ELECTRICAL AND COMPUTER ENGINEERING
Room D36, Head Hall

LABORATORY / ASSIGNMENT / REPORT
COVER PAGE

Course # : _____ECE2701_____________ Experiment # or Assignment # ___Lab 3___

Date: ___Friday, November 8________ Course Instructor: ____Howard Li____________

Title: _______EE2701 Experiment 3 – Simple Filters__________________
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Abstract

Filters are devices which control the frequency content of a signal [1]. The combination of a resistor and capacitor in series form a *single-order RC filter* - the arrangement of which dictate the properties of the network [2]. This allows the circuit to either pass high frequency signals, called a *high-pass filter*, or pass low frequency signals, called a *low-pass filter*. In what is called a *Fourier Series*, any wave can be mathematically modelled as the sum of sinusoidal waves. As such, these filters can shape any input wave by attenuating different frequency content to varying degrees [1]. This is measured in gain, which is defined as the ratio of the magnitude of V_{out} to the amplitude of V_{in} [1]. Filters achieve a frequency dependent gain through the use of reactive components, which have a frequency dependent impedance [2]. In addition, each filter has a specific cutoff frequency, which is the point in which the output voltage is $1/\sqrt{2}$ that of the input voltage in magnitude, but lagging by 45°. Conceptually, the phase angle is the angle between the phasors representing the input and output voltages [2]. Single-order RC filters also have a property called the *time constant*. RC networks exhibit exponential growth/decay properties, and their time constant, τ represents the rate of the grown or decay. In this lab, these properties of single-order RC high-pass and low-pass filters are examined.

1 Introduction

In EE2701 Experiment 3 - Sample Filters,the behaviour of first order resistor-capacitive filter networks were analyzed and characterized in order to better understand their behaviour and verify the theoretical models for them [1]. These filters consist of a single capacitor and resistor in series [2]. The background needed for this lab includes knowledge of single-order RC filters and their metrics, such as gain, phase-shift, cutoff frequencies, and time constants, as well as how to operate an oscilloscope and function generator. The theory required to complete this experiment includes understanding of the following topics: Complex Impedances, AC Voltage, and Capacitors and Resistors. These concepts are used in the analysis of the constructed circuits depicted in figures 1 and 2. In this experiment, two single-order RC filters are analysed - a high-pass filter and a low-pass filter. The tests are carried out by supplying either a sinusoidal wave or a square wave to its input and probing the input and output voltages on an oscilloscope, where measurements can be performed. The low-pass filter will have its frequency response characterized, while both filters will have their time constants, τ, measured through examining the output voltage response to step inputs [1]. Using the above theories and techniques, values for gain, phase angle, and τ were measured and are listed in tables 1 and 2. For the low-pass filter, the gain decreased and the phase angle increased as the frequency increased, which is the exact trend expected for this type of filter [2]. Additionally, these measured values were very near the theoretical values at the test frequencies. Finally, the measured time constants were only some-percent away from the theoretical ones. The measurements performed in this lab follow the theoretical ones, thereby verifying the theoretical models, and increasing our understanding of first order filters, therefore meeting the objective of this lab.

2 Experiment

2.1 Apparatus

2.1.1 Instruments

Rigol DS1000E Oscilliscope This dual-channel oscilloscope was used to measure the input and output signal characteristics of the filters under test.

Function Generator This device was the source for all signals throughout the experiment. It provided a variable amplitude, variable frequency signal for both the sine and square waves required.

Resistor Block For convenience over bare resistor components, a resistor block was used in the filter networks. This consisted of a resistor connected to two female banana plugs, all embedded within a small block of wood. Only a single $10k\Omega$ block was required.

Banana Connectors 6 Banana Connectors were required. Two of these were used to make electrical connections between the components of the filter networks, and the remaining four were used to connect the test and supply instruments to the network.

Capacitor Blocks Again, for convenience over bare capacitor components, capacitor blocks were used in the filter networks. These consisted of a capacitor connected to two female banana plugs, all embedded within a small block of wood. Two different capacitor blocks were needed to build the filter networks, these consisted of the following values:

- $3.3nF$ - C

- $100nF$ - C

These pieces of equipment slightly vary from that listed in the lab manual. Instead of resistor and capacitor blocks, single resistors and capacitors are listed in the lab manual, which do not contain female banana plugs. In addition, banana connectors were completely omitted from the lab manual. This discrepancy introduced resistances and inductances which the lab procedure did not account for, introducing errors in the results [1].

