Lab 5: Capacitors — Low- and High-Pass Filters

RC Low-pass Filter — Design

(a) We will start by building a low-pass RC filter. Draw a generic **low-pass** RC **filter** below, without component values yet. Where is the input, and where is the output?

(b) Write down the resistance R_R of the resistor and the reactance X_C of the capacitor as a function of frequency. Which is larger at high frequencies ($\omega \to \infty$)? At low frequencies ($\omega \to 0$)?

$R_R =$

$X_C =$

- At high frequency, is larger.
- At low frequency, is larger.

(c) You can think of the filter as a voltage divider, with the capacitor's reactance replacing one of the resistors. Using this conceptualization, circle the correct answers:

- At high frequencies ($\omega \to \infty$), most of the input voltage drops across

  (a) the resistor (b) the capacitor.

- At low frequencies ($\omega \to 0$), most of the input voltage drops across

  (c) the resistor (d) the capacitor.

(d) Set $R = 10\,\mathrm{k\Omega}$ and $C = 10\,\mathrm{nF}$. What is the crossover frequency f_c **in Hz**?

$f_c =$

(e) By what factor is the signal attenuated at the crossover frequency? How many decibels is this?

RC Low-pass and High-pass filters: compare

(a) Build the RC low-pass filter with $R = 10\,\mathrm{k\Omega}$ and $C = 10\,\mathrm{nF}$. Drive it with a sine wave from the function generator. Use CH1 and CH2 of the scope to observe the input and output waveforms.

Go to the crossover frequency you've found on the last page, and check the attenuation factor against your prediction. You may use the scope's Measure menu, in which you can find the function to measure and display the signal amplitude for each channel.

(b) "At very low frequencies, a capacitor can be considered an open circuit," and "At very high frequencies, a capacitor can be considered a short." Explain this statement in terms of what you have observed.

(c) Drive the circuit with a 10 kHz sine wave. Then, use the offset option on the function generator to add a 1 V offset to the waveform. Draw the input and output waveforms below, and explain the output in terms of the frequency response of the filter.[1]

[1] When we use a high-pass filter to block out DC, we often say we have used a *blocking capacitor*, or that we have *AC coupled* the signal. These are just different terms for high-pass filtering (often with a very low cutoff frequency) that is used specifically to block the DC component of a signal.

Time Permitting: RC Band-pass Filter

Sometimes, a physical signal of interest lies in between low- and high-frequency noises. A band-pass filter passes a "band" of frequencies of interest while attenuating those that are too high or low.

(a) Figure 1 shows a possible design of RC band-pass filters.

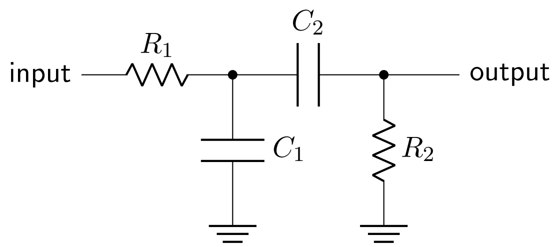

Figure 1: An RC band-pass filter.

We assume the input signal (what we want to transmit) is 1 kHz sine waves.

Let's consider the left-hand circuit, and choose the component values R_1, R_2, C_1, and C_2. We want to satisfy the following design critaria:

1. the crossover frequencies for the low- and high-pass filters are at least one decade from the center frequency of 1 kHz;
2. the input signal comes form a function generator with 1 kΩ source impedance.
3. the output of your filter drives a circuit of 1 MΩ input impedance.

Each time you connect two circuits, make sure that the source impedance is smaller than the load impedance by at least a factor 10.

$R_1 =$ $C_1 =$

$R_2 =$ $C_2 =$

(b) Build the circuit in real life. Does it behave as you would like it to?

(c) Does the order of the two stages matter? What happens if we swapped low-pass and high-pass filter, as shown below.

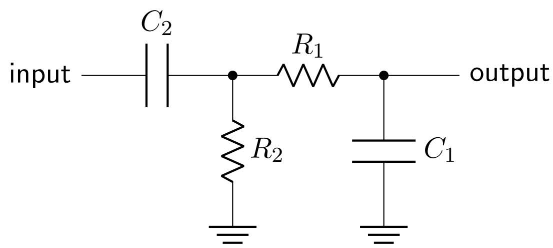

Figure 2: RC band-pass filter, swapped.

Predict what might happen, and test your prediction in the actual circuit.