EE 105 Spring 2026

Lab 1: Electronic Test Equipment, RC response, diode IV

Objective

This lab will help you become familiar with the equipment you will be using for the rest of the semester. For those that took EECS 16B before the new curriculum, several instruments will be familiar. For those that used the AD2 Waveform Generator, learning to use the equipment now will spare you many headaches later in the course.

Pre-Lab

You should become familiar with the lab equipment in advance. To begin, glance through the tutorials in the Labs section of bCourses (*/Files/Lab Documents/Equipment tutorials*); each describes an instrument that is used in these labs. For further reading, please refer to the device manuals.

P1. For the voltage divider in Figure 1, calculate V_{out} and the current through the 20 kΩ resistor.

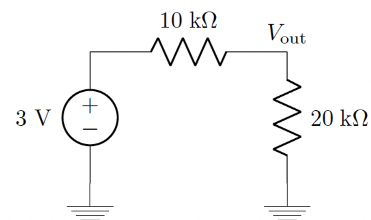


Figure 1: Resistor circuit.

P2. For the RC circuit in Figure 2:

P2.1 What is the time constant, τ (provide a numerical answer)?

P2.2 Derive the transfer function from V_s to V_{out}.

P2.3 What is the pole frequency in radians/s (ω_p), and hertz (f_p)?

P2.4 Sketch the bode plot (straight-line approximation). Make sure to label your axes and relevant values (e.g. slopes, pole frequencies, flat-line gain).

P2.5 Given the resistance (R) and magnitude (G) at a given frequency (ω), solve for C.

P2.6 Given the resistance (R) and phase (ϕ) at a given frequency (ω), solve for C.

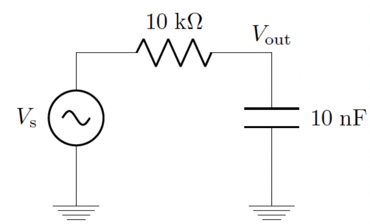


Figure 2: RC circuit.

P3. For a CR highpass circuit (Figure 2, but with the resistor and capacitor swapped):

P3.1 What is the time constant, τ (provide a numerical answer)?

P3.2 Derive the transfer function from V_s to V_{out}.

P3.3 What is the pole frequency in radians/s (ω_p), and hertz (f_p)?

P3.4 Sketch the bode plot (straight-line approximation). Make sure to label your axes and relevant values (e.g. slopes, pole frequencies, flat-line gain).

P4. For the diode circuit in Figure 3 (You do not need to know what a diode is to complete this section):

P4.1 If Vout is 0V, what is the current through this circuit?

P4.2 If Vout is 1V, what is the current through this circuit?.

P4.3 Plot these two points on a graph with I on the y-axis and V on the x-axis and draw a straight line connecting the two. This will be useful for the last section of your lab.

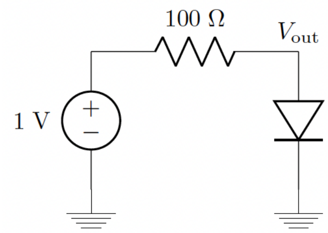


Figure 3: Diode circuit.

Lab

Each lab workstation has the necessary test equipment. You will also need the components listed in Table 1, breadboard and jumper wires, which should all be in the EE105 cabinet. Parameter analyzer cables will be provided by the GSI, while other cables are available on the racks.

Table 1: Components used in this lab.

Component	**Quantity**
20 kΩ resistor	1
10 kΩ resistor	1
100 Ω resistor	1
0.01 μF capacitor	1
1N4148 diode	1

Procedure

You can generally trust measurement equipment (like the digital multimeter and oscilloscope) to be more accurate than the output readings on generators (like the DC power supply and function generator). Several of these lab exercises involve measuring the output error on the generators using the digital multimeter (DMM) or oscilloscope.

When performing measurements or using multiple sources, be sure the ground terminals are connected appropriately. Usually, you will create one ground node in your circuit and connect all device grounds to that node.

Note: Be sure to answer the questions on the worksheet as you proceed through this lab. The worksheet questions are labeled according to the sections in the experiment.

