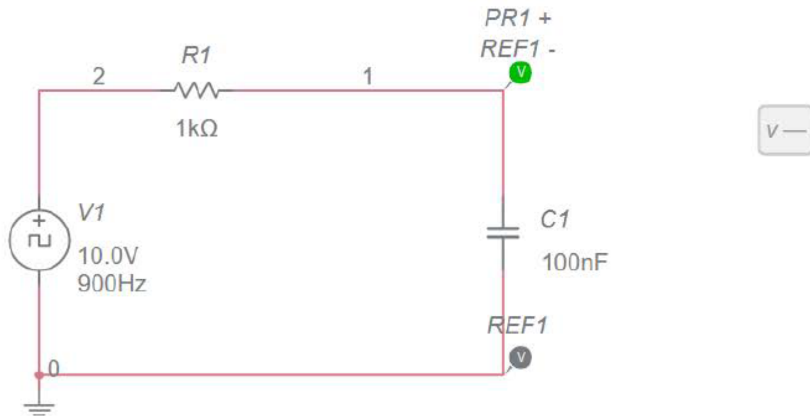
RC and RL Circuits – Finding Capacitance and Inductance

Consider the following circuit composed of a resistor and a capacitor



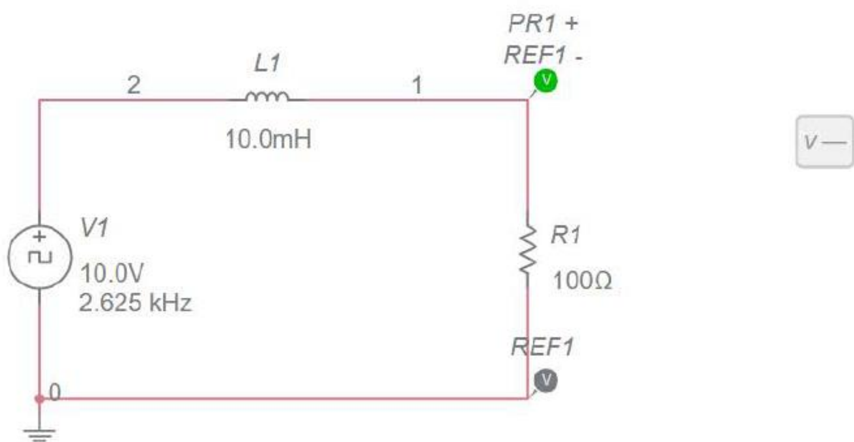
If one measures the voltage across the capacitor as a function of time as the capacitor is charging up, the equation is

$$V = V_0\left(1 - e^{-t/\tau}\right)$$

where τ is the capacitive time constant

$$\tau = RC$$

Similarly if one consider a circuit composed of a resistor and an inductor as shown below



This time one measures the voltage across the resistor and one finds the equation is

$$V = V_0\left(1 - e^{-t/\tau}\right)$$

where τ is the inductive time constant

$$\tau = \frac{L}{R}$$

Clearly, these equations are similar.

If one rearranges the equation, it could be written as:

$$\ln\left(1 - \frac{V}{V_0}\right) = \left(\frac{-1}{\tau}\right)t$$

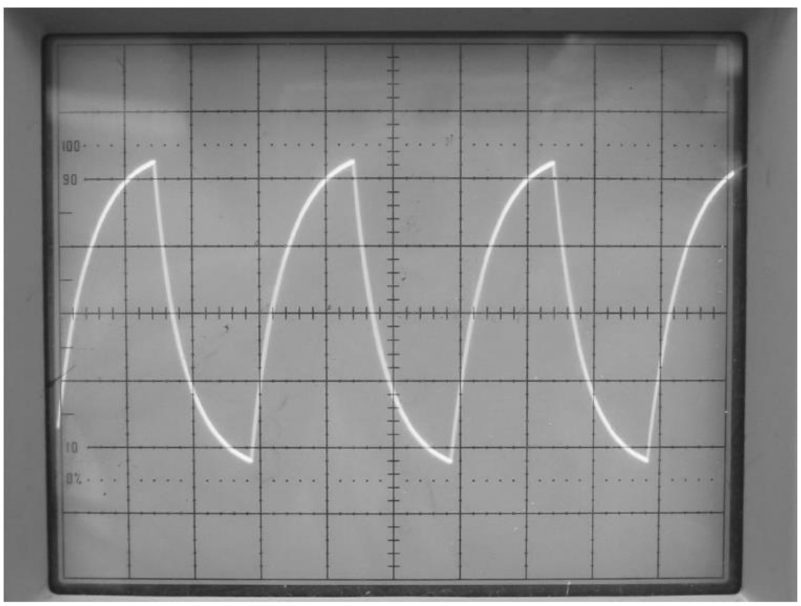
A plot of $\ln\left(1 - \frac{V}{V_0}\right)$ vs. t would produce a straight line with a slope = $\frac{-1}{\tau}$

