# Mixed Electronics Lab 1
# Oscilloscope Circuit Analysis

Caitlin Armstrong

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## 1 Introduction

In order to establish an understanding of instruments and measurement the students will experimentally determine the bandwidth of the oscilloscope probe. They will consider how the O-scope and Probe circuitry affect their measurements, and be able to discuss. The students will perform AC and DC analysis using their Oscilloscope. Additionally we will establish best practices for troubleshooting and lab notebooks.

## 2 Instruments

### 2.1 Function Generator

There are many different function generators built to a variety of specifications. Most Function Generators produce a range of wave forms including DC, sine waves, square waves, triangle and saw tooth waves. Additionally, function generator will operate across a specific range of frequencies. The frequency of the output can be easily adjusted in real time. To fully characterize the effect of a circuit a range of inputs should be tested, testing a circuit at incremental frequencies as set on the function generator is known as a "frequency sweep".

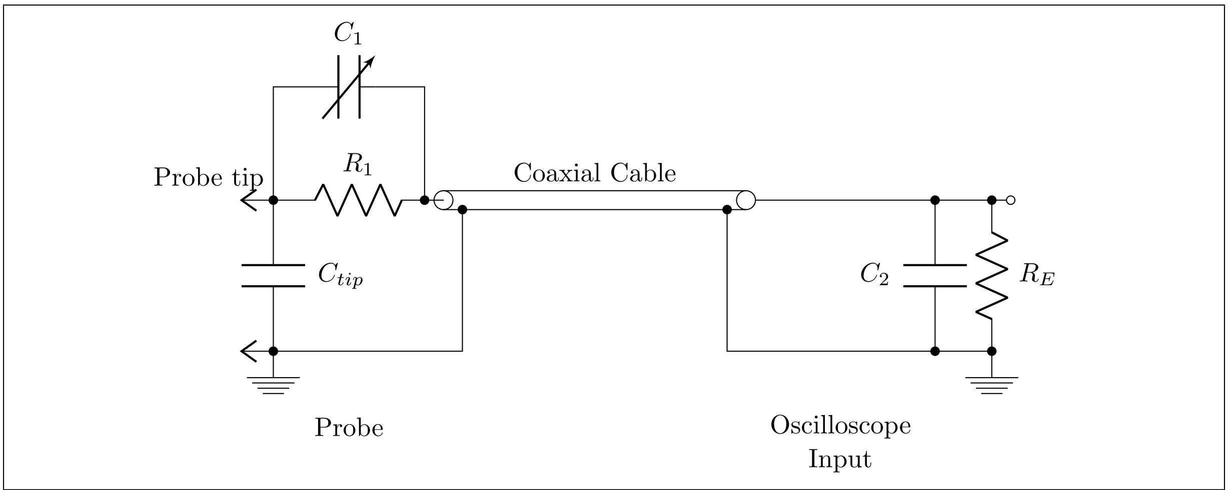


**Figure 1:** The internal circuitry of the Oscilloscope Probe. For a x1/x10 Probe $R_1$ switches from a 1 MΩ to a 10 MΩ resistor. C1 changes when the probe is calibrated.

### 2.2 Oscilloscope

Instrumentation and measurement is fundamental to the analysis of circuit design, and the methods used should be considered carefully. Circuitry within the different tools affect the accuracy and precision of measurements. The Primary tools for circuit analysis are an Oscilloscope, and Oscilloscope Probe. The default Oscilloscope screen displays time along the x axis, and voltage along the y-axis. Either axis can be scaled, to show more or less of the input. One important feature on multi-channel O-scopes is the math function. The math feature will display the difference, sum, dividend, or product of two inputs. To make accurate measurements from the O-scope you will need to use cursors. Cursors measure between two bars across the x-axis, y-axis, or both. The difference in time/voltage measured between the two cursors will be displayed on a side panel. This is how gain or phase will be measured in each lab.

## 2.3 Oscilloscope Probe

The Oscilloscope Probe has an internal circuit as shown in figure 1. The tune-able capacitor allows one to calibrate the probe, which should be done every time it's used. There are two settings on your probe, x1 and x10. These relate to the internal resistor. The x1 probe has greater sensitivity, but a more limited bandwidth, as it uses a 1 MΩ resistor. The x10 setting switches to a 10 MΩ resistor, scaling down the input voltage by 10, and reducing sensitivity. However, the x10 setting has a wider bandwidth.

From Figure 1 we see that the internal capacitor is variable. This allows one to re calibrate their probe for every new testing scenario. Calibrating the capacitance of the probe properly can be done using the calibration output on the O-scope. The output of the calibration signal should be a sharp square wave. The value of the capacitor can improve the shape of that signal for different frequencies. Examples of improperly tuned signals are shown in figure 2.