1 DC Measurements (DMM and DC Power Supply)

1.1 Supply accuracy

Before starting, make sure the DC power supply current limit is set to 0.1A. Select "Display Limit", toggle the "Voltage/Current" button so that the cursor is on the value of current, and adjust current until it sits at 0.1A.

Now, select the +6V output terminal and set the voltage limit to 5V. Measure the output with the digital multimeter (DMM). What is the percent error between the displayed output value and the actual output value? Now, record the errors for the following settings: +1V and +10V. Use the +6V output terminal for the first two settings (i.e. +1 V and +5 V) and the +25V output terminal for the +10V setting. Remember to press the "Output On/Off" button to turn on/off the output.

1.2 Voltage divider

On your breadboard, build the circuit shown in Figure 4. Compare the value calculated in Prelab P1 with the voltage measured at V_{out}. What is the percent error? Other than measurement error and noise, what might contribute to the deviation from the idealized calculation? *Hint:* Measure the resistor values using the DMM.

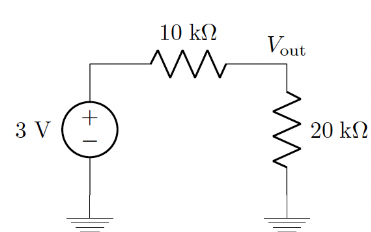


Figure 4: Resistor circuit to build.

1.2.1 Avoiding explosions

You are not supposed to connect the DMM to the terminals of a voltage source while the DMM is in current mode. Why not?

1.2.2 Current

Move the red multimeter probe from the top (voltage) port to the bottom (current) port. Connect the DMM in *series* with your circuit. If you are connecting the DMM without pulling resistor legs out of the breadboard, you are not connecting it in series and will short the DMM.

Measure the current through the 20 kΩ resistor and compare this to the value from prelab P1.

2 AC Measurements Basics (Oscilloscope and Function Generator)

The function generator panel often displays a different peak-to-peak voltage than what is measured at its output because the panel setting assumes a certain load impedance (please see the function generator tutorial for further details).

Note, "amplitude" refers to the maximum displacement from the offset while "peak-to-peak" (V_{pp}) refers to the voltage difference between the absolute maximum and minimum voltage points of the signal (i.e. double the amplitude).

2.1 Function generator amplitude

Set the function generator to output a 1 kHz, 1 V_{pp} sine wave according to the panel display. Now, measure the wave by directly connecting the function generator to the oscilloscope probes. Record the frequency and Vpp as measured on the oscilloscope in the 50Ω column of your lab worksheet.

Yikes! This is off by a factor of two! What is going on? The function generator powers on in a mode that assumes that you will be using it with a 50 Ω coaxial cable connected to a 50 Ω load resistance. This is very useful for high frequency signals, but not so useful for the things that you will do in the lab.

Set the function generator to the "high-impedance load" setting (refer to p. 40 of the Agilent33120A manual on bCourses). Now record the frequency and Vpp as measured on the oscilloscope in the High-Z column of your lab worksheet. The amplitude should be much closer to what you expect now.

Ensure you are in high-impedance mode for the rest of this lab (and for the rest of the semester unless specified). For further assistance in this calculation, please refer to Section 3: Voltage Divider Discussion from the Function Generator Tutorial.

2.2 Function generator amplitude frequency dependence

Increase the sinusoid frequency until you see that the measured amplitude starts to drop. What is this frequency? Now, increase the frequency to the maximum generator frequency. What is the error between the measured amplitude and the displayed amplitude setting? *Note:* Please use the cursors to measure the signal if there is significant noise in the displayed waveform.

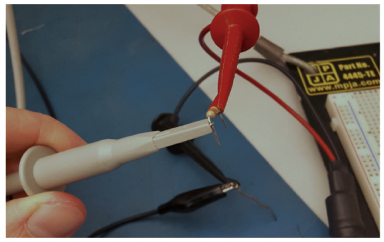
2.3 Noise and perceived amplitude

What is the smallest sinusoid that the generator can produce at 1 kHz (ensure you are in High-Z mode)? What is the error between the measured Vpp and the panel setting? Now, have the oscilloscope average over 64 measurements to compensate for system noise and to allow for better measurement accuracy. For assistance on using the averaging feature of the oscilloscope, please refer to Section 5.4: Using Averaging from the oscilloscope tutorial. What is the error now? Without averaging, does the oscilloscope over-measure or under-measure the Vpp value? Why?

