Justin Hsu

EEC 100 Lab 7

11/19/24

(1) Objective: Learn how to use the fourier series to analyze a periodic input signal and calculate the coefficients and phase angles of the different terms. Then see how a filter changes the phase angle of the input signal depending on its frequency.

(2) Prelab:

1. $A = 2.5V$, $T = 2ms$ $\qquad 2.5/2mS = 1250$

$$a_0 = \frac{1}{T}\int_0^T f(t)\,dt \qquad a_n = \frac{2}{T}\int_0^T f(t)\cos\left(\frac{2\pi n t}{T}\right)dt$$

$$a_0 = \frac{1}{2ms}\int_0^{2ms} 1250\, t\, dt \qquad a_n = \frac{2}{2ms}\int_0^{2ms} 1250t \cos\left(\frac{2\pi n t}{2ms}\right)dt$$

$$\boxed{a_0 = 1.25V} \qquad \boxed{a_n = 0}$$

$$b_n = \frac{2}{T}\int_0^T f(t)\sin\left(\frac{2\pi n t}{T}\right)dt$$

$$b_n = \frac{2}{2ms}\int_0^{2ms} 1250t \sin\left(\frac{2\pi n t}{2ms}\right)dt$$

$$b_n = \frac{5(\sin(2\pi n) - 2\pi n\cos(2\pi n))}{4\pi^2 n^2}$$

$$b_n = \begin{cases} \frac{-5}{2\pi n} & n \text{ is odd} \\ \frac{-5}{2\pi n} & n \text{ is even} \end{cases}$$

$$\boxed{V_s(t) = 1.25 - \frac{5}{2\pi}\sin(t) - \frac{5}{4\pi}\sin(2t) - \frac{5}{6\pi}\sin(3t) - \dots}$$

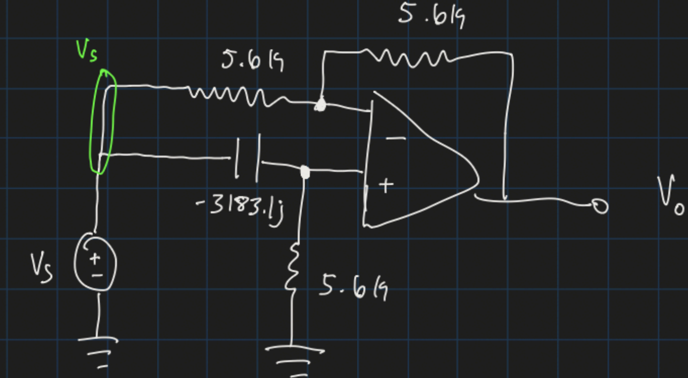
2.

$T = 2\,ms$

$f = \frac{1}{2ms} = 500\,Hz$

$500 \times 2\pi = 3141.6$

$C = \frac{1}{j\omega C} = -3183.1j$



$$V_p = V_s\left(\frac{5.6k}{-3183.1j + 5.6k}\right) = V_s(0.756 + 0.43j) = V_n$$

$$V_n \Big| \quad \frac{V_n - V_s}{5.6k} + \frac{V_n - V_o}{5.6k} = 0$$

$$-2\tan(\omega CR) + 180°$$

$$V_n - V_s + V_n - V_o = 0$$

$$2V_n = V_s + V_o$$

$$2V_s(0.756 + 0.43j) - V_s = V_o$$

$$\frac{V_o}{V_s} = 0.512 + 0.86j$$

$$\boxed{H(j\omega) = 1 \angle 59.24°}$$

$$\boxed{H(j\omega) = \frac{j\omega - \frac{1}{RC}}{j\omega + \frac{1}{RC}}}$$

This is a all pass filter since $|H(j\omega)| = 1$

3. $V_0 = 1.25\, |H(j0)| \cos\{\angle H(j0)\}$

$= 1.25\,(-1)\cos(\pi)$

$\angle[H(jn\omega_0)] = -2\tan^{-1}(\omega CR) + 180°$

$= 1.25$

$$V_0(t) = 1.25 + \sum_{n=1}^{\infty} \frac{-5}{4\pi n^2} |H(jn\omega_0)| \sin\{n\omega_0 t + \angle[H(jn\omega_0)]\}$$

$$= 1.25 + \left[\frac{-5}{4\pi}\left(|H(j\omega_0)| \sin\{\omega_0 t + \angle H(j\omega_0)\}\right]\right. + \left[\frac{-5}{16\pi}\left(|H(2j\omega_0)| \sin\{2\omega_0 t + \angle H(2j\omega_0)\}\right.\right.$$

