Authors: Mario Palacios and Andrew Peterson

California State University, Sacramento

Lab 8-10: Low Pass Filters

EEE 117 Lab – Section 04: Tuesday, 4:30pm – 7:10pm

Abstract:

For this lab we want to consider the sinusoidal response of the first order filters. The effect of loading, which means applying a load resistor to the output of the circuit, on the frequency response will be investigated. Passive and Active circuits will be used during this experiment, the schematics can be found in figure one. The circuits will be built on a breadboard and the results will be recorded on a spreadsheet. These results will then be compared to the ones created on PSPICE.

Introduction:

For the beginning part of the experiment the circuits being built can be seen in figure one. The RC circuit is referred to as the Passive Circuit and the Active Circuit is referring to the one with an Operational Amplifier (op-amp). Make sure to calculate the transfer functions for the four circuits (Passive Unloaded/Loaded and Active Unloaded/Loaded), and get their theoretical values. These calculations can be seen in figures two through five.

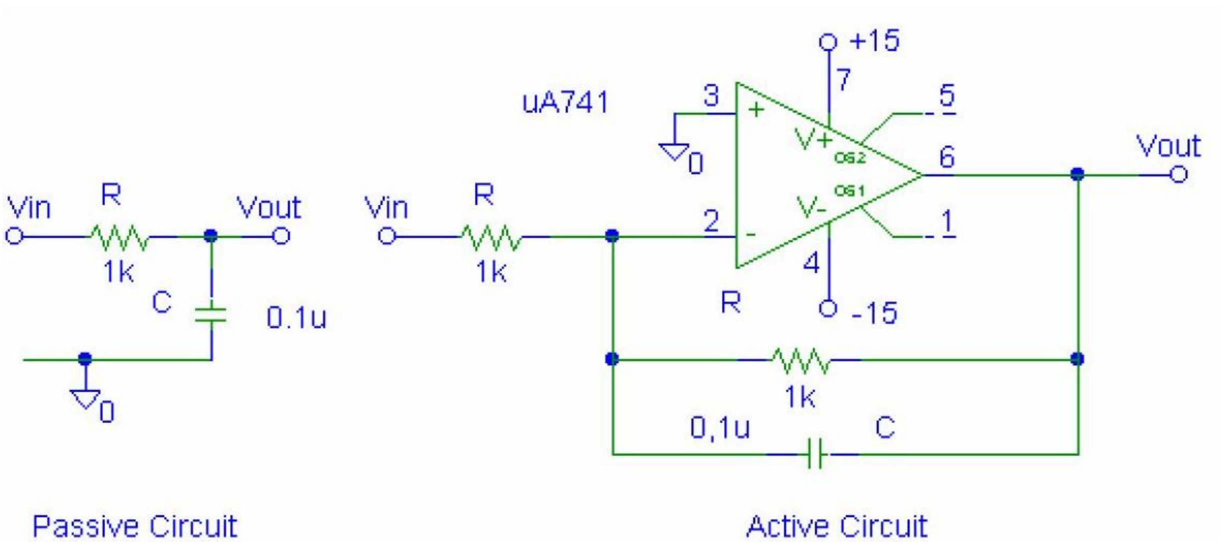

Figure 1. The Circuits Being Investigated Passive Circuit on the Left and Passive Circuit on the Right

We will measuring the low frequency gain, which is about 100Hz, and phase shift at the output for a sinusoidal input. This will be done for both circuits and then a 1kΩ load resistor across its terminals, for a total of four measurements. Then slowly increase the frequency until the output is reduced by 3db, also known as the half-power point, corner frequency, and which located at the .707 point. Measure the gain and phase at this frequency for each of the four circuits. Afterwards use PSPICE to plot the frequency response (gain and phase) of each of the four circuits. The data table being used to record the measurements should display low frequency gain and phase, while also the 3bd frequency.

