THREE-BAND HEARING AID

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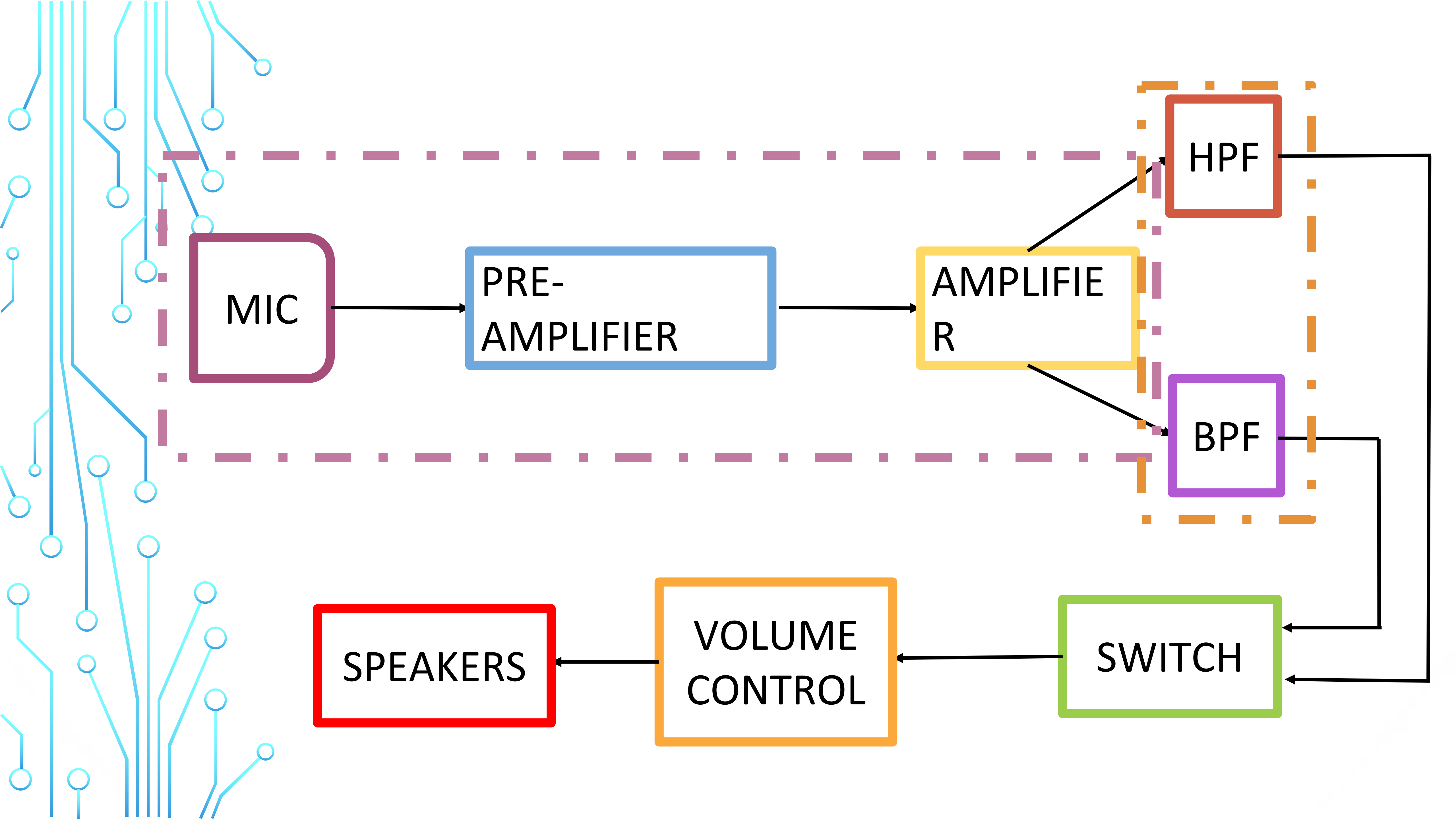
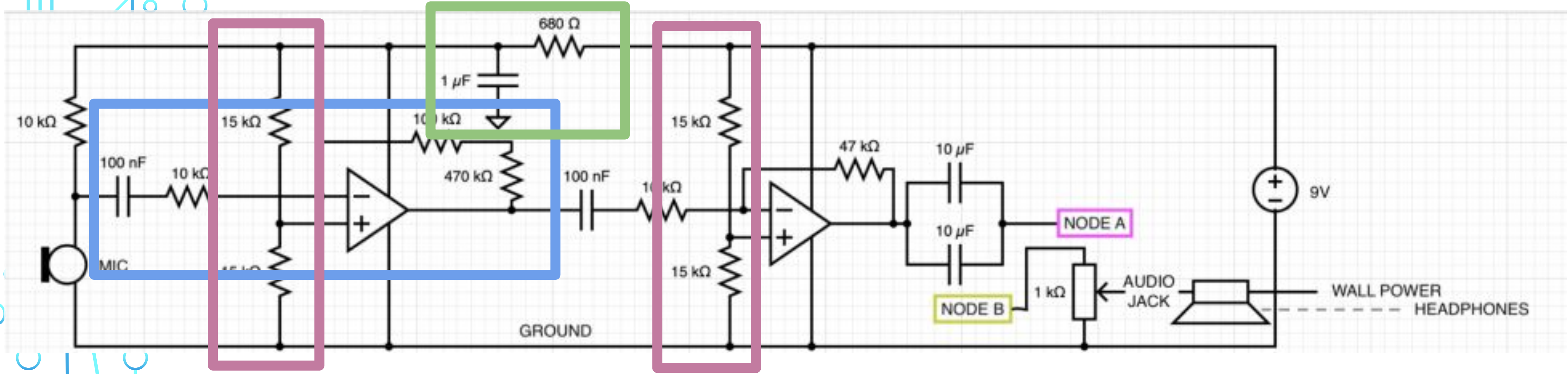
Background

- Normal human hearing range
  - 0-20 dB
  - 20-20,000 Hz
- Hearing loss occurs for many reasons
  - Age
  - Noise-induced damage
  - Genetics
- **High-frequency** hearing loss is the most common
  - Women/children's voices
  - Birds chirping
  - Words that end with s, th, h, f
- Two types of hearing aids
  - **Analog**
  - Digital
- Hearing aids typically have **20** bands

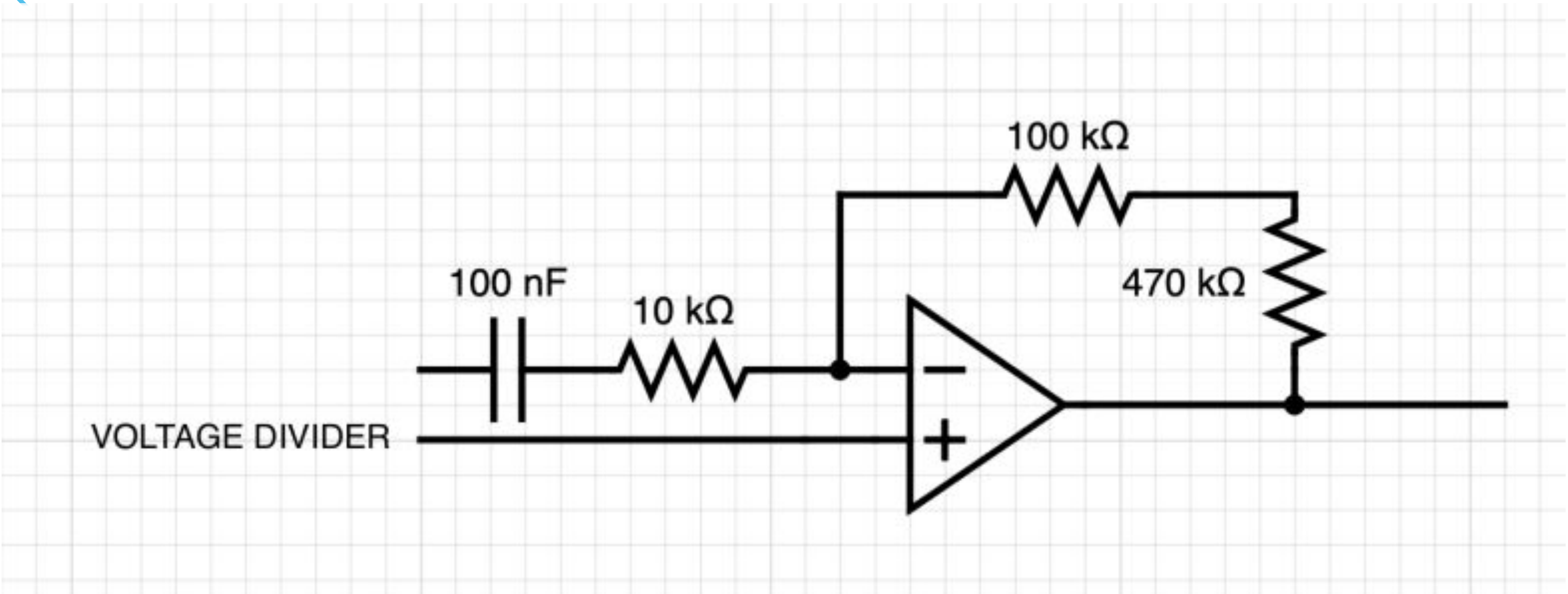
Block Diagram


MIC
PRE-AMPLIFIER
AMPLIFIE R
HPF
BPF
SWITCH
VOLUME CONTROL
SPEAKERS

Circuit Schematic



680 Ω
1 μF
10 kΩ
15 kΩ
100 kΩ
100 nF
10 kΩ
470 kΩ
100 nF
10 kΩ
15 kΩ
47 kΩ
10 μF
10 μF
NODE A
9V
MIC
15 kΩ
NODE B
1 kΩ
AUDIO
JACK
WALL POWER
HEADPHONES
GROUND

