Electronics Lab

RL and RC circuits

Introduction:
This experiment is the first that deals with signals (voltages and currents) that change over time. In order to generate and analyze such signals, you will use two more pieces of equipment, the oscilloscope and the function generator.
In the experiment, you will use both one-time perturbations of a DC circuit (transients as induced by a switch) and continuously varying signals.

At the end of the lab, you will be able to:
- Describe how RC and RL circuits respond to varying signals.
- Measure the time dependent response of an RC/RL circuit
- Measure time dependent signals on the oscilloscope

Topics you need to be familiar with:
- Capacitors and inductors as energy storing circuit elements
- Transients in RC/RL circuits
- RC time constant
- Simple exponential functions, steady-state values

Questions

1. In what form do capacitors/inductors store energy?

2. Why can a circuit with a capacitor and n ($n>1$) resistors be reduced to a circuit with a single capacitor C and a single resistor R?

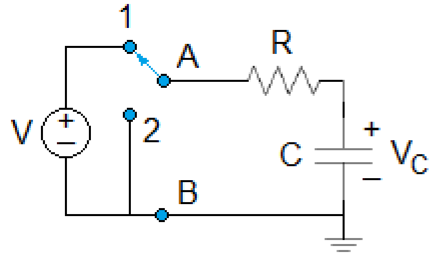
3. How do you get a short/long time constant in an RC/RL circuit?

4. What circuit elements do capacitors/inductors resemble immediately after a circuit has been perturbed? Why?

Experiment 1: Basic RC circuit

a) Calculate the time constant τ of the circuit shown below, where R is 10MΩ, C is 10μF and V is 10V.

b) What inductor would you use to obtain the same τ in an RL circuit?



Build the circuit. CAUTION: Make sure you connect the capacitor correctly (polarity!)

b) Throw the switch to position 1 and use a watch to record the capacitor voltage V_C as a function of time. Use the DMM to read off V_C. Then throw the switch to position 2 and record V_C versus t as the capacitor discharges. Consider the moment when you switch to position 2 as t=0 for this cycle. Repeat this measurement a few times (at least 3). Record your values.

c) Take the average value of V_C at your chosen times and plot V_C in volts versus time in seconds, for both charging and discharging cycles. For the charging cycle the capacitor voltage is

$$V_c = V_o e^{-t/\tau}$$

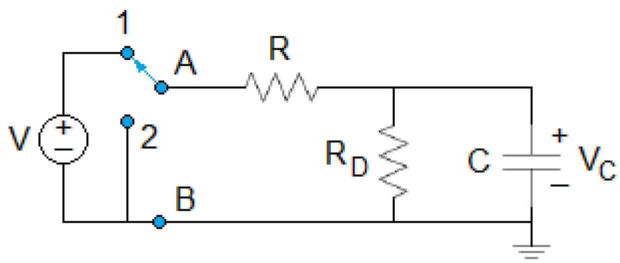
For the discharging cycle it is

$$V_c = V_o (1 - e^{-t/\tau})$$

Determine the RC time constant τ of the circuit, which is equal to the time after the voltage drops to 37% of its original value (discharging cycle) or rise to 63% of its final value (charging cycle). A more accurate way to determine the time constant for the discharging cycle is to plot the same data on a semi log-scale, i.e. plot $\ln(V_C)$ versus t because we can rewrite the equation for the capacitor voltage as $\ln(V_C)=\ln(V_o)-t/\tau$. What type of curve do you obtain? Find τ from this curve.

d) Compare your measured value for the time constant with your initial calculation. Discuss possible reasons for discrepancies.

e) One reason for inaccuracies is the finite resistance of the DMM R_D. Your circuit actually looks more like the following figure:



Calculate the time constant of this modified circuit.
Determine the internal resistance of the DMM from your measured data.

Experiment 2: Transient response on the oscilloscope

a) Replace your circuit elements with R=22kΩ and C=1μF. Calculate the new time constant.

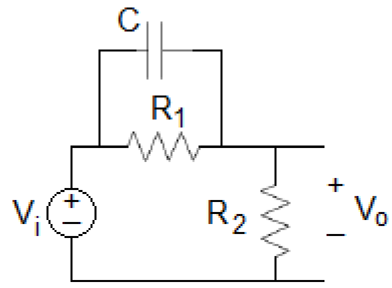
b) You will no longer be able to use a watch to observe the response. We will use the oscilloscope instead. The scope replaces the DMM in your circuit.

c) Replace the DMM with the scope. Use channel 1 across points A and B and channel 2 for V_C. Start with a sweep rate of 20 ms/div on the scope. Set the input coupling to DC and triggering to AUTO. Throw the switch back and forth and describe what you see on the scope.

d) Replace the circuit to the left of A and B with the function generator. Set the generator to a square wave with a period of 5τ. Set the scope's trigger to channel 1 and the triggering slope to positive. Observe the signal voltage V from the function generator on channel 1 and V_C on channel 2. Determine the time constant from the scope image.

e) Increase the frequency of the square wave signal. Adjust the time scale on the scope such that you see 2-3 periods of the applied signal on the screen. Observe V_C for each frequency and compare V_C and V. What happens as the frequency increases? Why?

Experiment 3: First order response of an RC network.



Using the supplied components, construct the circuit shown in the figure above on a breadboard. Use the values of R_1 = 100 kΩ, R_2 = 47 kΩ, C_1 = 0.1 μF or close to those values from the components available.

a) Calculate the time response of the circuit above.

b) Use the function generator to apply a step in the input voltage V_i and set the oscilloscope to record both the input V_i and output V_o of the circuit. Record the step response and determine the time constant τ. Compare the measured responses with those that you computed in part (a).

Experiment 4: RL circuit.

a) Build a circuit similar to the one from experiment 2, but using a 10mH inductor instead of the capacitor. Measure its time constant using the oscilloscope and function generator with appropriate values of resistance and frequency.