Lab 7: Charging and Discharging of RC circuits

Objective:

- To learn the use of Signal Generators and Oscilloscope.
- Investigate the behavior charging and discharging of RC circuits with changing Time Period, T of the input Square wave.

Introduction:

Time varying signal: A signal whose values changes with time.
Peak Voltage = maximum voltage of a signal. It is often denoted by **Vp**
Time period: Time required to complete 1 cycle. It is denoted by **T**.
Frequency: No. of cycles completed in 1 second. It is denoted by **f.** Its unit is in Hz.

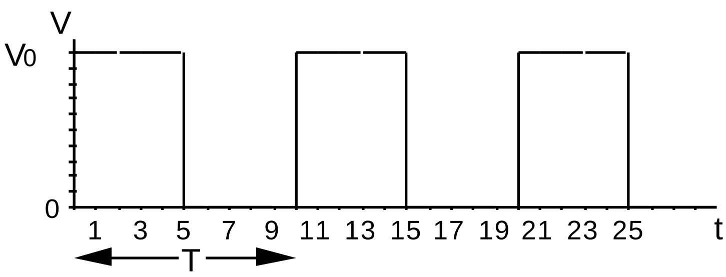
Relationship between T and f:

$$T = 1/f$$

A few examples of Time varying signals:

1. Sin wave
2. Square wave
3. Triangular wave

A typical square wave looks like below:



V0 = maximum voltage (amplitude)
T = Time period of the signal

Signal generator is a device that allows you to generate a time varying signal that has a particular frequency and amplitude (Vp). You can adjust your time period by adjusting your frequency.

RC circuits

What is a Capacitor?

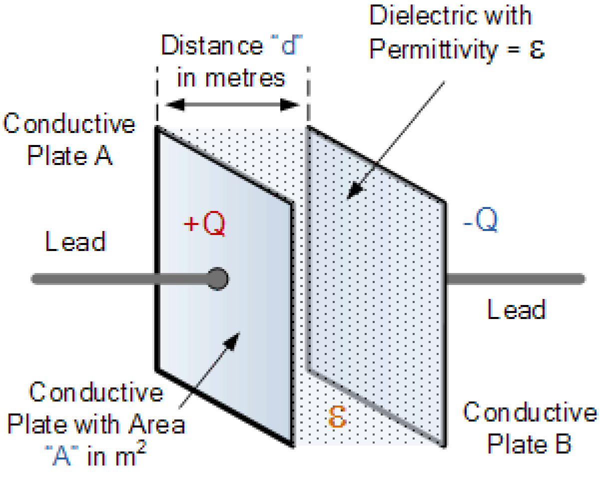
Capacitor is an electronic component that stores electric charge.

Capacitor construction: The capacitor is made of 2 close conductors (usually plates) that are separated by a dielectric material, which is a poor conductor (or a insulator).

When the two plates are connected to power supply (one connected to positive polarity, other connected to negative polarity) An electric field is generated across the dielectric (between the plates) due to which one plate accumulates positive charge and the other plate accumulates negative charge. There is no direct flow of current from one plate to other.

The capacitance is the amount of electric charge that is stored in the capacitor at voltage of 1 Volt. It is measured in units of Farad (F).

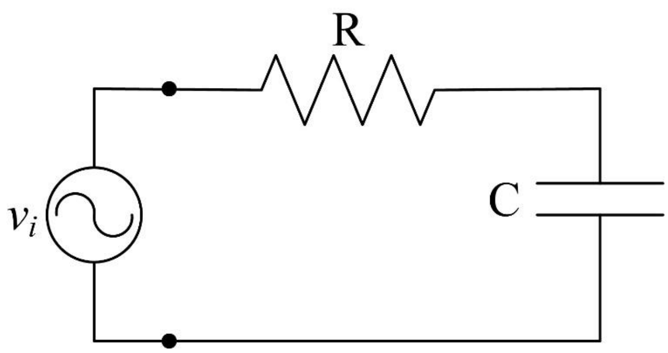
The capacitor is open circuit to direct current (DC) circuits and short circuit in alternating current (AC) circuits.



$$C = \frac{\epsilon A}{d}$$

$$Q = CV$$

Consider a series RC circuit with a time-varying input source (such as a square wave).

