Experiment 3: RC Filters

No formal lab report required. A brief report showing your graphs and calculations will suffice.

Purpose

At the end of the lab, you will have gained and solidified the following skills:

- measuring properties of signals with the oscilloscope
- constructing basic circuits on the breadboard
- using logarithmic scales to plot exponential data
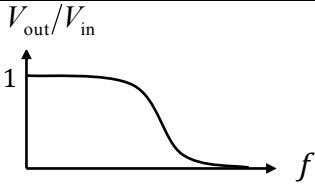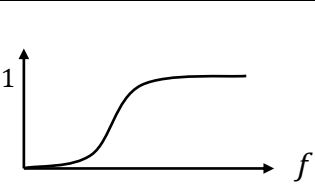
Introduction

In this lab, you will investigate the behaviour of circuits consisting of resistors and capacitors.

In the first part of the lab, you will measure the voltage across a capacitor as it discharges through a resistor. When a voltage source is removed, the voltage across the capacitor decreases exponentially as

$$V_C(t) = V_0 \exp(-t/RC),$$

where V_C is the voltage across the capacitor, V_0 is the voltage across the capacitor at $t = 0$, and RC is the time constant.

In the second part of the lab, you will construct passive filters and measure the gain of the filter (i.e. V_{out}/V_{in}) for a range of (sine wave) frequencies. The two filter types you will investigate are low-pass and high-pass.

Low-Pass	High-Pass
allows only low frequency signals to pass	allows only high frequency signals to pass
$\dfrac{V_{out}}{V_{in}} = \left[1 + (2\pi fRC)^2\right]^{-1/2}$	$\dfrac{V_{out}}{V_{in}} = \left[1 + \dfrac{1}{(2\pi fRC)^2}\right]^{-1/2}$

The *half power point* (a.k.a *3db point*) describes the range of frequencies a filter can pass. The frequency at which the output signal is half the maximum power ($1/\sqrt{2}$ or 0.707 times the peak-to-peak voltage of the maximum) is the half power point.

(**Note:** The half power point is defined in relation to the maximum output power of a filter, not the input power. All filters operate at less than 100% transmission efficiency, even over frequencies the filter is designed to let pass.)

In this lab, you will construct various circuits on a *breadboard*. The breadboard allows you to easily and temporarily connect wires and electronic devices. The rows and columns are connected internally as shown in the diagram below.
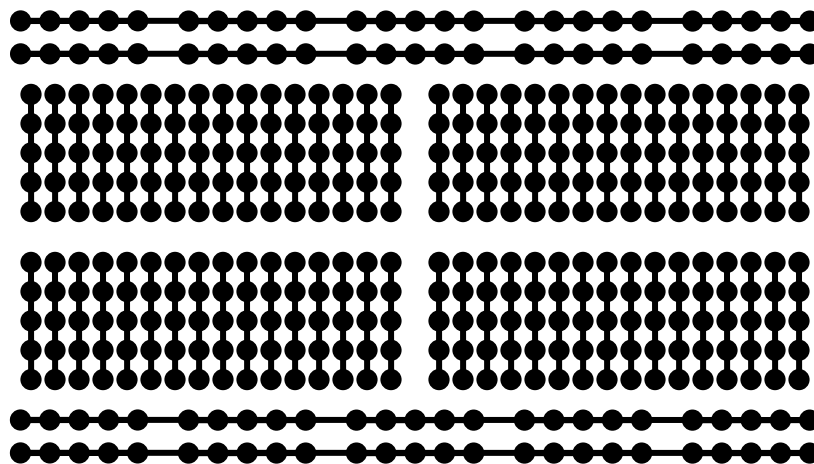

It is good practice to use the horizontal *bus strips* for your common ground, input signal and output signal. The vertical *terminal strips* are used as the main circuit area holding most of your electronic components.
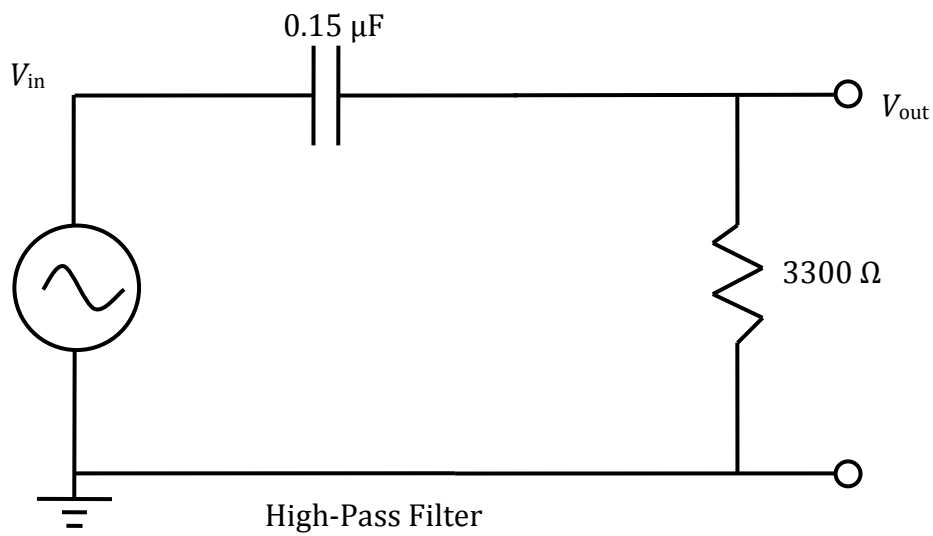
Procedure

(1) Construct the circuit shown below, using the breadboard. The black stripe on the diode is the side where current can go out but not in. Set the function generator to provide a square wave of frequency 400 Hz. Look at the input signal and the output signal on the oscilloscope. On the oscilloscope, use the cursor tool in tracking mode and record about 20 data points (voltage and time) for the exponential decay portion of the output signal. In your report, plot the natural log of the voltage as a function of time and determine the time constant, *RC*, from the line of best fit. Compare with the values of the components used. Also, describe the purpose of the diode in this circuit.