Therefore the time constant could be found from

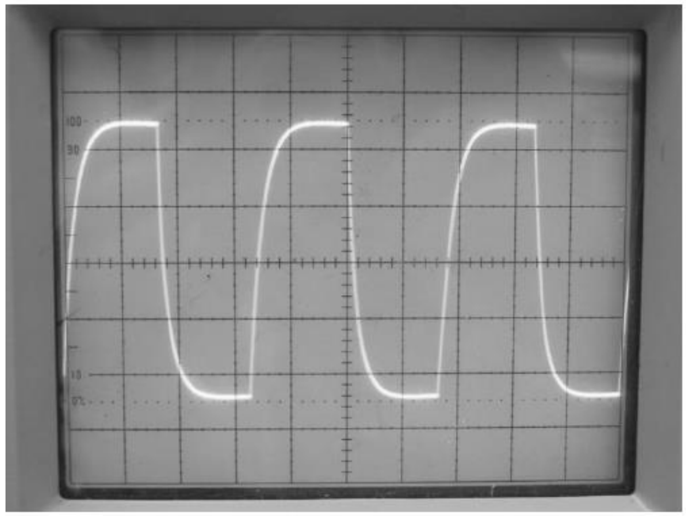
$$\tau = \frac{-1}{slope}$$

Once you have the time constant, you could also find the capacitance or inductance if you know the resistance.

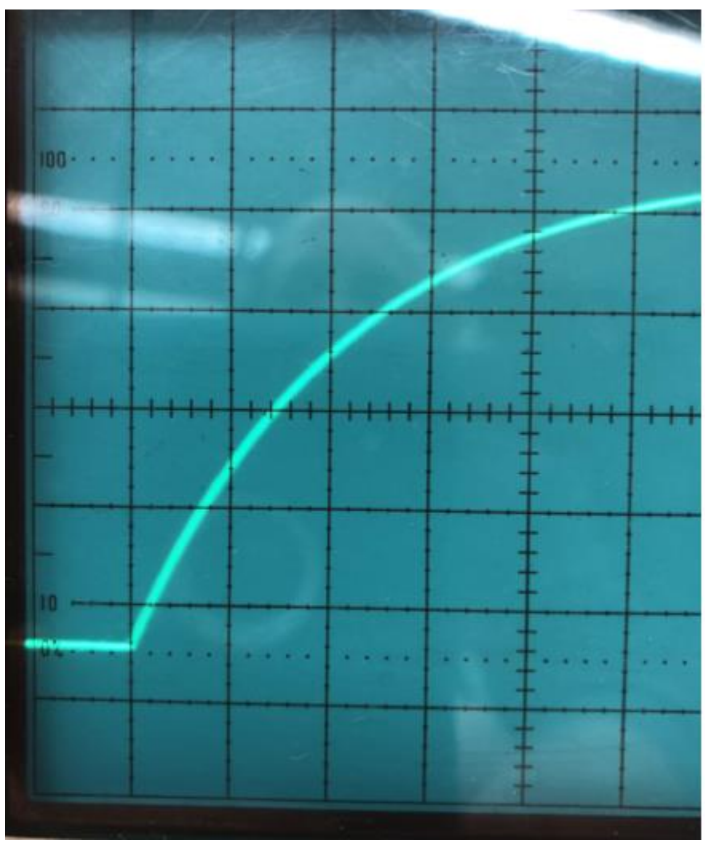
Set up the first circuit for the Capacitor circuit Set the signal generator to Square wave and use a frequency around 1 to 10 KHz. You should be able to adjust the frequency and the time base on the oscilloscope to produce the following looking signal



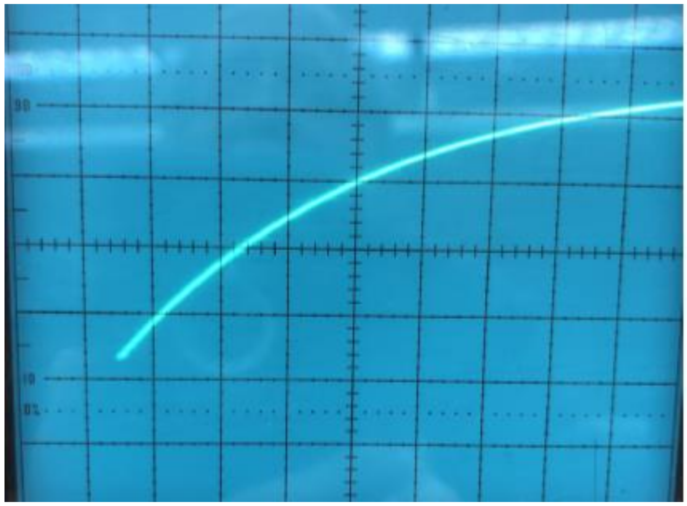
This is known as a shark tooth signal. The capacitor is just reaching full charge for a moment and then it is discharging. If you have a shorter height and you have a sharp point at the top, then you are not fulling charging the capacitor and your frequency is too high, try lowering it some.



