SIERRA COLLEGE	MECH 10 - Lab 13 RC Time Constants	Mechatronics Real Skills Real Jobs

Name: Cayce Beames
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Professor Steven Gillette

Abstract
In this lab, I used the digital oscilloscope, circuit trainer, a digital multimeter, resistors, capacitors, and a 555 timer integrated circuit to create circuits that demonstrated the charge and discharge capabilities of capacitors, observe the behavior of the circuits on the oscilloscope, and calculate resistance/capacitive time constant, charge and discharge times, and monostable operation time of the circuits. I also calculated the error percentage between the calculated and observed values.

Learning Objectives

- Characterize the output of an RC time constant circuit
- Calculate RC time constants for specified components
- Calculate and measure frequency and period

Notes:

1. Took all voltage measurements relative to ground (unless otherwise stated)
2. Recorded relevant measurements and calculation results in data tables
3. Recorded all measured values on the circuit schematics
4. Used all available precision in calculations, rounded off answers to 3 significant figures

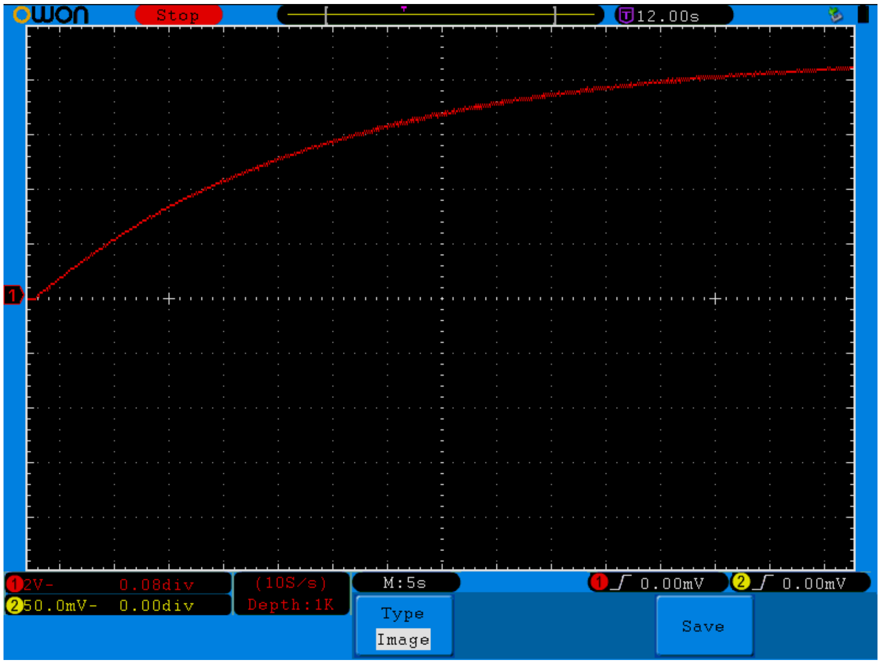
Materials

Quantity	Description
1	Digital oscilloscope
1	GS Trainer
1	DMM
	Circuit 1
1	R1 – 1MΩ resistor Mea = 0.984MΩ
1	C1 – 15µF capacitor Mea = 13.67µF
	Circuit 2
1	CMOS 555 timer
1	R1 – 3.3KΩ resistor Mea = 3.44KΩ
1	C1 – 0.22µF capacitor Mea = 0.21µF
	Circuit 3
1	CMOS 555 timer
1	R1 – 270KΩ resistor Mea = 270.7KΩ
1	C1 – 3.3µF capacitor (tantalum) Mea = 3.27µF
1	C2 – 0.01µF capacitor Mea = 0.21µF

Procedure – RC Time Constant (Circuit 1)

1. Measured and recorded all resistance and capacitance values for the resistors and capacitors used in this lab. Used these measured values (not the labeled value) for all calculations.

