The Great Equalizer

A Circuits Lab Project of Epic Musical Proportions

Group 1
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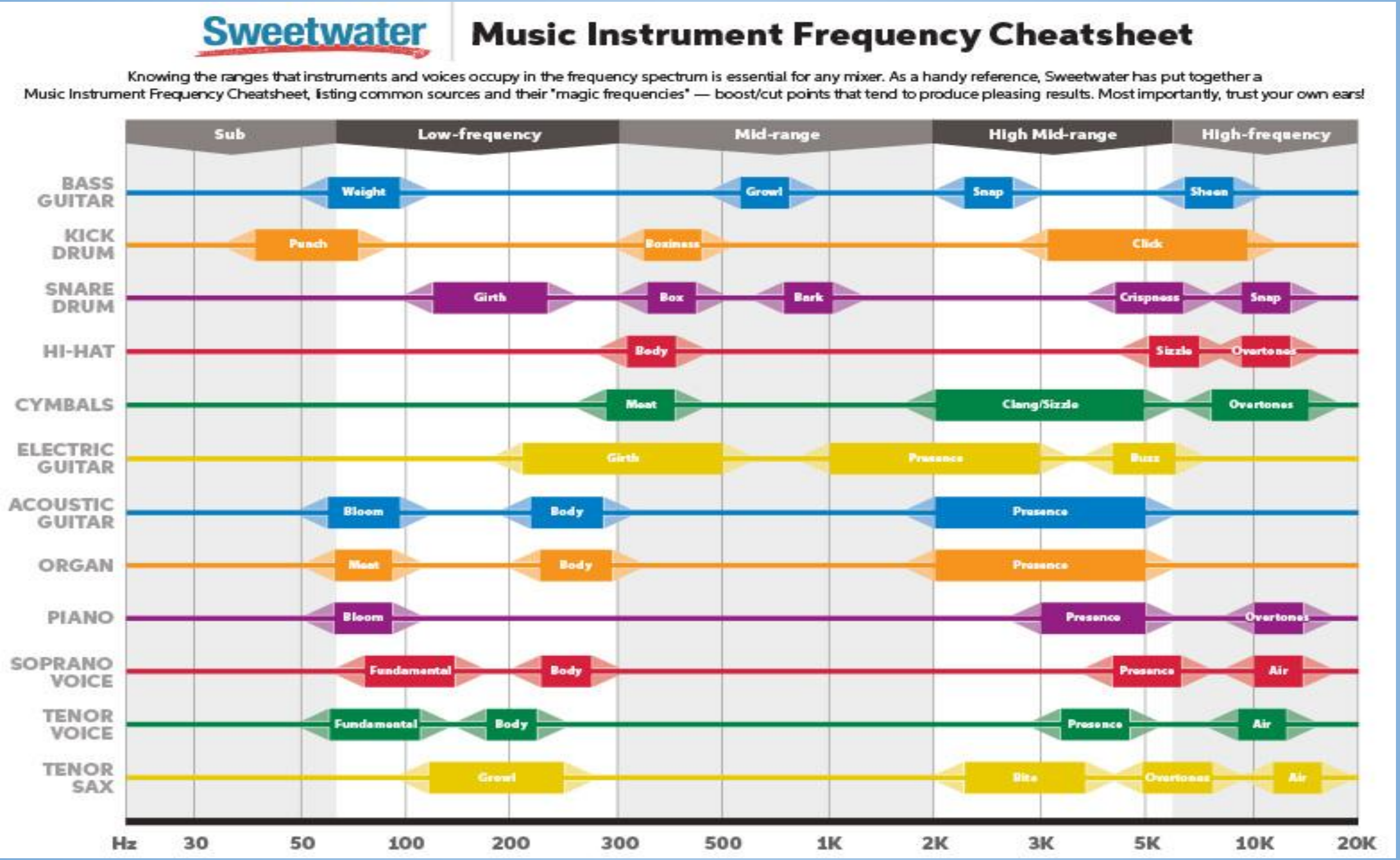
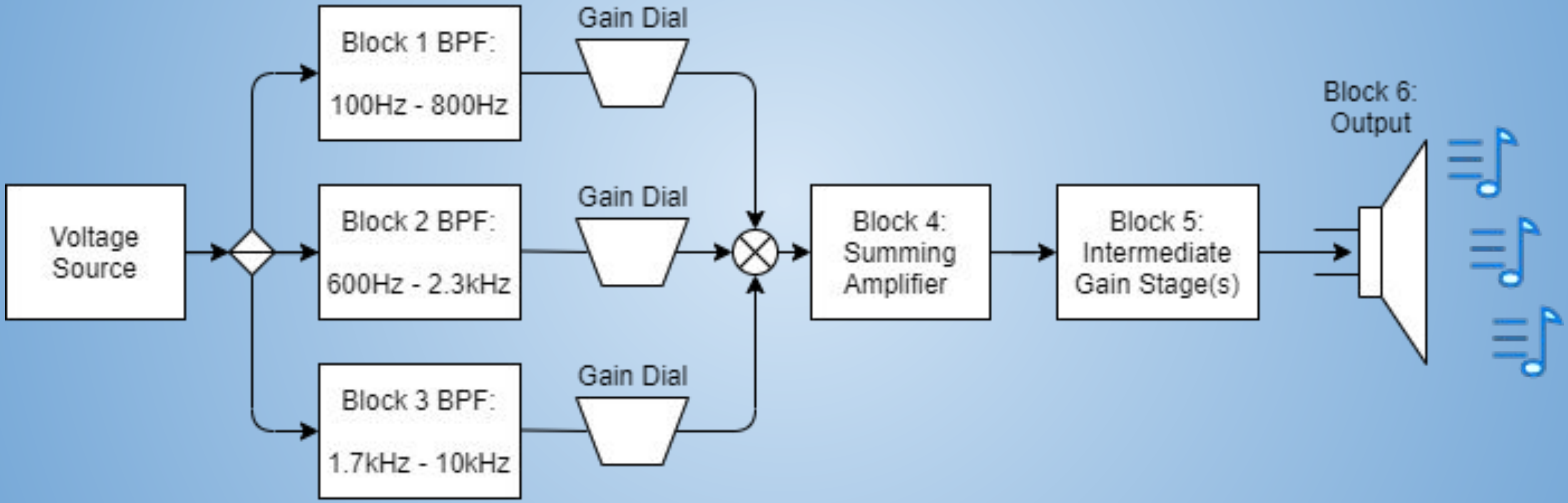
Presentation Outline

- Introduction
- Block Diagram
- Specifications
- Hand Calculations and Matlab Script
- Simulations and Frequency Response
- Artisanally Handcrafted Equalizer Circuit
- Demonstration
- Conclusion

