Lab #5 Low Pass Filter Lab(OP27, OP97, or LM741)

EEE 117L Monday Lab

Prof Cottle.

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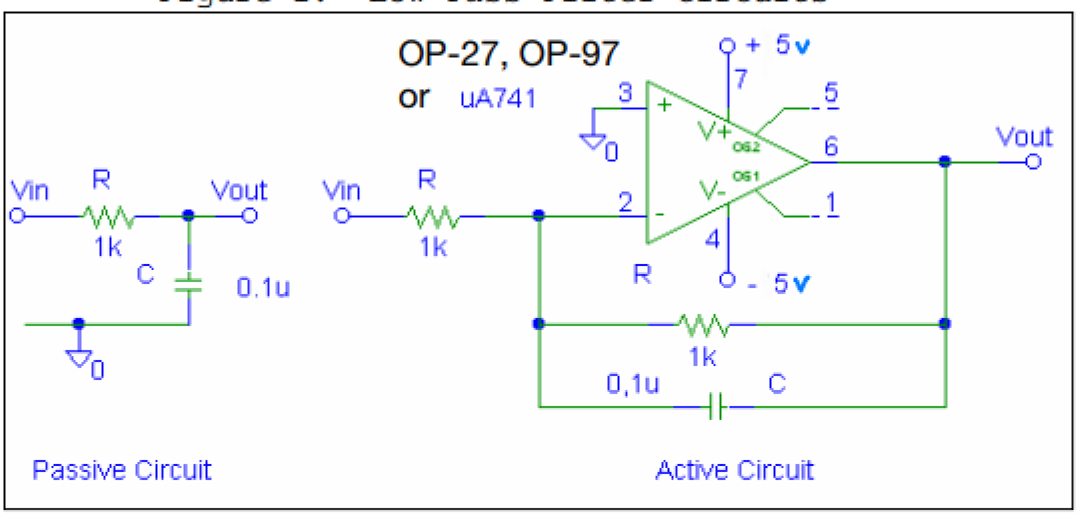
Figure 1. Low Pass Filter Circuits



Introduction

This lab was an introduction to Low-Pass filters. A Low-Pass filter is defined as a filter that passes signals with frequency lower than a selected cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency Using a resistor and a capacitor in series, I was able to create a simple Low-Pass filter. In Part 1 I studied the effect of applying a load resistor to the output of the circuit on the frequency response. I measure the phase and gain shift as well as half point frequency. Part 2 dealt with using the Fourier Series in circuit analysis.

Part 1 Sinusoidal Steady State Frequency Response

Low Pass Filters

Low Frequency Gain and Phase Shift (Passive)						
	Theoretical Value		Experimental Value		PSPICE Value	
	Gain	Phase	Gain	Phase	Gain	Phase
Passive	0.952	-3.78	1.5	In phase	0.950	-3.774
Passive (1K)	0.5	-1.18	0.5	In phase	0.312	-1.9

