ECE 182 Lab #2 Low Pass Filters
Day of Submission:09/12/2025
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Circuit Design and Schematic

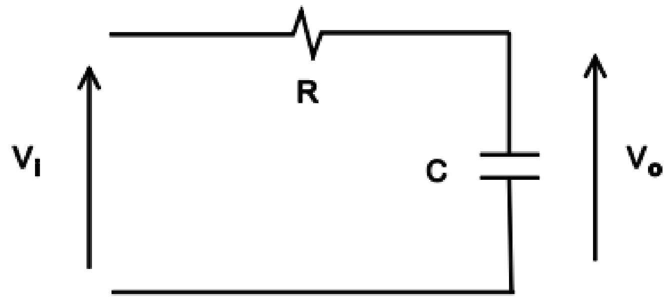


Fig 1 First order passive filter

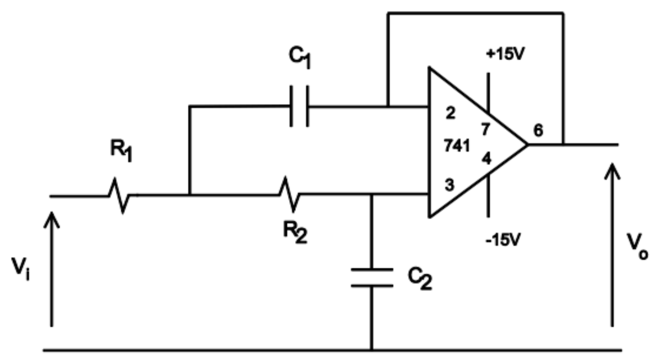


Fig 2 Second order active filter

Figure 1
- Theoretical vs Experimental Value
- R: 159.15ohm = 147.96ohm
- C: 1microfarad = 0.9696 microfarad

Figure 2
- Theoretical vs Experimental Value
- R1: 159.15ohm = 147.96ohm
- R2: 182.40ohm = 179.80ohm
- C1: 1microfarad = 0.9696 microfarad
- C2: 1microfarad = 0.9688 microfarad

Equations for Theoretical Basis

Figure 1 Magnitude Response Equation

$$\boxed{|H(j\omega)| = \frac{1}{\sqrt{1+\left(\frac{\omega}{6970.48}\right)}}}$$

Figure 2 Magnitude Response Equation

$$\boxed{|H(j\omega)| = \frac{1}{\sqrt{\left(1-\frac{\omega}{(6325.86)^2}\right)^2+\left(\frac{\omega}{3149.27}\right)}}}$$

Results and Calculations

Figure 1 and 2 on Breadboard

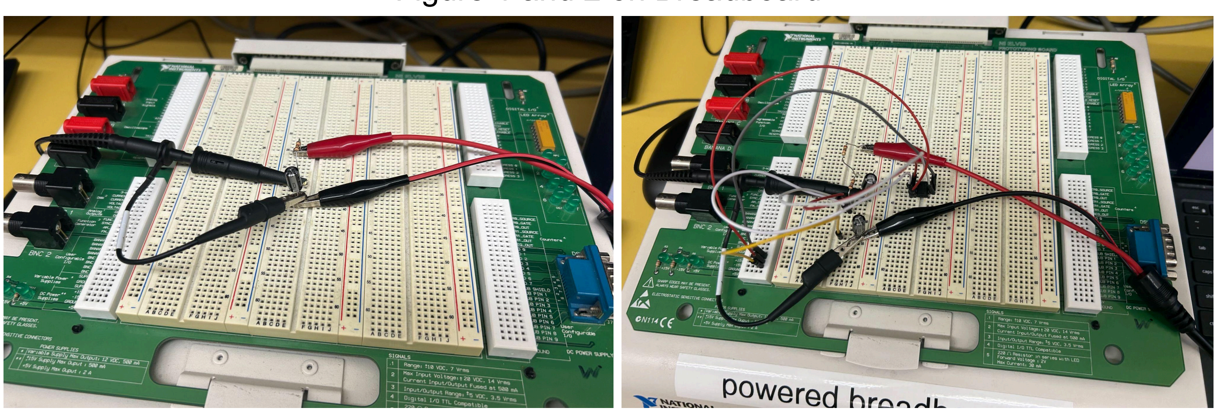


Figure 1 and 2 Data and Graphs

Figure1				
Vin (V)	Vout (V)	Frequency (Hz)	|H| = Vout/Vin	Mag (dB)
1	1.03	100	1.03	0.256744494
1	0.98	300	0.98	-0.17547849
1	0.88	500	0.88	-1.11034656
1	0.79	700	0.79	-2.04745817
1	0.7	900	0.7	-3.0980392
1	0.66	1000	0.66	-3.60912129
1	0.62	1100	0.62	-4.15216621
1	0.59	1200	0.59	-4.58295977
1	0.53	1400	0.53	-5.51448261
1	0.48	1600	0.48	-6.37517525
1	0.44	1800	0.44	-7.13094647
1	0.4	2000	0.4	-7.95880017

