EE 220/220L Circuits I (Fall 2019)
Laboratory Project 10 RL and RC Circuits

Background

In this laboratory, we will be examining the voltages across a capacitor and an inductor when a rectangular pulse is input into the circuits shown below in Figures 1a and 1b. The resistance R_S is the internal resistance (i.e., Thevenin resistance R_T) of the function generator, not a separate resistor.

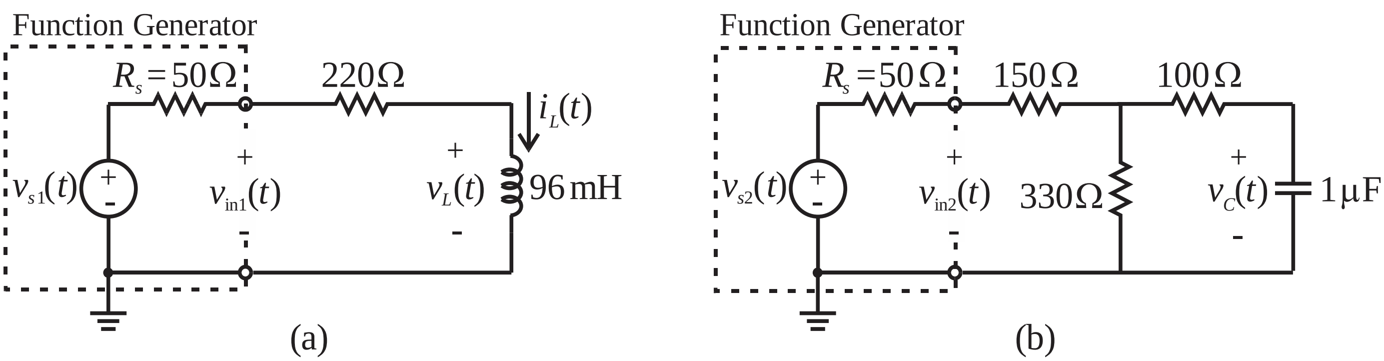

Figure 1 (a) RL and (b) RC step response circuits.

Preliminary

1) For an input signal or pulse $v_{s1}(t) = 7\,[u(t) - u(t - 1.2 \text{ ms})]$ V (a pulse with an amplitude of **7 V** and duration of 1.2 ms), find the current through the inductor $i_L(t)$ for $t \geq 0$ for the circuit shown in Fig. 1a. Then, find the voltage $v_L(t)$ across the inductor for $t > 0$. Assume $i_L(0) = 0$ A and the resistance of the inductor is negligible. Using MATLAB, calculate & plot $v_L(t)$ for $0 \leq t \leq 2.4$ ms. Insert plot and m-file in logbook. Label horizontal and vertical axes. Title plot "EE 220L Lab 10 RL circuit, *your name*, *date*". Put *filename*, EE 220L Lab 10, RL circuit, *your name*, & *date* in comment lines at top of m-file.

2) For an input signal or pulse $v_{s2}(t) = 7\,[u(t) - u(t - 1.2 \text{ ms})]$ V (a pulse with an amplitude of **7 V** and duration of 1.2 ms), find the voltage $v_C(t)$ across the capacitor for $t \geq 0$ for the circuit shown in Fig. 1b. Assume $v_C(0) = 0$ V. Using MATLAB, calculate and plot $v_C(t)$ for $0 \leq t \leq 2.4$ ms. Insert plot and m-file in logbook. Label horizontal and vertical axes. Title plot "EE 220L Lab 10 RC circuit, *your name*, *date*". Put *filename*, EE 220L Lab 10, RC circuit, *your name*, & *date* in comment lines at top of m-file.

3) Have the lab instructor/TA sign your preliminary before you do the experiment.