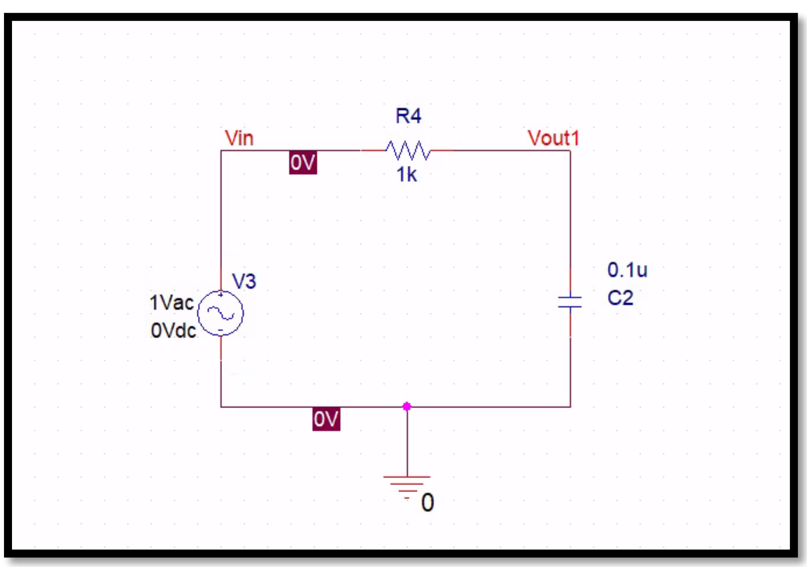


Figure 1 Low Frequency Gain and Phase Shift Before 1K resistor

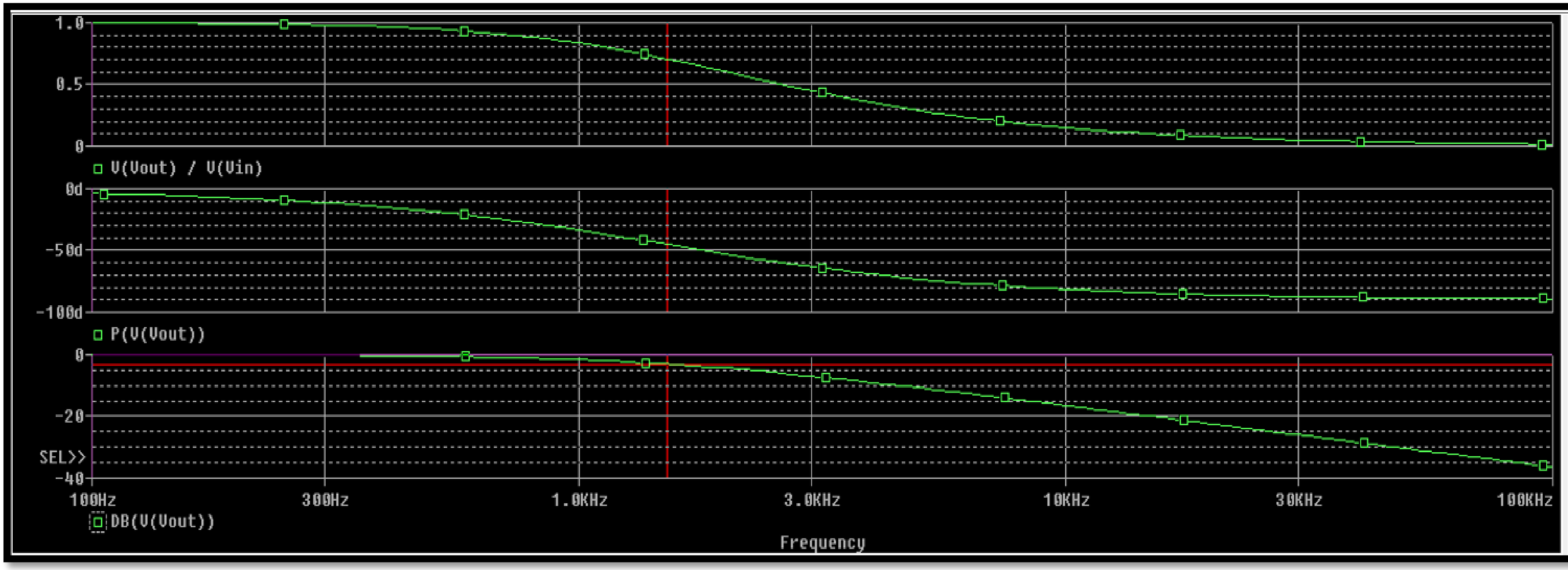


Figure 2 Low Pass Gain and Phase Shift after 1K resistor

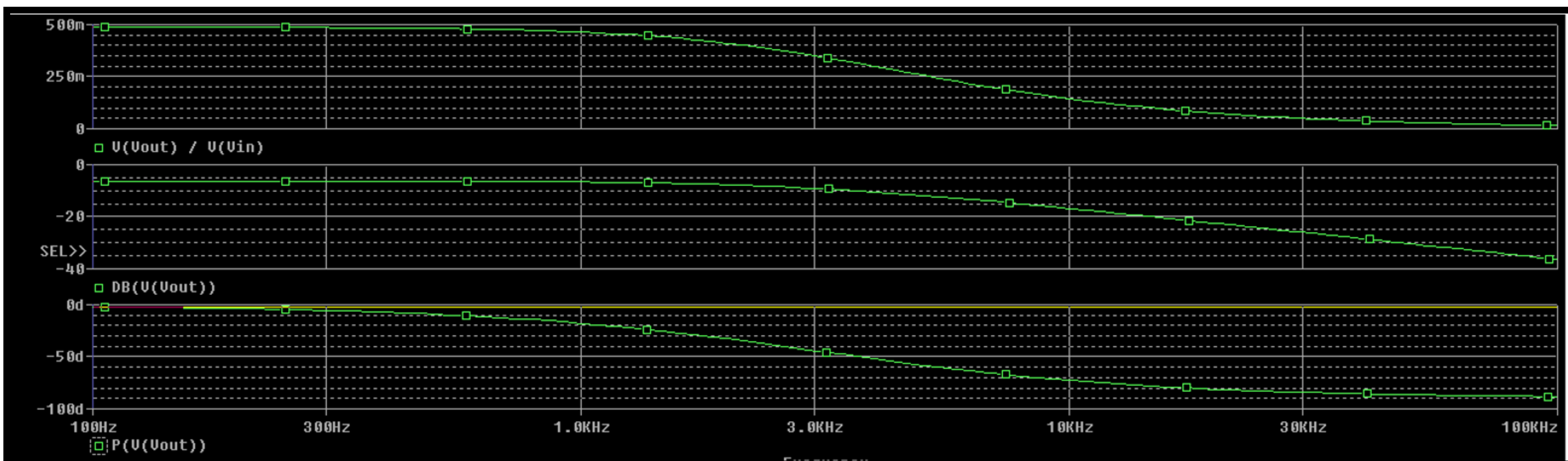


Figure 3 Passive Circuit

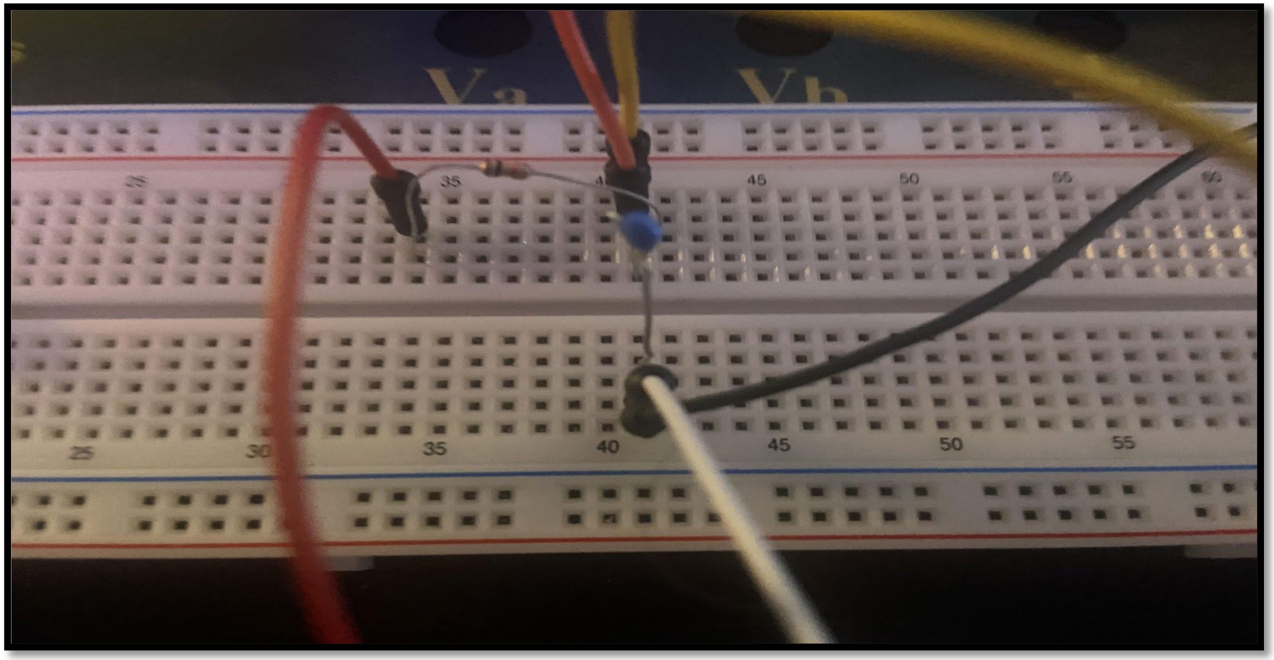
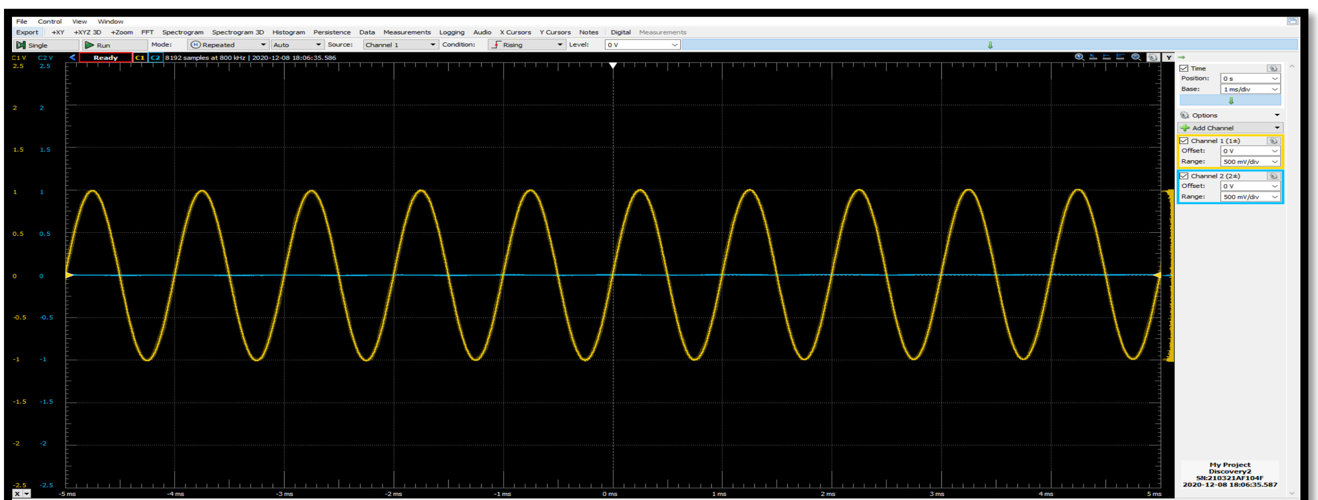


