EE 2010 Circuit Analysis
Lab 07: Frequency Response of Passive 2nd-Order Circuit

Lab Section: **Printed Name (Last, First):**

Learning Objectives:

- Reinforce the frequency-dependent characteristics of circuits containing dynamic elements
- Be able to simulate a "Frequency-Sweep" simulation
- Understand the concept of a frequency-dependent transfer function
- Understand the concept of frequency-selective "filtering"
- Be able to observe the dynamics of amplitude and phase changes in the frequency domain
- Be able to simulate and verify an RLC band-pass filter

A. Before coming to lab:

1. Background

1.1 Read this discussion of Band-Pass filters.

1.2 Watch this instructional video about RLC band-pass and band-stop (or band-reject) filters.

2. RLC Series Band-Pass Circuit Simulation

For this lab, we employ the "AC-Sweep" function in a Multisim simulation to observe the frequency-dependent behavior of circuits with dynamic elements.

2.1 Construct a simulation of the circuit shown below:

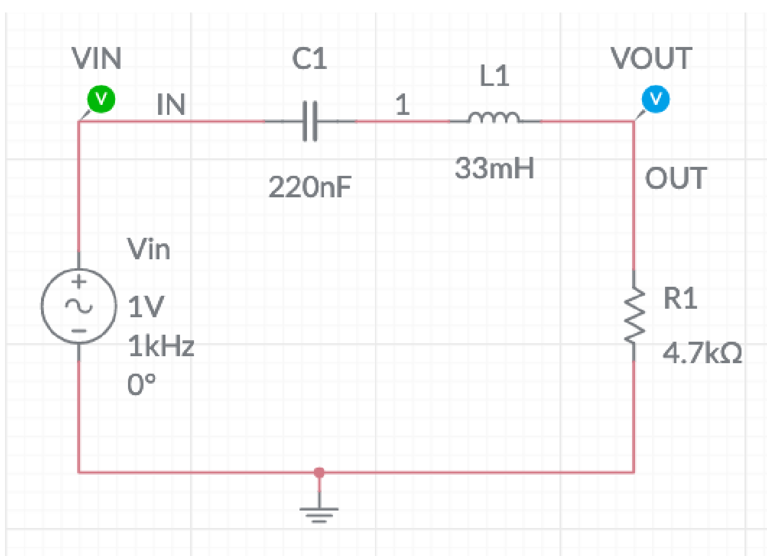


Figure 1: RLC Band-Pass circuit schematic diagram

2.2 We have set the input waveform as a constant-amplitude sinusoid. We will observe the "output voltage" to gain insight to the operational transfer function of the circuit.

