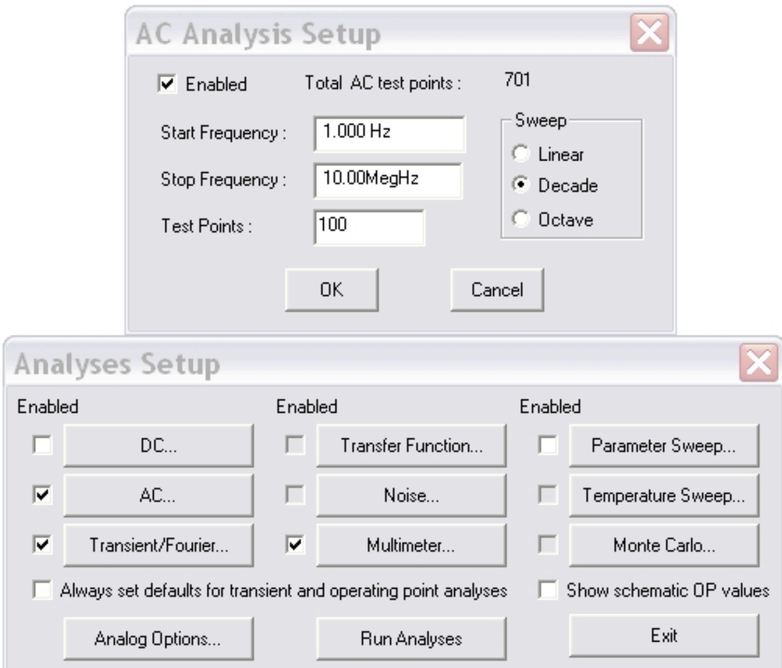
MMI401 Lab 2

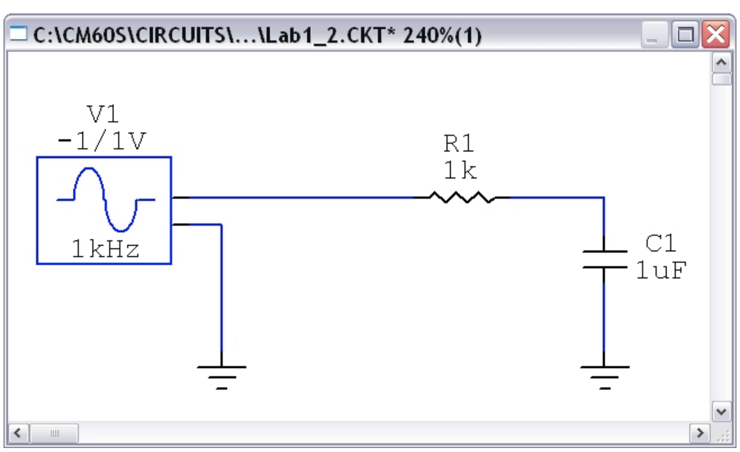
First Order Passive Filters

First open up a circuit from the last lab, then setup CM to add the Frequency Response analysis plot. Save this as your template for this lab. To add the Frequency Response Analysis, you need to enable it in Analysis Setup and set the following parameters (make sure you get 701 analysis points in total)

