E104: Laboratory 2

Forced Response for Electrical Systems

Oct 29, 1999, 11:00-12:30

1 Administrative

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- Lab 3 will take place on: Friday Nov 12
- The report for this lab is due on: Friday Nov 5

2 Objective

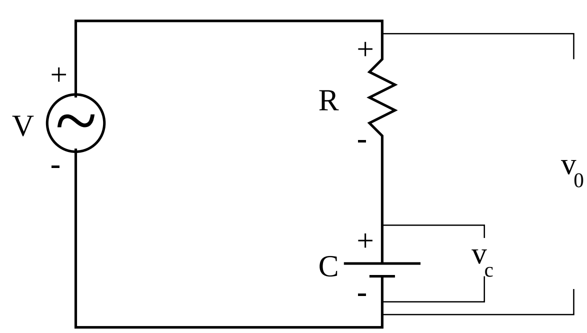
The objective of this lab is to analyze the forced response of a simple electrical dynamic system with capacitance and inductance. Specifically, we will determine the frequency response, transfer function and some physical parameters using a sinusoidal input.

3 Prelab

Read through the lab. This is a long lab, so you need to be prepared. Make sure that you understand how the circuits work and derive the equations before the lab. If you have questions, send me e-mail.

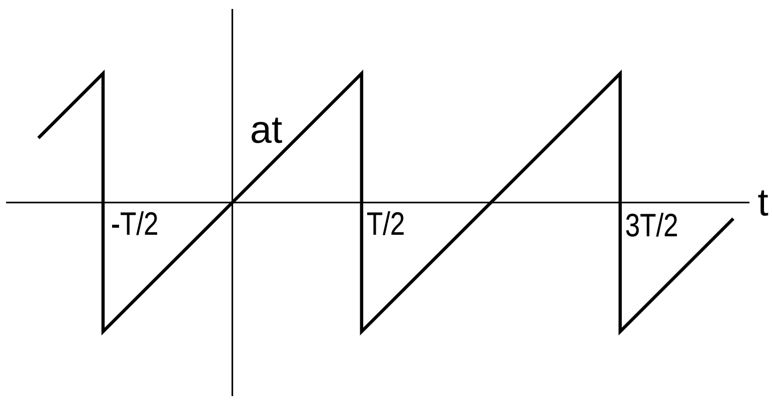
4 Forced and Total response of the RC circuit

We are continuing with the RC circuit of lab 1. To look at forced response, we use a function generator instead of the constant voltage source. The circuit looks as follows:



Before connecting the function generator to the circuit, play around with it until you can generate waveforms that are positive, but below 10V ($0 < V_0(t) < 10V$) at all times; this is necessary to protect the electrolytic capacitor.

1. What is the transfer function from V_0 to V_C?
2. Generate a sinusoidal input V_0 (with an offset!) and examine the forced response (i.e., after the transient has died out). Measure the amplitude ratio and the phase difference between $V_0(t)$ and $V_C(t)$. Use this to get a better estimate of C. Do this at several frequencies (pick your own – which data points are most useful??). The math is very simple if you use the transfer function you derived earlier and work with complex numbers.
3. How does the superposition principle help here?
4. Now discharge the capacitor ($V_C(0) = 0$) before turning on the sinusoidal input $V_0(t)$. The total response will consist of the forced part you examined in the previous question and a transient part that depends on the initial condition. Make a sketch and give the analytical form of the total response (actual parameters not required).
5. Look at the response to square and sawtooth waves at several frequencies. Sketch the forcing function and the total response for an interesting case of the sawtooth input and record some data points. Do this well enough so that you can compare these to the theoretical response later.
6. Is this a useful circuit?



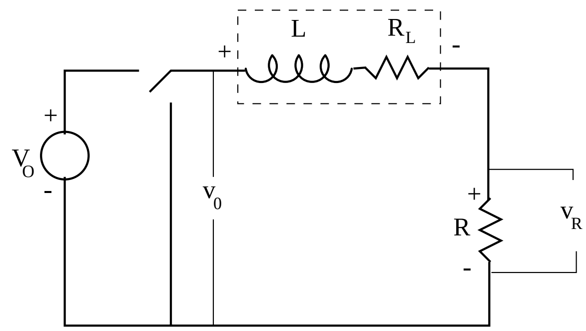
7. For the sawtooth input, calculate the total response $V_C(t)$ by solving the EOMs. Two hints: the forced response to a function of the form at will be of the form $At + B$ where A and B can be solved for by plugging the solution back into the equation of motion; the initial condition here is that V_C at the beginning of a period has to be equal to V_C at the end of the previous period.
8. Do the theoretical and actual response match?

5 Inductance

The goal of this experiment is to look at the behavior of an inductor (a.k.a. "coil" or "choke"). Just as we did for the RC circuit, we will look at the natural response and at the forced response for sinusoidal inputs.

1. Since we are working with a real inductor, we must come up with a good model for the coil (a wire around a metal core). It is not going to be a pure inductance L. Instead, since real wires have some small resistance, we will model our real inductor with an ideal inductor L in series with a resistor R_L.

2. First, we will look at the natural response, using the coil with a series resistor R. (The circuit diagram is shown below.) Derive the theoretical response using the EOMs for this system.



3. Measure the resistance of both the resistor and the inductor.

4. Sketch the natural response and compare it qualitatively to the theoretical response. What is the time constant for this system?

5. Next, we will look at the forced response of the coil. To do this, we will use the same circuit as shown above, leaving the switch in the powered position. Find the theoretical transfer function from V_0 to V_R.

6. Now apply a sinusoidal voltage and sketch the input and output curves on the same graph. What are good frequencies to use?

7. Measure the amplitude and phase difference between the input and output voltages. Using these values, compute the unknown parameter L in the model of the real inductor.