$$\frac{V_{out}-V_{in}}{1k}+0.1\mu * sV_{out}=0 \rightarrow V_{out}(s0.1\mu+\frac{1}{1k})=\frac{V_{in}}{1k} \rightarrow V_{out}(\frac{s0.1m+1}{1k})=\frac{V_{in}}{1k} \rightarrow \frac{V_{out}}{V_{in}} = \frac{1}{s0.1m\ +\ 1} \rightarrow \boldsymbol{\frac{V_{out}}{V_{in}}=\frac{10k}{s+10k}}$$

$$\omega_c = 10k \rightarrow f_c = 1592\ Hz$$

Figure 2. Transfer Function for Passive Unloaded Circuit with Cut-Off Frequency

$$\frac{V_{-}-V_{in}}{1k}+\frac{V_{-}-V_{\mathrm{out}}}{1k}+\mathrm{s}0.1\mu(V_{-}-V_{\mathrm{out}})=0 \rightarrow V_{-}=V_{+}=0 \rightarrow -\frac{V_{in}}{1k}-\frac{V_{out}}{1k}-s0.1\mu V_{out}=0$$

$$\rightarrow V_{out}\left(\frac{1}{1k}+s0.1\mu\right)=-\frac{V_{in}}{1k} \rightarrow V_{out}\frac{\mathrm{s}0.1\mathrm{m}+1}{1\mathrm{k}}=-\frac{V_{in}}{1k} \rightarrow \frac{V_{out}}{V_{in}}=-\frac{1}{s0.1m+1}$$

$$\rightarrow \boldsymbol{\frac{V_{out}}{V_{in}}=-\frac{10k}{s+10k}}$$

$$\omega_c = 10k \rightarrow f_c = 1592\ Hz$$

Figure 3. Transfer Function for Active Unloaded Circuit with Cut-Off Frequency

$$\frac{V_{out}-V_{in}}{1k}+0.1\mu * sV_{out}+\frac{V_{out}}{1k}=0 \rightarrow V_{out}\left(s0.1\mu+\frac{1}{1k}+\frac{1}{1k}\right)=\frac{V_{in}}{1k} \rightarrow V_{out}\left(\frac{s0.1m+2}{1k}\right) = \frac{V_{in}}{1k} \rightarrow \frac{V_{out}}{V_{in}}=\frac{1}{s0.1m\ +\ 2} \rightarrow \boldsymbol{\frac{V_{out}}{V_{in}}=\frac{10k}{s+20k}}$$

$$\omega_c = 20k \rightarrow f_c = 3183\ Hz$$

Figure 4. Transfer Function for Passive Loaded Circuit with Cut-Off Frequency

$$\frac{V_{out}-V_{-}}{1k}+s0.1\mu(V_{out}-V_{-})+\frac{V_{out}}{1k}=0 \rightarrow V_{out}\left(\frac{1}{1k}+\frac{1}{1k}+s0.1\mu\right)=V_{-}\left(\frac{1}{1k}+s0.1\mu\right)$$

$$\rightarrow V_{out}\left(\frac{s0.1m+2}{1k}\right)=V_{-}\left(\frac{s0.1m+1}{1k}\right) \rightarrow V_{-}=V_{out}\left(\frac{s0.1m+2}{s0.1m+1}\right)$$

$$\frac{V_{-}-V_{in}}{1k}+\frac{V_{-}-V_{out}}{1k}+s0.1\mu(V_{-}-V_{out})=0$$

$$\rightarrow \frac{V_{out}\left(\frac{s0.1m+2}{s0.1m+1}\right)}{1k}+\frac{V_{out}\left(\frac{s0.1m+2}{s0.1m+1}-1\right)}{1k}+s0.1\mu V_{out}\left(\frac{s0.1m+2}{s0.1m+1}-1\right)$$

$$=-\frac{V_{in}}{1k} \rightarrow V_{out}\left(\frac{s0.1m+2}{0.1s+1000}+\frac{1}{0.1s+1000}+\frac{s0.1\mu}{s0.1m+1}\right)=-\frac{V_{in}}{1k}$$

