Lab 1 RC Circuit

Group 8: Muhan Li Man Sun Mingxiao An
EE233 Circuit Theory

DEPARTMENT OF ELECTRICAL ENGINEERING, UNIVERSITY OF WASHINGTON, SEATTLE, WA, 98195

***Abstract*—**

I. INTRODUCTION

II. LAB PROCEDURE

III. EXPERIMENTAL PROCEDURE AND ANALYSIS

A. The RC Response to a DC Input

1) Square Wave Input Analysis:

We built the circuit in figure 1 with a resistor of $10\text{k}\Omega$ and a capacitor of 0.01μF. We set the function generator to provide a square wave input with the period $T = 4.00000000\text{ms}$ and the voltage of $V_{pp} = 5$V with offset $+2.5$V, which generates a square wave of maximum voltage 5V and minimum 0V.

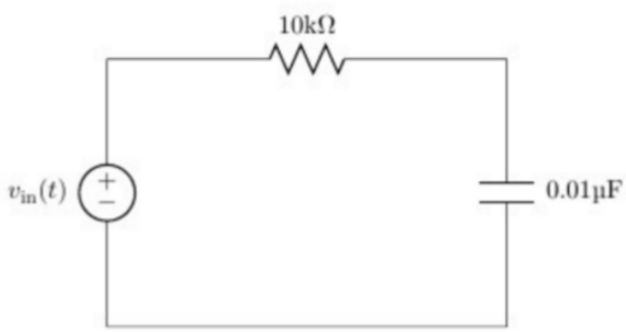

Fig. 1. RC circuit for square wave input analysis

We used channel 1 of the oscilloscope to verify the input and measured the output voltage of the capacitor by channel 2. Figure 2 is the screen output of two and half cycles.

Analyze #1:

The oscilloscope did display the same waveform plotted in Prelab#7. They are of the same shape, and both of their peaks and valleys reach the input waveform. Meanwhile, no obvious difference is found.

Using the *Cursor* menu, we recorded the period T, as well as the range of the output signal. Then we measured the time value of the 10%, 90%, and 50% point of V_{out}. The results are shown in table I.

Analysis #2:

After calculating the rise time, fall time, and delay time of the RC circuit, we got table II

2) Time Constant Measurement: After we connected the circuit in Graph[1] in the lab instruction, we detected a waveform on our oscilloscope. To calculate its time constant accurately, we need as many data as possible. According to the

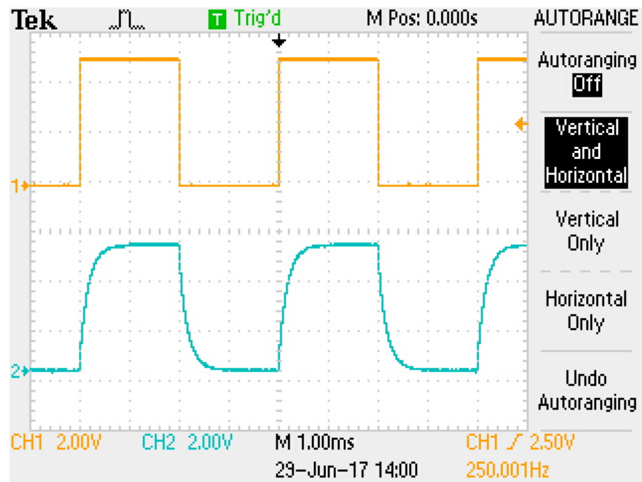

Fig. 2. The waveform of input and measure

TABLE I
MEASUREMENTS OF THE OUTPUT SIGNAL

name	value
period	4.000ms
max voltage	5.120V
min voltage	0.000V
time of $10\%V_{out}$ (LH)	16.0μs
time of $90\%V_{out}$ (LH)	364μs
time of $50\%V_{out}$ (LH)	116μs
time of $10\%V_{out}$ (HL)	$??\mu$s
time of $90\%V_{out}$ (HL)	$??\mu$s
time of $50\%V_{out}$ (HL)	$??\mu$s

TABLE II
MEASUREMENTS OF THE OUTPUT SIGNAL

name	actual value	theoretical value	PE
rise time	348μs	$220\mu s$	58.2%
fall time	$??\mu$s	$220\mu s$	??%
delay time (LH)	116μs	$69\mu s$	68.1%
delay time (HL)	$??\mu$s	$69\mu s$	??%

instruction, we recorded 10 points separately for the original circuit, two-stage and three-stage. When we were selecting our testing points, we tried to pick more where the voltage rose(or fell) more rapidly with time. Also, we noticed that the measurements were not stable on the oscilloscope if its value was too small, so we paused the screen on random to record a relatively accurate number.