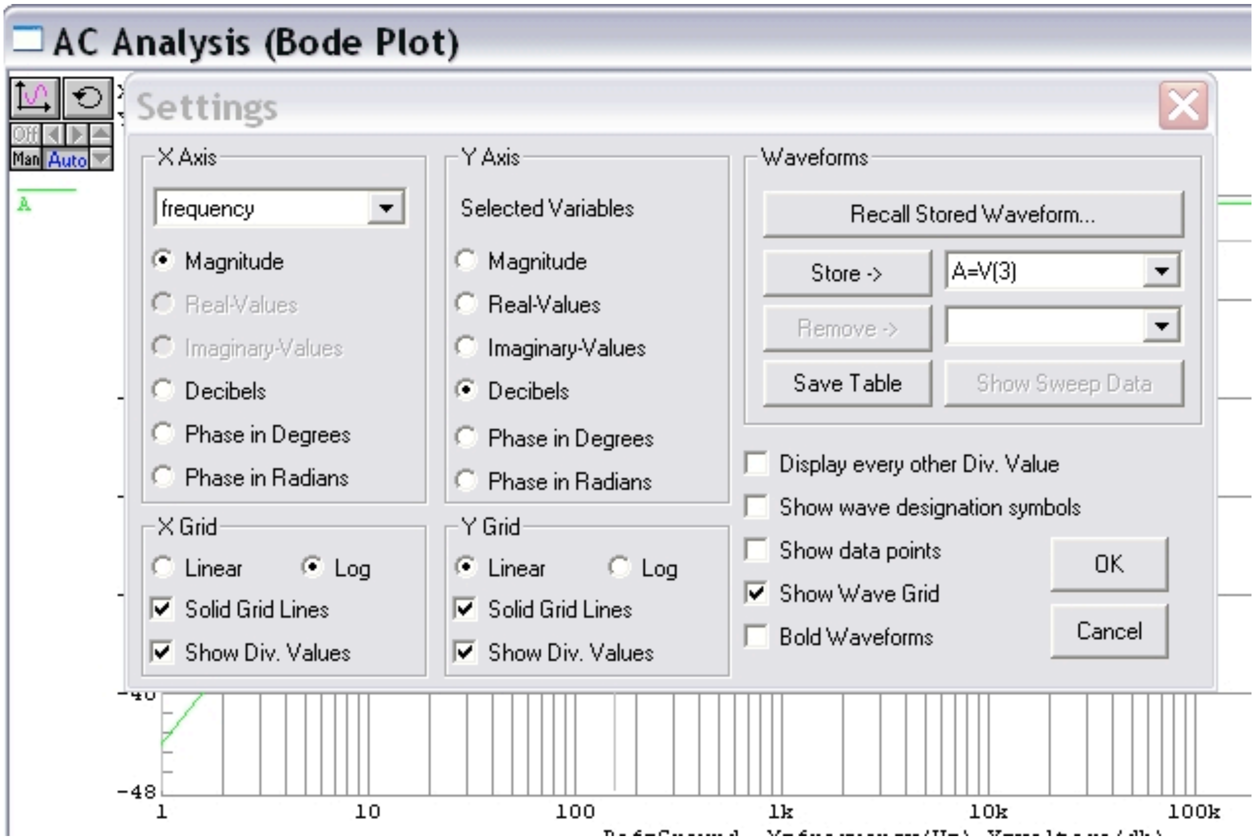


Circuit 1: Test for Analysis Setup

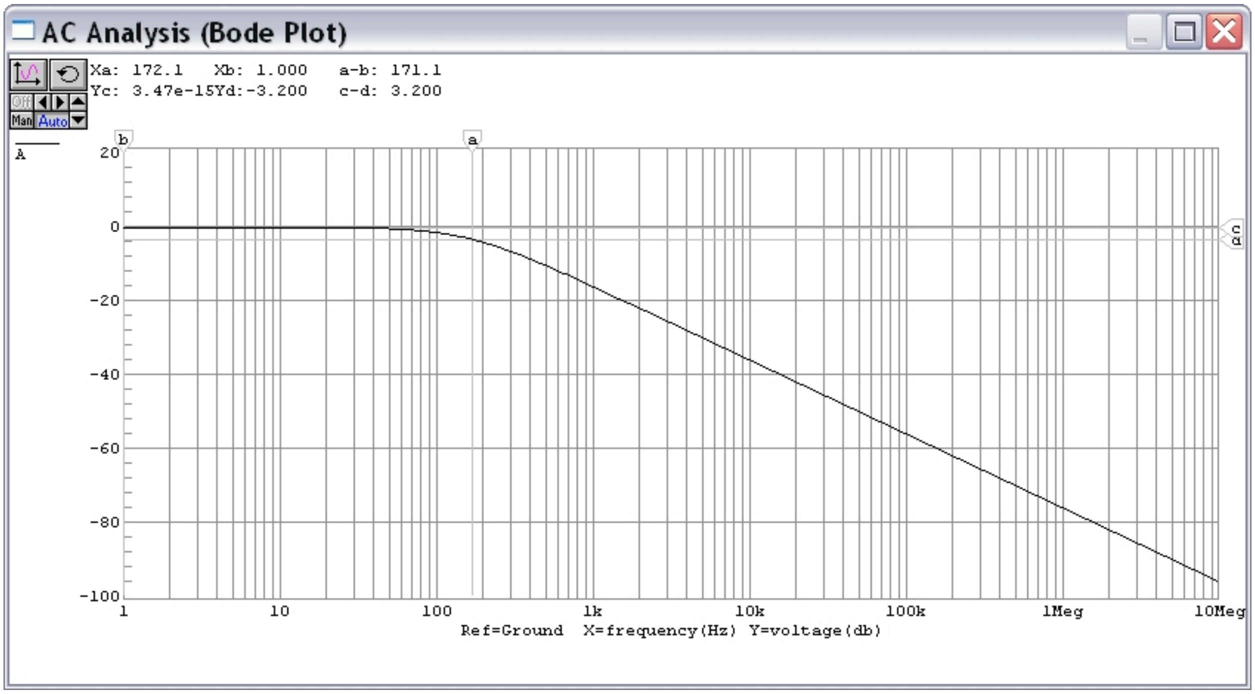
This circuit is a check to make sure your setup is correct. You will need to modify the Analysis Window setup too. For this circuit, implement a simple 1st Order RC LPF with a 1uF cap and 1k resistor as shown here:



Probe the output point between the R and C and you should get the LPF curve you expect, but you need to setup the AC Analysis Plot correctly by clicking on the little pink sinusoid in the upper left and setting up as follows:



The TA will show you how to use the A,B,C,D analysis bars to figure out what the cutoff frequency is:



For me it looks like about 172 Hz at the 3dB frequency fc. Verify this is basically correct using the equation in the book for the cutoff frequency calculation. Use the same ABCD bars to show that the rolloff is -20dB/decade (or 6dB/per octave) - where are the decade and octave lines on this plot?

In these next circuits, several of the items marked “Lab Questions” are really just you using screenshots to show that CM is giving you the proper results.

Circuit 2: 1st Order LPF

Design a 1st Order LPF with f_c = 1kHz. Let C = 0.1uF; calculate and use the exact resistor value.

Lab Questions:

a) use CM to show the -3dB frequency is correct

b) use CM to show the asymptotic roll-off is -20dB/dec or -6dB/oct

Circuit 3: 2nd Order Cascaded LPF

You can make a 2nd Order LPF by cascading two identical 1st Order stages, one after the other. Do that in CM by cut/paste the sections in series.

Lab Questions:

a) use CM to show that the f_c is now wrong for the two stages cascaded. The f_c will shrink to a lower value for the cascaded filters. Also, show the asymptotic roll-off is now -40dB/decade
b) calculate the shrinkage factor, $s(n) = (\text{cascaded } f_c)/(1^{st} \text{ Order } f_c)$

Circuit 4: 2nd Order Cascaded LPF, corrected

Now, redesign the 1^{st} Order Stages to compensate for the shrinkage. Leave one component alone (either R or C) and modify the other component to produce a new 1^{st} Order stage that, when cascaded with an identical 1^{st} Order stage, produces a new 2^{nd} Order LPF with the proper $f_c = 1\text{kHz}$ – use the calculated value for the new component and:

Lab Questions:
c) use CM to show the new -3dB frequency is now correct for the cascaded stages.

Additional Circuits: These can be done during the lab time or during the next week or a combination depending on how much time you have left in lab and how confident you are about using Circuit Maker.

Circuit 5: HPF Terminated in a 600ohm load

Design a HPF with a $f_c = 1\text{kHz}$; let C = 0.1uF calculate and use the exact Resistor value.

Lab Questions:
a) use CM to show the -3dB frequency is correct
b) use CM to show the asymptotic roll-off is -20dB/dec or -6dB/oct

Terminate the filter in a 600 ohm load (ie connect a 600 ohm resistor across Z2 in the impedance divider)

a) use CM to show the -3dB frequency is now <u>incorrect</u>
b) **Derivation** - derive the transfer function for a 1st Order HPF Terminated in a load resistance RL.
c) Derive the equation for the new (incorrect) cutoff frequency of the HPF and plug your values in to make sure you are getting the same value.

Circuit 6: 5kHz HPF, no Load Termination

Design a 1st Order HPF with f_c = 5kHz. Pick a capacitor value from the table of Standard Cap Values (at http://mmi401wp.pbworks.com) and calculate the resistor value. The resistor should be between 100 ohms and 100k – if it is not, pick another cap value and try again.

Lab Questions

a) Write the transfer function H(w) for the HPF and plug in your design values. Manually calculate, then plot the Frequency Response at the following frequencies, the same as we did in class. This is a bit time consuming but basically just a calculator exercise.