$$\rightarrow V_{out}\left(\frac{s0.2m+3}{0.1s+1000}\right)=-\frac{V_{in}}{1k} \rightarrow \boldsymbol{\frac{V_{out}}{V_{in}}=-\frac{0.5s+5k}{s+15k}}$$

$$\omega_c = 15k \rightarrow f_c = 2387\ Hz$$

Figure 5. Transfer Function for Active Loaded Circuit with Cut-Off Frequency

Simulations and Data Collection:

Passive Circuit Unloaded					
	100 Hz		1.592k Hz		
	Measured	Calculated	Reduced	Calculated	% Error
Gain	-0.087	-0.0171	-3.3	-3	9.09%
Phase	-3	-3.595	-45.3	-45	0.66%
Active Circuit Unloaded					
	100 Hz		1.592k Hz		
	Measured	Calculated	Reduced	Calculated	% Error
Gain	-0.048	-0.0171	-2.98	-3	0.67%
Phase	-3	-3.595	135	131	2.96%
Passive Loaded					
	100 Hz		3.183k Hz		
	Measured	Calculated	Reduced	Calculated	% Error
Gain	-6.09	-6.029	-9.21	-9	2.28%
Phase	-1.87	-1.799	-44.6	-45	0.89%
Active Load					
	100 Hz		2.387k Hz		
	Measured	Calculated	Reduced	Calculated	% Error
Gain	-0.36	-0.0171	-3.14	-3	4.45%
Phase	176.4	175	136.2	131	3.81%

Figure 6. Data Table with Gain and Phase for All Four Circuits, Along with Cut-Off Frequency

