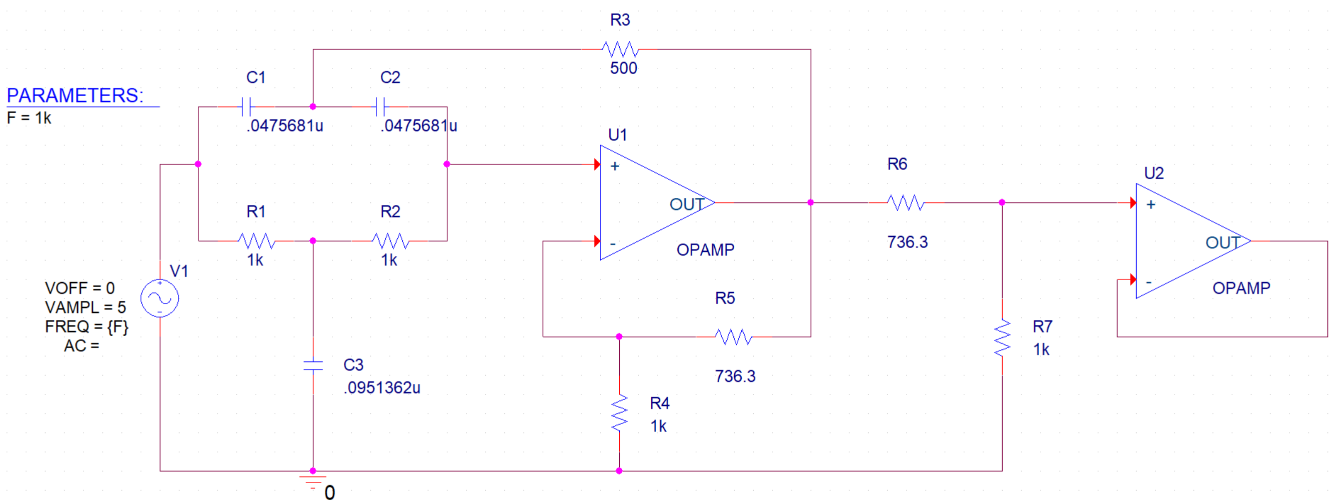
ECE 2101L Lab #9

Band Stop Filter



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December 11th, 2020

Objective

The objective of the lab is to explore band stop filters and the magnitude responses that they produce, as well as be able to find the transfer function of a circuit designed to produce a band stop response.

Materials

The necessary equipment needed for the lab are as follows

1. Breadboard
2. 4 BNC Clip Connectors
3. Clip Leads
4. 2 .0475681μF and one .0951362μF Capacitor
5. 4 1kΩ, 2 736.3Ω, and one 500Ω Resistors
6. 2 Op Amps
7. LCR Meter
8. Digital Multimeter
9. Oscilloscope
10. Function Generator