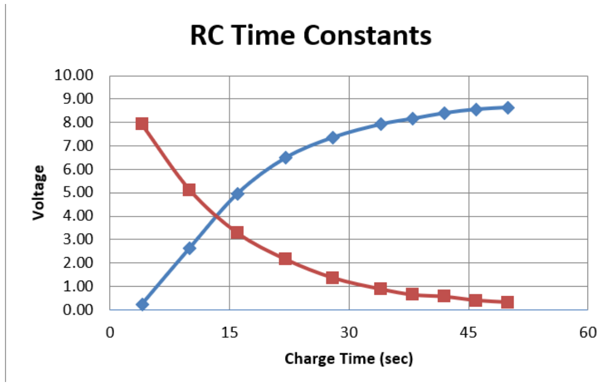
2. Set the trainer power supply to 10V. Turned off the trainer and built Circuit 1. Measured = 9.98V
3. Connected the oscilloscope probe to V_{out}, with the probe ground tied to trainer ground. Set the scope to 2V/div, 5 sec/div, DC Coupling.
4. **Charge Curve** - When the oscilloscope sweep reached the left side of the screen, turned on the trainer.
5. When the oscilloscope sweep reached the right side of the screen toggle the scope RUN / STOP button to STOP. Captured the scope screen for lab report.



6. **OPTIONAL** - Used the CURSOR menu to determine charge times and voltage levels to complete the spreadsheet data table for this lab. Included the resulting data table and graph in lab report for extra credit.

RC Time Constants

Time (seconds)	Charge V_{out}	Discharge V_{out}
4	240.00E-03	7.92E+00
10	2.64E+00	5.12E+00
16	4.96E+00	3.28E+00
22	6.48E+00	2.16E+00
28	7.36E+00	1.36E+00
34	7.92E+00	880.00E-03
38	8.16E+00	640.00E-03
42	8.40E+00	560.00E-03
46	8.56E+00	400.00E-03
50	8.64E+00	320.00E-03



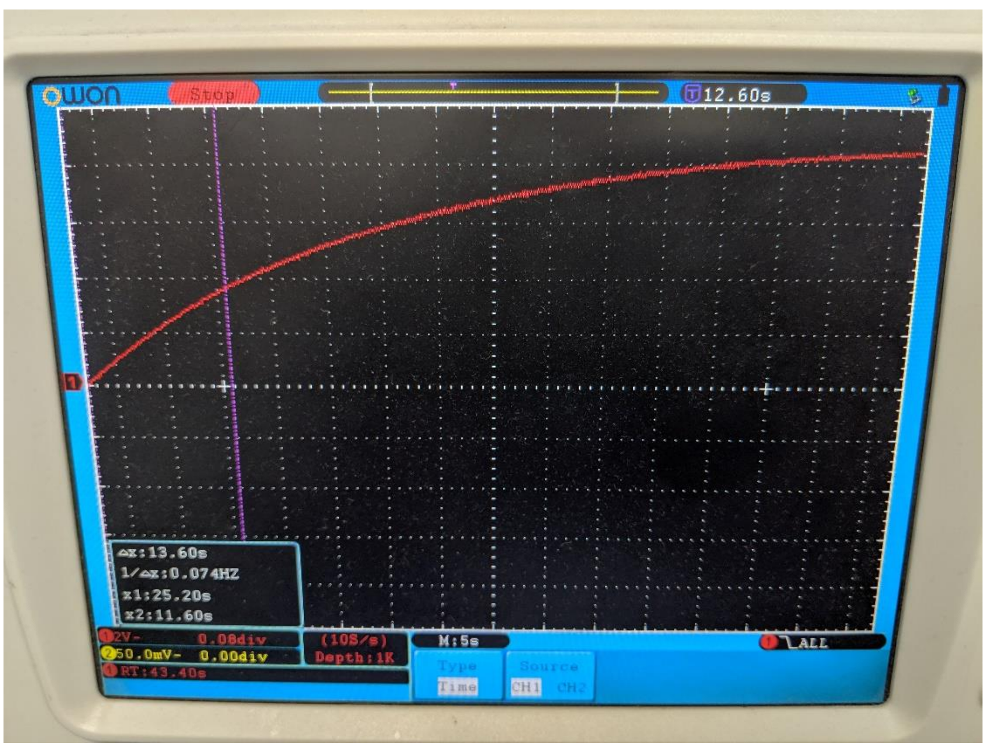
7. ***Calculated and recorded*** the RC time constant for this circuit using the RC Time Constant formula.