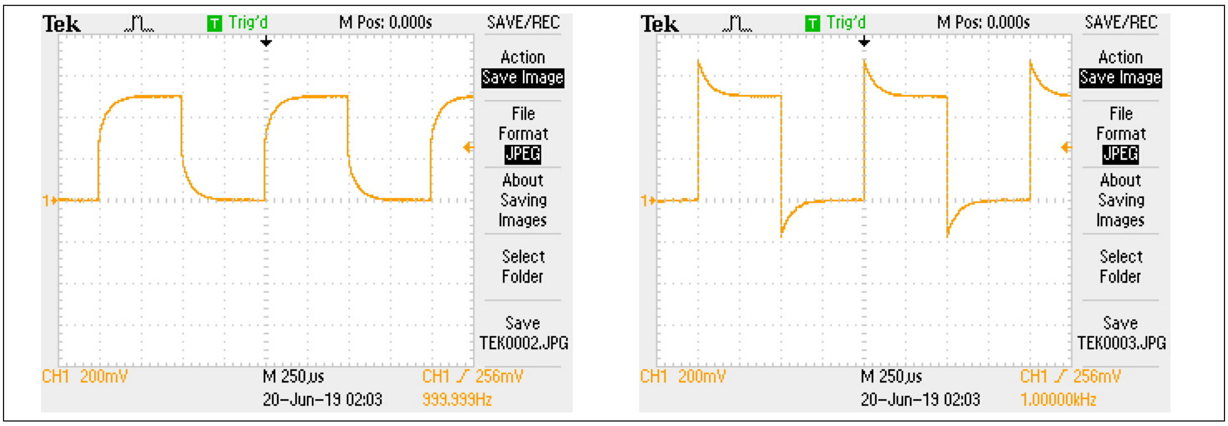


**Figure 2:** The figure on left side shows an example of a square wave measured through an over-damped probe, while the figure on right side shows the same waveform measured with an under-damped probe

## 2.4 AC Analysis

1. Set the Function Generator to Output a 1 kHz Square Wave.
2. Connect the Oscilloscope probe directly to the output.
3. Using the Oscilloscope Cursors, measure the amplitude and frequency of the signal.
4. Be prepared to discuss where on the signal you made your measurements, and how that may or may not affect your accuracy.
5. Using the measurement function on your oscilloscope, record the frequency and amplitude.
6. Determine the percent error of your measurements.
7. Tune the probe at x1 and x10 attenuation.
8. Set the Function Generator to output a 1 kHz sine wave, with a 2 Volt peak to peak amplitude.
9. Using the O-scope and Probe, measure the signal from the function generator. Use your cursors to measure the frequency and amplitude response of the probes internal circuit.
10. Look up the data sheet for your probe, find the bandwidth for both the x1 and x10 setting, Does your probe over or under perform?

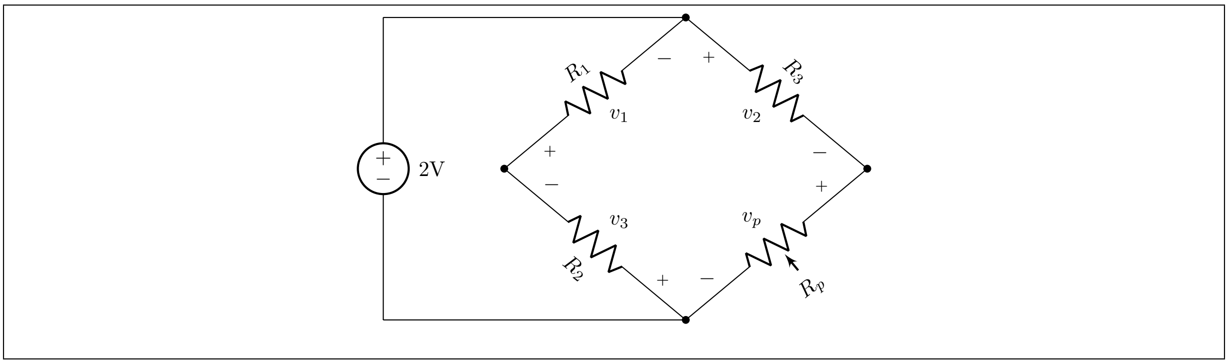


**Figure 3:** The Wheatstone bridge is a tool to sort resistors. It works using voltage division and standard ratios. When the ratio of $R_1$ to $R_2$ is the same as between $R_3$ and $R_p$, then there will be no difference in voltages, and no current will flow between nodes. If $R_1$ is $10\,\mathrm{k}\Omega$ and $R_2$ is $50\,\mathrm{k}\Omega$, $R_3$ and $R_p$ would need to match a 2:1 ratio.

## 2.5 DC Analysis

1. Use the function generator to supply a DC output of 1 volt
2. Using an amp meter adjust the potentiometer until no current is flowing between nodes a and b. What does this tell you about the value of the resistor.
3. Measure the resistance of the potentiometer and determine the error seen.
4. Replace R2 with any other resistor between 1 and 10k, and using your voltmeter adjust the potentiometer until you have matched the voltage across R2.
5. Again, measure the resistance across the potentiometer and determine the percent error.
6. Discuss differences in accuracy between the two measurement methods.

## 2.6 Building an O-scope Probe

1. Begin this exercise by comparing the readings from the oscilloscope probe, and basic circuit probes.
2. Build the Oscilloscope probe circuit seen in figure 1, for a x1 attenuation. Using the basic probes, show how different values of the capacitor affect your readings
3. attempt to manually tune the probe circuit by selecting the correct value for the capacitor. Explain why you chose this value, and describe how you confirmed its performance.
4. Repeat steps 1-3 for for an O-scope probe built to a x10 attenuation.