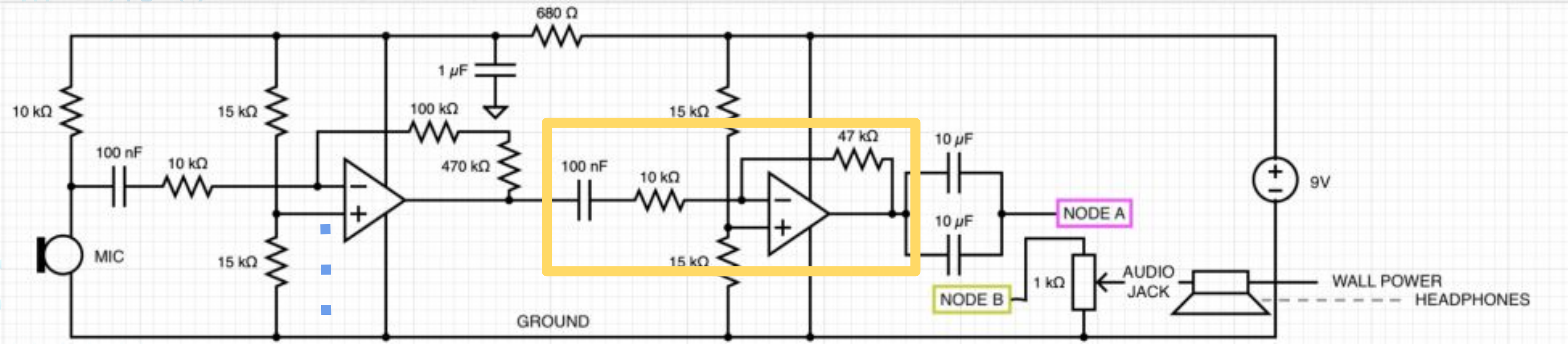


HIGH PASS FILTER

GAIN = 570kΩ/10kΩ = 57

CUTOFF FREQUENCY = $\dfrac{1}{2\pi(100*10^{-9})(10*10^{3})}$

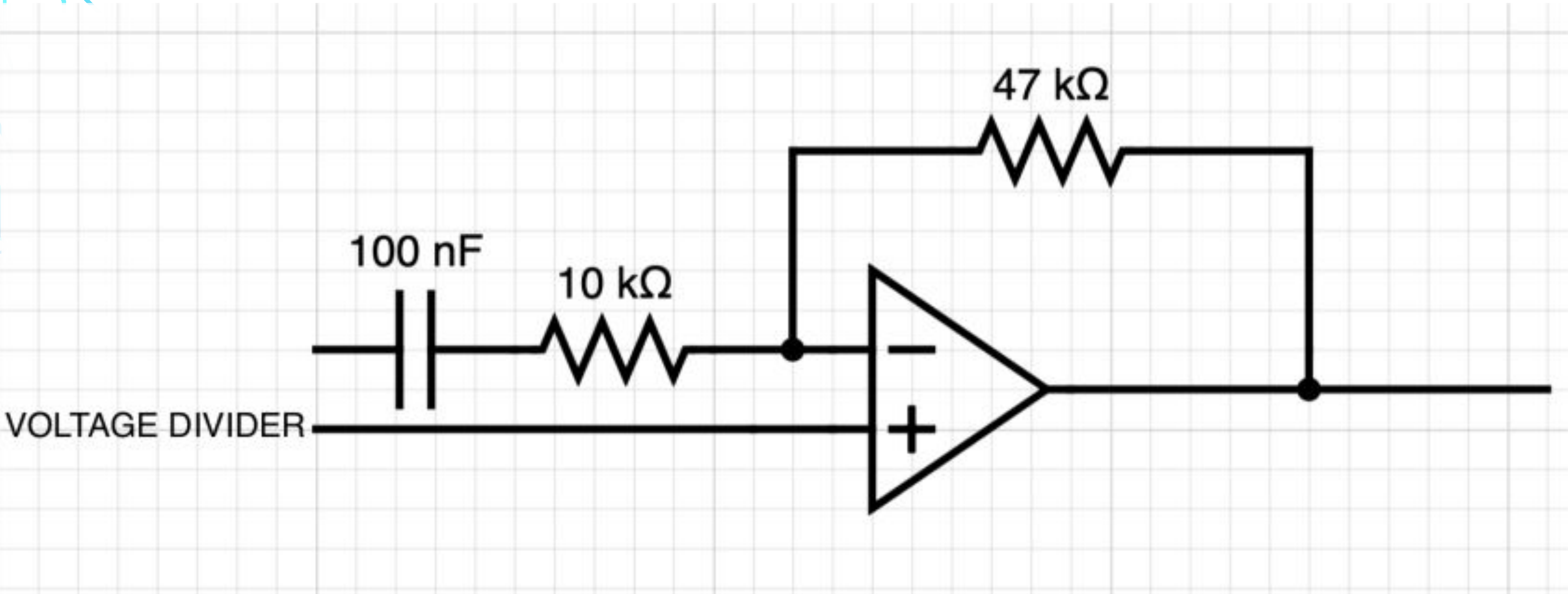
= 159 Hz



HPF #1

Gain: 57

f_c= 159 Hz

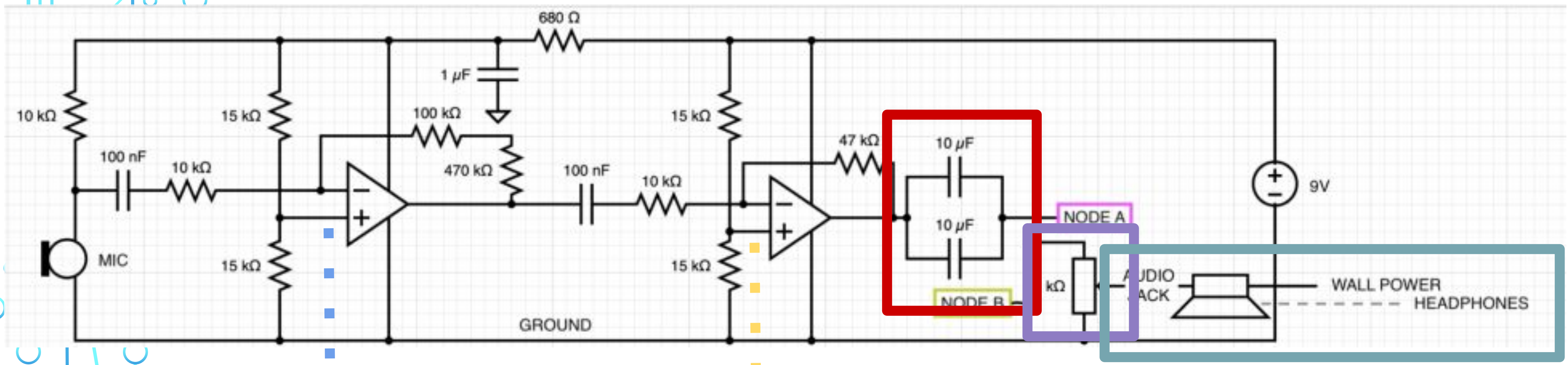


HIGH PASS FILTER

GAIN = 47kΩ/10kΩ = 4.7

$$\text{CUTOFF FREQUENCY} = \frac{1}{2\pi(100*10^{-9})(10*10^{3})}$$

$$= 159 \text{ Hz}$$



HPF #1

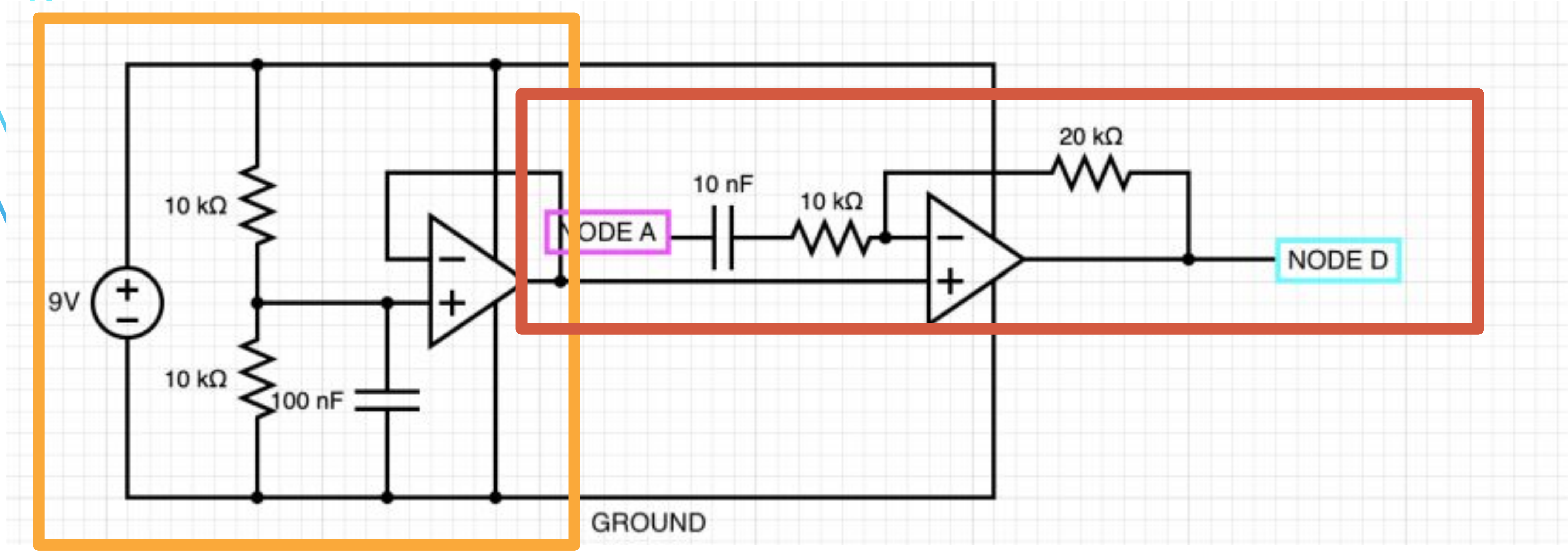
Gain: 57

f_c= 159 Hz

HPF #2

Gain: 4.7

f_c= 159 Hz



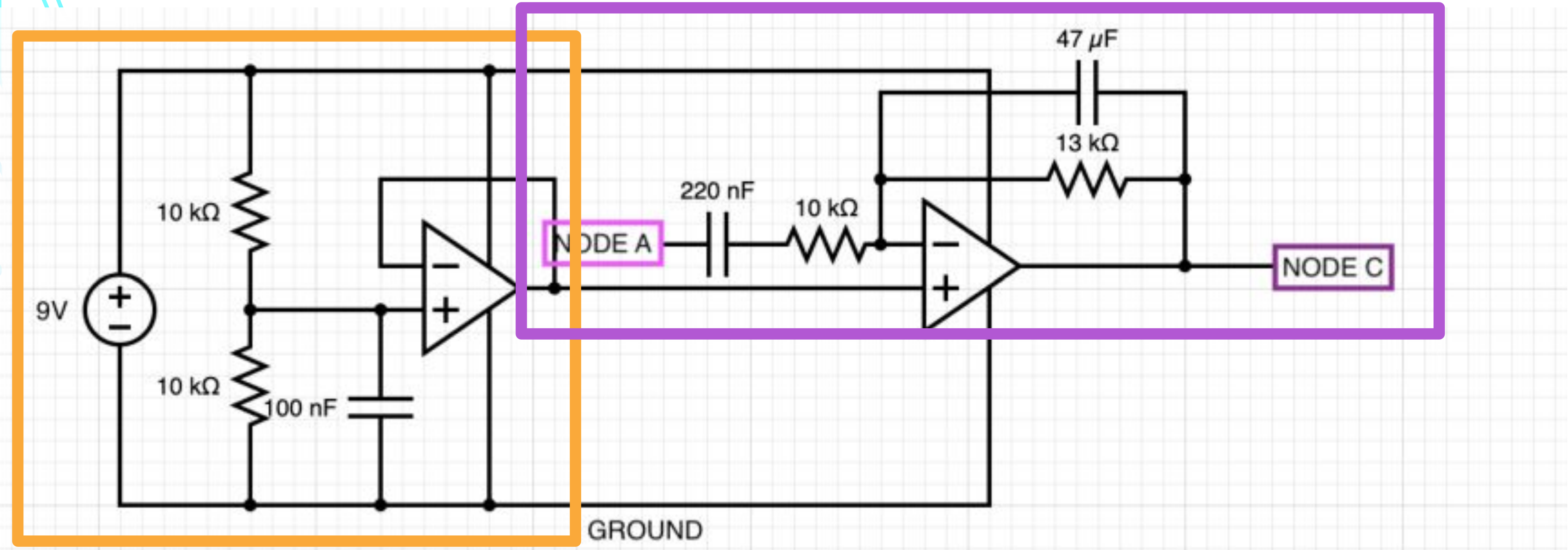
VOLTAGE DIVIDER

HIGH PASS FILTER

GAIN = 20kΩ/10kΩ = 2

CUTOFF FREQUENCY = $\frac{1}{2\pi(10*10^{-9})(10*10^{3})}$

= 1591 Hz



VOLTAGE DIVIDER

BAND-PASS FILTER

GAIN = 13kΩ/10kΩ = 1.3

LOW CUTOFF FREQUENCY = $\dfrac{1}{2\pi(220*10^{-9})(10*10^{3})}$ = 72 Hz