$$t = R * C$$

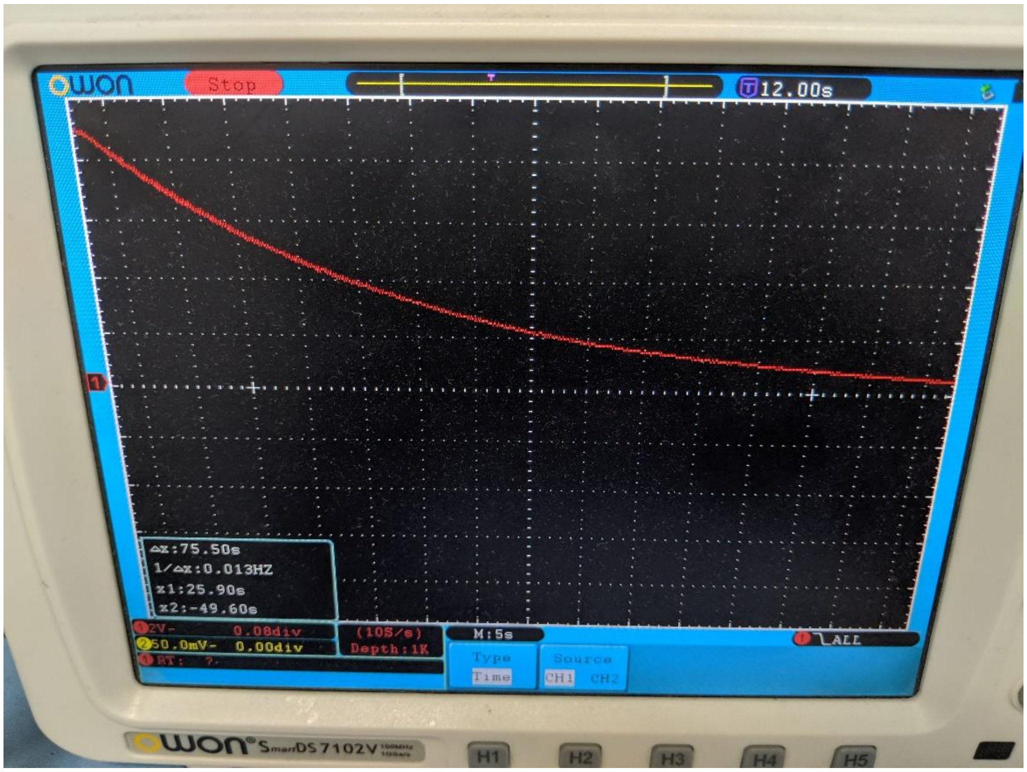
$$t = 0.984M\Omega * 13.67\mu F$$

$$t = 13.45sec.$$

8. Marked the time constants on the waveform screenshot (or on the spreadsheet graph.)



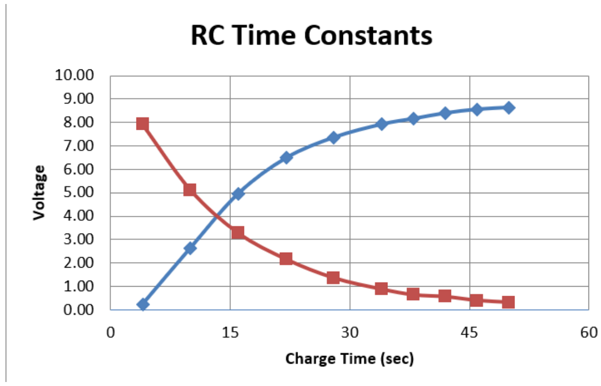
9. **Discharge Curve** – Toggled the scope back to a RUN state. When the oscilloscope sweep reached the left side of the screen, turned off the trainer.
10. When the oscilloscope sweep reached the right side of the screen toggled the scope RUN / STOP button to STOP. Capture the scope screen for your lab report.



11. **OPTIONAL** - Used the CURSOR menu to determine charge times and voltage levels to complete the spreadsheet data table for this lab. Modified the x-axis scale to show the time constant for this circuit. Included the resulting data table and graph in your lab report for extra credit.