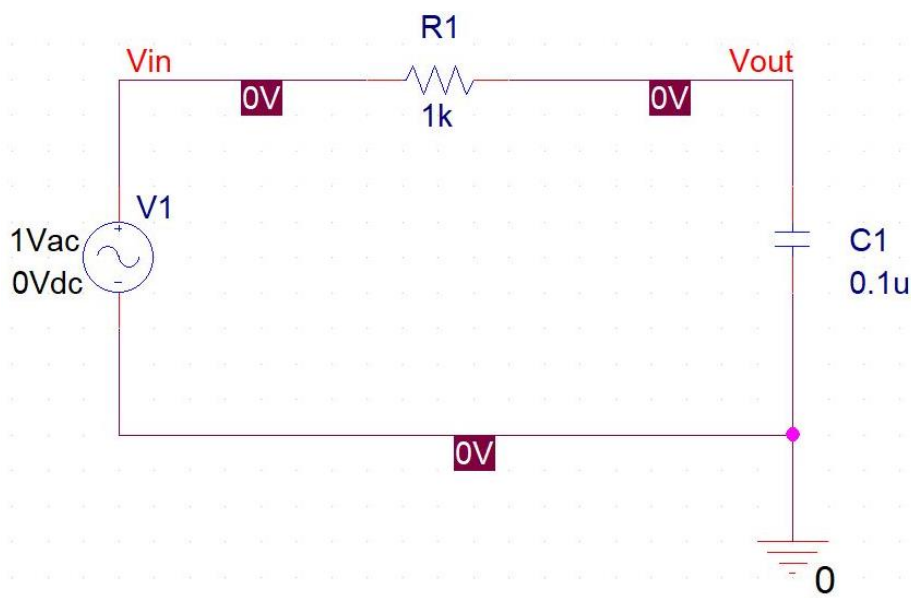

Figure 7. Passive Unloaded Circuit Diagram

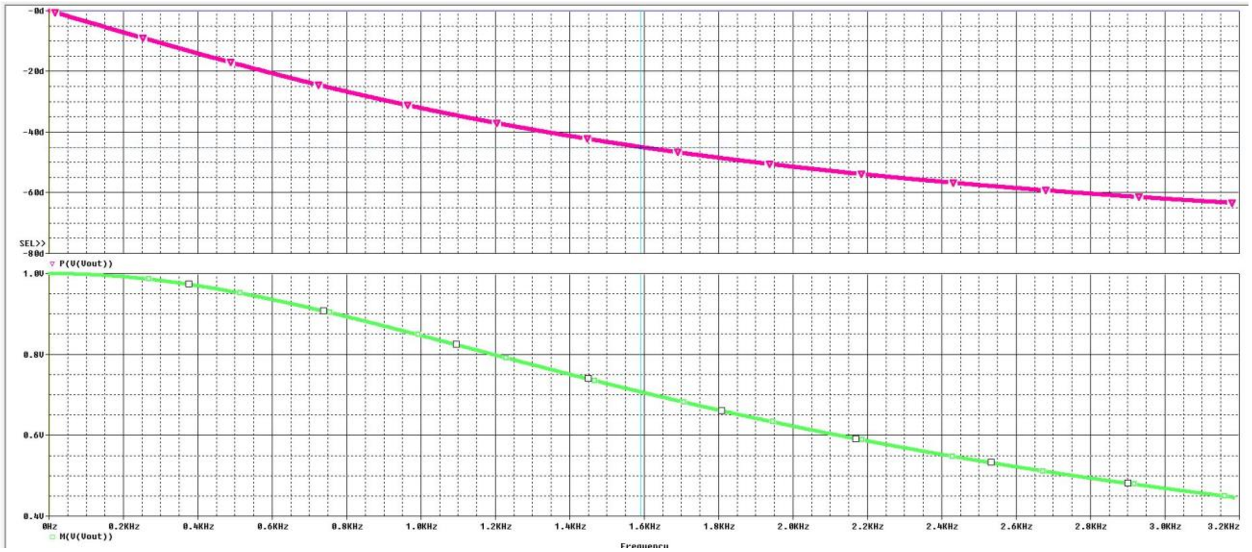

Figure 8. Passive Unloaded Graph with Magnitude of V_{out} on the Bottom and Phase of V_{out} on the Top

	Trace Color	Trace Name	Y1	Y2	Y1 - Y2
		X Values	1.5910K	1.0000	1.5900K
		M(V(Vout))	707.250m	1.0000	-292.750m
	CURSOR 1,2	P(V(Vout))	-44.990	-36.000m	-44.954