When we were measuring the voltages and their according time, we used the Cursor whose type was time and took Channel 2 as its source. We settle one of the cursor at start point of a rising or falling action, and moved the other cursor slightly. We also scaled the width of the waveform to get a more accurate move.

Our recordings for the original circuit are shown in the table below.

TABLE III
EXPERIMENT RECORD IN THE ORIGINAL CIRCUIT

No	Voltage(V)	time(μs)
1	0.64	24.0
2	1.32	56.0
3	1.96	88.0
4	2.16	100
5	2.76	140
6	3.14	176
7	3.76	248
8	4.20	340
9	4.40	412
10	4.60	512

Analyze #4:

Then we apply the data in Excel, we get a plot[3].

After we tried to conduct(for details, please check the Appendix) the formula under the Analysis #4 in the instruction file, we found that we need to adjust the value of y-axis from $V_{out}(t)$ to $\frac{V_0 - V_{out}(t)}{V_0}$ so that the unit of voltage is unrelated to the final result, also leaving the exponential part alone on the right side of the equality mark. Also, it is the y-axis(ratio) that needs to be logarithmic, not x-axis(time). After making y-axis logarithmic, it is equivalent to applying the ln operation to both side of the equation and taking the left side as y. Thus making the right side become $-\frac{t}{\tau}$. Then we can fit the current plot to a linear line and calculate the time constant from the inverse of the line's slope as shown in the graph[4].

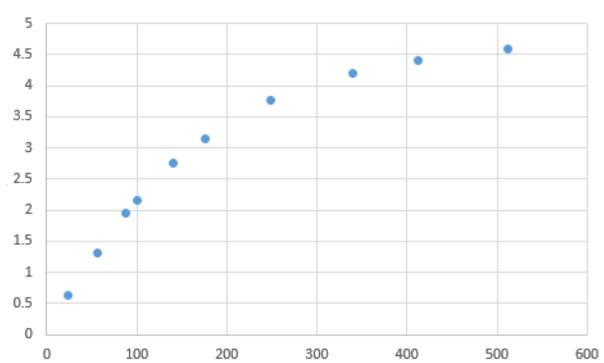

Fig. 3. plot on the Voltage of capacitor in the original circuit with time.

Then we fit a linear line to this plot, and we get a slope of -4970. we get its inverse $2.012 \times 10^{-4} s$. Also, we calculated the theoretic value for τ and got $\tau = RC = 10k\Omega \times 0.01\mu F = 1 \times 10^{-4} s$, which led to a 101% error.

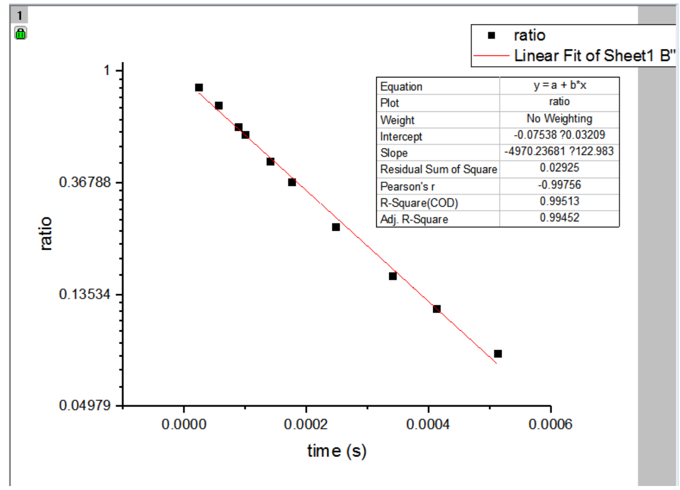

Fig. 4. plot on the logarithmic ratio () in the original circuit with time.

We think it was pretty strange, so we used the multimeter to measure the actual value of the resistor and capacitor we used in our circuit. From measurement, we found that the real value of resistor was 10.1kΩ, which was quite near to its printed value 10kΩ. However, the capacitor's real value had a great error with its printed value. The capacitor we used had an actual capacity of 18.3nF. After we put the real value of our elements into the calculation of theoretical value of time constant, we got
$\tau = RC = 10.1k\Omega \times 18.3nF = 1.85 \times 10^{-4}$, which led to a percent error of 8.76%, a quite better result than before.
But there are still some difference. We discussed and think that the possible resource of difference may among the list below:
1. The oscilloscope had a measure error on the output signal.(May caused by the interference of the current in the circuit and other reasons)
2. The resistor in the cables and experimental boards were not taken into account.
3. The capacitor showed an unstable value for its capacity when we measured it, so its capacity may be easily influenced by some factors in the environment(such as temperature).
4. The capacitor may act like a resistor or an inductor at extreme frequencies.

Analyze #5:

To finish this analysis, we built a two-stage circuit and then a three-stage circuit. Our two-stage circuit is built according to graph[5].