<u>Pre-Lab</u>

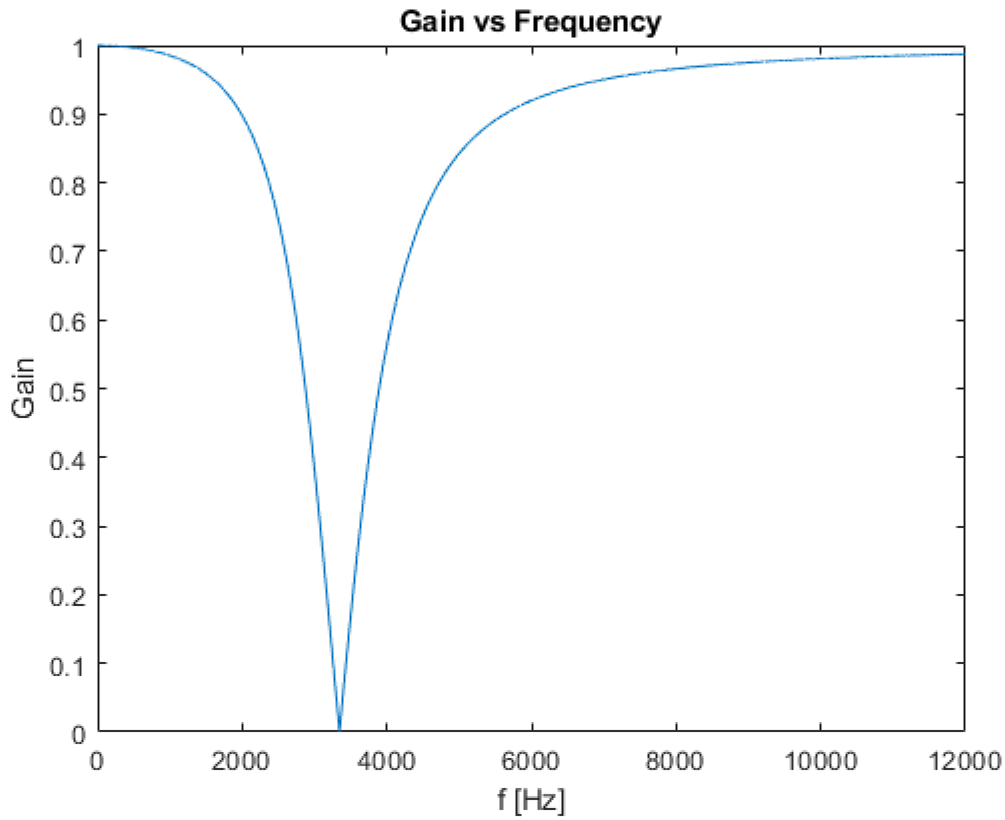


Figure 1: MATLAB Plot

Procedure

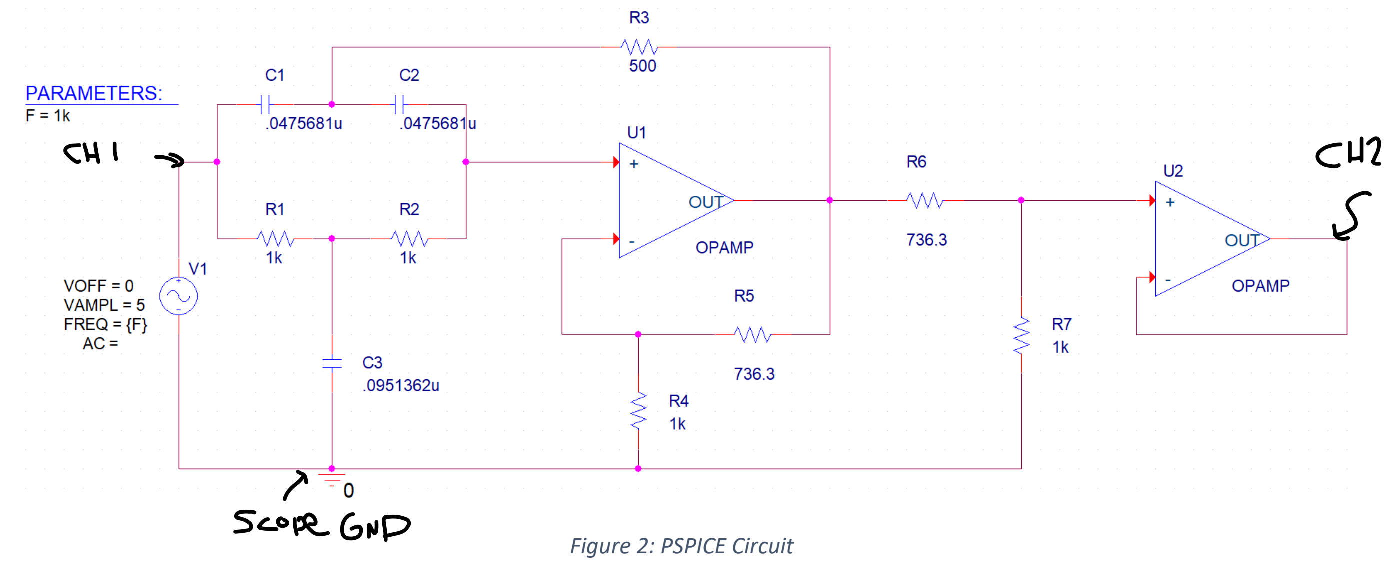