2.3 In the simulation control bar, select the "AC-Sweep" simulation mode.

2.4 Set the sweep parameters as opened by selecting the settings icon as shown below:

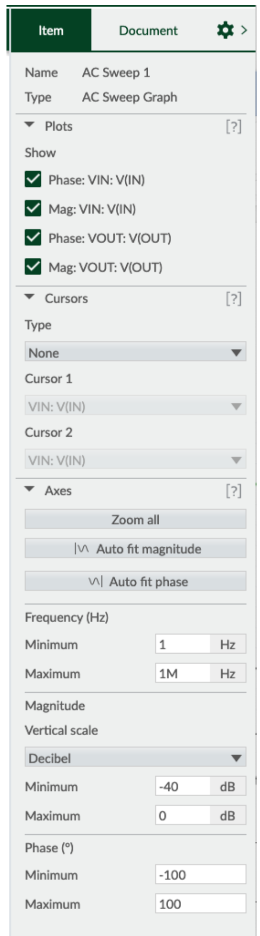


Figure 2: AC-Sweep Simulation mode

2.5 Notice especially the "Log" sweep mode and the minimum and maximum frequencies of 1Hz and 1M Hz.

2.6 These settings determine the limits and appearance of the resulting simulation as shown below:

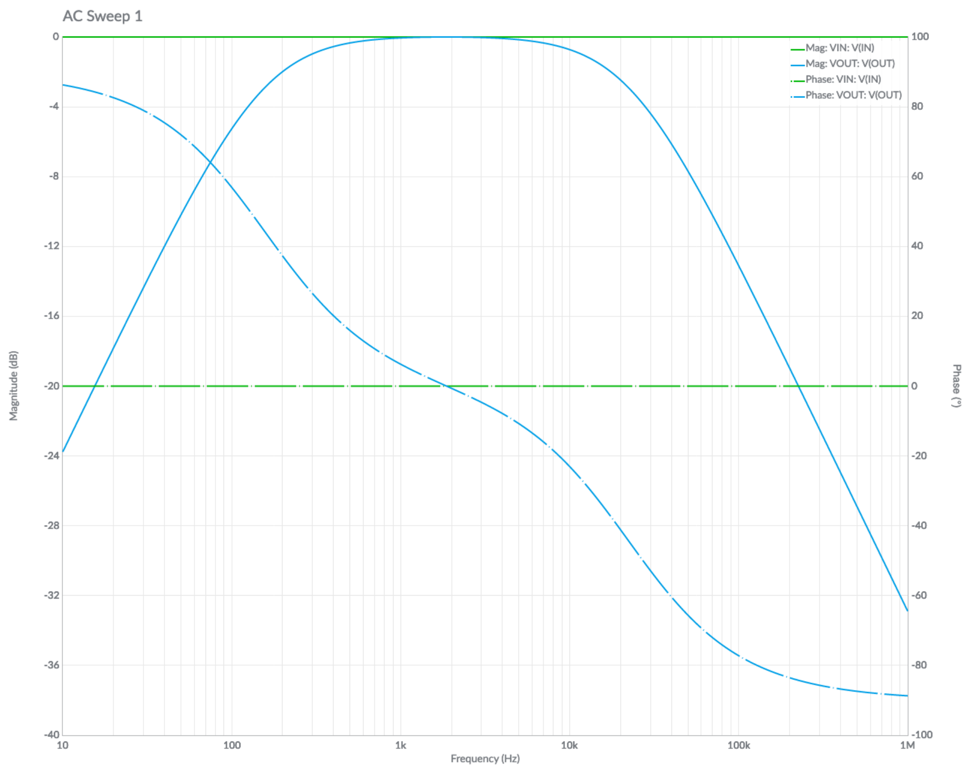


Figure 3: AC-Sweep Simulation for a Series RLC Band-Pass Filter

2.7 This figure illustrates the magnitude and phase of the transfer function $H(s)$ for frequencies ranging from 1Hz to 1MHz.

2.8 Run the simulation and capture the results. Include the schematic and the AC-sweep figures in your lab report.

3. Observations

3.1 Notice that the amplitude curve indicates attenuation at both low and high frequencies, but no attenuation in the “pass-band” frequencies. Hence the name “band-pass filter”

3.2 While we will not now dwell on the implications of the phase shift, we note that the phase is also influenced by the operation of the RLC combination.

4. RLC Parallel Band-Pass Circuit Simulation

As before, we employ the "AC-Sweep" function in a Multisim simulation.

