

## Lab 4

### Multisim Evaluation of an RC Network

### Prelab Exercises

ALL GRAPHS MUST BE FULLY LABELED AND DRAWN NEATLY!

NO ANSWERS ARE COMPLETE WITHOUT THE UNITS! AS ALWAYS, SHOW YOUR WORK!

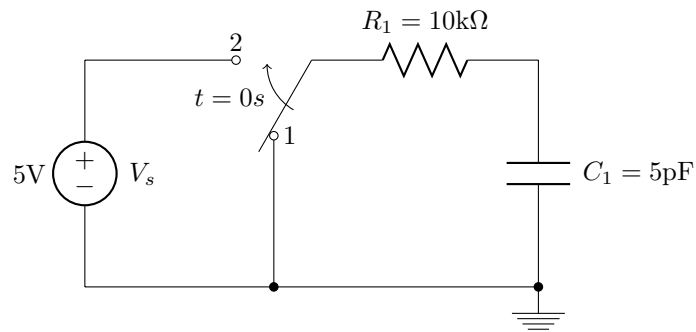


Figure 1: Circuit for prelab exercises

For steps 1, 2, and 3, assume the switch has been in position 1 for a long time. At  $t = 0\text{s}$ , the switch moves to position 2 and the capacitor begins to charge.

For step 4, assume the switch has been in position 2 for a long time. At  $t = 0\text{s}$ , the switch moves to position 1 and the capacitor begins to discharge.

1. Plot the charge curve for the capacitor using the 2/3 estimation method given in class.
2. Answer the following:
  - (a) What is the time constant for the circuit?
  - (b) What will the capacitor voltage be at  $t = 150\text{ns}$ ?
  - (c) What will the resistor voltage be at  $t = 150\text{ns}$ ?
  - (d) What will the resistor current be at  $t = 150\text{ns}$ ?
  - (e) How much time must pass for the capacitor voltage to reach 1V?
3. Plot the charge curve using the capacitor charge formula given in class.

4. Assume the capacitor is fully charged, and the switch moves to position 1 at  $t = 0$ sec. Plot the discharge curve using the capacitor discharge formula given in class.

## Lab Exercises

The purpose of this lab is to analyze an RC network using Multisim. It is assumed that you remember (or can look up) the software procedures you used last week in Lab 3, so these instructions will focus on the new features we haven't used before. You can refer back to last week's notes to refresh your memory on other portions.

### Part 1

1. Creating the Circuit: You will start by creating the circuit shown in Figure 2 in the Multisim workspace.

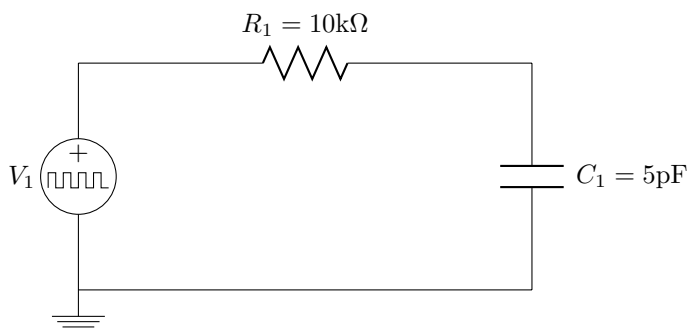


Figure 2:

It is the same circuit you analyzed in the prelab.

There are two new components in this circuit that we didn't use last time.

- The capacitor can be found in the "Basic" group.
- Unlike in last week's simulation, the voltage source you will use today will be a 0 to 5V pulse signal (Vpulse). The purpose of the pulse is to model the behavior of a switch operating between positions 1 and 2 (as in the prelab version of this circuit). When the pulse is low (0V), it behaves as if the switch is in position 1 and when the pulse is high (5V), it behaves as if the switch is in position 2.

You will need to define the parameters of the pulse source. For the purpose of this exercise, you will create a waveform that is 5V for the first 500ns and 0V for the next 500ns, then repeats this pattern. We will use a special voltage source in the component library to accomplish this.