2.1.2 Filter Networks

Depicted below are the two filter networks that are analyzed in this lab.

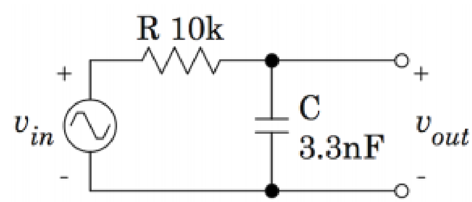

Figure 1: Single Order RC Low Pass Filter [1]

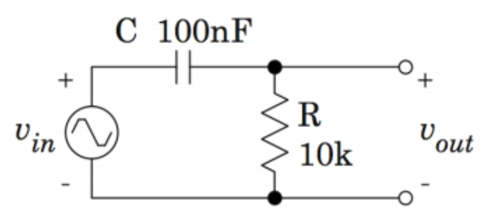

Figure 2: Single Order RC High Pass Filter [1]

2.2 Descriptions

2.2.1 Theory

Periodic alternating current signals are often sinusoidal in nature, having the mathematical form:

$$f(t) = F_m \sin(\omega t + \phi)$$

Where F_m is the amplitude, ω is the angular velocity, and ϕ is the phase shift of the signal [1]. Conveniently, any periodic waveform can be modelled as a sum of related sinusoids, becoming a *Fourier Series*. As such, all periodic signals can be treated as the sum of pure sinusoids [1].

Networks which manage the frequency content of a signal are called *filters*. Filters operate based on the principle of frequency dependent impedances of reactive components, such as capacitors and inductors [2]. For pure capacitors, inductors, and resistors, their impedance is calculated as follows [2]:

$$\begin{aligned} \boldsymbol{Z_C} &= \frac{1}{j\omega C} = \frac{1}{\omega C}\angle -90^\circ \\ \boldsymbol{Z_L} &= j\omega L = \omega L\angle 90^\circ \\ \boldsymbol{Z_R} &= R + j0 = R\angle 0^\circ \end{aligned}$$

When constructed in the networks shown in figure 1 and 2, the components form a voltage divider, following the equations below, respectively [1]. Note that for the following equations, symbols with *lp* or *hp* suffixes denote the value for the *low-pass* or *high-pass* network.

$$\begin{aligned} \boldsymbol{V_{out-lp}} &= \boldsymbol{V_{in}}\frac{\boldsymbol{Z_C}}{\boldsymbol{Z_C} + \boldsymbol{Z_R}} \\ \boldsymbol{V_{out-lp}} &= \boldsymbol{V_{in}}\frac{1}{1 + j\omega CR} \end{aligned}$$

$$\begin{aligned} \boldsymbol{V_{out-hp}} &= \boldsymbol{V_{in}}\frac{\boldsymbol{Z_R}}{\boldsymbol{Z_C} + \boldsymbol{Z_R}} \\ \boldsymbol{V_{out-hp}} &= \boldsymbol{V_{in}}\frac{j\omega CR}{1 + j\omega CR} \end{aligned}$$

If the amplitude of V_{in} is held constant, the output voltage, V_{out}, depends only on ω. With the relationship between the output voltage and the input voltage established, the gain, G, of the network, as well as the phase shift, θ, can be calculated as depicted below [1].
By definition of gain [2]:

$$\begin{aligned} G &= \frac{|\boldsymbol{V_{out}}|}{|\boldsymbol{V_{in}}|} \\ G_{lp} &= \frac{1}{\sqrt{1 + \omega^2 R^2 C^2}}; \omega = 2\pi f \\ G_{lp} &= \frac{1}{\sqrt{1 + (2\pi f)^2 R^2 C^2}} \end{aligned}$$

Through the properties of multiplying vectors when described in polar coordinates, theoretical values for phase angle can be solved [2]:

$$\theta = \angle \boldsymbol{V_{out}} - \angle \boldsymbol{V_{in}}$$
$$\theta_{lp} = -\arctan(\omega RC)$$
$$\theta_{lp} = -\arctan(2\pi f RC)$$

However, the experimental value of phase angle can be found indirectly by measuring the period of the input signal, T, and the time delay of the output signal from the input signal, T_d. With these values, and the following equation, the phase angle magnitude can be extrapolated from the time delay [1].

$$\theta = \frac{T_d}{T} \times 360^\circ$$

As can be seen in the equations for phase angle and gain, when $\omega \approx 0$, the output voltage is approximately the input voltage, and the phase shift becomes almost 0. Conversely, when $\omega \approx \infty$, the gain becomes ≈ 0 and the phase approaches 90°, causing the output voltage to also become 0 [2].

