ECE 3254 Laboratory
Passive Filters
Laboratory #4 Fall 2009
PRELAB (100 points total)

Name ________________________
Date: ________________
Bench: __________

Prelab assignment (to be completed before coming to Lab 4):
Read over entire laboratory #4. Show all work (equations, values, etc.) to receive credit.

Questions:

1. For the high pass circuit shown in figure 4-1, derive the equation for V_{out} in terms of $j\omega$, V_{in}, R_1, C_1, and R_2. Show derivation from loop eq, node eq, or voltage divider for credit. (5 points)

2. For figure 4-1 let $R_1 = 22\ k\Omega$, $C_1 = 0.1\ \mu F$, $R_2 = 22\ k\Omega$, and $Vin = 5\sin(2\pi ft)$, and:

   Find the cutoff frequency f_{low} in Hz. (5 points)

   Find Vmax - the passband (maximum) output RMS voltage. (5 points)

   Find the passband gain in dB (referenced to V_{in}). (5 points)

   Enter the results of your calculations for Db_{max} and f_{low} in Part I-5 on the data sheet.

3. Model the high pass circuit for #2 above in Pspice and obtain a frequency response plot from 1Hz to 10kHz with Vin = 3.54 Vrms and 40 steps per decade. (see the Prelab notes for details)

   Edit the schematic drawing information to add your name, ECE 3254 Prelab 4-3, and the date. Save your schematic.

   On your AC sweep plot:
   Add a dB trace for Vout referenced to Vin.
   Use cursors to identify and label the values for Vmax and dBmax in the passband, and f_{low}.
   Add a label with your name, and ECE 3254 Prelab 4-3.
   Print your schematic and AC sweep plot. (10 points)

   From the Pspice simulation: (3 points)

Passband Vo_{max} = ______________, Passband dB_{max} = _____________, f_{low} = ________________

How do the results from Pspice compare to the calculated values? (1 points)

Enter the results of your Pspice simulation for Db_{max} and f_{low} in Part I-5 on the data sheet.

4. For figure 4-1 change R_1 to 47 kΩ and let $C_1 = 0.1\ \mu F$, $R_2 = 22$ kΩ, and $Vin = 5\sin 2\pi ft$, and:

   Find the new cutoff frequency f_{low} in Hz (5 points)

   Find the new passband output RMS voltage (5 points)

   Find the new passband gain in dB. (5 points)

   Enter the results of your calculations for Db_{max} and f_{low} in Part I-5 on the data sheet.

5. For the low pass circuit shown in figure 4-2, derive the equation for V_{out} in terms of jω, V_{in}, R_1, C_2, and R_2. Show derivation from loop eq, node eq, or voltage divider for credit. (5 points)

6. For figure 4-2 let $C_2 = 0.001\ \mu F$, R_1= 22 kΩ, $R_2 = 22$ kΩ, and $Vin = 5\sin(2\pi ft)$, and:

   Find the cutoff frequency f_{high} in Hz (5 points)

   Find the passband output RMS voltage (5 points)

   Find the passband gain in dB. (5 points)

Enter the results of your calculations for dB_{max} and f_{high} in Part II-5 on the data sheet.

7. Model the low pass circuit for #6 above in Pspice and obtain a frequency response plot from 100Hz to 100kHz with Vin = 3.54 Vrms and 40 steps per decade. See Prelab notes for tip.

   Edit the schematic drawing information to add your name, ECE 3254 Prelab 4-7, and the date. Save your schematic.

   On your AC sweep plot:
   Add a dB trace for Vout referenced to Vin.
   Use cursors to identify and label the values for Vmax and dBmax in the passband, and f_{high}.
   Add a label with your name, and ECE 3254 Prelab 4-7.
   Print your schematic and AC sweep plot. (5 points)

   From Pspice: (3 points)

   Passband Vo_{max} = _______________, Passband dB_{max} = ______________, f_{high} = _________________

   How do the results from Pspice compare to the calculated values? (1 point)

Enter the results of your Pspice simulation for dB_{max} and f_{high} in Part II-5 on the data sheet.

