

## PHYS245 Lab: RC circuits

Purpose:

- Understand the charging and discharging transient processes of a capacitor
- Display the charging and discharging process using an oscilloscope
- Understand the physical meaning of the RC constant
- Measure the RC constant using the oscilloscope
- Use the RC circuit as a low-pass filter and measure the transfer function

Equipment list: ELVIS II, 5.0 k resistors, and 4.7 nF capacitor, jump wires, banana-to-minigrabber cable, coaxial cables

Resistor-capacitor circuit (RC circuit) is widely used in electronics as a filter circuit. It is essential to understand how a RC circuit functions. In this Lab, you will have a chance to periodically charge and discharge a capacitor using a square wave and visualize the charging and discharging process on the Scope.

The RC circuit can be used as a low pass filter. You will measure the amplitude of the output signal as a function of the frequency and plot the graph in Origin.



## Pre-Lab Exercises

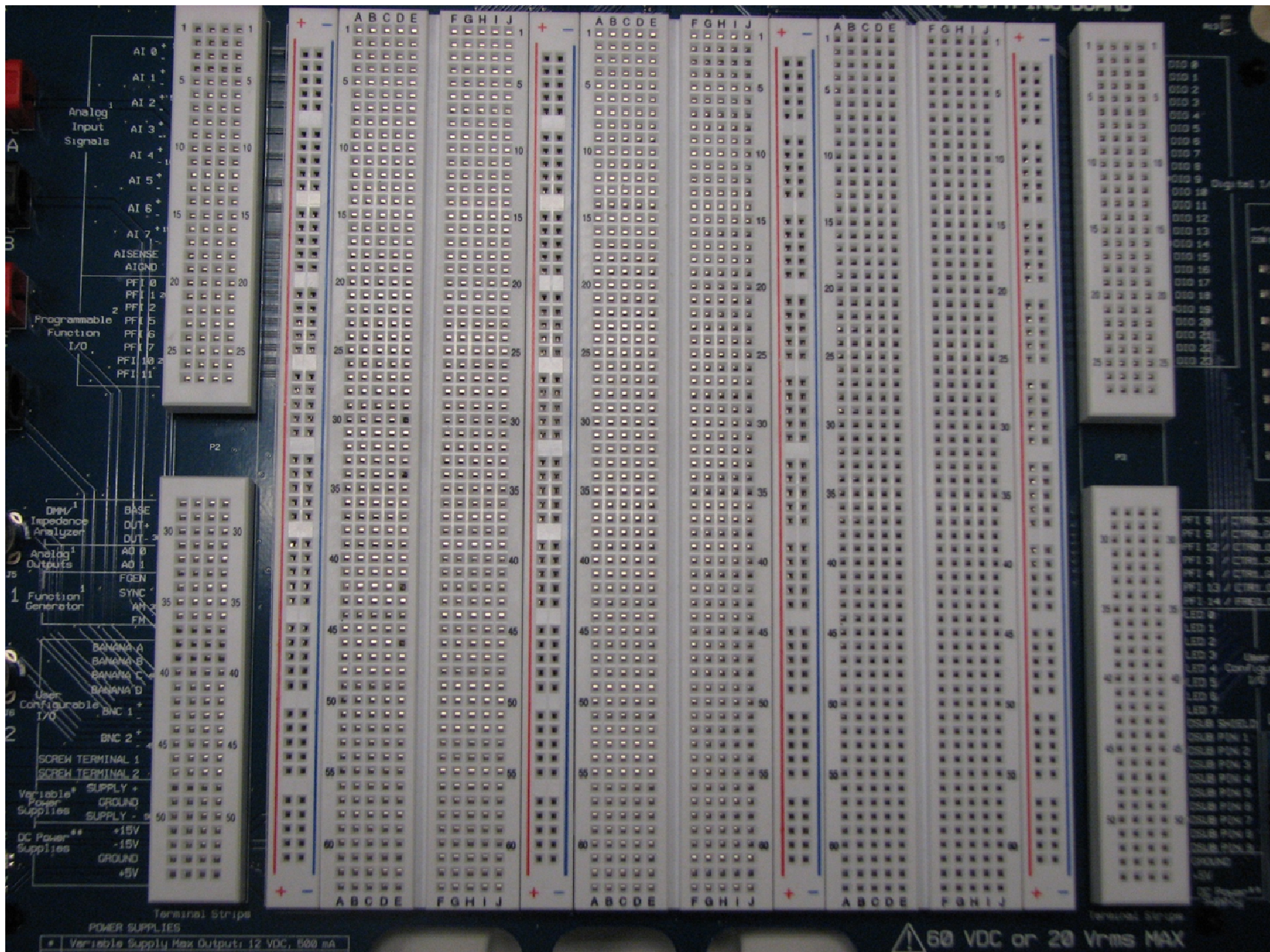
Thoroughly read through this manual and practice circuit construction on the prototyping board picture on next page.