Figure 2: PSPICE Circuit

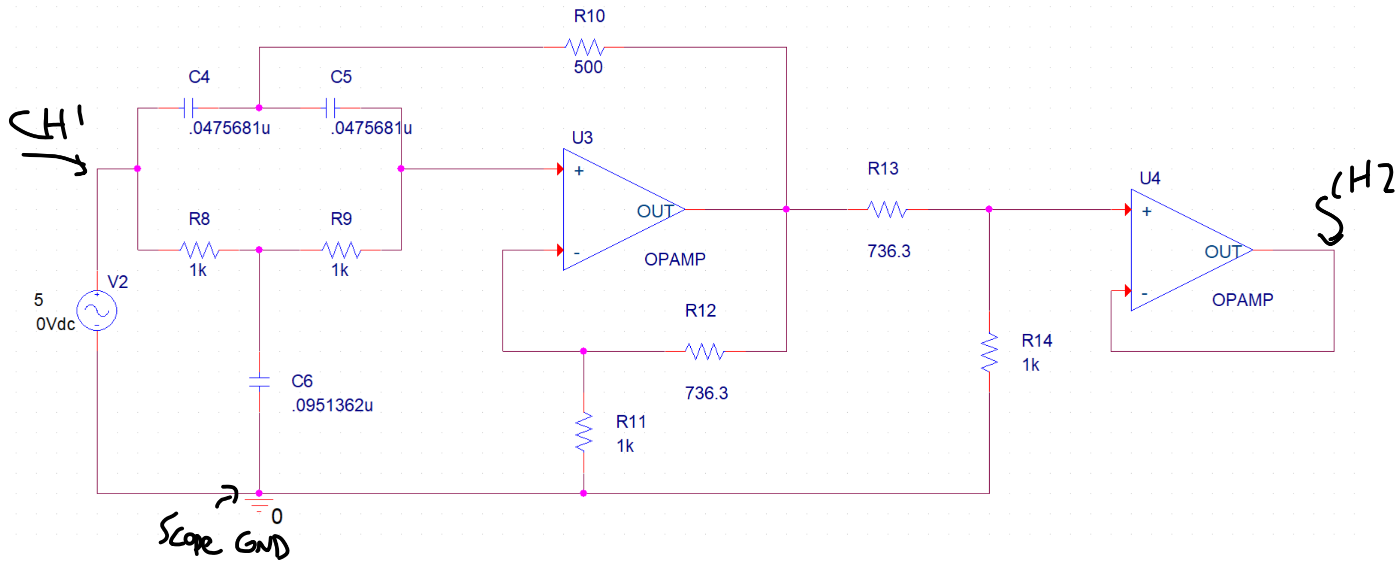


Figure 3: PSPICE Circuit For Magnitude Response (Post Lab)

