# Experiment 1
# Introduction to Electronic
# Test Equipment

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## 1.0  Objective

In this experiment, you will become familiar with the test equipment in the laboratory and will become reasonably adept at using the HP 54615B oscilloscope to perform DC and transient measurements.

## 2.0  Procedure

### 2.1  Oscilloscope and Signal Generator

1. Use "PROBE ADJUST" signal (under the "beam find" button)  to insert a 1 kHz, 5 V p-p (peak to peak) square wave into the first input, Ch1. Set that channel for AC coupling. The waveform should be 5 divisions high on the 1V/div scale. If the waveform looks very distorted, adjust the probe using a screwdriver.

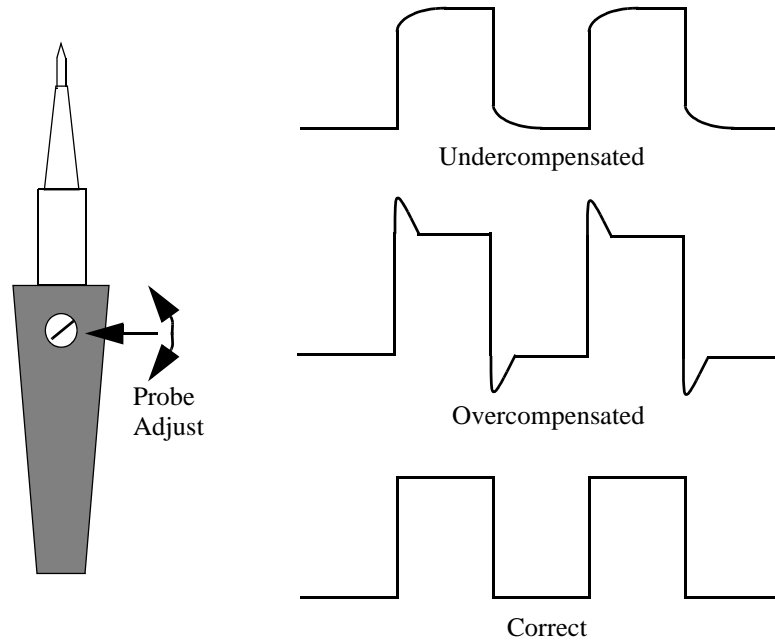===================================== Lab Tip ======================

The probes that come attached to the oscilloscopes are 10x probes. Readings should be read from the 10x markings. All other cables are 1x cables and results should be read using the 1x markings.

**FIGURE 1.**     Effects of adjusting the Probe Adjust screw on test waveform. (Note that adjustment is not normally necessary.)



2. Repeat these steps for the second channel, Ch2.

3. Now connect a DC power supply to the vertical input and vary its voltage. Check the accuracy of the panel meter on the power supply using the scope readings. What is the maximum voltage the supply will produce? How accurate is the power supply's panel? Can this experiment be done with the vertical input on *AC* mode? why or why not? What is the difference between DC and AC coupling?

4. Now connect the HP 8116A signal generator to the vertical input. Set the generator to an arbitrary frequency and determine the accuracy of the generator's display by comparing the period of the sinusoid on the scope with the period of the sinusoid on the display. Play around with different frequencies and amplitudes. How closely do the two measurements agree? What is the maximum peak-to-peak amplitude available from the generator? The minimum? Vary the *TRIGGER LEVEL* control and note the effect on the waveform. What is happening?

5. Set the generator to output a pulse. Compare the period and frequency readings on the generator controls to those actually observed on the scope. What is the shortest pulse width (in seconds) that you can generate? The longest? (Note that this may depend on the frequency.)

## 2.2 Triggering

Unless specified otherwise, set the triggering source to the input you are examining, and use "auto" triggering.