Introduction



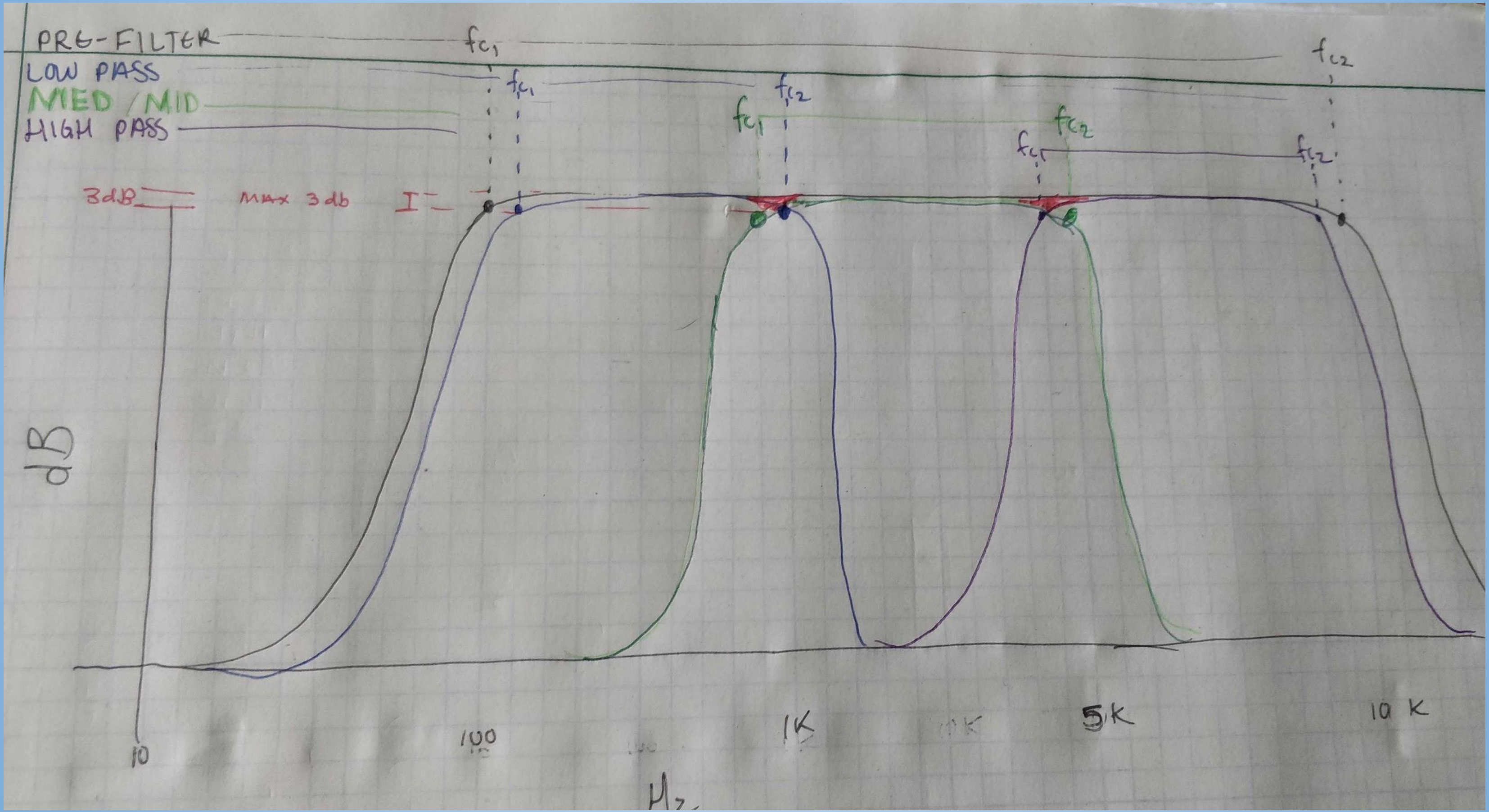
Block Diagram



Specifications

- Input: 0.2Vp, 5mA max, 100Hz-10kHz simulate with 3 different frequency ranges
- Output: Load is 8 ohms. Max Gain: 3 per stage, 2.5Vp max, 10mA
    - (Make sure you can produce 10mA at 2.5V maximum)
- Demonstrate operation by simulations showing the output signal versus input and showing with a frequency sweep the filtering that your equalizer is performing.
- Inductors, capacitors, and resistors listed in Appendix H are the only passive devices.
- Max of 3 total inductors and capacitors in any 1 filter stage.

Frequency Design Diagram



Frequency Design Hand Calcs

100 Hz	$C_1 = \frac{1}{2\pi(10)100} = 159\mu F$
600 Hz	$C_2 = \frac{1}{2\pi(10)600} = 26.5\mu F$
800 Hz	$C_3 = \frac{1}{2\pi(10)800} = 19.9\mu F$
1700 Hz	$C_4 = \frac{1}{2\pi(10)1700} = 9.36\mu F$
2300 Hz	$C_5 = \frac{1}{2\pi(10)2300} = 6.92\mu F$
10 000 Hz	$C_6 = \frac{1}{2\pi(10)10\,000} = 1.59\mu F$

$10{,}000 - 100 = 9900$ $\frac{9900}{3} = 3300$

assume gain=1

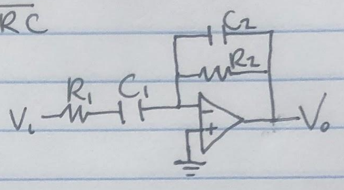
$R_1 = R_2 = 10\Omega$

① 100 -> 3400

② 3400 -> 6700

③ 6700 -> 10000

$f_c = \frac{1}{2\pi RC}$



① $C_1 = \frac{1}{2\pi(10)100} = 159\mu F$

$C_2 = \frac{1}{2\pi(10)3400} = 4.68\mu F$

② $C_2 = \frac{1}{2\pi(10)6700} = 2.38\mu F$

③ $C_2 = \frac{1}{2\pi(10)10000} = 1.59\mu F$

since the capacitor & frequency are inversely proportional, use a lower cap value to get a larger frequency cutoff

Frequency Response - MatLab Calcs

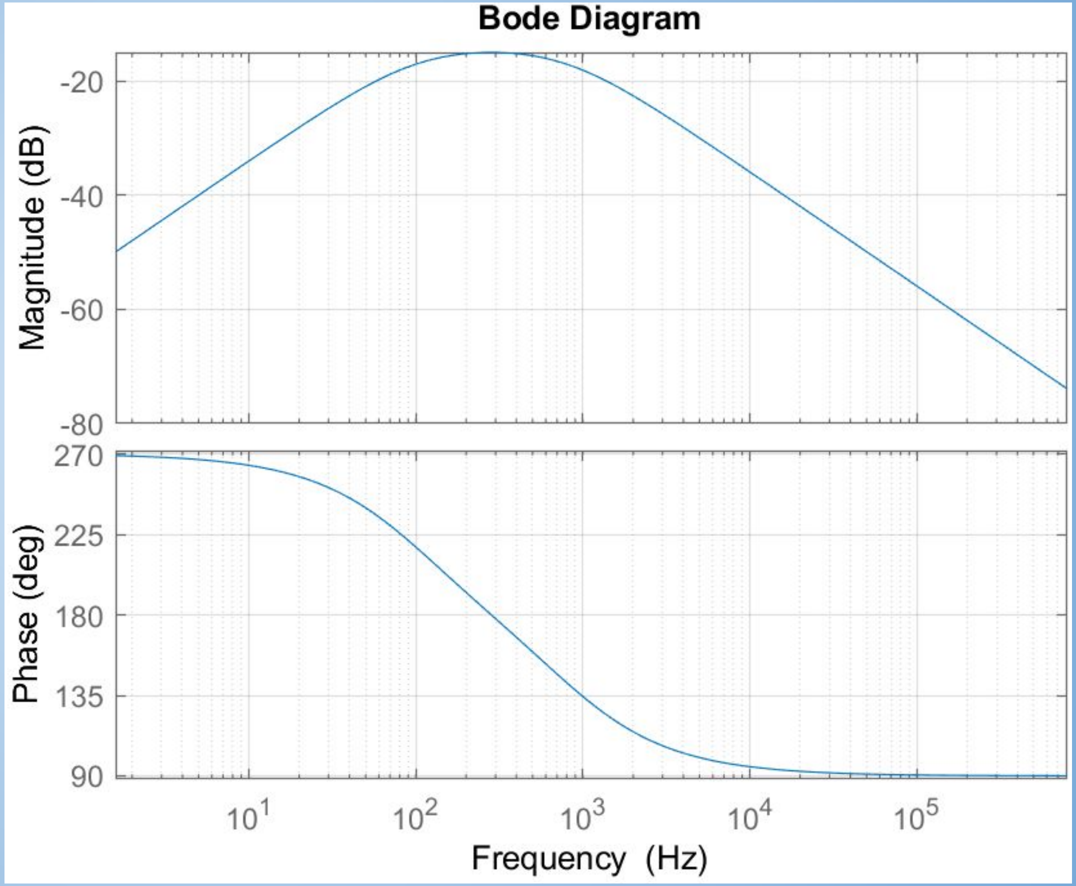
Calculations for Block 1 - [Matlab Script]

```
% Block 1: 100Hz - 800Hz
fh1 = 100;                wh1 = fh1*2*pi;
fl1 = 800;                wl1 = fl1*2*pi;
fc1 = sqrt(fh1*fl1);      wc1 = fc1*2*pi;

cap = 4.7e-6; cap
R1 = 1/(cap * wc1); R1   % We'll adjust R1 to the nearest App H value
R1 = 120; k1 = -1;       % Block 1 has a gain of -1 (-R1/R1)

% Now to find the transfer function of Block 1 (matrix of s coefficients):
B1 = tf([.2 * k1*wl1 0],[1 wh1+wl1 wh1*wl1]); B1
```