Results

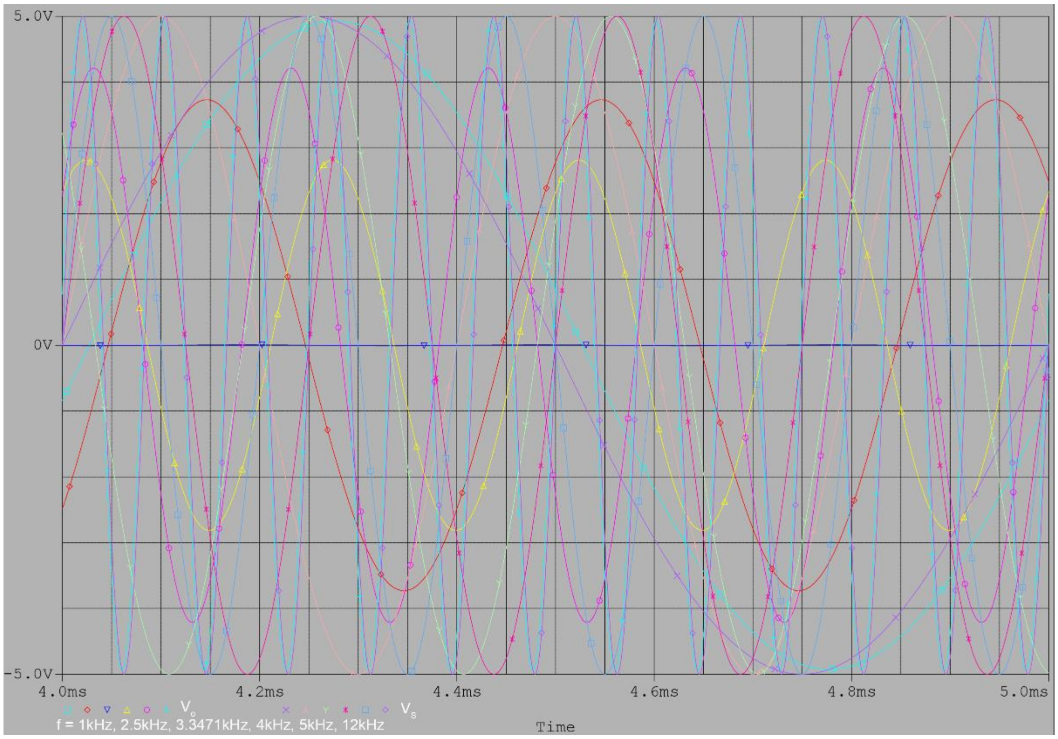


Figure 4: Plot For The Response For Various Frequencies (Not Used)

