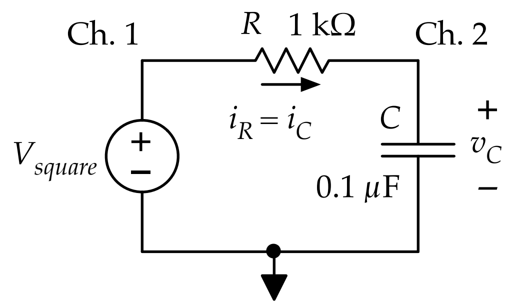
## RC, RL, and RLC transients

This week, we examine simple *RC* and *RL* transients, and take a brief look at *RLC* transients. Be sure to bring a flash drive for recording oscilloscope traces. During lab, your lab instructors will demonstrate the use of cursors on the oscilloscope to measure particular times and voltages. Also, be sure to measure the values of the components used in your circuits.

### RC transients

Build the circuit shown in Fig 1. The source voltage is the function generator set to produce a square wave. (Don't forget to set the output to "High Z".) Set the square-wave amplitude so that the square wave oscillates between 0 V and +10 V. (Set the "high" and "low" values directly. Or set the amplitude at 10 $V_{pp}$ and introduce an offset of +5V.) Set the square-wave frequency to 500 Hz.

Figure 1.




1. Calculate the expected $V_i$ and $V_f$ of the capacitor voltage for the upward and downward transitions. Calculate the expected peak value of the capacitor current during the transient. Also, calculate the time constant for the rising and falling transients. Make sketches of the expected upward and downward transients.

2. Observe the source voltage and capacitor voltage simultaneously on the oscilloscope. Adjust the time and voltage settings so that you can clearly see the rising and falling transients of the capacitor. Record a clear trace of the rise and the fall for your report.

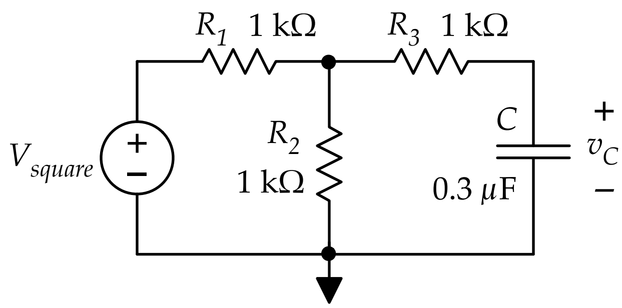
3. Use the oscilloscope cursors to measure the time constants of the rise and of the fall. To do this, measure the time needed to reach 6.32 V during the charging phase and 3.68 V during the discharge phase. (In your report, be sure to explain why these voltages correspond to one time constant.)

4. Use the math function (A-B) to display a trace of the resistor voltage. Of course, the resistor voltage provides a direct measure of the current in the circuit. Display the current transient together with the capacitor voltage transient. Record a clear trace for your report.

5. Compare the measured results with your expectations.

Now build the circuit shown in Fig. 2. (You may need to use a combination of capacitors to obtain 0.3 $\mu$F. If you are not sure of the value of whatever combination you have made, take your breadboard to the LCR meter and measure it.) Again, use a square wave as the source. Set the square wave amplitude so that it oscillates between 0 and 10 V and the frequency to 100 Hz. (If needed, you can adjust the frequency to help produce a better trace on the oscilloscope.)

Figure 2.




1. Calculate the expected $V_i$ and $V_f$ of the capacitor voltage for the upward and downward transitions. Calculate the expected peak value of the capacitor current during the transient. Also, calculate the time constant for the rising and falling transients. Make sketches of the expected upward and downward transients.

2. Observe the source voltage and capacitor voltage simultaneously on the oscilloscope. Adjust the time and voltage settings so that you can clearly see the exponential transients of the capacitor. Record a clear trace.

3. Use the cursors to measure the time constants of the rise and of the fall. (Note that the voltage swing is smaller in this circuit, so you can't use 6.32 V to determine one time constant. Instead, choose a voltage that is in the middle of the swing, find the corresponding time, and use the results in the the capacitor charging equation to calculate the time constant.)

4. Use the oscilloscope math function to observe the capacitor voltage together with the voltage across $R_3$, which provides a direct measure of the capacitor current.