================================ Lab Tip ================================

You will always be using the HP 8116A in *Normal Mode*. The unit saves the settings each time it is turned off. To ensure that the signal generator is operating properly make sure:

- The following lights are **OFF**: **[AUTO]**, **[LIMIT]**, **[COMPL]** and **[DISABLE]**.
- Always operate the generator with the **AMP** and **OFS** instead of **HIL** and **LOL**.
- DTY setting should be 50

All other lights should be off; for further explanation, see the HP 8116A manual.
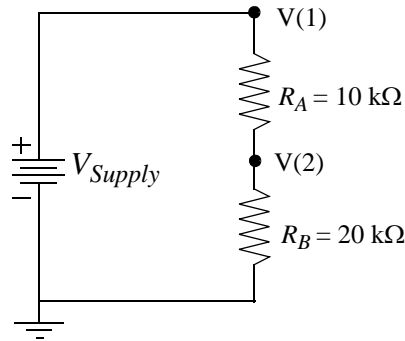
### 2.3 The Digital Multimeter

1. Construct the circuit below. Let $V_{Supply}$ be 10V.

**FIGURE 2.**

Simple Resistive Divider Circuit



2. Use the digital multimeter and the oscilloscope to determine the voltages at nodes 1 and 2. Compare the readings between the digital multimeter and the oscilloscope.

3. Derive a relationship for V(2) in terms of $V_{Supply}$, $R_A$ and $R_B$.

4. Calculate the current through resistor $R_B$. Measure the current with the digital multimeter. How do the results compare?

=============== Lab Tip ===============

Cables for the digital multimeter can be connected to it from both the front and the rear. This allows for quick voltage and current measurements by simply switching between the *Front/Rear* button.

5. Beware of the hazards of the current mode. The resistance across the multimeter is nearly a short circuit in this mode. What happens if you connect an ideal ammeter across the terminals of a voltage source? [DON'T DO IT!] Discuss this point with your TA, if you don't understand the concepts.

### 2.4 The HP 4155A/B as a Parameter Analyzer

1. Using the digital multimeter, measure the resistance on a 10 kΩ carbon resistor.

2. Carefully plot the resistor's I-V characteristic, using the oscilloscope and DMM. Label all relevant points.

3. Using the HP-4155, determine the resistor's *I-V*, using the diode program.

4. Connect the resistor to the appropriate SMUs and plot its *I-V* characteristic.

5. Use the cursor and marker to find the slope of the curve. From the slope, find the resistance of the resistor.

6. Obtain a hard-copy of the graph.

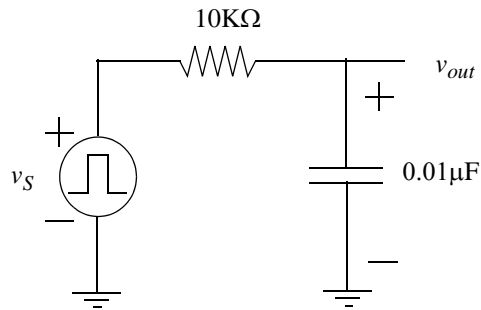7. Comment on the similarities and differences of the two I-V characteristics.

### 2.5 Transient Analysis

**1.** Construct the following *R-C* circuit. You should have seen this circuit many times in your introductory circuits course.

**FIGURE 3.**                    Lowpass Filter Circuit



**2.** Let $v_s$ be a square wave with a frequency of 1kHz and a 50% duty cycle.

**3.** Place channel 1 of the oscilloscope at $v_s$ and channel 2 at $v_{out}$.

**4.** Display both waveforms on the oscilloscope. Sketch the waveforms and label all the relevant points.

**5.** Repeat step 2 with frequencies of 100 Hz, 10 kHz, and 100 kHz.

### 2.6 Second order circuit: frequency response

**1.** Insert a 100 nH inductor in series with the 10 kΩ resistor in the lowpass filter circuit above. Apply the 1 kHz, 50% duty cycle square wave that you applied in the previous circuit.

**2.** Connect $v_{out}$ to channel 2 and $v_s$ to channel 1 of the oscilloscope and display both waveforms on the oscilloscope.

**3.** Sketch the waveforms and label all relevant points.

**4.** Repeat the measurement for resistor values of 665 Ω, 200 Ω, 100 Ω, 50 Ω, and zero Ω. Note that there is a parasitic series resistance associated with the inductor that means that the waveform will still have some damping.