2.4 Breadboard capacitance

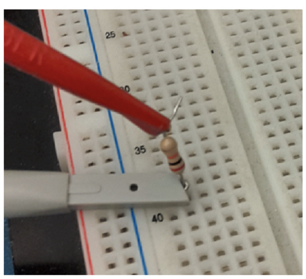
Set the function generator to output a 1 MHz, 1 Vpp sine wave. Measure the input signal with the oscilloscope to verify the amplitude setting.

Now connect a series resistance of 10 kΩ to the function generator and measure the voltage on the opposite terminal of the resistor with an oscilloscope. Do not use the breadboard. Make the connections in the air, as shown here:

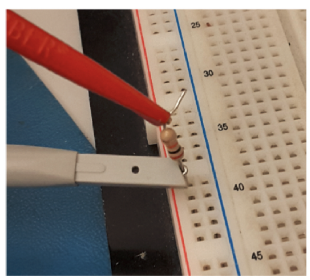


Is the measured voltage still 1 Vpp? Why? Estimate the associated parasitic capacitance from the measurement (refer to prelab for useful equations).

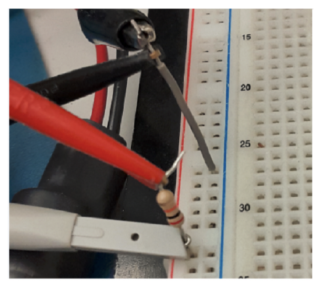
Measure the voltage on the second terminal of the resistor in the following configurations and repeat the measurements and calculations. Which case has the highest parasitic capacitance? Why?



Resistor connected to a terminal strip.



Resistor connected to a supply strip.



Resistor connected to a supply strip, ground connected to a ground strip.

3 RC Response

On your breadboard, build the RC circuit shown in Figure 5. The source V_s should be a 1 kHz sine with a V_{pp} of 1 V. You should get similar answers for sections 3.1, 3.2, and 3.3.

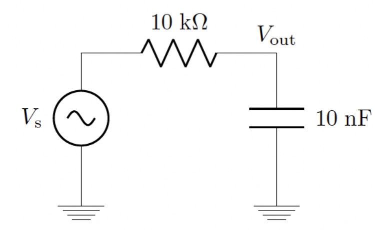


Figure 5: RC circuit to build.

3.1 Magnitude response

First, calculate $|V_{out}/V_s|$ using the ideal values of the RC circuit at 1 kHz.

Then, measure the amplitudes of the input and output waves. Determine $|V_{out}/V_s|$ based on your oscilloscope measurements. This represents the magnitude of the transfer function at 1 kHz. Estimate the time constant of this single-pole system based on this measurement (refer to the prelab for useful equations).

3.2 Frequency response

First, calculate the phase using the ideal values of the RC circuit at 1 kHz.

Measure the phase of the input and output waves. This represents the phase shift of the transfer function at 1 kHz. Estimate the time constant of this single-pole system based on this measurement (refer to the prelab for useful equations).

3.3 Step response

Change the voltage source to a square wave. Using the cursors on the oscilloscope, estimate the RC time constant of the circuit.

