

## Time-varying signals: the function generator, RMS measurements, and the oscilloscope

The primary purpose of this lab is to become familiar with the tools and techniques for doing circuit measurements when the voltages and currents are changing with time. The primary tools are the multimeter (now used in AC mode), the function generator for creating time-varying input signals, and the oscilloscope for observing time-varying waveforms. There are two tutorials describing some of the basic operations of the function generator and the oscilloscope. These can be read ahead of time. The lab itself has a few exercises to illustrate some typical AC measurements.

### Prior to lab

- The circuits in this lab can be easily analyzed using voltage/current dividers and source transformations, so it is helpful if you have read those class notes.
- Read through the tutorial for the function generator.
- Read through the tutorial for the oscilloscope.
- It is convenient to have a USB drive available for recording oscilloscope traces. If you have a spare, you might consider adding it to your lab kit. It does not need to be big — a couple of gigabytes is more than enough capacity.

### Simple voltage divider

1. For the voltage divider circuit shown in Fig. 1, calculate the expected voltages on the three resistors if source voltage is 5 V.
2. Build the circuit on your breadboard. For the source, use the function generator set to a sinusoid with a frequency of 1000 Hz and amplitude of 5 V<sub>RMS</sub>. (Set the amplitude using RMS units. Don't forget to set the output to "High-Z".)
3. Use the voltmeter — set to AC volts — to measure the source voltage, and then measure the ac voltage across each resistor. For each measurement, try swapping the leads to see the effect. (Recall, AC measurements have no defined polarity.) Confirm that the measurements match expectations. Use Ohm's law to calculate the current in each resistor.
4. Use channel 1 of the oscilloscope to observe the source sinusoid. After using the Auto Scale button to obtain an initial trace, make scale adjustments so that the trace is zeroed at the center and fills most of the screen and so that are about three periods of the sine wave on the screen. Then use channel 2 of the oscilloscope to observe the voltage signal across  $R_3$ . (Of course, you must use the same negative connection for both.) Record a screen shot of the two traces together to include in the report.

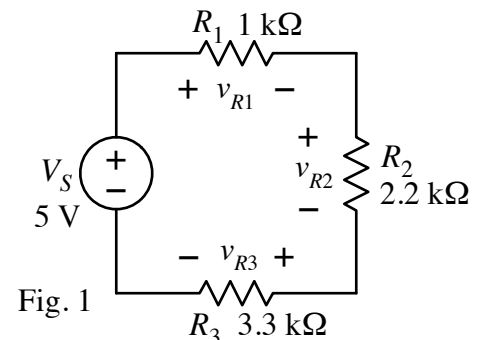
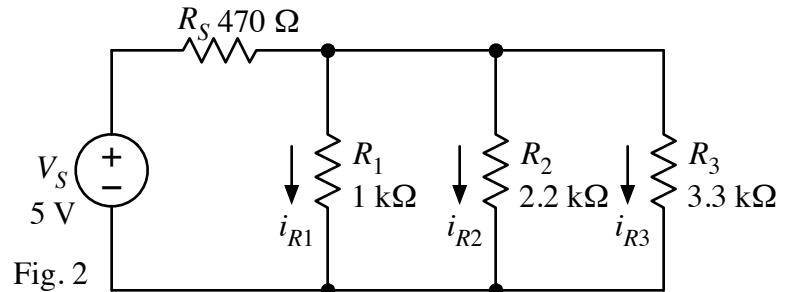


Fig. 1

- On the oscilloscope add RMS voltage measurements for channels 1 and 2. Also, add a frequency measurement. Record a screen shot of the two traces together to include in the report.
- Change the source waveform to a square wave. Separate the traces so that the source trace is in the upper half of the screen and the resistor trace is in the bottom half. Adjust the vertical scales so that the traces fit nicely. Record a screen shot of the two traces. Then change the waveform to a triangle and make adjustments to the scale settings as necessary to have a clean display. Record a screen shot of the two triangle traces.

### Simple current divider

- Use a source transformation to show that the circuit in Fig. 2 can be viewed as a current source connected to a four-resistor current divider arrangement. Calculate the expected currents in  $R_1$ ,  $R_2$ , and  $R_3$ .



