EXPERIMENT 5: RC TIME CONSTANT

The last experiment introduced the use and operation of the oscilloscope function of the Pasco Interface system on the computer. In this experiment we will use the oscilloscope to examine one important type of electronic circuit, the RC circuit. We will also use the Power Amplifier as a programmable power supply (or Signal Generator) to drive the circuit.

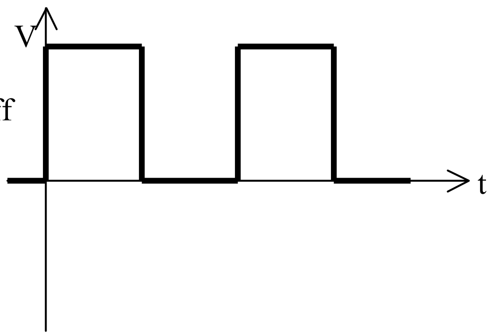
BACKGROUND

In the text, the charging and discharging of an RC circuit is described as, and you are asked to visualize, a process of a mechanical switch in series with a resistor and capacitor, with the switch changed back and forth between two positions, one for charging and one for discharging the capacitor. (See Chapter 27, Section 27-15 and Figure 27-16.) While this is a possible way to study the charging and discharging of a capacitor, a programmable power supply (or a signal generator with variable frequency) can serve the same purpose more easily. An oscilloscope, with Voltage Sensor probes connected in parallel across the capacitor (and possibly also across the resistor) allows us the monitor the charging and discharging of the capacitor, since the charge is proportional to the voltage on the capacitor; that is, $q = C V$.

Although voltages and frequencies will be specified in the procedures below, be prepared to change either quantity, if it seems that such a change will give a better chance to make the desired readings. In particular, we want to make sure that the frequency of the power supply is slow enough to allow the capacitor to charge completely, or nearly so, as shown in Figure 28-14 in the textbook.

The Power Amplifier will supply the voltage to drive the charging of the capacitor. When the Power Amplifier is in an Off cycle, the capacitor will discharge through the resistor in the circuit. You are to study the pattern of the charging capacitor and the current, quantitatively and qualitatively.

ADVANCE STUDY ASSIGNMENT



1. The graph at right represents the voltage applied to an RC circuit. The voltage is turned on and off electronically, many times a second (say 20 Hz). Use the graph in your textbook to sketch the voltage on the capacitor as a function of time, on the graph at right, assuming that the capacitor charges fully before the voltage drops to 0.
2. Now, using a different color, or using a dotted line, plot the voltage across the resistor on the same graph above. (Hint: to help with this, recall that the voltage in the resistor will be proportional to the current. You can use the expression for q in the text to find i, by the relation $i = dq/dt$. Pay attention to algebraic signs. Alternately, use the loop theorem, and draw V_R by the fact that $V_C + V_R = V_{\text{Power Supply}}$, which is the graph sketched above.)
3. Starting with equation 28-30 in the text, calculate, as a multiple of the value RC, the time at which the voltage (and charge) on the capacitor will reach 80 % of its maximum value, starting from $V = 0$. Your answer will be in the form $t = y * RC$, where y will be a number, or some constant.

PROCEDURE A

1. Turn on the Interface box and computer as usual, and call up Data Studio. Connect the Power Amplifier, both virtually on the computer, and actually. (Look in the procedures of the last lab directions if you need instructions on dragging icons and selecting display options.) Connect Voltage Sensors (virtually and actually) to Analog Channels B and C. Drag the oscilloscope icon ("Scope") to Voltage Sensor on Analog Channel B.
2. Before making any physical connections, make sure that the Power Supply is turned off, both with the switch on its back, and virtually, on the Power Amplifier (or Signal Generator) control window on the monitor.
3. Connect one end of the 100 μF capacitor on the RLC circuit board to the Power Amplifier, using a stackable banana plug cord. Connect the other end of the capacitor to one end of the 33 Ω resistor. By connecting the other end of the 33 Ω resistor to the other terminal of the Power Amplifier, the capacitor and the resistor are now in series with the Power Amplifier. Verify that the circuit you have is the one sketched in Figure 28-13, with the Power Amplifier serving as the battery, switch, and discharging path.
4. Now connect the Channel B Voltage Sensor to either end of the capacitor, by stacking the banana plugs. Be sure to observe polarity in connecting the Voltage Sensor (the positive end of the Voltage Sensor should be connected to the positive terminal of the Power Amplifier, or to a circuit element which is connected to the positive terminal; the same applies to the negative).
5. On the signal generator window of the Power Amplifier, select the voltage output which looks like the sketch for the Advance Study Assignment. (The choice should be fifth on the list under the sine wave button on the control window, labeled positive square wave.) Adjust the output (called amplitude in the window) to 3.0 V and select 20 Hz for the frequency.
6. At this point, ask the instructor to check your circuit, and after it is checked, turn on the Power Amplifier, both on the control window and on the back of the Power Amplifier box. Click on "start" on the Data Studio window. You should see the trace indicating the voltage on the capacitor. Recall this voltage is proportional to the charge on the capacitor, since $q = C V$. If necessary, adjust the scale on the oscilloscope window to produce a good display (filling the scope display, but showing a complete cycle). Using the Offset buttons may be helpful here. Remember the Single Trace button (the red numeral 1 at the top of the scope window) will stop the motion of the trace. Sketch two cycles on Data Table A, # 6.
7. Click the Stop button, and now change the inputs to the oscilloscope program. Drag the words "Voltage, Ch C" in the data window, and drop them under the box to the right of the scope display that says "Voltage, Ch B". This should add a second trace to the oscilloscope when you click Start. Also drag the words "Output voltage" under the boxes for Voltage Ch B and C. This will display three traces on the oscilloscope, all as a function of time, in three colors.
8. Now connect the second Voltage Sensor across the terminals of the resistor, remembering to observe polarity. On Experiment Setup window, double-click on Voltage Sensor (to utilize Analog Channel C). Now turn on the Power Amplifier, click Start, and sketch the display you observe. It may be useful on Data Table A # 8. Use different colors, or dotted and dashed lines to distinguish among the three traces. Label the traces. Pick some arbitrary time, and read and record below the sketch all 3 voltages (for the C, the R and the output).