For a 4.7 nF capacitor and a 5.0 k $\Omega$  resistor, calculate the RC time constant.

Answer the following questions:

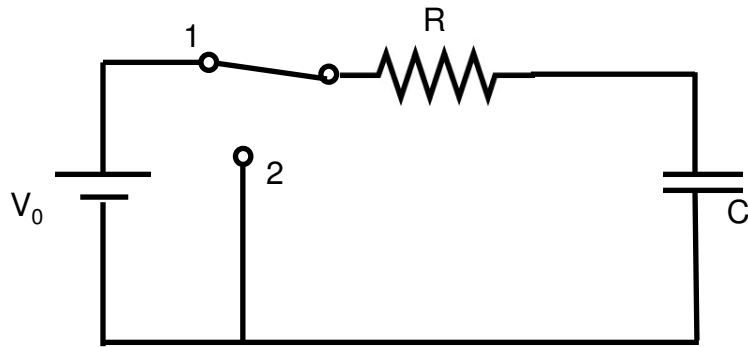
- The longer the RC time constant, the longer it takes to charge or discharge the capacitor, true or false?
- The square wave in experiment I is used to charge and discharge the capacitor periodically, true or false?
- For a capacitor and a resistor in series, most of the a.c. voltage drops on the capacitor at very high frequency, true or false?



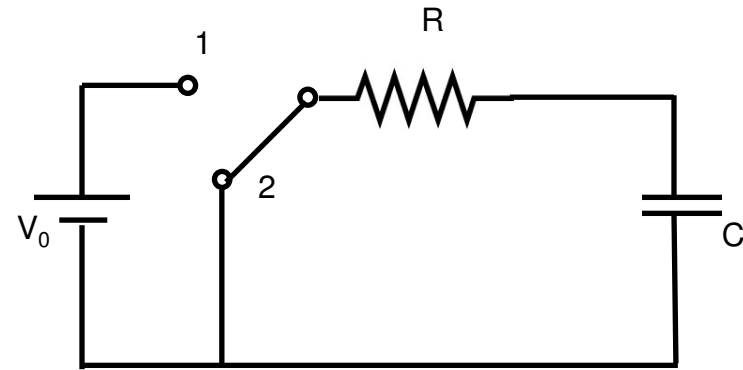


# Experiment I: Charging and discharging a capacitor and RC constant

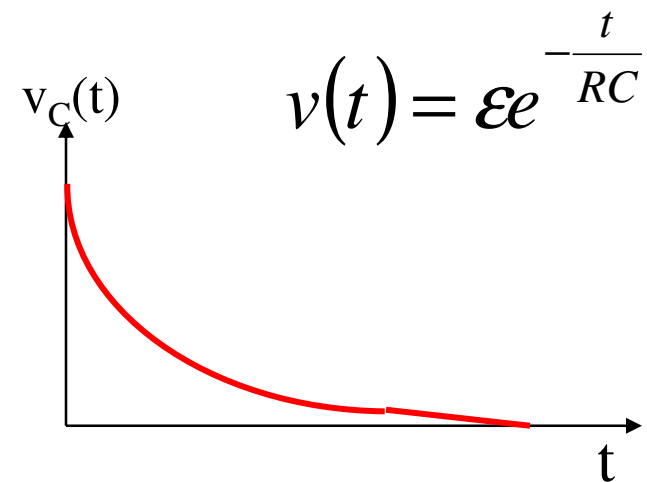
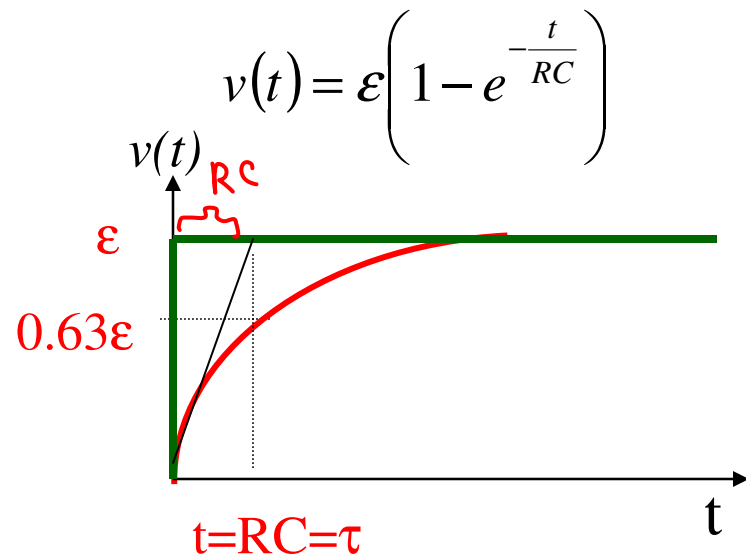
The following figures are quick summary of what you have learned in the lecture in regard to charging and discharging a resistor