Figure 4 Waveforms



Working on PSPICE with the low pass filters was quite challenging at first however with several pointers and traces I finally derived the phase and gain. If labeled correctly the values can be found with these functions:

Gain = “V(Vout)/V(Vin)”

Phase Shift = “P(V(Vout))”

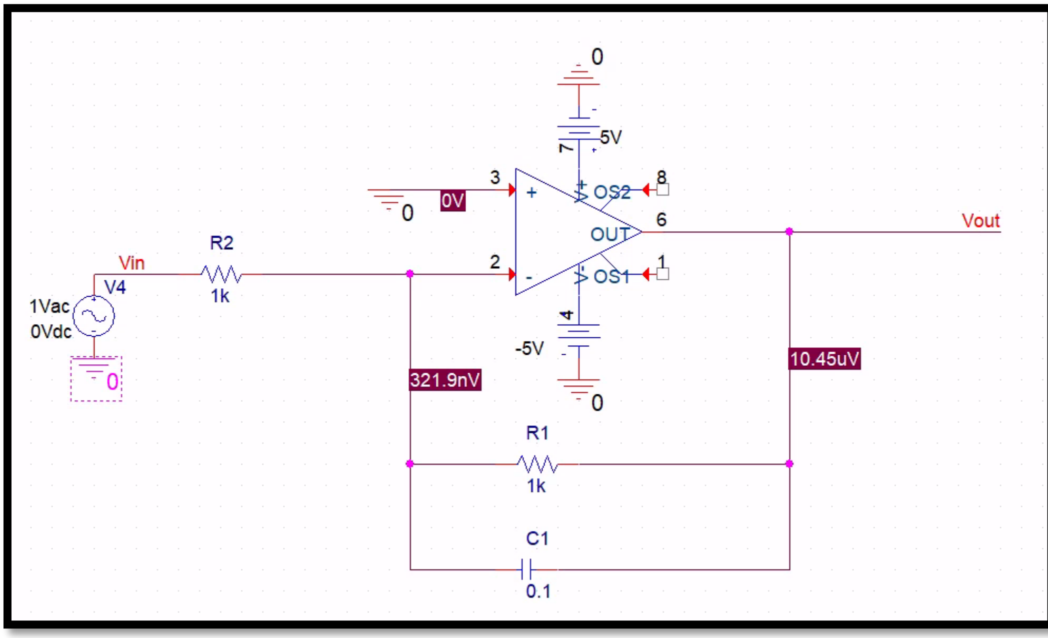
Frequency = “DB(V(Vout))”

Using these functions, in figure 1 i derived that the gain 0.950 and the phase was -3.774 In figure 2 the same traces were used to find the gain and phase shift of the passive circuit with the 1k load resistor. Using the PSPICE results, the cursor was used to derived the gain to be 0.312 and the phase shift to be -1.9. In step 2 I had to measure the gain and phase shift at a specific frequency. Also known as the half-power point, it is described as when the frequency is increased until the output is reduced by 3db. Using the half-power frequency formula of 1/2piRC (R= 1k and C=0.1uF), resulting in the frequency being 1590Hz. The data below is half-power frequency Gain and Phase Shift

	Theoretical Value		*Experimental Value*		*PSPICE Value*	
	Gain	Phase	Gain	Phase	Gain	Phase
Passive	0.616	-40.48	0.715	-41.62	0.706	-45.02
Passive, 1k	0.338	-21.03	0.50	-27.13	0.431	-22.19

A note that I found that was a 1k load resistor was added to the circuit, both the amplitude and the phase shift change.