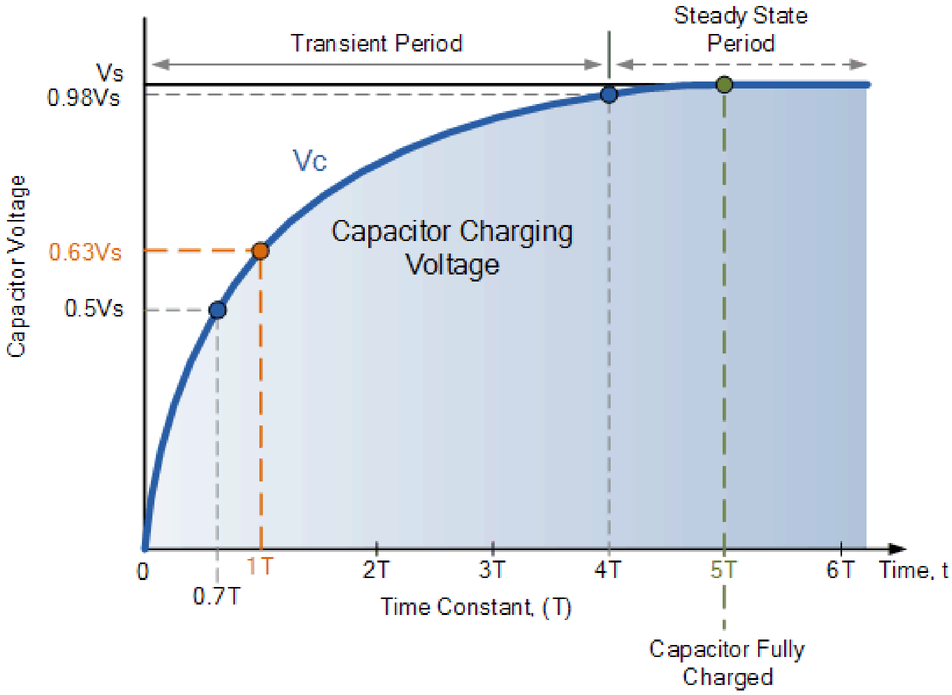


RC charging:

When the input is positive, the capacitor will charge up gradually through the resistor until the voltage across the capacitor reaches that of the supply voltage.

The time also called the transient response, required for the capacitor to fully charge is equivalent to about **5 time constants** or 5T.

τ = R x C, in seconds, where R is the value of the resistor in ohms and C is the value of the capacitor in Farads. This then forms the basis of an RC charging circuit were 5T can also be thought of as “5 x RC”.



<u>From the graph, understand what is τ</u>

Voltage, Vc across the capacitor varies with time according to the formula:

$$V(t) = V_0\,(1 - e^{-t/RC}),$$

RC Discharging:

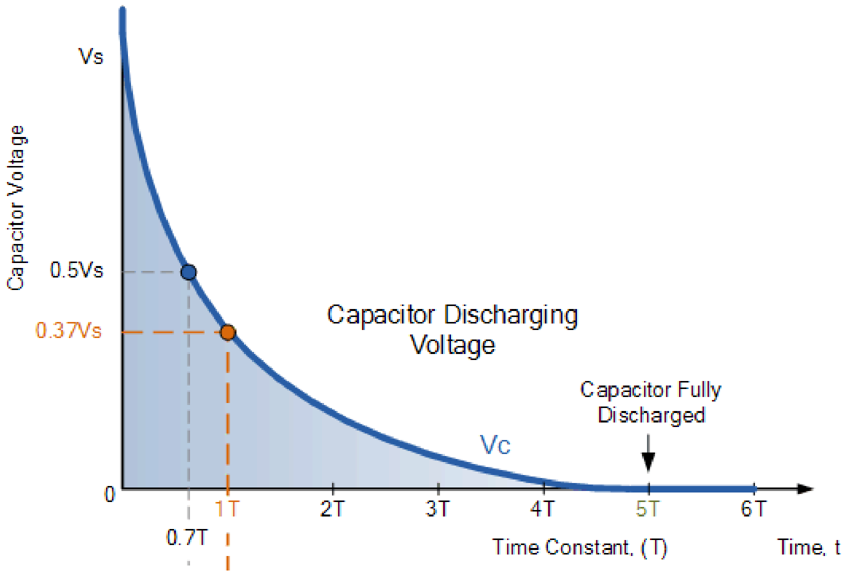
Now, when the input signal becomes negative, the capacitor would start discharging itself back through the resistor.

For a RC discharging circuit, the voltage across the capacitor (Vc) as a function of time during the discharge period is defined as:

$$V(t) = V_0 e^{-t/RC}$$

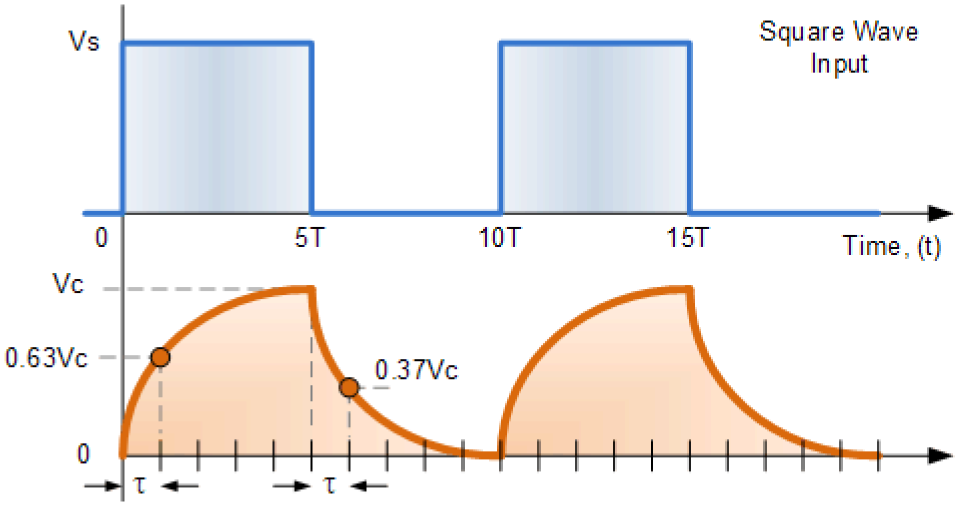
Where:

- Vc is the voltage across the capacitor
- Vs is the supply voltage
- t is the elapsed time since the removal of the supply voltage
- RC is the *time constant* of the RC discharging circuit