PROCEDURE B

9. Now turn off Channel C on the oscilloscope (by clicking on Channel C to the right of the oscilloscope display; a box should appear around it only, and then enter delete on the keyboard). Output voltage and Voltage, Ch B should remain. Insure that the Power Amplifier (Signal Generator) is still adjusted to the signal shown in the ASA questions and at 3.0 V. Turn the Power Amplifier on, and adjust the trace to fill the oscilloscope screen. You should also enlarge the oscilloscope screen to fill most of the monitor, either by maximizing the oscilloscope window, or keeping it on window and enlarging the window by dragging the side and bottom out. (You should enlarge the Data Studio window to fill the monitor if you have not already done so.) Also, be sure your scales are chosen so that the trace fills as much of the oscilloscope screen as possible.
10. Now, the maximum voltage should be 3.0 V if you have followed directions above. 80 % of that is 2.4 V. Use the smart tool (the xy graph button at top left of the scope window). Record the time when the voltage on the capacitor is 0 at the start of a cycle, by placing the dotted vertical axis of the smart tool at that point. Now record the maximum voltage on Data Table B # 10, and also record 80 % of that value. Finally, record the time when the voltage on the capacitor reaches that 80 % value, again by using the trace function of the oscilloscope.
11. Calculate RC from the results of the time above and the result of Advance Study Assignment 3. Enter this in Data Table B # 10.
12. Now add the variable resistor box in series with the resistor on the RLC circuit board, and set the resistance to 15 Ω. Record the time for 80 % maximum voltage on the 48 Ω line of Data Table B # 12. (Use the 48 Ω line because we have 33 Ω in series with 15 Ω.) Fill in the 33 Ω line with the data from procedure # 10. Add successive values of 15 Ω on the resistance box and fill in all boxes of Data Table B # 12.

PROCEDURE C

13. Now put the 330 μF capacitor in series with the 100 μF on the RLC board, and repeat procedures above with R values from 33 Ω to 100 Ω, using only the decade resistance box, not the resistors on the RLC board. You may need to adjust the frequency to ensure that the capacitor reaches final voltage, and is not shut off before reaching that value by the Power Amplifier turning off.

PROCEDURE D (CALCULATIONS)

14. Fill in the RC values of Data Tables B # 12 and C by calculating as directed in Procedure 11.
15. Plot graphs of RC vs R for the two data tables in Procedure 14.
16. Calculate the slopes for the two graphs, and enter on the corresponding Data Table. Compare the slopes calculated with theoretical values and comment.

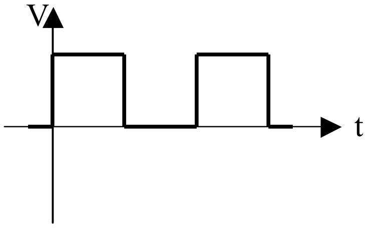
QUESTIONS

1. In the sketch for Procedure 8, add up the voltages on the resistor and capacitor at the time you chose to read them, paying attention to algebraic sign, and compare this sum to the voltage of the output. How do the two voltages compare? Is this what should be expected, and why? Should this work at any time, other than the particular time you picked?

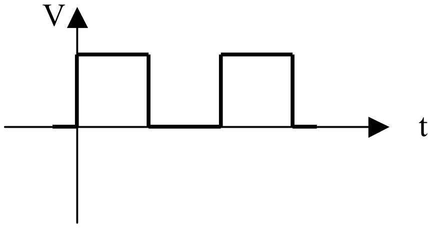
2. Why was the slow frequency of 20 Hz chosen? If a capacitor of 4.0 μF and a resistor of 5.0 Ω were used, what frequency would make the oscilloscope trace look similar? Sketch what the oscilloscope trace would look like with the new C and R values and the original 20 Hz frequency.

DATA TABLE A

6



8



DATA TABLE B

10

	33Ω 100μf
t (V = 0)	
V_{max}	
t (.8 V_{max})	
$RC_{calculated}$	

____

12

V_{max}	0.8 V_{max}	t (ms)	RC (ms)	R (Ω)
		Slope calculated:		

DATA TABLE C

V_{max}	0.8 V_{max}	t (ms)	RC (ms)	R (Ω)
		Slope calculated:		

____