Lab 3 Write Up
Transient Response of RC/RL Circuits
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Abstract: In this lab we fed off chaos and demonstrated madness. We created an RC circuit with a voltage source on a switch and measured the natural response of the RC circuit. Next we created a similar RC circuit and hooked it up to the waveform generator to be viewed through the oscilloscope. We observed the affect of varying the frequency of the voltage waveform input. Lastly we designed a custom RC circuit to match a set of requirements.

Introduction: Our goal is to measure and understand the behavior of capacitors and the voltage stored within them in RC circuits.

First we created a basic series RC circuit with a switch that connected and disconnected this circuit from a voltage source. We measured the voltage over the capacitor with a voltmeter on 10 second intervals (the RC time constant) from charged to discharged and vice versa. We plotted this data to give a clear depiction of the nature of the natural response of our RC circuit.

Next we created another RC circuit. This one however had an RC time constant of about 0.022 seconds. Since this was too short of a time constant to be viewed via the voltmeter, we exchanged our voltage source for a waveform generator and our voltmeter for a digital oscilloscope. Using these tools, we were able to view a clear waveform of both the input (square wave) and the "output" voltage over the capacitor. We also observed the effect that varying the frequency of the input waveform had on the shape of the response waveform.

Lastly, we created a custom RC circuit according to a set of specifications. This circuit involved a capacitor, some resistors, and a light bulb. The specifications included a required time constant and a required power dissipation over the light bulb.

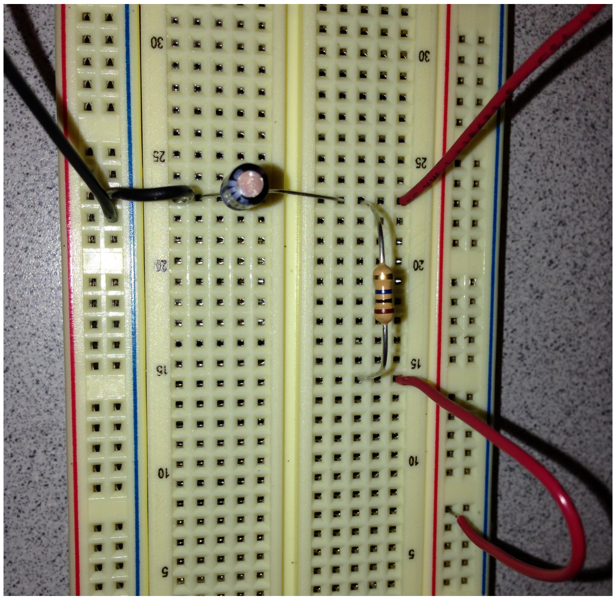
Materials:

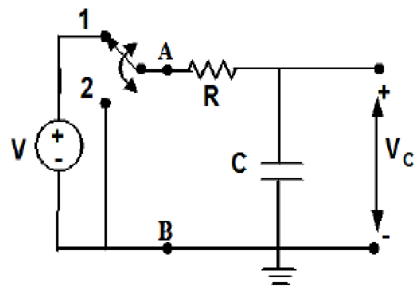
3x 1 kOhm Resistors (CFR-25JB-1K0)
1x 1 MOhm Resistor (CFR-25JB-1M0)
1x 22 kOhm Resistor (CFR-25JB-22K)
1x 1 microF Capacitor (ECE-A1HKA010)
1x 10 microF Capactitor (ECE-A1HKA100)
Voltmeter
Waveform Generator
25V Power Supply

Section 2.1

Methods:

1) Create Series RC circuit with R = 1 MOhm, C = 10 microFarads, V = 10 Volts.





2) Measure the voltage across the capacitor while charging and discharging the capacitor. This is accomplished by hooking up from voltmeter to the leads of the capacitor and switching the switch from contact point A to B (begin discharging) and B to A (begin charging).
3) Plot the data to see a clear trend in voltage.
4) Calculate the time constant by solving for t when $V_c = 0.63*V_{in}$. Compare this to the expected time constant RC.
5) Calculate internal resistance of multimeter.