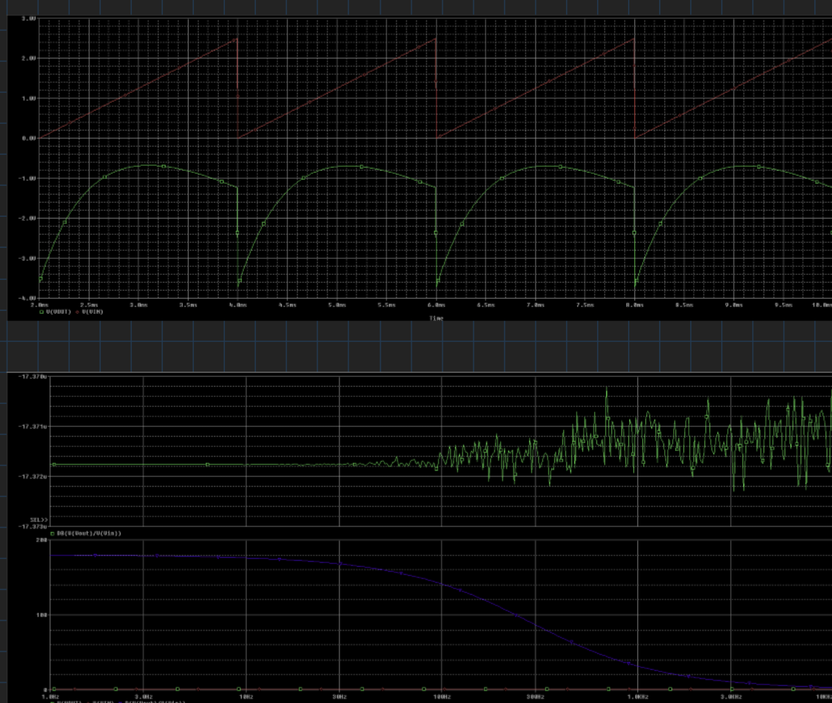
$$= 1.25 + \left(\frac{-5}{2\pi}\sin(10\pi t + 59.24°)\right) + \left(\frac{-5}{4\pi}\sin(10\pi t + 31.73°)\right) + \left(\frac{-5}{6\pi}\sin(10\pi t + 21.46)\right)$$

(3) Simulation:

Simulations

$V_{o,max}$: ~ − 0.677mV

$V_{o,min}$: ~ −3.61 V

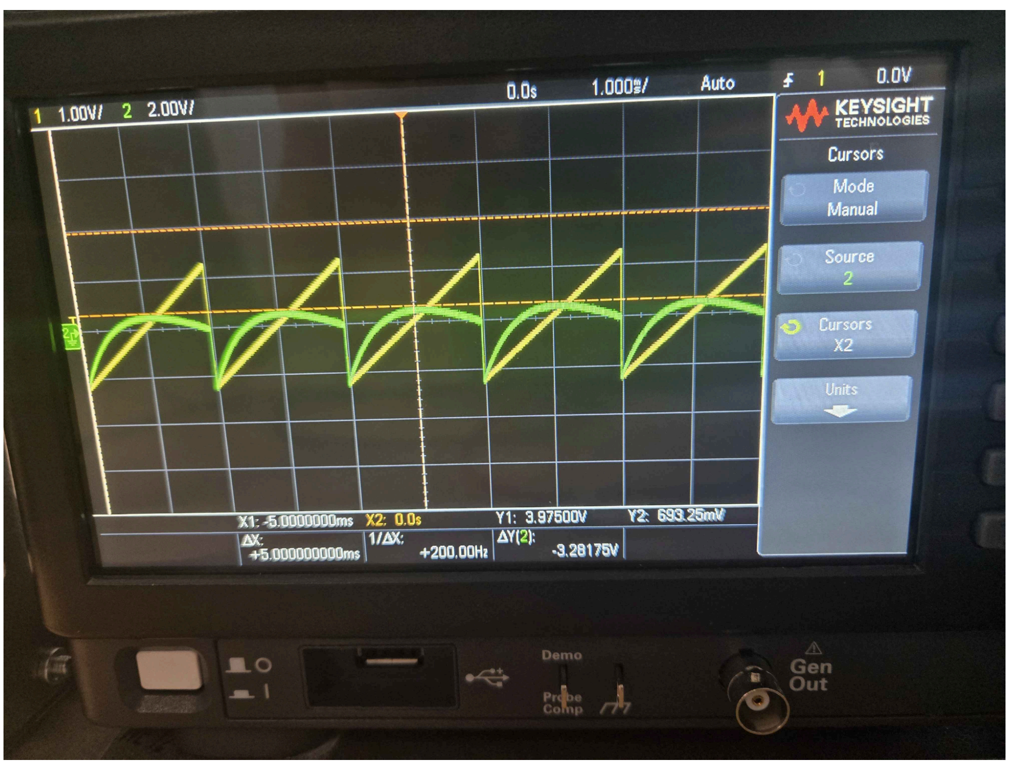


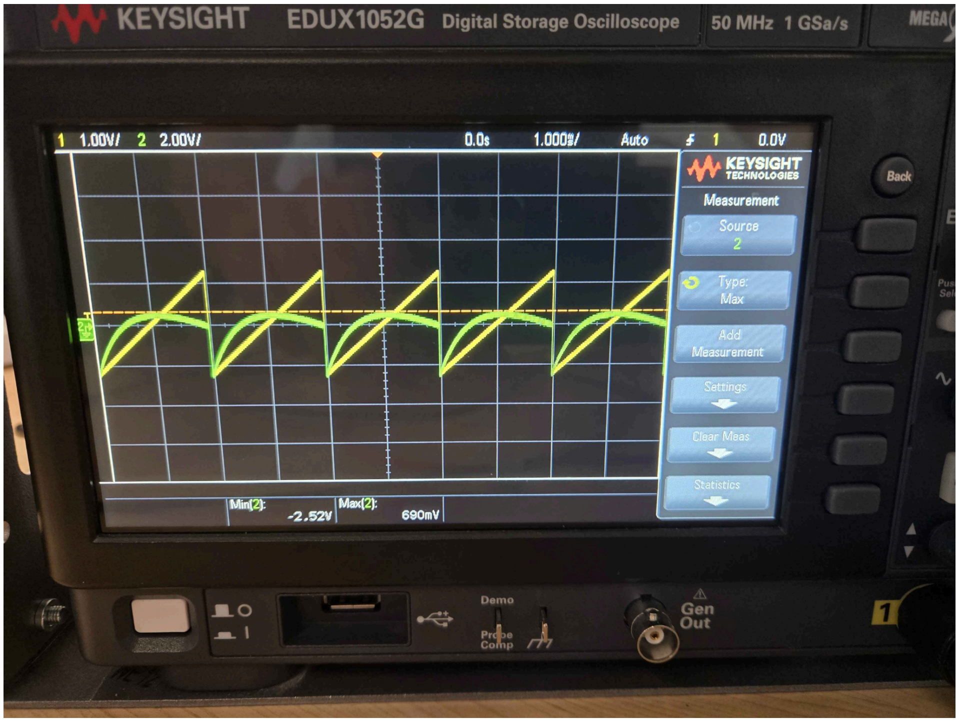
This ckt behaves as expected because we can see from the dB output that it behaves like the sum of a bunch of sinusoids added together, and the bottom graph shows an expected freq cutoff for a filter

(4) Experiment:

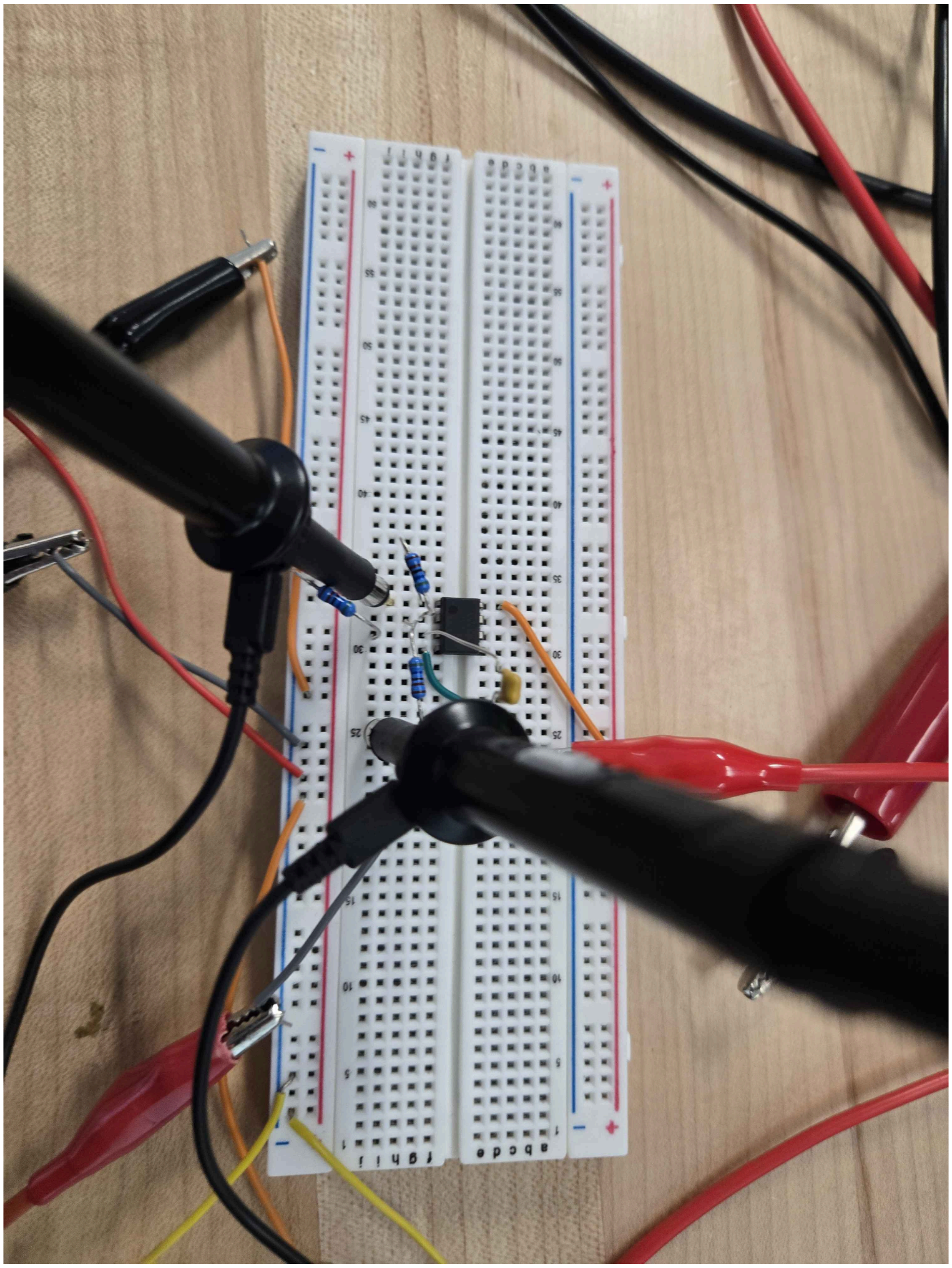
11. On the function generator, change the waveform to be a Sine wave. Select the frequencies in the table below and set the amplitude to be **2 Vpp**. On the oscilloscope, observe how the magnitude and phase of output signal change. Is it as you expected? What is the purpose of this circuit?

Frequency	Does the magnitude $\|V_o\|$ change?	Phase $\angle V_o$ Value (deg)
10 Hz	Yes/No	172
1000 Hz	Yes/No	30
10000 Hz	Yes/No	0
100000 Hz	Yes/No	-7




KEYSIGHT
EDUX1052G Digital Storage Oscilloscope
50 MHz 1 GSa/s
1 1.00V/ 2 2.00V/
0.0s
Auto
1 0.0V
KEYSIGHT TECHNOLOGIES
Measurement
Source 2
Type: Max
Add Measurement
Settings
Clear Meas
Statistics
Back
Min(2): -2.52V
Max(2): 690mV
Demo
Probe Comp
Gen Out