Charging



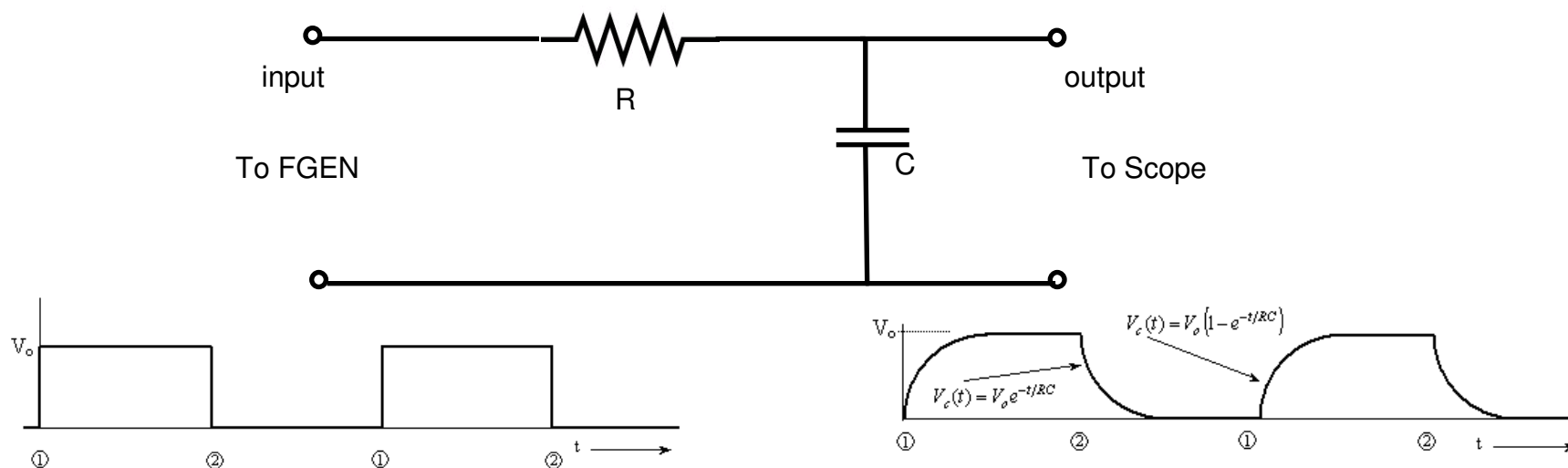
discharging



However, it is difficult to conduct an experiment based on the circuits in the previous page. Because the charging or discharging process happens during very short time scale ( $< \text{millisecond}$ ). If you want to display the capacitor voltage as a function of time on the Scope, you have to choose fast scan speed (a short timebase) to resolve the change of voltage on the short time scale. But even if you do choose a short timebase, the image will disappear from the Scope before you can see take a look, since the Scope scans fast.