Frequency Response - MatLab Calcs

Calculations for Block 1 - Results

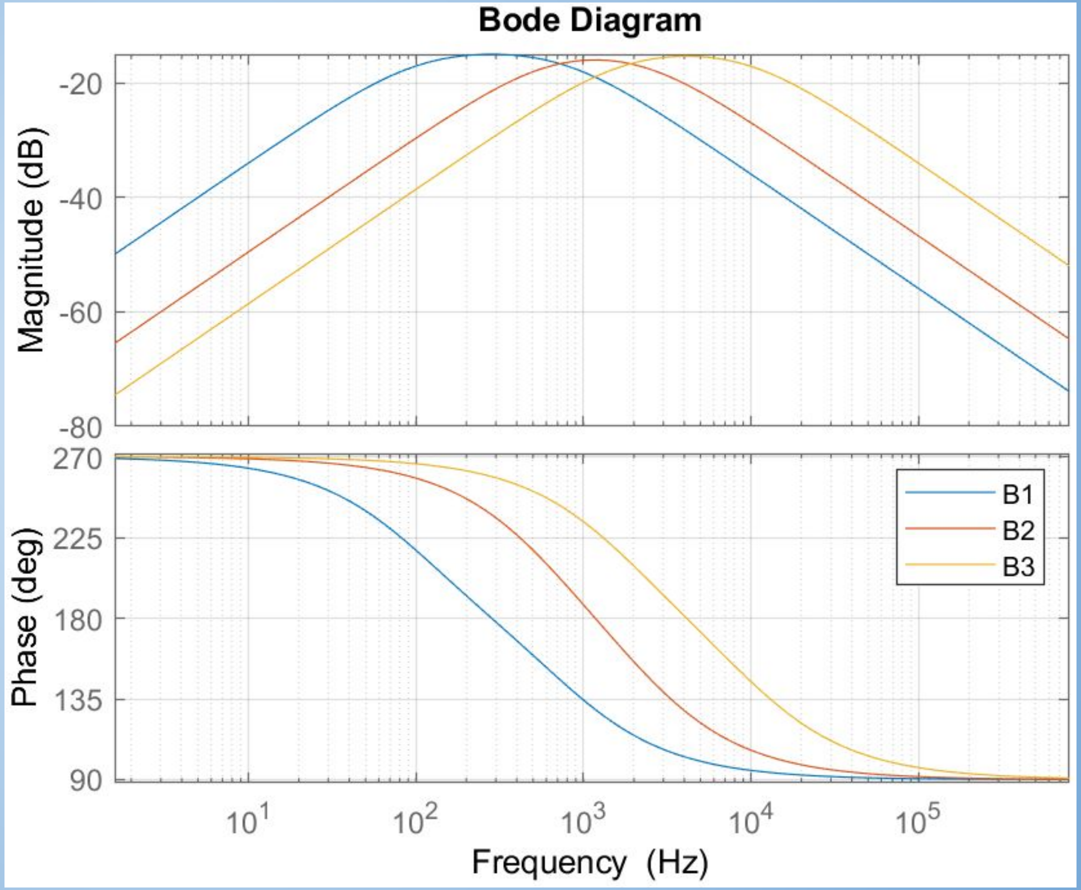
```
B1 =

            -1005 s
  ----------------------
  s^2 + 5655 s + 3.158e06

Continuous-time transfer function
```



Frequency Response - MatLab Calcs

All Blocks - Results

```
B1 =

           -1005 s
  ---------------------------
  s^2 + 5655 s + 3.158e06

B2 =

           -2890 s
  ------------------------------
  s^2 + 1.822e04 s + 5.448e07

B3 =

           -1.257e04 s
  ------------------------------
  s^2 + 7.351e04 s + 6.711e08
```



Frequency Response - MatLab Calcs

Block 4: Summing it up

```
% We have three variable resistors at this stage, each ranging from
% 3.3kOhms to 10kOhms. We will compute the lower and upper bound transfer
% functions:

kSAH = -10/3.3;      kSAL = -10/10;

Hsal = kSAL * (B1 + B2 + B3); Hsal
Hsah = kSAH * (B1 + B2 + B3); Hsah
```

```
Hsal =

        1.646e04 s^5 + 6.211e08 s^4 + 7.246e12 s^3 + 3.255e16 s^2 + 4.505e19 s
  ---------------------------------------------------------------------------------
  s^6 + 9.739e04 s^5 + 2.587e09 s^4 + 2.82e13 s^3 + 1.349e17 s^2 + 2.58e20 s + 1.155e23
```

```
Hsah =

        4.988e04 s^5 + 1.882e09 s^4 + 2.196e13 s^3 + 9.865e16 s^2 + 1.365e20 s
  ---------------------------------------------------------------------------------
  s^6 + 9.739e04 s^5 + 2.587e09 s^4 + 2.82e13 s^3 + 1.349e17 s^2 + 2.58e20 s + 1.155e23
```

Frequency Response - MatLab Calcs

Block 5: Intermediate Gain Stages and Plotting the Final Output

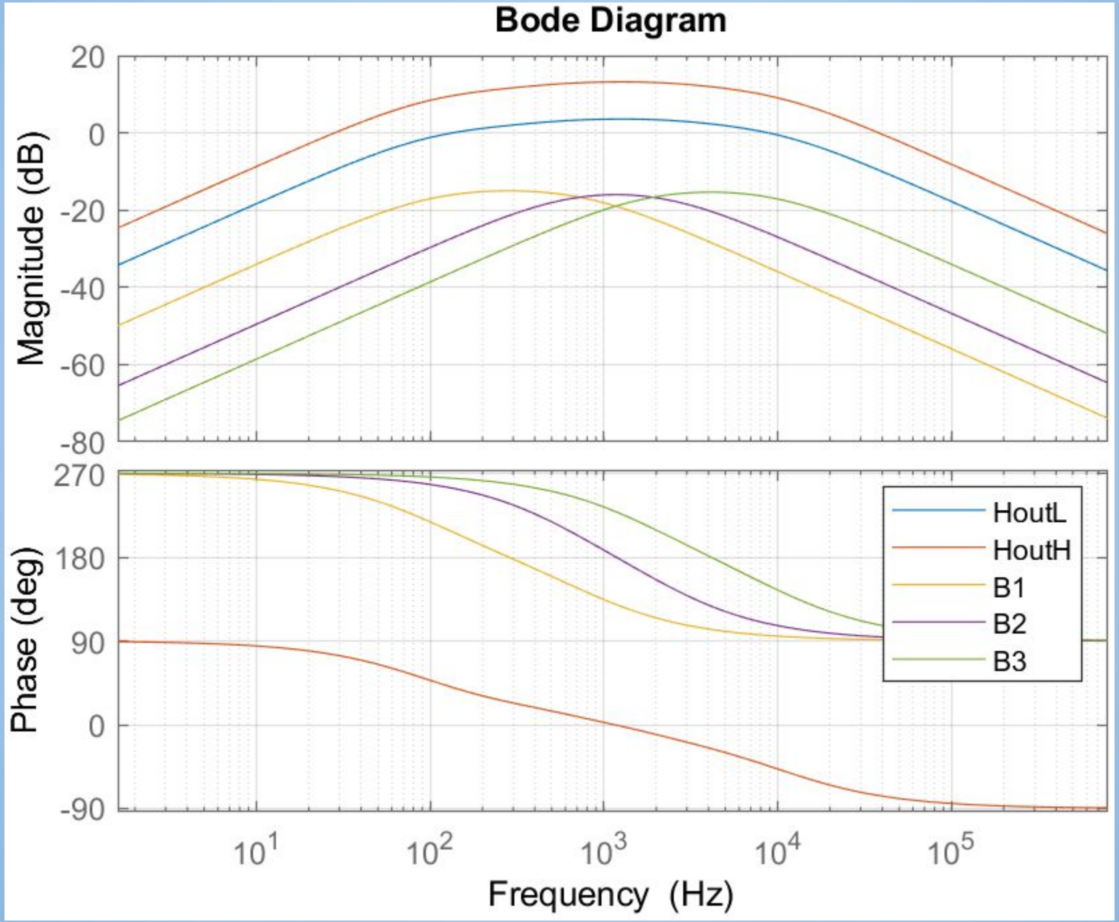
```
% Output Gain Stages
kINT = -10/3.3;     kLAST = -5.4/3.3;
kFIN = kINT * kLAST;

% Final Transfer Function:
HoutL = kFIN * Hsal; HoutL
HoutH =  kFIN * Hsah; HoutH

% Plot the Block BPFs against the final transfer functions:
h = bodeplot(HoutL, HoutH, B1, B2, B3, {10, 5e6});
setoptions(h, 'FreqUnits', 'Hz', 'Grid', 'on');
```

```
HoutL =

          8.163e04 s^5 + 3.08e09 s^4 + 3.593e13 s^3 + 1.614e17 s^2 + 2.234e20 s
  --------------------------------------------------------------------------------
  s^6 + 9.739e04 s^5 + 2.587e09 s^4 + 2.82e13 s^3 + 1.349e17 s^2 + 2.58e20 s + 1.155e23
```

