Voltage, Current, and Resistance II Lab 7

Equipment SWS with 750 interface, Power Amplifier II, analog DC voltmeter, analog DC ammeter, SWS voltage sensor, SWS current sensor, RLC circuit board, 4 black leads, 4 red leads

Read Again "Electrical Safety" at the beginning of this manual.

1 Purpose

To learn how voltages and currents are generated and measured with the SWS 750 interface and other equipment, and to investigate how voltage and current are related in resistors.

2 Voltage vs Current for a Resistor - AC Measurements

In the previous lab three discrete measurements of voltage and current for a resistor were made. Using the AC capabilities of the signal generator almost continuous measurements of voltage and current can be obtained. This saves time and allows measurements on non-ohmic circuit elements to be made quickly.

Click Sample V, Sample I, and auto. Program the interface voltage output for a triangular wave, 5 V amplitude, and 0.2 Hz. Connect the interface output across the 100 Ω resistor on the RLC circuit board. Open the graph display window by dragging the graph display icon to the voltage terminals. Click the "Add-A-Plot" button (icon with black triangle) in the graph display and program for output current. The graph display should have 2 vertical axes, one of output voltage, and the other of output current. The horizontal axis should be the default value of time. Click REC, run for about 10 s, and click STOP. Click the Auto-Scale button. Print out your graph (as well as other relevant results taken later). Discuss your graph.

Open a new graph display with output voltage on the vertical axis and output current on the horizontal axis. The data you just took will appear on this graph. Is Ohms law being obeyed? Click the statistics button (Σ icon) on the graph display and fit a straight line to your graph by clicking curve fit ▷ linear fit. What is the intercept (a1) and slope (a2) of the fitted line. Are they what you expect?

3 Voltage vs Current for a Filament

The resistors used so far are pretty good Ohm's law resistors. In this section you will examine the relationship between voltage and current for a filament. As a filament gets hot its resistant increases, and it does not obey Ohm's Law.

Remove the 100 Ω resistor from across the interface terminals and replace it with the #50 bulb on the RLC circuit board. Click Sample V, Sample I, and auto. Program the interface voltage output for a triangular wave, 5 V amplitude, and 0.01 Hz. Set up a graph display with voltage on the vertical axis and current on the horizontal axis. Click REC and take data for at least one full period (100 s) of the triangular voltage wave. Keep an eye on the bulb. Discuss your results.

The rather low frequency of 0.01 Hz in the previous data was chosen so that the filament temperature was approximately in equilibrium with the current. Put another way, if a steady current were applied to the filament the temperature the filament ultimately reached would be close to the temperature of the filament when that same current was reached by slowly sweeping the voltage across the filament. What do you think would happen if the voltage were swept very quickly? Change the frequency to 20 Hz, and change the sampling rate to 500 Hz. Click REC and take data until the data points settle down. Is the filament Ohmic? Can you explain this result? The first data points differ from the rest of the data points because the filament needs time to heat up to the average power. You can avoid most of this problem by clicking MON, awaiting for a short while, then clicking STOP and immediately clicking REC.

4 The Filament and Thermal Hysteresis

Hysteresis is the lagging of one variable behind another. It leads to functions which are not single valued. If the voltage across the filament is increasing the temperature at a given current is less than when that current is applied steadily. If the voltage across the filament is decreasing the temperature at a given current is higher than when that current is applied steadily. Investigate this effect by applying a 1 Hz triangular 5 V voltage wave to the filament and observing the data on a voltage versus current graph display. Can you tell which curve was obtained by sweeping the voltage up and which by sweeping the voltage down?

5 Thermal Relaxation Time of Filament

Suppose a steady current is applied to a filament for a long enough time so that the temperature of the filament is constant. The current is then abruptly set to zero. The filament, which is above the temperature of its surroundings, will lose energy to the surroundings by the following mechanisms.

1. Emission of electromagnetic radiation. This will be the dominate mechanism at higher temperatures.
2. Conduction through the filament supports. At much lower temperatures this will dominate.
3. Conduction by the surrounding gases. This will not be important as the filament is in a vacuum.

The time it takes for the filament to approximately reach ambient temperature is called the "thermal time constant." When the heating voltage is 20 Hz the period of the heating voltage is short compared to the thermal time constant. From cycle to cycle the filament does not have the time to change its temperature by very much. At 0.01 Hz the period is somewhat long compared to the thermal time constant. At any given current the filament temperature is close to the steady steady value. At 1 Hz we have in-between situation where hysteresis is observed.

6 Measuring Resistors in Series and Parallel

Connect the 33 Ω and 100 Ω resistors on the RLC circuit in series across the output of the interface. Measure the resistance and compare to the theoretical value for resistors in series. Measure the resistance in the simplest way you can think of using the equipment you have.