Half-power Also known as *cutoff*, is the frequency at which the output voltage is $\frac{1}{\sqrt{2}}$ times as large as the input voltage. This point can be specified as a frequency, $f_c = \frac{1}{2\pi RC}$, or as an angular velocity, $\omega_c = \frac{1}{RC}$ [1]. At this point, the relationship between output voltage and input voltage can be explained using the following equations [2]:

$$\boldsymbol{V_{out}} = \frac{1}{j1} V_{in}$$
$$\boldsymbol{V_{out}} = \frac{1}{\sqrt{2}} V_{in} \angle -45^\circ$$

Time Constants These are values that reflect the rate at which exponential functions grow or decay, and are denoted with τ. Single-order filters, like those analyzed in this lab, can be mathematically modelled using exponentials [2].

$$V_{decay}(t) = V_{max}(e^{-t/\tau})$$
$$V_{growth}(t) = V_{max}(1 - e^{-t/\tau})$$

As such, one time constant represents the time required for the modelled circuit to grow or decay by $1 - e^{-1} \approx 63.2\%$ when a step input is supplied [2]. This can be used to characterize R-C networks in single-order filters [2].

2.2.2 Procedure

1. After acquiring the listed materials, the low-pass filter depicted in figure 1 was constructed using the function genrator as the AC source.

2. V_{in} was probed with channel one of the oscilloscope and the function generator was configured to create a peak-to-peak sinusoidal voltage of 8.0V with no DC offset. V_{out} was then probed with channel two. The oscilliscope was set to use DC coupling and use a trigger sensitive to channel one.

3. For the frequencies $0.1f_c$, f_c, and $10f_c$, the amplitudes of these voltages, the input wave's period, T, and the time delay of the output waveform with respect to the input signal, T_d, was measured and logged in table 1.

4. From here, the voltage gain magnitude, G in V/V, and the phase shift, θ in degrees, was calculated for each of the frequencies of interest. The results of these calculations were also logged in 1.

5. The input voltage waveform was chnaged to a 1 kHz square wave and the oscilliscope graph was captured and printed. Using this graph, the RC time constant of the circuit was measured.

6. The high-pass filter depicted in figure 2 was constructed using the function generator as the AC source.

7. Next, the frequency of the square wave created by the function generator was changed to 100 Hz and the resulting wavefroms were printed. From that waveform, the RC time constant of the high-pass RC network was derived.

8. The measured RC time constants were compared with the calculated time constants found during the pre-lab preparation.

9. Once the lab was complete, the aparatus was cleaned and powered down.

[1]

2.3 Calculations and Results

In the pre-lab section, the theoretical time-constants, τ, for both filters were calculated, along with the cutoff frequency and angular velocity of the low-pass filter. The theoretical time constants can be found in table 2, and the theoretical cutoff frequency is shown in table 1.

Once the low-pass filter, shown in figure 1, was built and connected to the oscilloscope and function generator, the signal characteristics were measured. This included the peak-to-peak input voltage, v_{in}, the peak-to-peak output voltage, v_{out}, the period of the waveforms, T, and the time delay of the output signal with respect to the input voltage, T_d. These measurements were carried out at $0.1f_c$, f_c, and $10f_c$; the results of which can be found in table 1.

With these values measured, the gain and phase angle between the output and input voltages can be calculated using the equations depicted in the theory section. Calculations for gain and phase are illustrated below for all three frequencies of interest. The results of which can be found in table 1.