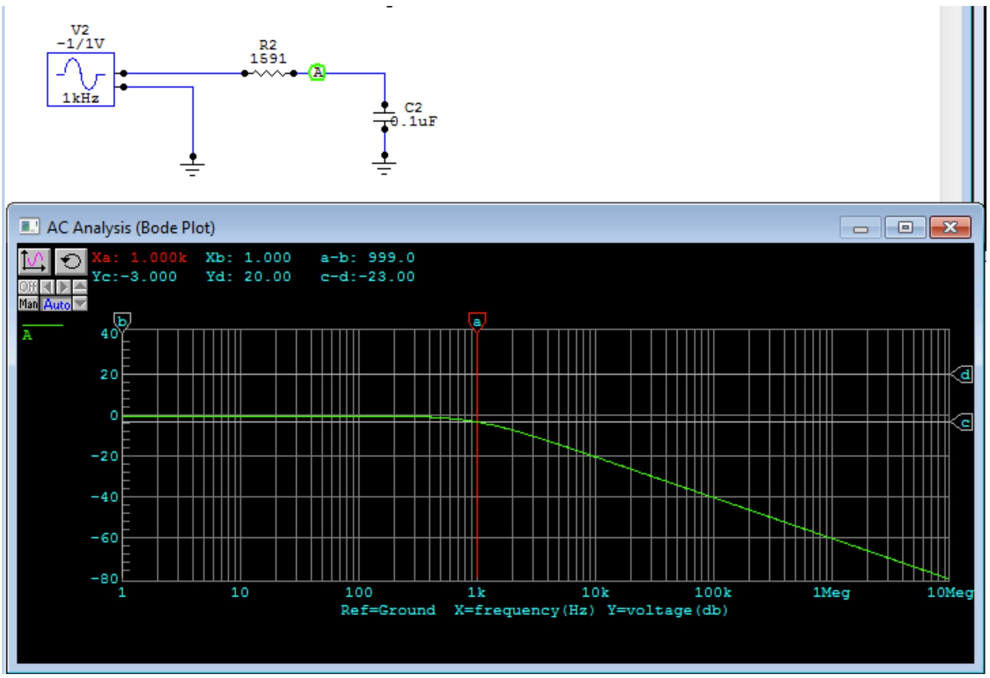
0 Hz
10 Hz
100 Hz
1 kHz
5 kHz
10 kHz
20 kHz

b) use your calculated results to show that f_c = 5kHz and the roll-off is -20dB/dec or -6dB/oct
c) Use CM to show that your hand-made plot is correct.

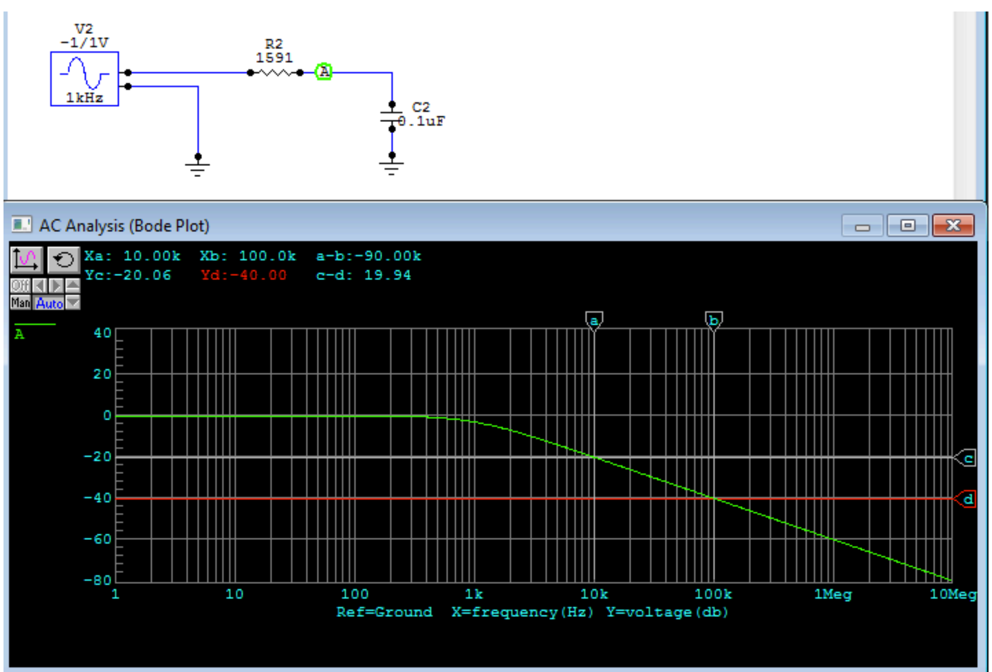
Nate Paternoster

Circuit 2

a:

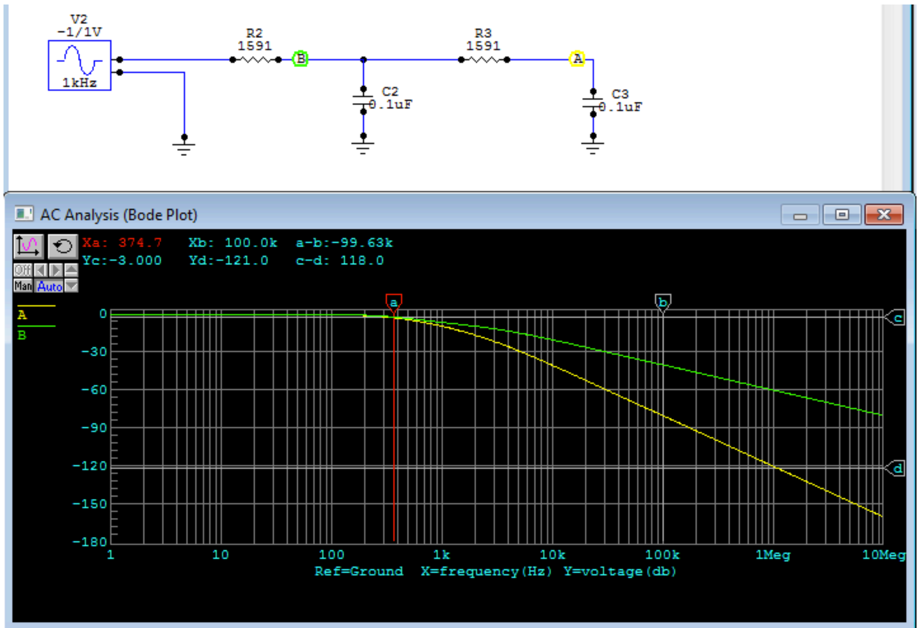


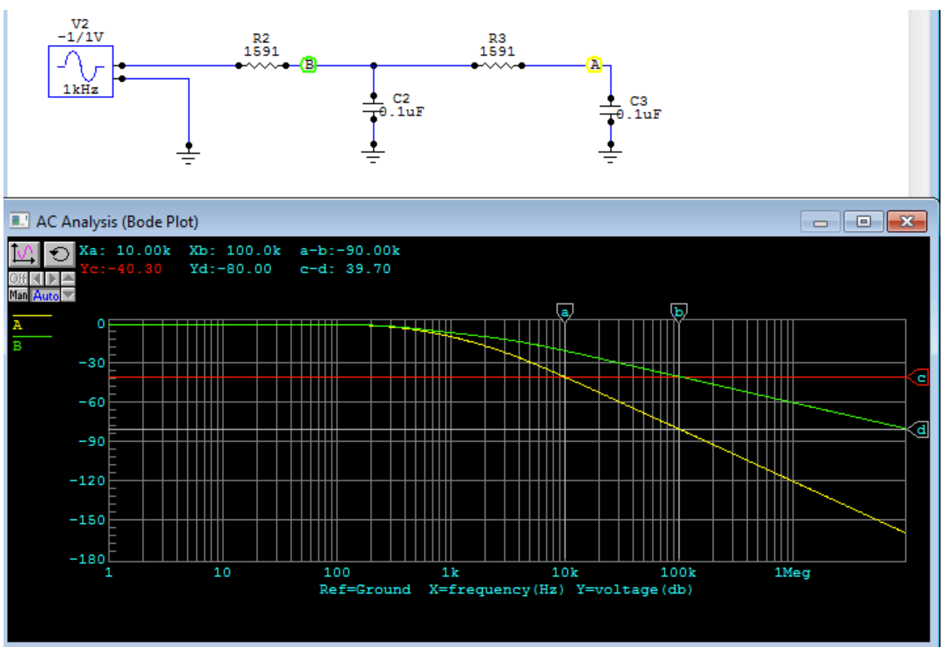
b:



Circuit 3

a:



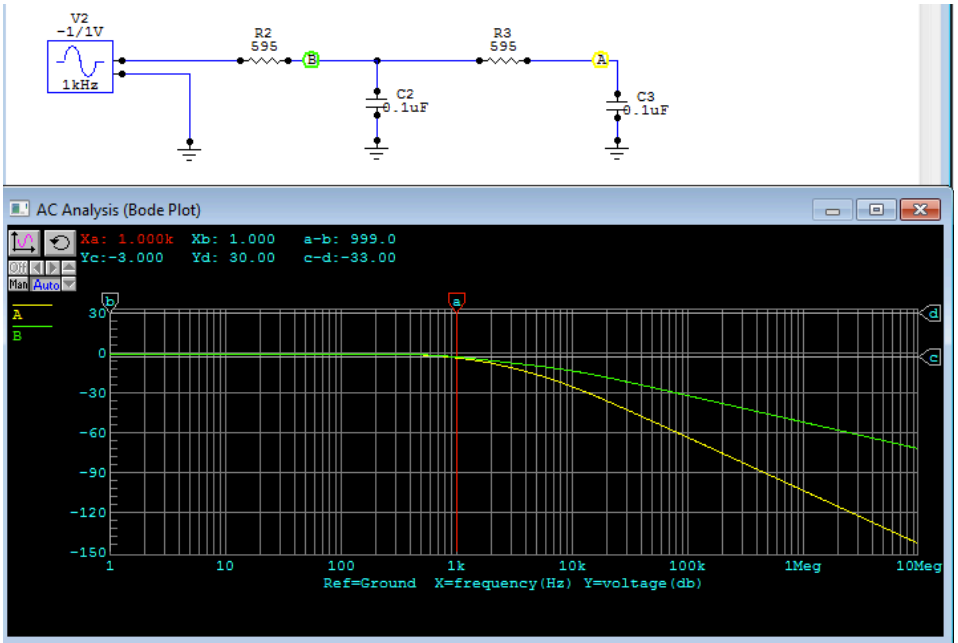


b:

s(n) = (cascaded fc)/(1st Order fc)
s(n) = (374.7Hz)/(1000Hz)
s(n) = .375

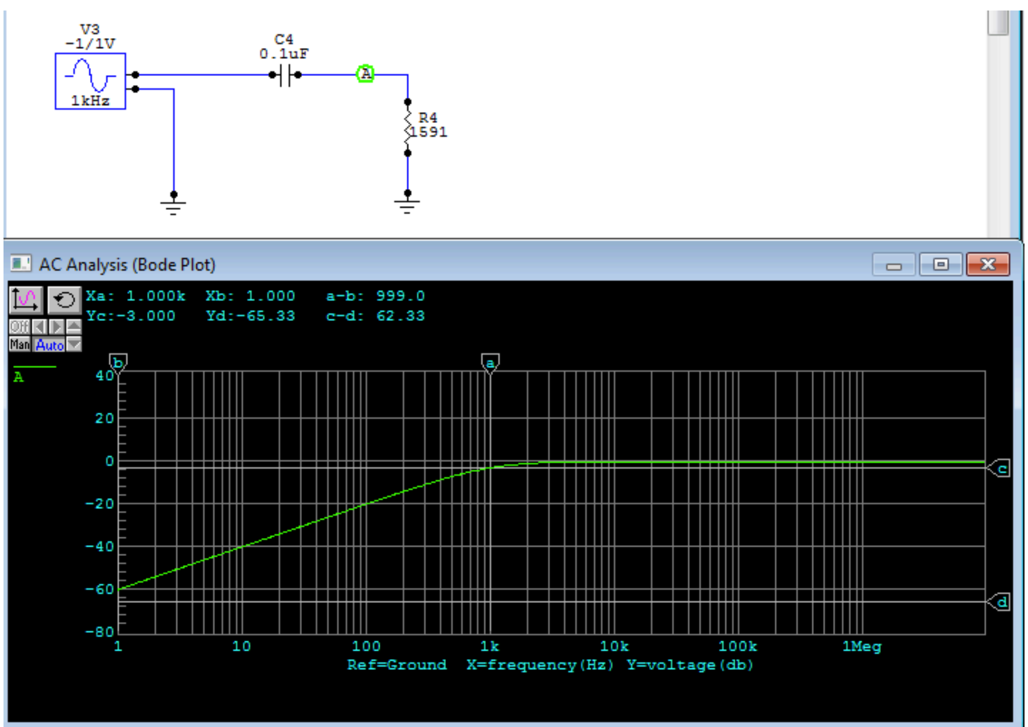
Circuit 4

c:

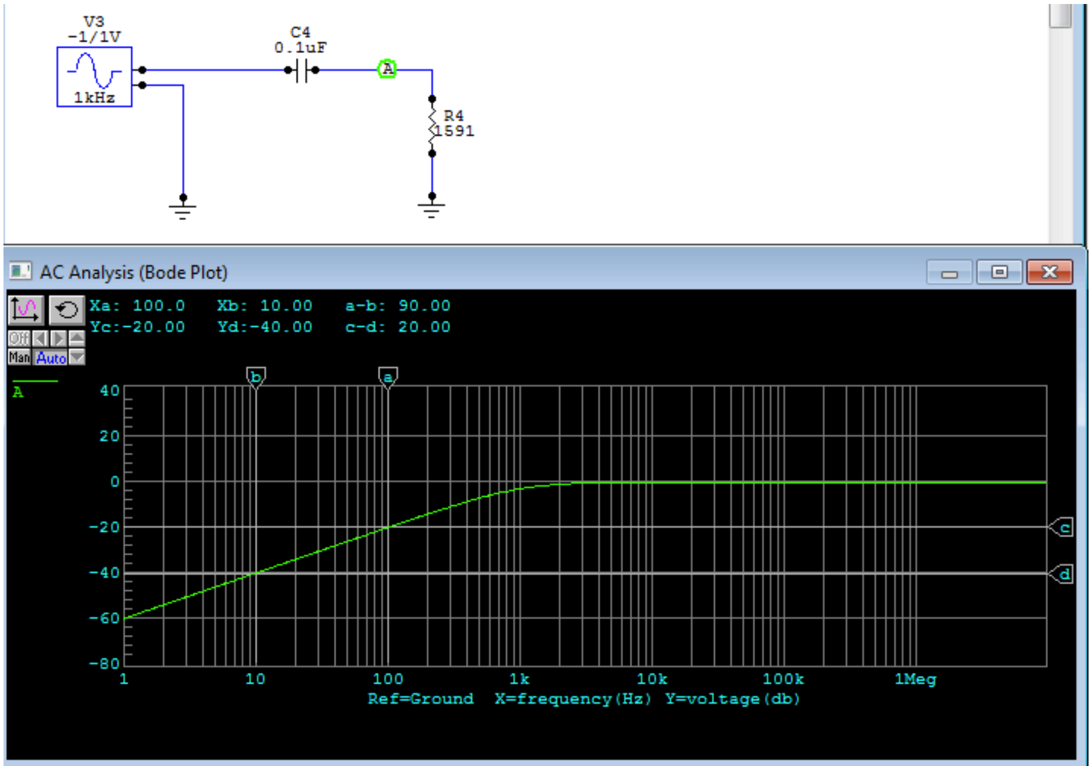


Circuit 5

a:

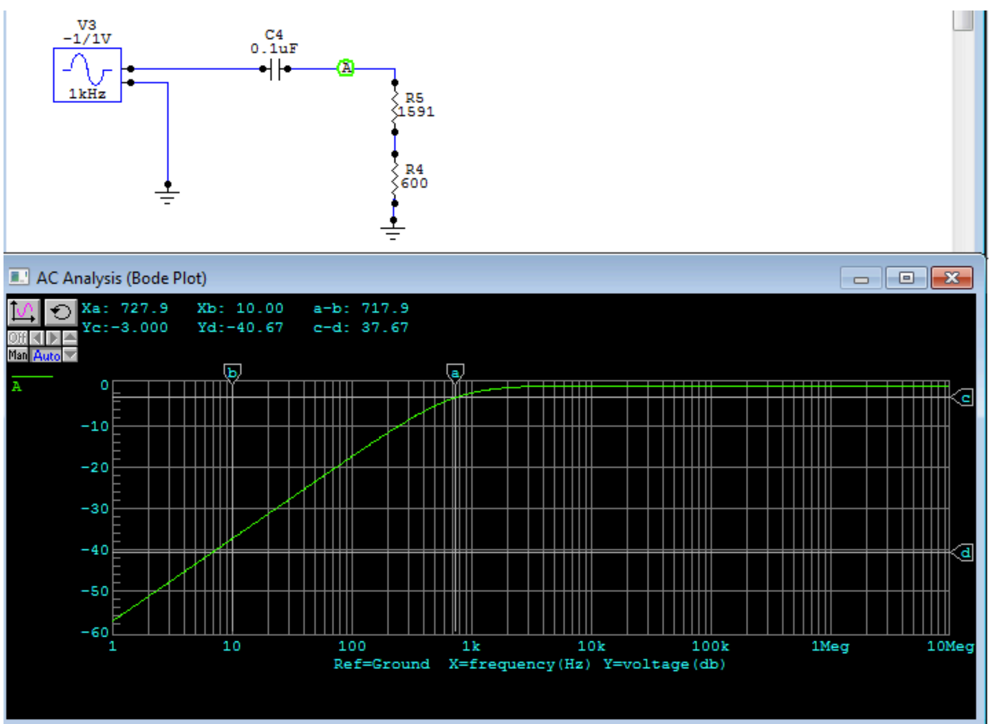


b:



Circuit 5 w/ 600 ohm load

a:



b:

$$\frac{V_{out}}{V_{in}} = \frac{Z_2}{Z_1 + Z_2}$$

$$\frac{V_{out}}{V_{in}} = \frac{(R_4 + R_5)}{\frac{1}{j\omega C} + (R_4 + R_5)}$$

$$\frac{V_{out}}{V_{in}} = \frac{j\omega C(R_4 + R_5)}{1 + j\omega C(R_4 + R_5)}$$

$$H(j\omega) = \frac{j\omega C(R_4 + R_5)}{1 + j\omega C(R_4 + R_5)}$$

$$|H(\omega)|^2 = (\frac{j\omega C(R_4 + R_5)}{1 + j\omega C(R_4 + R_5)})(\frac{j\omega C(R_4 + R_5)}{1 - j\omega C(R_4 + R_5)})$$

$$|H(\omega)|^2 = \frac{1}{1 + (\frac{1}{\omega C(R_4 + R_5)})^2}$$

$$|H(\omega)| = \frac{1}{\sqrt{1 + (\frac{1}{\omega C(R_4 + R_5)})^2}}$$

c:

$$|H(\omega_c)|^2 = \frac{1}{1 + (\frac{1}{\omega_c C(R_4 + R_5)})^2}$$

$$0.5 = \frac{1}{1 + (\frac{1}{\omega_c C(R_4 + R_5)})^2}$$

$$0.5 + 0.5(\frac{1}{\omega_c C(R_4 + R_5)})^2 = 1$$

$$(\frac{1}{\omega_c C(R_4 + R_5)})^2 = 1$$

$$\frac{1}{f_c 2\pi C(R_4 + R_5)} = 1$$

$$f_c = \frac{1}{2\pi C(R_4 + R_5)}$$

$$f_c = \frac{1}{2\pi(0.1\mu F)(600\Omega + 1591\Omega)}$$

$$f_c = 726.4Hz$$

Circuit 6

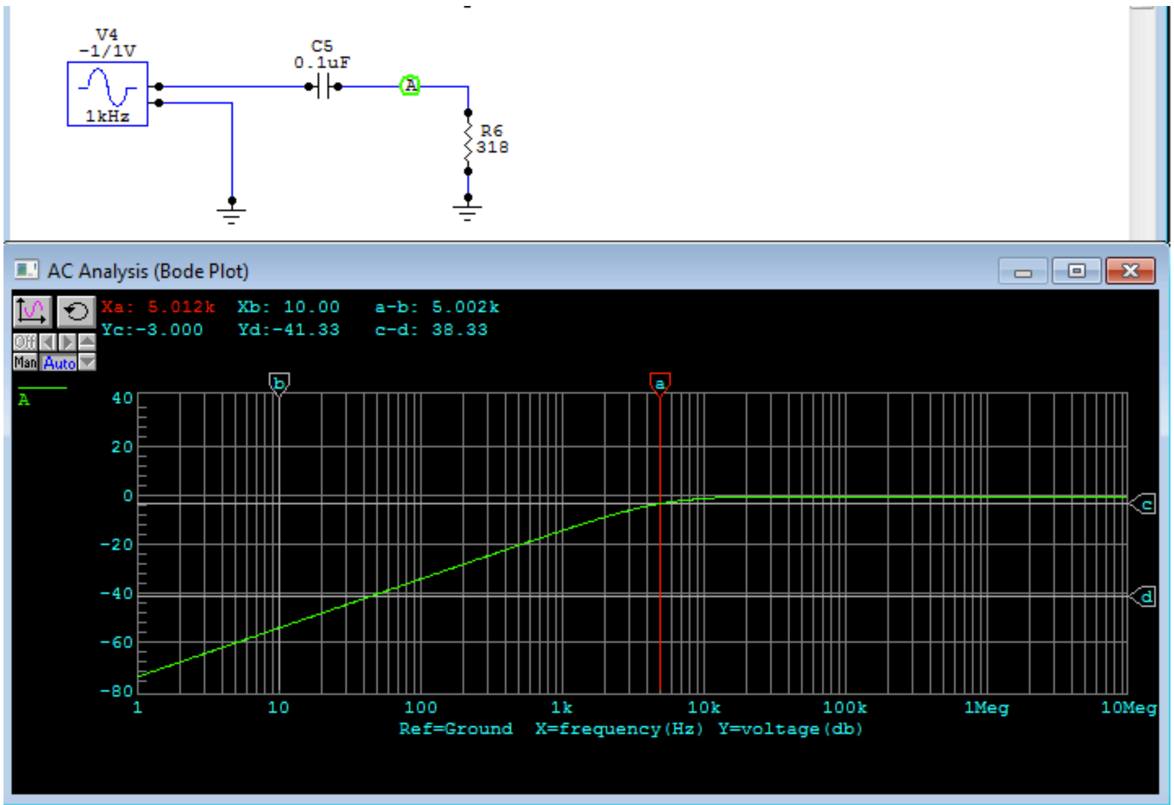
a:

$$|H(\omega)| = \frac{1}{\sqrt{1 + (\frac{1}{\omega RC})^2}}$$

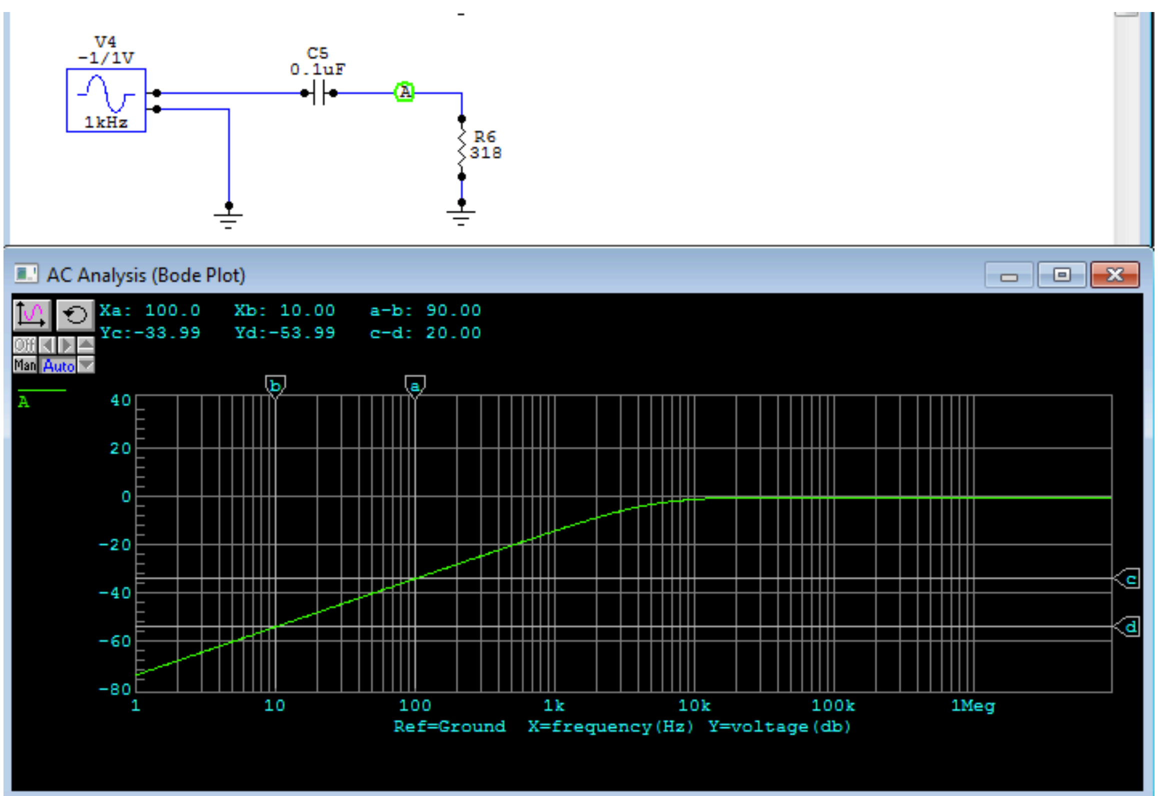
when $C = 0.1\mu F$
when $R = 318\Omega$

f (Hz)	$\lvert H(\omega)\rvert$	dB
0	1.0	0
10	.002	-54.0
100	.020	-34.0
1k	.196	-14.2
5k	.707	-3.0
10k	.894	-.973
20k	.970	-.265

b:



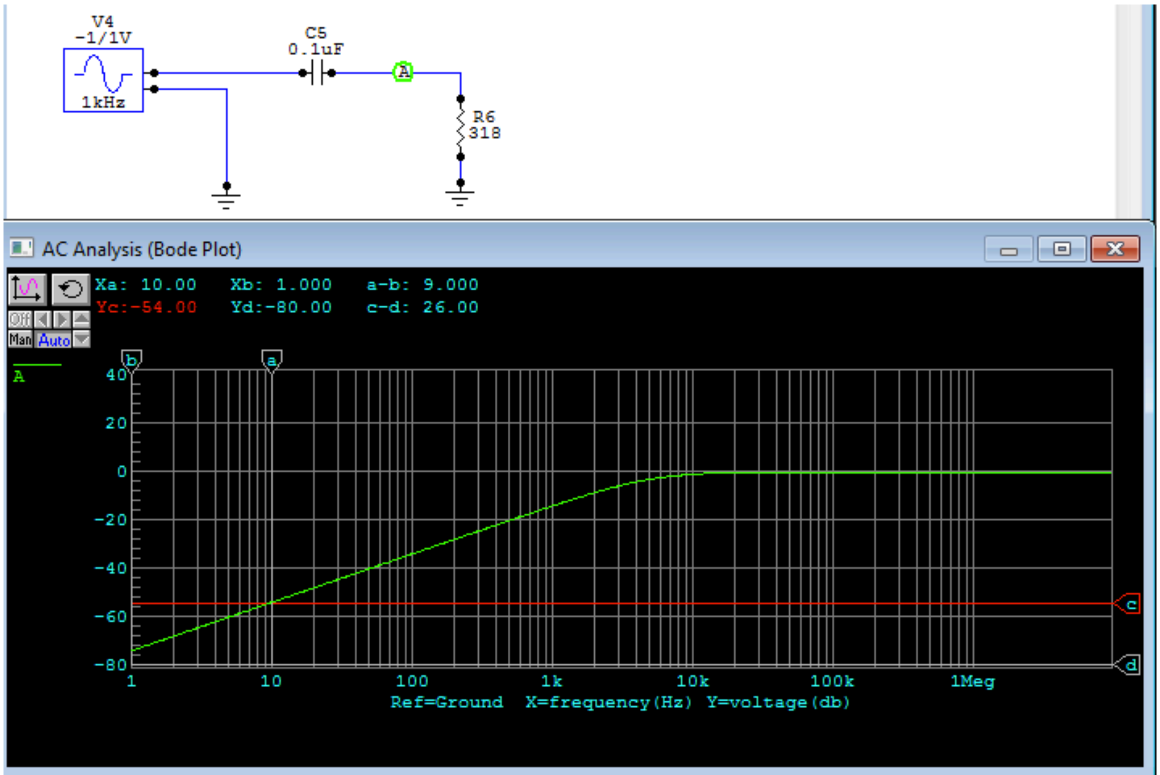
V4
-1/1V
1kHz
C5
0.1uF
A
R6
318
AC Analysis (Bode Plot)
Xa: 5.012k Xb: 10.00 a-b: 5.002k
Yc:-3.000 Yd:-41.33 c-d: 38.33
Ref=Ground X=frequency(Hz) Y=voltage(db)



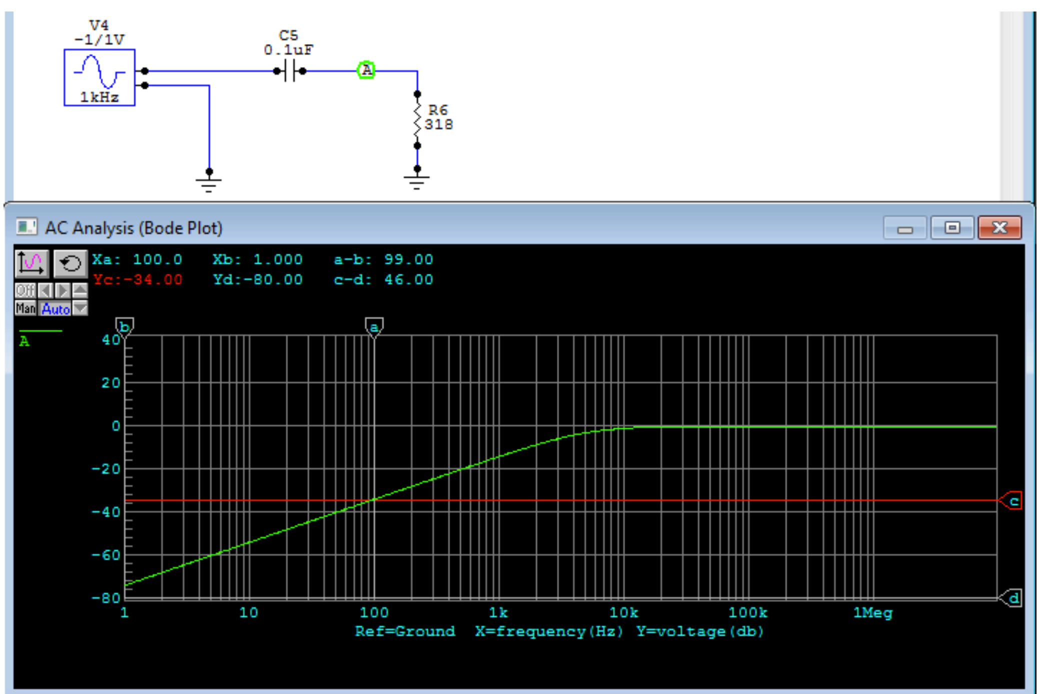
V4
-1/1V
1kHz
C5
0.1uF
A
R6
318
AC Analysis (Bode Plot)
Xa: 100.0 Xb: 10.00 a-b: 90.00
Yc:-33.99 Yd:-53.99 c-d: 20.00
Ref=Ground X=frequency(Hz) Y=voltage(db)

c:

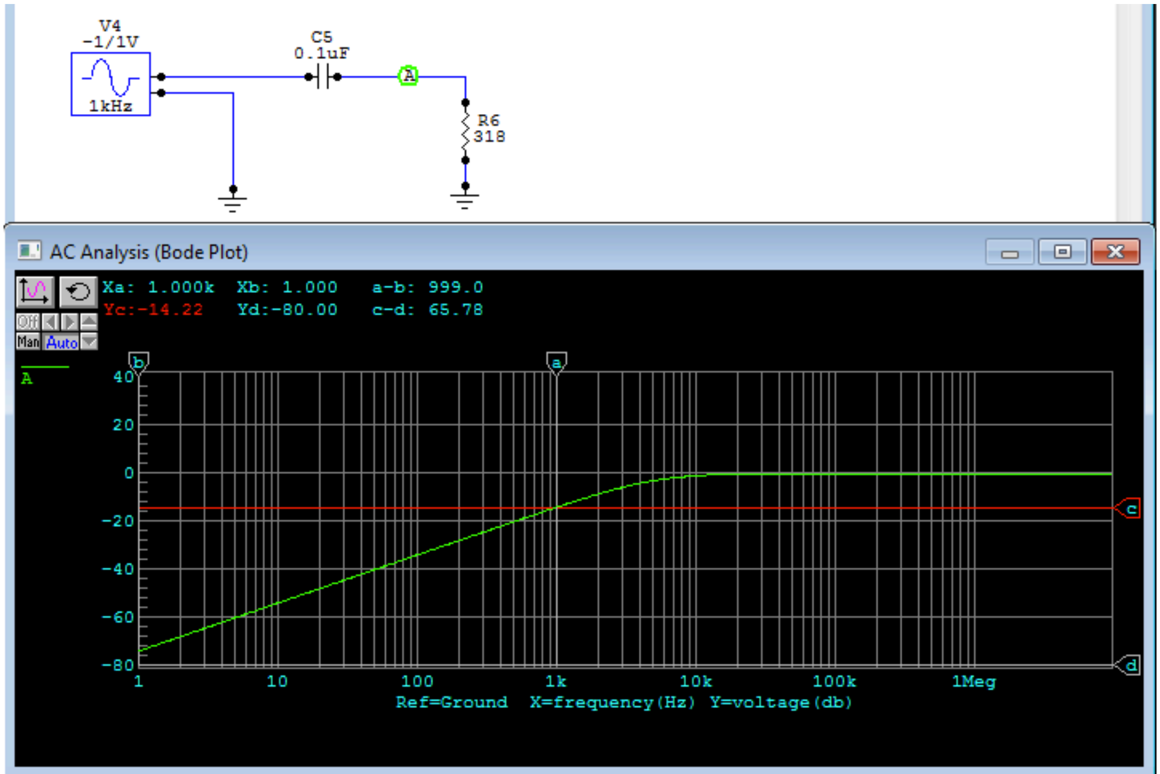
at 10Hz



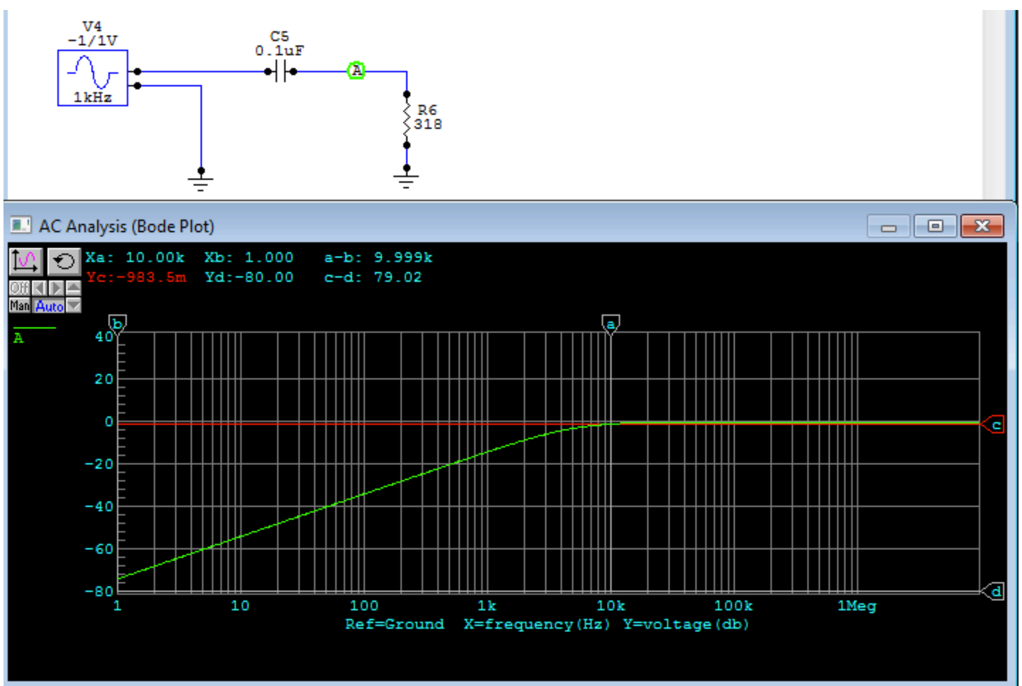
at 100Hz



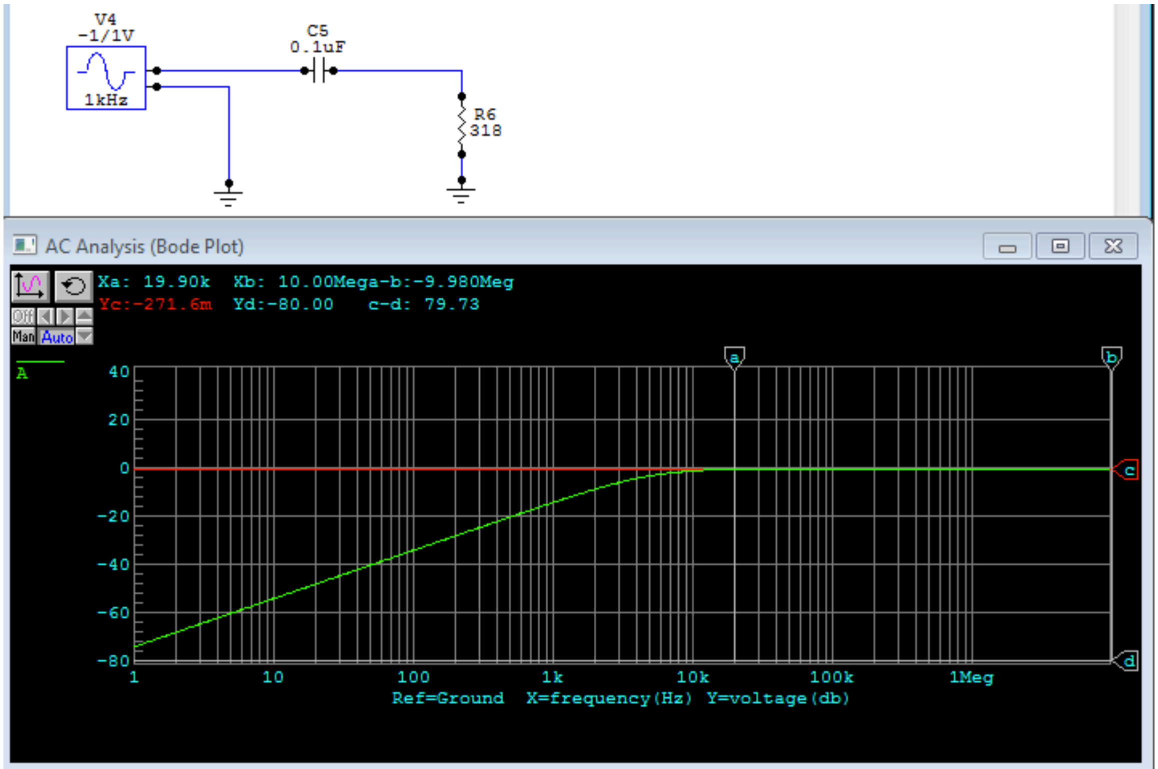
at 1kHz



at 10kHz



at 20kHz


V4
-1/1V
1kHz
C5
0.1uF
R6
318
AC Analysis (Bode Plot)
Xa: 19.90k Xb: 10.00Mega-b:-9.980Meg
Yc:-271.6m Yd:-80.00 c-d: 79.73
Off
Man
Auto
A
40
20
0
-20
-40
-60
-80
1
10
100
1k
10k
100k
1Meg
Ref=Ground X=frequency(Hz) Y=voltage(db)