HIGH CUTOFF FREQUENCY = $\dfrac{1}{2\pi(47*10^{-6})(13*10^{3})}$ = 260 Hz

HPF #1

Gain: 57

f_c= 159 Hz

COMBINED

+

Gain: 267.9

f_c= 159 Hz

HPF #2

Gain: 4.7

f_c= 159 Hz

optional filters

HPF #3

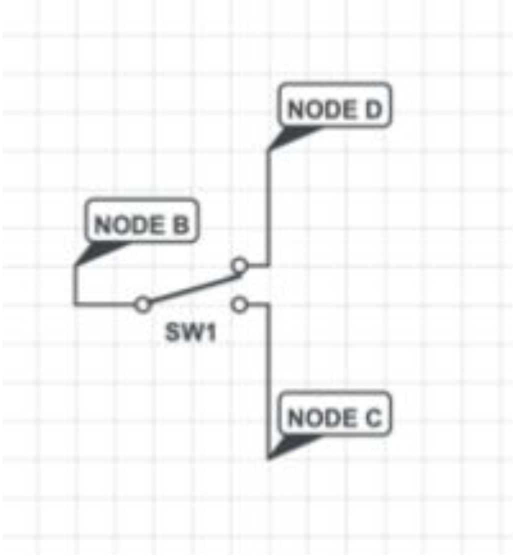
Gain: 2

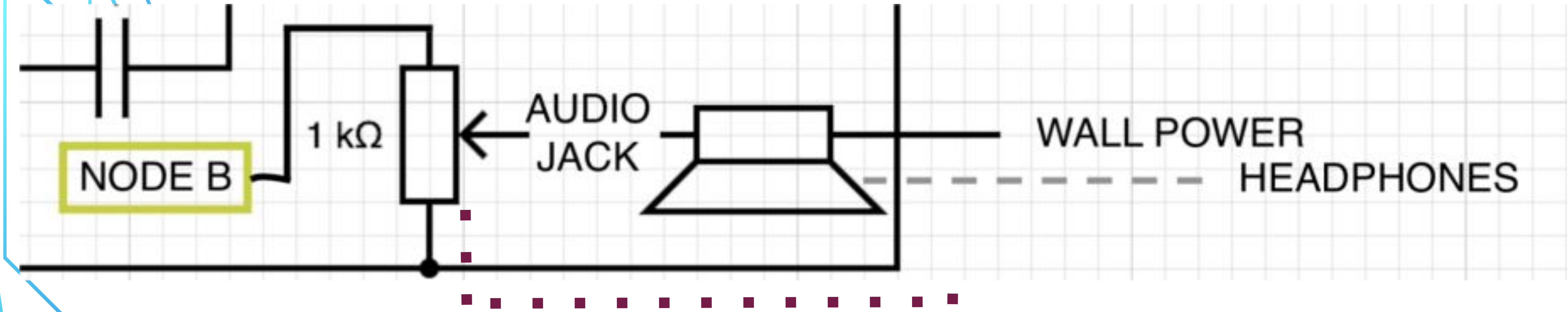
f_c= 1591 Hz

BPF

Gain: 1.3

f_c= 72 & 260 Hz





PREVIOUS CALCULATED GAIN + ADDITIONAL GAIN FROM THE POTENTIOMETER = OUTPUT

Test Case Demonstration

Motivation & Goal

Motivation:

★ Different filters work differently and properly.

Procedures:

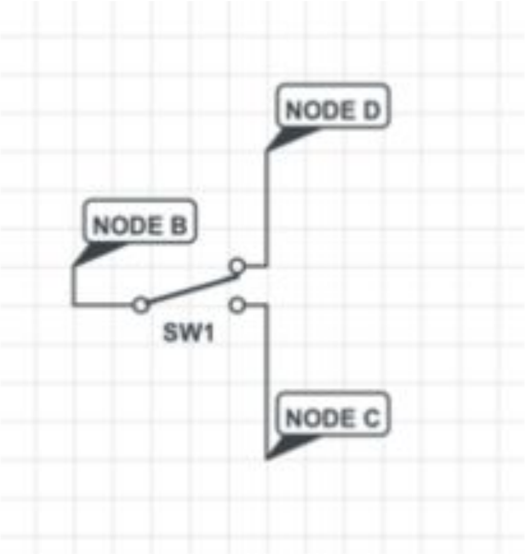
➔ Use function generator instead of the microphone
➔ Feed with different frequencies from 50-7000 Hz

Criteria for success:

❑ Correct Gain Frequency Response + Bode Plots
❑ Hear & Visualize the amplified signal

Hear the frequencies!