- To define the parameters of the pulse we want to use, double click on the voltage source and make the following settings in the *PULSE\_VOLTAGE* settings window. Keep the default settings for any parameter not listed below:
  - \* Initial Value = 0V
  - \* Pulsed Value = 5V

- \* Pulse Width = 500ns(be sure to check the units!)
  - \* Period = 1000ns(units!)
  - \* Double-check the settings and click OK
  - \* The source label should now note the proper voltage and time parameters, as in the diagram above.
- Print a copy of your design and put it in your lab book. Remember to use the print preview and print options controls (*File* menu) to make it print an appropriate size.

## 2. Simulating the Circuit:

Multisim allows the user to observe how a circuit behaves over time. Specifically, you will observe how a 5V source charges the capacitor in an RC network (and how the capacitor discharges in the same network when the source shuts off). We will use the software's *Transient Analysis* feature to make these observations.

- From the *Simulate* menu, select *Analyses: Transient Analysis*. This opens the *Transient Analysis* parameters window.
- We want to observe the capacitor for at least one charge and discharge cycle, so we must run the analysis for at least the duration of the pulse source period. Therefore we will set the simulation to run for 1000ns.
  - In the Analysis Parameters tab, leave the start time at 0 and set the end time to 1000ns (or 1 $\mu$ s) by typing 0.000001 into the *TSTOP* window. You can also type “1e-006” if you like (Multisim will translate your decimal value to this notation for you anyway, which you will see if you re-open this window later).
  - Click the *Minimum number of time points* button and leave it at 100. This ensures that we plot plenty of data points to get a smooth curve. If you forget this step it will plot fewer points, connecting them with straight lines, and the curve will look chunky.
- In the Output tab, add V(1) and V(2) to the selected variables list so it will plot both the source voltage and the capacitor voltage.
- Click the *Simulate* button and a *Grapher View* window will appear showing your plot. It should look like the one in Figure 3. To toggle the background color between black and white, from the *Graphs* menu, select *Black and White Color*.

## 3. Analyzing the Plot:

- Notice that while the pulse reads 5V from 0s to 500ns, the capacitor is shown to be charging, while during the low portion of the pulse wave (500ns to 1 $\mu$ s) the capacitor is discharging.
- In the *Grapher View* window, from the *Cursors* menu, select *Show Cursors*. A *Transient Analysis* data window will open. Drag it to the vacant area in the upper right of the screen above the discharge curve so we have an unobstructed view of the charge curve.
- We will use the cursors to make measurements from the plot. Their default position is on the vertical axis. At the top of the voltage axis you will see a small colored (probably pink) triangle pointing downward. Grab it with your mouse and drag it to the right. It will pull a vertical line of a different color (probably yellow or blue) out into the plot. There are two cursors, so you can go back to the vertical axis, grab the other one, and drag it into the plot area too.  
Watch the values in the *Transient Analysis* window change as you move the cursor around. This data represents the (x,y) coordinates for the point on the plot where the cursor intersects the plotted curve. There is a separate column for each curve. And there are separate (x,y) values for