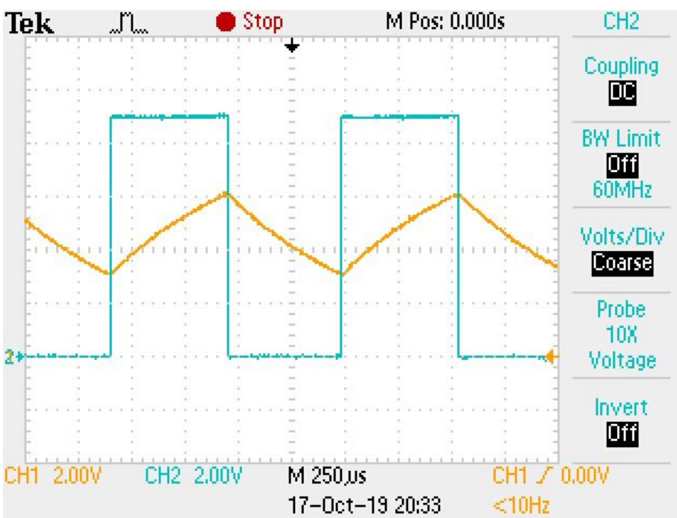
RC Time Constants

Time (seconds)	**Charge V_{out}**	**Discharge V_{out}**
4	240.00E-03	7.92E+00
10	2.64E+00	5.12E+00
16	4.96E+00	3.28E+00
22	6.48E+00	2.16E+00
28	7.36E+00	1.36E+00
34	7.92E+00	880.00E-03
38	8.16E+00	640.00E-03
42	8.40E+00	560.00E-03
46	8.56E+00	400.00E-03
50	8.64E+00	320.00E-03



Procedure – Astable Multivibrator (Circuit 2)

12. Built circuit 2. Noted that V_S = 9V for this circuit.
13. Turned on the digital oscilloscope. Set oscilloscope probes to 10x and pressed the default setup button. Set the scope for DC coupling, 2V/div, with a **250µS/div** time base.
14. Connected scope probe 1 to V_C. Connected scope probe 2 to V_{OUT}.
15. ***Captured and recorded*** the two waveforms on a scatter plot, one on top of the other (with the 0V lines on top of each other) to show the signal's phase and voltage relationship.

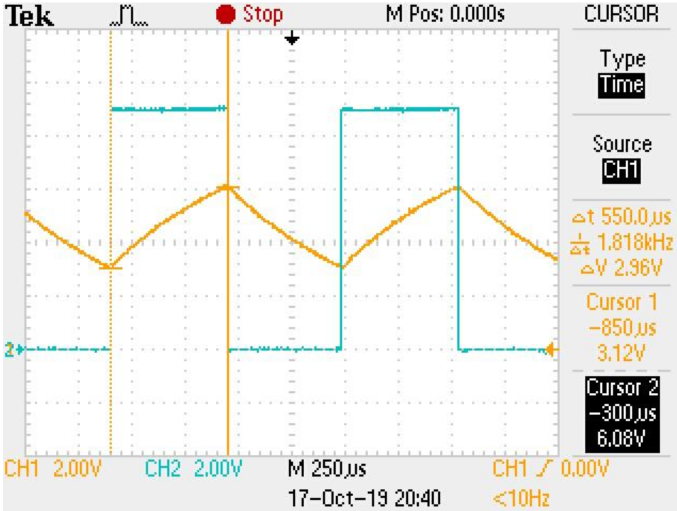


16. ***Calculated and recorded*** the expected capacitor charge (T_C) and discharge (T_D) times using the **Charge & Discharge Times (expected)** formula.

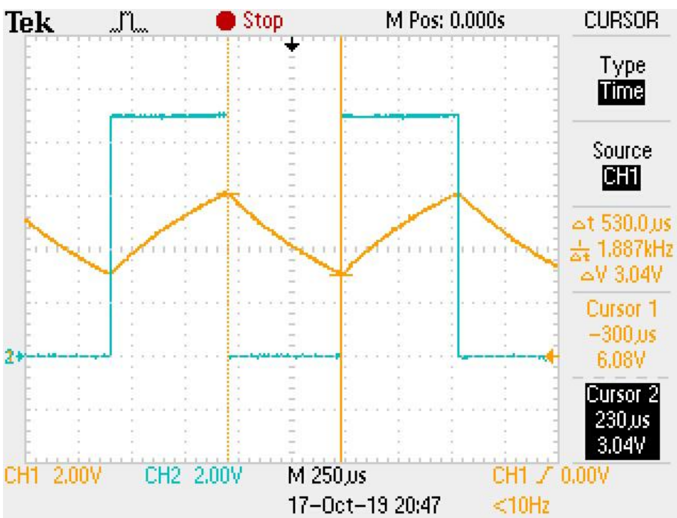
$$\boldsymbol{T_D = T_C = 0.69 * 3.44K\Omega * 0.21\mu F}$$

$$\boldsymbol{T_D = T_C = 498.5\mu s}$$

17. ***Measured and recorded*** the capacitor charge and discharge times using the oscilloscope. Compared the expected and measured values using the % Error formula.