Experiment

1) With function generator connected directly to the oscilloscope, set up $v_{s1}(t)$. Use a 416.7 Hz (2.4 ms period) **7 V_{pp}** square wave for the input with the DC offset adjusted so that the "negative" half-cycle is at 0 V. Measure and record the value of the resistor and DC wire resistance of the inductor R_{wire}. Then, set-up the RL circuit shown in Fig. 1a (remember that R_s is internal to the function generator). Adjust the function generator and oscilloscope so that you see only one period ($T = 1/f$) with CH1 and CH2 reference levels **centered** on screen.

   a) Display the input $v_{in1}(t)$ (CH 1) and output $v_L(t)$ (CH 2) voltages on the oscilloscope. Save **bitmap** image of oscilloscope display to a USB flash drive, print, label waveforms, and insert in logbook.

   b) Measure (use cursors) and record (in table) $v_L(t)$ at 0.2 ms (200 µs) intervals for $0 \leq t \leq 2.4$ ms. Note, you will need to separately record both $v_L(t = 1.2^- \text{ ms})$ and $v_L(t = 1.2^+ \text{ ms})$.

2) With function generator connected directly to the oscilloscope, set up $v_{s2}(t)$. Use a 416.7 Hz (2.4 ms period) **7 V_{pp}** square wave for the input with the DC offset adjusted so that the "negative" half-cycle is at 0 V. Measure and record the values of the resistors. Then, set-up the RC circuit shown in Fig. 1b (remember that R_s is internal to the function generator). Adjust the function generator and oscilloscope so that you see only one period ($T = 1/f$) with CH1 and CH2 reference levels at **bottom** of screen.

   a) Display the input $v_{in2}(t)$ (CH 1) and output $v_C(t)$ (CH 2) voltages on the oscilloscope. Save bitmap image of oscilloscope display to a USB flash drive, print, label waveforms, and insert in logbook.

   b) Measure (use cursors) and record (in table) $v_C(t)$ at 0.2 ms (200 µs) intervals for $0 \le t \le 2.4$ ms. Also, estimate/measure $V_{C,SS}$. [**Hint:** Increase period (or lower frequency) on function generator to allow circuit more time to reach steady-state, will need to increase time scale on oscilloscope.]

3) Have your experimental data signed-off before tearing down the last circuit.

Analysis and Conclusions

- Use the measured $v_L(t)$ data to find the measured time constant $\tau_{RL,\text{meas}}$ & functions for $v_L(t)$. Then, use the measured resistances (don't forget R_s & R_{wire}) and $\tau_{RL,\text{meas}}$ to estimate the actual inductor value L_{meas}.
- Use the measured $v_C(t)$ data to find the measured time constant $\tau_{RC,\text{meas}}$ & functions for $v_C(t)$. Then, use the measured resistances (don't forget R_s) and $\tau_{RC,\text{meas}}$ to estimate the actual capacitor value C_{meas}.
- Compare the measured time constants and component values to those calculated/used in the preliminary (use two tables & show % differences). Discuss/explain any differences.
- For each circuit (i.e., once for RL circuit and once for RC circuit), use Matlab to plot the measured data (dots), your analytic solution from the preliminary (dashed line), and your experimental solution (solid line) for the output voltages for times $0 \le t \le 2.4$ ms on a single graph (use a legend). Label horizontal and vertical axes. Title plot "EE 220L Lab 10, R*x* Circuit, *your name*, *date*". Put filename, EE 220L Lab 10, part *x*, your name, & date in comment lines at top of m-file. Cut & paste m-file and figure from MATLAB into a computer-generated document and insert into your logbook.
- Is it reasonable for the form of the inductor current to resemble the capacitor voltage, and for the capacitor current to resemble the inductor voltage? Why?

Hint: To find experimental time constants, consider a portion of the $v_L(t)$ or $v_C(t)$ waveform where the voltage is decaying from some starting value V_{start}. Then, after some time interval $\Delta t = t_{\text{start}} - t_{\text{later}}$, the voltage has decayed to some smaller value $V(\Delta t)$. Mathematically, this gives:

$$V(\Delta t) = V_{\text{start}} e^{-\Delta t/\tau_{\exp}} \quad \Rightarrow \quad \tau_{\exp} = \frac{-\Delta t}{\ln(V(\Delta t)/V_{\text{start}})} = \frac{\Delta t}{\ln(V_{\text{start}}/V(\Delta t))}$$

To minimize measurement errors, calculate $\tau_{\exp}$ using several data points $V(\Delta t)$ where voltage is changing significantly with respect to time and take an average. Use same V_{start} for all calculations. To better understand, the process, see the Lab 10 example posted under the EE 220 Lab link or http://montoya.sdsmt.edu/ee220/handouts/first_order_circuits_time_domain_measurements.pdf.