Lab 7

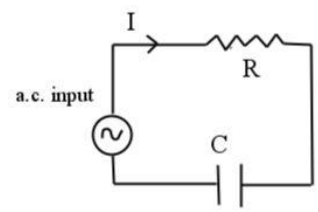
RC Series Circuits – Time Dependence

What You Need To Know:

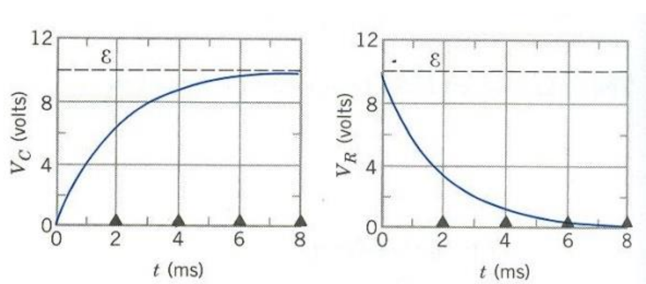
The Physics A capacitor is a device for storing charge. The capacitance C of a capacitor depends only on the geometry and material make up of the capacitor nothing else. The units of capacitance are the Farad. For a parallel plate capacitor with nothing between the plates we would have, $C = \frac{\varepsilon_o A}{d}$, where A is the area of the plates and d is the separation of the plates. The voltage across the capacitor is given as $V_c(t) = \frac{q(t)}{C}$. Clearly the voltage builds up over time when the current in the circuit is switched on, charge builds up on the plates until a maximum charge is reached when $V = \varepsilon$.

The maximum voltage across the capacitor is the amount supplied by the power source $\varepsilon = V_{battery}$. Do not exceed the voltage rating of the capacitor. A given size of capacitor can only hold so much charge, then it fails *"catastrophically" by explosion*. A loud pop and acrid smoke. Do not attempt this!

The voltage loop law for the circuit on the right gives, $\varepsilon - IR - \frac{q}{C} = 0$. Here the ac supply has voltage ε. In terms of the charge we may write, $C\varepsilon = RC\frac{dq}{dt} + q$.



We may solve this to find, $q(t) = C\varepsilon\left(1 - e^{-t/t_\tau}\right)$, and from this we get, $I(t) = \frac{\varepsilon}{R}e^{-t/t_\tau}$. The time constant is $t_\tau = RC$. The diagram below shows the capacitor charging up.



You find $t_{1/2}$ from looking at the either the voltage gain across the capacitor or voltage drop over the resistor. When the voltage is half the max value measure $t_{1/2}$ from the time scale, using the relevant time/div. scaling on the scope. You can use $t_{1/2}$ to find the time constant τ_c .When the capacitor is discharging the equation for $V_c(t)$ decreases to zero looks like, $V_c(t) = \varepsilon e^{-t/t_\tau}$. Note that when $t = t_{1/2}$ then $V_c = \frac{\varepsilon}{2}$.

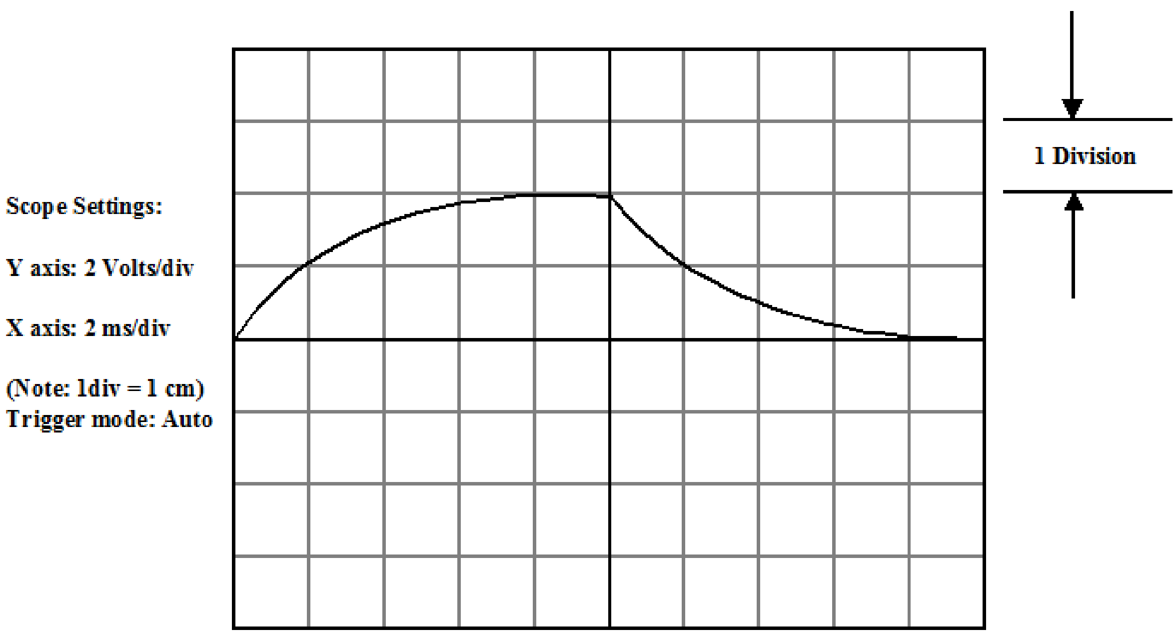
We can solve this to find the time constant τ_C . Measuring the $t_{1/2}$ value allows us to write, $t_{1/2} = \tau_c \ln 2$ where $\ln 2 = 0.693$. Note that $\tau_c > t_{1/2}$.