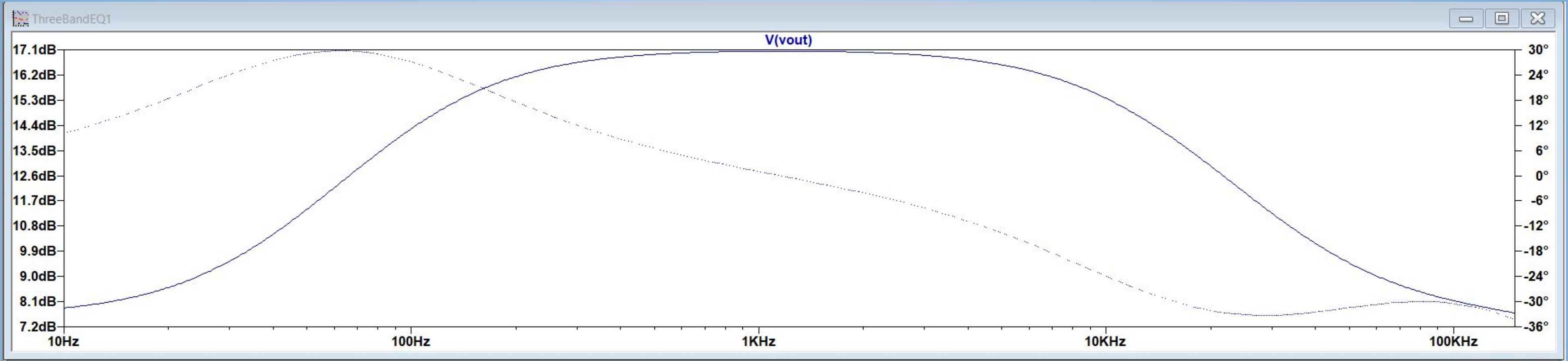
```
HoutH =

          2.474e05 s^5 + 9.332e09 s^4 + 1.089e14 s^3 + 4.892e17 s^2 + 6.769e20 s
  --------------------------------------------------------------------------------
  s^6 + 9.739e04 s^5 + 2.587e09 s^4 + 2.82e13 s^3 + 1.349e17 s^2 + 2.58e20 s + 1.155e23
```