3.4 Cutoff frequency

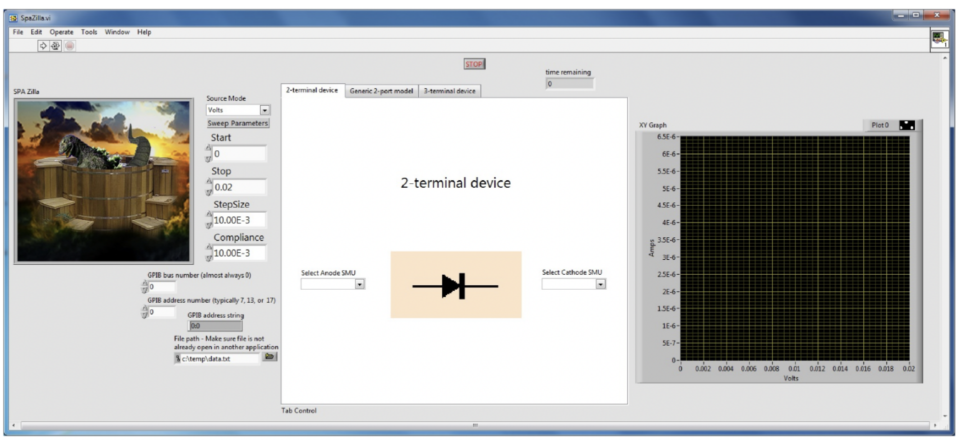
Using your estimated time constant, calculate the pole frequency, f_p, then measure the magnitude and phase at $0.1f_p$, f_p, and $10f_p$.

3.5 High pass

Using a 1 kHz square wave input, swap the R and C elements to make a high pass filter. Why does the voltage go above and below the input? Estimate the time constant and attach a photo of your oscilloscope output. Then, switch back to a 1 kHz sine wave and repeat section 3.4 using the high pass circuit.

4 Parameter Analyzer Basics

The parameter analyzer can be operated manually from the equipment panel, but the recommended way is to use a Windows-based software. It will allow us to save the measurement results as well. To open the software, log-in to the Windows desktop machine with your instructional account. The program name is `SpaZilla`. If you don't have the icon on the desktop, the path is `C:\SpaZilla`. The SpaZilla interface is:



In the middle section, choose 2-terminal device (default), and the SMU-s that your device is connected to. The left section:

- **Voltage source:** Volts for sweeping the voltage and measuring the current, Amps for sweeping the current and measuring the voltage.
- **Start, Stop, Step Size:** The sweeping parameters.
- **Compliance:** The limit on the measured parameter (current limit for Volts in Source Mode, voltage limit for Amps in Source Mode).

- **GPIB bus number:** Should be 0.
- **GPIB address number:** For older instruments it appears on the parameter analyzer panel on the bottom-left corner. For newer instruments, go to *System* > *Miscellaneous* to see the number.
- **File path:** the location of the measured result (text file). To run the measurement, click on the right arrow button on the top-left of the screen.

4.1 Resistor IV Curve

Using the Agilent4155C/HP4145A/B, plot the I–V characteristic of a 100 Ω resistor, sweeping the voltage from -1 V to 1 V. What is the measured resistance according to your plot? Attach the plot to your lab worksheet. For assistance with the parameter analyzer, please refer to the parameter analyzer tutorial.

4.2 Diode IV curve

Now plot the I–V characteristic of a 1N4148 diode, sweeping the voltage from −1 V to 1 V. You don't have to understand the diode principle of operation (we will study it later in this class), just think about it as a "black-box" device with some unknown I–V characteristics. Note that a diode is a non-symmetric device (unlike a resistor or (some) capacitors); it has a positive and negative terminals:

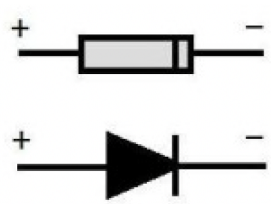


Figure 6: Diode physical appearance (top) and symbol (bottom).

Again, attach the plot to your lab worksheet. *Note:* The I–V curve might flatten out due to the 100 mA current limit of the parameter analyzer.

4.3 DR Load Line

Using your empirical plots from above and load-line analysis, determine the value of V_{out} for the circuit shown in Figure 7. *Hint:* What is common to the resistor and the diode in this circuit? Verify your calculated operating point by building the circuit and measuring the voltage with the DMM.

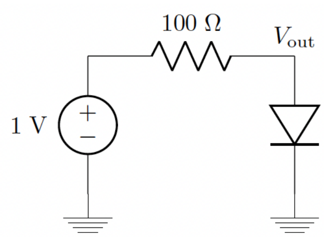


Figure 7: Diode circuit to build.