EXPERIMENT #1 DESIGN AND TESTING OF RESISTOR CIRCUITS ECE212H1F

OBJECTIVES:

- To apply your prior knowledge of circuit theory and your lab skills to carry out some simple exercises that involve design, analysis, implementation, and testing.
- By the end of this lab, students should be able to
    - remember the basic relationships of resistors in combination
    - remember the colour code for resistors (found in section 7 of the ***Laboratory Equipment Instruction Manual*** listed below)
    - remember how to carry out basic circuit measurements
    - design, implement, and test some simple resistor networks

GENERAL COMMENTS:

- This lab reviews the following concepts from ECE110 Electrical Fundamentals: resistive circuits, sinusoidal signals, and AC power. The concepts are summarized in the Introduction.

  References: 1) ***Laboratory Equipment Instruction Manual*** (handout posted on Quercus under 'Labs') and 2) Textbook, *Ch. 2 Basic Laws*.
- Review methods of DC voltage measurement, DC current measurement and resistance measurement using a digital multimeter, DMM.
- Recall that a signal has to be adjusted to a required value before it is connected to a protoboard.
- Bring a calculator for hand calculations.
- **Reporting Expectations:** Results computed in the design and analysis portion of each part of the experiment serve as a prerequisite for the experimental part. All calculations, analysis, design schematics, as well as subsequent measured and calculated results must be recorded in your lab-book. Your lab book must be bounded (e.g. no binders).

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INTRODUCTION:

(A) RESISTIVE NETWORKS

The purpose of this experiment is to review the basic relationships of resistors in combination:

In series, resistances add: $R_{eq} = R_1 + R_2 + R_3$

In parallel, conductances add: $G_{eq} = G_1 + G_2 + G_3$ or $R_{eq}{}^{-1} = R_1{}^{-1} + R_2{}^{-1} + R_3{}^{-1}$

Voltage division: $V_{out} = \frac{R_2}{R_1+R_2} \times V_{in}$

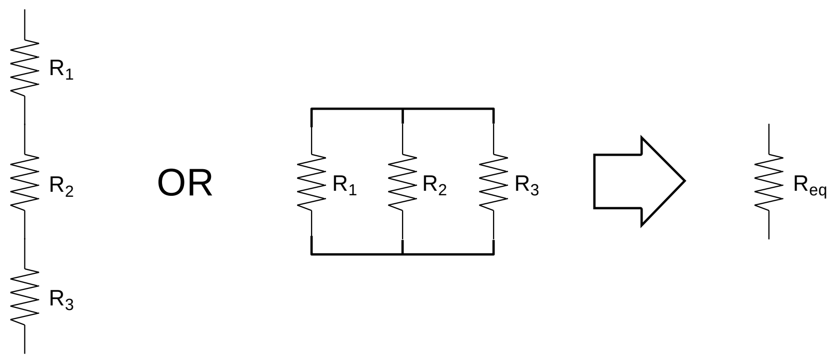

Fig. 1 Series and parallel resistor combinations.

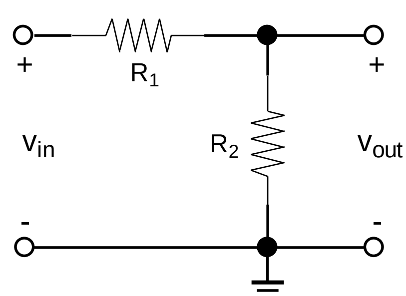

Fig. 2 Voltage divider network

(B) AC POWER

When a sinusoidal voltage, $v(t)=v_0\sin(\omega t)$, instead of a DC voltage is applied to a resistor, the current in the resistor is a sinusoidal function of time too, $i(t)=i_0\sin(\omega t)$. The power delivered to the load at any given time is $p(t)=v(t)*i(t)$. This is called ***instantaneous power*** and it is a function of time. The average power delivered to the resistor is obtained by averaging the instantaneous power over a period of the sinusoid:

$$P_{avg} = \frac{1}{2} v_0 \cdot i_0 = V_{rms} \cdot I_{rms} \text{ where } V_{rms} = \frac{1}{\sqrt{2}} v_0 \text{ and } I_{rms} = \frac{1}{\sqrt{2}} i_0$$