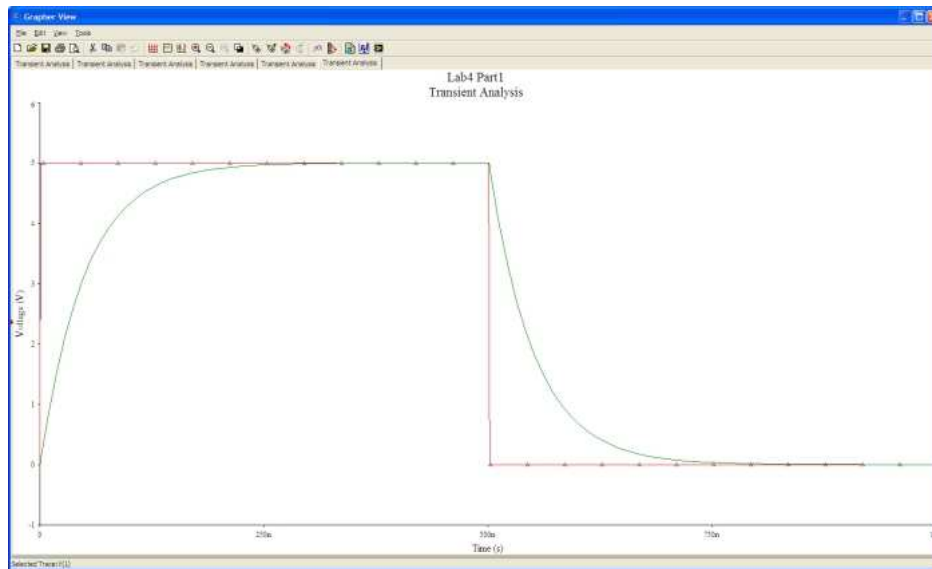


Figure 3: Transient analysis plot

each cursor. X represents the time value and Y represents the voltage value. Using these cursors you can extract numerical results from the plot. Note that, for each curve, the analysis window also calculates the difference between the X and Y values for the two cursor positions (and it calls these dx and dy). Using this you can make time and voltage difference measurements for any two points on either curve.

We are primarily interested in the capacitor charge and discharge curves for measurement's sake, but we have displayed the source voltage on this plot to help us remember what the state of the source is for the charge and discharge scenarios. We won't be taking measurements of the source voltage however, so you can ignore that column in the analysis window.

- Making measurements:
  - (a) A rule of thumb states that the time it takes for a capacitor to charge from 10% to 90% of its maximum value is approximately equal to 2.2 times the time constant for that circuit. Move one cursor to where it intersects the curve at a value of 0.5V (10% of 5V) and the other to 4.5V (90% of 5V). Keep track of the voltage value the cursor is at by watching the *Transient Analysis* window. When you are as close as you can get to 0.5 and 4.5V, take note of the elapsed time difference between them. Divide this time value by 2.2 to calculate the time constant. How does this number compare to the RC time constant value you calculated in the pre-lab?
  - (b) Leaving one cursor at the origin, position the second cursor at the 150ns mark. Read the capacitor voltage at this point. Does this value agree with what you calculated in part 2b of the pre-lab?
  - (c) Leaving the cursors as they are (in step 2 above), label your plot (Edit: Page Properties). In the Title window type your name and "RC=50ns".
  - (d) Print the plot. To keep from using an entire sheet of paper for the print job, go to *File: Print*. In the *Select Pages* window select the active tab to print (should be already checked) and click OK. When the print dialog window opens, click on the *Properties* button. Locate *Pages per*

*sheet* and choose 4 which will force your printout to a quarter-page size. Print the plot and tape it into your lab book. Note that it will print black on white regardless of whether you have selected the white or black background on the display.

