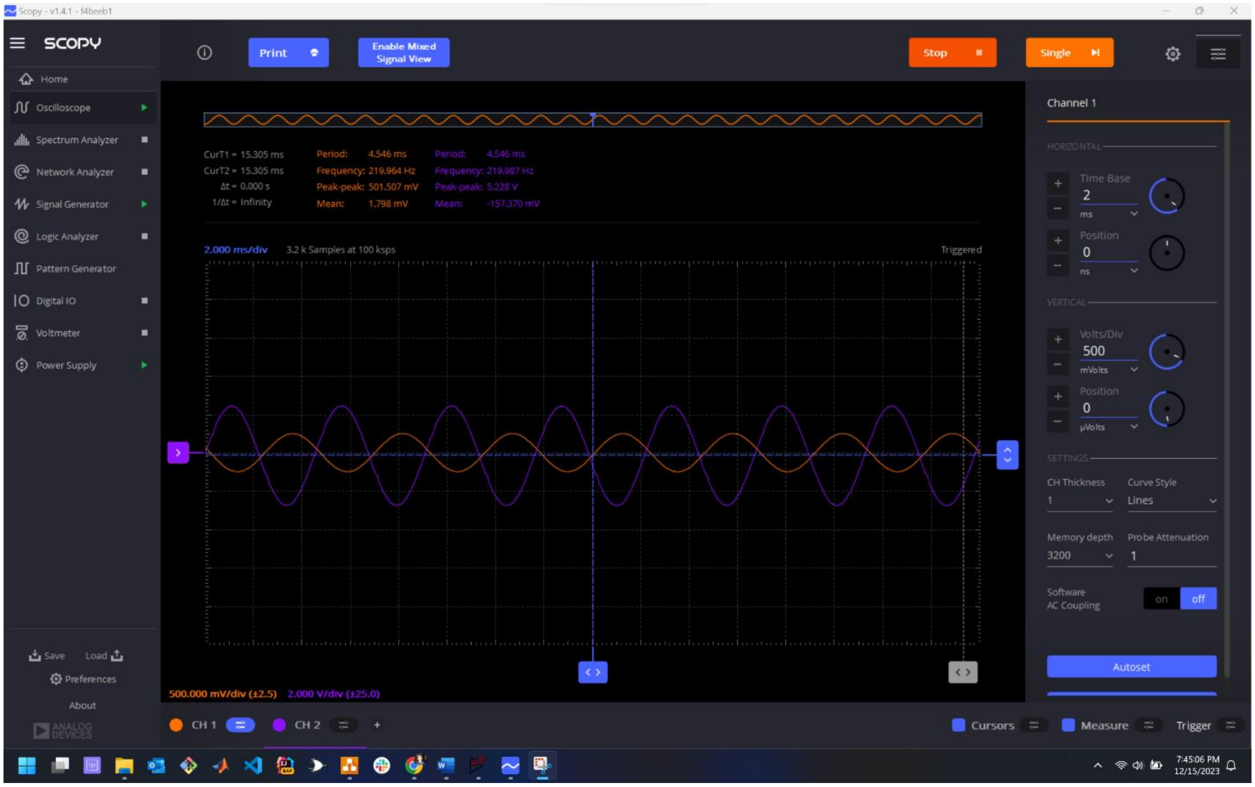


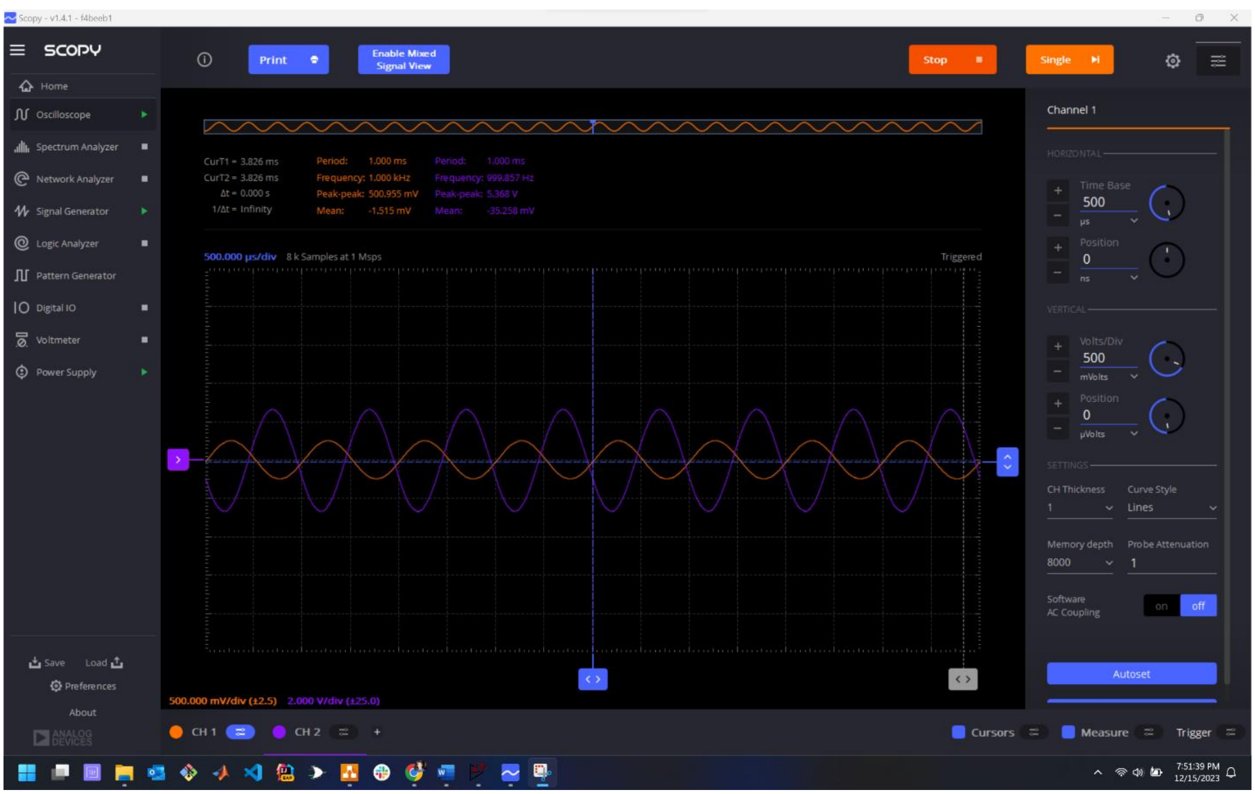
Simulation

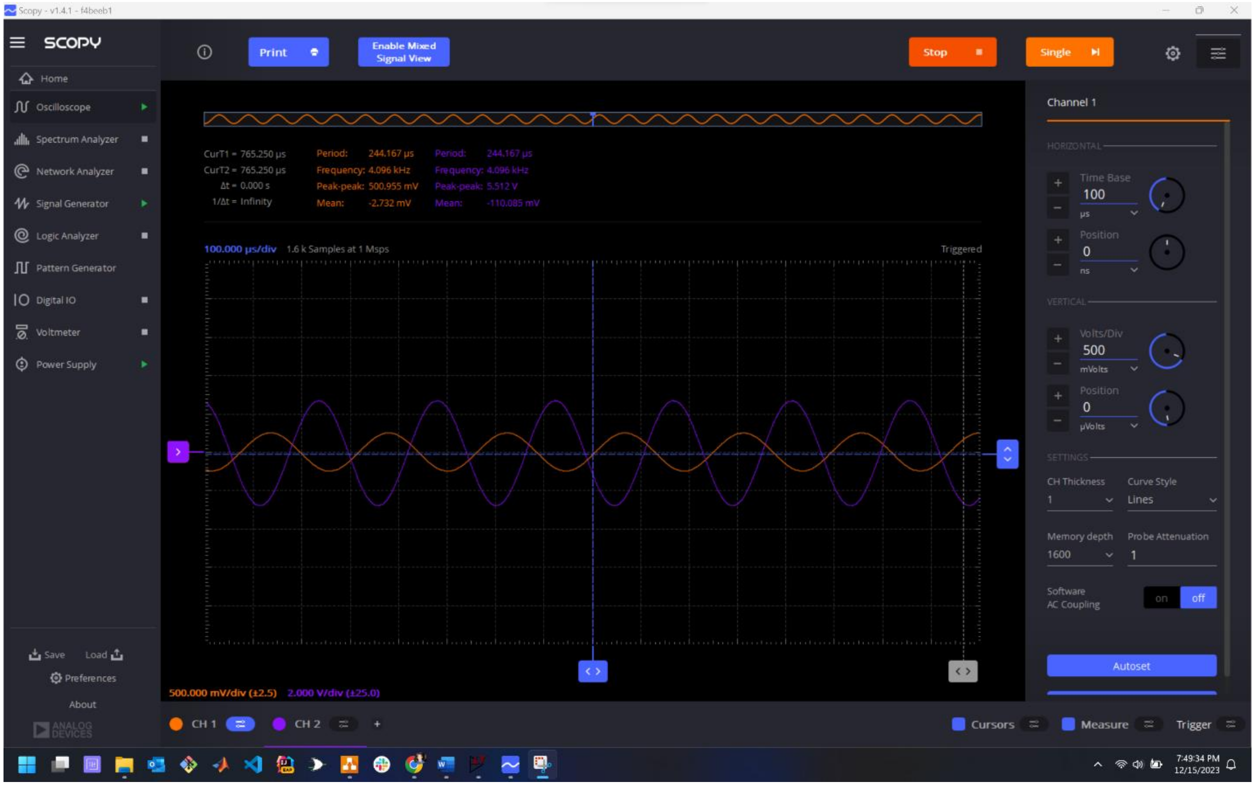


LTspice - [Audio_Equalizer_Schematic.raw]
File View Plot Settings Simulation Tools Window Help
Audio_Equalizer_Schematic.asc
Audio_Equalizer_Schematic.raw
V(hpf)
V(bpf)
V(lpf)
7dB
0dB
-7dB
-14dB
-21dB
-28dB
-35dB
-42dB
-49dB
-56dB
-63dB
-70dB
-77dB
1Hz
10Hz
100Hz
1KHz
10KHz
100KHz
x = 38.229Hz y = 7.890dB