Measure the resistance of these same resistors in parallel and compare to the theoretical value for resistors in parallel. (You should not use the 10 Ω resistor. It will draw too much current.)

7 Voltage Sensor and Analog Current Meter

This section will familiarize you with the SWS voltage sensor and with a moving coil analog current meter. The internal resistance of the analog current meter will be measured and the effect on the current in the circuit measured.

The SWS voltage sensor is an analog sensor and if it is plugged into channel A or B of the interface "floats." This means that neither of the leads has to be connected to ground. The analog current meter is of the moving coil type. Turn its sensitivity knob to the least sensitive position (1 A) before inserting it into the circuit. When connecting the current meter avoid the red terminal marked 10 A. (When the meter is used on the 10 A scale, the sensitivity is not affected by the sensitivity knob.)

Connect the 10 Ω resistor and the DC current meter in series. Connect this series combination across the interface voltage terminals. Connect the 2 leads of the voltage sensor across the 10 Ω resistor and plug the sensor into analog channel A. Drag the analog plug icon to channel A and choose voltage sensor. Use a digits display to measure the output of the voltage sensor. Click Sample V, Sample I, and auto. Program the interface voltage output for 0.1 V DC. Internally sample the output voltage and output current of the interface using two digital displays and using an appropriate number of decimal places. Click MON. For the various sensitivities of the analog current meter record the voltage output of the interface, the voltage across the resistor, and the currents measured by the analog meter and the digital meter. Discuss your results. Does the analog current meter affect the current in the circuit? What is the resistance of the analog current meter on its different scales? How does turning the sensitivity knob change the sensitivity of the current meter?

Click New from the File menu and then click Don't Save.

8 Using the Power Amplifier II

The purpose of this section is to familiarize you with the use of the Power Amplifier II. The Power Amplifier II increases the voltage and current capabilities of the 750 interface. The maximum voltage output is 10 V and the maximum current is 1 A. Check that the Power Amplifier II is connected to channel C of the interface. Drag the analog plug icon to channel C and choose Power Amplifier. The signal generator window appears with the power amplifier icon at the lower left hand corner and the sample V button in the right experimental set-up window will be in. Program for 9 V DC. Don't forget to click auto. Connect the 10 Ω resistor and the SWS current sensor in series, and connect the series combination across the output terminals of the power amplifier. Plug the voltage sensor into channel A and monitor the voltage across the 10 Ω resistor with a digits display. Plug the current sensor into channel B and monitor the current with a digits display. Internally monitor the output voltage of the Power Amplifier II by dragging a digits display icon to the icon terminals marked V. Internally monitor the output current of the Power Amplifier II by dragging a digits display icon to the PWR AMP icon. Note: you cannot monitor the PWR AMP current by dragging a digits display icon to the icon terminals marked I. Try it!) Click MON and explain your results. The SWS current sensor is a precision 1 Ω resistor.

The voltage across this resistor give the current. Does this sensor affect the current in this circuit?

Design and construct a single circuit that will allow you to simultaneously measure the same current in the analog current meter and the SWS current sensor. Do these two meters agree?

9 Voltage from the Power Amplifier: Summary

The procedures for obtaining a voltage from the power amplifier are summarized.

- Check that the power amplifier is plugged into channel C and is on. Drag the analog plug icon to channel C and choose power amplifier. The power amplifier icon, which must be present, and the signal generator window, will appear. The sample V button in the right experimental set-up window will be in. Click auto in the signal generator window. (Contrast this procedure to obtaining voltage from the interface, where the signal generator window was opened by clicking the sample V button and no power amplifier icon appeared.)
- The output voltage can be monitored using any display as long as the sample V button is in.
- The current can be monitored by dragging a display to the PWR AMP icon. The current cannot be monitored by dragging a display to the icon terminals marked I.
- Choosing waveform, voltage, and frequency is identical to the interface case.

10 Suggestion

You will need the voltage output of the signal generator and power amplifier II in future labs. If you have time, put a 100 Ω resistor across the terminals of the interface and review the procedures for getting a voltage from the interface and measuring the voltage and current internally.

Review the procedures for getting a voltage from the power amplifier and measuring the voltage internally (current cannot be measured internally).

11 Comment

Parts of these labs have dealt with ohmic and non-ohmic resistors, while other parts have been tutorials on how to use the voltage and current capabilities of SWS. If you needed to check on the value of a resistor, do not use the procedures in these labs. Pick up a digital multimeter. Time varying voltages are best examined using an oscilloscope. That's a future lab.

12 Finishing Up

Please leave your bench in a tidy fashion. Thank you.