$$T_C = 550\mu s$$



$$T_D = 530\mu s$$

$$\boldsymbol{Error}\ \%_C = \frac{\mathbf{550}\boldsymbol{\mu s} - \mathbf{498.5}\boldsymbol{\mu s}}{\mathbf{498.5}\boldsymbol{\mu s}} * \mathbf{100}\%$$

$$\boldsymbol{Error}\ \%_C = \frac{\mathbf{51.5}\boldsymbol{\mu s}}{\mathbf{498.5}\boldsymbol{\mu s}} * \mathbf{100}\%$$

$$\boldsymbol{Error}\ \%_C = \mathbf{0.103} * \mathbf{100}\%$$

$$Error\ \%_C = \boxed{10.3}$$

$$Error\ \%_D = \frac{530\mu s - 498.5\mu s}{498.5\mu s} * 100\%$$

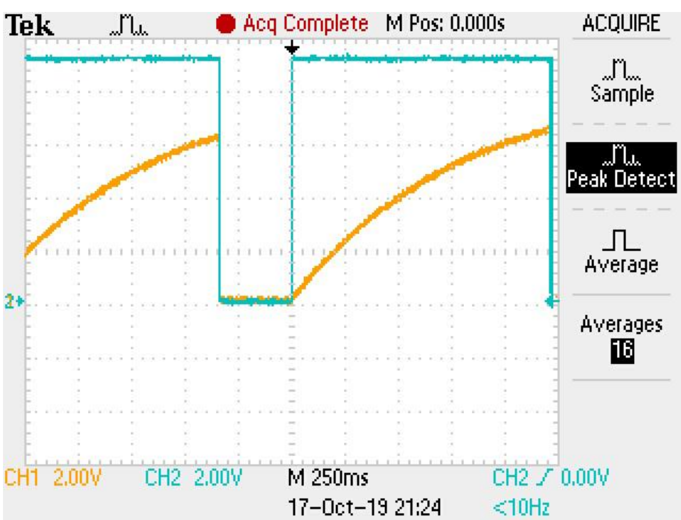
$$Error\ \%_D = \frac{32\mu s}{498.5\mu s} * 100\%$$

$$Error\ \%_D = 0.064 * 100\%$$

$$Error\ \%_D = \boxed{6.4\%}$$

Procedure – Monostable Multivibrator (Circuit 3)

18. Built circuit 3. Noted that V_S = 9V for this circuit.
19. Turned on the digital oscilloscope. Set oscilloscope probes to 10x and pressed the default setup button. Set the scope for DC coupling, 5V/div, with a **250mS/div** time base. Selected ACQUIRE and set the scope to PEAK DETECT.
20. Connected scope probe 1 to V_C. Connected scope probe 2 to V_{OUT}.
21. Pressed the oscilloscope SINGLE SEQ button and waited while the scope annunciates ARMED, then READY.
22. Quickly cycled the digital switch high-low-high to trigger the one-shot (monostable multivibrator) while observing the scope display. The scope will display **Trig'd**, then **Acq Complete** when the wave form has been acquired.
23. Captured the two waveforms as before.

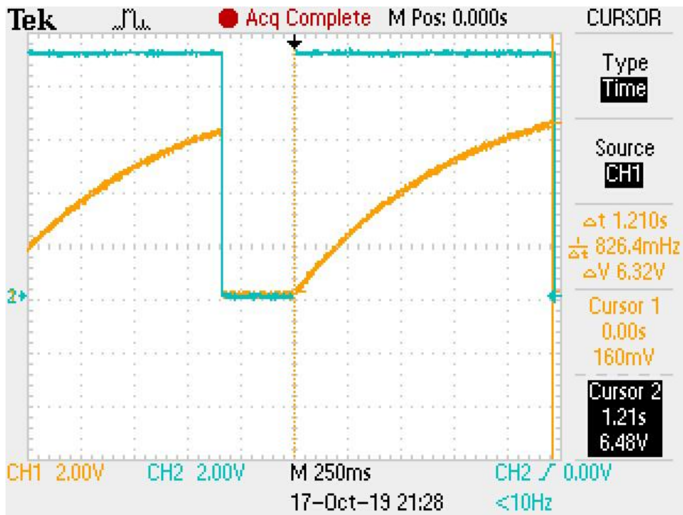


24. ***Calculated and recorded*** the expected operation time of the output using the Monostable Operation Time formula.

