Lab 1: Linear Components

1.1 General Lab Comments

The laboratory will be the most important component of this course. All students should come away from the course feeling comfortable with basic practical electronics and associated techniques. Please obtain a lab notebook, preferably hardcover with quadrille paper. This will be the primary record of your lab work. Your lab report should include any pre-lab notes which are useful to you for carrying out the in-lab work. All data, observations, notes, calculations, etc. should be entered in the notebook. Provide headings for your entries which correspond to those of the lab instructions. Clearly indicate the location of required material within your report. Your notebooks will be turned in to your T.A. within a few days of the lab for grading. Your notebook should also include all material relating to your project.

1.2 Goals of this Lab

The primary goal of this lab is to become familiar with lab instrumentation and methodology. The prototype board (or "breadboard"), digital volt meter (DVM), oscilloscope, resistors and capacitors, and cables will be used throughout the course. In particular, students unfamiliar with oscilloscope operation should use this lab as an opportunity to develop their skills. Read Appendix A of the text prior to the lab and please seek help from your T.A. or instructor if you have trouble setting up the equipment or getting it to work properly. The important point is to learn how to use the tools.

A secondary goal is to understand basic circuits involving resistors and capacitors which are elementary building blocks of electronics, specifically the voltage divider, and simple RC high-pass and low-pass filters.

1.3 Voltage Divider

Construct the voltage divider circuit shown below in Fig. 1. For V_{in}, use the +0—15V variable DC power supply provided on the prototype boards. Layout your circuit on the board in an orderly manner, for example setting up one column which carries the +V and one for ground.

1.3.1

Use your DVM to measure the voltage across and (separately) the current through the 15kΩ resistor for three different power supply voltages, *e.g.* 5V, 10V, and 15V. Determine $R = V/I$ each time. (Remember that to measure current, you have to break the circuit and insert the DVM, in current mode.)

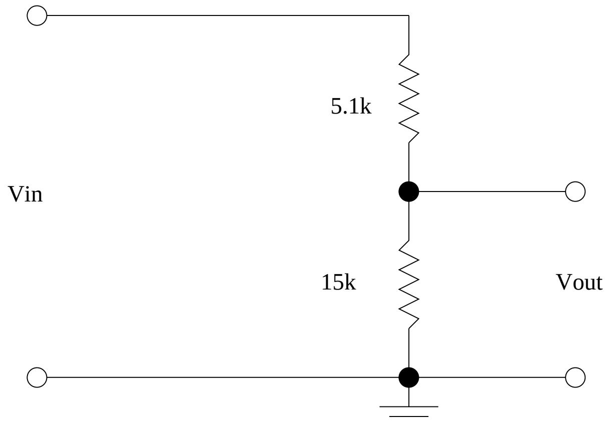

Figure 1: Voltage divider.

1.3.2
Set the power supply at +10V. Place a 15kΩ load resistor across the output of your divider. Measure the voltage across the load.

1.3.3
Remove the load resistor. We wish to directly determine the Thevenin equivalent circuit of your divider. Measure the open circuit voltage, $V_{\rm open}$ (which is just $V_{\rm out}$). Now measure the short circuit current, $I_{\rm short}$, by shorting the output and measuring this current. Determine $V_{\rm Th}$ and $R_{\rm Th}$. Now use these values to build the Thevenin equivalent circuit. Place the 15kΩ load resistor in this circuit and verify that $V_{\rm out}$ is as before.

1.4 Measurement Limitations

Set the power supply at +10V. Build a voltage divider using two 15kΩ resistors. Measure $V_{\rm out}$. Repeat this measurement for dividers constructed of a pair of 100kΩ, 1MΩ, and 10MΩ resistors. In principle, each divider should give the same output. However, the input resistance of the DVM begins to load the circuit when the output resistance of the circuit to be measured becomes comparable. Using these measurements, estimate the input resistance of the DVM.

1.5 Low-pass RC Filter

Construct the low-pass filter circuit shown below in Fig. 2. (Remember that "MF" is really μF.) Connect a 10X probe to your oscilloscope; set the coupling to DC and the triggering to AUTO. Input a 500Hz square wave to your circuit using a function generator. Using the probe, establish the input square wave on the scope. Now connect to and display the output signal. The rise and fall of the square pulses are no longer sharp, due to the charging of the capacitor. Use the scope to measure the rise (or fall) time, and hence calculate the RC time. Does it equal $R \times C$? (Remember that the time to rise to 63% of full value, or fall to 37% of full value, is the "RC time".)

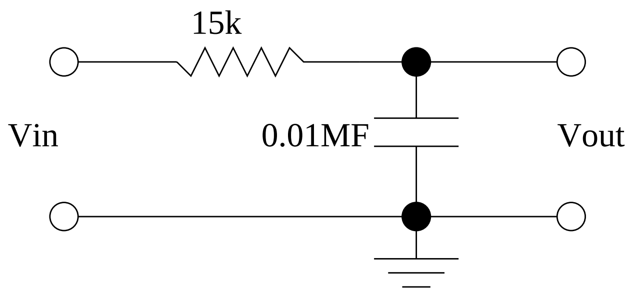

Figure 2: Low-pass filter.

1.5.1

Drive the circuit above with a 100kHz square wave. Sketch the input and output wave forms. Repeat with a 100kHz triangle waveform and a 100kHz sine wave. Does the term "integrator" for this circuit seem apt ?

1.5.2

Using a sine wave input, we wish to determine the circuit's response as a function of frequency. In this way, we will determine the so-called "transfer function" of the circuit. Vary the input frequency while measuring the amplitude of the output using the scope. Plot your data for amplitude versus frequency. The f_{3db} point occurs where the ratio of output to input amplitude is $1/\sqrt{2}$. Determine this point. In theory, we expect $f_{3db} = [2\pi RC]^{-1}$. Compare this to your measurement.

1.5.3

At a frequency of about 10 times the f_{3db} point, measure the phase shift of output relative to input. There are several ways to do this. Perhaps the most straightforward way is to use a second 10X probe to trigger the scope with the input signal. Display both input and output traces and note the shift in time.

1.6 High-pass RC filter

Rearrange the previous circuit to produce a high-pass filter (differentiator), as shown below in Fig. 3. Using an input sine wave as before, vary the input frequency to verify the high-pass property and to determine the f_{3db} point.

1.6.1

As a special case of the high-pass property, verify that your circuit completely blocks DC signals. Add a DC offset to your input signal with the function generator while viewing the output on the scope.

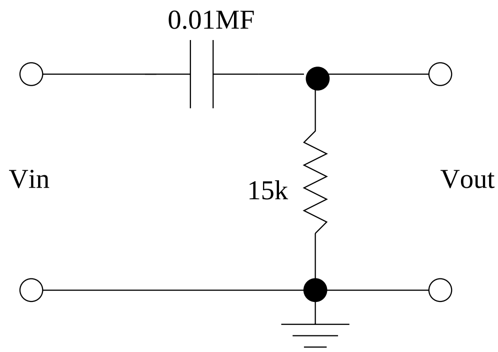

Figure 3: High-pass filter.