Physics 320 - Fall 2017
LAB 4 - RC Filters

Kenneth Hahn and Michael Goggin

Objectives: Understand RC coupling. Understand the frequency dependence of RC filters. Improve ability to use oscilloscope.

To Turn In: The lab sheets with the specified information, the answers to the questions, and any graphs asked for in the lab.

As always, you should do the lab in your notebook and only transfer final data and answers to your data sheet when you are happy with it.

Part 1 - RC Coupling

In this part of the lab exercise you will investigate the propagation of a square pulse through an RC circuit. The pulse is actually just one square from a square wave created by the function generator. The pulse width is one half the square wave period. See the figure below.

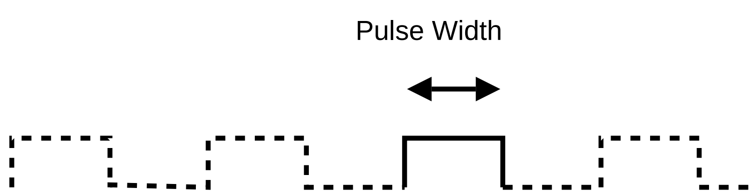


Figure 1: Square wave with one pulse indicated.

Using a function generator, you will send in a pulse and observe the output signal as the pulse width is changed. The pulse width is determined by the frequency of the function generator. You will also vary the RC time constant to see what effect this has on the output. The aim of this section is to understand what the RC coupling can do to the input pulse. In certain cases there will be virtually no change from the input to the output. In others, the output will look radically different than the input. Sometimes the output is essentially zero. Other times the maximum peak of the output exceeds the maximum value of the input. All of these should be observed. A full understanding of RC coupling will allow you to predict the shape of the output pulse if you know the input pulse width and the RC time constant. **Work toward that understanding.**

You should notice that the pulse is part of an AC signal (a square wave). Yet you can also imagine it as two strings of DC emfs: a -5 V, a +5 V, -5 V,+5 V, ... So, we can think about the role of capacitors with DC voltages and allow for the transient effects (charging and discharging). The charge/discharge aspect of the RC circuit should be very evident to you as you proceed.

Do the RC coupling exercises 4 times; use two different RC values and set up the circuit in both orientations: high pass and low pass. See Part 2 for the circuit setups. Using the oscilloscope you will want to *simultaneously* measure both the input signal and the output signal. **Note that the wire along the**

bottom is the ground connection. It is along this wire that you must make all ground connections, this includes the function generator, frequency meter (if needed), and both channels of the oscilloscope.

Note: It is important for you to be working on your understanding of the oscilloscope at this time. You should become very comfortable with the features of adjusting the amplitude and time scales; making amplitude (voltage) and time (period, frequency, phase) measurements; AC, DC, and Ground; triggering externally or on an input channel; viewing one or both channels.

Part 2 - High Pass Filter

The RC circuit shown below is a first order *high pass* filter. As in Part 1, using the oscilloscope you will want to *simultaneously* measure both the input signal **(this time use a sine waveform from the function generator)** and the output signal. Note that the wire along the bottom is the ground connection. It is along this wire that you must make all ground connections, this includes the function generator, frequency meter, and both channels of the oscilloscope.

Measurements: Study this circuit as a function of frequency. You will want to understand the output signal compared to the input signal as a function of frequency for various values of R and C. Not only will you be concerned with *amplitude* but also the *phase difference* between the two signals. [1] Eventually you will need to draw graphs of V_{out}/V_{in} versus frequency and of the phase difference, $\Delta\phi = (\Delta t/T)2\pi$, versus frequency. For graphs, make a Bode diagram (plot $20\log(V_2/V_1)$ vs. frequency on a log scale). Frequency should *always* be plotted on a log scale. You are generally covering 5 to 6 orders of magnitude for frequency.

Since you will study a large frequency range (10 Hz - 1 MHz), you should quickly cover the entire range, increasing or decreasing by powers of ten. Then you can determine the ranges where the ratio V_{out}/V_{in} and $\Delta\phi$ are changing rapidly.