## Part 2

1. Theoretical work for Figure 4 below:

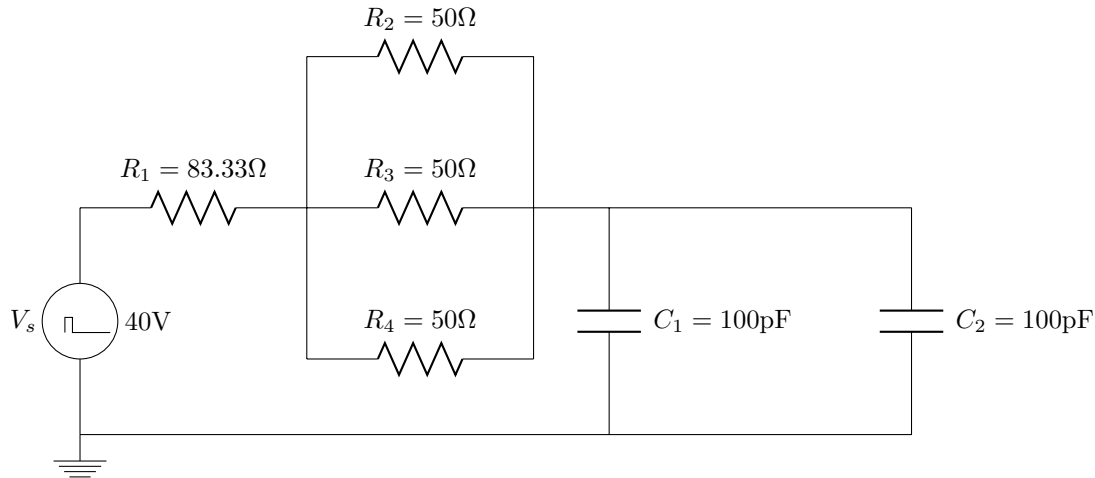


Figure 4:

- (a) Using what you know about the series and parallel relationships of resistors and capacitors, reduce the schematic in to a circuit with a single equivalent resistor and capacitor. Fully label your schematic.
  - (b) What is the RC time constant for the circuit?
  - (c) Sketch the capacitor charging and discharging curves using the 2/3 approximation method. Fully label your plots.
2. Create the circuit in Figure 4 using Multisim. Use the full diagram rather than your reduced version. Remember to close the old design file and start a new one for this circuit. Save your drawing, print out a copy (make it small enough to fit nicely in your lab book!), and tape it into your lab book.
    - Configure the *Transient Analysis*: Remember from earlier, go to the *Simulate* menu and select *Analyses: Transient Analysis*.
      - For  $V_s$ , configure a pulse signal with a 40V peak amplitude that is 150ns in length. Use a period of 300ns.
      - We also want to use a shorter period of time for this plot because the time constant is shorter than the first circuit. In the *Analysis Parameters* tab, leave the start time at 0 and set the end time to 500ns. This will increase our accuracy when picking points on the plot. Also, you want to be sure you're plotting at least 100 points (check the box).

- Remember too that you'll have to add the proper variables to the list in the Output tab. There will be several voltages to choose from, and you want to plot  $V_{ceq}$  which is the voltage across the parallel capacitors... as usual, this means you'll have to look at the net report to determine which net connects  $C_1$  and  $C_2$  (or double click on the wire that connects them and it will tell you how it has named that node). There is more than one voltage that will look like a capacitor charge/discharge curve so you must first confirm the correct one.
  - Simulate and analyze your circuit as before.
    - Determine the time constant for this circuit by using the 10% to 90% risetime method.
    - Again on this plot, put your name and the time constant information in the plot title.
    - Print out a copy of your plot that shows the cursors in the 10% and 90% of total voltage amplitude positions. Remember to print 4 pages per sheet to control the size. Tape the printout into your lab book.
3. **Extra Credit:** Return to the Transient Analysis setup screen and configure it to plot the current through the main loop of the RC circuit (essentially this should be the same as the source current, so look at the netlist if necessary to determine which current to add to the plot list). Rather than adding it directly to the outputs list, instead create an expression that multiplies the current times (-50) which will magnify its magnitude (this makes it easier to see and undoes the negative reference Multisim uses to indicate that it's in the opposite direction of the source voltage drop). We are less concerned with the current value and more concerned with its behavior—the shape of the curve, so scaling it by a factor of 50 just helps us see it better, otherwise it would be so small compared to the voltages plotted that it would simply look like a flat line.

Simulate the circuit. Observe how the change in voltage corresponds to a change in current. Contemplate the reason for this relationship and explain why it looks like this. (If you have had calculus, knowing that current is the derivative of voltage will be helpful in your analysis, but you can still evaluate the relationships without calculus). How does change in voltage effect change in current? Why? Why is current changing signs as the capacitor alternates between charging and discharging (explain in terms of what is going on in the circuit, and in the mathematics if you know calculus). Print a copy of the plot and put it in your lab book.