RC Circuit
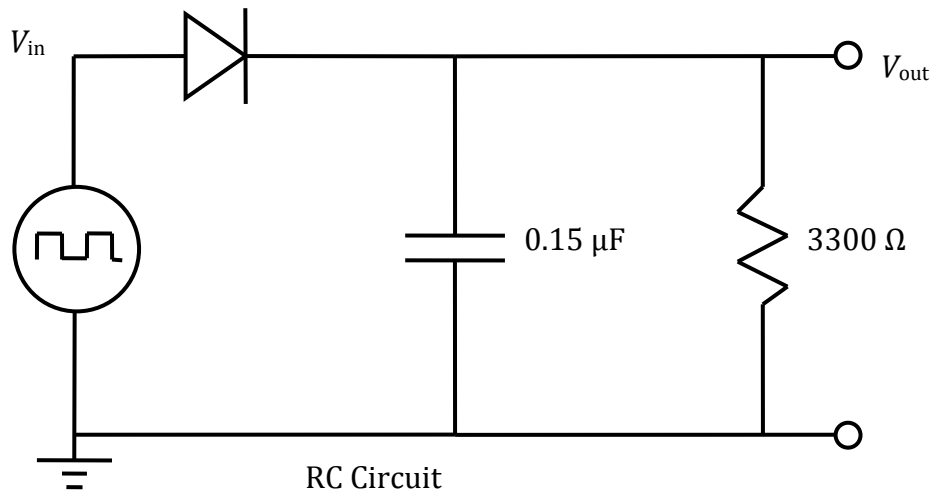
(2) Construct a low-pass filter as shown below. Measure the 'gain' of the filter (i.e. V_{out}/V_{in} using peak-to-peak values) for a range of (sine wave) frequencies that spans the limits of human hearing (approx. 20 Hz to 20 kHz). Adjust the frequency and make sure the circuit behaves as you expect. Record data for the following frequencies: 20, 40, 60, 80, 100, 200, 400, 600, 800, 1000, 2000, 4000, 6000, 8000, and 10000 Hz. Record both V_{out} and V_{in} as well as the frequency using the measure tool on the oscilloscope. (Hint: For accurate results, make sure you can see at least a few periods on the screen and zoom in on your output voltage scale so that the output signal fills the screen.) Plot your data along with the theoretical curve. Use a logarithmic scale for frequency (i.e. a semi-log graph, see last page) or plot your gain against the base10 logarithm of frequency. What is the half power point for this filter? Does it match the theoretical value based on the components used?
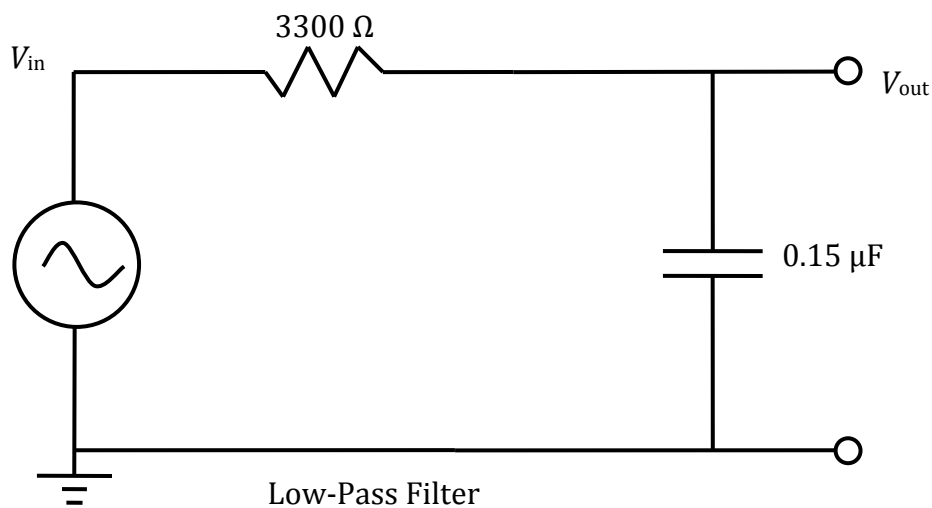
Low-Pass Filter

(3) Construct a high-pass filter as shown below. As before, measure the gain for the same range of frequencies, plot the results against the theoretical curve, find the half power point and compare with the theoretical value.

0.15 μF

V_{in}

V_{out}

3300 Ω

High-Pass Filter

Example of Semi-log Graph

$\frac{V_{Out}}{V_{In}}$

Frequency (Hz)