BPF

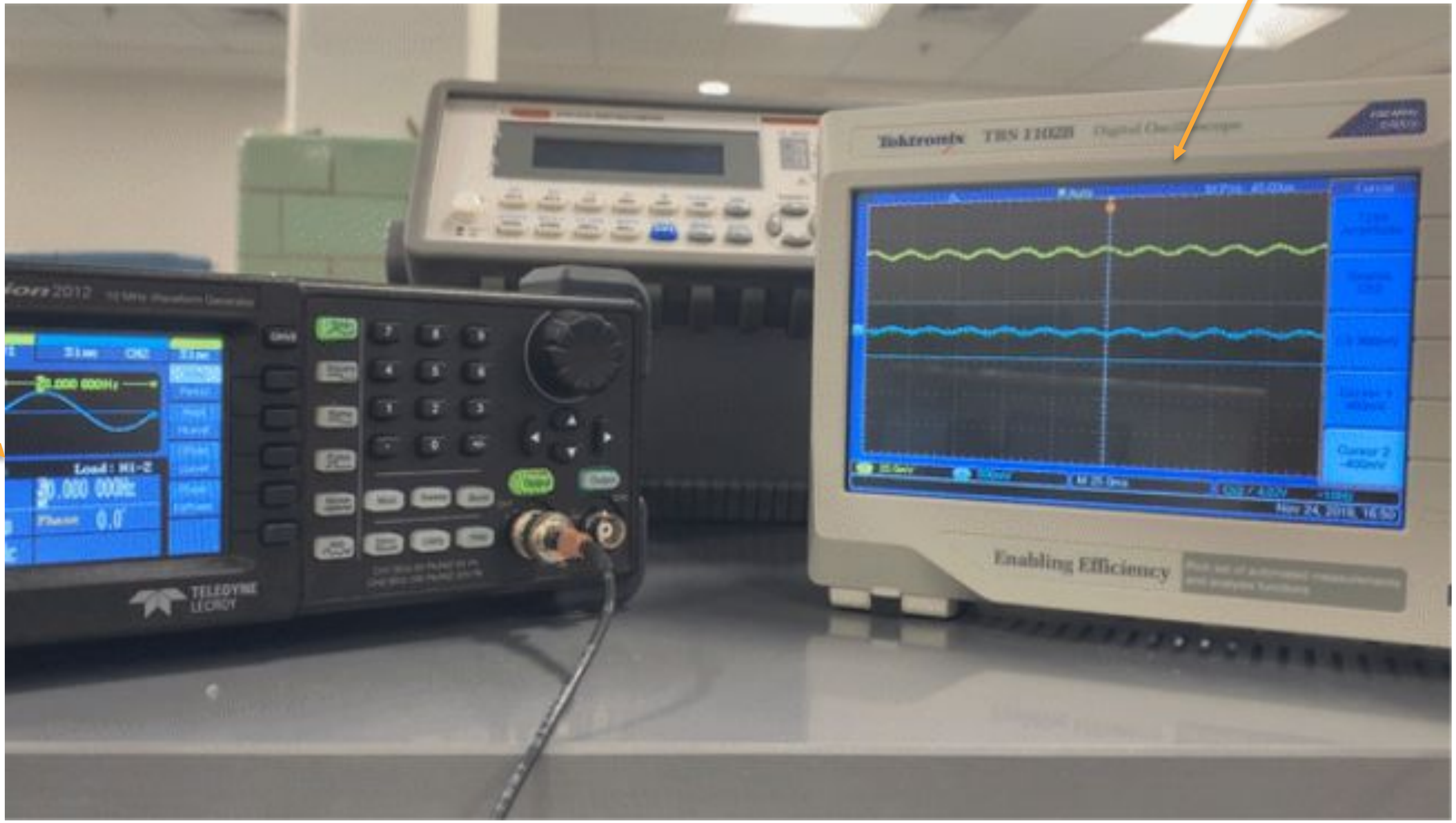


HPF

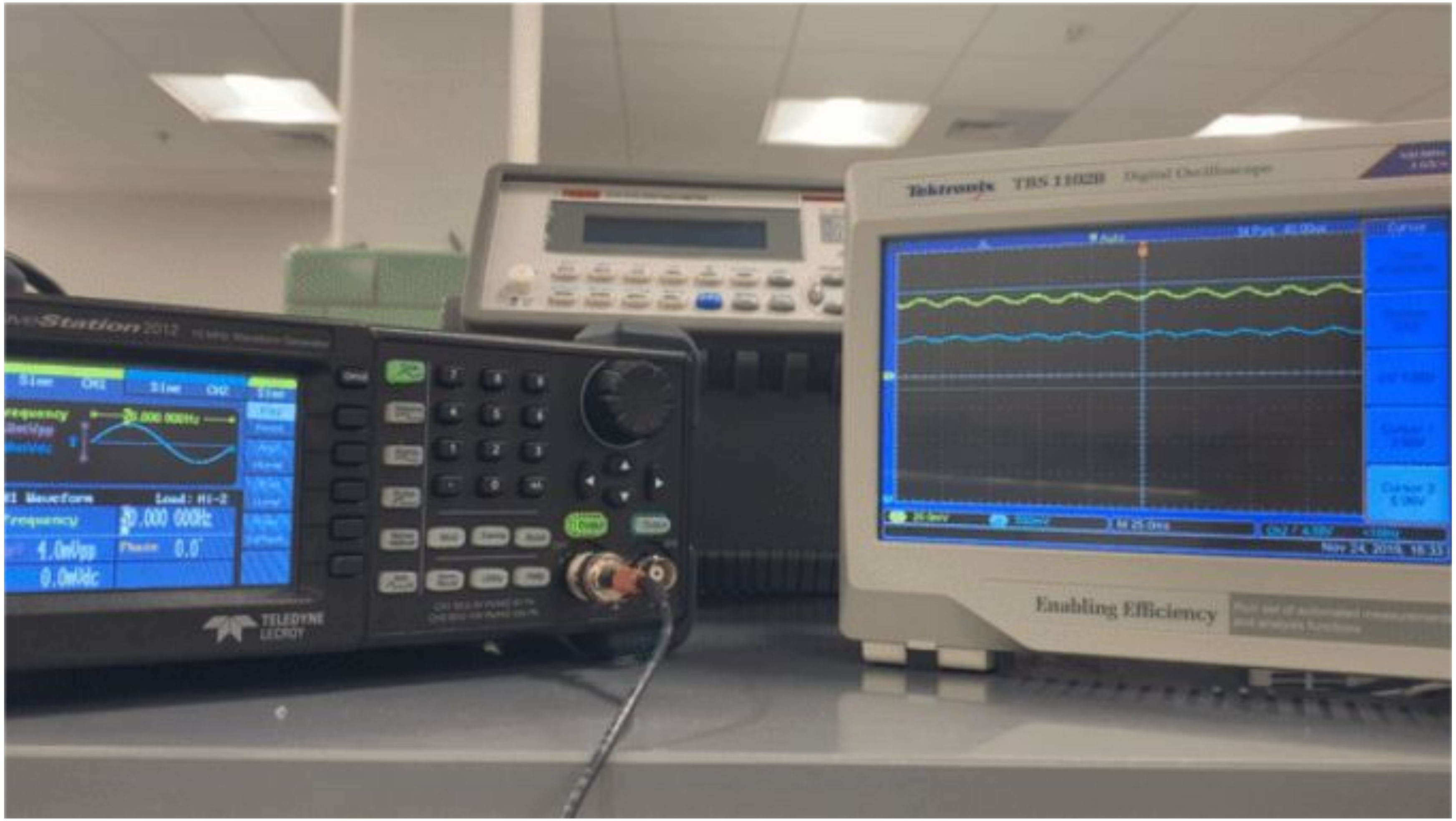
Without Optional Filtering

4mV

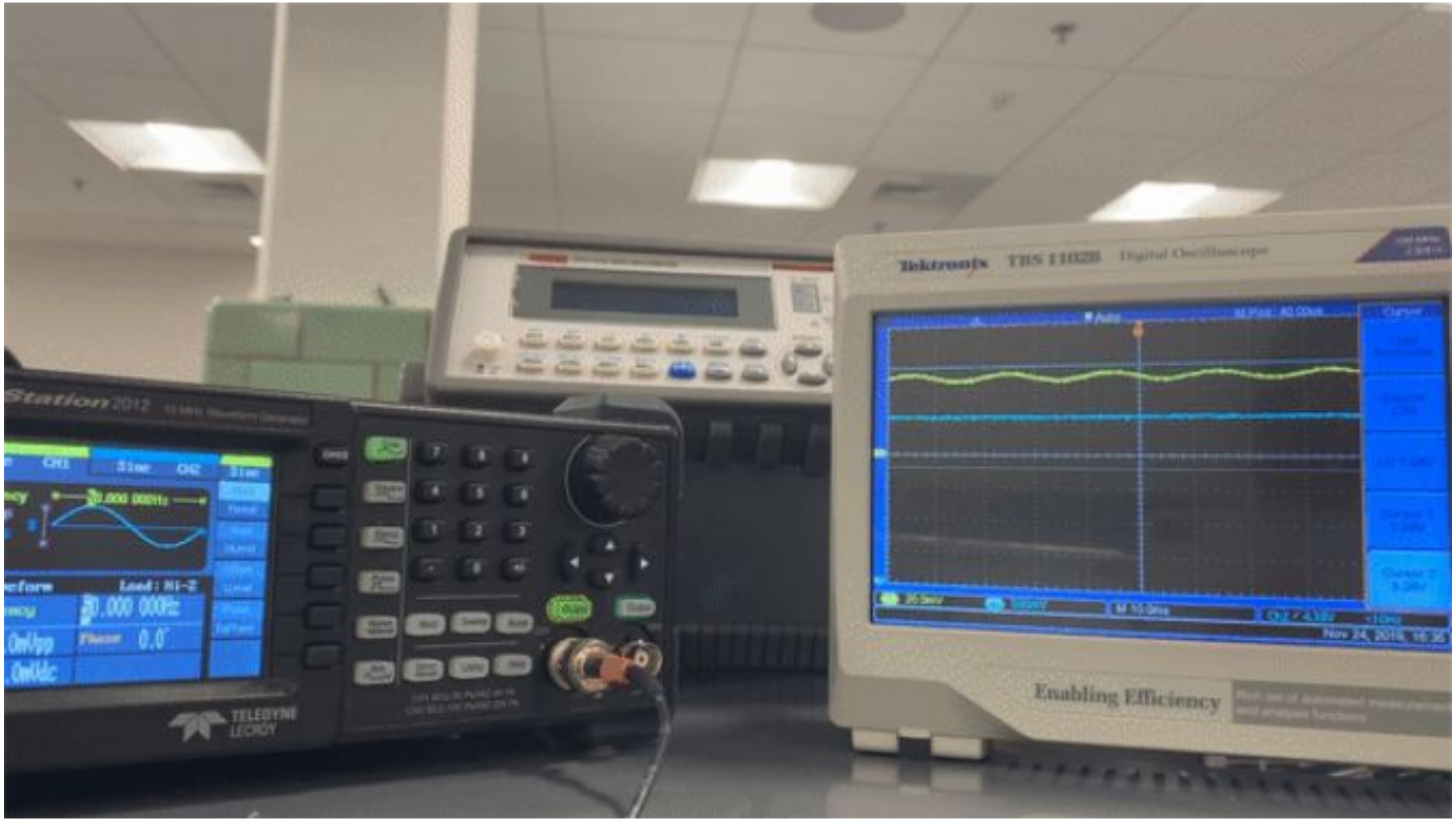
Increase the freq.
50 Hz – 7000 Hz



+ Band Pass Filter



+ High Pass Filter



Quantitative Analysis

Design

For all three cases:

HPF, BPF, no additional filters

At frequencies:

50, 100, 200, 400, 800, 1600, 3200, 5000, 7000 Hz

Record

Output voltage amplitude

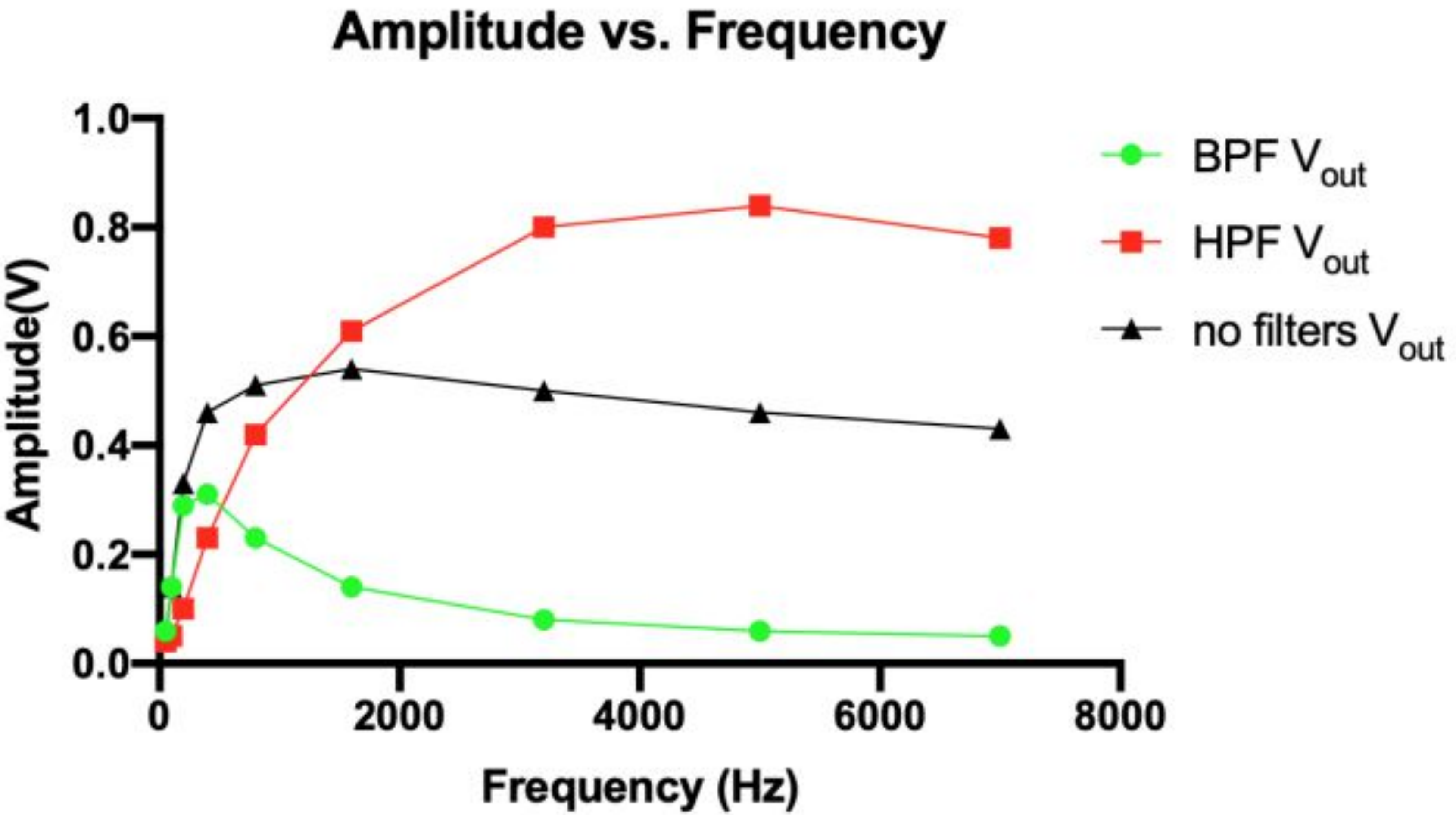
Plot

Bode Plot & Gain Frequency Response

Vout vs. Vin Data

X	Group A	Group B	Group C
Frequency (Hz)	BPF V_{out} (V)	HPF V_{out} (V)	no filters V_{out} (V)
X	Y	Y	Y
50	0.06	0.04	0.05
100	0.14	0.05	0.14
200	0.29	0.10	0.33
400	0.31	0.23	0.46
800	0.23	0.42	0.51
1600	0.14	0.61	0.54
3200	0.08	0.80	0.50
5000	0.06	0.84	0.46
7000	0.05	0.78	0.43

