Lab 2 - Terminal Relationships

Objectives

The main purposes of this lab are to introduce the basic laboratory procedures necessary to evaluate the current flowing through single two-terminal components, to learn how to use breadboards to build circuits, and to use test and measurement instruments like an oscilloscope to perform measurements.

Laboratory Equipment

Solderless Breadboard

A breadboard is used to facilitate the construction of circuits by providing a means for making fast temporary connections between components. You can see that there are hundreds of holes on the board, and connections are made by placing two components or wires in different holes that are connected together under the board.

The connections follow a simple pattern, but getting the pattern wrong can result in serious circuit problems, so make sure you clearly understand the pattern. There is a pair of holes in a line which runs horizontally along the top of the breadboard and two lines running along the bottom. Each of these four lines has two metal strips running underneath. For each individual line, all of the holes are connected to each other under the board. The lines are marked with blue and red lines. They are typically used for ground and dc voltages, and sometimes for function generator signals.

Note that between these 4 lines of holes, there are 30 lines of holes. Each line has five holes, then a small plastic gap, and then five more holes. These holes are labeled a-e on one side of the gap and f-j on the other side of the gap. For each of the 30 lines, the five holes labeled a-e are connected together and the five holes labeled f-j are connected together. Most of the time, it will be between these sets of 5-hole connections that the components will be placed.

In this lab we will make use of a few resistors, inductors, capacitors, and a diode. In the following paragraphs we briefly describe the labeling scheme for resistors so that you can determine their values in the laboratory.

Resistors

Resistors come in many sizes and shapes (and types) and you can read about them in detail in catalogs, books, and on the Internet. We will always use resistors that are rated for a power of ¼ watt (above which they will get hot, start to smoke, and ultimately be destroyed). A standard color code is used to determine their value. There are generally 4 bands of color across the resistor, the rightmost band is the tolerance (the color that is not part of the code). The

remaining three colors determine the resistance according to the formula:

$$R = C_1 C_2 \times 10^{C_3} \quad \Omega$$

Where C1, C2 and C3 each represent digits from 0..9, according to the table below. Thus, if the color sequence were red-black-yellow [2,0,4], that would correspond to a R = 20 x 10^4 = 200 kΩ resistor. Remember that a DMM should always be used to get a more accurate answer for the resistance of a resistor, but the color codes are essential because a multimeter cannot be used to measure a resistor that is connected to the circuit, or soldered to a circuit-board. Resistors with tighter tolerance often have five bands, with the first three representing the resistance, the fourth representing the exponent, and the fifth designating the precision.

BLACK	0
BROWN	1
RED	2
ORANGE	3
YELLOW	4
GREEN	5
BLUE	6
VIOLET	7
GREY	8
WHITE	9
GOLD	±5%
SILVER	±10%

Pre-lab Preparation

1. Resistor: Calculate the current through a 51 Ω resistor when it is connected to an AC source with a peak-to-peak amplitude of 2V and a frequency of 5 kHz.
2. Capacitor operation: Calculate the current through a 0.1 µF capacitor when it is connected to an AC source with a peak-to-peak amplitude of 4V and a frequency of 5 kHz.
3. Calculate the current through a 10 µF capacitor when it is connected to an AC source with a peak-to-peak amplitude of 10V and a frequency of 5 kHz.
4. Sketch (do not calculate) what you expect the current through the capacitor to look like if the voltage source is a square wave.
5. Calculate the current through a 4.7 mH inductor when it is connected to an AC source with a peak-to-peak amplitude of 4V and a frequency of 5 kHz.
6. Sketch (do not calculate) what you expect the current through the inductor to look like if the voltage source is a square wave.

Instructions

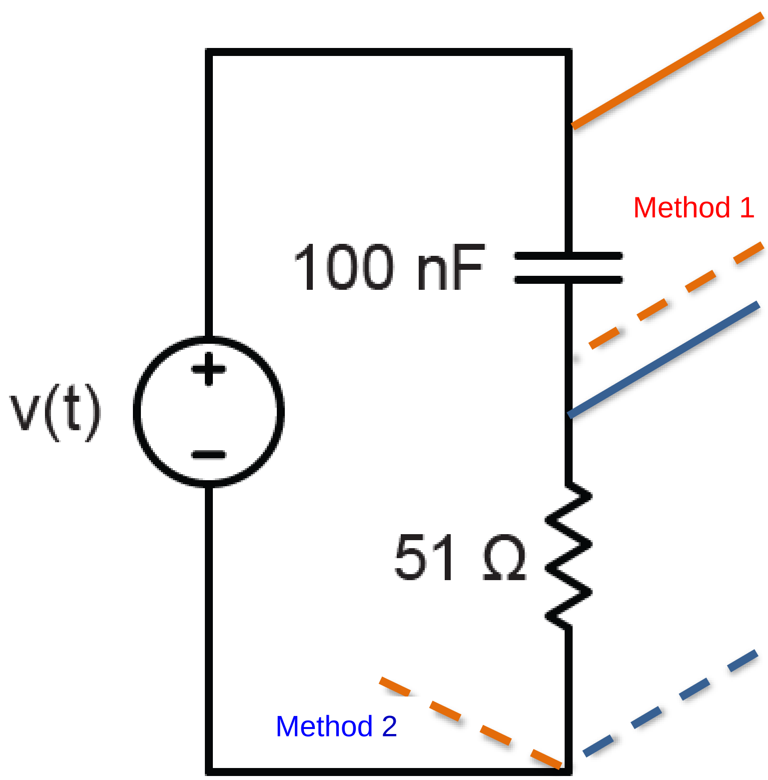
0. Measure and record the resistances and capacitances of the resistors and capacitors, respectively, that you will use in the lab.

