Electronic Measurement Devices & Elementary Circuit Theory

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(2nd Week Pre-Experiment Lab Report)

I. RESEARCH QUESTIONS

a. Understanding basic electronic measurement devices and understanding how elementary devices work.

b. Using *NI ELVIS* in a basic experiment (*NI ELVIS* being a prototyping board used in testing circuits[1]) and thus being able to understand elementary circuit theory and relevant concepts.

II. THEORY

A. Electronic Measurement Devices and Basic Apparatus

1. *Digital Multimeter, DMM*

Multimeters in general are measuring instruments that can measure multiple electrical properties. The one we use in this experiment in particular is the *Tektronix DMM4020*.

2. *Oscilloscope*

Oscilloscopes are electronic devices that graphically display changing voltages throughout time as graphs on a display.

B. Elementary Circuit Theory

1. *Peak, Peak-to-peak, and Root-mean-square (rms) Values*

Peak values, following their name, denote maximum values of alternating quantities. *Peak-to-Peak values*, not to be confused with peak values, are the difference between the highest and lowest values in a waveform. Lastly, *Root-mean-square values*, often denoted by the abbreviation rms, is the square root of the arithmetic mean of the squares of a signal's values. The calcuations differ by whether the signal is continuous or discrete. When the case is a set of finite n values $\{x_1, x_2, ..., x_n\}$,

$$x_{\text{rms}} = \sqrt{\frac{1}{2}(x_1^2 + x_2^2 + \cdots + x_n^2)} \tag{1}$$

When the signal in discussion is a continuous waveform or function, the summations transform into an integral,

$$f_{\text{rms}} = \sqrt{\int \frac{1}{T_2 - T_1} \int_{T_1}^{T_2} [f(t)]^2 \, dt} \tag{2}$$

where the waveform would be defined over the time interval $T_1 \leq t \leq T_2$.

2. *Superposition Theorem*

In electrical circuits, the *superposition theorem* is a theorem derived from the superposition principle in physics, stating that in a linear system, the response of the constituents (most commonly the current or voltage) having more than one independent source is the superposition of the individual responses of the sources hence the name.

III. METHODOLOGY

A. Function Generator and the Oscilloscope

1. Turn on the *NI ELVIS* and specifically the function generator from the *NI ELVIS* software. Set the waveform as the sine wave, letting the frequency be 100 Hz, and the V_{pp} be 5 V (visual, this should correspond to waves that have an amplitude of 2.5 V, half the peak-to-peak values that are set).

2. Turn on the *Oscilloscope TBS1102B* by connecting the function generator's "+"output (FGEN) with CH1, one of oscilloscope's input terminals using BNC cables and wires.

3. Eliminate the DC offset signal by setting the Oscilloscope's coupling (DC, AC) setting as AC, and detect signals manually or using "autoset". If the auto set signals are not clearly seen, manually scale the voltage (horizontal axis) and time (vertical axis). Using the oscilloscope, measure the V_{pp} signal and calculate V_{rms}, comparing it with the V_{rms} value shown in the oscilloscope.

4. Change the function generator's waveform and frequency to square waves (1 kHz) and triangle waves (10 kHz), repeating the experiments from above. If there is a difference between values, think of what has changed (the fact that the the form factors are different gives

[1] Personal notes and records are in red text.

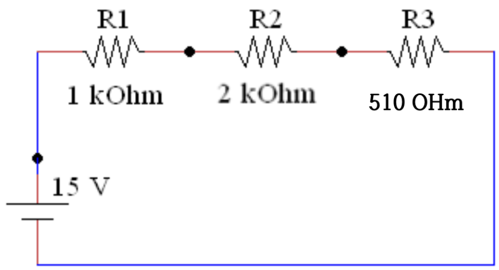

FIG 2-1. Series resistor circuit.

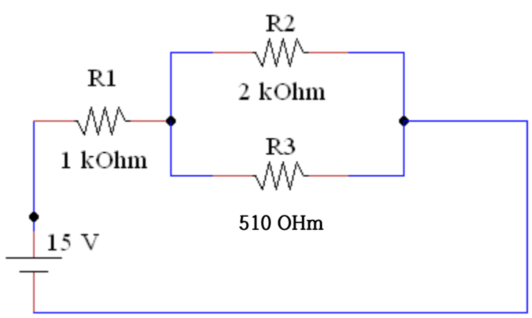

FIG 2-2. Parallel resistor circuit.

a hint) (in this step, this discrepancy can be understood as from the fact that the root-mean-square value is anologically a quantity that describes the area under the curve, and as the signal forms go from sine, triangle, and square, this quantity can be expected to clearly increase).

5. Change the square waves' (1 kHz) duty cycle to 20% and 80%, repeating the experiments above.

6. After constructing the circuit shown in Figure 1, the voltage across resistor R_1 is measured using an oscilloscope. Resistor R_1 and R_2 are chosen to be arbitrary resistances of 10 kΩ or less. The voltage across resistor R_1 can be measured by taking the difference between the signals of CH1 and CH2 on the oscilloscope. Utilizing the differential function (or subtraction feature) present in the oscilloscope, the voltage across resistor R_1 is measured and compared against theoretical values.