EQUIPMENT

- Calculator (bring your own)
- **Components**: 4 resistors (picked at random, from 10 kΩ to 100 kΩ), and some connecting wires
- Equipment on the lab bench:
  - Protoboard
  - DC power supply
  - 2 digital multimeters (DMN)
  - GW Function Generator Model GFG-813
  - TEKTRONIX TDS 210 oscilloscope

EXPERIMENT

1.1 Resistors in Series and in Parallel

Experiment:

- Record the values of all 4 resistors based on their colour code. Brown Black Brown 100 Ω | Brown Black Orange 10 kΩ | Brown Black Orange 10 kΩ | Brown Black Red 1 kΩ
- Use the 4 resistors to create the largest possible resistance. Connect up the resistors on the protoboard, then measure and record the resistance value of the network and compare it with the expected value. Actual: 20.71 kΩ Expected: 21.1 kΩ
- Repeat the previous exercise but now use these 4 resistors to create the smallest possible resistance.

1.2 Voltage Dividers

Experiment:

- **HAND DESIGN & ANALYSIS:** Design a voltage divider network that would most closely produce an output voltage of 1/3 of the input voltage if your lab station number is odd, or 2/3 of the input voltage if your lab station number is even. <u>Use any two of your four large-value resistors.</u> In your lab-book, draw your circuit, clearly showing the resistor values. Write down the expected ratio between the input and output voltage.
- **TESTING**: Set up your DC power supply for a voltage of 3V. Connect up the resistors on the protoboard. Test your voltage divider by applying the 3V and measure the resulting output voltage using a DMM. Record all voltage values and calculate the voltage division ratio. Compare your result with your expected value.
- Repeat the previous exercise but now <u>use as many of the four resistors as needed</u>. Place resistors in series and parallel combinations as you see fit. There are many possible combinations so test yourself to see how close you can get to the required voltage division ratio! *Make sure your circuit, calculations, and measured results are all recorded in your lab-book.*

- Calculate the expected current in the resistor or resistor combination represented by ‘R_2’ in Fig. 2. Set up the DMM for DC current measurement and measure this current. Calculate the power dissipated in ‘R_2’. Compare your measured result with the expected one and record both values in your lab book.

DO NOT DISASSEMBLE THE LAST VOLTAGE DIVIDER – LEAVE IT ON THE PROTOBOARD FOR THE NEXT PARTS.

1.3 Sinusoidal Waveforms

Experiment

- Set up the function generator for a sinusoidal wave of a few kHz. Display the waveform on the oscilloscope. Use the oscilloscope display to adjust the amplitude of the sine wave to approximately 6V peak-to-peak (3V amplitude). Record both peak-to-peak voltage and the frequency in your lab book.
- Verify frequency and peak-to-peak voltage first by checking the VOLTS/DIV and TIME/DIV settings on the oscilloscope, then by using the cursors.
- Connect the signal to the input terminal of the voltage divider circuit you designed in part 1.2 and display the input signal on CH1 of the oscilloscope.
- Connect CH2 of the oscilloscope to the output terminal and display both waveforms simultaneously.
- Sketch both waveforms in your lab book. Make sure the axes are labeled correctly.
- Record the peak-to-peak voltage of the output waveform. Calculate the voltage division ratio and verify your result is consistent with your result in part 1.2.
- The peak-to-peak voltage across resistor or resistor combination represented by ‘R_1’ in Fig. 2 cannot be measured directly using the oscilloscope. Explain why and make a plan how to use the oscilloscope to measure it indirectly.
- Use the method you determined in the previous step to measure the peak-to-peak voltage across ‘R_1’.

1.4 Average Power

Experiment:

- Set up the DMM for AC voltage measurement and measure the voltage of the input and output signals. Explain in which way these results are different from the peak-to-peak voltages in part 1.3, i.e. what are you measuring with the DMM?
- Set up the DMM for AC current measurement and measure the current in the resistor or resistor combination represented by ‘R_2’ in Fig. 2. Record its value in your lab book.
- Use the voltage and current from the previous two steps to calculate the average power delivered to ‘R_2’. Record it in your lab book. What is the peak instantaneous power in ‘R_2’?