Resistor

1. Connect a 1 kΩ resistor to the function (waveform) generator via the breadboard. Set the frequency to 5 kHz and the output to 2 Vpp. Make a plot of the output voltage for appropriate time and voltage scales.
2. Connect the 51 Ω resistor to the function generator via the breadboard. Keep the frequency at 5 kHz and the output at 2 Vpp. Make a plot of the output voltage for appropriate time and voltage scales.
3. Change the output to a square wave. Make a plot of the output voltage for appropriate time and voltage scales.

Capacitor

1. Build a series RC circuit with R = 1 kΩ and C = 0.1 μF. Set the sine wave frequency to 5 kHz and the output to 4 Vpp. Make a plot of the output voltages for appropriate time and voltage scales. You should plot the voltage across the resistor and the voltage across the capacitor.



Note, there are two ways of plotting these voltages on the ADALM2000 but only one way on most standard oscilloscopes.

Method 1: Since the ADALM2000's oscilloscope leads are floating (not grounded), you may (for example) connect the first probe across the capacitor, with the orange lead at the top and the orange/white lead below where the capacitor is connected to the resistor. Then you would connect the second probe to the resistor. The blue wire would connect to the same point as the orange/white wire and the blue/white wire would connect to the lower terminal of the resistor. In this configuration, the probes measure the voltages directly.

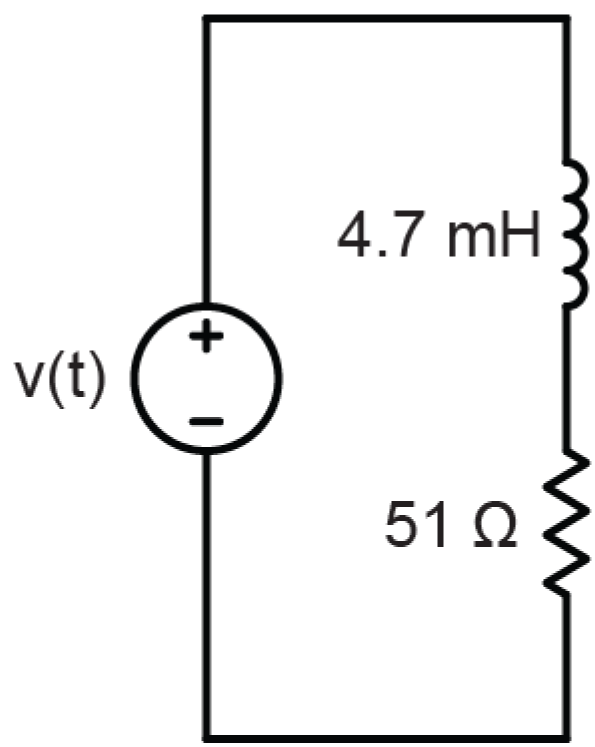
Method 2: However, standard oscilloscopes have grounded probes that must all be connected to the same node or the parts of the circuit will be "shorted out". The ground wire should be connected to the lower resistor terminal, which is connected to the power supply. For the

ADALM2000, this means that both the orange/white and the blue/white wires are connected together. Then the positive channel one probe would be connected to the top of the capacitor and the positive channel two probe would be connected to the top of the resistor. For this configuration, channel two reads the resistor voltage but the capacitor voltage is found via a math operation: the Channel one voltage MINUS the Channel two voltage. This later technique needs to be used onsite. Online students can use whichever technique they prefer.

2. In the circuit from the previous task, replace the 0.1 µF capacitor with the 10 µF capacitor and the resistor with 51 Ω. Set the sine wave frequency to 5 kHz and the output to 4 Vpp. Make a plot of the output voltages for appropriate time and voltage scales. You should plot the voltage across the resistor and the capacitor.
3. Change the output to a square wave. Make a plot of the output voltage for appropriate time and voltage scales.

Inductor

1. Build a series RL circuit with R = 51 Ω and L= 4.7 mH. Set the sine wave frequency to 5 kHz and the output to 4 Vpp. Make a plot of the output voltages for appropriate time and voltage scales. You should plot the voltage across the resistor and the voltage across the inductor.
2. Change the output to a square wave. Make a plot of the output voltage for appropriate time and voltage scales.



Post-lab Analysis

Generate a lab report "following" the sample report available in Appendix A. Mention any difficulties encountered during the lab. Describe any results that were unexpected and try to account for the origin of these results (i.e. explain what happened). In ADDITION, answer the following questions:

1. Do you think the function (waveform) generator is an ideal, independent voltage source? Why or why not? Justify your answer as clearly as possible – back up your answer with data!
2. Plot the voltage across and the current through the 0.1 µF capacitor. Is the current what you expected? Justify your answer with both text and equations.
3. Using the data for capacitor voltage and current, estimate the capacitances used in your circuit. How closely do they agree with the multimeter measurements (if you can measure capacitance)?

4. Describe the similarities and differences between the currents of the two capacitors subjected to sine waves. Did one perform more closely to the theoretical expectation than the other? Explain.
5. Explain the behavior of the current through the capacitor subjected to the square wave both qualitatively and quantitatively, if possible.
6. Plot the voltage across and the current through the 4.7 mH inductor. Is the current what you expected? Justify your answer with both text and equations.
7. Using the data for inductor voltage and current, estimate the inductance used in your circuit. How close is it to the nominal value (4.7 mH)?
8. Explain the behavior of the current through the inductor subjected to the square wave both qualitatively and quantitatively, if possible.
9. Which real components behaved more closely to ideal components: the inductors or the capacitors? Explain your answer and back your opinion with data!