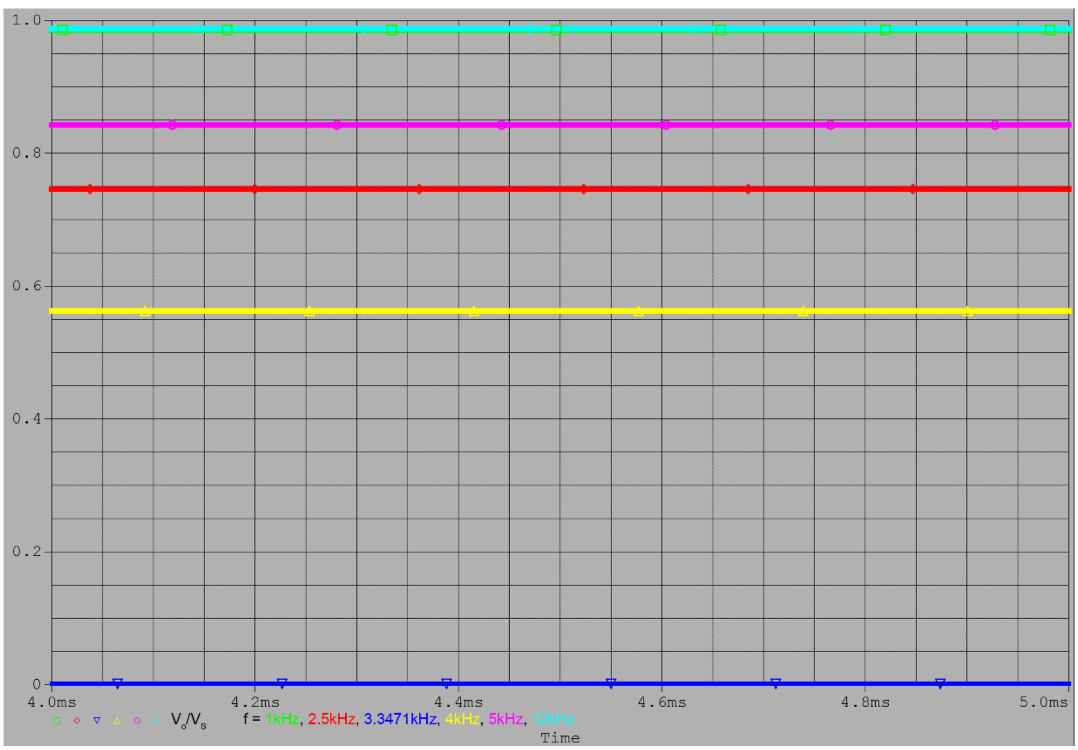


Figure 5: Plot For Magnitude For Various Frequencies

CURSOR 1,2	MAX(V(U2:OUT))/MAX(V(V1:+))	985.345m
	MAX(V(U2:OUT))/MAX(V(V1:+))	746.182m
	MAX(V(U2:OUT))/MAX(V(V1:+))	707.376m
	MAX(V(U2:OUT))/MAX(V(V1:+))	1.4366m
	MAX(V(U2:OUT))/MAX(V(V1:+))	562.762m
	MAX(V(U2:OUT))/MAX(V(V1:+))	705.626m
	MAX(V(U2:OUT))/MAX(V(V1:+))	842.613m
	MAX(V(U2:OUT))/MAX(V(V1:+))	987.523m

