MEASUREMENTS AND INSTRUMENTATION

LAB #1: Introduction to Electronic Instrumentation

Equipment:
DC Power Supply (Protek 3015B)
Digital Multimeter (FLUKE 187)
Function Generator (Tektronix CFG250)
Oscilloscope (Tektronix TDS 2014)
Battery
Resistor box

Objectives:

The purpose of this laboratory is to acquaint you with several of the electronic instruments that you will be using routinely in future labs. You will be asked to use these instruments to perform a number of simple measurements, but you will not always be given step-by-step instructions on how to use them. Rather, you are expected to use the operating manuals that come with each instrument to educate yourself. Use the manuals as a guide, but do not be afraid to intelligently "knob-twist." Your lab instructor will remind you of several simple measures to protect the equipment. At the end of this experiment, you should have gained considerable facility in using these very useful instruments.

Procedure:

In a lab notebook (not loose-leaf) record your measurements and answer all the questions posed in the lab handout (labeled as "Q"). Use the paragraph subsection numbers 1.1, 1.2, etc. in your notebook record.

1 Digital Multimeter [Fluke 187_Manuals]

This device is a real "jack of all trades"; it will be as useful as an extra pair of hands when you begin to take measurements. It measures electrical voltage, current, or resistance.

1.1. Look up the specified multimeter accuracy for DC voltage readings.

Q: What is it for resistance readings?

Q: Within what accuracy will the instrument measure a DC signal of 100 mV?

Q: Within what accuracy will the instrument measure an AC signal of 100 mV at a frequency of 100 Hz?

Q: Within what accuracy will the instrument measure a resistance of 1000 ohms?

1.2. Measure the voltage of a battery. Reverse the leads and observe what the meter does. This polarity indication is a nice feature of the meter. Analog meters will “pin out" if the wrong polarity is used, and this can cause damage to this type of instrument.

Q: How much current were you drawing from the battery in #1.2? (Hint: Check the impedance specifications for a DC voltage measurement.)

1.3. Connect the multimeter to the + and - terminals on the DC power supply. Set the current-limiter knob (A_{adj} knob) at 12 o'clock, turn both voltage knobs full CCW, and switch the unit on. With the meter on the 5-VDC range, slowly increase the coarse voltage control of the power supply.

Q: What happens when the voltage exceeds 5V?

(N.B.: It is a good practice when measuring a completely unknown voltage to start out on the highest range and move downward until the desired resolution is obtained. Try this with the voltage control turned up a little higher.)

1.4. Turn the vernier (fine) voltage knob on the power supply full CCW and measure the voltage. Then turn it full CW.

Q: What is the range of fine voltage control for the power supply?

1.5 Measure the resistance of each of the five resistors in the resistor box and record the measured resistance values along with the color code for each.

Q: Are all of the resistors within the tolerance indicated by the color code?

2 Function Generator [CFG 250_Manuals]

This instrument produces a variety of voltage wave shapes (e.g., square wave and sine wave) of various amplitudes and frequencies; it has many uses in measurement systems.

2.1. Set the “Amplitude" knob, the “DC Offset" knob, and the “Duty" knob at their center positions. From the FUNCTION section, select the sine wave. Push in the 100-Hz knob to give a 100-Hz sine-wave voltage with zero DC offset (to be discussed later). Connect the multimeter to the MAIN output, and set the multimeter to read AC volts.

Q: Determine the maximum output voltage available from the function generator by using the multimeter. How does this compare with the maximum value stated in the manual?

Hint: Try to find out the peak-peak voltage output for the function generator

2.2. Switch the function generator to 10 Hz, then to 1 Hz, then to 0.2 Hz, leaving the output level fixed. Record the observed voltage readings.

Q: What did you find? Discuss your observations with the lab instructor and write down an explanation.

Go back to 100 Hz and set the voltage output level to 1 volt, as read on the multimeter (Hint: you may have to change the output range of the function generator and change the amplitude to achieve this), and set the DC OFFSET knob to zero. You will look at this signal on the oscilloscope.

3 Oscilloscope [TDS 2014_Manuals]

The oscilloscope or "scope" is the basic instrument for dynamic measurements. The virtue of this instrument lies in its tremendous flexibility. It can be used to observe signals ranging in amplitude from a fraction of a millivolt to hundreds of volts at speeds from nanoseconds (10^{-9}) to as much as minutes. A great many things can be done with a scope. We will not go into great detail in this experiment. Additional techniques will be picked up from the future experiments. In ASE369K we will use both an instrument-type oscilloscope (Tektronix TDS 2014) and a "virtual oscilloscope," which is based on the LabView software package. In LAB 1 you will only use the TEK scope.

3.1. Your oscilloscope has, in general, four major sections, which control the operation of the instrument. They are the "VERTICAL" control section, the "HORIZONTAL" control section, the "TRIGGER" control section, and the "MENUS" section. There are many other minor knobs controlling various functions such as the intensity of beams, focus, etc. Your instructor will identify them for you.

3.1a. The first section is the "VERTICAL" section, into which the outside signals are fed. Your scope has four channels (CH-1~CH-4) to receive outside signals. Press CH1 MENU to activate CH1. Turn the voltage control knob for CH-1 to 0.5 volt/div.

3.1b. The second section is the "HORIZONTAL" control section. Set the SEC/DIV knob to 5 ms, and then center the horizontal <– POSITION –> knobs (COARSE and FINE).

3.1c. The third section is the "TRIGGER" control section. Press TRIG MENU then select Type=Edge, Source=CH1, Slope=rising, Mode=auto, Coupling=DC.