Figure 9. Half – Power Point of Passive Unloaded Circuit

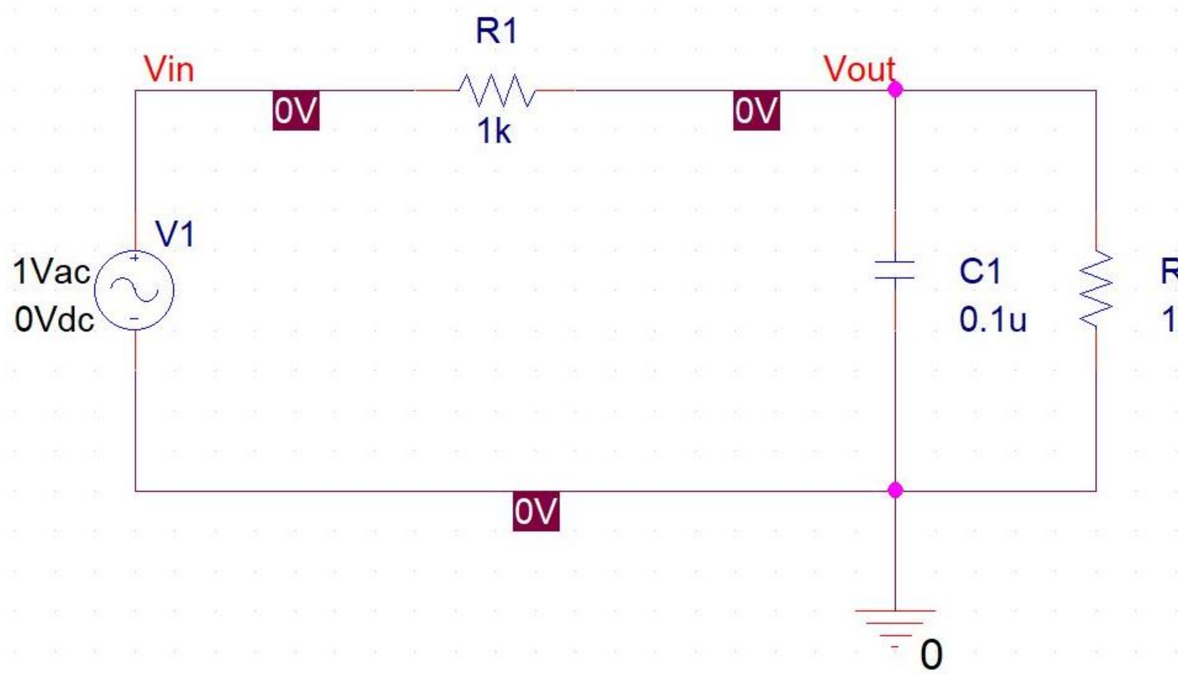

Figure 10. Passive Loaded Circuit Diagram

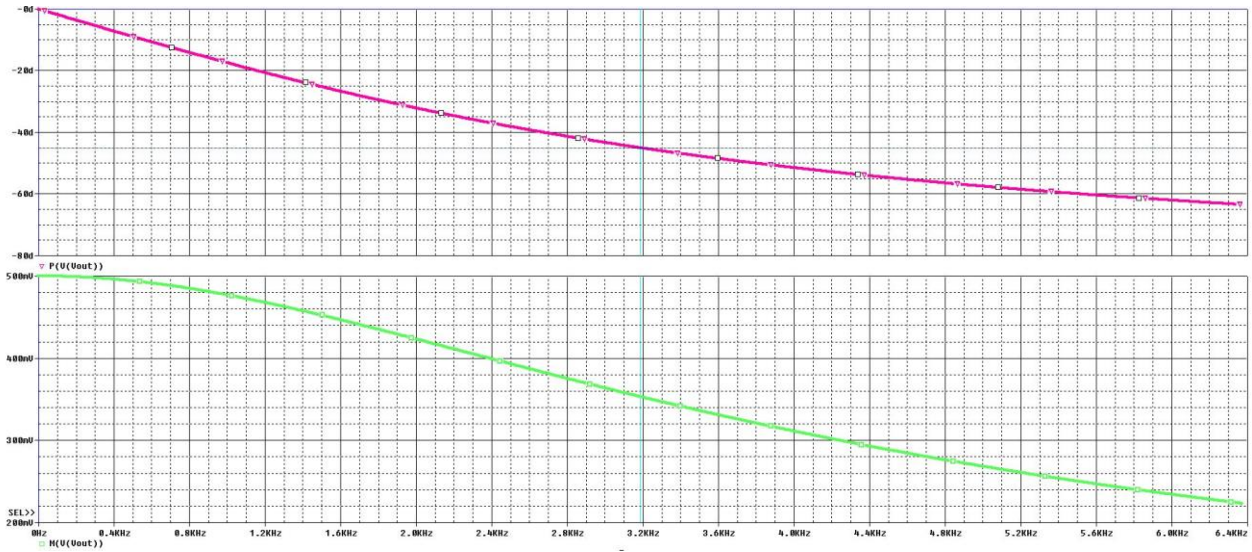

Figure 11. Passive Loaded Graph with Magnitude of V_{out} on the Bottom and Phase of V_{out} on the Top

Trace Color	Trace Name	Y1	Y2	Y1 - Y2
	X Values	3.1856K	1.0000	3.1846K
	M(V(Vout))	353.415m	499.999m	-146.583m
CURSOR 1,2	P(V(Vout))	-45.022	-18.000m	-45.004