What You Need To Do:

RC circuits make excellent timing circuits since the capacitor charges and discharges at a set rate. You can imagine switching a motor to go forward and then backward for a time when it hits a relay switch and charges up an RC circuit… robotics application, or a light made to switch on and off with the charge discharge cycle like a strobe. You will be making a strobe light with a simple LED later on. First we need to make sure you have understood the theory so you can apply it in the experiments.

<u>This lab has 3 parts.</u>

1) You will be completing a simple RC calculation given sample data.
2) You will be hooking up an RC circuit and viewing the voltage vs. time across the capacitor on the CH 1 of the oscilloscope.
3) You will be making a simple LED flashing circuit (basic strobe)

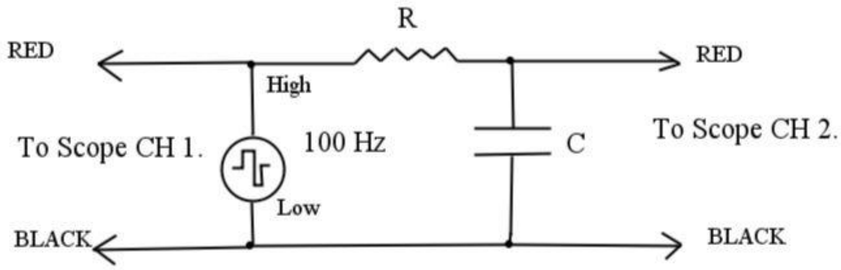


Part 1 Consider the oscilloscope display above. This shows the voltage across a capacitor in an RC circuit. The left part of the curve corresponds to charging, the right half to discharging the capacitor. The resistor is 2 kΩ.

A) From the trace determine the value of the Capacitance C.

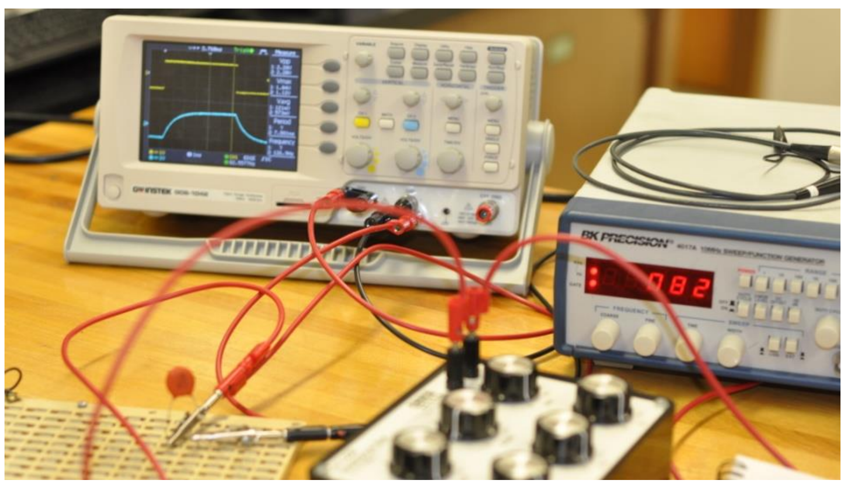
B) What is the time constant for the circuit τ ? **HINT**: For $t_{1/2}$ find when the voltage is half its maximum value!!

C) What is the voltage across the battery terminals?

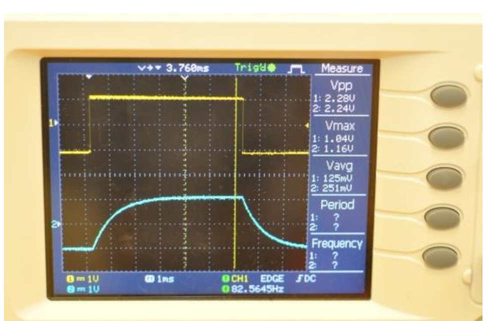


Part 2 Here we will show the capacitor voltage vs. time on the scope CH 2. We will also show the square wave from the generator on the same scope on CH 1. Above is the simple figure for the set up. Use the resistance box for R.

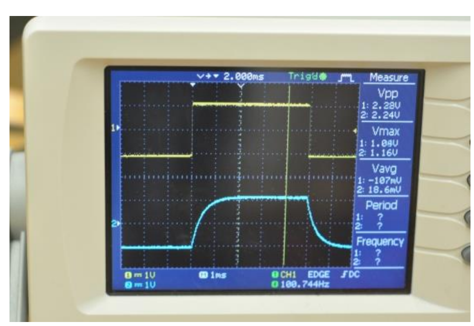
CH 1 and CH 2 of the scope have a common ground. It is not necessary to runs leads to both ground (black) terminals. You may need to adjust the frequency of the generator so you see a full charge charging cycle. You may find 80 Hz better than 100Hz as in the diagram. This will give you a nice full image on the screen. They both work.



If the square wave form is too fast the capacitor will start to discharge before it reaches its maximum voltage which should be the generator voltage, 2 volts. It is OK to adjust the time/div setting and the horizontal scale can be adjusted left and right to get a good reading of the scale.



Using 80 Hz signal



Using 100 Hz signal

You will be measuring $t_{1/2}$ and find the time constant for several values of R and C. Fill in the table below.

R (kΩ)	**C** (μF)	$\mathbf{t_{1/2}}$ (μs)	$\boldsymbol{\tau_C} = \boldsymbol{RC}$ (μs)	$\boldsymbol{\tau_C} = \mathbf{t_{1/2}/0.693}$
10	0.05			
20	0.05			
30	0.05			
40	0.05			