# ECE 214 - Lab #1— Test Equipment Loading

26 January 2016

**Introduction** In this lab you are to determine the voltage ratio, $V_{OUT}/V_{IN}$, produced by the voltage divider with resistors $R_a$ and $R_b$ shown in Figure 1, and with capacitors $C_a$ and $C_b$ shown in Figure 2.

This lab illustrates that the impedance of test equipment and cables must always be considered when determining the true value of the voltage being measured across a circuit element.

A voltage generator or battery has a source impedance. Measurement equipment such as an oscilloscope has an input impedance (that presents a load to the circuit). Each cables that connect the circuit to the test equipment introduce an additional impedance to the circuit.

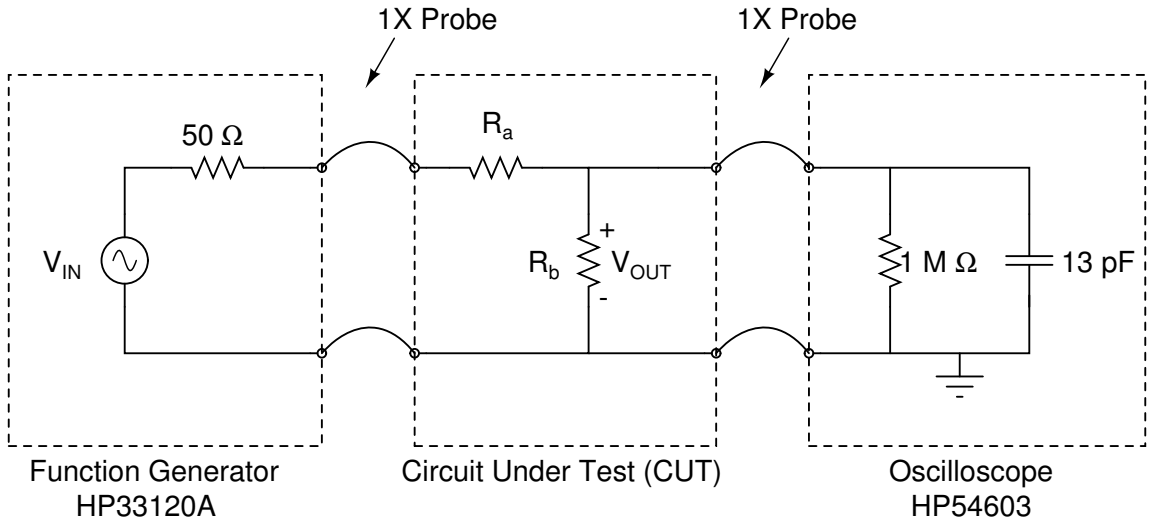


Figure 1: Test set–up and resistor divider circuit for Lab #1.

## Lab Procedure

### Part A

1. Configure the HP33120A Function Generator (FG) to generate a 1kHz sinusoidal signal with $V_{IN} = 1$V peak. Make sure you understand the relationship between the voltage displayed on the FG and the value of $V_{IN}$.
2. Connect the output of the FG directly to the input of the HP54603 Oscilloscope (scope) and measure the FG output voltage and frequency. Verify that the FG is producing a 1V peak signal with a frequency of 1kHz.

**Part B**

1. Use the Tenma 72-1025 LCR Meter to measure the capacitance of your 1X probes at a frequency of 1kHz. Also measure the Dissipation Factor (D) of the probes at a frequency of 1kHz.
2. Obtain two resistors with each of the following values: 10Ω, 10kΩ, and 1MΩ. Measure the resistance of each resistor using your digital volt meter (DVM).
3. Place resistors, $R_a$ and $R_b$, with the values given below on the white breadboard in a series circuit.
   (a) $R_a = 10\Omega, \quad R_b = 10\Omega$
   (b) $R_a = 10k\Omega, \quad R_b = 10k\Omega$
   (c) $R_a = 1M\Omega, \quad R_b = 1M\Omega$
4. Set the FG to generate a 1kHz sinusoidal signal with peak voltage $V_{IN} = 1V$. Verify both the frequency and peak voltage using the scope then connect the FG and scope to the resistors $R_a$ and $R_b$ as shown in Figure 1.
5. Use the scope to measure the peak value of the output voltage ($V_{OUT}$) across resistor $R_b$ for the three cases above. Record all results in your engineering notebook.
6. In an ideal world, where the FG has no source resistance, the probes are perfect connectors, the scope has no input resistance, and the values of the resistors are exact, what would be the ratio of $V_{OUT}/V_{IN}$?
7. Using the measured values of the resistors, the measured capacitance of the 1X probe, the output resistance of the FG and the input impedance of the scope, calculate the expected ratio of $V_{OUT}/V_{IN}$ for the three cases. Show all calculations in your notebook. Complete the following table and record the results in your notebook:

| $R_a$ | $R_b$ | $V_{OUT}$ / $V_{IN}$ | | | |
|---|---|---|---|---|---|
| | | Ideal | Calculated | Measured | % Error |
| 10Ω | 10Ω | | | | |
| 10kΩ | 10kΩ | | | | |
| 1MΩ | 1MΩ | | | | |

Note: The % Error is determined by:

$$\%\text{Error} = 100 * \frac{|\text{Calculated} - \text{Measured}|}{\text{Calculated}}$$

8. Explain in your notebook any discrepancy between the measured and calculated values. Indicate possible sources of the error.

**Part C**

1. Change the FG output to a square wave with a 1V peak amplitude. Keep the frequency at 1kHz.
2. Record in your notebook the shape of the rising edge of the signal, as observed on the oscilloscope, for each set of resistors above. Expand the sweep time to see the details of the signal (it is not just a vertical line).
3. Measure and record both the rise time and the time constant of the signals at $V_{OUT}$. The signal should appear similar to the response of a first order RC system.

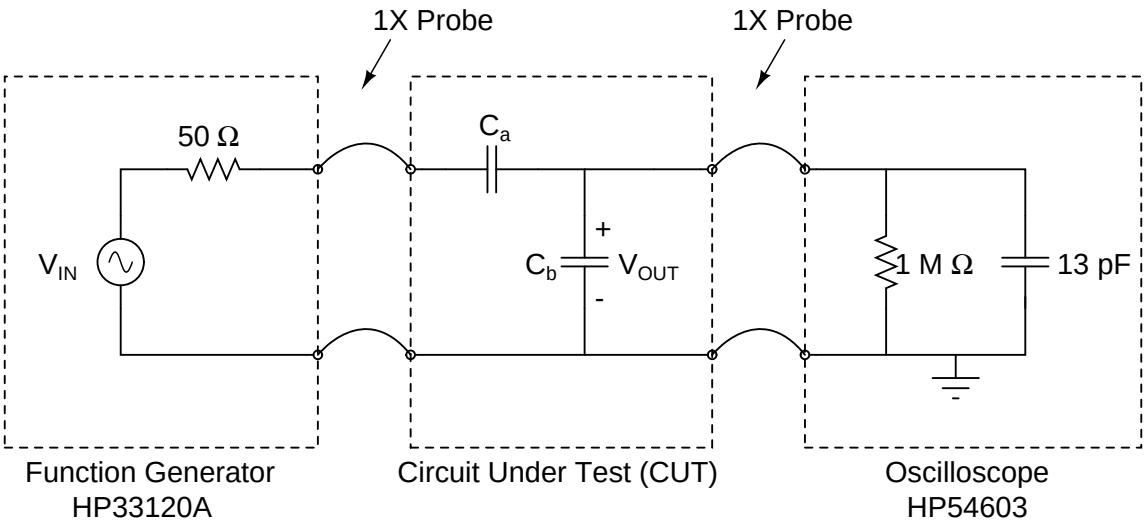


Figure 2: Test set–up and capacitor divider circuit for Lab #1.

**Part D**

1. Obtain two capacitors with each of the following values: 100pF and 3.3nF. Measure the capacitance of each capacitor using the Tenma 72–1025 LCR meter.
2. Place capacitors, $C_a$ and $C_b$, with the values given below on the white breadboard in a series circuit.
   (a) $C_a = 100\text{pF}, \quad C_b = 100\text{pF}$
   (b) $C_a = 3.3\text{nF}, \quad C_b = 3.3\text{nF}$
3. Set the FG to generate a 1kHz sinusoidal signal with peak voltage $V_{IN} = 1\text{V}$ and connect the FG and scope as shown in Figure 2.
4. Use the scope to measure the peak value of the output voltage ($V_{OUT}$) across capacitor $C_b$ for the two cases above. Record all results in your engineering notebook.
5. In an ideal world, where the FG has no source resistance, the probes are perfect connectors, the scope has no input resistance, and the values of the resistors are exact, what would be the ratio of $V_{OUT}/V_{IN}$?
6. Using the measured values of the resistors, the measured capacitance of the 1X probe, the output resistance of the FG and the input impedance of the scope, calculate the expected ratio of $V_{OUT}/V_{IN}$ for the three cases. Show all calculations in your notebook. Complete the following table and record the results in your notebook:

| $C_a$ | $C_b$ | $V_{OUT}$ / $V_{IN}$ | | | |
|---|---|---|---|---|---|
| | | Ideal | Calculated | Measured | % Error |
| 100pF | 100pF | | | | |
| 3.3nF | 3.3nF | | | | |

7. Explain in your notebook any discrepancy between the measured and calculated values. Indicate possible source of the error.

**Post-Lab**

What is the most important piece of information you learned in this laboratory? Provide a short summary of your major results and conclusions. Note the location of the summary in the Table of Contents of your notebook.