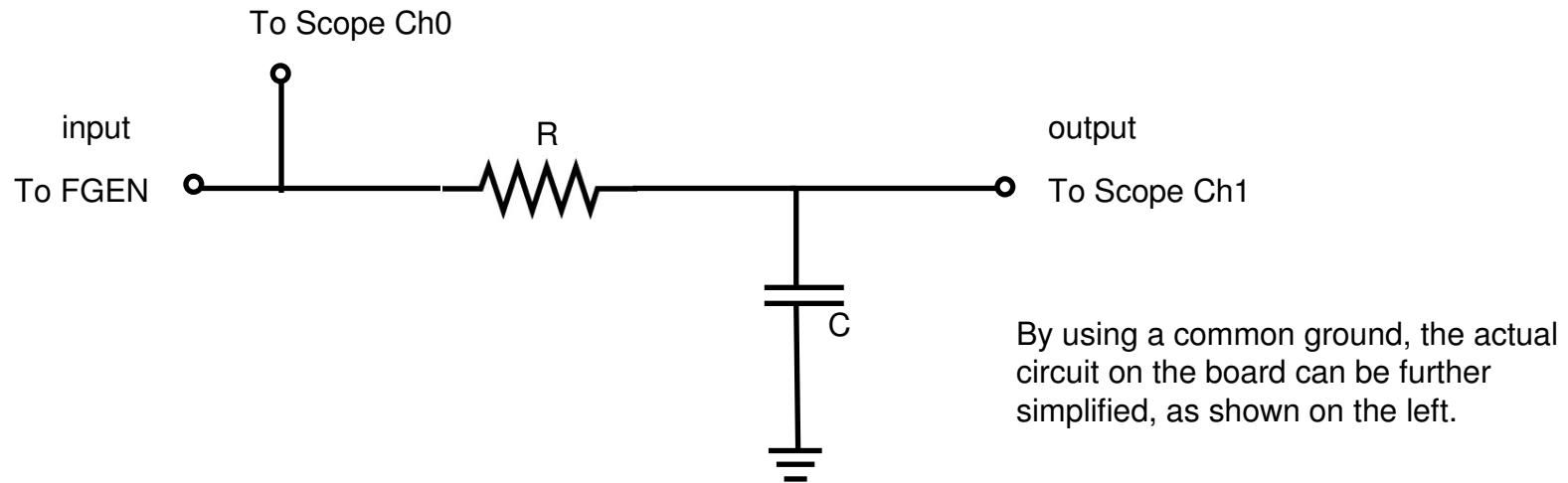
So one possibility is to charge and discharge the capacitor periodically at very fast pace. Imagine you toggle the switch back and forth rapidly. With repeated occurrences of charging and discharging, it is possible to have a stable image on the Scope (like a waveform) by using “Edge” trigger on the Scope. But it is impossible for you to toggle the switch back and forth in less than a millisecond.

Now a better way to do this experiment is shown in the figure below.



A square wave is delivered by FGEN. The voltage switches between  $V_o$  and 0 periodically. This is equivalent to toggling the switch between 1 and 2 in the figure on previous page.

Capacitor voltage as a function of time can be displayed on the Scope



You are given a  $5.6\text{ k}\Omega$  resistor and a  $4.7\text{ nF}$  capacitor. Build a RC circuit according to the above diagram. Deliver a  $3\text{ kHz}$  square wave signal with  $2\text{ V}$  peak-to-peak voltage from the FGEN clip on the distribution stripe to the input of the RC circuit.

Route the output signal from the capacitor to BNC #2, and then to Scope Ch1 by a coaxial cable. Display the waveform on the Scope.

As a comparison, you want to see original input square wave. You can route the input signal from FGEN clip to the BNC #1 clip by jump wire, and then to Scope Ch0 through coaxial cable.