In the same way as in the original circuit, we measure 10 points to compute its time constant. Like in the original circuit, we plot two figures to show the relative of our measures in two-stage. We then get the time constant of two-stage $\tau = -\frac{1}{slope} = -\frac{1}{-1825} = 5.479 \times 10^{-4}$.
And according to the circuit graph and some prelab exercise and the result of our measurement in analysis 4, we can easily compute the theoretical value of time constant in this case:
$\tau = 3RC = 3 \times 1.85 \times 10^{-4} = 5.55 \times 10^{-4}$ and the percent error $error = 1.28\%$.

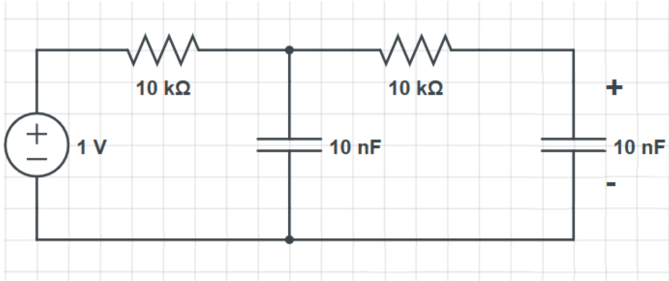

Fig. 5. the circuit graph of two-stage circuit

TABLE IV
EXPERIMENT RECORD IN THE TWO-STAGE CIRCUIT

No	Voltage(V)	time(μs)
1	0.04	20.0
2	0.08	30.0
3	0.16	50.0
4	0.48	90.0
5	0.80	130
6	1.68	250
7	2.40	360
8	3.04	500
9	4.28	1000
10	4.72	1650

Our three-stage circuit was built based on graph[8].
And our measure points are listed below:
Like in the original circuit, we plot two figures to show the relative of our measures in three-stage. We then get the time constant of three-stage $\tau = -\frac{1}{slope} = -\frac{1}{-864.4} = 1.157 \times 10^{-3}$.
And according to the circuit graph and some prelab exercise, we can easily compute the theoretical value of time constant in this case:
$\tau = 6RC = 6 \times 1.85 \times 10^{-4} = 1.11 \times 10^{-3}$ and the percent error $error = 4.23\%$.
We thought the reason for the difference may among these

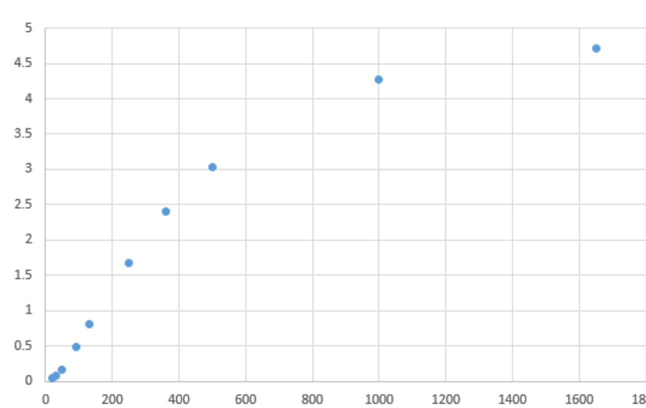

Fig. 6. plot on the Voltage of capacitor in the two-stage circuit with time.

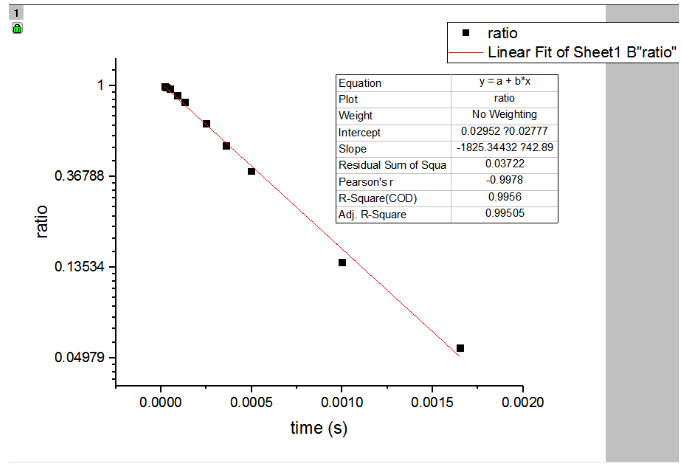

Fig. 7. plot on the Voltage of capacitor in the two-stage circuit with time.