Make your measurements for three different versions of the circuit:

1. $R = 1\text{k}\Omega$, $C = 0.1\mu\text{F}$

2. $R = 100\text{k}\Omega$, $C = 0.001\mu\text{F}$

3. Add a DC component to the input sinusoid for either circuit 1 or circuit 2. The DC component is added with the DC adjustment of the function generator. Make sure the oscilloscope channels are set to DC so that the DC portions can be seen on the screen. Describe what happens in this circuit with the addition of + or - DC at the input.

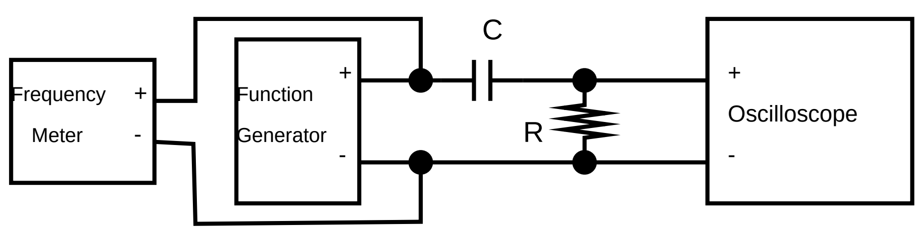


Figure 2: High pass filter.

[1] A very important point here: To be able to measure the phase difference between two signals the oscilloscope must be triggered properly!

Part 3 - Low Pass Filter

The RC circuit shown below is a first order *low pass* filter. (Note that the only difference between this and the high pass filter is where the output is.) Let $R = 3.3\text{k}\Omega$, $C = 0.1\mu\text{F}$. As you did with the high pass filter, carefully measure the output vs. the input over a wide range of frequencies. In your lab book, sketch the output/input vs. frequency. *You do not have to turn in a frequency plot for this filter.*

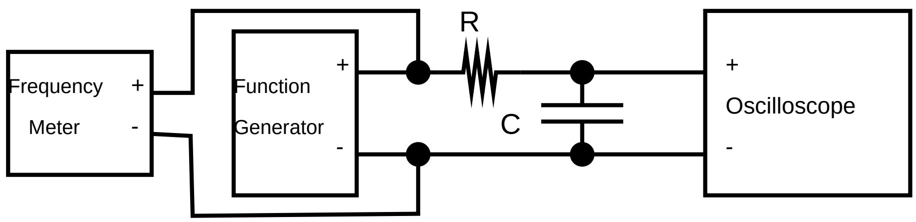


Figure 3: Low pass filter.

Name________________________

Date________________________

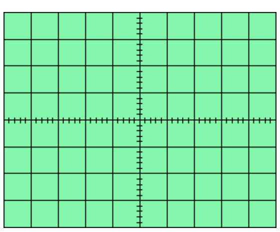
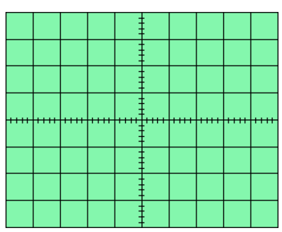
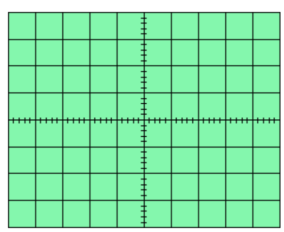
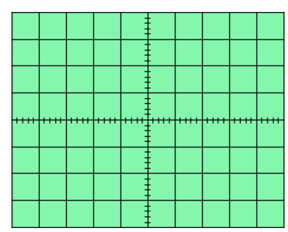
Data Sheet for Electronics Lab 4 - RC Filters

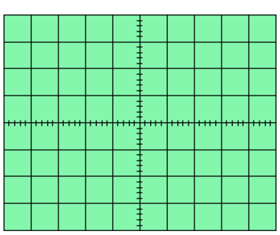
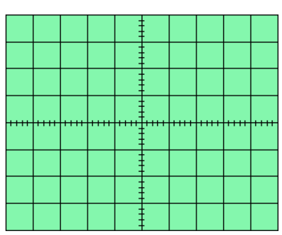
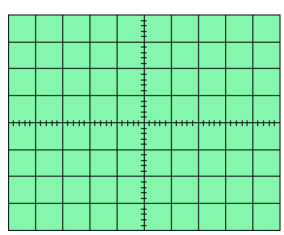
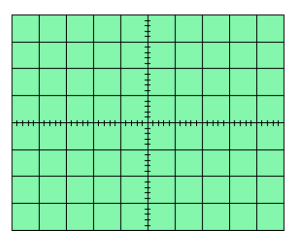
Part 1 - RC Coupling

