**Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

# ECE 101 LAB 4: TIME-VARYING SIGNALS

1. **Overview**

In this lab we observe signals such as ac (sinusoidal) and exponential signals that change with time. The lab introduces two more pieces of equipment. The function generator is used to generate time-varying signals such as sine waves, square waves, pulses and ramps. Oscilloscopes are tools that allow engineers to view signals graphically. The oscilloscope displays signals as a plot of voltage (amplitude) versus time. The oscilloscope is one of the most important instruments for electrical engineers to learn, and it is considerably more involved than the other instruments in the lab. You are not expected to learn everything about it in this lab! This is just an introduction; take your time and learn to navigate the basic menus and controls.

* 1. **Objectives**

You will learn to operate some new instruments and use them to study two types of time-varying signals.

* Learn to use a function generator and (the basics of) an oscilloscope
* Observe a time-varying signal in an RC circuit
* Relate observed waveforms to mathematical expressions
	1. **Equipment**
* Lab bench with Function Generator (“FG”), Oscilloscope (“scope”) and computer
* ECE 101 lab kit with protoboard, wires, cables, capacitor and resistors
1. **Lab assignments**
	1. **Time-varying Signals on Oscilloscope**

As in previous labs, you should have the Quick Guides open on the computer for reference (<http://web.cecs.pdx.edu/~ecelab>). This handout will only give general instructions; more detailed instructions specific to the equipment are in the guides. Different benches may have different models.

1. Turn on the scope. If not told otherwise, use these as default settings to start: channel 1, position at mid-point of screen, vertical scale 0.2 V/div, horizontal scale 0.2 ms/div (may be 0.25 ms/div on some models,) DC coupling. You can always use Autoset to get an initial display.
2. Turn on the FG and set it to produce a sine wave with amplitude 1 V (1 V peak-to-peak) and frequency 1 kHz. Connect it to the scope using the bnc-to-bnc cable.
* The period (time for one cycle in seconds) is 1/frequency (number of cycles per second in Hz.)

What is the period of a 1 kHz sine wave? \_\_\_\_\_\_\_\_\_\_

1. Verify that is the period you see on the scope by noting the horizontal scale (time/division) and the number of divisions for one cycle. (It should agree, so get help if it doesn’t!) Investigate what happens when you change the horizontal scale. Record the measured period (T) and the frequency (f) calculated from T on the next page.
2. Verify the peak-to-peak amplitude (Vp-p) you see on the scope by noting the vertical scale (voltage/division) and the number of divisions. If it doesn’t agree, there are two things to check. Some scope models have a 10x setting for a scope probe used to amplify small signals. If your output is 10x what you expect, you need to return this setting to 1x in the Probe Setup menu. Another thing to check is the input resistance of the scope. Some models have the option to change between 1 MOhm and 50 Ohmin the Coupling menu. If yours does, investigate what happens when you change between these two settings. If it’s not on yours, you will probably see 2 Vp-p instead of 1 Vp-p. This is because the FG has a 50 Ohm output and is expecting to have a load with a 50 Ohm input. It is intentionally producing twice the 1 Vp-p setting because it is expecting a 50-50 voltage divider! If the scope has a 1 MOhm input, you see almost the whole 2 Vp-p on the scope. There is a good discussion of this effect in the FG Quick Guide.
3. After you have verified the correct amplitude, also investigate what happens when you change the vertical scale. Record the measured Vp-p below.
4. There is also a Measure menu for making common measurements like these. Explore this menu and verify that you get the same results as by counting divisions.
* Measurements: Vp-p = \_\_\_\_\_\_\_\_\_\_\_ T = \_\_\_\_\_\_\_\_\_\_\_\_ f (calc. from T) = \_\_\_\_\_\_\_\_\_\_\_\_\_
1. Be sure to set your scope to DC coupling. With DC coupling, the entire signal (DC and AC) is displayed. With AC coupling, the DC portion is removed. Add a 0.5 Vdc offset to the FG output.
* Observe the signal on the scope – what happens when you add the offset?
* Now change the scope setting to AC coupling. What do you observe?
1. Explore the various settings on the FG and observe:
	1. Different waveforms (sine, square, etc.)
	2. Different frequencies
	3. Different amplitudes

Note that the scales on the scope need to be changed in coordination with the FG so that different frequencies and amplitudes can be clearly displayed. Sketch below two examples of waves that you displayed. Clearly indicate the amplitude and time scales from the scope and the settings from the FG.