Analysis:

Below are the measured results of step 2

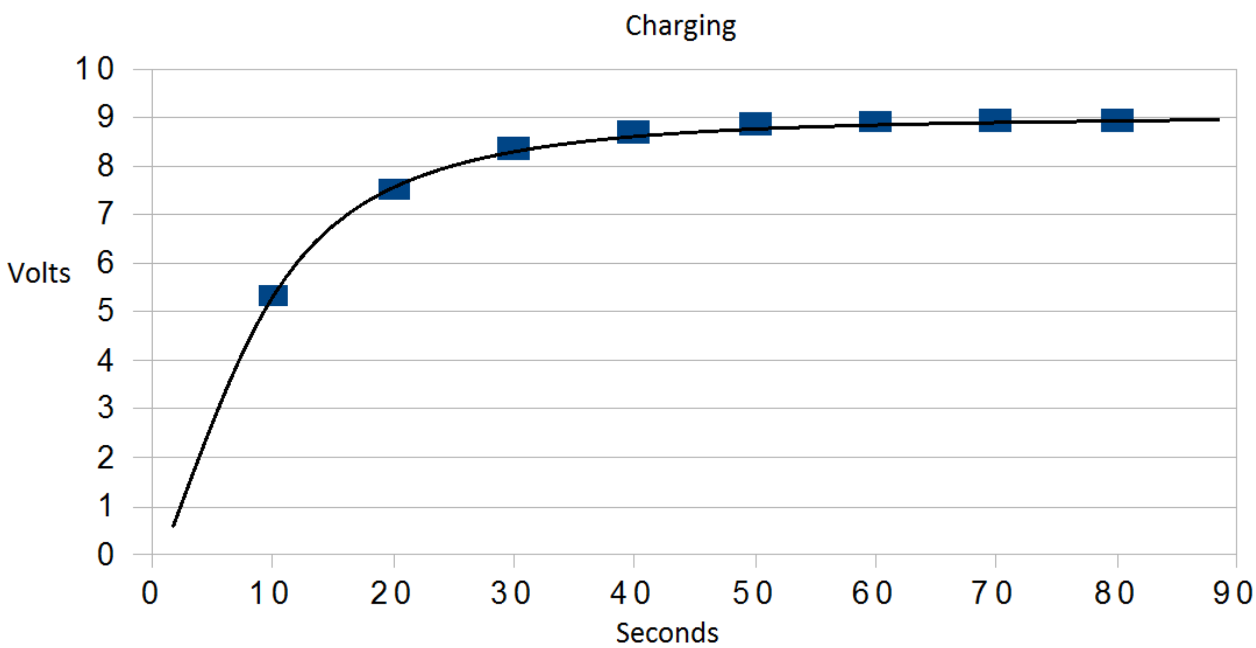
Charging

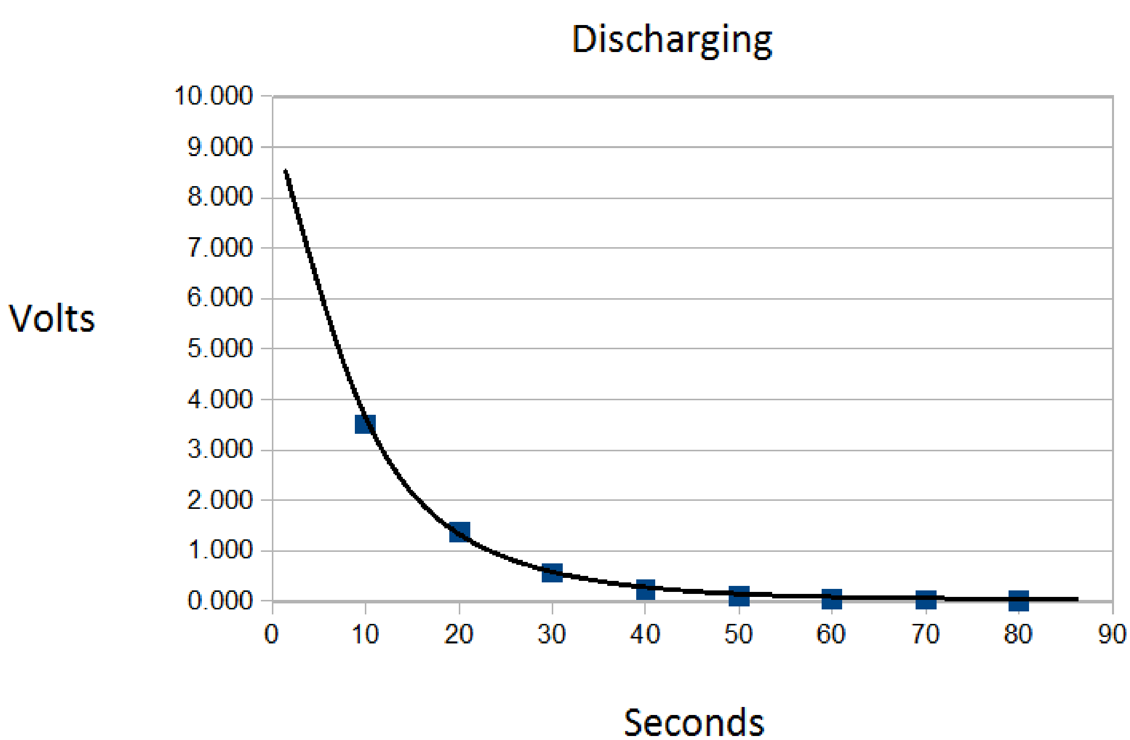
time	test1 (V)	test2 (V)	test3 (V)	Charge Avg (V)
10	5.300	5.380	5.350	5.340
20	7.500	7.550	7.500	7.525
30	8.350	8.410	8.400	8.380
40	8.690	8.740	8.740	8.715
50	8.830	8.880	8.890	8.855
60	8.920	8.930	8.940	8.925
70	8.920	8.960	8.970	8.940
80	8.930	8.970	8.990	8.950

Discharging

test1 (V)	test2 (V)	test3 (V)	Discharge Avg (V)
3.670	3.330	3.540	3.513
1.440	1.340	1.350	1.377
0.610	0.550	0.550	0.570
0.250	0.230	0.240	0.240
0.114	0.100	0.100	0.105
0.061	0.050	0.050	0.054
0.033	0.030	0.030	0.031
0.021	0.020	0.020	0.020

Here they are shown in graphical representation:





From the graphs, it appears that the first time constant RC is reached at about 14 seconds. This is when

$$V_c = .63 * V_{in}$$

This is almost half again as long as expected. This is most likely due to the internal resistance of the multimeter.

It can be clearly seen that our voltage maxes out over the capacitor at about 9.0 V. This is apparently attributed to the internal resistance of the multimeter. This resistance can be calculated as follows:

$$V_c = V_{in} (R_{ineternal} / (R_{internal} + R))$$

$$9.0 \text{ V} = 10.0 \text{ V} (R_{internal} / (R_{internal} + 1M))$$

$$9/10 = R_{internal} / (R_{internal} + 1M)$$

$$R_{internal} = 9 \text{ MOhms}$$

Given this finding, having a minimal R value in the RC circuit increases the voltage transfer from the power supply to the capacitor.

