CMPE 306

Lab VII: Transients in RC Circuits

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1. Purpose and Introduction

The purpose of this lab is to study the transient response of linear RC circuits with step inputs.

By the end of this labs session, students will be able to perform the following tasks:

1. Simulate an RC circuit in LTSPICE, including initial conditions.[1]
2. Construct an RC circuit on the breadboard.
3. Measure and illustrate characteristics of RC circuits.
4. Perform analyses on measured data to demonstrate the RC time constant.

2. Pre-Lab

For Spring 2014, this lab portion should be done using the circuit file provided on Blackboard. Figure 1 shows the first circuit for today's lab. For a pulsed voltage source, instead of the DC voltage value enter the PULSE command with the following parameters: `PULSE(V1 V2 Tdelay Trise Tfall Ton Tperiod Ncycles)`

For the pulsed voltage source circuit of Figure 1, we have an initial voltage (V1) of 0V, a final voltage (V2) of 6V, a time delay (Tdelay) of 0 sec, a pulse rise time (Trise) of 1 ns, a pulse fall time of 1ns, an on interval (Ton) of 0.5 ms, and a period (Tperiod) of 1 ms. I entered 1000 for Ncycles, the number of cycles, but the .tran command discussed below will modify this.

For the capacitor C1 in Figure 1, I have defined an initial condition (ic) of 0V.

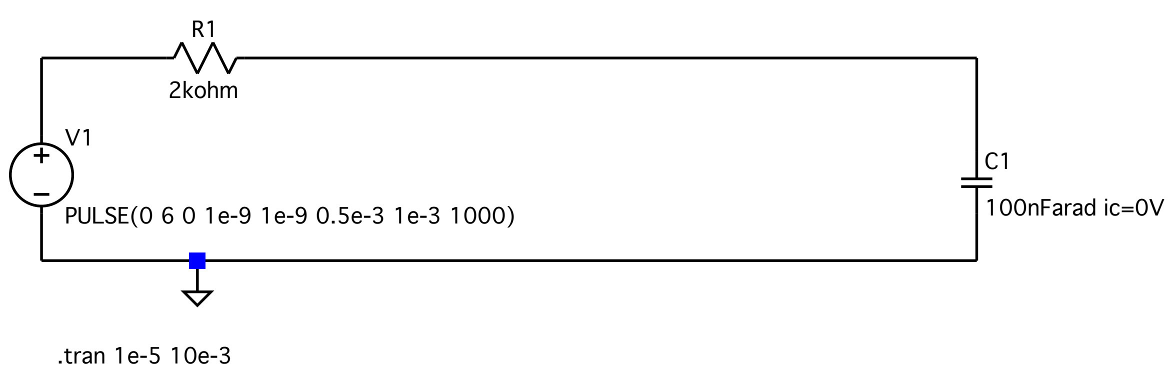

Figure 1 LTSPICE Simulation, Showing Pulsed Voltage Source, Capacitor Initial Condition, and Transient Response Command

1. Load the circuit file LabVII_RC1.cir containing the circuit of Figure 1. Run the simulation.

[1] This will eventually be a pre-lab exercise, but for Spring 2014 it is part of the lab itself.

2. From plotting window (which should come up immediately), select the Add Traces option. Add the trace for V(n001) and V(n002). You should see a plot that looks like Figure 2.