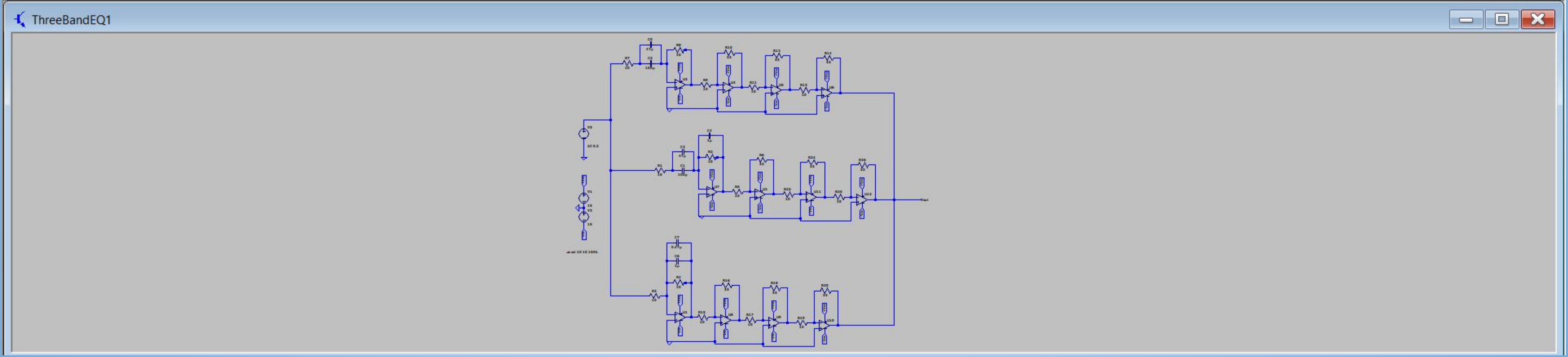
Frequency Response - Hand Calcs

Final Output



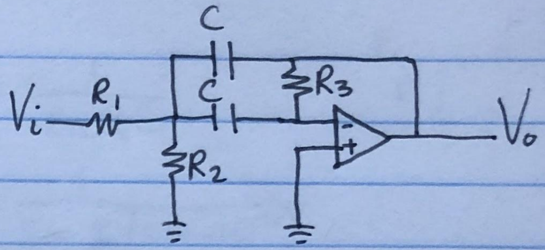
Frequency Response - Simulations





Frequency Response - Simulations

High Q Bandpass



$B = 10k - 100 = 9900 Hz$

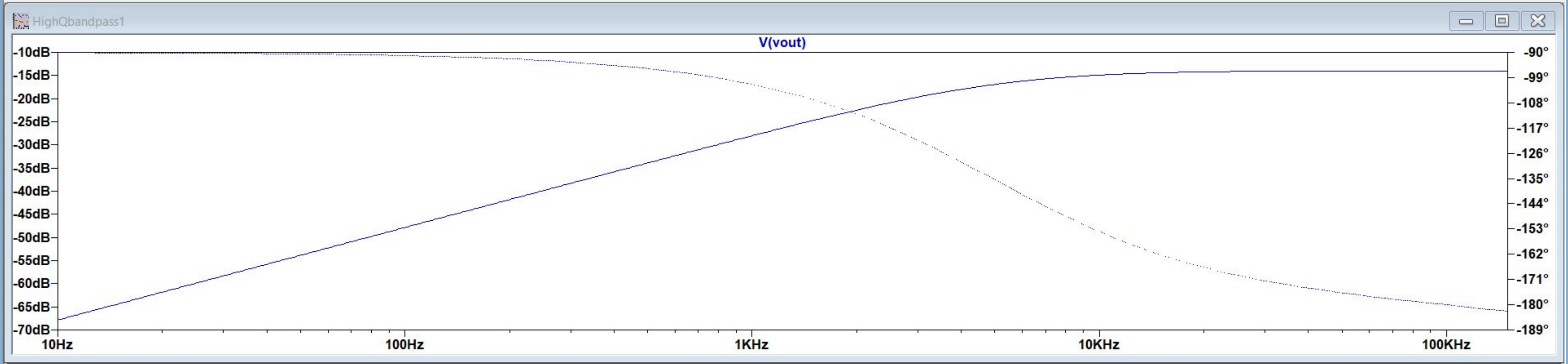
$\beta = 62832 - 628 = 62204 \, rad/s$

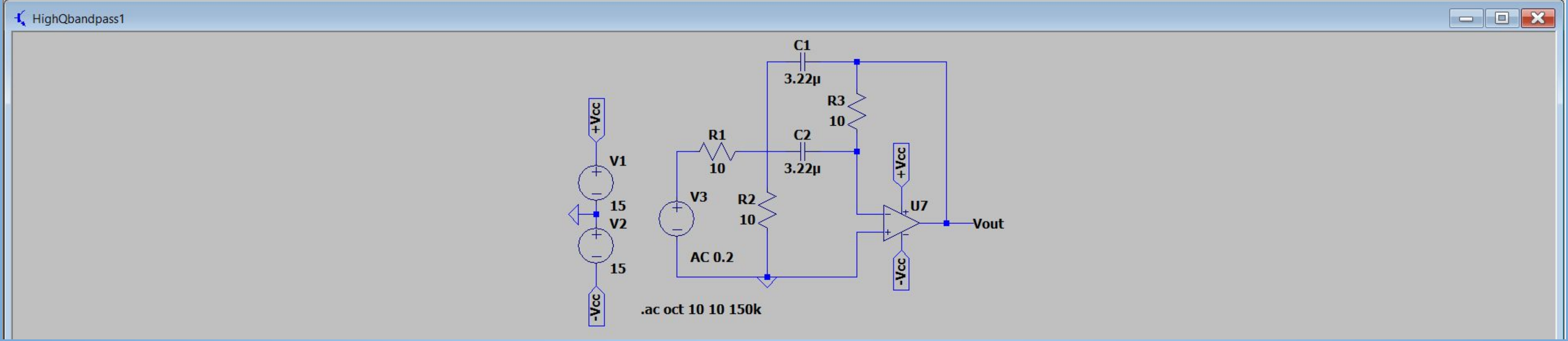
$\beta = \frac{2}{CR_3}$ $\quad 62204 = \frac{2}{10(C)}$

$\beta(CR_3) = 2$

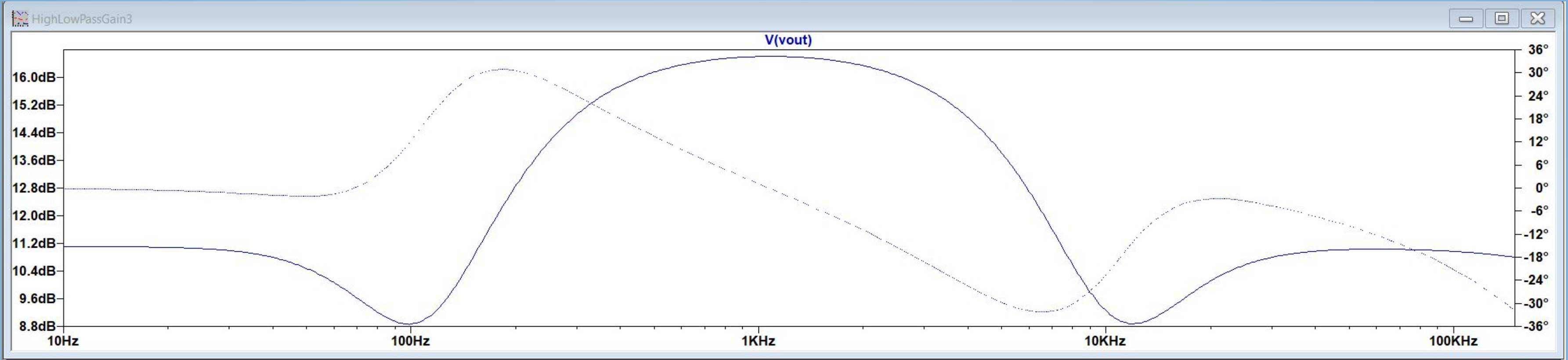
$C = \frac{2}{\beta R_3} = \frac{2}{62204(10)} = 3.22 \times 10^{-6}$