R ( )	C ( )	RC ( )	nominal frequency (Hz)	actual frequency ( )	pulse width ( )	picture #
			10			
			100			
			1000			
			10 k			
			100 k			
			1M			
			10			
			100			
			1000			
			10 k			
			100 k			
			1M			

Draw a circuit diagram here:

Sketch different oscilloscope traces here and label them with a number and write the number in the table on the appropriate line. Always indicate the voltage and time scales used for the traces and to distinguish the traces for each channel on a plot.

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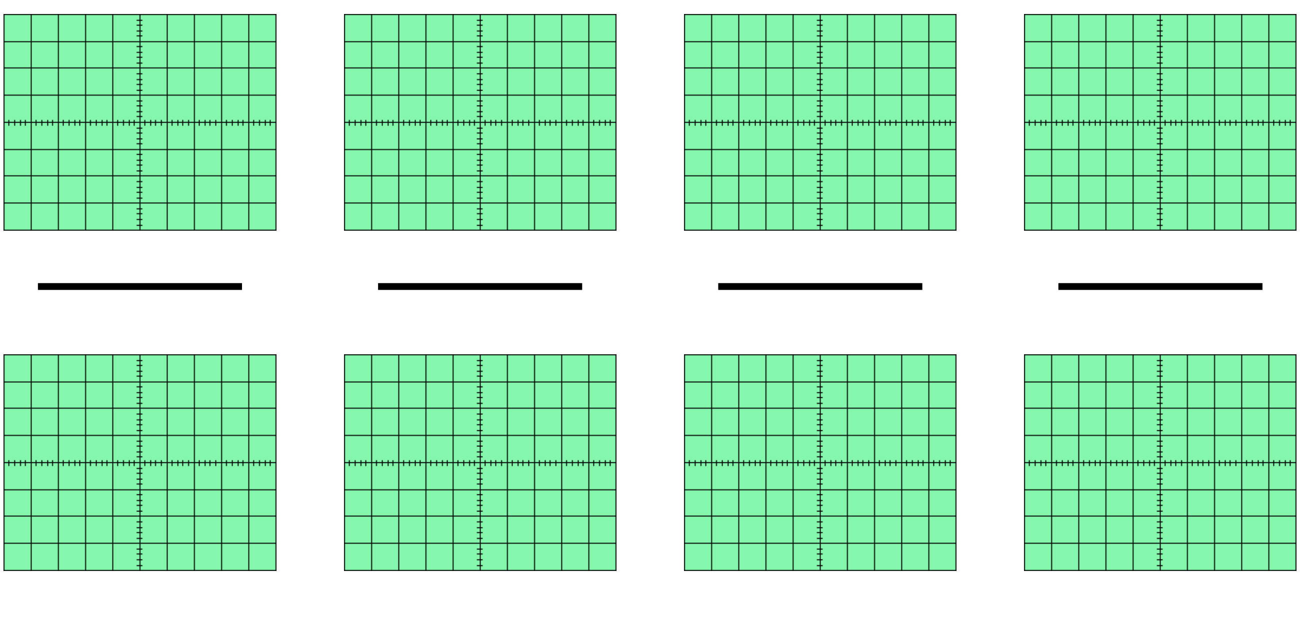

Name________________________________

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Data Sheet for Electronics Lab 4 - RC Filters

Part 2 - High Pass Filter

$R =$______________________ $C =$______________________

frequency ( )	V_{in} ( )	V_{out} ( )	V_{out}/V_{in}	Phase ( )

Use your favorite graphing program to make a Bode diagram of your data. Be sure to plot the phase. If you can put it on the same plot as the gain, great. Don't spend too long trying to do that though. Separate plots of gain and phase are ok.

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Part 2 - High Pass Filter, page 2

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