Amplitude vs. Frequency Plot



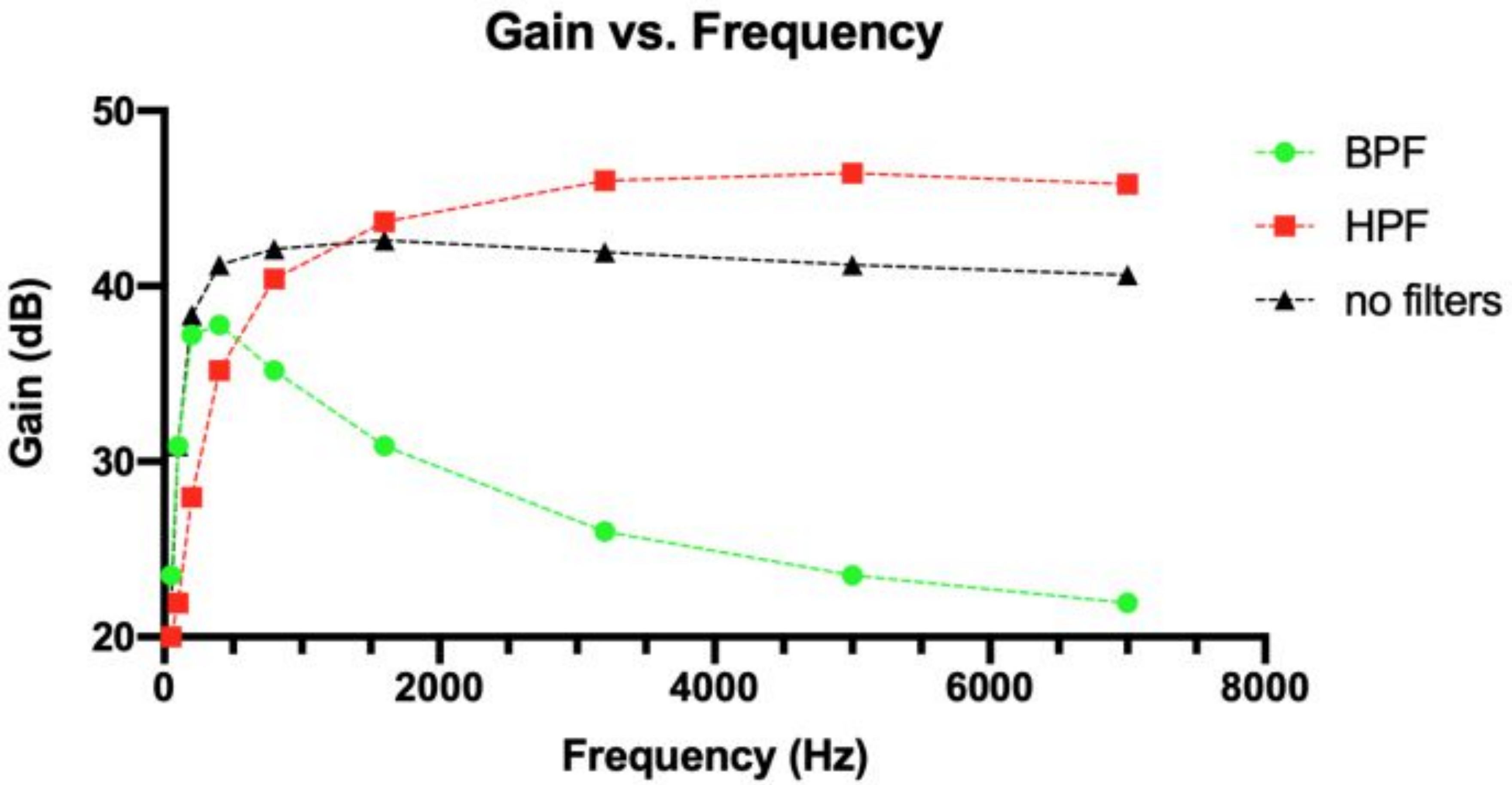
Gain Data

$$Gain\ (db) = 20 \log \frac{V_{out}}{V_{in}}$$

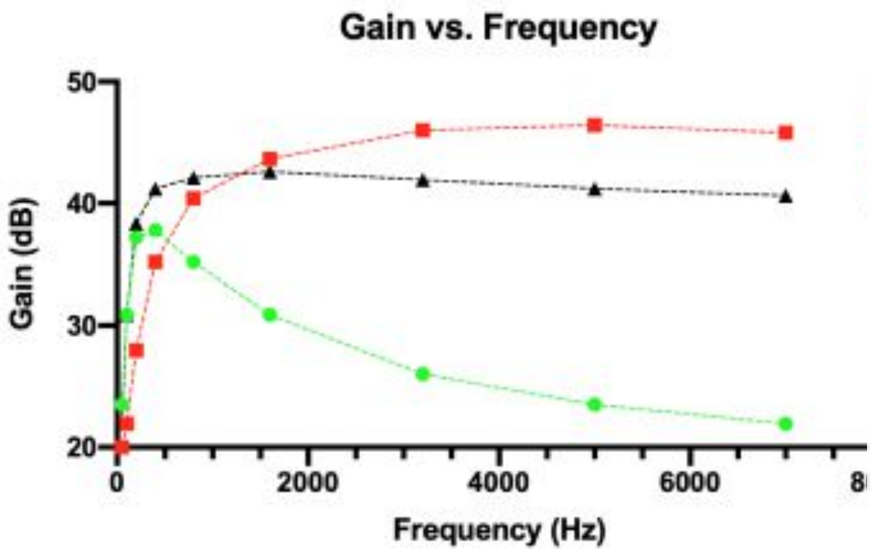
-3 db

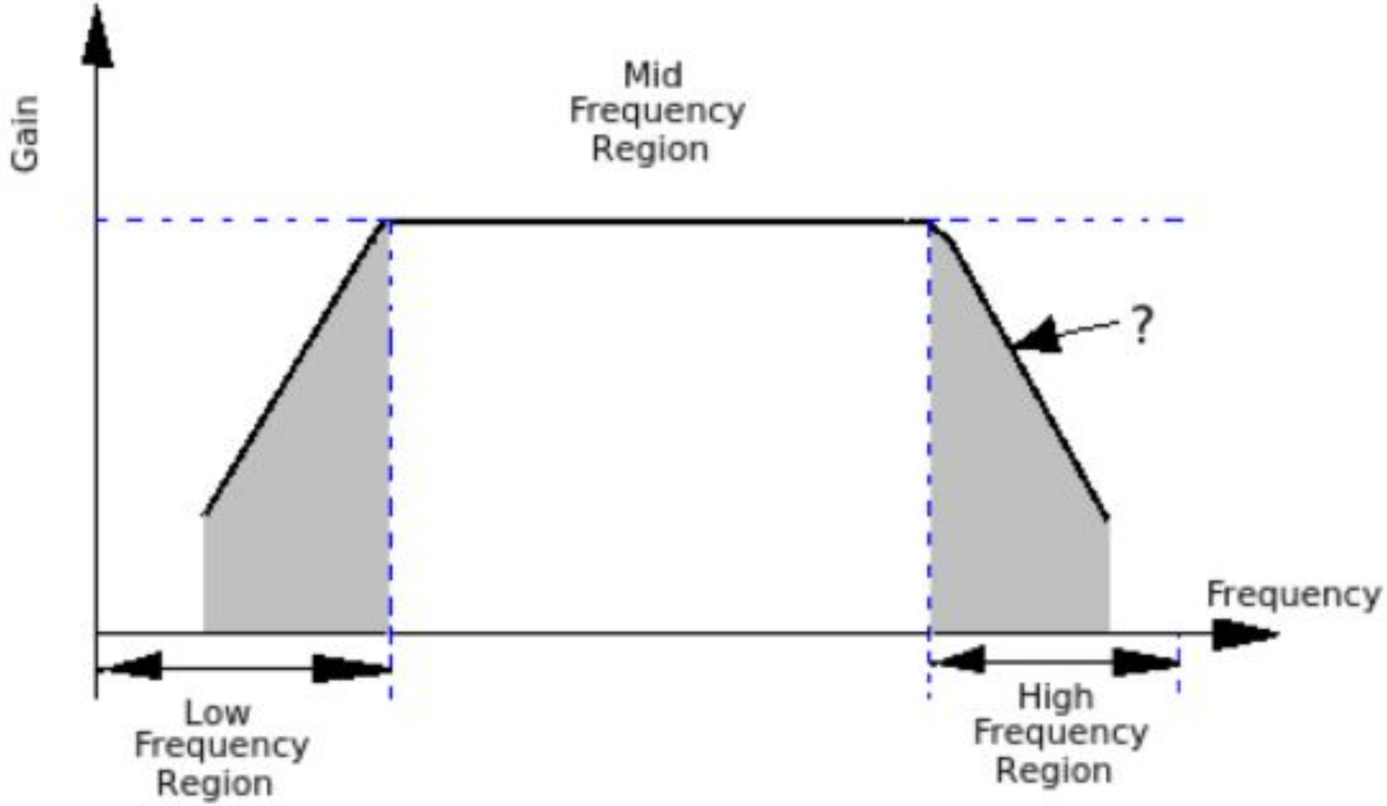
X	Group A	Group B	Group C
Frequency (Hz)	BPF Gain (dB)	HPF Gain (dB)	no filters Gain (dB)
X	Y	Y	Y
50	23.5218252	20.0000000	21.9382003
100	30.8813609	21.9382003	30.8813609
200	37.2067601	27.9588002	38.3290790
400	37.7860341	35.1933569	41.2139568
800	35.1933569	40.4237860	42.1102037
1600	30.8813609	43.6653969	42.6066754
3200	26.0205999	46.0205999	41.9382003
5000	23.5218252	46.4443859	41.2139568
7000	21.9382003	45.8006922	40.6281693

Gain vs. Frequency Plot



Gain vs. Frequency Plot





Bode Plot - BPF, f_{cutoff} = 72-260 Hz

$V_1 = V_{in} H_1(j\omega)$

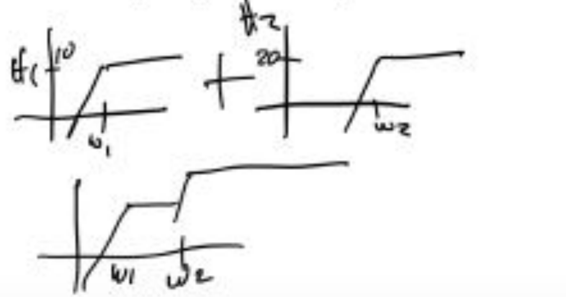
$V_o = V_1 H_2(j\omega)$

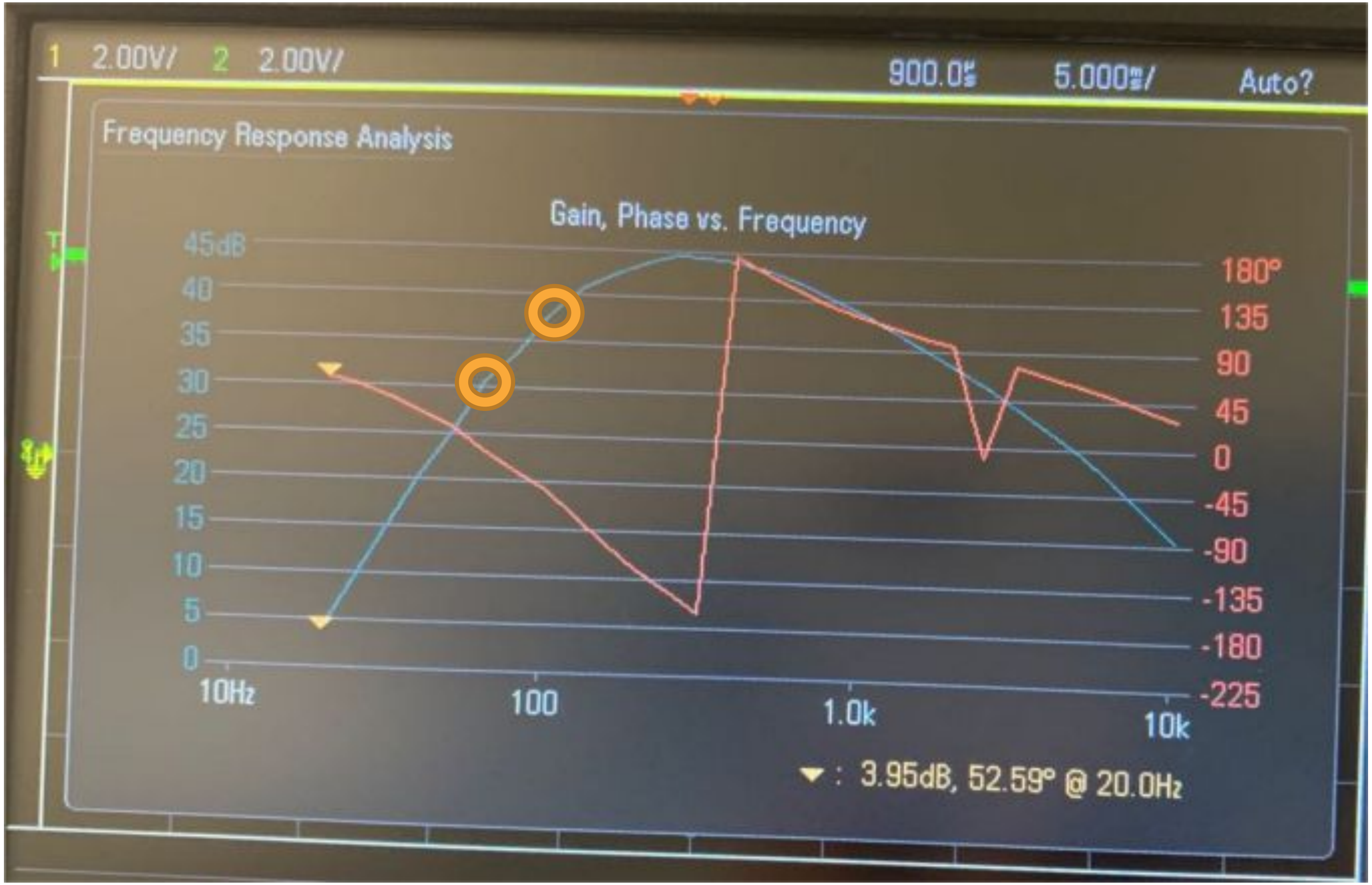
$V_o = V_{in} H_1(j\omega) H_2(j\omega)$

$\frac{V_o}{V_{in}} = H_1(j\omega) H_2(j\omega) H_3(j\omega)$

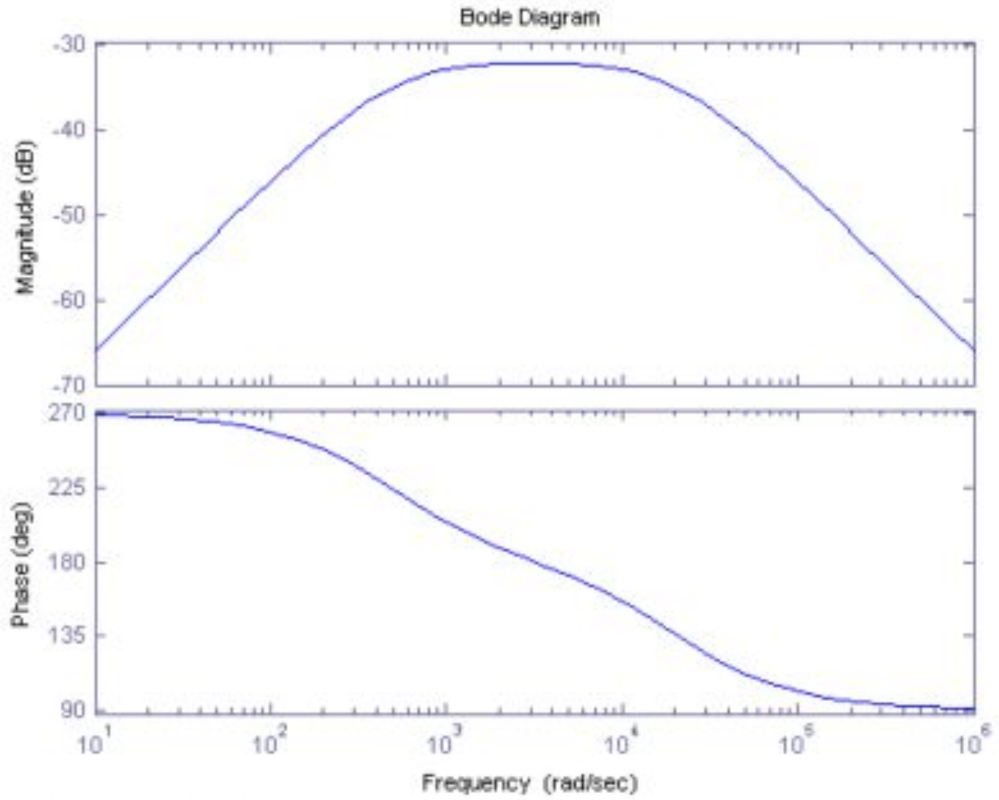
$\cancel{20} \log\left(\frac{V_o}{V_{in}}\right) = \log(H_1 H_2 H_3)$