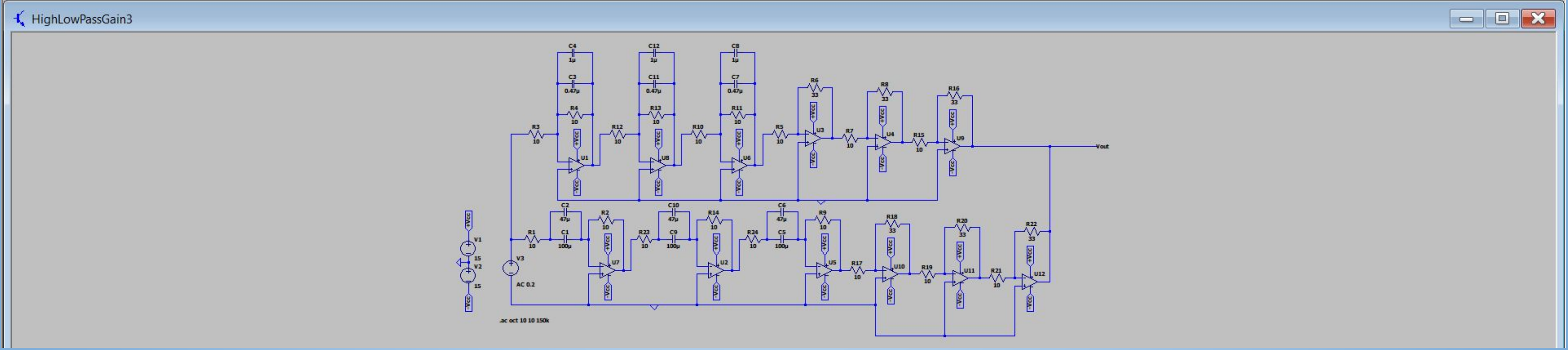
Frequency Response - Simulations





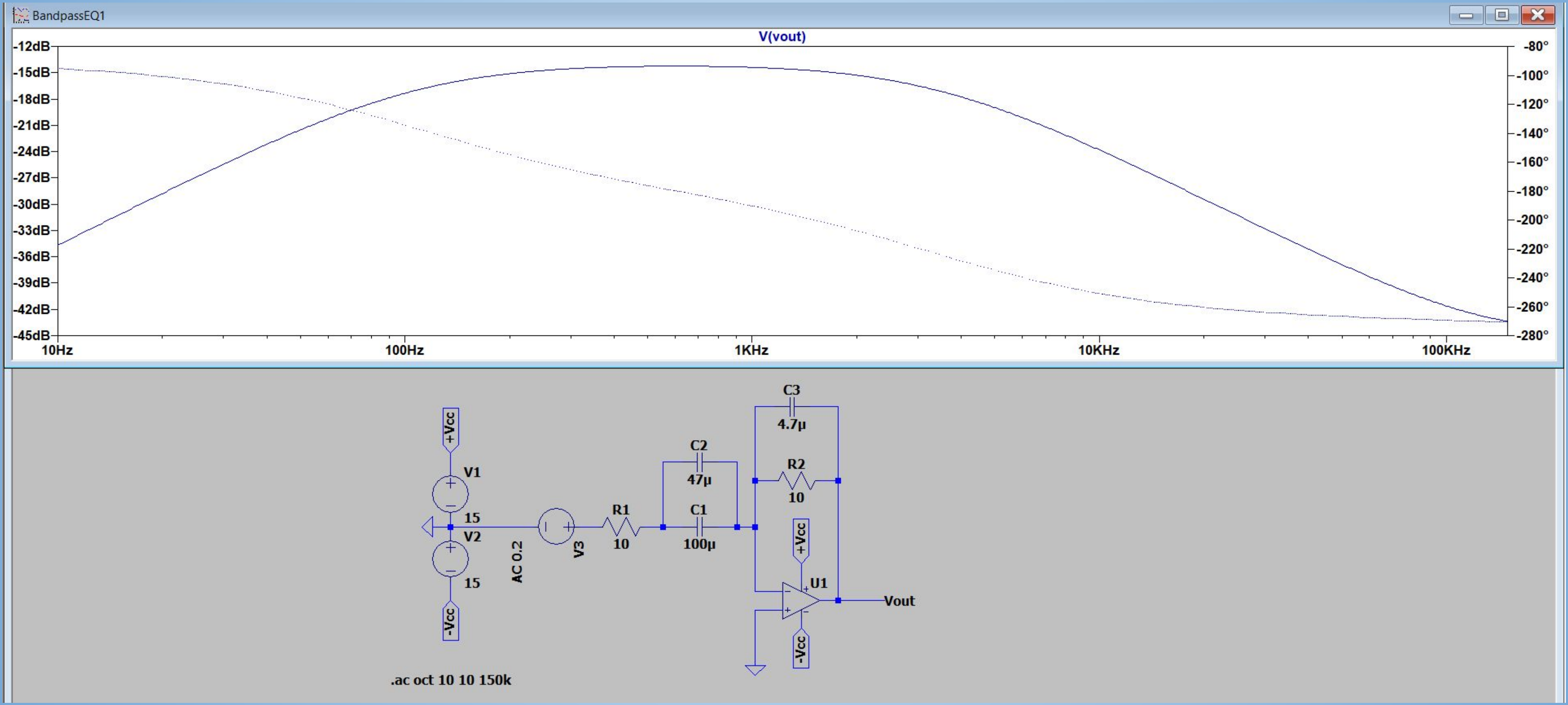
Frequency Response - Simulations





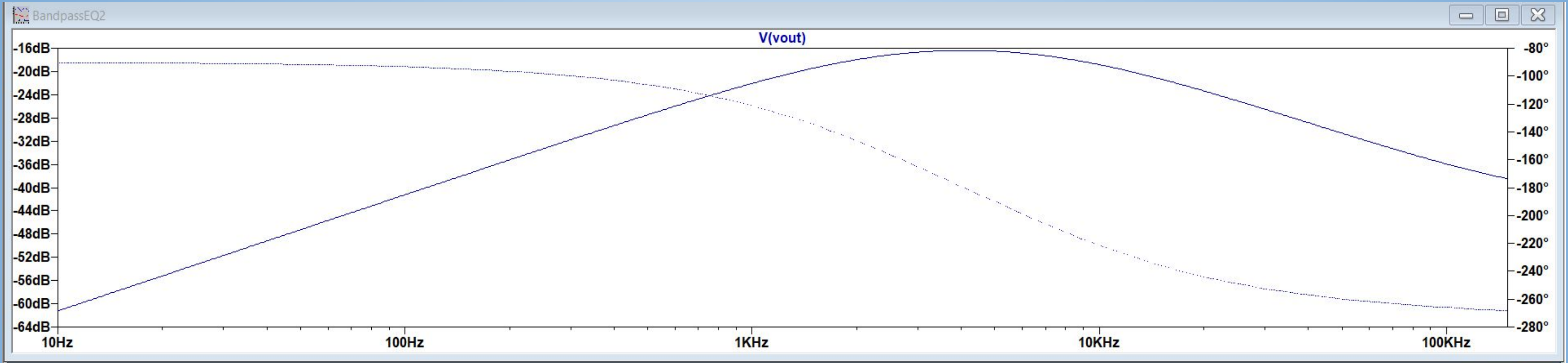
Frequency Response - Simulations

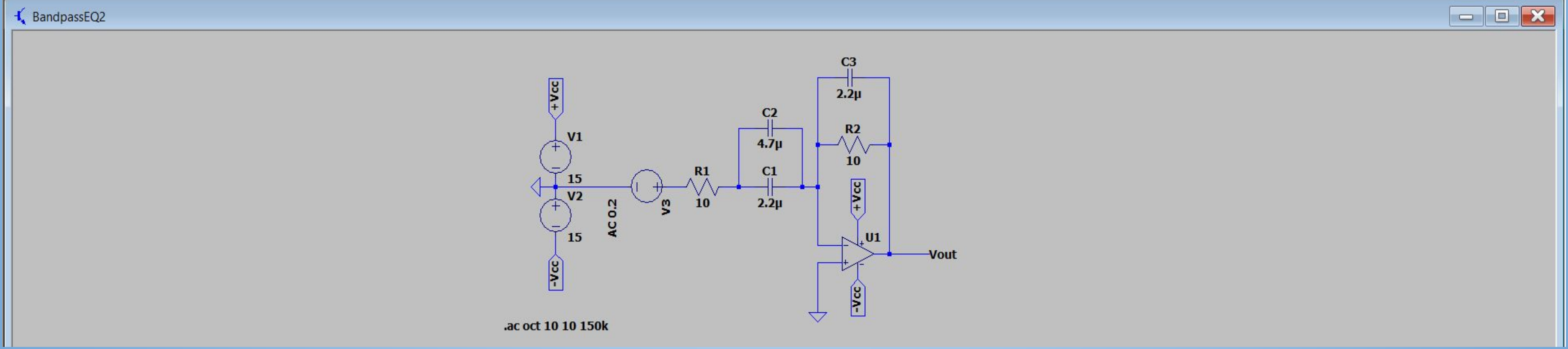
Block 1 : 100-800Hz



Frequency Response - Simulations

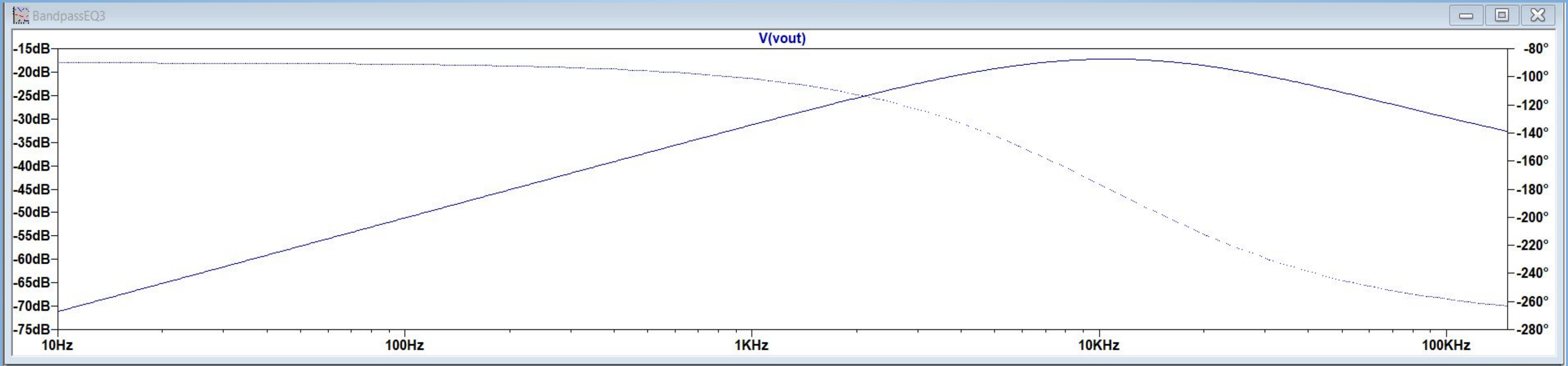
Block 2 : 600-2300Hz

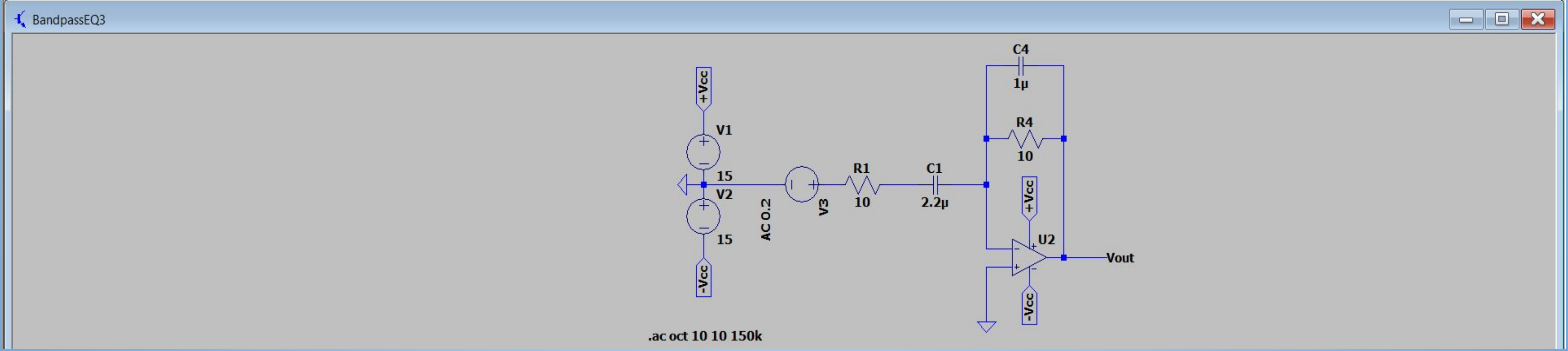




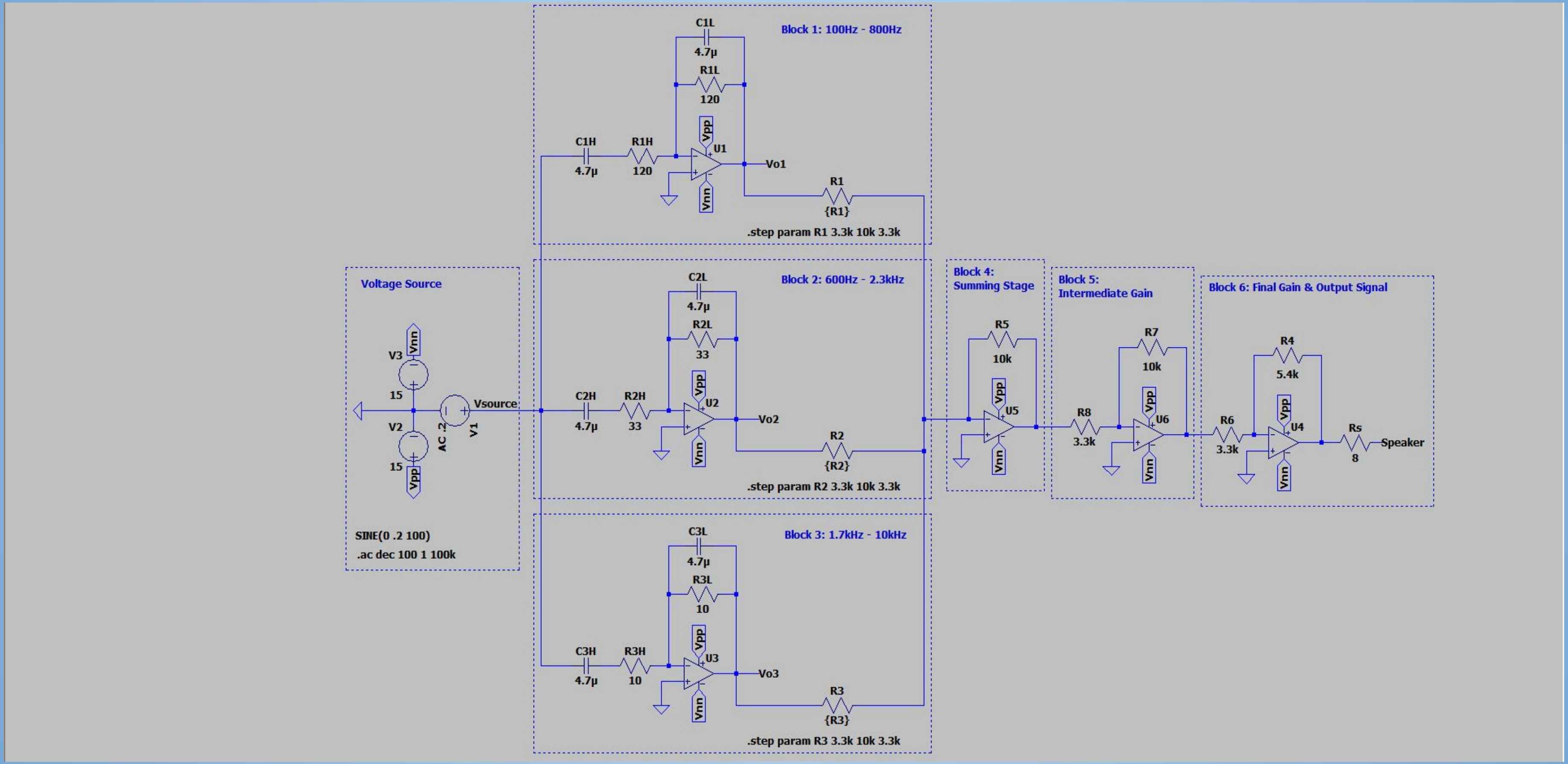