**Ask TA to verify your sketches and to check you off for that task. Do your sketches on a separate piece of paper, take a photo of them and include them in your final report. Crop the photo appropriately.**

For example: square wave, 1 Vp-p amplitude, 0.5 Vdc offset, 2 ms period

 0.5 V/div vertical scale, 1 ms/div horizontal scale

 ←0 V

* 1. **Non-sinusoidal Signals on Oscilloscope**

In this part of the lab we will look at an example of a time-varying signal in a circuit.

* + 1. **Background**

A capacitor (C) is an electrical component that can store and release charge. In a resistor, when the power is turned off, the voltage goes to zero immediately. In a capacitor, however, the stored charge cannot instantly disappear, and so the signal decays to zero in some measurable amount of time. When there is a resistor and capacitor present, as in the circuit on the next page, the voltage across the capacitor follows this equation: **V(t) = V0e-t/RC**. This is assuming the initial voltage V0 is switched off at time t = 0. You will see where this equation comes from in circuits class; we’ll just observe it for now.

The product R\*C is a time constant which characterizes the rate of exponential decay of the voltage. When t = RC, V = V0e-1 = 0.37V0.The figure below shows the voltage for two different time constants.



Figure 1. Exponential waveforms with two different time (RC) constants.

* What is the RC time constant for the 2nd waveform? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
1. Build the circuit below on the protoboard with a 1 kOhm resistor (or similar) and the capacitor in your kit (the flat, tan one – not the thermistor!). Make sure that you have more than one resistor of this value in your kit. (we should make sure there are 2-3 1kOhm resistors in the kit) The expected value for capacitance is C = 0.01 μF, where μ= 10-6, but it is possible not all kits have the same. (FYI: if it says “103” that means 10 x 103 pF = 104 x 10-12 = 10-8 F or 0.01 μF.) The FG should be set to produce a square wave with amplitude 1 V (add a 0.5 V DC offset as in step 3 so the pulse goes from 0 to 1 V) and frequency 1 kHz.



Figure . Measurement setup for RC measurements.

* Observe the capacitor voltage on the scope, and sketch what it looks like. You should see the capacitor charge up when the pulse is turned on, and discharge when the pulse is turned off. **Use a separate sheet of paper for your sketch and show it to your TA when done. Take a photo of it, crop it appropriately, and include it in here.**
* When the pulse goes off, estimate the time it takes for the voltage to go down from 1 V to about 0.37 V and record it in the table below. Compare that to the calculated time constant RC – are they close? What is the percent (%) difference?

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(Note: they should be somewhat close, so if they are vastly different you should check your work, especially the powers of 10! This measurement can be most easily made if you adjust the time scale to zoom in on the falling edge of the pulse. This can be a bit tricky – feel free to ask the TAs for help. )

Repeat with ½ of the original resistor value and again with a resistor value twice as large. Think about how you will accomplish this task. Do you see the signal decaying more slowly with the larger RC time constant?

* Sketch two of the waveforms and indicate RC constant values on them (as in Figure above). **Show your sketch to TA and include it in here.**

Table 1. Measured vs. calculated values of RC time constant.

|  |  |  |  |
| --- | --- | --- | --- |
| R (kOhm) | C (μF) | Calculated RC (s) | Measured time for V → .37V0 |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

* (Later) Describe your observations and comments on this lab below.
* (Later) Please reflect on your learning experience – what helped your learning and what detracted from it?