High Pass Filter



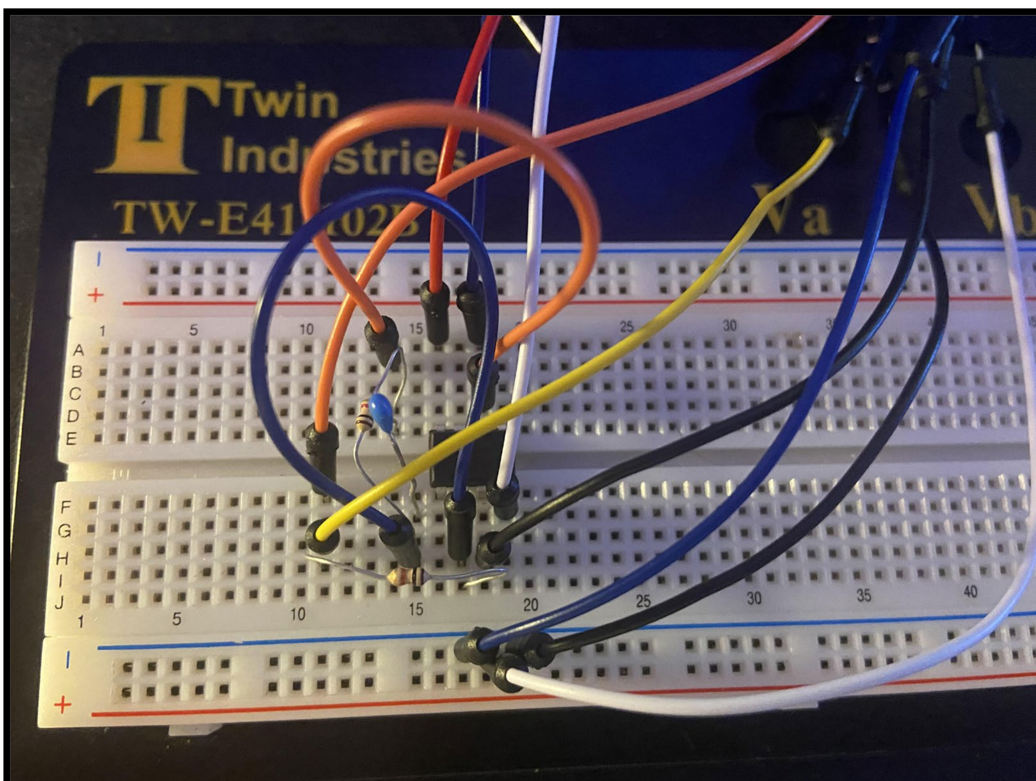
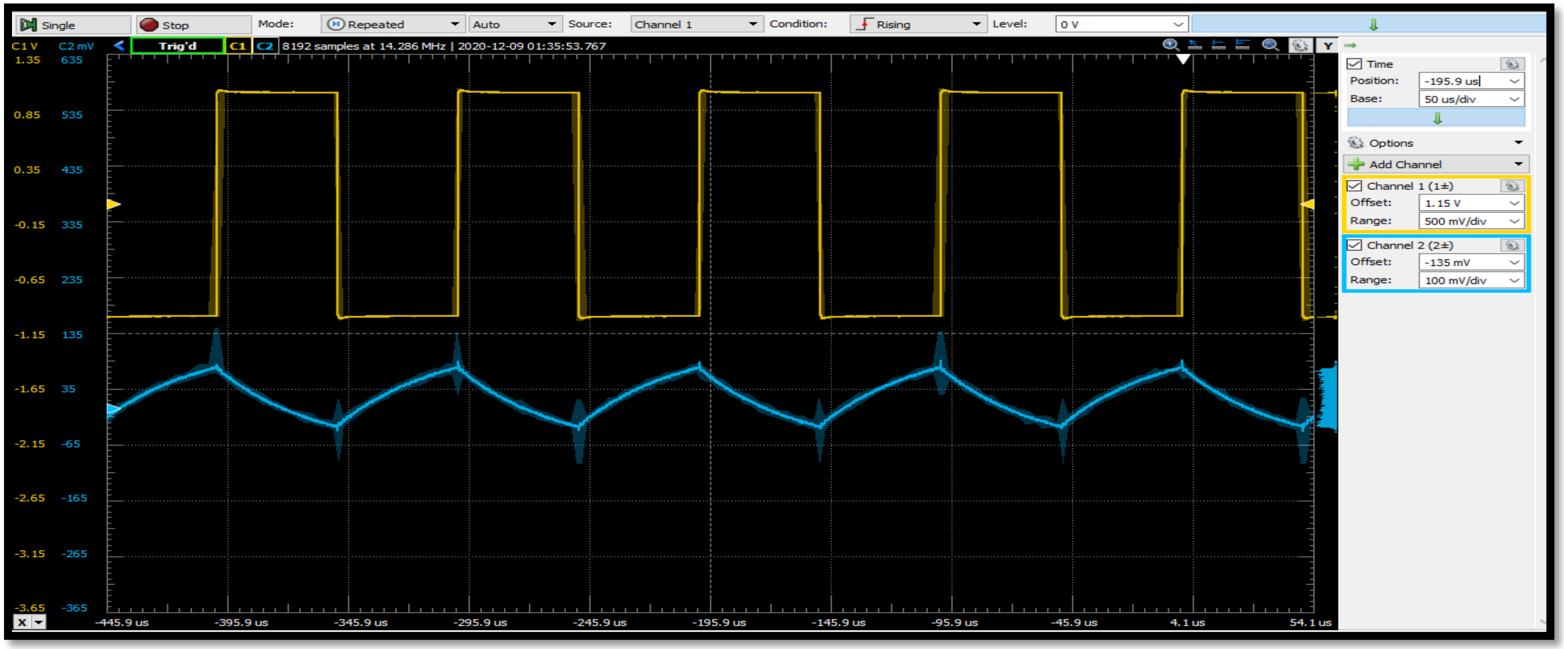