Figure 6: Measurement For Magnitude For Various Frequencies

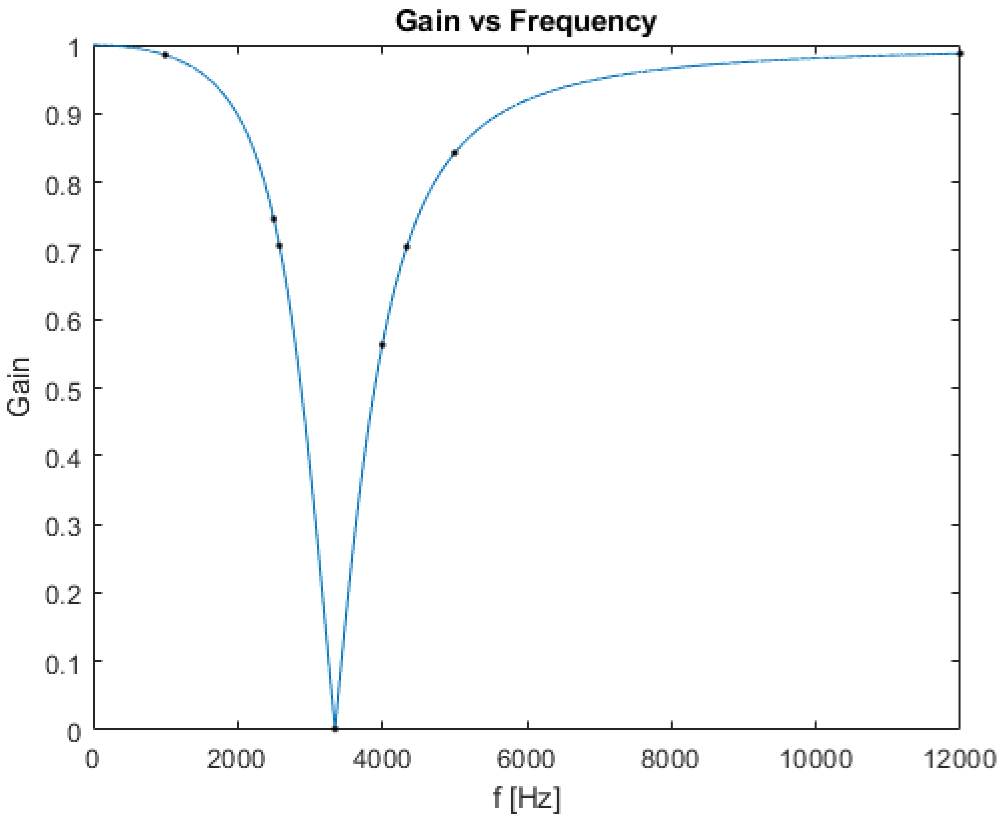


Figure 7: MATLAB Plot With Data In Black

<u>Data Table For Frequencies & Corresponding Gain</u>

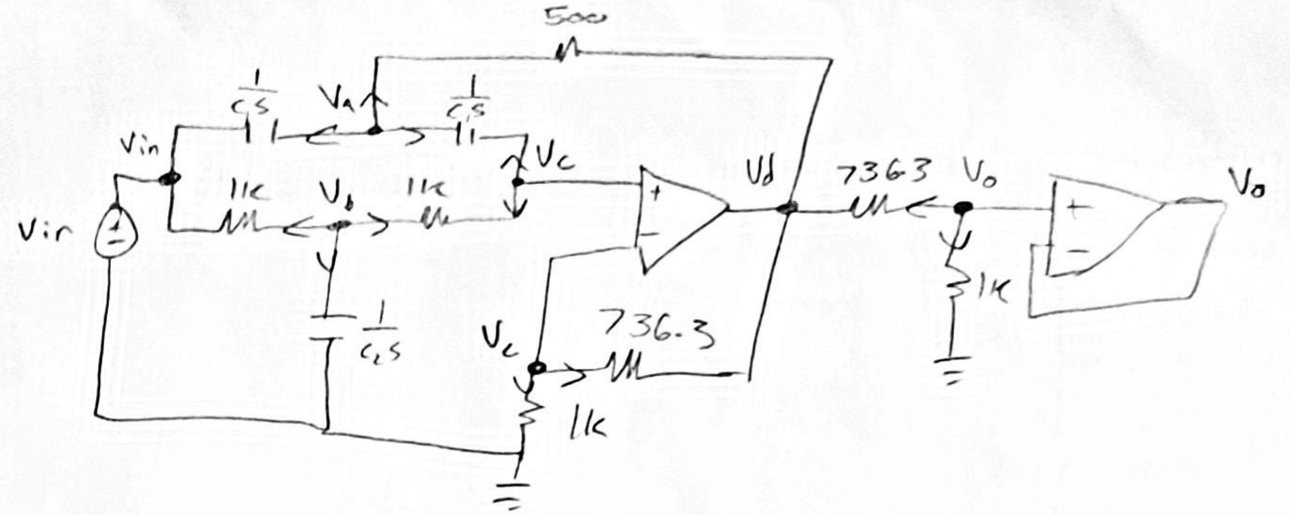
f [Hz]	|H(j*2*π)|
1k	985.345m
2.5k	746.182m
2.5774k	707.376m
3.3471k	1.4366m
4k	562.762m
4.3379k	705.626m
5k	842.613m
12k	987.523m

Analysis

We can see from our data that as we increase the frequency the gain decreases until f = 3.3471kHz, where the gain is incredibly small, about .0014, which is close enough to 0 for practical purposes. The gain then increases once more as we increase the frequency past this stopping point. The 3dB frequencies were found at about 2.5774kHz and 4.3379kHz and the band width of the filter would be 0Hz < = f <= 2.5774kHz and 4.3379kHz <= f . Our data closely matches the theoretical magnitude response since we used PSPICE to collect our data which is heavily based on theoretical calculations.

Problems

a.