Figure 12. Half – Power Point of Passive Loaded Circuit

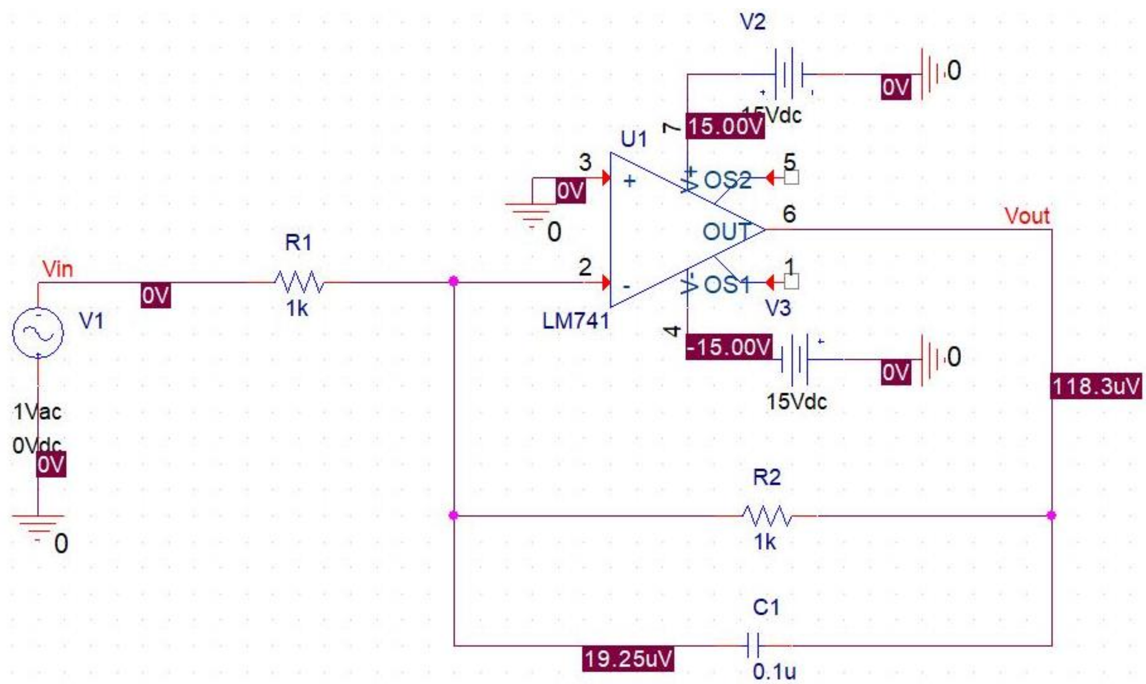

Figure 13. Active Unloaded Circuit Diagram

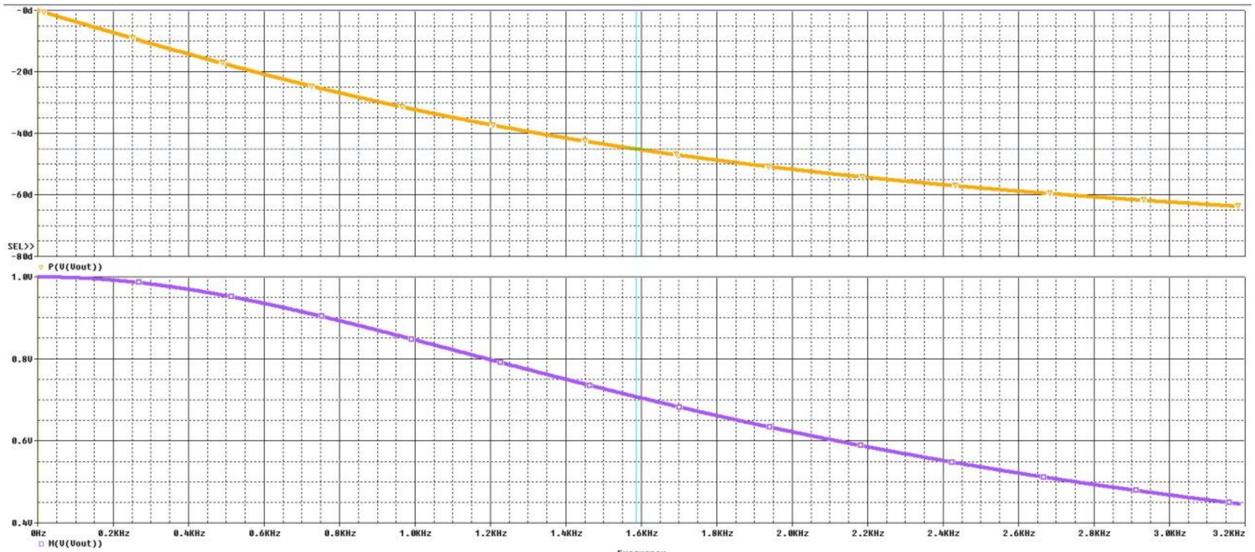

Figure 14. Passive Unloaded Graph with Magnitude of V_{out} on the Bottom and Phase of V_{out} on the Top

Trace Color	Trace Name	Y1	Y2	Y1 - Y2
	X Values	1.5856K	1.0000	1.5846K
	M(V(Vout))	707.919m	1.0000	-292.068m
CURSOR 1,2	P(V(Vout))	-45.038	-36.121m	-45.002

