University of Utah
Electrical & Computer Engineering Department
ECE 2210 Lab 8
Transients

Note : Bring a book to lab that shows second order differential equation solutions (underdamped, critically damped, and overdamped).

Objective
Observe the transient voltages present in RC, RL, and RLC circuits.

Equipment and materials from stockroom:
● ECE 2250 kit (If available)
● Resistor substitution box

Parts:
The following items may be bought from stockroom or may be in the ECE 2210 kit.
● 0.001 µF (may be marked 102) and 0.22 µF (224) capacitors
● 100 Ω (brn, blk, brn), 1 kΩ (brn, blk, red), and 22 kΩ (red, red, org) resistors
● 3 mH inductor

General Setup

Switch both scope inputs to DC and set the triggering to INT and CH2. Make sure all **CAL** knobs are clicked in position. Connect a BNC "T" connection to the output of the function generator. Hook one side of the "T": to CH2 of the scope and the other to a BNC-to-clip lead. This will be the input signal for all the circuits that follow.
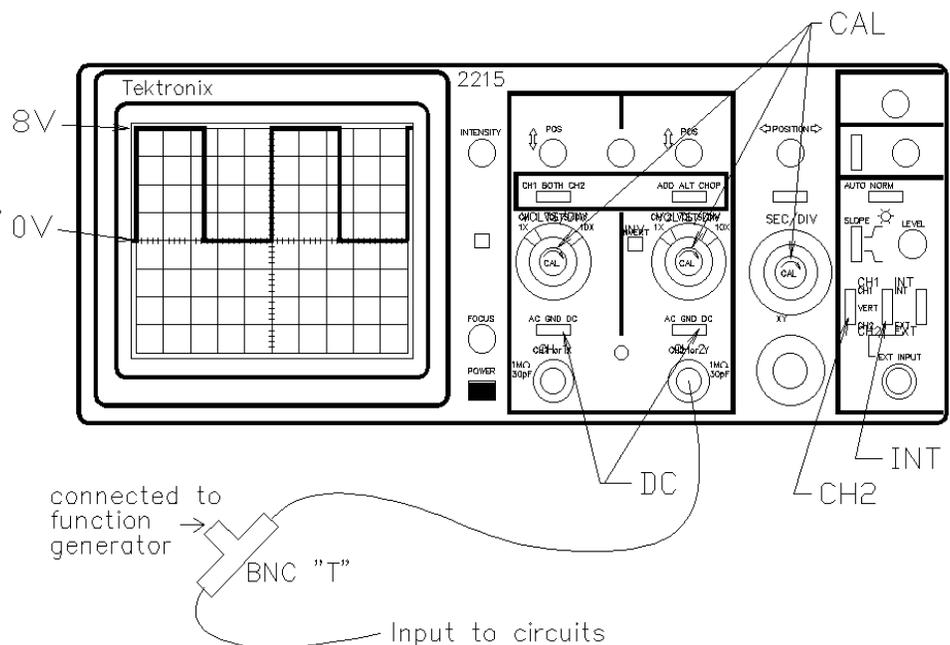
Set the HP or Agilent function generator to 4 Vpp square wave (actual output will be 8 Vpp). Press the "Offset" button on the function generator and adjust the DC offset to 2 V (actually 4 V). Display this waveform on the scope so that the center is 0 volts and the top is at 8 volts. This waveform will mimic the action of a switch that is alternately connected to a 8 V source and then ground, with one minor difference. The signal generator has 50 Ω output resistance that you should include in your circuit and calculations. It will simply act like an extra 50 Ω resistor in your circuit, located between the switch and the other elements.

Experiment 1, RC Transient

Construct the RC circuit shown on the next page. Set the function generator frequency to about 20 Hz. Set the scope to view CH1 and adjust it so that you can see two transients with each trace. You should see one transient when the signal generator "switches" from 0 to 8 V, and another when the function generator "switches" from 8 to 0 V.

I chose a low frequency for this first part so that you can see the scope beam move across the screen as it traces the transient response. Hopefully, with the scope trace moving so slowly, you won't forget that the horizontal axis represents time.
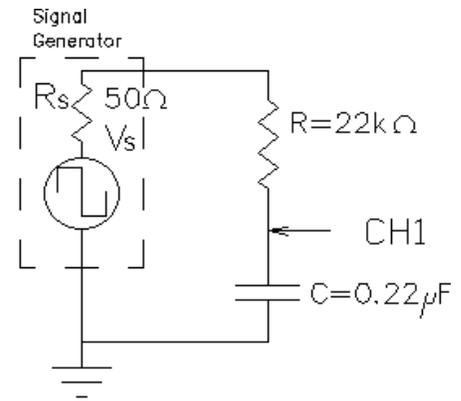
Observe the transient. Does it look like an exponential curve? Does the capacitor voltage ever change from one value to another instantaneously? Draw this transient (v_C) in your lab notebook. Make the vertical axis range of your drawing at least -8 V to +8 V so you can add a drawing of the resistor transient (v_R) later.