Figure 5 High pass filter with capacitor discharge at 10kHZ and 500Hz



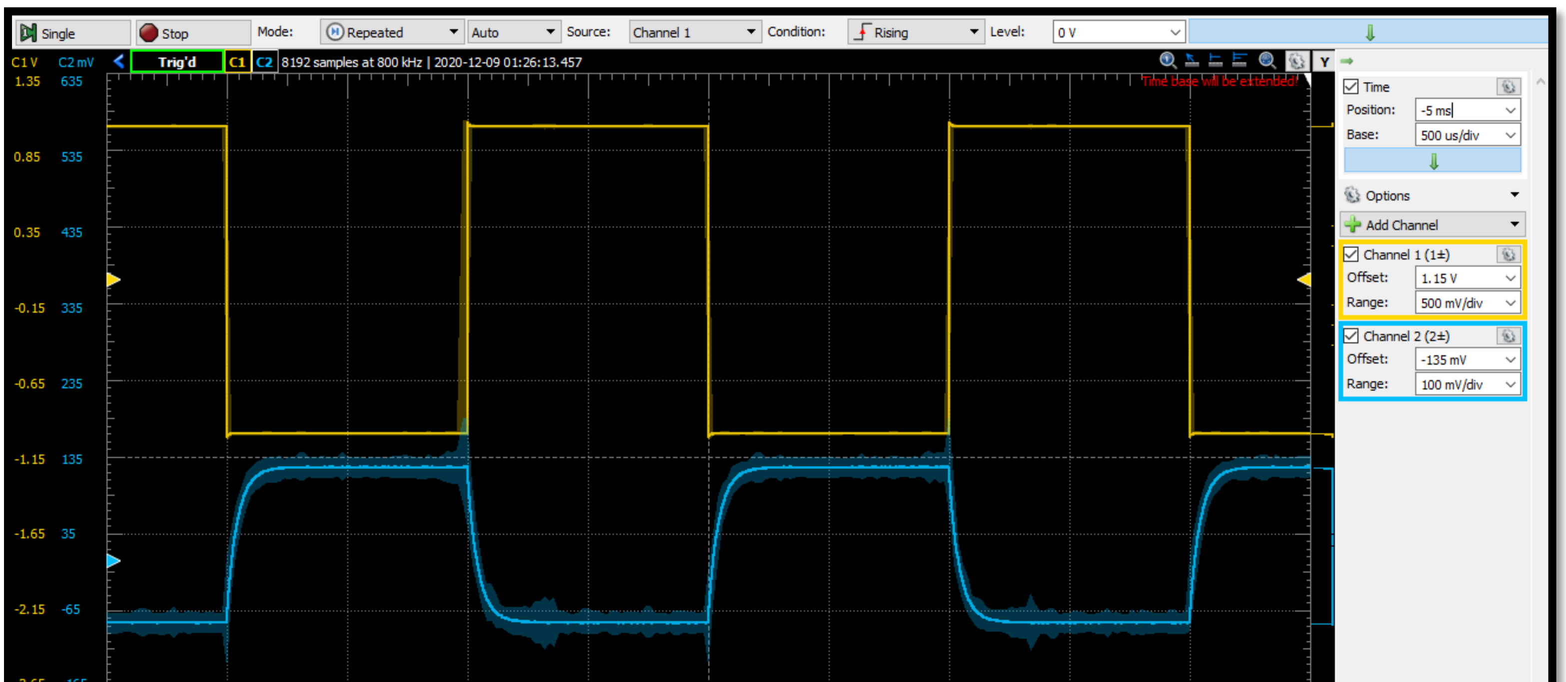
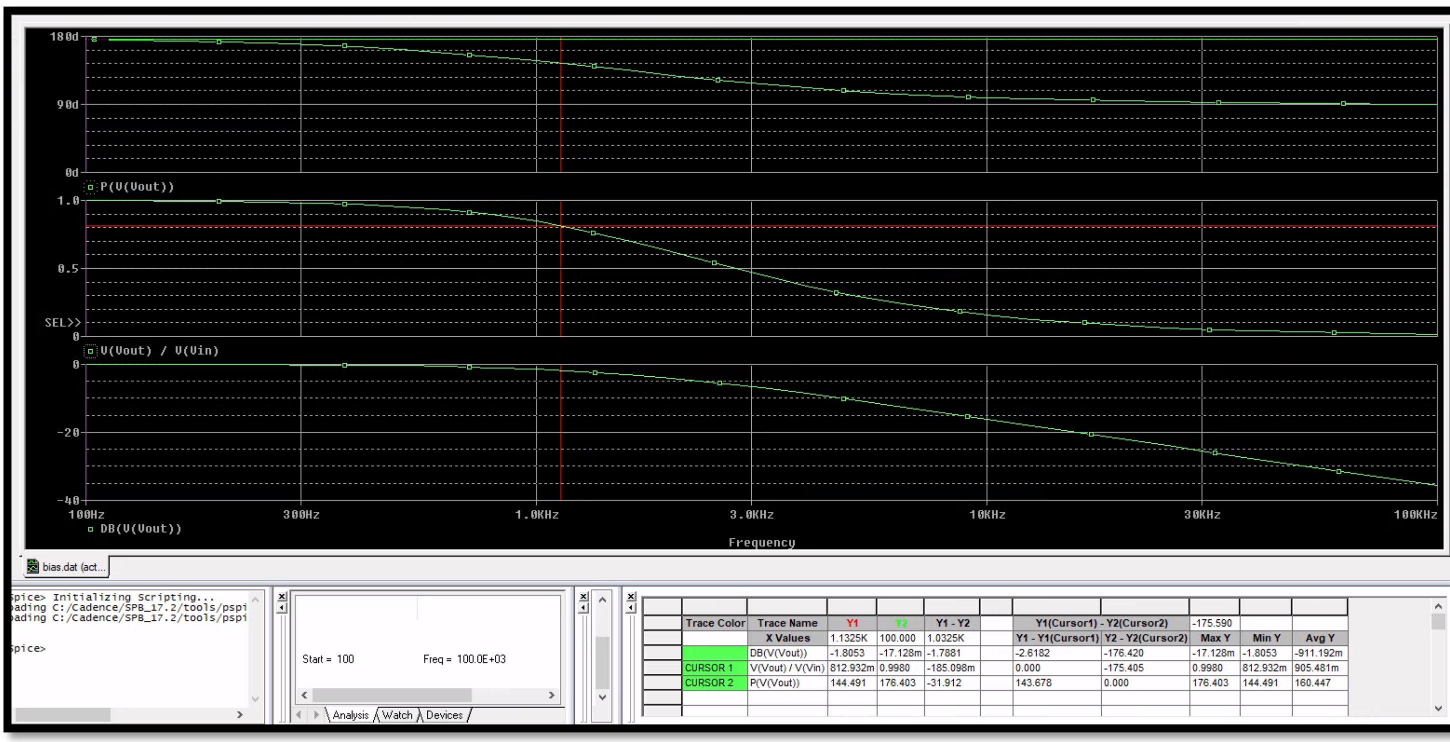


Figure 6 Low Frequency Gain and Phase Shift

	Theoretical Value		Experimental Value		PSPICE Value	
	Gain	Phase	Gain	Phase	Gain	Phase
Active	0.85	180	1	180	0.9980	176.403
Active 1k	1	180	1	180	0.9980	176.403

Deriving the phase shift was the easy on the table because the circuit is an inverting OPAMP and because of that I know that the shift will be 180 degrees. Using the input and output voltages the gain was 1 for the experimental value. Lastly using the courser from PSPICE I was allowed to derive the Gain and Phase shift which were roughly what I thought them to be.

