Lab 3: Passive Components
U.C. Davis Physics 116A

INTRODUCTION

In this lab you will build a Thévenin equivalent circuit. Then you will consider RC circuit. You will determine the time constant and then study how an RC circuit can be used as either a low-pass or high pass filter.

1. THÉVENIN EQUIVALENT CIRCUIT

In this section, you will build a circuit and its Thévenin equivalent and see how equivalent these two circuits really are. Construct the circuit shown in figure 1, a voltage divider with load resistance, R_L. For your lab report, calculate and measure the voltage at point V for two values of R_L, 1kΩ and 10kΩ. Be sure to include uncertainties in your both measurements and calculations and to discuss the agreement between the calculated and measured values.
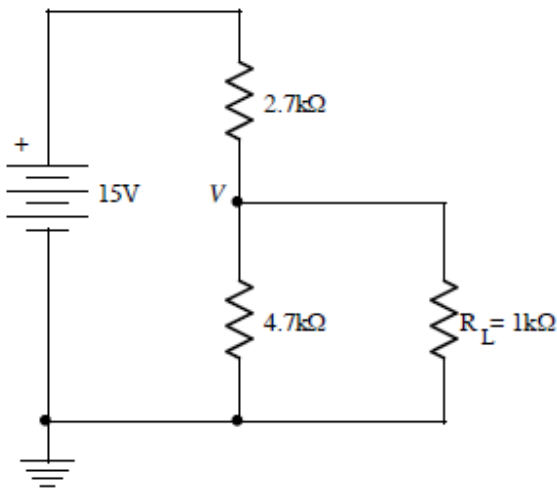

Figure 1: Circuit for demonstrating Thévenin equivalent.

Now calculate the r and e for the Thévenin equivalent of the above circuit. The Thévenin equivalent circuit is shown in figure 2. Construct this circuit using the variable voltage power supply for e and some combination of resistors for r. For your report, show your Thévenin calculation, measure your actual e, r, and voltage at V, and compare V with the circuit above and with theory.
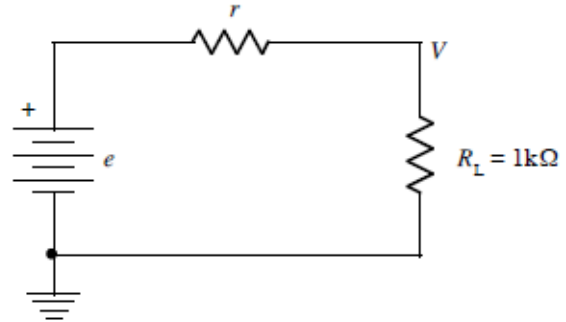

Figure 2: Thévenin equivalent for circuit of figure 1.

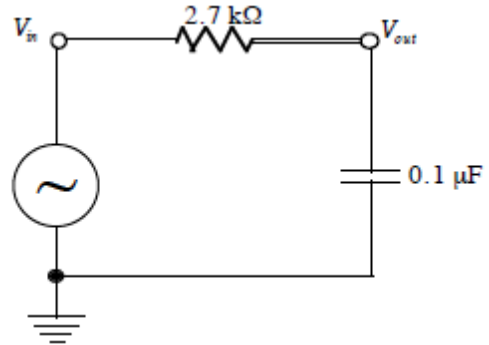## 2. THE TIME CONSTANT OF AN RC CIRCUIT

Figure 3: Simple RC Circuit

Set up the simple RC circuit illustrated in Figure 3. Use a capacitor with a 5% tolerance. Use the function generator as the voltage source. Set it for a square wave pulse with a frequency of 1 kHz and an amplitude of 2 V. Sketch the waveform in your lab notebook. From your sketch of the waveform, determine the time constant of the circuit. Compare this value to the theoretical value (RC).

Now repeat this measure procedure with two other capacitors with nominal values of 0.001 µF and 10 µF.

3. LOW PASS FILTER

In this section, you will measure the frequency response of a low pass filter circuit and see what the "low pass" name refers to. Construct the circuit shown in figure 3 (same as in the previous section)

using the function generator as the AC source. Use a 2V peak to peak sine wave as the v_{in} source signal. Use both channels of the oscilloscope to monitor v_{in} and v_{out} simultaneously showing their phase relationship as follows. Connect Ch. 1 to v_{in} and Ch. 2 to v_{out}. Set the oscilloscope to trigger on Ch. 1 only and adjust the trigger level until the trace starts at zero with positive slope. Ch. 1 will now display a sine wave. The phase difference of Ch. 2 will now be evident through the different starting value its trace and the overall displacement of the Ch. 2 waveform relative to Ch. 1.

The input and output signals can now be expressed as:

$v_{in}(t) = V_{inmax} \sin(\omega t),$

$v_{out}(t) = V_{outmax} \sin(\omega t + \phi),$

where V_{inmax} and V_{outmax} are the amplitudes of the input and output waveforms, respectively, ω is the angular frequency, and ϕ is the phase shift.

Calculate the break frequency (or corner frequency) $f_b = \omega_b / 2\pi$ for this circuit. Use this frequency and select 10 other frequencies, 5 above f_b and 5 below f_b,

For each frequency, measure the voltage gain, $A_v = V_{outmax} / V_{inmax}$, and the phase shift, ϕ, of v_{out} relative to v_{in}. Bear in mind that you will want to find the slope of the fall-off of the gain on the log-log plot at high frequencies.

For your lab report, include your f_b calculation, your gain and phase shift data, and 4 separate graphs of the data. First, make a linear-linear graph of gain *vs.* frequency and phase angle *vs.* frequency, indicating f_b on each. (That's 2 graphs.) Then, make a log-log plot of gain *vs.* frequency and a semi-log plot of phase angle (linear) *vs.* frequency (log), comparing the data to the theoretical Bode plots for gain and phase angle. (That's the other 2.)

4. HIGH PASS FILTER

Design an RC high-pass filter with $f_b = 10kHz$. Build it and take enough data to make Bode plots for gain and phase. For your report, include a description of how you designed the circuit and the two Bode plots (each of which includes data points and a theoretical plot).