Figure 15. Half – Power Point of Active Unloaded Circuit

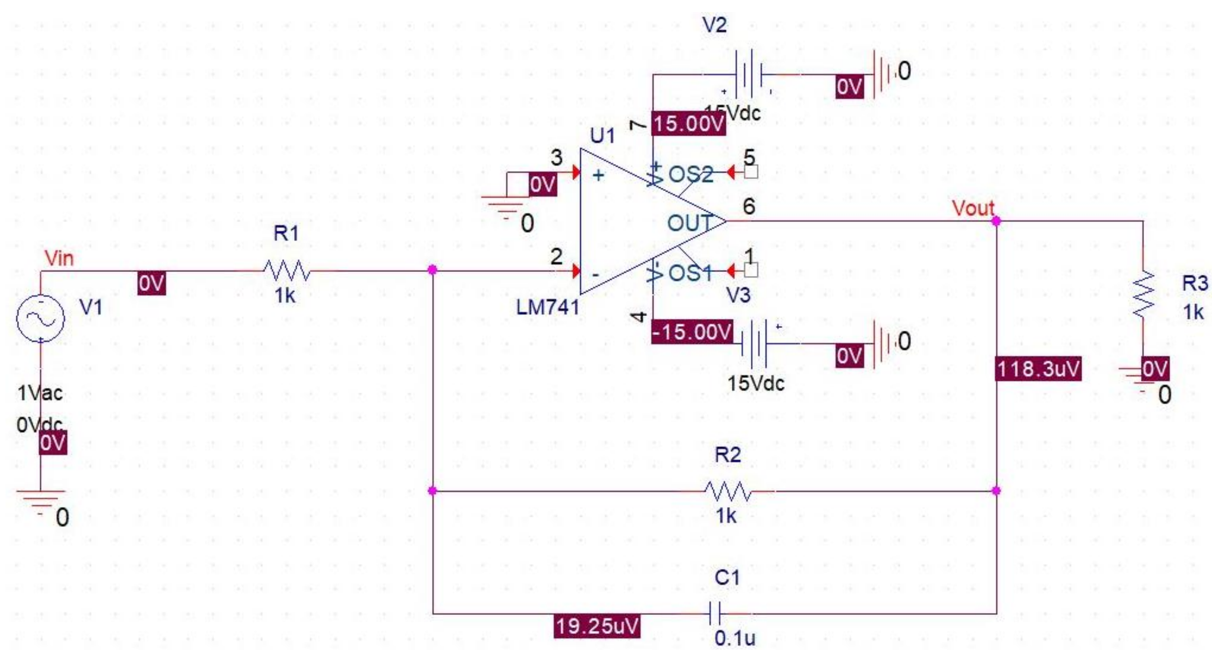

Figure 16. Active Loaded Circuit Diagram

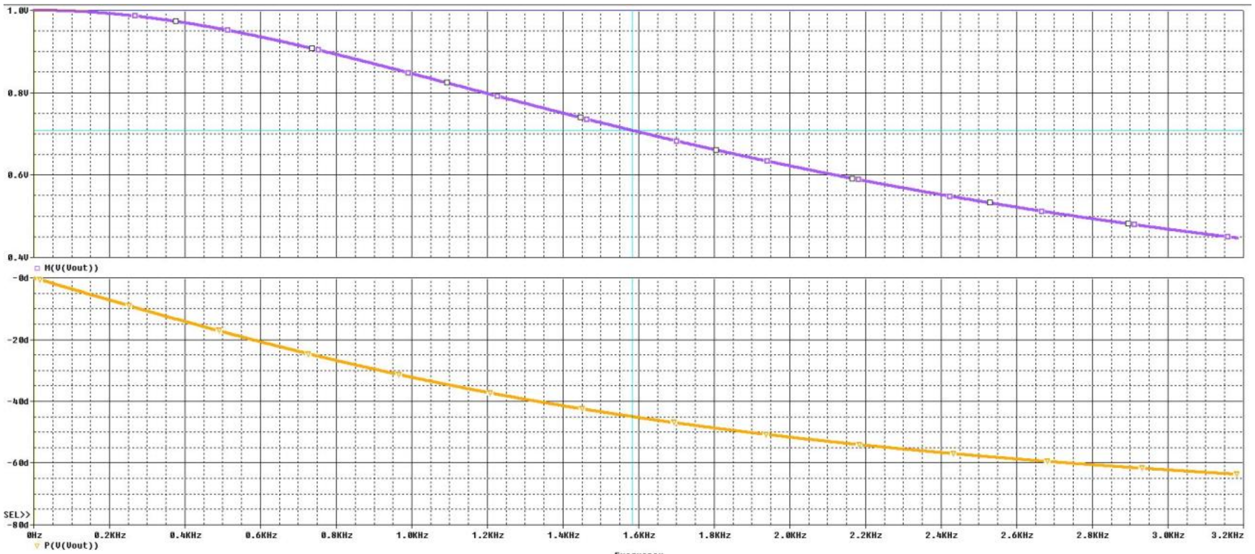

Figure 17. Passive Loaded Graph with Magnitude of V_{out} on the Top and Phase of V_{out} on the Bottom

	Trace Color	Trace Name	Y1	Y2	Y1 - Y2
		X Values	1.5838K	1.0000	1.5828K
		P(V(Vout))	-45.012	-65.092m	-44.947
	CURSOR 1,2	M(V(Vout))	708.292m	1.0000	-291.695m

Figure 18. Half – Power Point of Active Loaded Circuit

Results and Calculations:

Our data from the data table found in figure six compared to our results in PSPICE seem to match up very closely. When comparing the Half – Power Point from the four circuits our percent error ranges from two to nine percent. Overall any calculations that were done could only be done because of the transfer functions derived before we started the lab.

Conclusion:

In this lab we compared different gains and phase shifts for a Passive Unloaded/Loaded and Active Unloaded/Loaded circuits. Phase shift was then compared to the steady state response by adding a load resistor to both of the circuits. When comparing our values with the ones found in PSPICE we can conclude that our transfer functions are correct because the results found by using them match up closely to the ones in PSPICE. Overall this lab helped me understand how Low Pass Filters work in a circuit.