Figure 7PSPICE for Active Circuit



Using the curser in PSPICE I found the half-power point to be around 1.2kHz. Below are the measurements obtained for the gain and phase of the new output.

Figure 8 Half-Power point frequency gain and phase shift

	Theoretical Value		Experimental Value		PSPICE Value	
	Gain	Phase	Gain	Phase	Gain	Phase
Active	0.707	-45	0.716	-43.69	0.688	-44
Active, 1k	0.711	-45	0.716	-43.69	0.688	-44

When the 1k resistor was loaded into the circuit I noticed that the phase shift and gain did not change. I believe this is because the load resistor had no effect on the circuits Vout.

Part 2 Square Wave Input/ Fourier Series Analysis

In part 2 , we use the Passive RC circuit without a load resistor to produce a square wave input . The input wave show resemble the figure below.

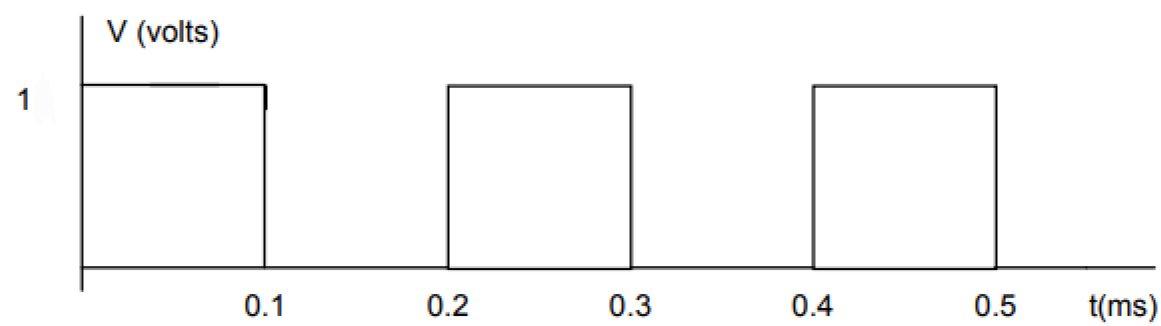


Figure 2 Square Wave Input

<u>Calculations</u>

Period t =0.2ms   Angular frequency = 10pi   Input = odd

$A_n = 0$ when $n > 0$

$B_1 = 6.3662$ $B_2 = 0$

$B_3 = 2.1221$ $B_4 = 0$

$B_5 = 1.2732$ $B_6 = 0$

$B_7 = 0.9094$ $B_8 = 0$

Fourier series of Vin(t)