7:02:20 PM
12/15/2023

Low-Pass, Band-Pass, and High-Pass Scopy Screenshots






Scopy - v1.4.1 - f4beeb1
SCOPY
Print
Enable Mixed Signal View
Stop
Single
Home
Oscilloscope
Spectrum Analyzer
Network Analyzer
Signal Generator
Logic Analyzer
Pattern Generator
Digital IO
Voltmeter
Power Supply
CurT1 = 765.250 µs
CurT2 = 765.250 µs
Δt = 0.000 s
1/Δt = Infinity
Period: 244.167 µs
Frequency: 4.096 kHz
Peak-peak: 500.955 mV
Mean: -2.732 mV
Period: 244.167 µs
Frequency: 4.096 kHz
Peak-peak: 5.512 V
Mean: -110.085 mV
100.000 µs/div 1.6 k Samples at 1 Msps
Triggered
500.000 mV/div (±2.5) 2.000 V/div (±25.0)
Channel 1
HORIZONTAL
Time Base
100
µs
Position
0
ns
VERTICAL
Volts/Div
500
mVolts
Position
0
µVolts
SETTINGS
CH Thickness
1
Curve Style
Lines
Memory depth
1600
Probe Attenuation
1
Software AC Coupling
on
off
Autoset
Save
Load
Preferences
About
CH 1
CH 2
Cursors
Measure
Trigger
7:49:34 PM
12/15/2023