$C_1 = .0475681\,\mu F \qquad C_2 = .0951362\,\mu F$

(a) $$\frac{V_a - V_{in}}{\frac{1}{C_1 s}} + \frac{V_a - V_c}{\frac{1}{C_1 s}} + \frac{V_a - V_d}{500} = 0$$

(b) $$\frac{V_b - V_{in}}{1k} + \frac{V_b - V_c}{1k} + \frac{V_b}{\frac{1}{C_2 s}} = 0$$

(C_1) $$\frac{V_c - V_a}{\frac{1}{C_1 s}} + \frac{V_c - V_b}{1k} = 0$$

(C_2) $$\frac{V_c - V_d}{736.3} + \frac{V_c}{1k} = 0$$

(O) $$\frac{V_o - V_d}{736.3} + \frac{V_o}{1k} = 0$$

$$H(s) = \frac{s^2 + 441900000}{s^2 + 11090\,s + 441900000}$$

b. Write a Spice program to find the magnitude of the transfer function of your circuit. Run your program and compare with your experimental results.

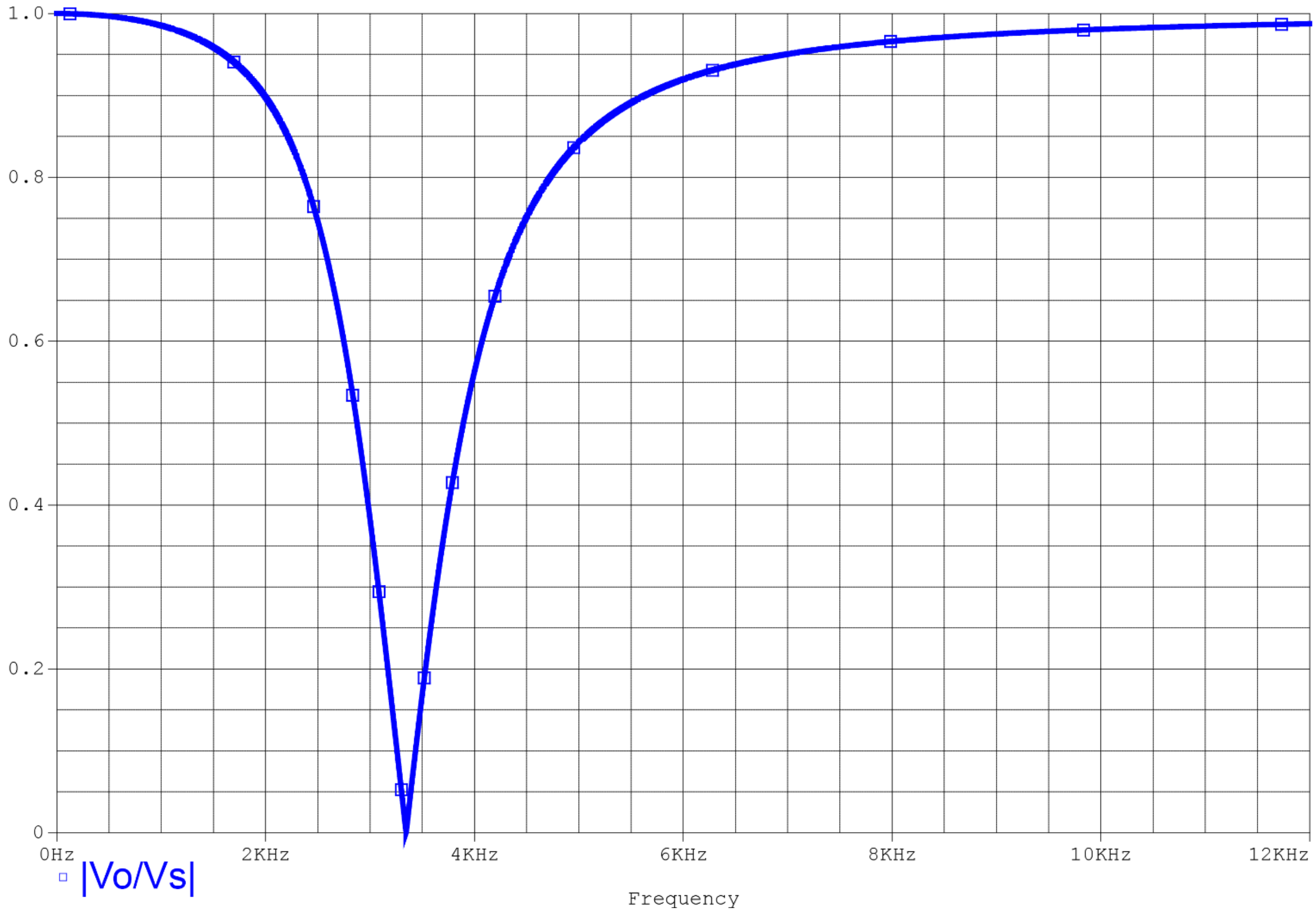


Figure 8: Magnitude of Transfer Function Using PSPICE

Appendix

```
%MATLAB Code
syms s va vi vb vc vd vo

spec = 'k.';

%Metric Units
k = 10^3;
m = 10^-3;
u =10^-6;

%Plots Used In THe Lab
H_TH(s) = (s^2 + 4.41940645 * 10^8)/(s^2 + 11087.0258*s + 4.41940645 * 10^8);
f = linspace(0,12*1000,10000);
plot(f,abs(H_TH(j*2*pi*f)))

xlabel('f [Hz]'); ylabel('Gain'); title('Gain vs Frequency');

hold on;

%Data Points
plot (1*k,985.345*m, spec)
plot (2.5*k,746.182*m, spec)
plot (3.3471*k,1.4366*m, spec)
plot (4*k,562.762*m, spec)
plot (5*k,842.613*m, spec)
plot (12*k,987.523*m, spec)
plot (2.5774*k,707.376*m, spec)
plot (4.3379*k,705.626*m, spec)

%Cap Values
C1 = .0475681*u;