4.1 Build the circuit shown below:

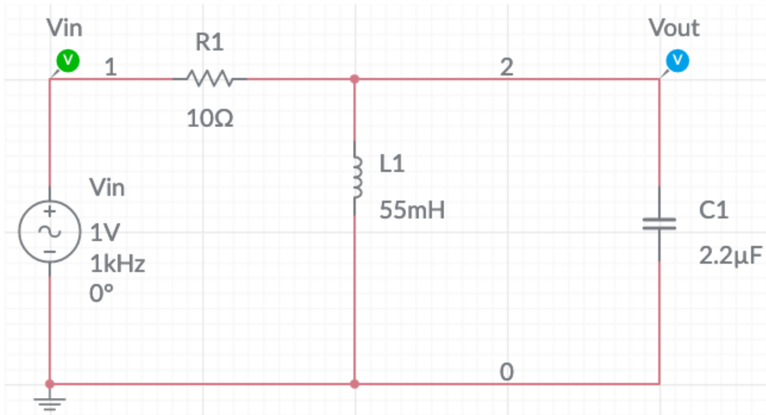


Figure 4: RLC Band-Pass circuit schematic diagram

4.2 Notice that we have changed the positions and values of some components to a parallel configuration.

4.3 Select the "AC-Sweep" simulation mode.

4.4 Set the sweep parameters to be the same as for the simulation study above.

4.5 Notice especially the "Log" sweep mode and the minimum and maximum frequencies of 1Hz and 1M Hz.

4.6 These settings determine the limits and appearance of the resulting simulation as shown below:

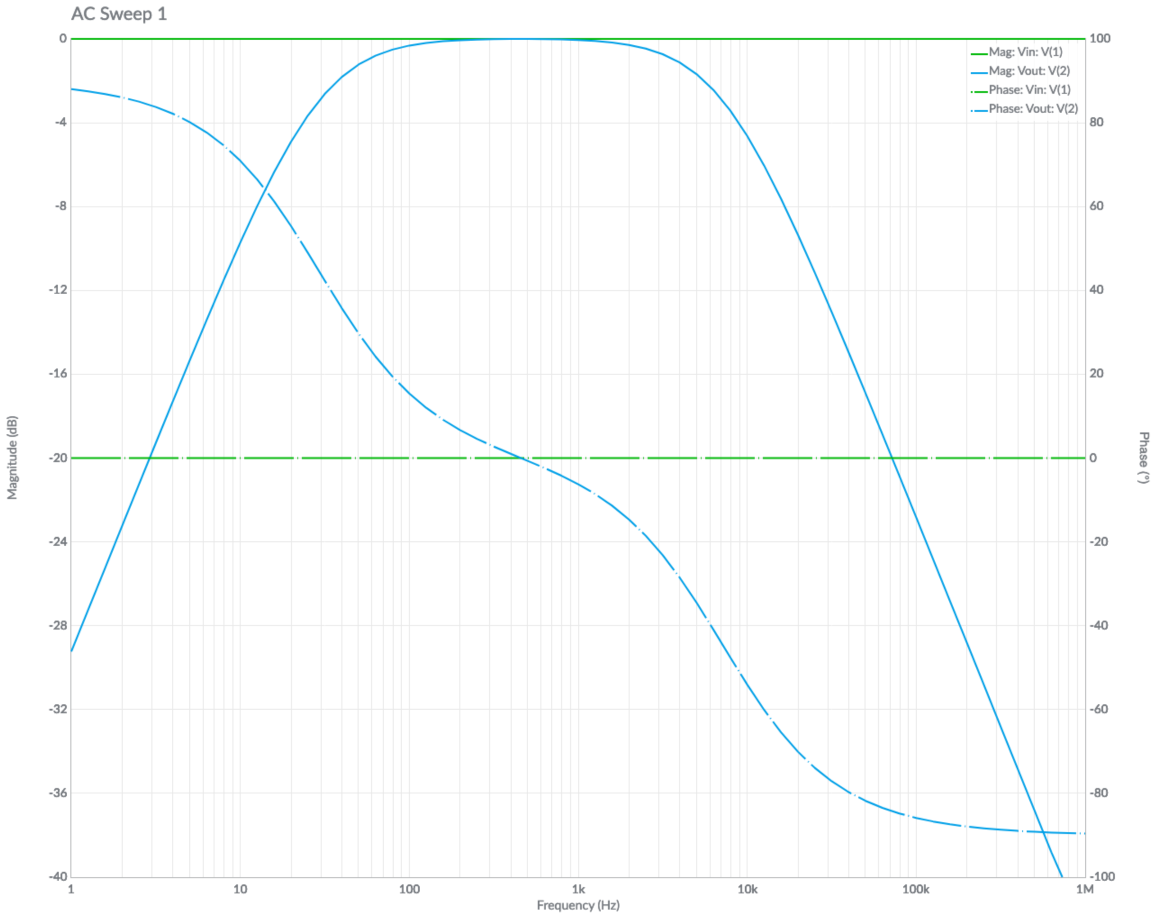