8. For figure 4-2 change C_2 to 470pf and let R_1 = 22 kΩ, R_2 = 22 kΩ, and Vin = 5sin(2πft), and:

   Find the new cutoff frequency f_{high} in Hz. (5 points)

   Find the new passband output RMS voltage. (5 points)

   Find the new passband gain in dB. (5 points)

Enter the results of your calculations for Db_{max} and f_{high} in Part II-5 on the data sheet.

9. Use Pspice to model the the circuit in Part III-1 (bandpass circuit) and obtain a frequency response plot from 1Hz to 100kHz with Vin = 3.54 Vrms and 40 steps per decade.

   Edit the schematic drawing information to add your name, ECE 3254 Prelab 4-9, and the date. Save your schematic.

On your AC sweep plot:
Add a dB trace for Vout referenced to Vin.
Use cursors to identify and label the values for Vmax and dBmax in the passband, f_{low}, and f_{high}.
Add a label with your name, and ECE 3254 Prelab 4-9.
Print you schematic and AC sweep plot. (5 points)

From Pspice: (2 points)

Passband Vo_{max} = _______________, Passband dB_{max} = _______________,

f_{low} = ____________________, f_{high} = ____________________

Enter the results of your Pspice simulation for dB_{max} in the passband, and f_{low} and f_{high} in Part III-2 on the data sheet.

ECE 3254
Filter Frequency Response
Laboratory #4
Last Revised: 09-17-2009

OBJECTIVES:

Circuits with components such as capacitors and inductors change characteristics as the frequency changes. Often, we would like to see how changing the frequency alters the output voltage of a circuit. In this lab, you will use a computer to capture the frequency response of several filters while an AC frequency sweep is applied to each filter input.

Some handy conversion formulas for sinusoidal voltages with no DC offset:
$V_{pp} = 2V_{peak} = 2\sqrt{2}V_{rms}$, V_{rms}, $= V_{peak}/\sqrt{2} = V_{pp}/(2\sqrt{2})$

PART I: HIGHPASS FILTER

The “high-pass filter” circuit is shown in Figure 4-1. C_1 blocks DC, impedes (or cuts off) low frequencies, and passes high frequencies. The cutoff frequency is f_{low}.

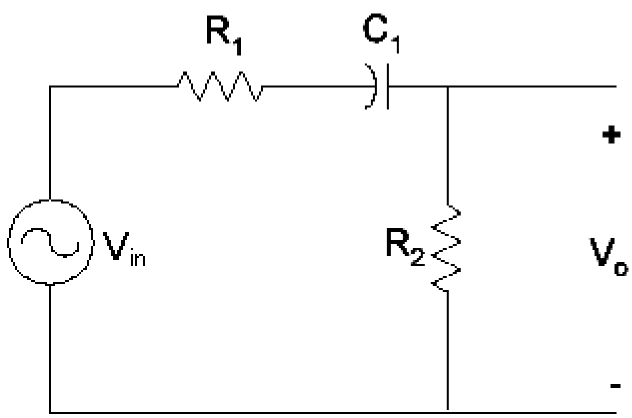

Figure 4-1 High Pass Filter

1. Construct the high-pass filter with $R_1 = R_2 = 22$ kΩ and $C_1 = 0.1$ μF (the capacitor may be marked 104)

2. Obtain the frequency response using the Computer's AC Sweep function as you did in Lab 1. (See Lab 1 for details of this procedure)

   Function Generator settings:
   - Amplitude: 10 Vpp
   - Sweep Parameters:
   - Initial Frequency = 1 Hz, Final Frequency = 10,000 Hz, 40 Steps per Decade

   When sweep is complete - save waveform to buffer. _________________.txt

3. Change R_1 to 47 kΩ. Run the AC Sweep again, using the new resistor, and save the data to the buffer. __________________.txt

4. Exit the AC Sweep (DONE) and use the overlay feature of the buffer to combine the data from the two measurements.

In the Buffer:

Click the Math Options drop down, select Overlay, hit GO.
For the top graph, select your first filename.
For the middle graph, select your second filename.
Click Overlay Waveforms OK
Click Save To Buffer ____________________.txt
Click Done to return to the Buffer.

5. Use the buffer to save your overlay file as a jpeg (y = dB normalized to the input voltage; x = log scale). Use a cursor to measure the maximum output of the frequency response for both resistor values.