$B_1 = 1.9308$ $B_2 = 0$

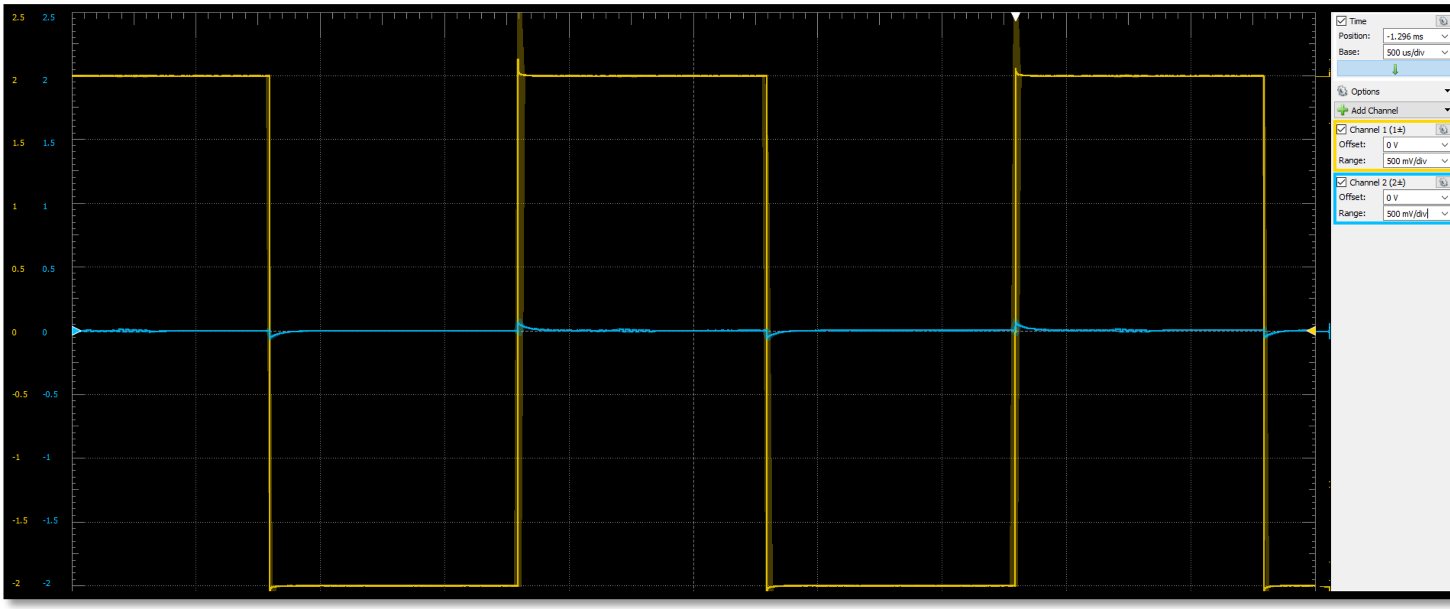
$B_3 = 0.22388$ $B_4 = 0$

$B_5 = 0.08088$ $B_6 = 0$

$B_7 = 0.04096$ $B_8 = 0$

<u>Experiment</u>

Figure 9 Wave input and output for RC input



<u>PSPICE Simulations Fourier</u>

Figure 10 Shows the PSPICE simulation with the VPULSE source

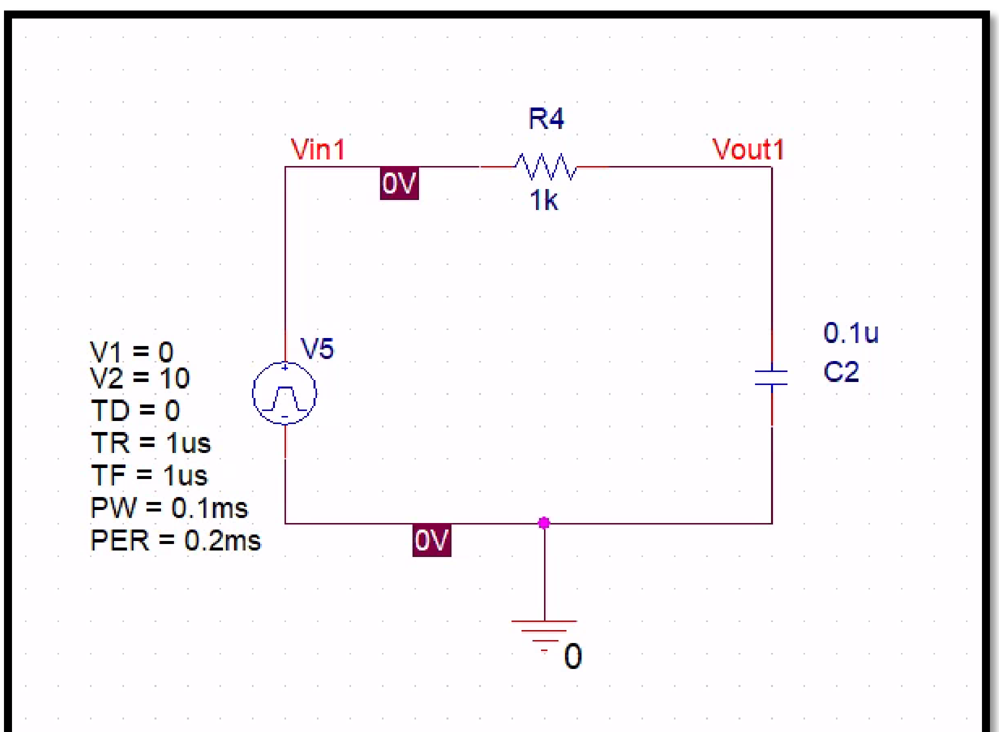


Figure 11 Simulated result of Vin and Vout

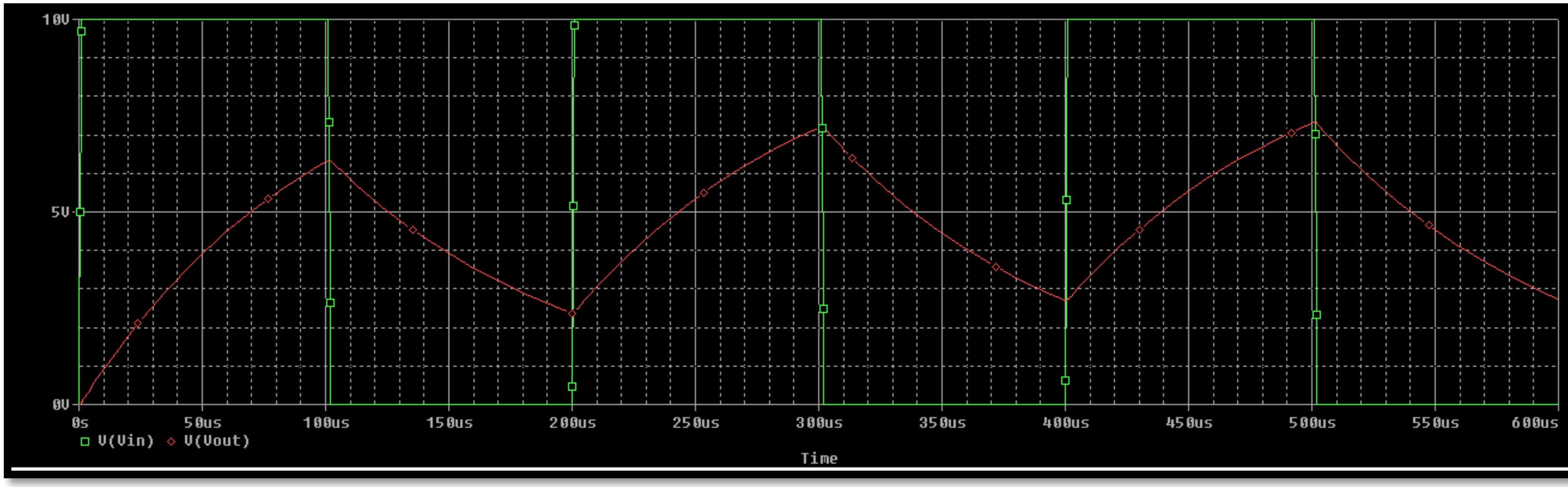


Figure 12 Fourier series waveform of the input and output

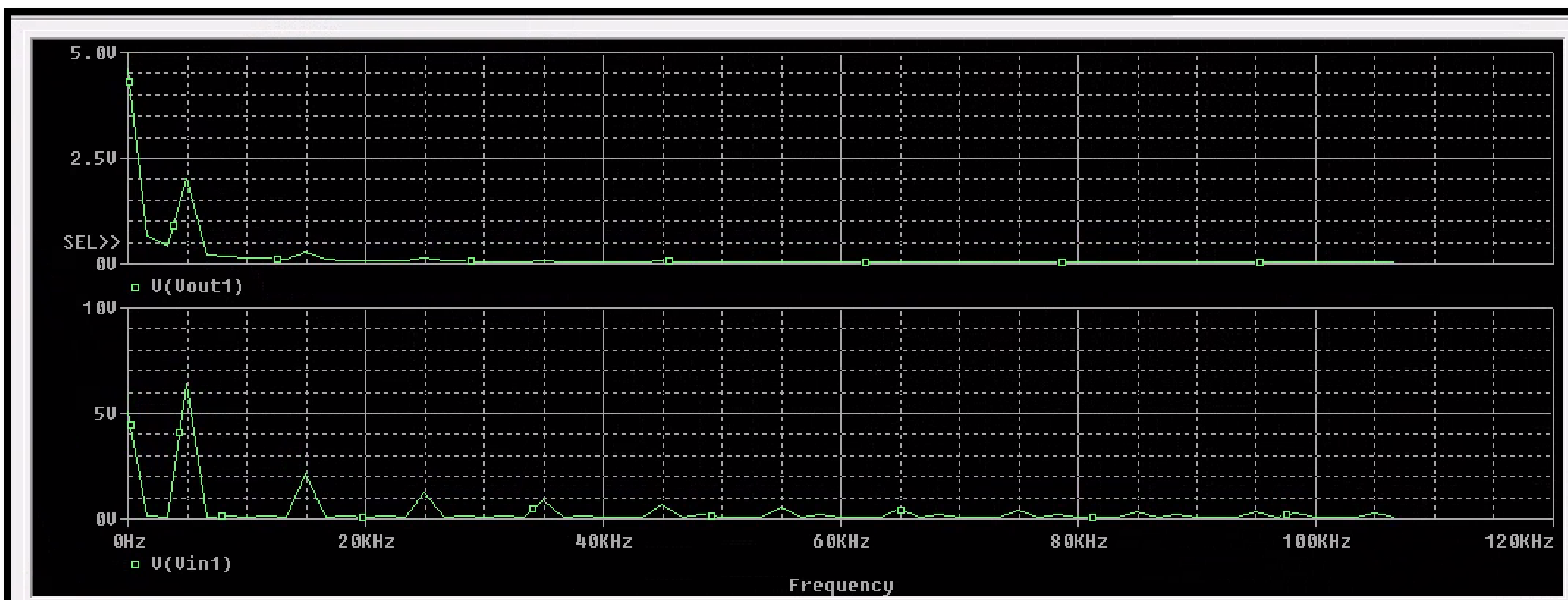


Figure 13 Fourier analysis of Vin1 and Vout1 for the passive circuit

FOURIER COMPONENTS OF TRANSIENT RESPONSE V(VIN1)

DC COMPONENT = 5.0495E+00

HARMONIC NO	FREQUENCY (HZ)	FOURIER COMPONENT	NORMALIZED COMPONENT	PHASE (DEG)	NORMALIZED PHASE (DEG)
1	5.0000E+03	6.3665E+00	1.0000E+00	-2.6732E+00	0.0000E+00
2	1.0000E+04	9.9062E-02	1.5560E-02	8.4654E+01	9.0000E+01
3	1.5000E+04	2.1228E+00	3.3344E-01	-8.0197E+00	-9.6260E-07
4	2.0000E+04	9.9206E-02	1.5583E-02	7.9307E+01	9.0000E+01
5	2.5000E+04	1.2745E+00	2.0019E-01	-1.3366E+01	-4.7965E-06
6	3.0000E+04	9.9446E-02	1.5620E-02	7.3961E+01	9.0000E+01
7	3.5000E+04	9.1125E-01	1.4313E-01	-1.8713E+01	-1.3361E-05
8	4.0000E+04	9.9785E-02	1.5674E-02	6.8615E+01	9.0001E+01

TOTAL HARMONIC DISTORTION = 4.1560E+01 PERCENT

FOURIER COMPONENTS OF TRANSIENT RESPONSE V(VOUT1)

DC COMPONENT = 5.0281E+00

HARMONIC NO	FREQUENCY (HZ)	FOURIER COMPONENT	NORMALIZED COMPONENT	PHASE (DEG)	NORMALIZED PHASE (DEG)
1	5.0000E+03	1.9322E+00	1.0000E+00	-7.4673E+01	0.0000E+00
2	1.0000E+04	8.8888E-03	4.6003E-03	-7.9578E-01	1.4855E+02
3	1.5000E+04	2.2368E-01	1.1576E-01	-9.0714E+01	1.3330E+02
4	2.0000E+04	4.5818E-03	2.3713E-03	-1.4221E+01	2.8447E+02
5	2.5000E+04	8.1156E-02	4.2002E-02	-9.7059E+01	2.7630E+02
6	3.0000E+04	3.2032E-03	1.6578E-03	-2.3682E+01	4.2435E+02
7	3.5000E+04	4.1947E-02	2.1709E-02	-1.0187E+02	4.2084E+02
8	4.0000E+04	2.5611E-03	1.3255E-03	-3.1888E+01	5.6549E+02

TOTAL HARMONIC DISTORTION = 1.2517E+01 PERCENT

Discussion Items

1.) **<u>Compare the various gains and phase shifts found in Part I.</u>**