Figure 5: AC-Sweep Simulation for a Parallel RLC Band-Pass Filter

4.7 Run the simulation and capture the results. Include the schematic and the AC-sweep figures in your lab report.

5. Observations

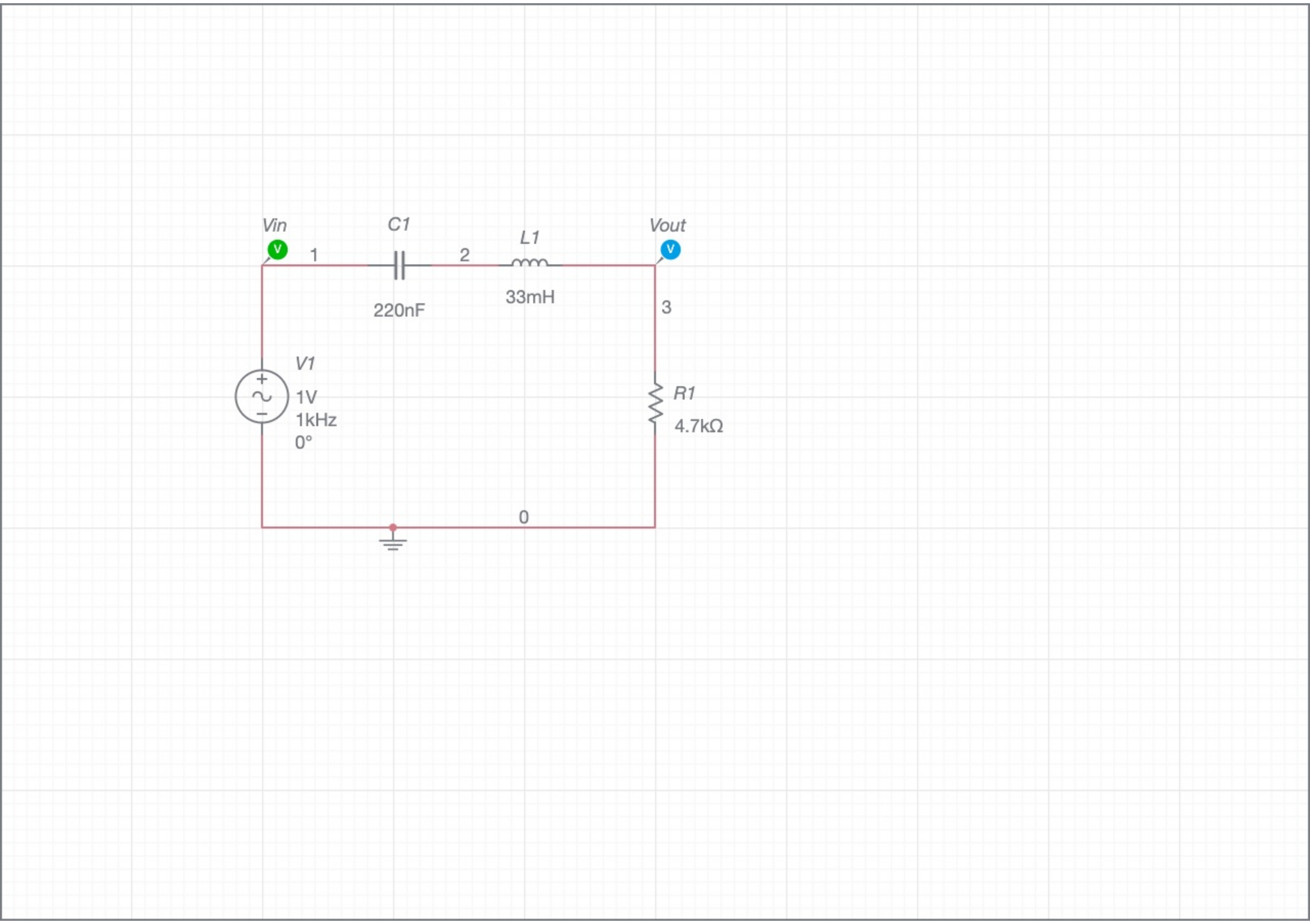
5.1 Notice that, as above, the amplitude curve indicates attenuation at both low and high frequencies, but no attenuation in the “pass-band” frequencies. Hence the name “band-pass filter”

5.2 While we will not now dwell on the implications of the phase shift, we note that the phase is also influenced by the operation of the RLC combination.