Gain Calculations

$$G_{lp-measured} = \frac{|V_{out}|}{|V_{in}|}$$

$$G_{0.1f_c} = \frac{7.84V}{8.00V}$$
$$G_{0.1f_c} = 0.980$$

$$G_{f_c} = \frac{5.68V}{8.00V}$$
$$G_{f_c} = 0.710$$

$$G_{10f_c} = \frac{0.790V}{8.00V}$$
$$G_{10f_c} = 0.0988$$

Phase Angle Calculations

$$\theta_{measured} = \frac{T_d}{T} \times 360°$$

$$\theta_{0.1f_c} = \frac{32\mu s}{2076\mu s} \times 360°$$
$$\theta_{0.1f_c} \approx 5.55°$$

$$\theta_{10f_c} = \frac{25.2\mu s}{208\mu s} \times 360°$$
$$\theta_{10f_c} \approx 43.62°$$

$$\theta_{10f_c} = \frac{4.7\mu s}{20.8\mu s} \times 360°$$
$$\theta_{10f_c} \approx 81.35°$$

Table 1: Frequency Response Data for RC Low-Pass Filter

f (Hz)		$\lvert V_{in}\rvert$ (V_{pp})	$\lvert V_{out}\rvert$ (V_{pp})	T (μs)	T_d (μs)	G (V/V)	θ (deg)
$0.1f_c$	482.29	8.00	7.84	2076	32	0.980	5.55
f_c	4822.88	8.00	5.68	208	25.2	0.710	43.62
$10f_c$	48228.77	8.00	0.79	20.8	4.7	0.0988	81.35

As described in the theory section, the time constant indicates the rate at which RC circuits, modelled by exponentials, either grow or decay [2]. To measure this value, a step was supplied in the form of a square wave, which had a long enough period such that the system was able to reach *steady-state* on each half of the wave [1]. From here, it was possible to measure the time constant by measuring the amount of time required for 63.2% Captures of the oscilliscope display illustrate both the input and output voltages for both types of filters, and are shown in figures 3 and 4.

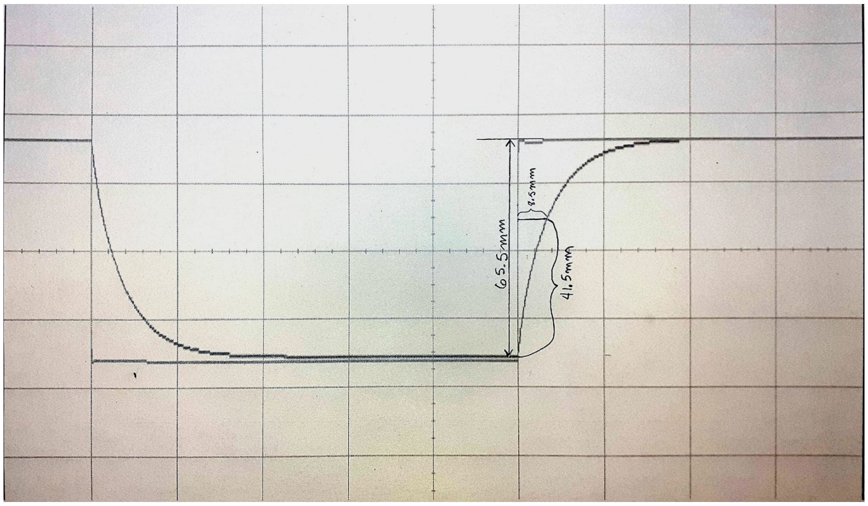

Figure 3: Oscilloscope Capture of Low-Pass Filter Step Response

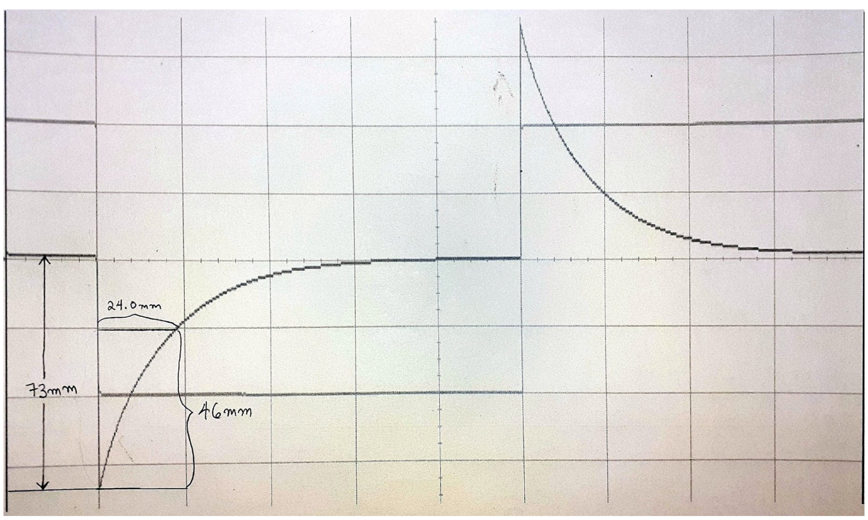

Figure 4: Oscilloscope Capture of High-Pass Filter Step Response

Note: The length of half of the signal period was measured to be 127.0

mm for both captures.