**5.** Which resistor values lead to an underdamped response in the time domain, which is indicated by "ringing." Do your measurements agree with the theoretical predictions you've learned in lecture?
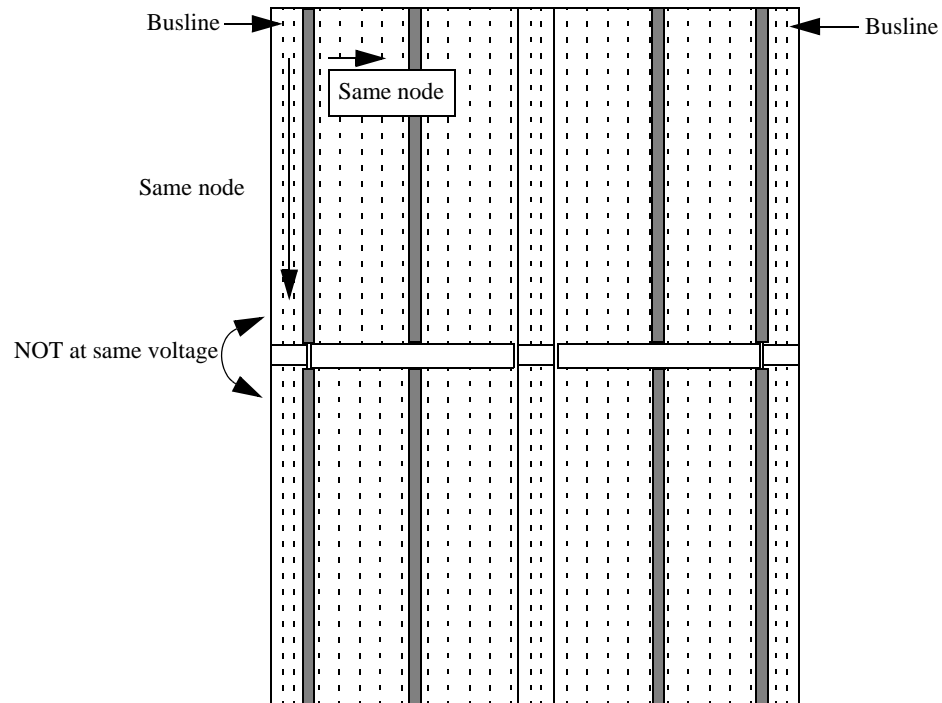
## 3.0 Appendix

### 3.1 Breadboard Basics

**FIGURE 4.**

FIGURE 4. Layout of breadboard -- Fig. 5 has wiring. Two vertical buslines in center are omitted.



The breadboard is where you will be doing most of your work in lab. Here are some points to remember:

- The buslines are at the same voltage vertically.
- The top half of the busline is not at the same voltage as the bottom half. You should use a jumper if you intend to work on both halves of the board.
- The central sections of the breadboard are at the same voltage horizontally.

Shown below is the metal network for the breadboard.

**FIGURE 5.**                    Metal Connections within the Breadboard

Metal Line
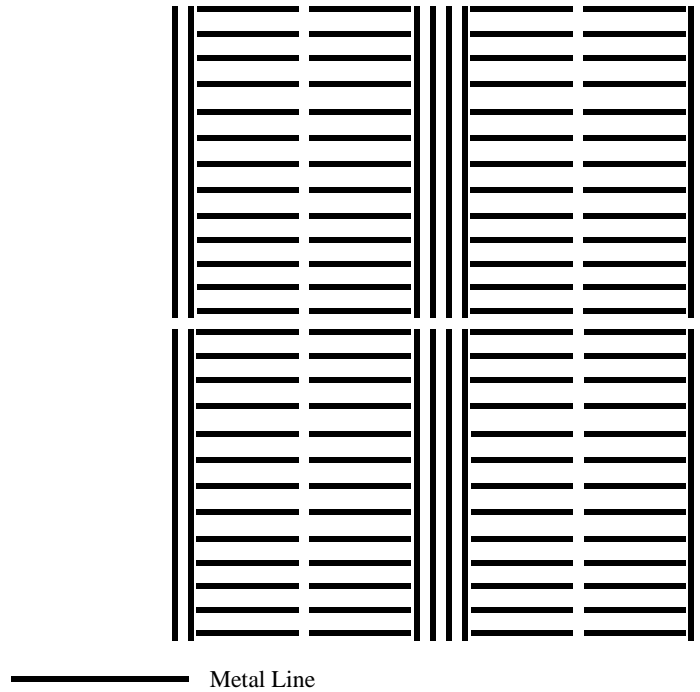
When wiring, it is important to keep your work neat! This discipline will save time for you (and your TA) in debugging when your circuit doesn't work. Below are some tips.

- Keep your wires short
- Do not loop wires over the chip.
- Use the buslines for Ground or a DC supply voltage (e.g. $V_{CC}$)
- Sometimes, you can get cleaner signals if you short the metal base of the breadboard to the circuit's ground.

Figure 6 shows identical connections using good and bad wiring techniques. Note how the resistor on the good side does not "loop" over the chip. Instead, it gets from point A to B by making "manhattan" (90 degrees) turns along unoccupied sections of the breadboard.

**FIGURE 6.**                    Proper and Improper Wiring Practices
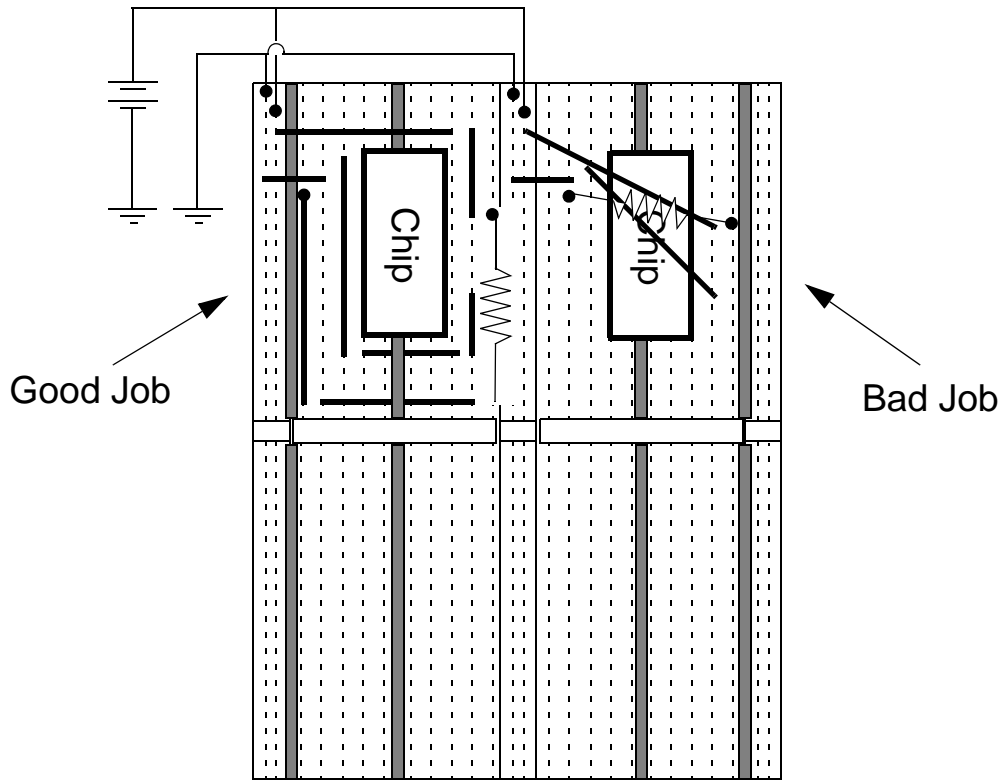


### 3.2  Plotting current-voltage characteristics using the oscilloscope

The oscilloscope measures voltages, so it cannot directly measure a current.  One approach to measuring currents is to insert a relatively small series resistor, as shown in the figure below, with the two-terminal device under test (in this case, a 10 kΩ resistor).
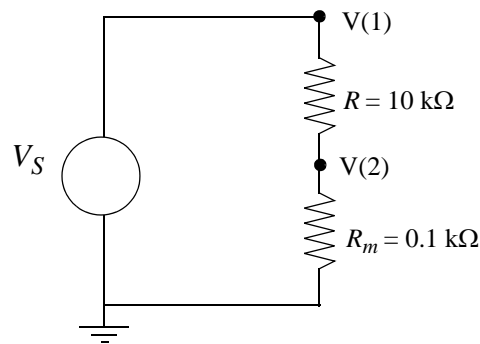
The voltage V(1) can be connected to the X probe and the voltage V(2), which is directly proportional to the current through the 10 kΩ resistor, can be connected to the Y probe.   In order to plot the *I-V* characteristic, you must select the XY mode of the oscilloscope.  Do this by going to the main menu and selecting "XY."  This plot is a good approximation to the *I-V* characteristic of the 10 kΩ resistor, but it must be scaled by converting the *Y*-axis into mA.

Note that the plot has a 1% error, since we should be plotting voltage V(1) - V(2) on the X axis rather than V(1).