C2 = .0951362*u;
ZC1 = 1/(C1*s);
ZC2 = 1/(C2*s);

%Definitions of nodal eqn
node_a = (va-vi)/ZC1 + (va-vc)/ZC1 + (va-vd)/500 == 0;
node_b = (vb-vi)/k + (vb-vc)/k + (vb)/ZC2 == 0;
node_c = (vc-va)/ZC1 + (vc-vb)/k == 0;
node_d = (vc-vd)/736.3 + (vc)/k == 0;
node_e = (vo-vd)/736.3 + (vo)/k == 0;

%Solving Nodal Eqn
sol = solve(node_a,node_b,node_c,node_d,node_e,[va,vb,vc,vd,vo]);

%This was done to get H(s) in a format I can compare to the lab
```

```
H_TEMP = (simplify(sol.vo/vi))
```

H_TEMP =

$$\frac{2018417377896221955905199287847656 25\, s^2 + 892029807941224925661428730905934460239216 64}{2018417377896221955905199287847656 25\, s^2 + 223787228226998239872143102829595616870 4\, s + 892029807941224925661428730905934460239216 64}$$

```
[n,d] = numden(H_TEMP)
```

n = $2018417377896221955905199287847656 25\, s^2 + 892029807941224925661428730905934460239216 64$

d =
$2018417377896221955905199287847656 25\, s^2 + 223787228226998239872143102829595616870 4\, s + 892029807941224925661428730905934460239216 64$

```
H_num = vpa(n/201841737789622195559051992878476562 5,4)
```

H_num = $1.0\, s^2 + 4.419\mathrm{e}{+}8$

```
H_den = vpa(d/201841737789622195559051992878476562 5,4)
```

H_den = $1.0\, s^2 + 11090.0\, s + 4.419\mathrm{e}{+}8$

```
H(s) = (s^2 + 4.419e+8)/(s^2 + 11090 *s + 4.419e+8)
```

H(s) =

$$\frac{s^2 + 441900000}{s^2 + 11090\, s + 441900000}$$