3.2. Using a BNC-to-BNC cable, connect the MAIN output from the function generator to the CH-1 input of the oscilloscope. (Turn on the function generator if you turned it off after Section 2.) You should see a sine wave on the scope screen. There will be a display on the scope screen informing you about the settings. The TDS 2014 scope has a cursor feature that enables you to measure the amplitude and period (i.e., time for one cycle of the sine wave) of the signal displayed on the screen. Use MEASURE menu to get period, frequency, peak to peak etc. To measure the peak to peak ($p - p$) amplitude of the signal, press CURSOR menu then select Type=Voltage, Source=CH1. You should see two horizontal lines on the screen. Move one of these lines to the bottom of the sine signal (or any reference line) by rotating the knob. Now you can bring the other line to the reference line by rotating the knob. When these two lines coincide, $\Delta V = 0\ V$. Now, by turning the cursor1 and cursor2 knobs, move the line to the position where you wish to make a voltage measurement. Practice several times until you are comfortable with the procedure. Measure the $p - p$ voltage of the sine signal.

Q: How does it compare with the value measured on the multimeter? Explain the difference.

3.4. To measure the time (e.g., the period of the sine wave), press CURSOR menu then select Type=Time, Source=CH1. This time, you will see two vertical lines. The procedure for measuring ΔT is the same as that for measuring ΔV. Now measure ΔT for one cycle (the time between two consecutive peaks) and calculate the signal frequency.

Q: How does this compare with the frequency indicated on the function generator dial?

3.5. Now, go back to the “Trigger" section. Set the SLOPE switch to falling.

Q: What happens to the display? (Hint: Watch the beginning of the signal trace.)

3.6. Now turn the “amplitude" knob on the function generator and the “amplitude" and “time" (i.e., SEC/DIV) control knobs on the scope, and then observe the change of signal displayed on the screen. Also try the FREQ control knob on the function generator. Record your observations in your lab notebook.

Revised by NC 1/02.
Revised by Ravi 1/04.

Supplement to Lab. 1: Introduction to Electronic Instrumentation

Points to remember:

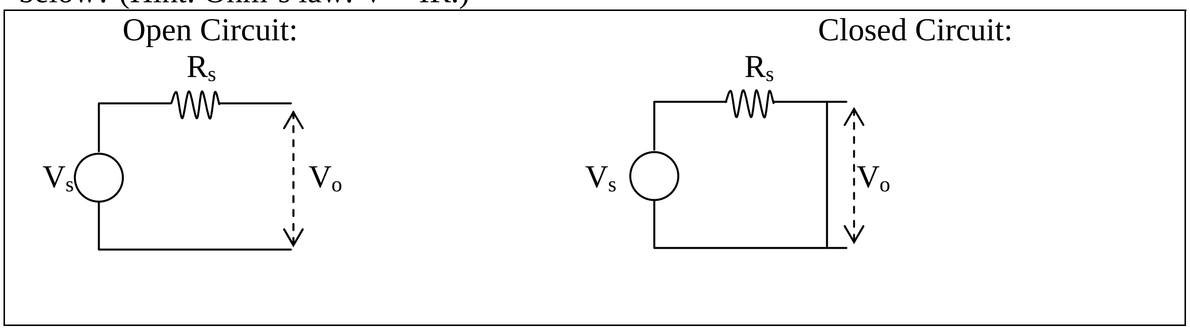
1. Read through labs before the scheduled lab.
2. Be careful with all instruments.
3. When comparing numerical results, give numerical answers (i.e. % error).

Sample Accuracy Calculation:
Accuracy is 0.03% of reading + 2 digits
Measured value: 3.000 V

$$Uncertainty = \left(\frac{0.03}{100}\right)\cdot(3.000V) + 2(0.001V) = 0.0029V$$

which is reported as ± 0.003V

Why is the output voltage higher when working into an open circuit versus the closed circuit as shown below? (Hint: Ohm's law: V = IR.)



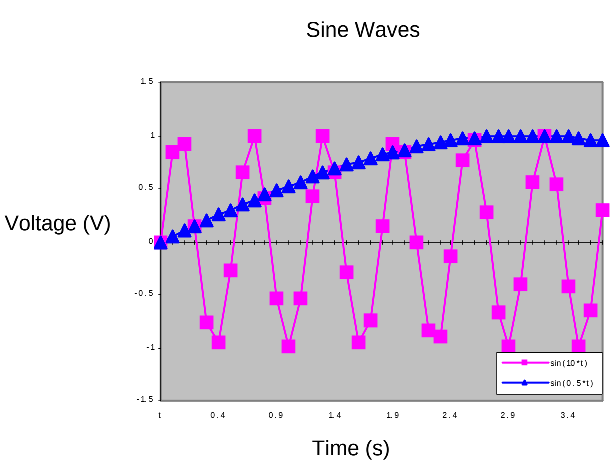
General definition of V_{rms} (used for AC)

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^T V^2 dt}$$

where T is the time period of integration. For a sine wave, $V = V_o \sin(\omega t)$

$$V_{rms} = \sqrt{\frac{V_o^2}{T}\int_0^T \sin^2(\omega t)dt} = \frac{V_o}{\sqrt{2}}$$

When computing the rms value of a signal, more cycles leads to more accurate computation:



The high-frequency curve (indicated by square markers) has many cycles within the integration period, and is integrated accurately. The low-frequency curve only has part of a cycle within the integration window; therefore, the integration (analog or digital) and the measured rms reading of the signal will be inaccurate.