Measure the time constant of this RC circuit. Measuring time constants can be a pain, but there is a little trick that you can use on the scope which will let you make this measurement a little faster. It turns out that $e^{-1} \approx 3/8$. Since there are 8 vertical divisions on the scope screen, if you can make the trace fill the screen properly, the trace will cross 5 (8-3) of those divisions in one time constant. Turn the TIME/DIV CCW until you can see the horizontal part of your exponential curve. That will be the steady-state value. Adjust the vertical POS knob so that this steady-state value is either the top or the bottom line of the screen. Adjust the VOLTS/DIV until the curve covers at least all 8 vertical divisions (don't worry if part of the curve is off the screen). Recheck the steady-state value, then turn the TIME/DIV CW until you can see a good exponential curve. Measure the time constant as shown below. You can measure either the charge curve or the discharge curve of the capacitor, but do confirm that the other curve appears to have the same time constant. (If you switch the trigger SLOPE
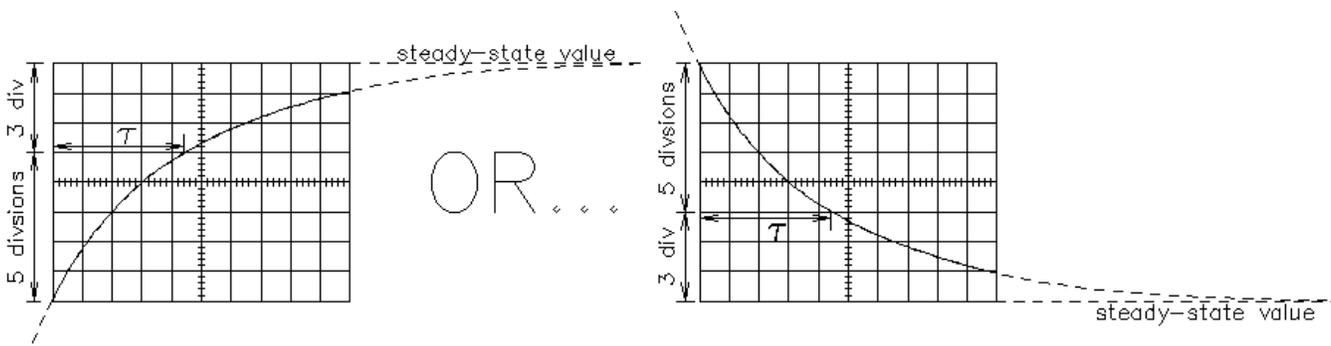

switch on the scope, you will change the visible curve.)

Calculate the time constant for this circuit and compare it to your measurement.
Swap the positions of the resistor and capacitor. Sketch this new transient (v_R) on your

previous sketch. If you added these two traces at each moment in time, would the sum be the input voltage (8 V)? Does the time constant of v_R appear to be the same as v_C?

Experiment 2, RL Circuit

Build the RL circuit shown at right. Turn up the function generator's frequency to about 2 kHz. Repeat all of experiment 1 for the RL circuit, except for the very last part where you switch the part positions. (You may do that for extra points.) Don't be surprised if you see the inductor voltage change instantaneously, in the inductor it's the current which shouldn't change instantaneously.
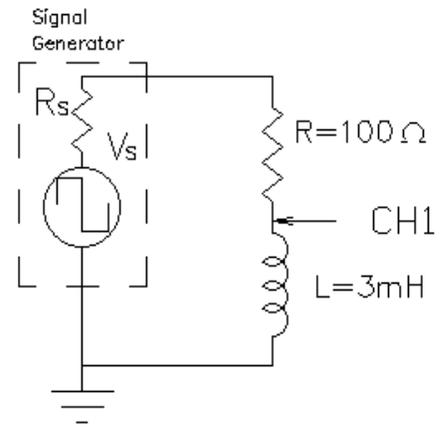
Remember to include the function generator's 50 Ω in your calculations (R=150 Ω for time constant calculation).