Frequency Response - Simulations

Block 3 : 1.7-10kHz

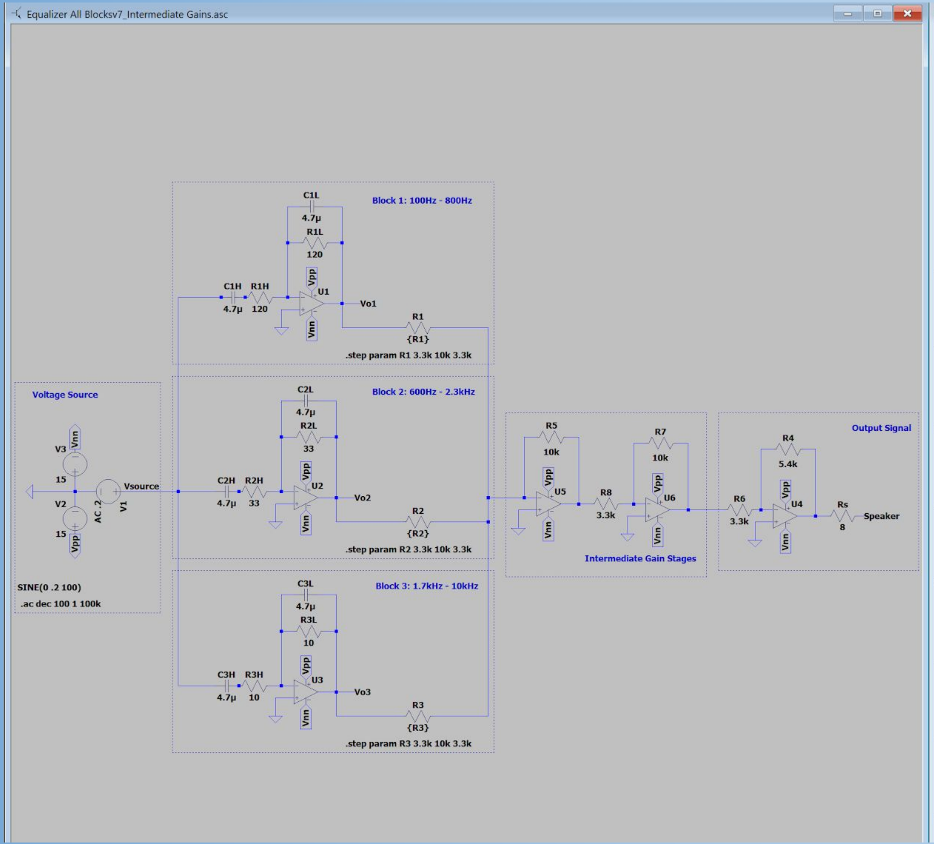


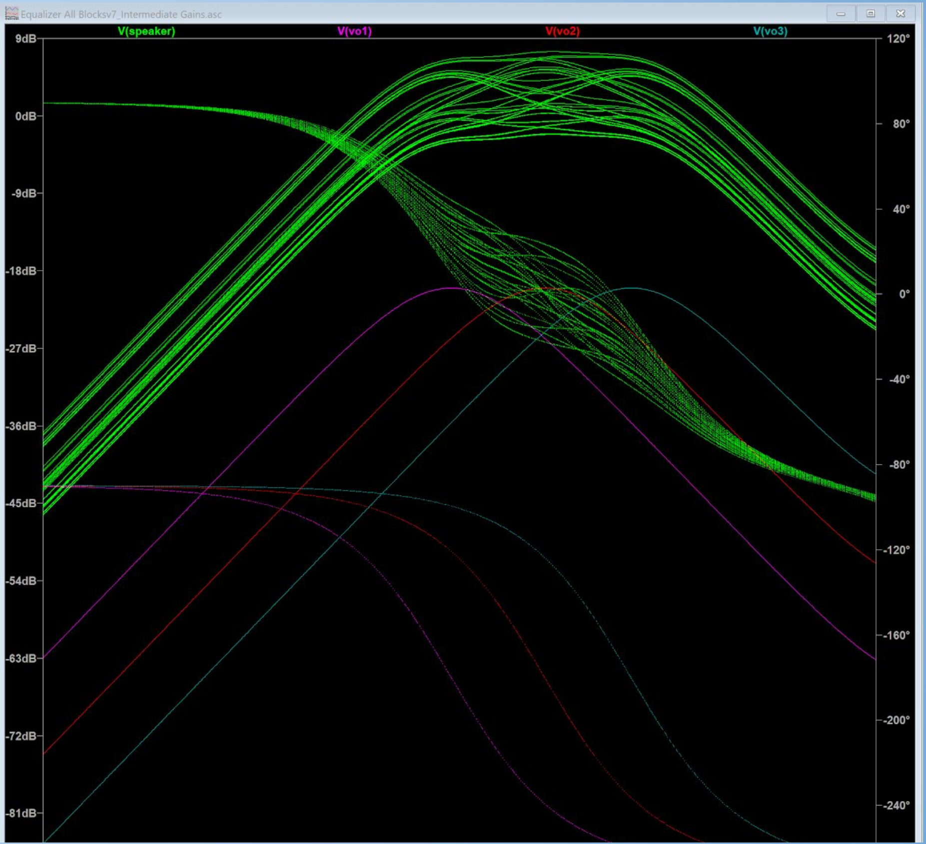


Frequency Response - Final Simulation



Frequency Response - Final Simulation

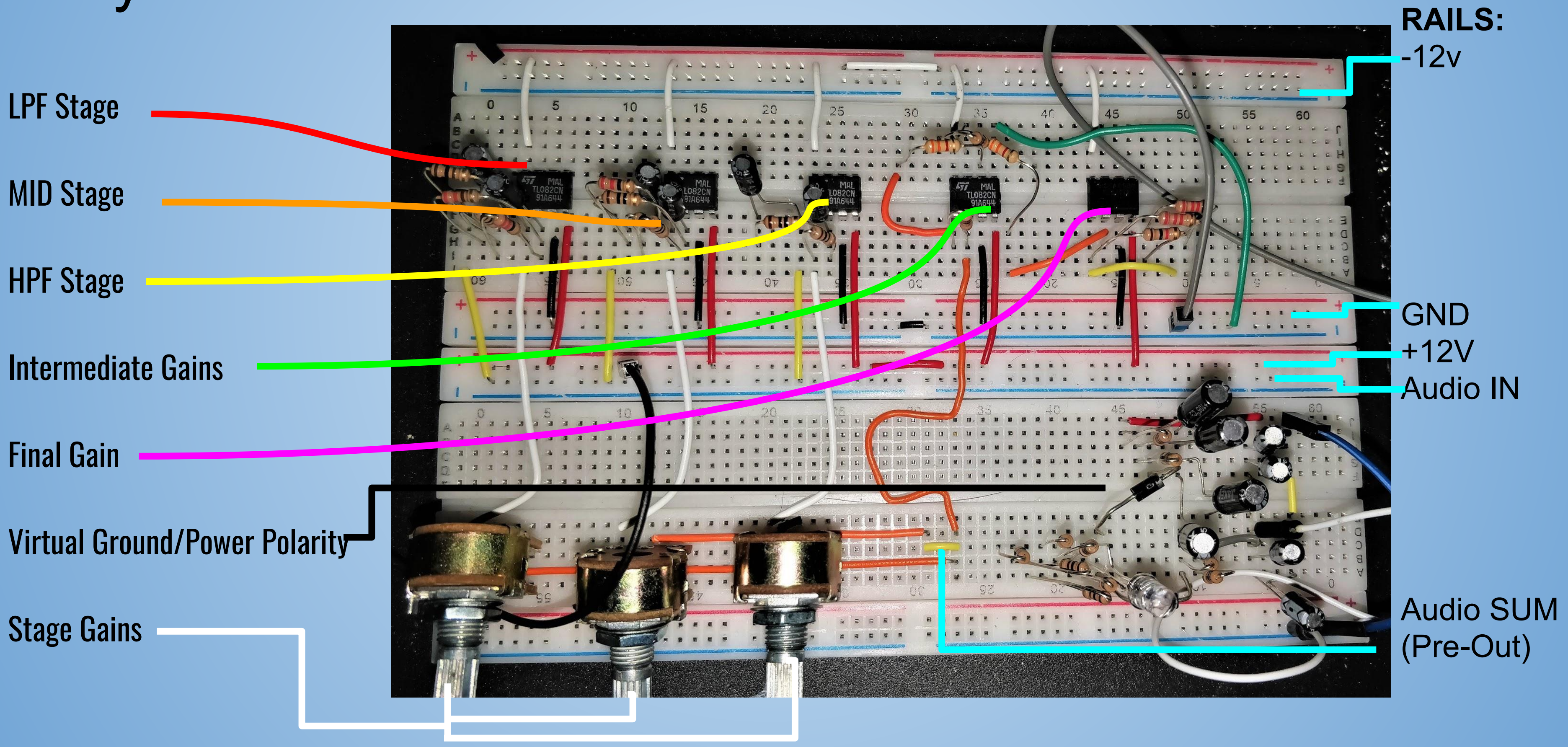




Bill of Materials

No.	Block	Item	Description	Qnty	Notes
1	All	TL082 & LM741	Op Amp	6	1 amp per block
2	Blocks 1 - 3	4.7uF	Capacitor	6	Standardized capacitor values across each BPF
3	Block 1	120 Ω	Resistor	2	Unity gain resistors
4	Block 2	33 Ω	Resistor	2	Unity gain resistors
5	Block 3	10 Ω	Resistor	2	Unity gain resistors
6	Blocks 1 - 3	3.3k - 10k Ω	Potentiometer	3	Adjustable gain for each band
7	Blocks 4 - 5	10k Ω	Resistor	2	Feedback resistors
8	Blocks 5 - 6	3.3k Ω	Resistor	2	Input resistors
9	Block 6	5.4k Ω	Resistor	1	Last block feedback, adjusted to keep final gain below 7.96 dB
10	Block 6	8 Ω	Resistor	1	Load resistor

Physical Build



Demonstration

Conclusion

Filters are fun!

Are there any questions?