Several measurements were made in order to obtain the gain and phase shift for a passive and active circuit. For the passive circuit, 4 different measurements were obtained. The first case was the low frequency response. Referring back to table 1 and the first row of values, one can say that values were very similar. Looking at the values, there was 1 percent error. Looking at the phase shift, the values were also close. There was 1 percent error as well. The experiment phase value was difficult to measure. The waveform was used and when looking at it, the output and input signals were very close to be in phase. When adding a load resistor, the values changed.

2.) **<u>Compare the steady state response of the active circuit to the response of the passive circuit when a load is added.</u>**

When the load resistor was added to the active circuit, the output was not affected by it. When the load resistor was added to the passive circuit, the output was affected. The first part was the corner frequency. As expected, the corner frequency was not the same in all cases. This was because when determining the frequency in the passive circuit, the load resistor was included into the calculations where in the active circuit, it was not. The gain and phase shift did not change with and without the load resistor

3.) <u>Compare the calculated Fourier series coefficients with the PSPICE generated coefficients.</u>

When calculating the Fourier series coefficients, I found the square wave to be odd. Comparing with the Vin coefficients in both cases, the highest percent error was 0.2%. When comparing the Vout coefficients in both cases, the highest percent error was about 2 percent.

4.) <u>Compare the experimental output to the PSPICE simulated output for the square wave input of Part II.</u>

Comparing the output of both graphs in Figure 12, both the maximum voltages were around 7 Volts with the minimum voltage was roughly around 3Volts. In the PSPICE simulated, the capacitor charged up to around 6 Volts and discharged around 2 Volts. I believe that this was due to the low frequencies of the capacitive reactance