LAB 25. OSCILLOSCOPE

Problem

How can we observe transient signals that are too fast for our senses to follow?

Equipment

Signal generator (computer with Capstone installed, ScienceWorkshop 750 Interface), multimeter, connector wires, precision resistor box, oscilloscope, capacitor, resistor, inductor

Background

A capacitor in series with a resistor charges and discharges in an exponential decay. If the capacitor's starting voltage is V_1 and the input voltage is switched to V_2 at time $t = 0$, the capacitor's voltage decays as $V = V_2 + (V_1 - V_2)\, e^{-t/\tau}$, where $\tau = RC$ is the time constant of the system.

In a similar fashion, an inductor in series with a resistor will show exponential changes in its voltage and current. At a steady voltage V_1, the current through the inductor and resistor will be $I_1 = V_1/R$. If the applied voltage changes to V_2 at time $t = 0$, the current will decay to $I_2 = V_2/R$ according to $I = \frac{V_2}{R} + \frac{V_1 - V_2}{R} e^{-t/\tau}$. Here, the time constant $\tau = L/R$.

Activity

We have only one oscilloscope and signal generator, so you may have to share, or to wait your turn.

RC Circuit

1. Set the signal generator to produce square wave output with an amplitude of 1 V. Connect the ground of the oscilloscope to the ground of the signal generator. Also connect the negative terminal of the circuit to the ground of the signal generator.
2. Connect the Channel 1 probe of the oscilloscope to the signal output of the signal generator. Verify that the output is a square wave, and verify the vertical (voltage) and horizontal (time) scales. (If the horizontal scale is off, you can adjust it using the "Horizontal Var Sweep" knob.
3. On the breadboard, make a series circuit in the order signal generator – resistor– capacitor – ground. Place the oscilloscope (Channel 1) probe at the input to the capacitor. Adjust the frequency and resistance to show good decay progress. Sketch the trace in your notebook. Note the amplitude and period of the signal.
4. Exchange the capacitor and resistor so that the order is signal generator – capacitor – resistor – ground. Place the oscilloscope probe at the input to the resistor. Sketch the trace in your notebook. Note the amplitude and period of the signal.

5. Measure and record the half-life $t_{½}$, the time for the signal to decay to ½ its initial value.
6. Repeat measuring the half-life with two more resistances. You may need to adjust the frequency of the signal and the parameters of the oscilloscope to get a reliable half-life reading.

LR Circuit

1. Change the circuit so that it contains a resistor and an inductor in the series generator-inductor-resistor.

Data Processing

Calculate the time constant τ from each measured half-life. From the resistance and the time constant, determine the capacitance of the capacitor or the inductance of the inductor.

Lab Report

Report your observations and findings in a written report with sentences and paragraphs. Use the standard sections: Abstract, Purpose, Theory, Experimental, Observations, Discussion, and Conclusion.

Theory Section

Identify the defining voltage formulas for capacitors, for resistors, and for inductors. Derive the differential equations governing the RC and LR circuits. Conceptually explain how the voltages across the resistor and capacitor in an RC circuit, and across the inductor and resistor in an LR circuit, change with time when the applied voltage changes.

Discussion Section

Report the qualitative shapes of the voltage signals across the capacitor and resistor, along with their periods and amplitudes. Do the shapes match their theoretically expected behaviors?

RC Circuits

Report your decay half-lives and estimated capacitances. If you could find the nominal capacitances of the capacitors, were they close to the capacitances you found from the signal decays? Compare and contrast the observed traces of the capacitor voltages and resistor voltages.

LR Circuits

Report your decay half-lives and estimated inductances. Compare and contrast the observed traces of the inductor voltages and resistor voltages.