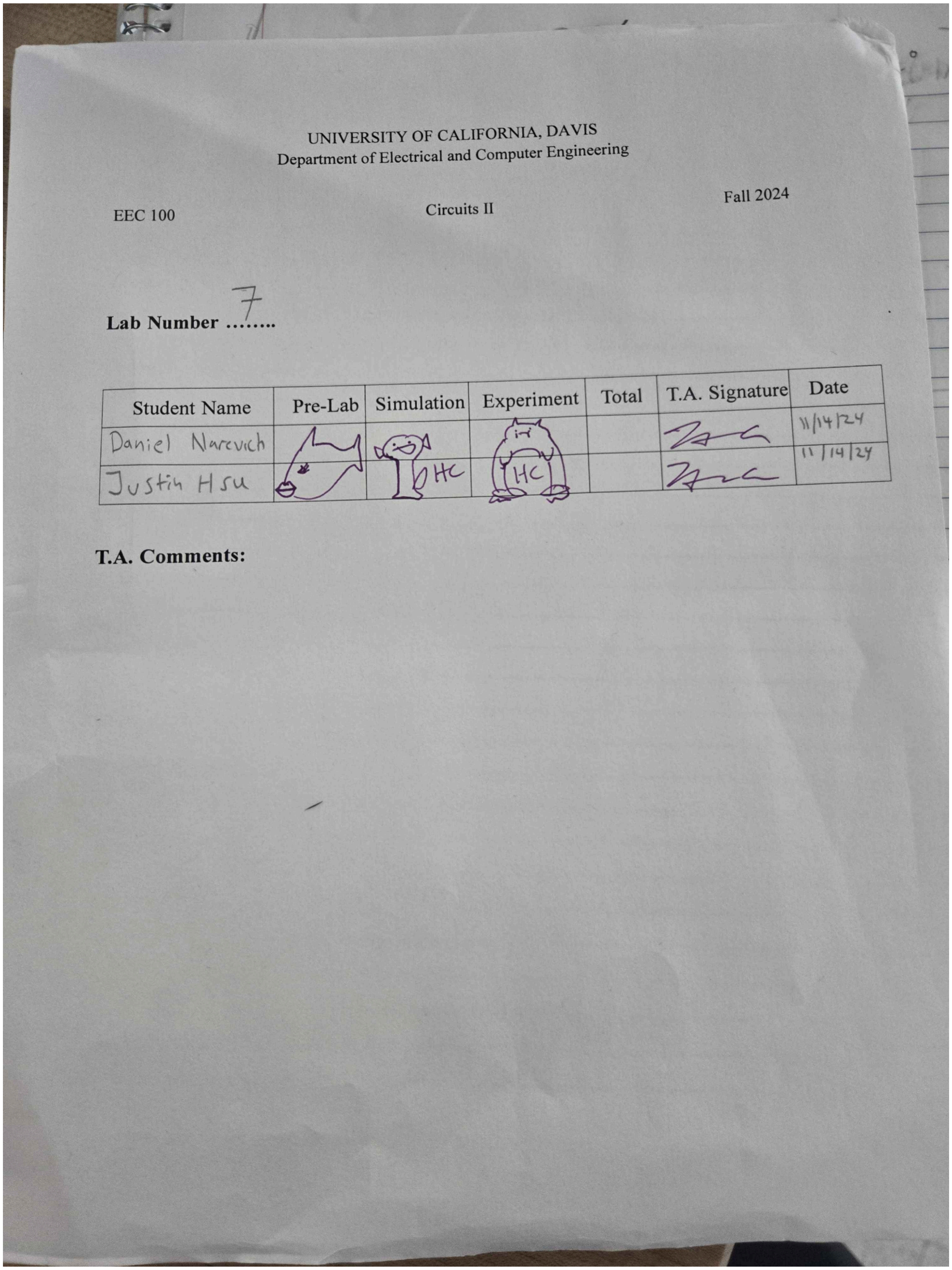
KEYSIGHT
EDUX1052G Digital Storage Oscilloscope
50 MHz 1 GSa/s
1 1.00V/ 2 2.00V/
0.0s
Auto
1 0.0V
KEYSIGHT TECHNOLOGIES
Acquisition
Normal
10.0MSa/s
Channels
DC 1.00:1
DC 1.00:1
Math
Ch1 + Ch2
1.00V/
0.0V
R1: 5.00V/ 0.0V
R2: 5.00V/ 0.0V
Back
ΔX: -67.000ns
1/ΔX: +14.925MHz
ΔY(2): +40.25mV
01:21 AM
Nov 15, 2024
Demo
Probe Comp
Gen Out



(5) Conclusion:

As the out input signal frequency changed, the phase change of the output varied, which is to be expected as that is what our calculated fourier series tells us. While our experimental measurements are slightly off (possibly due to non idealities in the circuit such as slightly different resistance and capacitance values, and an non ideal op-amp), they have phase changes as predicted by our calculated fourier analysis.

(6) Checkoff:



UNIVERSITY OF CALIFORNIA, DAVIS
Department of Electrical and Computer Engineering

EEC 100 Circuits II Fall 2024

Lab Number ...7.....

Student Name	Pre-Lab	Simulation	Experiment	Total	T.A. Signature	Date
Daniel Narevich						11/14/24
Justin Hsu		HC	HC			11/14/24

T.A. Comments: