Experiment No: 1

AIM:

Study the transient response of a series RC circuit and understand the time constant concept using pulse waveforms.

APPARATUS REQUIRED:

S.No	Apparatus	Specifications	Quantity
1.	CRO		
2.	Multimeter		
3.	Breadboard		
4.	Components		
5.	Connecting Wires		
6.	Function Generator		

COMPONENT REQUIRED:

S.No	Apparatus	Specifications	Quantity
1.	Resistor	2.2kΩ, 100kΩ	1 each
2.	Capacitor	0.1 µF, 0.01 µF	1 each

THEORY:

A capacitor has the ability to store an electrical charge and energy. The voltage across the capacitor is related to the charge by the equation V=Q/C for steady state values, or expressed as an instantaneous value dv=dq/C

We will study the transient response of the RC circuit, which is the response to a sudden change in voltage.

In this experiment, we apply a pulse waveform to the RC circuit to analyze the transient response of the circuit. The *pulse-width* relative to a circuit's *time constant* determines how it is affected by an RC circuit.

***Time Constant* (τ)**: A measure of time required for certain changes in voltages and currents in RC and RL circuits. Generally, when the elapsed time exceeds five time constants (5τ) after switching has occurred, the currents and voltages have reached their final value, which is also called steady-state response.

The time constant of an RC circuit is the product of equivalent capacitance and the Thévenin resistance as viewed from the terminals of the equivalent capacitor.

$$\tau = RC \qquad \text{.......... (1)}$$

A Pulse is a voltage or current that changes from one level to the other and back again. If a waveform's high time equals its low time, it is called a *square wave.* The length of each cycle of a pulse train is termed its *period* (**T**).

The *pulse width* (t_p) of an ideal square wave is equal to half the time period. The relation between pulse width and frequency is then given by,

$$f = \frac{1}{2\,t_p} \qquad \text{......... (2)}$$

A series RC circuit is shown in Figure1.

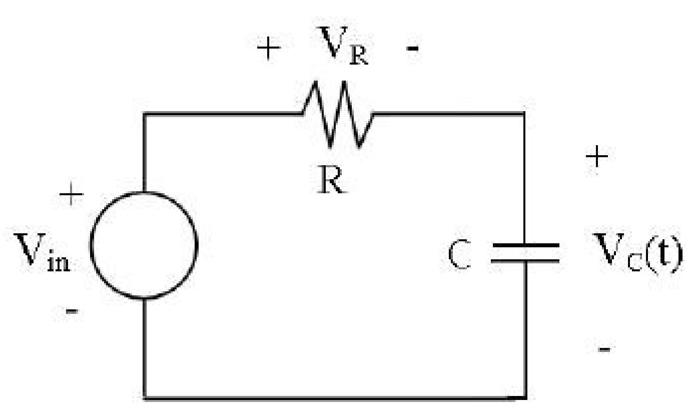


Figure 1.

From Kirchoff's laws, it can be shown that the charging voltage $\mathbf{V_C\ (t)}$ across the capacitor is given by:

$$V_C(t) = V(1 - e^{-t/RC}), \qquad t \geq 0 \qquad \ldots\ldots\ldots(3)$$

Where, V is the applied source voltage to the circuit for $t \geq 0$. $\tau = RC$ is the time constant. The response curve, showing capacitor charging for Series RC circuit to a step input with time axis normalized by τ is shown in Figure 2.

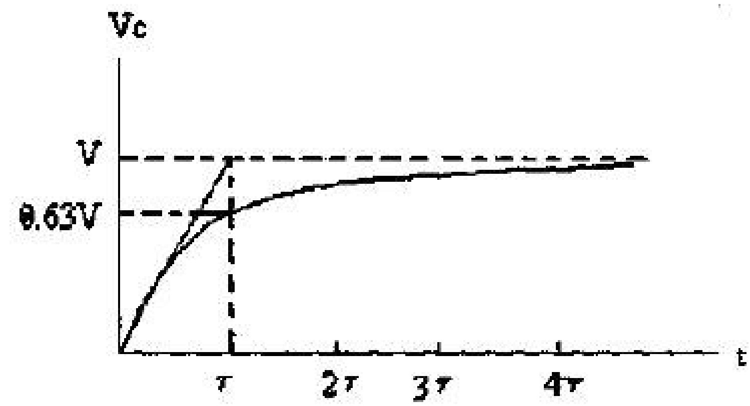
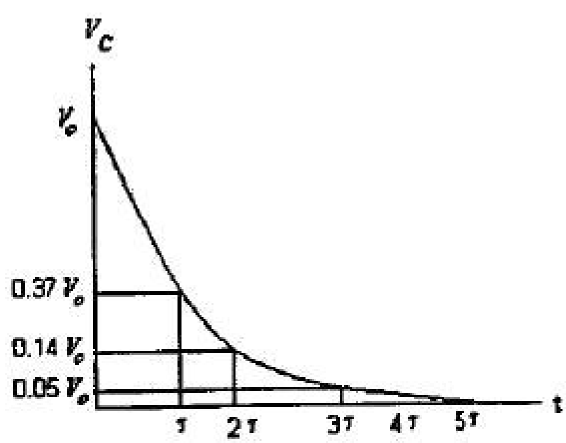


Figure 2.