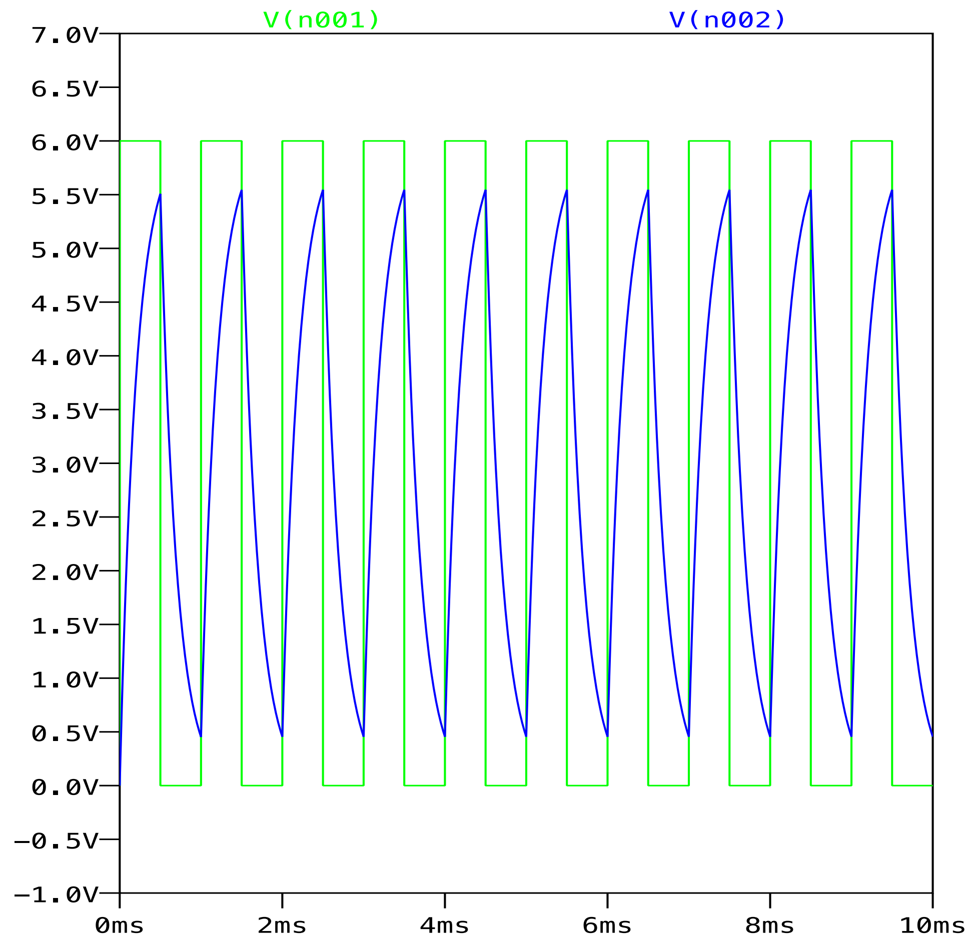

Figure 2: Square Wave input V(n001) and RC output V(n002)

3. Load the circuit LabVII_RC2.cir from Blackboard. This circuit is shown in Figure 3. Following the guidance given above, set the voltage source to be the same pulsed source as in Figure 1, and set the capacitor to a value of 100nF with 0V initial condition. Add the transient command.
4. Simulate the circuit. Plot and save the results for inclusion in the lab report.

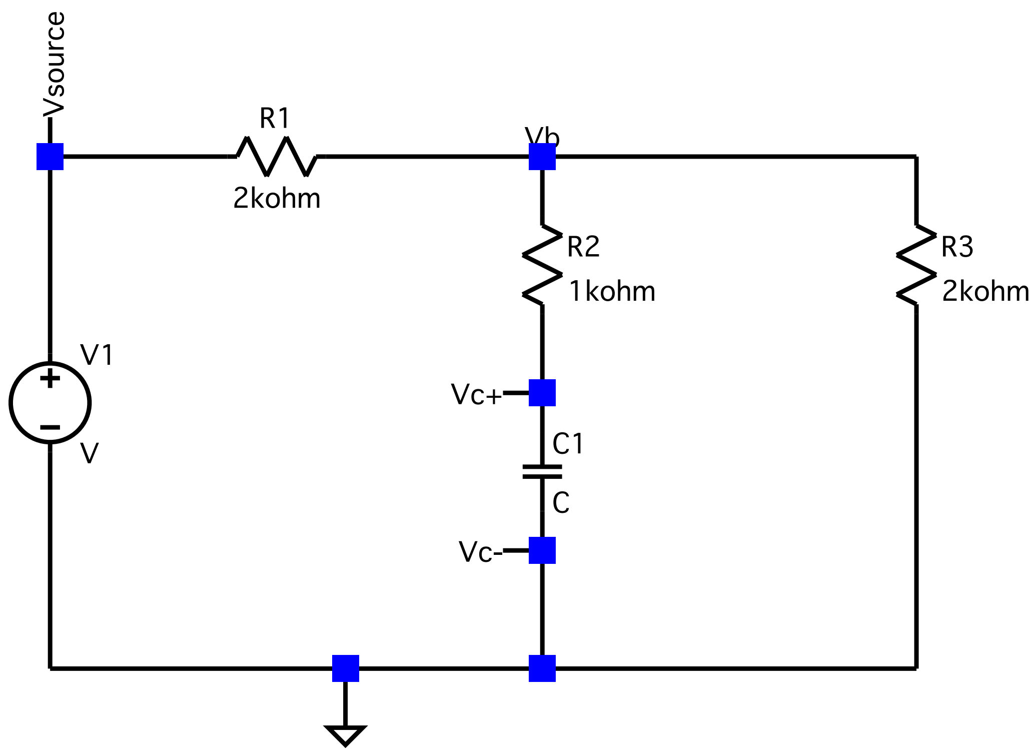

Figure 3 Circuit 2, without Voltage or Capacitor Definition

3. Equipment

This lab exercise uses the following equipment:

1) Tektronix AFG310 Arbitrary Function Generator
2) Tektronix 2012 Digital Storage Oscilloscope
3) BNC-to-BNC cable
4) Two BNC-to-alligator cables
5) $2\times 2\text{k}\Omega$, $1\text{k}\Omega$ resistors $2\times 20\text{k}\Omega, 10\text{k}\Omega, 51\text{k}\Omega$.
6) 100nF and 10nF capacitors.

4. .Procedure

4.1. Simple RC Network

1. Consider the circuit shown in Figure 1 Derive $v_C(t)$, and $v_R(t)$ for both the charging period $(0 < t < 0.5\text{ms})$ and the discharging period $(0.5\text{ms} < t < 1\text{ms})$ in lab report. Both partners may contribute to this derivation.

2. Using the square wave with DC offset from the function generator to create the periodic step function voltage shown as V(n001) in Figure 2. Note that the frequency of the AFG output is $\frac{1}{1\text{ms}} = 1000 \text{ Hz} = 1\text{kHz}$. Print and save the results (PR1).
3. Construct the circuit shown in Figure 1. Use the step function voltage created in 2) as the source.
4. Use the oscilloscope to measure the AFG input to the circuit (V(n001)) (using Channel 1) and the voltage across the capacitor (V(n002)) (using Channel 2) SIMULTANEOUSLY. Print Out the result (PR2). Vary the frequency of the square wave; observe, record, and comment the change of waveforms. Set the frequency back to 1kHz.
5. Measure the voltage across the resistor by displaying CHANNEL 1 – CHANNEL 2 on the oscilloscope. Print out the result (PR3). Is this what you expected from the measurement of step 4?
6. Calculate the time constants from measurements in 4) and 5). To do this, expand the time scale of the oscilloscope to have only two cycles on the display. Move the display using the horizontal position knob to place the start of the decay curve at the center reticule. Use the vertical cursor to find the level that is 36% of the peak voltage. Position the horizontal cursor at the intersection of the vertical cursor and the decay curve and read the time value from the time axis. Compare the two measured voltages with the theoretical calculations in lab report.
7. Change the capacitor to 10nF. Measure re-measure V(n001) and V(n002) and calculate time constants, using an appropriate frequency from the AFG. Print out the result (PR4). Comment on the results.
8. SHOW PRINT OUT (PR1~PR4) TO LAB INSTRUCTOR.

4.2. More Complicated RC Network

1. Construct the circuit shown in Figure 3. Use the same voltage source as in Step 2 of 4.1, above.
2. Derive the time constant in lab report from the circuit component values. Both partners may participate in this derivation.
3. Use the oscilloscope to measure $V_{Source}(t)$, $V_b(t)$, and $V_C(t)$, all relative to the ground. Print out the results (PR5, PR6, PR7).
4. Calculate time constants from measured $V_C(t)$. Compare with the predicted time constant in lab report. Both partners may participate in this comparison.
5. Use the results of Step 2 in this section to calculate all three resistor current. Use the computation to verify Kirchhoff's current law for $t = 0^-, 0, 20\mu\text{s}$, and $30\mu\text{s}$) in your lab report.
6. SHOW PRINT OUT (PR5~PR7) TO LAB INSTRUCTOR

4.3. Preparation for Next Lab

Next week, your Lab VIII will make use of capacitors and op amps. I will attempt to have the new lab writeup posted by class time on Thursday.

For the lab report for this week, please include all of the plots that you were asked to save, and all of the values you were asked to record.   Partners should participate in the derivations. Please indicate in your report if your partner participated or not.

5. Tear Down and Clean Up

1. Turn off the power supply, AFG, and oscilloscope and set the multimeter to the OFF position. Return the multimeter to your TA for storage.
2. Save your images or data to your memory stick. Then close the program and sign off of the computer.
3. Put your resistors and capacitors chip back in your lab kit. Return your lab kit to the TA for storage.
4. Return the BNC cables and BNC-to-alligator cables and hang them neatly in their proper rack.
5. Police your lab area: leave it neat and clean.
6. If you’re using your own laptop, there’s nothing else to clean up.
7. If you’re using the lab computer, save whatever work you want to your USB drive. Close LTSPICE if necessary. Eject your drive.