As can be seen in figures 3 and 4, measurements for tau were carried out on the captures. This measurement process was carried out as follows, and was done with a standard 30 cm ruler [1]:

1. The peak amplitude hight was measured.
2. 63.2% of the amplitude was calculated to find the relative amplitude growth/decay expected in a single time constant.
3. A horizontal line was drawn at the calculated vertical distance away from the steady-state output signal, at the point in which the input step occurred.
4. The length of half a signal period was measured.
5. Knowing the half-period time, a ratio was calculated between time and length on the horizontal scale.
6. Next, the horizontal length between the input step and the point in which the output voltage crossed the line representing the expected amount of growth/decay was measured.
7. Finally, using the ratio between horizontal length and time, and the measured horizontal length, a single experimental time constant was calculated.

The calculations of this procedure are shown below - the results of which can be found in table 2. Length measurements can be found directly on figures 3 and 4.

$$\tau = \frac{T_{half-period}}{L_{half-period}} \times L_\tau$$
$$\tau = \frac{\frac{1}{2f}}{L_{half-period}} \times L_\tau$$

$$\tau_{low-pass} = \frac{\frac{1}{2(1000Hz)}}{127.0mm} \times 8.5mm$$
$$\tau_{low-pass} \approx 3.346 \times 10^{-5}s$$

$$\tau_{high-pass} = \frac{\frac{1}{2(100Hz)}}{127.0mm} \times 24.0mm$$
$$\tau_{high-pass} \approx 9.449 \times 10^{-4}s$$

These results can be found int table 2, which also include the percent-difference of the experimental time constants to their theoretical values. Illustrated below, are the percent-difference calculations depicted in that table.

$$\%Difference = \frac{|\tau_{theoretical} - \tau_{experimental}|}{|\tau_{theoretical}|} \times 100\%$$

$$\%Difference_{low-pass} = \frac{|3.3 \times 10^{-5}s - 3.346 \times 10^{-5}s|}{|3.3 \times 10^{-5}s|} \times 100\%$$
$$\%Difference_{low-pass} \approx 1.4\%$$

$$\%Difference_{high-pass} = \frac{|1.0 \times 10^{-3}s - 9.449 \times 10^{-4}s|}{|1.0 \times 10^{-3}s|} \times 100\%$$
$$\%Difference_{high-pass} \approx 5.5\%$$

Table 2: Low-Pass Filter Time Constants

	Calculated	**Measured**	**% Difference**
Figure 1	3.3×10^{-5}	3.346×10^{-5}	1.4
Figure 2	1.0×10^{-3}	9.449×10^{-4}	5.5

2.3.1 Analysis

Theoretical Values

Gain Calculations

$$G_{lp-theoretical} = \frac{1}{\sqrt{1+\omega^2R^2C^2}}$$
$$G_{lp-theoretical} = \frac{1}{\sqrt{1+(2\pi f)^2R^2C^2}}$$

$$
\begin{aligned}
G_{0.1f_c} &= \frac{1}{\sqrt{1+(2\pi(0.1\times f_c))^2R^2C^2}} \\
G_{0.1f_c} &= \frac{1}{\sqrt{1+(2\pi\times 482.29Hz)^2(10k\Omega)^2(3.3nF)^2}} \\
G_{0.1f_c} &\approx 0.995
\end{aligned}
$$

$$
\begin{aligned}
G_{f_c} &= \frac{1}{\sqrt{1+(2\pi f_c)^2R^2C^2}} \\
G_{f_c} &= \frac{1}{\sqrt{1+(2\pi\times 4822.88Hz)^2(10k\Omega)^2(3.3nF)^2}} \\
G_{f_c} &= \frac{\sqrt{2}}{2} \approx 0.707
\end{aligned}
$$

$$
\begin{aligned}
G_{10f_c} &= \frac{1}{\sqrt{1+(2\pi(10\times f_c))^2R^2C^2}} \\
G_{10f_c} &= \frac{1}{\sqrt{1+(2\pi\times 48228.77Hz)^2(10k\Omega)^2(3.3nF)^2}} \\
G_{10f_c} &\approx 0.0995 \approx 0.100
\end{aligned}
$$