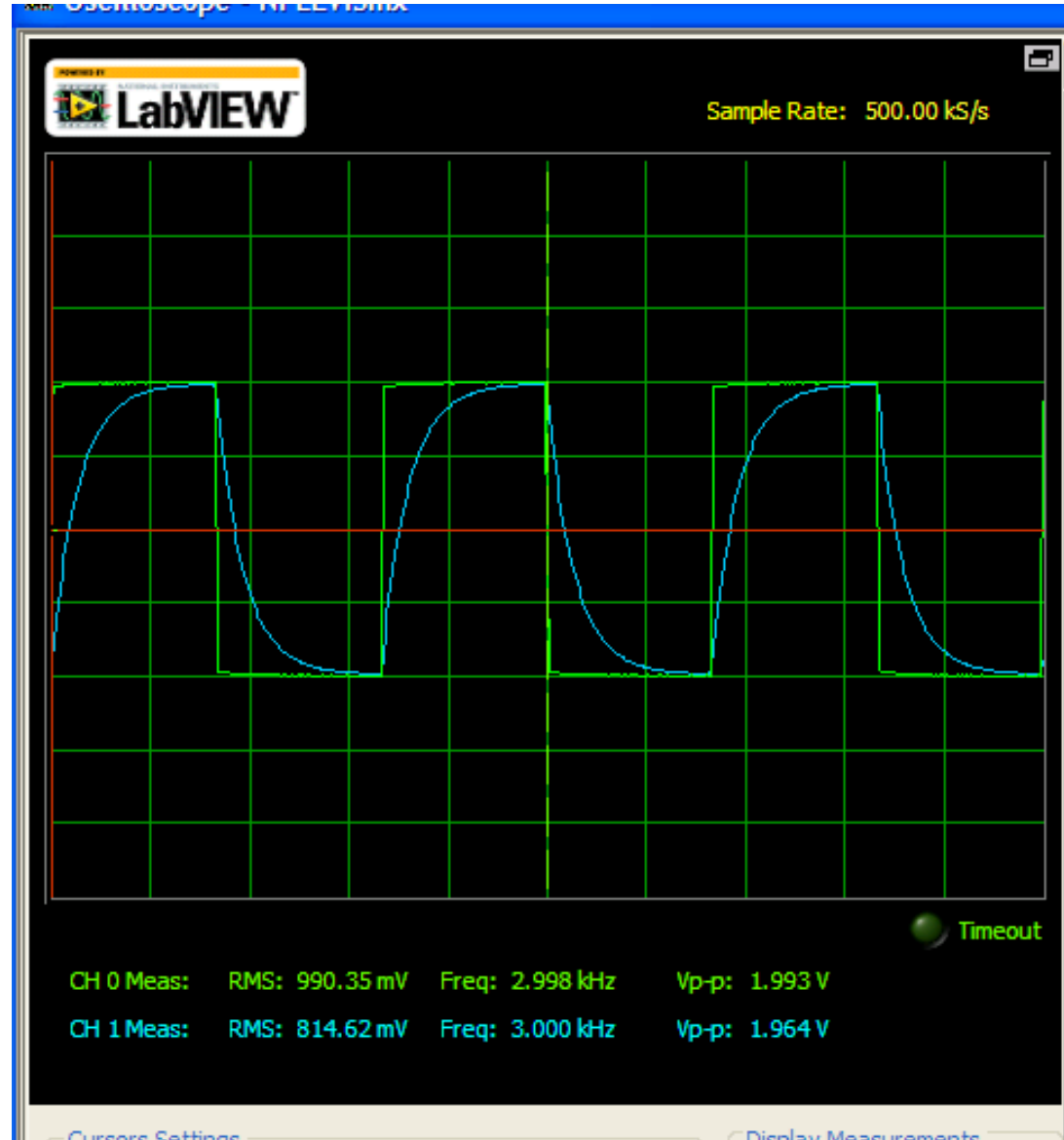
Display both Ch0 and Ch1 on the Scope. Adjust “Vertical Position” for Ch0 to offset the square wave vertically. This way, the input and output waveform are shifted vertically, and allows for a better comparison.

Remember to adjust timebase and sensitivity scale to have proper viewing of the signals.

Start with “Immediate” Triggering mode, which means no particular triggering. Once you get clear waveform (which is moving on the screen”, switch to “Edge” trigger mode. A stable image can be obtained.

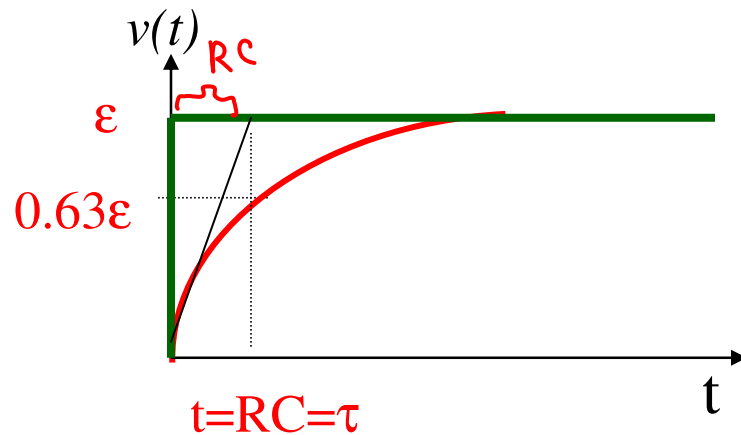


The screen shot on the right shows the input square wave signal and the output on the capacitor.