If you see the image above, your frequency is too low and you are keeping the capacitor charged for longer than necessary. Try increasing your frequency. When you have the proper pattern, you want to first make sure the pattern fills the 0 to 100 % scale on the oscilloscope face. Adjust the voltage out of the function generator and/or adjust the volts per division on the oscilloscope. Once you have the 0 to 100% filled, you can now expand the curve horizontally by adjusting the time base until you see something similar to



Notice how the curve comes to touch the 0% line and a vertical line that we can now use as a reference to mark the start of time. If the curve does not go all the way down such as this picture shows



You want to arrange it so that if you could draw the line down to 0% it would hit that corner of 0% and the vertical line. This will be a judgement call on your part where that is. You expand the pattern by adjusting the time base and you move the curve vertically using the horizontal position controls above the time base knob. There are two one for coarse and one for fine movements. Finally, if the curve does not extend down to the bottom, you adjust the trigger level knob. The lab instructor will help with this.

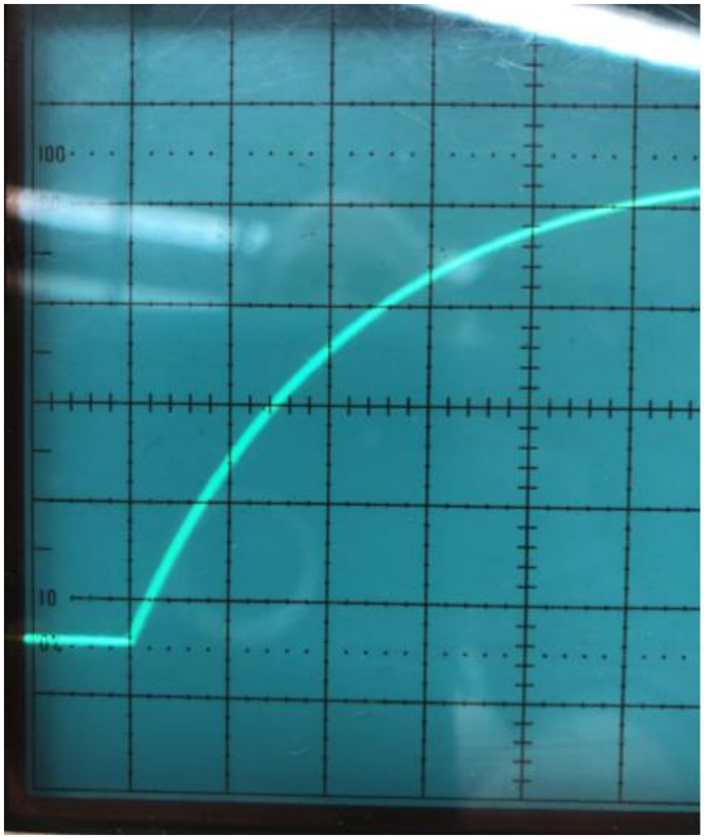
What you have on the screen now is a voltage on the y-axis and time on the x-axis. For the voltages you are going to use the following percentages

% Voltage	$\frac{V}{V_0}$
10%	0.1
30%	0.3
50%	0.5
70%	0.7
90%	0.9

Note: these are the solid horizontal lines on the display.

You are going to determine what the time is at these values for voltage. To do that, you need to read what the time base is on. **Be sure the time base is clicked into position so that it is calibrated.** Then you determine how many major boxes are between the curve and the vertical line we are using as the origin. Then you multiply the number of boxes times the time base and you have the time value.

As an example consider the following curve



The time base is 50 μs or 0.05 ms. Below I am giving you what I would read off for the voltage and time values needed

V/V0	**t - boxes**	**t (μs)**
0.1	0.2	10
0.3	0.7	35
0.5	1.4	70
0.7	2.5	125
0.9	4.7	235

So for the first row, I am judging the curve crosses the 10% line at 0.2 boxes from the origin, so

$$0.2\ x\ 50\ \mu s = 10\ \mu s$$

After you get your patterns like this, you need record these values yourself. The Worksheet will provide the full data tables and the data analysis you will do for this experiment.