EE2CI5 Lab 2: Resistive Circuits

1 Introduction

In circuits with only direct current (DC) sources, we can use a voltmeter to measure the potential difference between the terminals of a component in the circuit, and we can use an ammeter to measure the current flowing in a branch of the circuit. These meters have two probes, one of which is labelled positive, the other negative. Typically, the positive probe is red and the negative probe is black. A drop in potential from the positive probe to the negative probe registers a positive voltage, and the flow of positive charge into the positive probe and out of the negative probe registers a positive current. When designing a circuit experiment, as you will do in this lab, an important component of the design process is the choice of the voltmeter and the ammeter that will be used to perform the measurements. The importance of this choice is due to the so-called "observer effect" — the act of observing a phenomenon changes the phenomenon. In the design of an experiment, we need to ensure that the changes that are imposed by the measurement equipment are negligible. (Often we will also have to satisfy budgetary constraints, which will affect the nature of the measurement equipment that is available.) In selecting appropriate voltmeters and ammeters for an electrical circuit experiment, we need to consider the following:

- A voltmeter is connected in parallel with the component of interest, and hence it must have a relatively high resistance. This is necessary in order to ensure that when the meter is connected, the fraction of the current that flows through the meter rather than through the component is small. (The concept of current division is important in assessing this fraction.)
- An ammeter is connected in series with the branch of interest, and hence it must have a relatively low resistance. This is necessary in order to ensure that when the meter is connected, the fraction of the voltage that is dropped across the meter rather than across the components in the branch is small. (The concept of voltage division is important in assessing this fraction.)

In the lab, you will be introduced to the colour coding scheme for labelling resistors. As printing technology improves, and as passive components move to surface mounted form, the use of this code is decreasing, but it is still important in practice. The TAs will introduce the code in the lab.

2 Objective

The objective of this lab is for you to become familiar with hooking up series/parallel circuits with resistive elements, and calculating and measuring currents and voltages. It will also familiarize you with some of the difficulties associated with making current and voltage measurements.

3 Equipment

- Function generator
- Variable power supply
- Multi-meter.
  In voltmeter mode, the resistance of this meter is approximately 10 MΩ.
- Oscilloscope
- Hook-up wire
- Assortment of resistors (see below)

4 Resistor Values

In this lab, we will use moulded carbon resistors that are rated at 1/4 W. The values of the resistors that we will use are in the following table. You will be able to identify the resistors using the colour code.

Quantity	**Value**
1	56 Ω
3	100 Ω
4	390 Ω
4	1 kΩ
2	2.2 kΩ
1	3.3 kΩ
1	4.7 kΩ
1	5.6 kΩ
1	12 kΩ
1	18 kΩ
1	5.6 MΩ
1	10 MΩ

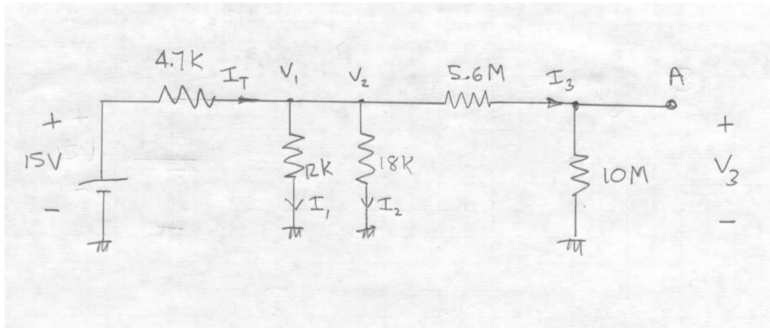

Figure 1: Circuit for Part 1.

5 Pre-Lab Exercises

This laboratory will consist of two experiments. The pre-lab exercises are arranged accordingly.

5.1 Analysis of a given circuit (2 marks)

Consider the circuit of Figure 1. Calculate the voltage values V_1, V_2 and V_3, and the current values I_1, I_2, I_3 and I_T.

5.2 Analysis of your own circuit (2 marks)

For this part, you can choose the circuit you wish to work on. Propose a circuit with two or three nodes or meshes, using only resistor values from the above table. Include a DC voltage source (which is your DC power supply) and a sinusoidal source, which is your function generator, set to a sinusoidal waveform. Due to the internal ground of the function generator described below, ensure that one terminal of the sinusoidal source is connected to the ground of your circuit. Note that if you work independently, it is quite unlikely that the circuit you propose here will be the same as that of any other lab group.

Analyze your circuit to obtain all values for several voltages and currents. The analysis is a bit tricky, but here are some hints.

- We can model the sinusoidal voltage waveform from the function generator as a function of time: $V_{ac}(t) = V_p \cos(2\pi f t)$, where f is the frequency in Hz, and V_p is the amplitude (1/2 the peak-to-peak amplitude).
- The DC voltage source can be modelled as $V_{dc}(t) = V_s$.
- To determine the voltage or current anywhere in the circuit, as a function of time, bear in mind that Ohm's law, KCL and KVL all hold at every instant of time.
- Alternatively, some of the circuit simplification techniques discussed in recent lectures may assist in your analysis.

6 Experiments

The laboratory consists of two experiments.

6.1 Circuit in Fig. 1

In this experiment we will consider the circuit in Fig. 1.

- **(1 mark)** Construct the circuit in Fig. 1, and measure the values that you computed in the pre-lab. Is there any discrepancy? If so, explain.
- **(2 marks)** For the write-up for this part of the lab, present your analysis of the above circuit, and then give your experimental results. *Note that a naive analysis will give a wrong answer.* This error is not due to resistor tolerance. Think about what is happening to the circuit when the voltmeter is placed across the output! Re-do your analysis to take this into consideration.

6.2 Your own circuit

In this experiment, you will consider your own circuit.

- **(1 mark)** Construct the circuit and measure the voltages and currents. Compare your theoretical findings with your measurements.
  - Note that the function generator connects to a co-axial cable. This means that one of the terminals of the function generator is a metal ring, and the other is a dot in the centre of the ring. The metal ring is connected to ground through the instrument. Therefore, in your circuit, you must connect the function generator from a node directly to ground. If it is connected across two non-grounded nodes, the one connected to the outer ring will necessarily become ground.
  - Do *not* use your ammeters or voltmeters for measurements in this part of the lab. Due to the fact that the waveforms are offset sinusoids, these instruments will give you the wrong answer. These instruments give an accurate representation of a sinusoidal waveform only if there is no DC offset. For sinusoidal waveforms, these instruments are calibrated to give the root–mean square (rms) value of the waveform, which is $V_p/\sqrt{2}$.
  - Use the scope to make voltage and current measurements. You can measure the current waveform through a resistor by placing a scope probe on each side of the resistor. Then set up the scope to show the *difference* between Ch1 and Ch2. The current value is then the difference voltage divided by the resistor value.
- **(2 marks)** For your write-up, show your proposed circuit, and all your analysis. Then present your experimental results, and compare them with your predicted values.