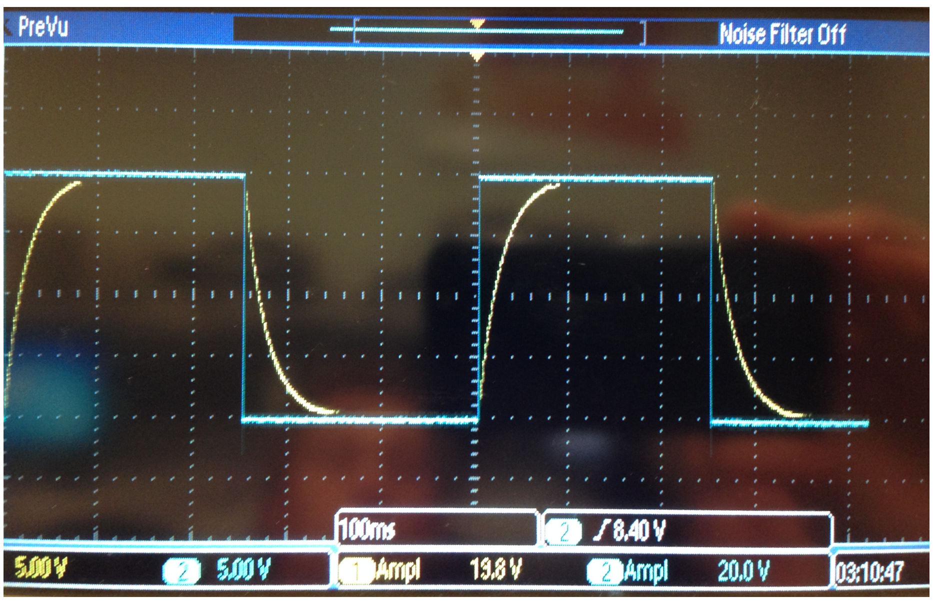
Section 2.2

Methods:

1) Design new RC cicrcuit similar to that from 2.1. R = 22 kOhm, C = 1 microFarad.
2) Remove voltmeter and connect V_c outputs to oscilloscope.
3) Remove voltage source and attach waveform generator.
4) Increase frequency of input waveform and observe what happens.

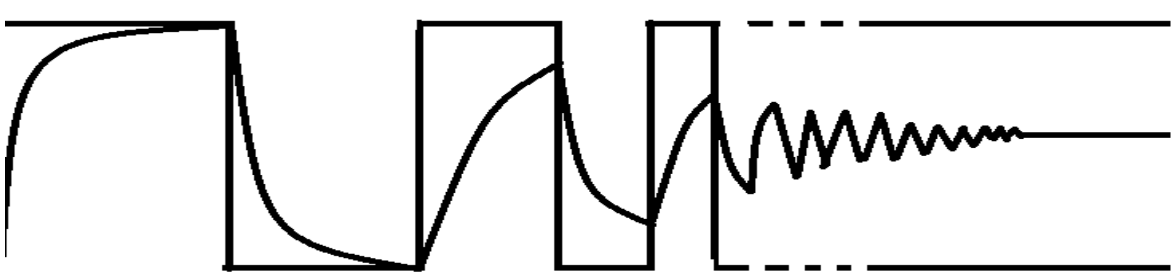
Analysis:

Here is the display from the oscilloscope at a frequency of 2 Hz:
Note: the RC time constant is about .022 seconds.



We set the frequency for this display to be much slower than 6RC (this is around 20RC).

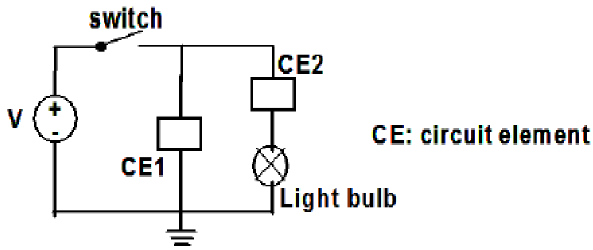
As we increased the frequency to faster periods the “flat” portion of the wave (the portion in line with the input square wave) shortened. This happened until very high frequencies were observed. Once these sufficient frequencies were reached, the capacitor no longer had time to completely charge and discharge. The following rough image, shows what it looked like to rapidly turn up the frequency.