Phase Angle

$$
\begin{aligned}
\theta_{lp-theoretical} &= -\arctan\left(\omega RC\right) \\
\theta_{lp-theoretical} &= -\arctan\left(2\pi fRC\right)
\end{aligned}
$$

$$
\begin{aligned}
\theta_{0.1f_c} &= -\arctan\left((2\pi\times 0.1\times f_c)RC\right) \\
\theta_{0.1f_c} &= -\arctan\left(2\pi(482.29Hz)(10k\Omega)(3.3nF)\right) \\
\theta_{0.1f_c} &\approx -5.71^\circ
\end{aligned}
$$

$$
\begin{aligned}
\theta_{f_c} &= -\arctan\left(2\pi f_cRC\right) \\
\theta_{f_c} &= -\arctan\left(2\pi(4822.88Hz)(10k\Omega)(3.3nF)\right) \\
\theta_{f_c} &= -45.00^\circ
\end{aligned}
$$

$$
\begin{aligned}
\theta_{10f_c} &= -\arctan\left((2\pi\times 10\times f_c)RC\right) \\
\theta_{10f_c} &= -\arctan\left(2\pi(48228.77Hz)(10k\Omega)(3.3nF)\right) \\
\theta_{10f_c} &\approx -84.29^\circ
\end{aligned}
$$

Where the negative angles indicate that the output voltage lags the input voltage.

Frequency Responses The low-pass RC filter analyzed in this lab present a low-impedance path to ground only when high frequencies are supplied, as caused by the frequency dependent impedance of the capacitor, governed by the equation $\boldsymbol{Z_C} = \frac{1}{j\omega C}$ [1]. This creates a voltage divider, who's gain reduces as the frequency increases, as described by the equation $G_{lp} = \frac{1}{\sqrt{1+\omega^2 R^2 C^2}}$[1] [2].
The results of this experiment aligned with the theoretical expectations. Firstly, the gain measurements of the low-pass filter decreased as the frequency increased in a similar manner to the theoretical calculations. Secondly, when the extremities of the input frequency were reached, $\omega \approx \infty \Rightarrow f \approx \infty$ and $\omega \approx 0 \Rightarrow f \approx 0$, the output voltages met the expected values of $V_{out} \approx 0$ and $V_{out} \approx V_{in}$ [1].
Not only did the gain follow the properties of a low-pass filter, but the phase angle did too. Based on the theoretical values for phase angle above, the phase shift increases magnitude as the frequency increases. Conceptually, this is because the capacitive reactance increases as the frequency does and has more of a contribution to the circuit. The phase angle magnitude approaches $90°$. At the extremities of frequency, $f \approx 0$ and $f \approx \infty$, the phase angle also reached the extremities: $\theta \approx 0°$, and $\theta \approx 90°$, respectively.
Both the characteristics of gain and phase angle followed the theoretical characteristics for low-pass filters.

Time Constants Following the alignment of the experimental frequency response with the theoretical, the measured time constants in this experiment were approximately that of the theoretical calculations. As shown above, and in table 2, small errors indicate the accuracy of the measurements. Each square wave response acted differently. In the low-pass filter, the output voltage magnitude effectively lagged the input voltage, where it slowly approached the steady state. This follows what was expected, as the abrupt step consists of mostly high frequency content, which the filter effectively blocked, and the steady-state consists of low frequency content, which the filter allowed to completely pass [2]. The exact converse occurred with the high-pass filter. The output voltage shot up with the step, and slowly decayed to 0 V, not the steady-state voltage. This behaviour coincides with the filter's properties - the high frequency content was allowed to pass completely, while the low frequency content was effectively blocked [2]. The time constants and the behaviour of the step-response aligns with the theoretical filter characteristics.

3 Discussion

Overall, the results of the experiment followed those calculated in the preparation. The encountered errors were small enough that the compared values could always be considered equivalent, allowing the two circuits to exhibit the same time constants and frequency responses as those calculated, and therefore meet the expected theoretical model. Nevertheless, errors still existed in the results, which can mostly be attributed to systematic errors in the procedure. Some of the errors include:

- The tolerances of the resistors. All resistors and capacitors used had 5% manufacturing tolerances and the procedure did not declare to measure them [1]. Performing component measurements prior to constructing the sources would minimize this error.