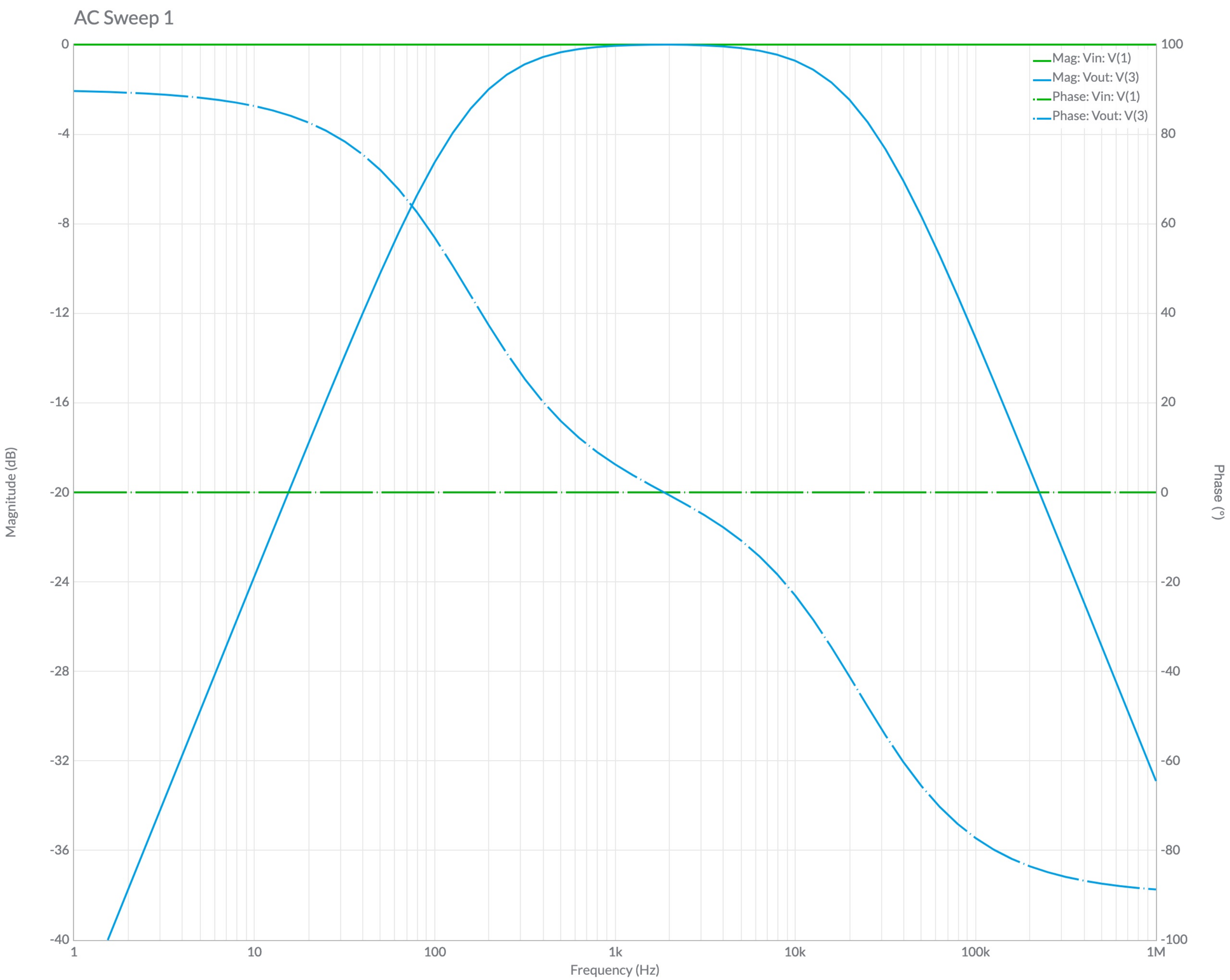
Explore “what ifs” by changing the values of R, L, and C. Note that by simply adjusting these values, the filter characteristics change dramatically to enable the realization of a wide variety of filter functions.

Explore “what ifs” by changing the values of R and C. Note that by simply adjusting these values, the “cutoff” frequency of the low-pass or high-pass filter can be realized as desired.