The discharge voltage for the capacitor is given by:

$$V_C(t) = V_O\, e^{-t/RC}, \qquad t \geq 0 \qquad \ldots\ldots.(4)$$

Where V_O is the initial voltage stored in capacitor at $t = 0$, and $\tau = RC$ is time constant. The response curve is a decaying exponentials as shown in Figure 3.



t	$e^{-t/\tau}$
τ	0.37
2τ	0.14
3τ	0.05
4τ	0.02
5τ	0.01

Figure 3.

PROCEDURE:

1. Set up the circuit shown in Figure1 with the component values R = 2.2 kΩ and C =0.1 μF.

2. Set the Function Generator to generate a $4V_{p-p}$ square wave and apply as input voltage to the circuit.

3. Observe the input square wave on channel 1 and output, across the capacitor, on channel 2 of the CRO. Set the volt/div same for both the channels, as shown in Figure 4.

4. Observe the response of the circuit for the following three cases and record the results.

a. t_p >> 5τ : Set the frequency of the function generator output such that the capacitor has enough time to fully charge and discharge during each cycle of the square wave. So Let t_p = 15τ and accordingly set the function generator frequency using equation (2). The value you have found should be approximately 150 Hz. Determine the time constant from the waveforms obtained on the CRO. (At t= τ, V_c (t) =0.63V from equation (3)).

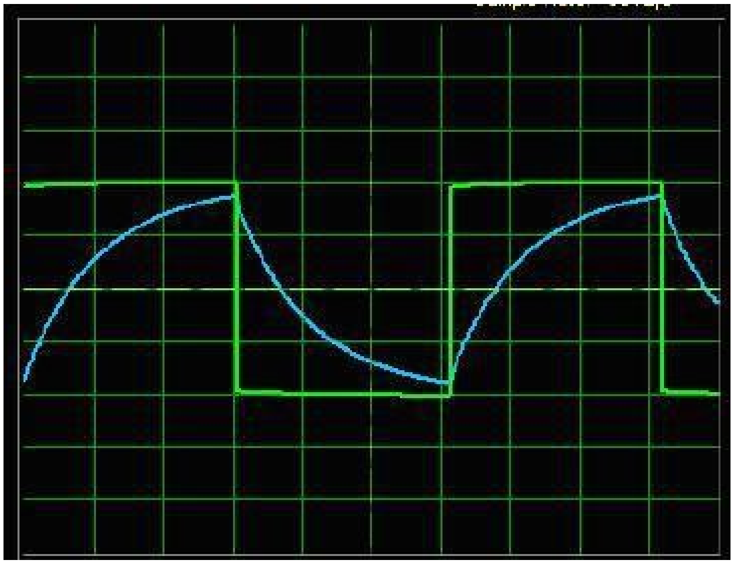
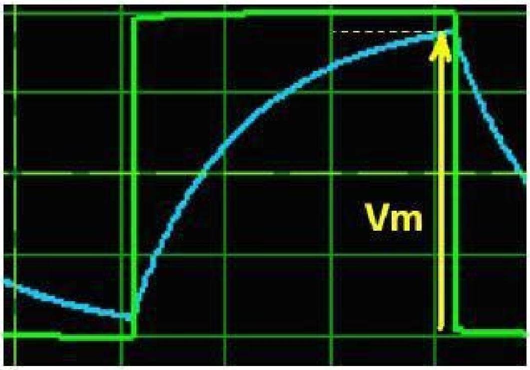


Figure 4.

b. t_p = 5τ : Set the frequency such that t_p = 5τ (this should be 450 Hz)**.** Since the pulse width is exactly 5τ, the capacitor should just be able to fully charge and discharge during each pulse cycle. From the figure determine τ (see Figure 2 and Figure 5 below.)



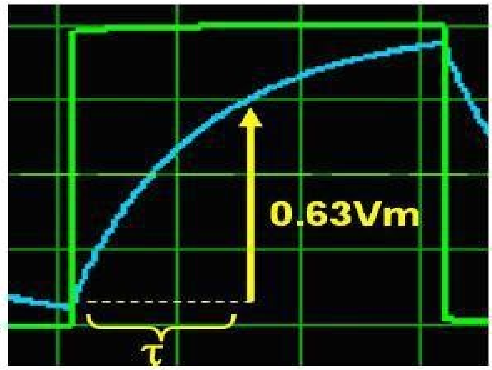


Figure 5.

c. $t_p \ll 5\tau$: In this case the capacitor does not have time to charge significantly before it is switched to discharge, and vice versa. Let $t_p = 0.5\tau$ in this case and set the frequency accordingly.

5. Repeat the procedure using R = 100 kΩ and C = 0.01 μF and record the measurements.

OBSERVATION TABLE:-

Value of R	Value of C	Time constant	
		Observed	Calculated

RESULT:-

PRECAUTIONS:

1. Care should be taken that low value resistances are not connected across the circuit
2. .Ammeter should be connected in series and voltmeter should be connected in parallel.
3. Take care to use the proper polarity when measuring voltage and current.