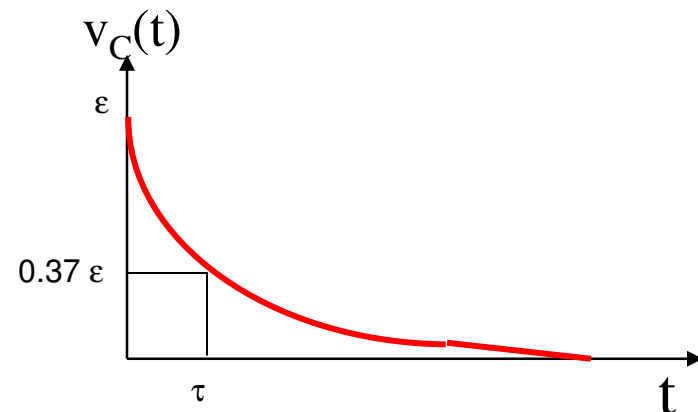


Now disable Ch0 by unchecking “Enable” of Ch0. Adjust the Volt/Div value, so that the waveform in Ch1 occupy most of vertical scale, but does not go beyond the limit. This is to maximize the accuracy of the following measurements.

From the Ch1 output waveform, try your best to estimate the time constant of this RC circuit. Refer to the following pictures for reference.



In the charging curve, The time it takes to charge to the 63% of the full voltage equals to the RC constant  $\tau$ .



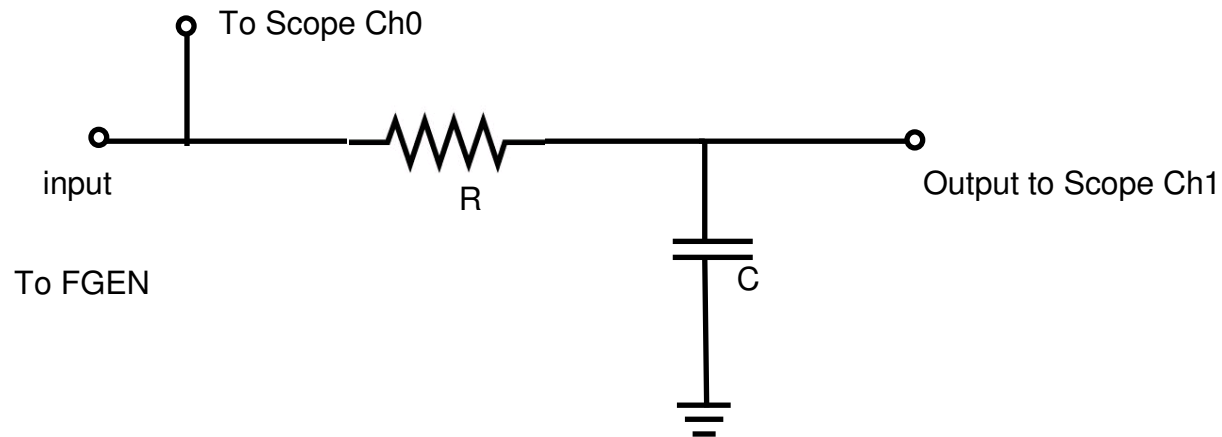
In the discharging curve, the time it takes to discharge to 37% of the full voltage (losing 63%) equals to the RC constant  $\tau$

Compare the measurements with the calculated RC constants.

Change the frequency of the input square wave, and pay attention to the change of the output signal.



## Experiment II: Use RC circuit as a low pass filter



The RC circuit can be used as a filter. The above circuit, which you have used, can act as a low pass filter. The circuit is the same as the one you have used in part 1. But in this experiment, send in a sine wave as input. The output is also a sine wave. But the magnitude and phase is different from the input sine wave. Measure the amplitude as a function of the frequency. Plot the results in Origin.