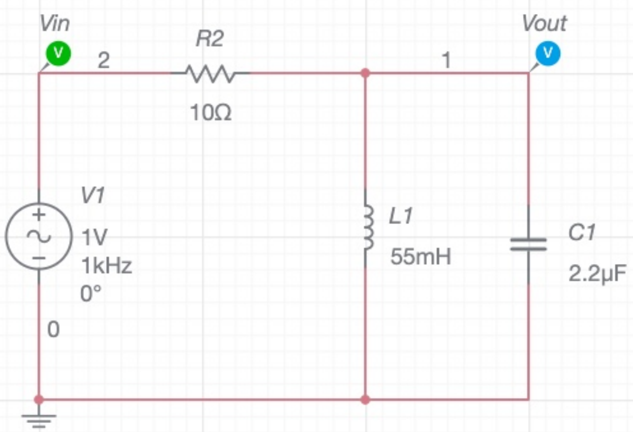
You will have the opportunity to experiment with this circuit configuration in the lab and see how this circuit behaves on the oscilloscope. You will be able to observe the change in magnitude of the signal as well as the phase change.

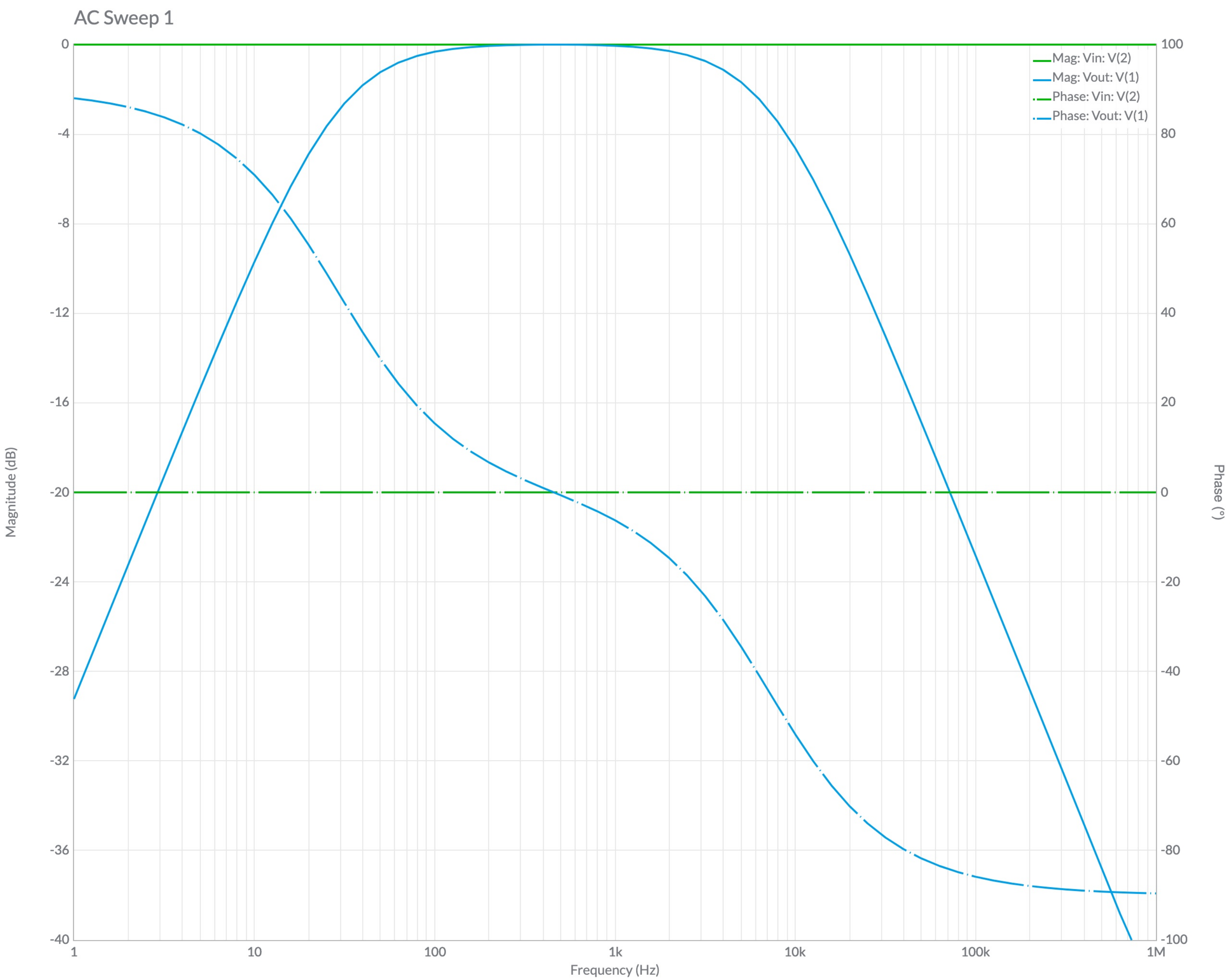


Vin
C1
L1
Vout
V
V
1
2
220nF
33mH
3
V1
1V
1kHz
0°
R1
4.7kΩ
0



AC Sweep 1
Mag: Vin: V(1)
Mag: Vout: V(3)
Phase: Vin: V(1)
Phase: Vout: V(3)
Magnitude (dB)
Phase (°)
Frequency (Hz)
0
-4
-8
-12
-16
-20
-24
-28
-32
-36
-40
100
80
60
40
20
0
-20
-40
-60
-80
-100
1
10
100
1k
10k
100k
1M


Vin
R2
2
1
Vout
V
V
10Ω
V1
1V
1kHz
0°
L1
55mH
C1
2.2µF
0



AC Sweep 1
Mag: Vin: V(2)
Mag: Vout: V(1)
Phase: Vin: V(2)
Phase: Vout: V(1)
Magnitude (dB)
Phase (°)
Frequency (Hz)
0
-4
-8
-12
-16
-20
-24
-28
-32
-36
-40
100
80
60
40
20
0
-20
-40
-60
-80
-100
1
10
100
1k
10k
100k
1M

B. In Lab Procedures

In this lab session you will realize and validate the RC filter from the Pre-Lab simulations.

For the In-Lab experience, it would be helpful to once again watch **this video** on measuring phase with a two-channel oscilloscope.

1. Construct the series RLC filter