7. In the circuit depicted in Figure 1, set the waveform to a sinusoidal wave, with a frequency of 5 Hz, and a peak-to-peak voltage V_{pp} of 1V. To observe stable waveforms at low frequencies and low amplitudes, utilize the trigger mode. Set the trigger mode to either rising edge or falling edge and adjust the trigger level while observing the waveform.

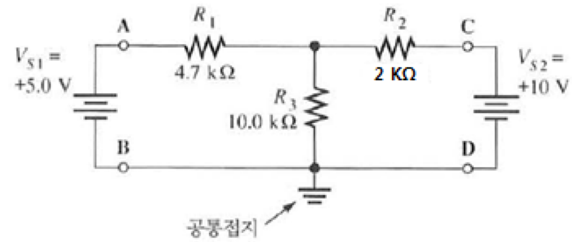

FIG 3-1. Superposition theorem.

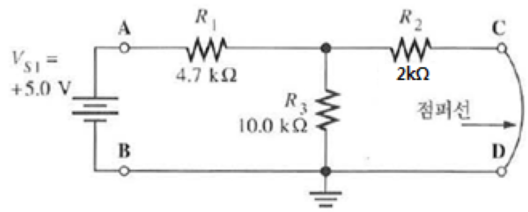

FIG 3-2. Superposition theorem.

B. NI ELVIS and the Multimeter

1. After constructing the circuit depicted in Figure 2-1, use a multimeter to measure the voltage and current across each resistor. Take note that the connection methods for voltage and current measurements differ on the multimeter. Compare the measured results with the calculated theoretical values.

2. In the circuit shown in Figure 2-1, use a multimeter to measure the total resistance from R_1 to R_3. Perform this measurement both with the 15V power supply disconnected and then with the 15V power supply connected. Compare the measured results with theoretical values and discuss which measurement method is appropriate based on the comparison.

3. Repeat the same measurements and discussions as described for Figures 2-1, but this time for the parallel resistor circuit shown in Figure 2-2.

4. This time, remove the 15 V DC voltage from the circuit depicted in Figure 2-2 and apply an AC voltage of 5 V_{pp} with a frequency of 1kHz using the NI ELVIS function generator. The positive terminal "+"of the function generator is connected to the FGEN, while the negative terminal "-"is connected to the SYNC. Measure the AC voltage and current, instead of DC voltage and current, across each resistor using a multimeter, and compare the measured values with theoretical calculations.

5. Construct the circuit shown in Figure 3-1 using only NI ELVIS. This circuit should include two voltage sources connected to a common ground reference. Use the 5V terminal for one power source and the VPS for the other.

6. Remove the 10V power supply as shown in Figure 3-2 and connect a wire between points C and D. This wire represents the internal resistance of the 10V power supply. (You can consider the internal resistance of a DC power supply or battery to be 0 Ω.)

7. To calculate the equivalent resistance R_T as viewed from the +5 V terminal, and to confirm the calculation, remove the +5 V power supply and measure the resistance between points A and B. Then, using R_T, calculate the total current I_T flowing from the +5 V power supply. Designate the current flowing through R_1 as I_1 and record its value. Utilize the principle of current division to compute the currents flowing through R_2 and R_3 by employing the following equation. Assume all currents to be positive:

$$I_2 = \frac{R_2}{R_2 + R_3} \times I_T$$

$$I_3 = \frac{R_3}{R_2 + R_3} \times I_T$$

Using the calculated currents and resistance values, compute the expected voltage across each resistor. Then, connect the 5V power supply and measure the voltage across each resistor using a DMM. Compare these measured values with the calculated ones.

8. In Figure 3-2, remove the +5 V power supply from the circuit, disconnect the jumper wire on the right, and reconnect the +10 V power supply. Repeat the same process as in step 3. However, if the current direction is the same as in the previous case, record it as positive "+"; if it's in the opposite direction, record it as negative "-". Similarly, the calculated voltages will also have either a positive "+"or negative "-"sign.

9. Compute the algebraic sum of all currents and voltages obtained so far. Then, reconnect the +5V power supply and measure the voltage across each resistor. Calculate the currents using these voltage measurements and compare these values with the algebraic sum calculated earlier.

[1] Griffiths, D. Introduction to electrodynamics. *Pearson Education,* (2014), pp. 59–60.

[2] Halliday, D., Resnick, R., and Krane, K. Physics, volume 2. *Wiley, 2nd Edition* (2010), pp. 845–852.

[3] The Sogang University Physics Department. Experimental physics 1 manual. *"Electronic Measurement Devices, Elementary Circuit Theory"*.

[4] Wikipedia. Multimeter. `https://en.wikipedia.org/wiki/Multimeter`.

[5] Wikipedia. Oscilloscope. `https://en.wikipedia.org/wiki/Oscilloscope`.

[6] Wikipedia. Root mean square. `https://en.wikipedia.org/wiki/Root_mean_square`.