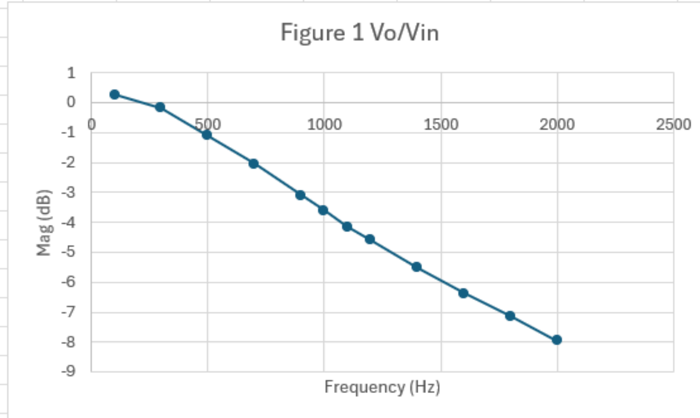


Figure2				
Vin (V)	Vout (V)	Frequency (Hz)	|H| = Vout/Vin	Mag (dB)
1	1	100	1	0
1	0.89	300	0.89	-1.01219987
1	0.79	500	0.79	-2.04745817
1	0.7	700	0.7	-3.0980392
1	0.64	900	0.64	-3.87640052
1	0.62	1000	0.62	-4.15216621
1	0.6	1100	0.6	-4.43697499
1	0.59	1200	0.59	-4.58295977
1	0.57	1400	0.57	-4.88250289
1	0.56	1600	0.56	-5.03623946
1	0.55	1800	0.55	-5.19274621
1	0.54	2000	0.54	-5.3521248

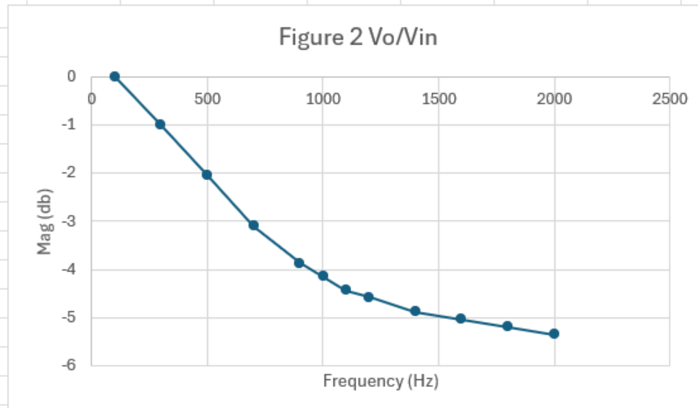
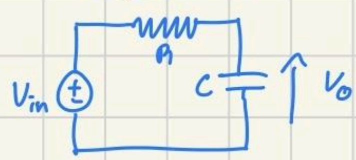


Figure 1 Calculations

Figure 1



$$f_c = \frac{1}{2\pi RC}$$

$$\left(f_c = \frac{1}{2\pi R \cdot 1\mu F}\right) 2\pi \cdot 1\mu F$$

$$\left(2\pi \cdot 1\mu F \cdot 1kHz\right)^{-1} = \left(\frac{1}{R}\right)^{-1}$$

$R_{calculated} = 159.15 \text{ ohm}$ $\quad C = 1\mu F$

$R_{actual} = 150 \text{ ohm}$ $\quad C_{experimental} = 0.9696 \mu F$

$R_{experimental} = 147.96 \text{ ohm}$

Find $\frac{V_o}{V_{in}}$ Magnitude Response

$$V_o = V_{in}\left(\frac{C}{R + C}\right)$$

$$V_o = V_{in}\left(\frac{\frac{1}{sC}}{R + \frac{1}{sC}}\right)$$

$$\frac{V_o}{V_{in}} = \left(\frac{\frac{1}{sC}}{R + \frac{1}{sC}}\right) sC$$

$$H(s) = \frac{V_o}{V_{in}} = \frac{1}{1 + sCR}$$

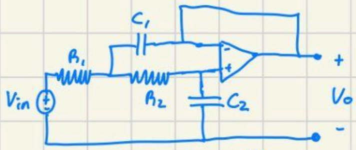
$$H(j\omega) = \frac{V_o}{V_{in}} = \frac{1}{1 + j\omega CR}$$

$$|H(j\omega)| = \frac{1}{\sqrt{1 + (\omega RC)^2}} = \frac{1}{\sqrt{1 + \left(\frac{\omega}{\omega_c}\right)^2}} \qquad \omega_c = \frac{1}{RC} = \frac{1}{(147.96)(0.9696\mu F)} = 6970.48$$

$$\boxed{|H(j\omega)| = \frac{1}{\sqrt{1 + \left(\frac{\omega}{6970.48}\right)}}}$$