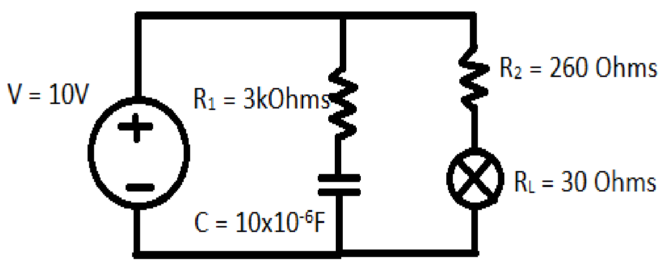
Section 3

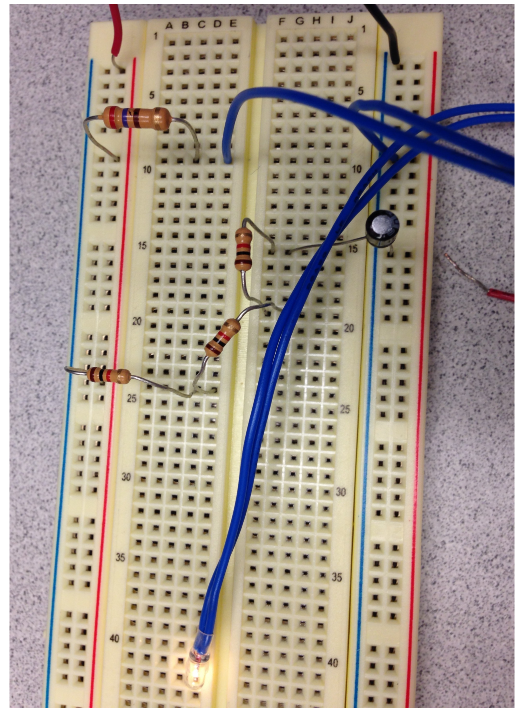
Methods:

1) Create parallel RC circuit similar to the figure below that satisfies the given requirements.



2) Ours looked like the following diagram:





3) Operate the switch and observe its affect on the bulb brightness.

Analysis:

I understand the reasoning behind this portion of the lab however we were not given appropriate equipment to complete it. With R_2 = 260 Ohms, the power dissipation of the light bulb with the switch open is 35 mW (very close to the specification). This R value of 290 Ohms however would require a large capacitor (114 micro Farads) in order to achieve the desire RC time constant of 30 ms. We do not have this big of a capacitor in our kit. To circumvent this, we put 3 1kOhm resistors in series with the capacitor. When the switch was opened, this increased total resistance to 3.3 kOhm and resulted in a time constant of 30 ms. Unfortunately, this also vastly reduced the voltage across the light bulb as the voltage divider equation below clearly shows:

$$V_o = V_{in} \text{ (30 Ohms/ 3.3 kOhm) } = 0.009\ V_{in}$$

This caused the light bulb to more or less instantly turn off, as the combination of a very short (30 ms) time constant and high resistance rapidly cut voltage from the bulb. With a larger capacitor, I would expect to see the light bulb gradually dim to off when the switch is opened. Again this would be much more visible with a high time constant.

Conclusion: This was an interesting lab. We learned a good deal about capacitors and their behavior in RC circuits. We also improved our skills at using oscilloscopes to view waveform outputs of circuits. In part 1, we plotted the voltage across a capacitor against time to measure the time constant RC. Other than the error resulting from the internal resistance of the Multimeter, these results looked very much like we expected.

In part 2, we created another RC circuit and attached its output V_c to the oscilloscope. We fed the circuit with a 10V square wave and observed the output. The output followed the square wave but had a logarithmic delay attributed by the charging and discharging of the capacitor. It was interesting to see the incomplete charging and discharging as frequency was increased.

As a side note, we hooked our 8 Ohm speaker up at this point to both the square wave input and the circuits output. We noted that the V_c driven speaker had a softer sound than the square wave, attributed by the capacitor "smoothing out" the waveform. Not that it had anything to do with the lab, but we had a deal of fun altering the frequency of the input and making phat beats.

Lastly in part 3, we were to design an RC circuit that followed the given specifications. We did so, however I do not believe it is at all an optimum circuit for the desired effect. With a larger capacitor (and therefore a larger RC time constant), I believe the results would have been much more interesting. Overall, it was a very interesting lab though.