   Now use the **red cursor** to measure the cutoff frequency with R1 = 22 kΩ, and the **blue cursor** to measure the cutoff frequency with R1 = 47 kΩ. *Do not hit the SAVE button until you have recorded your data on the Data Sheet and positioned the cursors.*

   Print one copy of the jpeg, title the print "Highpass Response", clearly label the two traces and their cutoff frequencies, write all names on the print and attach it to one of the lab reports.

PART II: LOWPASS FILTER

The opposite of the high-pass filter is the low-pass filter, as shown in Figure 4-2. C2 shunts high frequency components to ground but impedes low frequencies, thus passing low frequencies to the output. The cutoff frequency is f_{high}.

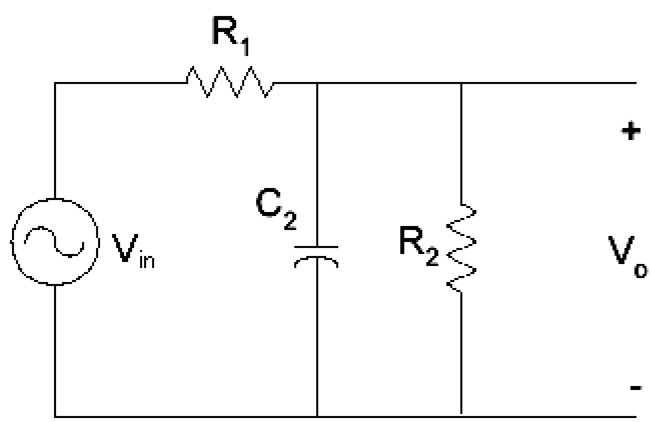

Figure 4-2 Low Pass Filter

1. Construct the low-pass filter with R1 = R2 = 22 K and C2 = 0.001µF (may be marked 102 or .001).

2. Using the computer to capture Vo versus frequency with the input voltage = 10Vpp. Measure 15 points per decade between 100 Hz and 100 kHz. Save this data to the buffer. ____________.txt

3. Change C2 to 470 pF (marked 471). Redo the frequency response using the computer and save the data to the buffer. ____________________.txt

4. Go to the Buffer and overlay the frequency response curves for the two capacitor values. ____________________.txt
5. Use the buffer to save your overlay file as a jpeg (y = dB normalized to the input voltage; x = log scale). Use the **red cursor** to measure the cutoff frequency with C2 = 0.001µF, and the **blue cursor** to measure the cutoff frequency with C2 to 470 pF. *Do not hit the SAVE button until you have*

recorded your data on the Data Sheet and positioned the cursors.

***Print one copy of the jpeg,** title the print "Lowpass Response", clearly label the two traces and their cutoff frequencies, write all names on the print and attach it to one of the lab reports.

PART III: BANDPASS FILTER

A combination of the low and high-pass filters gives what is called a band pass filter, i.e. a filter allows only frequencies between f_{low} and f_{high} to pass. This filter has two cutoff frequencies, f_{low} and f_{high}, with the passband lying between them.

Suppose $C_1 >> C_2$, then

a) at low frequencies, C_1 impedes the signal, hence A_v is low, where $A_v = V_o/V_i$.
b) At high frequencies, C_1 passes the signal but C_2 shunts the signal to ground, hence A_v is low.
c) In the middle frequencies, which correspond to the filter passband, C_1 acts like a short circuit and C_2 acts like an open circuit. Thus the middle frequencies are transmitted.
d) $[A_v]$ max occurs at some middle frequency.

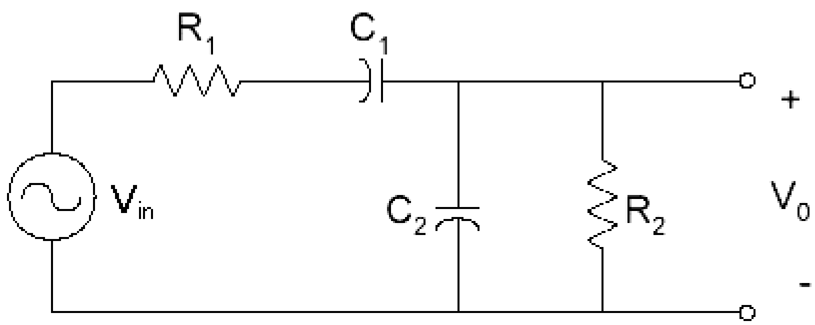

Figure 4-3 Bandpass Filter

1. Construct the bandpass filter of Figure 4-3 with $R_1 = R_2 = 22$ kohms, $C_1 = 0.1\ \mu F$ (may be marked 104) and $C_2 = 0.001\ \mu F$ (1000pF, may be marked 102).