Figure 2 Calculations

Figure 2



$$f_c = \frac{1}{2\pi}\left(\frac{1}{R_1 R_2 C_1 C_2}\right)^{1/2}$$

$$f_c = \frac{1}{2\pi}\sqrt{\frac{1}{(159.15\Omega) R_2 \, 1\mu F \, 1\mu F}}$$

$$2\pi f_c = \sqrt{\frac{1}{(159.15\Omega) R_2 \, 1\mu F \, 1\mu F}}$$

$$\left(2\pi(1000) = \sqrt{\frac{1}{(159.15\Omega) R_2 \, 1\mu F \, 1\mu F}}\right)^2$$

$$\left(39478\text{kHz} = \frac{1}{(159.15) R_2 \, 1\mu F \, 1\mu F}\right) 1.59\times 10^{-10}$$

$$(0.00628)^{-1} = \left(\frac{1}{R_2}\right)^{-1}$$

$$\boxed{R_2 = 159.159}$$

Calculated vs experimental

$R_1 = 159.15$ ohm $= 147.96$ ohm

$R_2 = 182.40$ ohm $= 179.80$ ohm

$C_1 = 1\ \mu F = 0.9696\ \mu F$

$C_2 = 1\ \mu F = 0.9688\ \mu F$

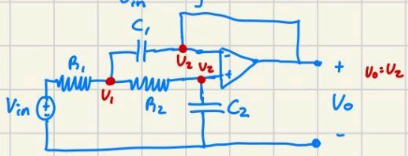
$$|H(j\omega)| = \frac{2}{\sqrt{\left(1 - \frac{\omega}{\omega_0^2}\right)^2 + \left(\frac{\omega}{Q\omega_0}\right)}} \qquad \omega_0 = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}} \qquad Q = \frac{\sqrt{R_1 R_2 C_1 C_2}}{(R_1 + R_2) C_2}$$

$$\omega_0 = \frac{1}{\sqrt{(147.96)(179.80)(0.9696\mu F)(0.9688\mu F)}} = 6325.86$$

$$Q = \frac{\sqrt{(147.96)(179.80)(0.9696\mu F)(0.9688\mu F)}}{(147.96 + 179.80)(0.9688\mu F)} = 0.4978$$

$$\boxed{|H(j\omega)| = \frac{1}{\sqrt{\left(1 - \frac{\omega}{(6325.86)^2}\right)^2 + \left(\frac{\omega}{3149.27}\right)}}}$$

Find $\frac{V_o}{V_{in}}$ Magnitude Response



V_2:
$$\frac{V_2 - V_1}{R_2} + sC_2 V_2 = 0$$

$$V_1 = V_2(1 + sR_2C_2)$$

V_1:
$$\frac{V_1 - V_i}{R_1} + \frac{V_1 - V_2}{R_2} + sC_1(V_1 - V_0) = 0$$

$$V_0 = V_2$$

$$\frac{V_1 - V_i}{R_1} + (V_1 - V_2)\left(\frac{1}{R_2} + sC_1\right) = 0$$

$$V_1 - V_2 = V_2 s R_2 C_2$$

$$V_1 - V_{in} = V_2(1 + sR_2C_2) - V_{in}$$

$$\frac{V_2(1 + sR_2C_2) - V_{in}}{R_1} + V_2 s R_2 C_2\left(\frac{1}{R_2} + sC_1\right) = 0$$

$$\frac{V_2}{R_1}(1 + sR_2C_2) - \frac{V_i}{R_1} + V_2 sC_2 + V_2 s^2 R_2 C_1 C_2 = 0$$

$$V_2\left(\frac{1 + sR_2C_2}{R_1} + sC_2 + s^2 R_2 C_1 C_2\right) = \frac{V_i}{R_1}$$

$$V_2(1 + sC_2(R_1 + R_2) + s^2 R_1 R_2 C_1 C_2) = V_i$$

$$H(s) = \frac{V_o}{V_{in}} = \frac{1/(R_1 R_2 C_1 C_2)}{s^2 + s\frac{(R_1 C_1 + R_2 C_1)}{R_1 R_2 C_1 C_2} + \frac{1}{R_1 R_2 C_1 C_2}}$$

$$H(s) = \frac{V_o}{V_{in}} = \frac{2}{s^2(R_1 R_2 C_1 C_2) + s(R_1 C_1 + R_2 C_1) + 1}$$

$$|H(j\omega)| = \frac{2}{\sqrt{\left(1 - \frac{\omega}{\omega_0^2}\right)^2 + \left(\frac{\omega}{Q\omega_0}\right)}} \qquad \omega = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}} \qquad Q = \frac{\sqrt{R_1 R_2 C_1 C_2}}{(R_1 + R_2) C_2}$$

Summary

For the first order RC low pass filter which was designed to have a cutoff frequency of 1kHz. With the measured resistance being around 148 ohms and the capacitor being 0.9696 microfarads, theoretically fc=1/(2piRC) should be around 1.1kHz. The reason for the increase in cutoff frequency is caused by the lab not having a 159.15 ohm resistor which would have been exactly 1kHz cutoff frequency. However the -3db cutoff was around 0.9/1KHz which corresponds with our theory. For the Sallen and Key low pass filter theory predicts cutoff frequency to be near 1kHz. The measured response matched this behavior, but the actual cutoff frequency from what we tested was around 700Hz. This lower cutoff frequency could have been caused by component tolerances, source calibration, or parasitic effects. However, our data overall matched our theory even with higher than expected error due to lab equipment and not having proper resistors.