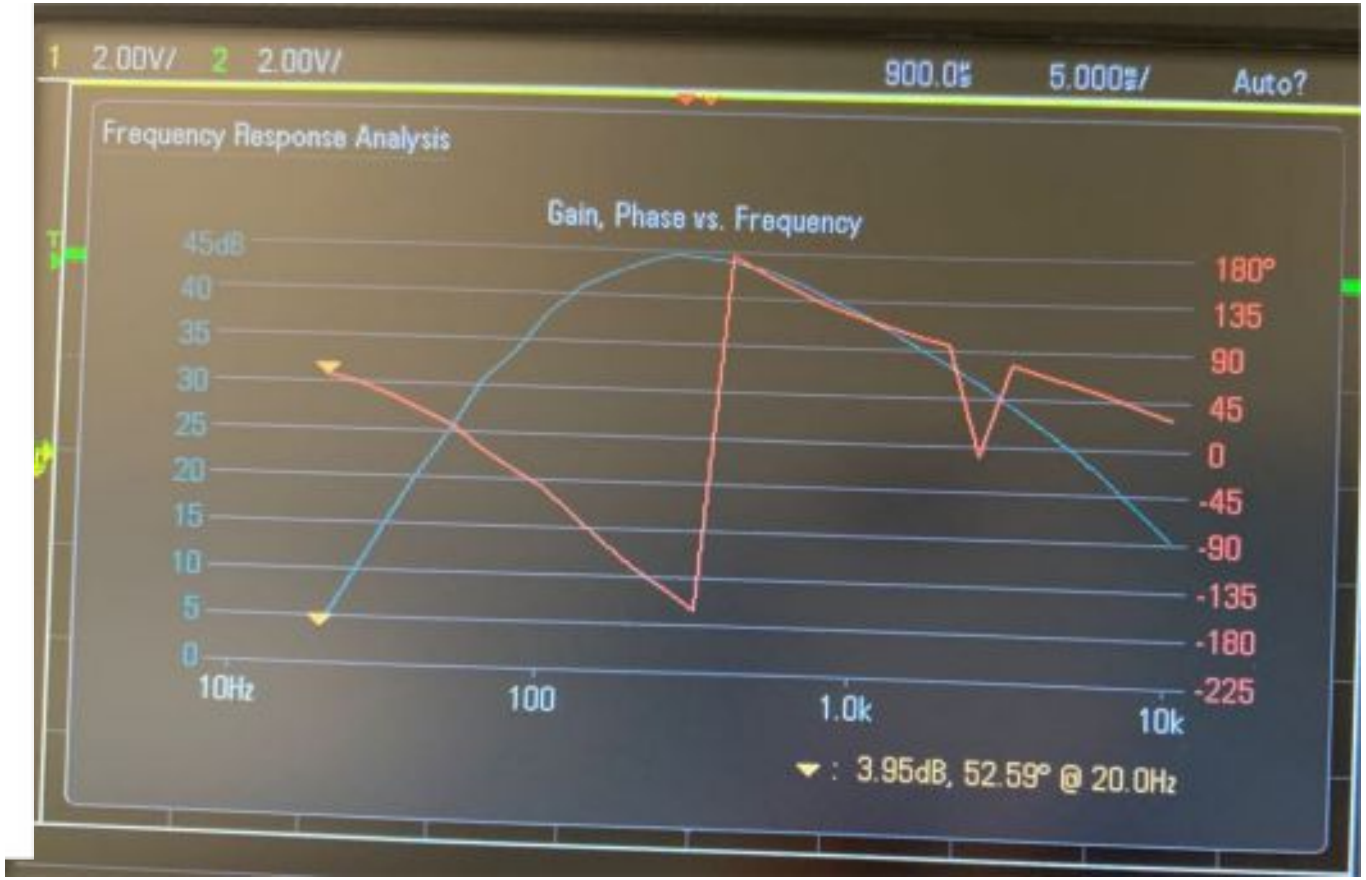
$= \log H_1 + \log H_2 + \log H_3$





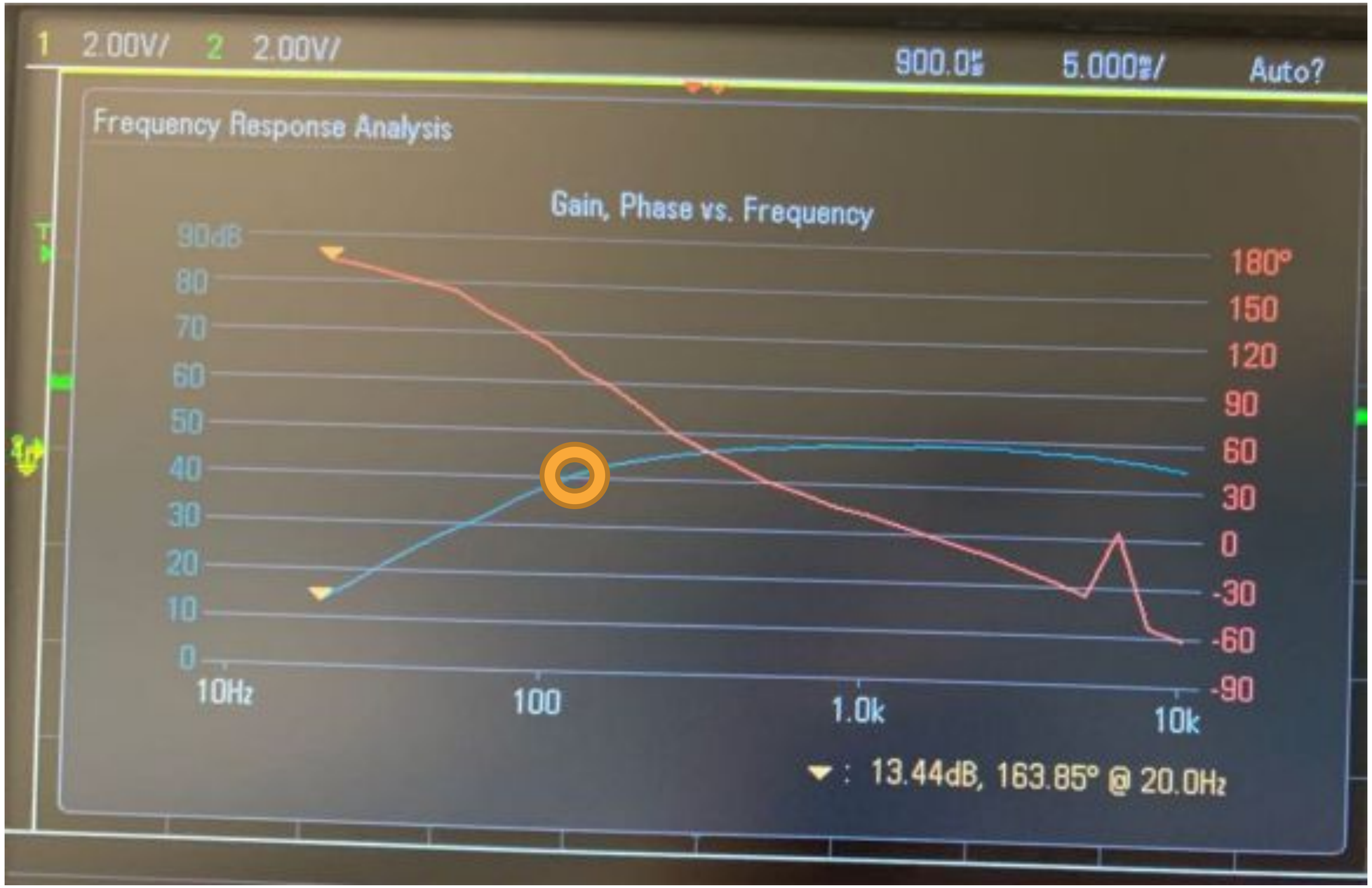
Bode Plot - BPF, f_{cutoff} = 72-260 Hz





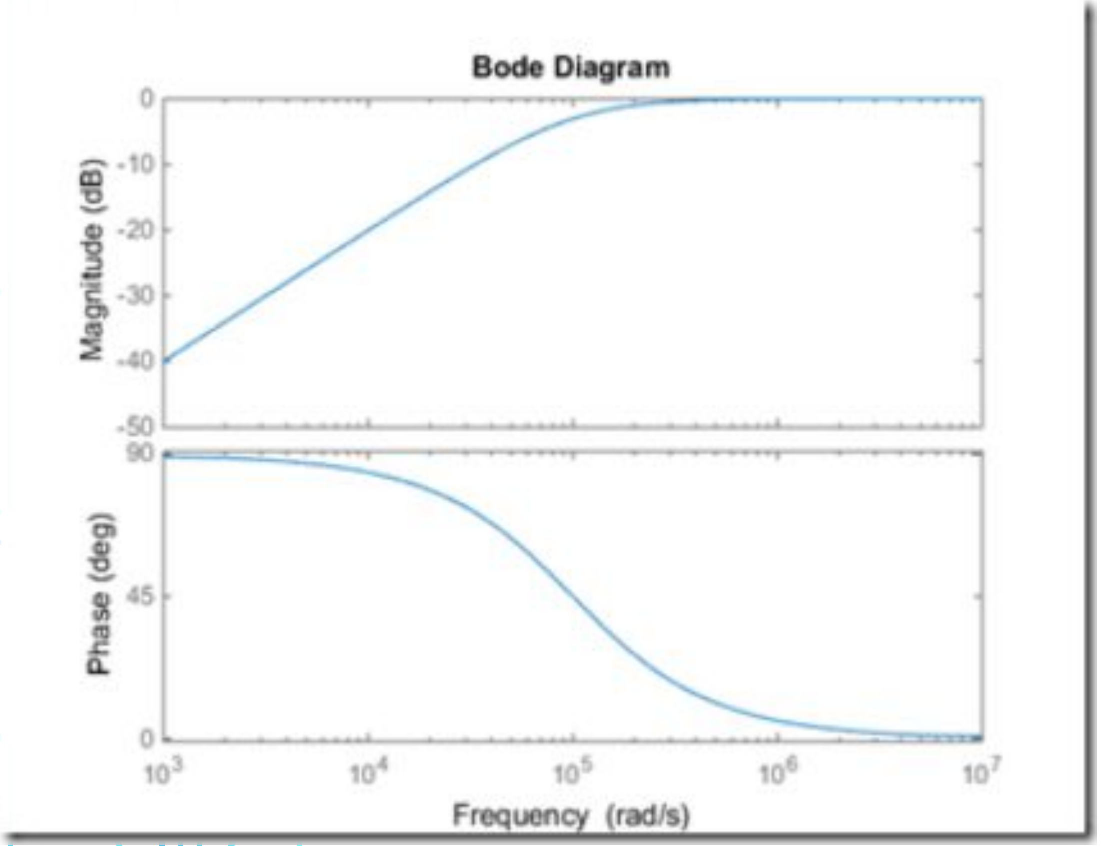
Bode Plot - no additional filtering

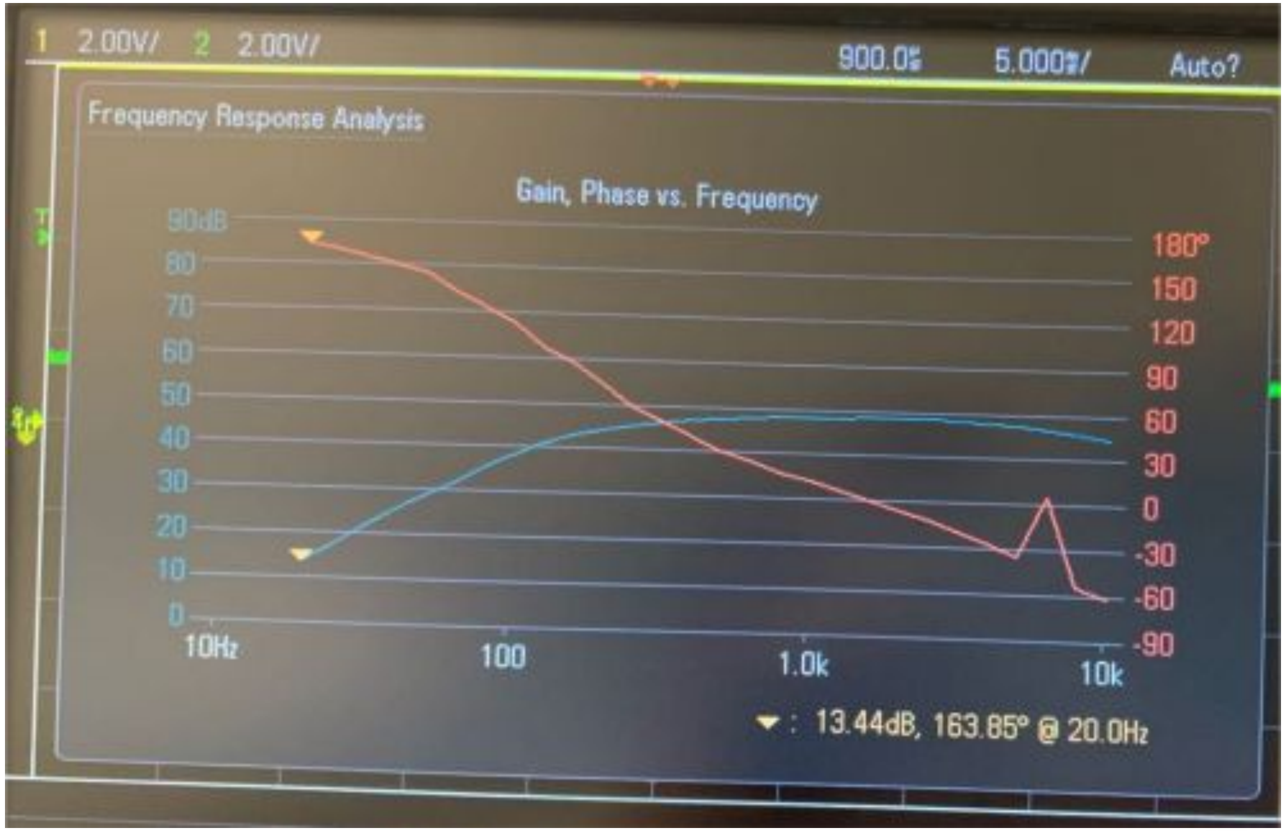
$f_{cutoff} = 159\ Hz$



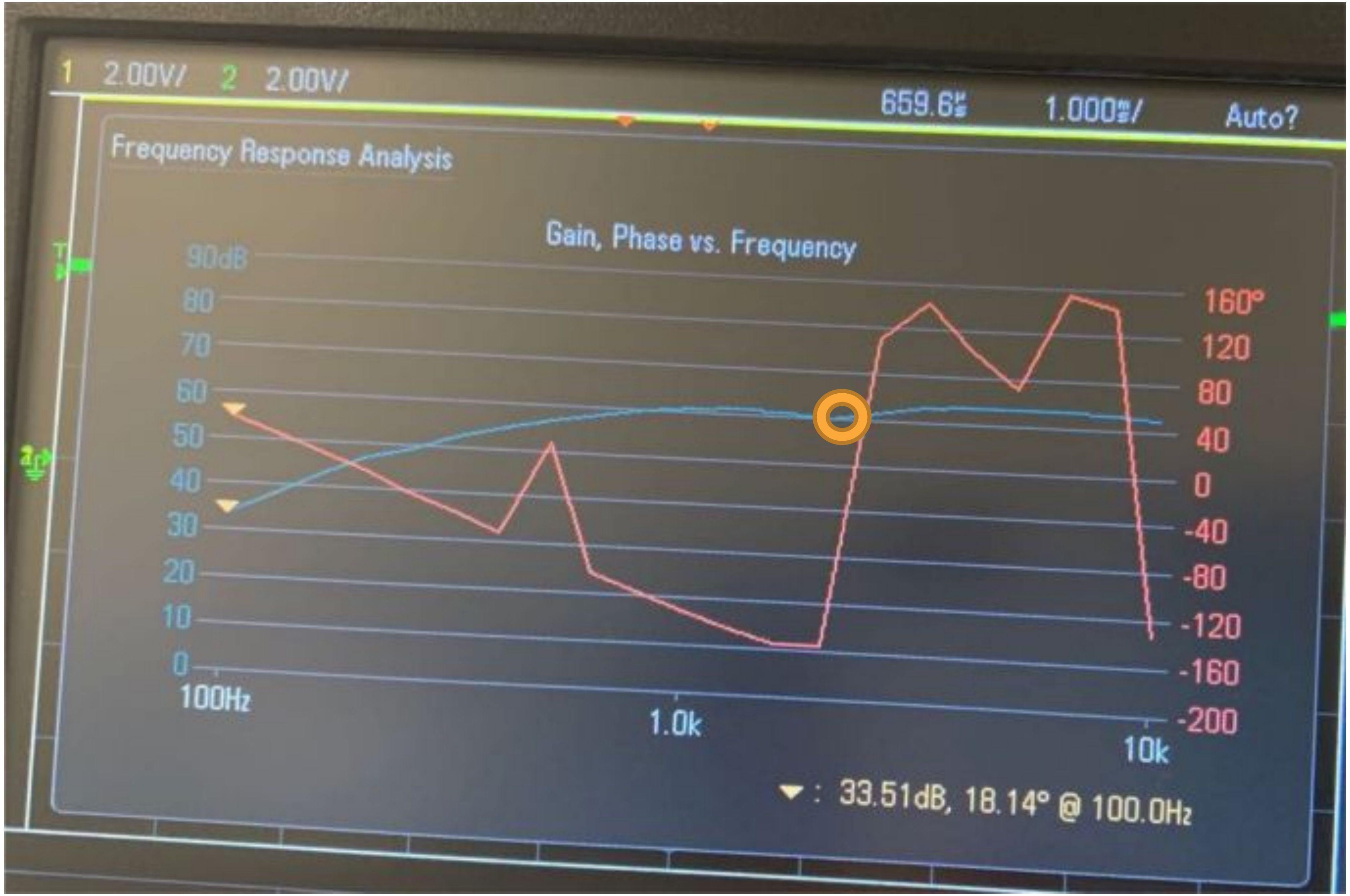
Bode Plot - no additional filtering

$f_{cutoff} = 159\ Hz$





Bode Plot - HPF, $f_{cutoff} = 1591\ Hz$



Conclusion & Limitations

Advantages of this hearing aid

- + Two optional filtering options (switch)
  - 2 HPF
  - 2 HPF + HPF - clear + ambient environment
  - 2 HPF + BPF – no noise
- Can adjust volume
  - potentiometer

Limitations

- Distortion or Screeching noise
- Only has three bands
- Not soldered
- Needs a buffer
- Not battery powered
- Eliminate ambient noise and amplify only human voice
- Saturation
- …

Final Device Demonstration

References

- https://www.healthyhearing.com/report/52448-Understanding-high-frequency-hearing-loss
- https://electronicsforu.com/electronics-projects/low-cost-hearing-aid-2
- https://www.careerride.com/mchoice/rc-coupled-amplifier-practical-frequency-response-11653.aspx
- https://www.sciencedirect.com/topics/engineering/high-pass-filters
- https://pages.jh.edu/~bmesignals/analysis_of_frequency_space.html

THANK YOU!