2. Perform an AC sweep from 1 Hz to 100 kHz, sampling 40 points per decade with the input voltage = 10Vpp. Save your bandpass response as a jpeg (y = dB normalized to the V_{in}; x = log scale). Position the **red cursor** at the low frequency cutoff f_{low} and the **blue cursor** at the high frequency cutoff f_{high}. *Do not hit the SAVE button until you have recorded your data on the data sheet and positioned the cursors.*

   ***Print one copy of the jpeg,** title the print "Bandpass Response", clearly identify (label) the two cutoff frequencies and the passband, write all names on the print and attach it to one of the lab reports.

3. (5 points) Shut down Windows, return cables to racks, return parts to correct drawer bins, return adapters to container, turn off bench power, clear bench, and place seat under bench.

ECE 3254 Lab 4 Data Sheet **Date**______________ **Bench**_________
(100 points total)
Names: ________________________ ______________________ ______________________
by first name: 3rd alphabetically – wiring 1st alphabetically – Labview 2nd alphabetically – data sheet

PART I: HIGHPASS FILTER

5. *Theoretical values from the Prelab calculations:*
   $R_1 = 22\ k\Omega$: *passband gain* dB_{max} = ______________ , *Cutoff freq* f_{low} = ______________

   $R_1 = 47\ k\Omega$: *passband gain* dB_{max} = ______________ , *Cutoff freq* f_{low} = ______________

   Theoretical values from Pspice:
   $R_1 = 22\ k\Omega$: *passband gain* dB_{max} = ______________ , *Cutoff freq* f_{low} = ______________

   Measured values:.
   $R_1 = 22\ k\Omega$: dB_{max} = ____________ $dB_{@cutoff}$ = ____________ f_{low} = ______________

   $R_1 = 47\ k\Omega$: dB_{max} = ____________ $dB_{@cutoff}$ = ____________ f_{low} = ______________

   Compare the two response plots. What did changing R_1 do to the filter output?

   How do the measurements compare to the Prelab calculations and the Pspice model?

   Calculate the % error for the f_{low} measurements. Is this error reasonable and what could it be caused by?

PART II: LOWPASS FILTER

5. *Theoretical values From the Prelab:*
   .$C_2 = 0.001\ \mu F$: *passband gain* dB_{max} = ______________ , f_{figh} = ______________

   $C_2 = 470\ pF$: *passband gain* dB_{max} = ______________ , f_{high} = ______________

   Theoretical values from Pspice:
   $C_2 = 0.001\ \mu F$: *passband gain* dB_{max} = ______________ , *Cutoff freq* f_{high} = ______________

   Measured values:.
   $C_2 = 0.001\ \mu F$: dB_{max} = ___________ $dB_{@cutoff}$ = ___________ f_{high} = ____________

   $C_2 = 470\ pF$: dB_{max} = ___________ $dB_{@cutoff}$ = ___________ f_{high} = ____________

Compare the two response plots. What did changing C_2 do to the filter output?

How do the measurements compare to the Prelab calculations and the Pspice model?

Calculate the % error for f_{high} measurements. Is this error reasonable and what could it be caused by?

PART III: BANDPASS FILTER

2. *Theoretical values from Pspice:*

dB_{max} = ________________ , f_{low} = __________________, f_{high} = _______________

Measured dB_{max} = _______________, f_{low} = _________________ f_{high} = ___________________

How do the measurements compare to the results of Pspice model?

On your print of the AC Sweep, explain the effect of the capacitors on the bandpass filter response. (Hint: Discuss and/or show the frequency range for which C_1 acts like an open circuit and the frequency range for which C_1 is a short circuit. Then do the same for C_2 and combine the results.