- The precision and accuracy of the oscilloscope was not mentioned in the lab and was a limiting factor while performing the measurement. Although fairly accurate, the oscilloscope was not perfect, causing some error while reading the values, most noteably, while it performed measurements of period. Using higher end equipment would allow for more accurate measurements.

- Not accounting for the resistance and inductance of the banana connectors. Banana connectors weren't even mentioned in the lab equipment, which is troublesome since they have instrinsic inductance and resistance [3] [1]. Expanding the procedure to account for these resistances would reduce error in the measurements.

- Manual length measurements had to be performed on the oscilliscope captures while measuring the time constants [1]. Due to the finite accuracy and precision of pencils and standard rulers, errors were induced into the measurements. To mitigate these errors, a more modern oscilliscope could be used, which provide simultaneous horizontal and vertical cursors to measure the time constant.

4 Conclusion

In this lab, the behaviour of first-order capacitive filters were analyzed using an oscilloscope and a function generator [1]. The frequency characteristics of a low-pass filter were analyzed, including its gain and produced phase shift, by measuring these values at three different frequencies: $0.1f_c$, f_c, and

$10f_c$. To carry this out, capacitor and resistor blocks were connect in the network shown in figure 1, where sinusoidal waves were supplied by a function generator, and an oscilloscope measured the input and output voltage waves. Additionally, the time constant of RC networks were analyzed using the existing low-pass filter, and the high-pass filter depicted in figure 2 [1]. For the first test, the low-pass filter had gain values of $G_{0.1f_c} = 0.980$, $G_{f_c} = 0.710$, $G_{10f_c} = 0.0988$, at the indicated frequencies. Using the math functions on the oscilloscope, the signal period, T, and the time delay between the output and input signal, T_d, could be easily measured, allowing the phase angle, θ, to be measured. These results are shown for the specified frequencies: $\theta_{0.1f_c} = 5.55°$, $\theta_{f_c} = 43.62°$, $\theta_{10f_c} = 81.35°$. These follow the theoretical trends and are approximately the theoretical values. Not only this, but the measured time-constants found in the second set of tests, $\tau_{lp} = 3.346 \times 10^{-}5$ and $\tau_{hp} = 9.449 \times 10^{-}4$, were only 1.4% and 5.5% away from the theoretical values. The small discrepancies can be attributed to the largely systematic errors in the experiment, such as the long leads with unaccounted for intrinsic inductances [3]. Nevertheless, the results of the tests performed in this lab followed the experimental values and trends. This validates the theoretical models and further improves the understanding of the single-order RC filters, thereby fulfilling the objectives of this lab.

5 Summay of Roles

Justen G. Di Ruscio

1. Formatting and Outline
2. Theory
3. Experiment
4. Conclusion
5. Bibliography

Stephen W.W. Cole

1. Abstract
2. Introduction
3. Procedure
4. Discussion

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[2] H. Li, "Ece2701 lectures," October 2019.

[3] W. Lindenbach, "The secret life of a wire," *Nuts and Volts*, 2019.

[4] H. Li, "Lab marking scheme," Winter 2008. EE3312.

6 Appendicies

6.1 Prelabs - Stephen, Justen

Prelab 3

Sunday, November 3, 2019 7:32 PM

$\tau_{(fig3\text{-}2)} = 10k\Omega \cdot 3.3nf = 33\mu s$

$\tau_{(fig3\text{-}3)} = 10k\Omega \cdot 100nf = 1ms$

$$f_c = \frac{1}{2\pi \cdot 33\mu s} = 4822.87\,Hz$$

$$\omega_c = \frac{1}{33\mu s} = 30303.\overline{03}\ rad/s$$

$0.1f_c = 482.287\,Hz$

$10f_c = 48228.7\,Hz$

Pre-Lab 3

Tuesday, October 29, 2019   9:07 PM

1. $\tau = RC = (10k\Omega)(3.3nF) = 3.3\times10^{-5}s$

$\omega_c = \frac{1}{RC} = \frac{1}{3.3\times10^{-5}s} = 30303.\overline{03}\ rad/s$

$\omega_c = 2\pi f_c \rightsquigarrow f_c = \frac{\omega_c}{2\pi} \doteq 4.822877\ kHz$

2. $\tau = RC = (10k\Omega)(100nF) = 1\times10^{-3}s$

3. notes: Read ✓