- Build the circuit on your breadboard. For the voltage source, use the function generator set to a sinusoid with frequency of 100 Hz and amplitude of 5 V<sub>RMS</sub>.
- Set up the ammeter to measure the current through the voltage source. (Change the leads at the input, change the mode to AC amps, and wire the ammeter so that it is in series with the source.) Why doesn't the measured current match the value of the current source determined by the source transformation in part 1? Then measure the AC currents through resistors  $R_1$ ,  $R_2$ , and  $R_3$ . Again, try swapping the meter leads to see the effect. Confirm that the current measurements for the three resistors do match expectations from the current divider calculation in Part 1. Use Ohm's law to calculate the voltage across each resistor.
- Use channel 1 of the oscilloscope to observe the source sinusoid. After using the Auto Scale button to obtain an initial trace, make scale adjustments so that the trace is zeroed at the center and fills most of the screen and so that are about three periods of the sine wave on the screen. Then use channel 2 of the oscilloscope to observe the voltage signal across the three resistors in parallel. (Again, use the same negative connection for both channels.) Record a screen shot of the two traces together to include in the report.
- Change the source waveform to a square wave. Separate the traces so that the source trace is in the upper of the screen and the resistor trace is in the bottom half. Adjust the vertical scales so that the traces fit nicely. Record a screen shot of the two traces. Then change the waveform to a triangle and make adjustments as necessary to have a clean display. Record a screen shot of the two triangle traces.

### A circuit with a capacitor

The following measurements will be slightly mysterious because we don't yet know about capacitors and the effects they have in circuits. However, one of the important lessons from lab is to become confident in doing measurements — even when we don't necessarily understand how the circuit is supposed to work. In fact, performing measurements on a “mysterious” circuit is a good way to begin figuring out how it works. We will learn about capacitors (and inductors, which are close relatives) later in 201. We will repeat some of these measurements once we understand the capacitors better.

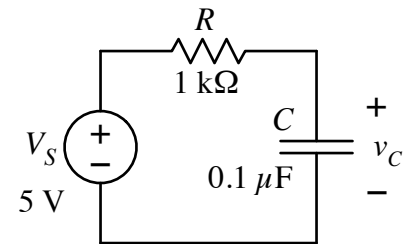


Fig. 3

1. Build the circuit shown in Fig 3. (A  $0.1\text{-}\mu\text{F}$  capacitor capacitor is labeled as 104. The lab instructor can help you identify the right part.)
2. For the source, use the function generator set to produce a square wave with the following properties: frequency = 500 Hz, upper voltage level = 5 V, lower voltage level = 0 V. (Set a high and low voltages directly or set the peak-to-peak voltage to 5 V and introduce an offset of 2.5 V.)
3. Observe the source voltage using channel 1 of the oscilloscope. Adjust the settings so that there are about three periods of the square wave on the screen and the vertical scale is set to 1 V/div.
4. Use channel 2 to observe the capacitor voltage. Note the very different behavior of the capacitor voltage compared to the resistor on the previous exercise. This is because the capacitor is an energy storage device, and it takes time to add and remove energy. The exponential curve of the capacitor voltage as it ramps up and down is indication of the time delay that results when using capacitors in circuits.
5. We can observe the current in the circuit by observing the voltage across the resistor — from Ohm's law,  $i = v_R/R$ . The  $v_R$  waveform is directly proportional to the current. With the probes attached to the source and the capacitor — observing  $V_S$  and  $v_C$  — we can use some math to get  $v_R$  directly without trying to use a third probe. Use the “Math” function to subtract subtract  $v_C$  (channel 2) from  $V_S$  (channel 1) and display it on the screen. The result should be a “spike” similar to the seen in the practice problems. Move the traces so that they are “stacked” on the screen — the source voltage at the top, the capacitor voltage in the middle, and the current curve at the bottom. Adjust scale setting so that the traces are all visible and spaced nicely. Save a screen shot of the three traces together to include in the report. When finished, turn off the math function to remove the resistor voltage trace.
6. Now, switch the function generator to a sinusoid with the following properties: frequency = 1000 Hz and amplitude =  $5\text{ V}_{\text{RMS}}$ .
7. Observe the source voltage using channel 1 of the oscilloscope. Adjust the time base so that there are three or four periods of the sinusoid on the oscilloscope and set the vertical scale to 1 V/div.

8. Use channel 2 to measure the capacitor voltage. Display the two traces together on the oscilloscope. Note the amplitude difference and the time shift between the two sinusoids. Record a screen shot of the two traces together.
9. Use the math function, as described in step 5 above, to add a trace for the resistor voltage, which is a direct measure of the current in the circuit. Arrange the traces so that all three are clearly visible and save a screen shot.
10. Remove the resistor voltage trace and move the source and capacitors traces so that are both centered on the screen. Change the sinusoid frequency to 100 Hz. Note the change in the capacitor voltage waveform. Record a screen shot.
11. Change the frequency to 10,000 Hz (10 kHz). Note the change in the capacitor voltage waveform. Record a screen shot.
12. Finally, set the frequency back to 1 kHz. Use the voltmeter — set to measure AC volts — to measure the AC source voltage, the resistor voltage, and capacitor voltage. Do the measurements follow KVL? These sinusoids seem to be rather sneaky!

### **Reporting**

Prepare a report describing your work for Lab 2. Refer to the class web site for the due date.