Experiment 3, Series RLC Circuit

Construct the circuit shown at right. Set the substitution box to 0 Ω (or temporarily short it). Observe the transients. Are they the type of thing you expect? Switch the scope trigger SLOPE to look at other transient. Sketch at least one of them in your notebook. Measure the frequency of the *ringing* (oscillation). Remember that the frequency is 1/T (the period). Try to measure the time constant of the decay, look at the drawing below. Look at the calculations in the appendix and find the calculated values for ω, f, α and τ for this circuit. Compare your measured f and τ to the calculated values
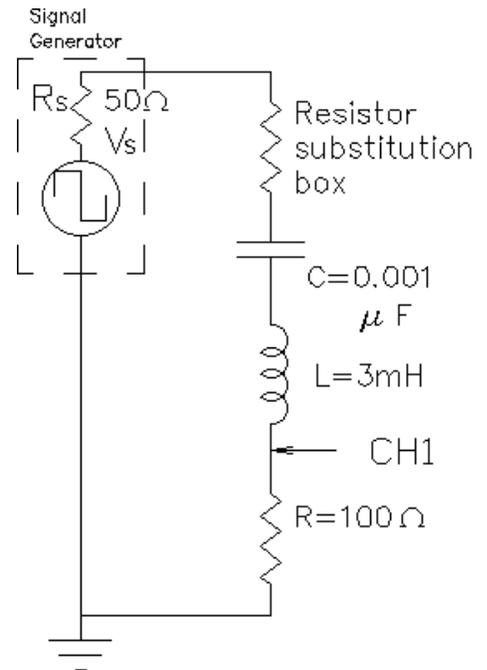
Increase the circuit resistance using the substitution box. At some value of R, you will get critical damping. (Look at your ODE book or a circuits book for a figure showing critical damping.) Adjust the substitution box value and try to find the R that causes critical damping. It turns out to be very difficult to see if the curve is underdamped (ringing), critically damped (one ring) or overdamped (no ringing). It all looks about the same when you're close to the critical damping point. That's OK, do the best you can. I actually want you to see that these curves aren't very different from one another, even though they are calculated very differently. Comment on this in your notebook. Record your R and then add 150 Ω to it to account for the other resistances in this circuit and call the total R_T. Compare this value to the R_T value calculated from theory in the appendix.
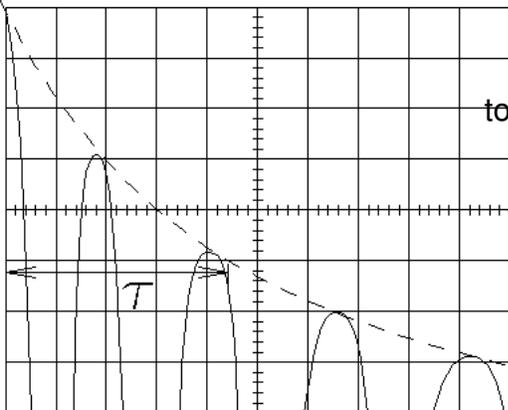
Experiment 4, Parallel RLC Circuit

Measure the winding resistance of your inductor (R_L) with an ohmmeter. Construct the circuit shown at right. Note that R_L is part of your inductor and is not added separately. It is shown here so that you can see how it's included in the calculations.

Reduce the signal generator frequency to about 200 Hz and observe the transients. Are they the type of thing you expect? Change the scope trigger slope to look at both transients. Sketch one or both of them in your notebook. Measure the frequency of the *ringing* (oscillation) and try to measure the time constant of the decay. Compare your measured f and τ to the calculated values you can find in the appendix.
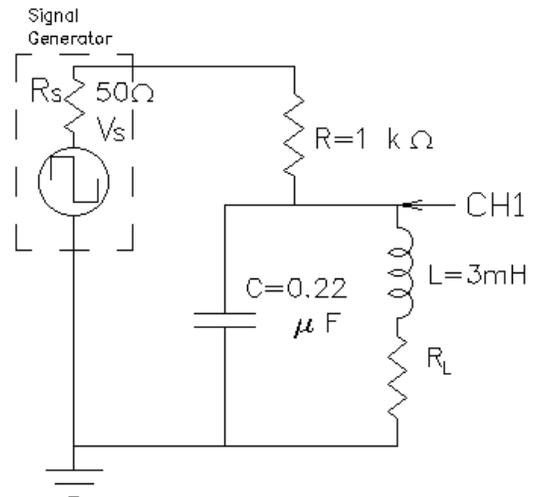
Conclusion

As always, check off your notebook.

Be sure to comment about how well theoretical calculations describe the actual circuit behaviors. Talk about how well general waveform shapes agree as well as measured numbers.