5. Compare the measured results with your expectations.

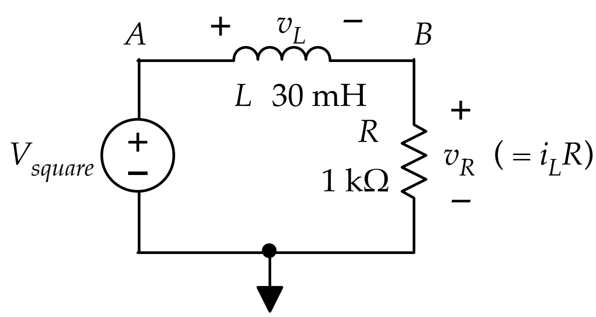
### RL transients

Build the circuit shown in Fig 3. using two of the 15-mH inductors in series to create a 30-mH inductance from the lab. Note that the circuit is the Thevenin equivalent of the standard current source / resistor / inductor circuit that we worked out in detail in lecture. Use the same amplitude for the square-wave source, but set the frequency to 2000 Hz.

Use the ohm-meter to measure the *resistance* of the two inductors in series. Note that this will have affect your measurements — the parasitic resistance will reduce the maximum current and create a resistive voltage divider in the circuit, requiring you to adjust your calculations accordingly.

For further insight into what will happen, look at the inductor SPICE problem of homework problem. In fact, you may even want to include the results from that SPICE simulation in the report for this lab.

Figure 3.




1. Assuming that the inductor is ideal, calculate the expected $I_i$ and $I_f$ of the inductor current for the upward and downward transitions. Then calculate again, but include the measured parasitic resistance of the inductor. Calculate the expected peak value of the inductor voltage during the transient. Also, calculate the time constant for the rising and falling transients. Make sketches of the expected upward and downward transients.

2. Observe the source voltage and *resistor* voltage simultaneously on the oscilloscope. Of course, the resistor voltage is a direct measure of the current in the circuit. Adjust the time and voltage settings so that you can clearly see the exponential transient of the resistor voltage. Also, you can adjust the frequency of the source if that helps provide a more useful waveform. Record a clear trace for your report.

3. Use the cursors to measure the time constant of the rise and fall of the current.

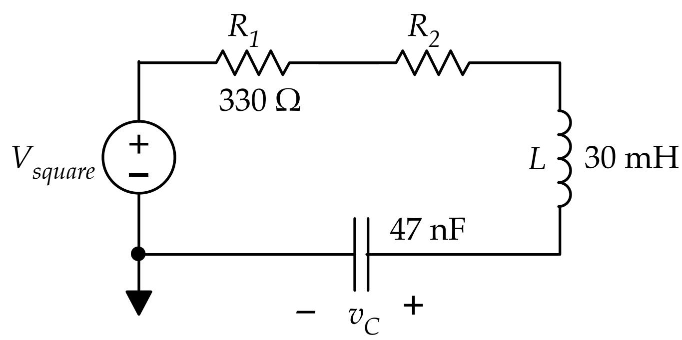
4. Use the math function (A-B) to display a trace of the inductor voltage. Display the inductor voltage waveform together with the resistor voltage. Record a clear trace for your report.

5. Compare the measured results with your expectations.

## RLC transients

Build the circuit shown in Fig 4. The source is a square wave that switches between 0 and 10 V with a frequency of 500 Hz. (If needed, you can change the frequency in order to get clear oscilloscope traces in the following measurements.)

Figure 4.




1. Set $R_2$ = 3.3 kΩ. Do a calculation to show that this corresponds to the circuit being overdamped. Then observe the source voltage and the capacitor voltage together on the oscilloscope. Record a set of traces for your report. Use the cursors to measure the 10%-90% rise and fall times.

2. Now set $R_2 = 0$ (i.e. remove it). Do a calculation to show that this corresponds to the circuit being underdamped. Calculate the expected oscillation frequency. Then observe the source voltage and the capacitor voltage together on the oscilloscope. Use the cursors to measure the frequency of the ringing oscillation. Record a set of traces for your report. Compare the measured frequency to your calculated value. (Include the series resistance of the two inductor when doing the calculations.)

3. Finally, use a 10-kΩ potentiometer for $R_2$. Observe the capacitor voltage together with the source voltage on the oscilloscope. Note how you can make the circuit switch back and forth between underdamped and over-damped behavior by adjusting the value of the pot.

## Reporting

Prepare a report discussing your calculations and measurements from each part of this lab. Be sure to include calculated and measured values for the time constants. (Measured means from the oscilloscope trace – not just from component values.) The report is due in one week at your lab time.