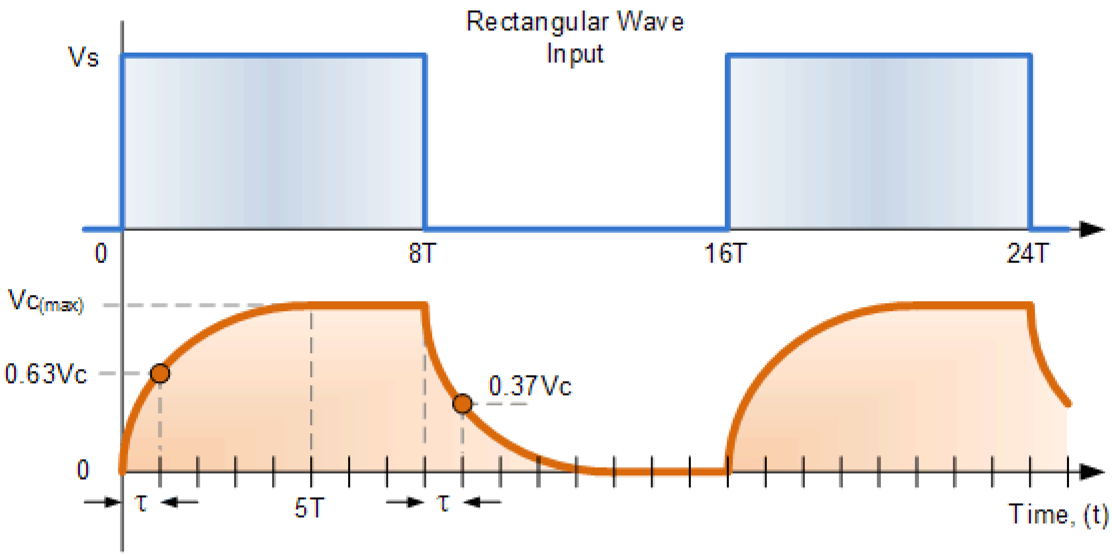


How Does Time period, T of the input signal effects the charging-discharging of capacitor?

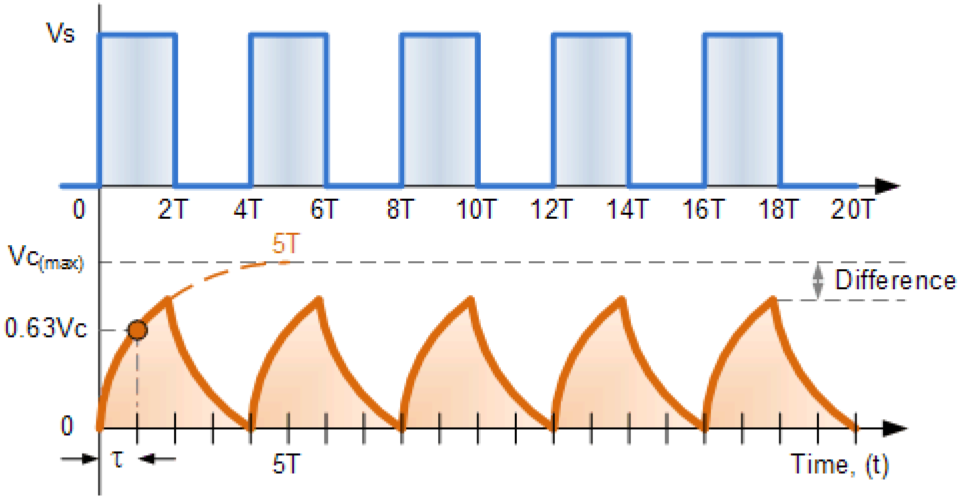
When T=10RC



When T >> 5RC



T < 5RC



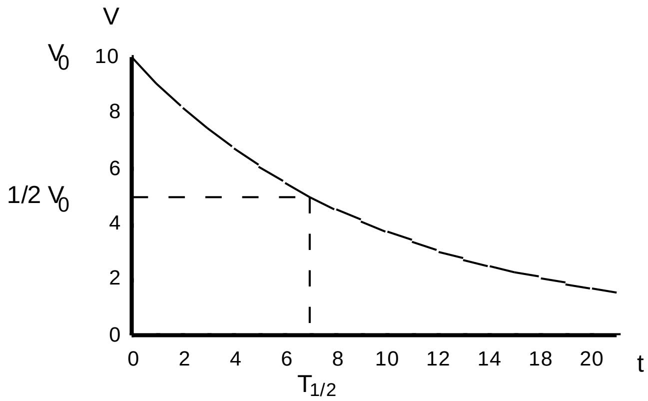
2 Methods to find τ

Method 1:

- Move your graph vertically up so that it is completely above the x-axis.
- Calculate the voltage 0.63Vs (or 0.63Vc)
- Put on the “cursor” and set the horizontal line at the voltage calculated.
- Observe the point the cursor cuts the graph. Measure the corresponding time

Method 2:

An indirect method of finding the time constant, τ is by measuring the time required for the voltage to fall to V_o /2. This time interval is called the half-life, $T_{1/2}$, and then calculate τ using the formula below:



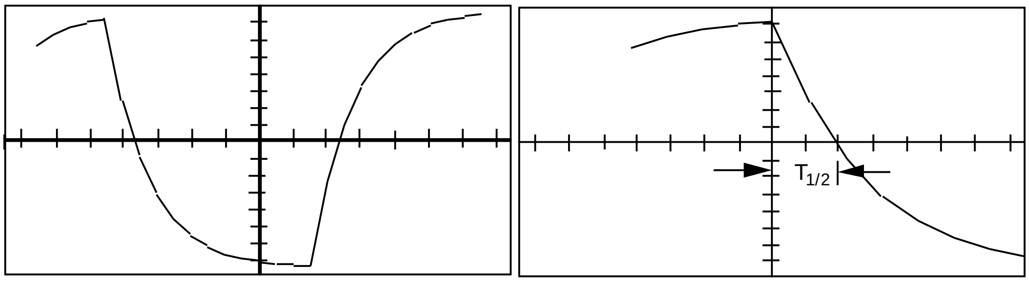
$$\tau = T_{1/2} / \ln 2$$
$$= T_{1/2} / (0.693)$$

Technique to find $T_{1/2}$ from oscilloscope:

- Change oscilloscope gain (volts/cm) and sweep rate (ms/cm) until you have a large pattern on the screen. Make sure the sweep speed is in the “calibrated” position so the time can be read off the *x*-axis.

- Set the ground properly so that the waveform extends equal distances above and below the axis.
- Move the waveform to the right until the start of the discharge of the capacitor is on the vertical axis (Figure 6b). You may find it helpful to expand, or magnify, the trace. The sweep time is now a factor of five or ten faster than indicated on the dial.

•The half-life, $T_{1/2}$ is the time where the discharging phase cuts the x-axis.



Task 1: Using Signal Generator to generate Square Wave.

Generate a square wave with frequency 100Hz and a 5v peak. Observe the pattern in the oscilloscope and vary the frequency until T=10ms.

What is the frequency value?
f = __________

Task 2: Construct an RC circuit such that R = 5k, C = 0.22uF. Input is a 10v(p-p) square wave.

Procedure:

1. Calculate the value of input frequency such that T = 10RC
2. Adjust the frequency of the input signal to that calculated in part 1. Connect the Channel 1 of oscilloscope to the input signal. Adjust the input peak to peak value to 10v.Now connect channel 2 of oscilloscope with the capacitor.

3. Measure τ from the oscilloscope (Using any 1 of the methods explained above)
4. Measure the final output voltage of the capacitor, Vc
5. Measure the time the capacitor charges up to Vc.
6. Measure the time the capacitor starts to discharge
7. Measure the time the capacitor stops discharging
8. Calculate the input frequency such that T=30RC
9. Repeat steps 2-7.
10. Calculate the input frequency such that T= 3.5ms (T<5RC)
11. Repeat steps 2-7.

Data Collection for Lab 7

NORTH SOUTH UNIVERSITY

DEPARTMENT OF ELECTRICAL & COMPUTER ENGINEERING

EEE41L/ETE141L

Group: ________ Instructor's Signature: ___________

Data Table:

Measurement	**T=10RC**	**T=30RC**	**T=3.5ms**
Frequency of input signal			
Time constant, τ			
Final Output Vc			
Measure the time the capacitor charges up to Vc			
Time the capacitor starts to discharge			
Time the capacitor stops discharging			

Report:

1. In separate graph papers, draw the charging-discharging phase for the RC circuit for 3 different values of T. **The graphs should be drawn using values from Table-1.**

2. Explain what is time constant, τ.

3. Theoretically calculate τ and compare with the measured value of τ.

4. **Using the data table**,**explain in details** the charging-discharging pattern for all the 3 cases.