1.1 Assemble the circuit to resemble the simulated RLC circuit below.

1.2 Construct a simulation of the circuit shown below:

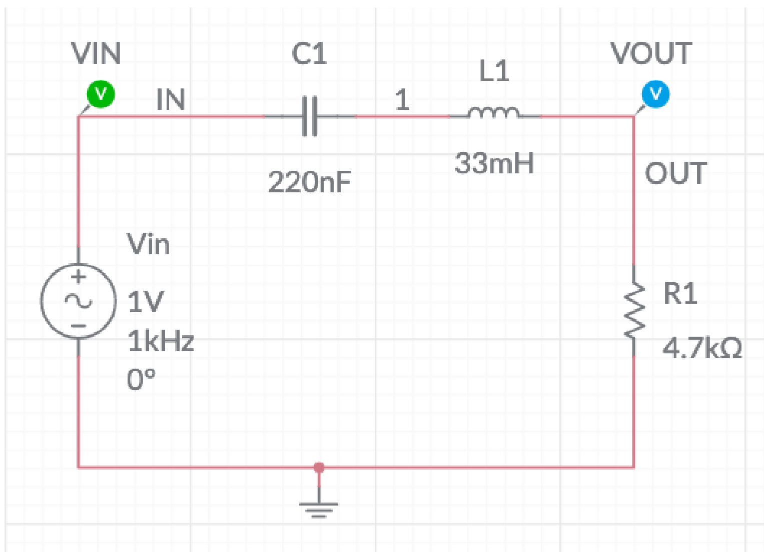


Figure 6: RLC Band-Pass circuit schematic diagram

2. Oscilloscope Frequency and Phase Measurements of a series RLC filter

In this section we'll operate the function generator and the oscilloscope to determine the frequency and phase response of a linear circuit.

2.1 Turn on the function generator. Set the wave type to a sine wave, the amplitude to 5V, and the frequency to 100Hz.

2.2 Connect one channel of the oscilloscope to the function generator (this is the reference signal) and the other channel across the resistor.

2.3 Turn on the oscilloscope. Press the **Auto-scale** button to get the waveform in to view on the oscilloscope.

2.4 The three *Measure* buttons can be used to obtain amplitude, frequency, and time measurements.

2.5 Press the **Voltage** button to open up the Voltage Measurement Softkey Options at the bottom of the display. Make sure that the **Source** is set to whichever source the oscilloscope are probes connected to. Select the V_{p-p} option to measure the peak-to-peak voltage.