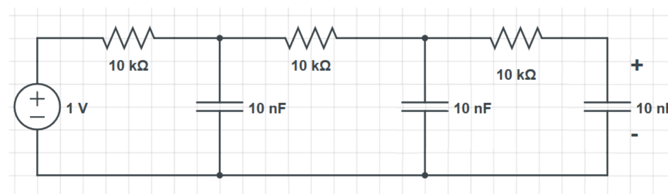

Fig. 8. the circuit graph of three-stage circuit

TABLE V
EXPERIMENT RECORD IN THE THREE-STAGE CIRCUIT

No	Voltage(V)	time(ms)
1	0.04	100
2	0.24	180
3	0.52	250
4	0.82	330
5	1.28	450
6	1.80	600
7	2.40	810
8	3.00	1110
9	3.60	1550
10	3.92	1930

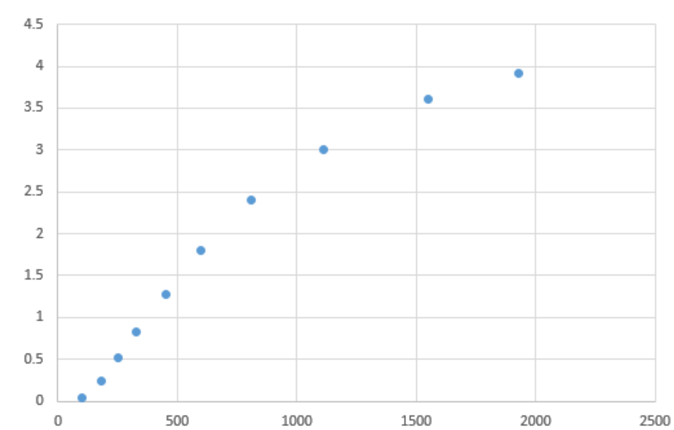

Fig. 9. plot on the Voltage of capacitor in the three-stage circuit with time.

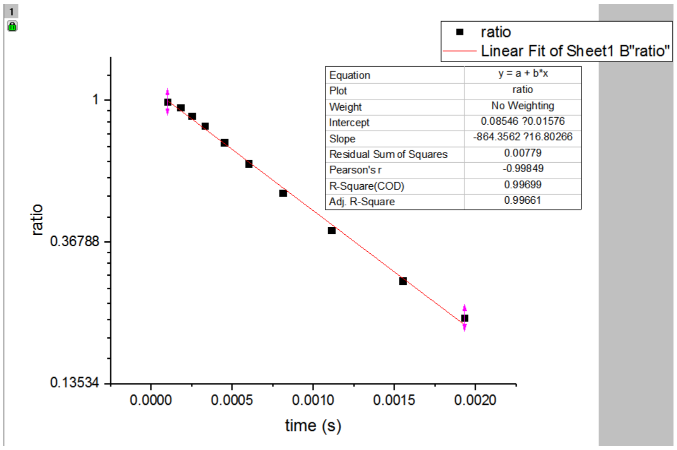

Fig. 10. plot on the Voltage of capacitor in the three-stage circuit with time.

reasons:
1. Some existing reasons that we have already mentioned in Analysis 4.
2. The resistors and capacitors we used to build two-stage and three-stage circuit may be different from those in the original circuit, thus causing some difference.
3. Other equipment errors caused by adding more elements and wires in our circuit.

B. The RC Response to a Sinusoidal Input

IV. Conclusions

We completed all the circuit building and measurements required in this lab, and got a result that fit our computation result in prelab. We also used our result to finish the analysis part in this lab, which gave us some hints to do our lab with more efficiency.

TABLE VI
Team Roles

Activity	Student Name
Prelab/Circuit Analysis	Muhan Li
Prelab/Simulations	Mingxiao An
Prelab/answer questions	Man Sun
Circuit construction	Mingxiao An
Data collection	Muhan Li, Man Sun
Data analysis	Muhan Li, Man Sun
Lab report writing	Mingxiao An, Muhan Li, Man Sun

V. Appendix

Procedure of conduction in Analysis #4:

From the lab instruction, we get a formula
$Ratio(t) = \frac{|v_{out}(t) - v_{in}|}{|V_0|} = e^{-\frac{t}{\tau}}$
In the process of rising, we can take v_{in} as V_0, because it stays at this value during the whole rising process.
$Ratio(t) = \frac{|v_{out}(t) - V_0|}{|V_0|} = e^{-\frac{t}{\tau}}$
Because the whole rising process shows that the capacitor is charging, which means that $v_{out} - V_0 < 0$ holds true during the whole rising. Also, we can make sure that V_0 is always a positive number in this case. Then we conducted our computation for Ratio(t).
$Ratio(t) = \frac{v_{out}(t) - V_0}{V_0} = \frac{v_{out}(t)}{V_0} - 1$
Then, if we apply $\ln$ operation to the Ratio(t) and exponential part, we get this.
$\ln(Ratio(t)) = -\frac{t}{\tau}$
So the exponential part becomes linear, which is easy to analysis.