$$\boldsymbol{T_{op} = 1.1 * 270K\Omega * 3.3\mu F}$$

$$\boldsymbol{T_{op} = 0.981s}$$

25. Used the captured waveform to ***measure and record*** the operation time of the 555 output. Compared the measured and expected values using the % Error formula.



$$\boldsymbol{Error\ \%_D = \frac{1.21s - 0.980s}{0.980s} * 100\%}$$

$$\boldsymbol{Error\ \%_D = \frac{.23s}{.980s} * 100\%}$$

$$\boldsymbol{Error\ \%_D = 0.235 * 100\%}$$

$$\boldsymbol{Error\ \%_D = 23.5\%}$$

Formulas

% Error

$$\%Error = \frac{measured - \exp ected}{\exp ected} x100\%$$

Where;
%Error = % change between measured and expected values
measured = a value taken from direct measurement
expected = a value taken from component or process specifications

RC Time Constant

$$\tau = R \times C$$

Where;
τ = RC time constant (seconds)

R = resistance (Ohms)
C = capacitance (Farads)

Note – 5 time constants are required for a capacitor to completely change from an initial voltage value to a fully charged or discharged value.

Charge & Discharge Times (expected)

$$T_C = T_D = 0.69 \times R \times C$$

Where;
T_C = expected charge time
T_D = expected discharge time
0.69 = 555 trigger constant
R = resistance (Ohms)
C = capacitance (Farads)

555 Period (expected)

$$T = T_C + T_D$$

Where;
T = total period (seconds)
T_C = expected charge time
T_D = expected discharge time

Monostable Operation Time

$$T_{op} = 1.1 \times R \times C$$

Where;
T_{op} = operation time (seconds)
1.1 = 555 trigger constant
R = resistance (Ohms)
C = capacitance (Farads)

Critical Thinking

1. How can you change the Circuit 2 output frequency?

   Because the charge and discharge times are based on the values of the resistor and capacitor in the circuit, to change the output frequency in circuit 2, one would need to change either the value of the resistor, or the value of the capacitor such that the charge and discharge times increase or decrease.

2. How can you change the Circuit 3 one-shot time?

   As in the previous answer, the charge and discharge times are based on the product of the resistance and the capacitance in the circuit. Therefore, the Circuit 3 one-shot time is also dependent on the values of the resistor connected between the source and pins 6 and 7 and the capacitor connected between pins 6 and 7 and ground.

3. Describe an application for an RC time constant circuit.

   The circuit that was built as part of this lab is a good example of an application of timed logic. Timed logic can be used in circuits such as light or sound beacons that have a specific requirement for on / off times. A light beacon could be an aviation warning light at the top of a tower. A sound beacon could be an annunciator letting vision impaired persons know that it is safe, or unsafe to cross the street.

Conclusion

This lab was a very good opportunity to not only learn about RC time constant circuits, but also to increase familiarity with the oscilloscope. You may notice that I used two different oscilloscopes in this lab. I had made an error in class in my data capture and did not want to wait for the next available class or free lab availability. I used the Owon SDS7102V oscilloscope available at the HackerLab. This permitted the opportunity to learn how to use another manufacturer’s equipment and to have additional time to experiment with the circuits discussed in the lab.

Grading Criteria

		Points Possible	Points Earned
Documentation	Abstract, introduction, experiment, data results, conclusions, attachments, clarity, spelling, grammar	**10**	
RC Time Constant	Waveform captured with time constants shown	**5**	
Astable Multivibrator	Waveform captured	**5**	
	Expected charge and discharge times calculated and compared to measured values	**5**	
Monostable Multivibrator	Expected output operation time calculated and compared to measured value	**5**	
	Waveforms captured	**5**	
Critical thinking	Questions answered completely & accurately. State conclusions drawn and lessons learned from the lab	**10**	
On-time submittal	Lab report is submitted in accordance with the assignment due date as posted on Canvas	**5**	
	Total	**50**	
Optional	Spreadsheet data tables and graphs (with time constants) included	**5**	

Lab Report Format

Abstract - a summary and high-level overview of the lab and its results
Introduction - State the objectives of the laboratory and list the equipment required
Experiment - Describe the procedure used to carry out the lab
Data Results - list data taken in table or graphical format where appropriate
Conclusion - State the conclusions drawn and lessons learned from the laboratory activities. Answer any questions found within the lab procedure.
Attachments – grading criteria, verification signatures, circuit diagrams, lab procedures & notes