2.6 Measure the phase of the output by measuring the difference in time between zero-crossings of the two waveforms. Select the V_{p-p} option to measure the peak-to-peak voltage.

2.7 With the initial frequency at 100 Hz, fill out the following table adjusting the frequency of the input accordingly. As you change the frequency you will likely have to rescale the oscilloscope display.

Frequency (Hz)	V_{p-p} (V)	Amplitude (V)	Phase (degrees)
100	5.6	2.8	56.4
1000	10	5	7.92
2000	10	5	3.6
5000	10	5	-2.16
15000	9	4.5	-9.73

2.8 Were these the results that you expected from the filter we constructed? Describe the results. Compare to the results of the Pre-Lab.

expected, similar to the prelab

3. Construct the parallel RLC filter

1.1 Assemble the circuit to resemble the simulated RLC circuit below.

1.2 Construct a simulation of the circuit shown below:

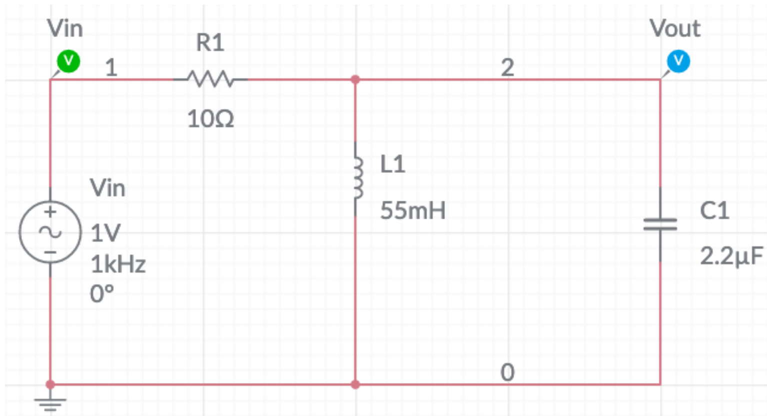


Figure 7: RLC Band-Pass circuit schematic diagram

4. Oscilloscope Frequency and Phase Measurements of an RLC filter

In this section we'll operate the function generator and the oscilloscope to determine the frequency and phase response of a linear circuit.

4.1 Turn on the function generator. Set the wave type to a sine wave, the amplitude to 5V, and the frequency to 100Hz.

4.2 Connect one channel of the oscilloscope to the function generator (this is the reference signal) and the other channel across the resistor.

4.3 Turn on the oscilloscope. Press the **Auto-scale** button to get the waveform in to view on the oscilloscope.

4.4 The three *Measure* buttons can be used to obtain amplitude, frequency, and time measurements.

4.5 Press the **Voltage** button to open up the Voltage Measurement Softkey Options at the bottom of the display. Make sure that the **Source** is set to whichever source the oscilloscope are probes connected to. Select the V_{p-p} option to measure the peak-to-peak voltage.

4.6 Measure the phase of the output by measuring the difference in time between zero-crossings of the two waveforms. Select the V_{p-p} option to measure the peak-to-peak voltage.

4.7 With the initial frequency at 100 Hz, fill out the following table adjusting the frequency of the input accordingly. As you change the frequency you will likely have to rescale the oscilloscope display.

Frequency (Hz)	V_{p-p} (V)	Amplitude (V)	Phase (degrees)
100	10	5	-1.44
1000	7.2	3.6	-7.56
2000	4.4	2.2	-15.1
5000	2	1	-28
15000	0.8	0.4	-38

4.8 Were these the results that you expected from the filter we constructed? Describe the results. Compare to the results of the Pre-Lab.

yes, it went from near 0 to very negative. it differs from the prelab since we used different components

C. Takeaways:

- The steady-state sinusoidal response of dynamic circuits is frequency-dependent.
- The frequency response of a dynamic circuit is characterized by both amplitude and phase.
- Both amplitude and phase responses can be measured by an Oscilloscope.
- The amplitude and phase responses are distinctive of the class of dynamic circuit under consideration.
- Frequency-selective filters are an essential part of all signal processing applications.
- Frequency-selective filters are easily designed and constructed from readily-available components.