

# Experiment 02

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Aditya Tripathy - ee24btech11001, Durgi Swaraj Sharma - ee24btech11018

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## Abstract

In Experiment-02, we studied the response of an RC circuit to a square wave input for different ranges of the time constant.

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## 1 Objective

To study the response of RC circuit to square wave input voltage signal when

1.  $RC = T$
2.  $RC \gg T$
3.  $RC \ll T$

## 2 Apparatus

- Oscilloscope
- Two channel function generator
- Connecting wires and probes
- Unpolarised capacitor ( $0.1\mu\text{F}$ )
- Resistors( $100\Omega$ ,  $10\text{k}\Omega$ ,  $1\text{M}\Omega$ )

## 3 Theory

The voltage across capacitor is governed by the following differential equation,

$$V(t) = RC \frac{dV_C}{dt} + V_C \quad (1)$$

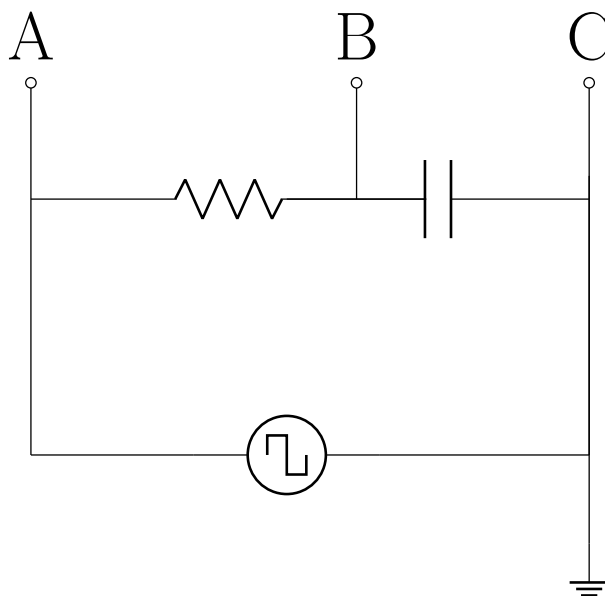
$$\Rightarrow \frac{dV_C}{dt} = \frac{1}{RC}(V(t) - V_C) \quad (2)$$

This can be solved numerically using trapezoidal rule,

$$V(t_{n+1}) = V(t_n) + \frac{h}{2RC}(V(t_{n+1}) + V(t_n) - V_C(t_{n+1}) - V_C(t_n)) \quad (3)$$

$$V(t_{n+1}) = V(t_n) \left( \frac{2RC - h}{2RC + h} \right) + \frac{h}{2RC + h}(V(t_{n+1}) + V(t_n)) \quad (4)$$

Now the aim is to study experimental response in the three aforementioned cases in light of theoretical solution.



## 4 Procedure

### 1. Connections

- Connect the first channel of the function generator to terminal A, and associated ground to C.
- Connect the first channel of the oscilloscope to terminal A, and the associated ground to C.
- Connect the second channel of the oscilloscope to terminal B, and the associated ground to C.
- Ensure scaling is 10X both on the probe wires and the oscilloscope.

### 2. Device Setup

- Construct the circuit as shown in the figure above.
- Use appropriate values of the components for the three separate cases.
- Use the square wave output function in the function generator and use the Time Period option to set the desired time period for the voltage signal.
- To capture the response to first few cycles of input voltage signal, set an appropriate trigger level, set "Sweep = Normal" under "Mode Coupling" menu and set "Trigger = Manual" on the function generator.

3. Make sure that you either use an unpolarised capacitor, with an input voltage signal with high of 5Vrms and low value of -5Vrms, or use an electrolytic capacitor with same high value but low value of 0mV with the longer terminal of the capacitor connected to higher potential.

## 5 Justification

We will be using Python along with Matplotlib and Numpy libraries to verify our experiment's results. The following code plots out the theoretical response of the RC circuit to the input square wave using the numerical solution shown above.

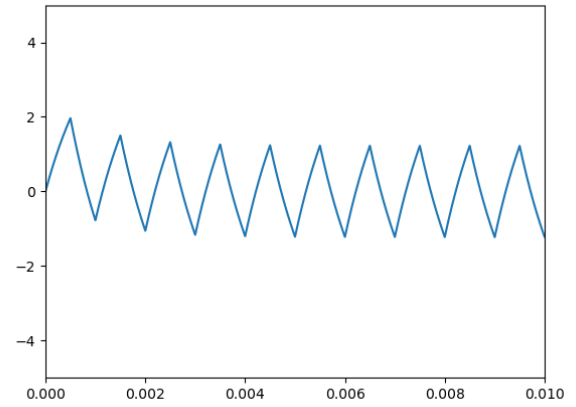
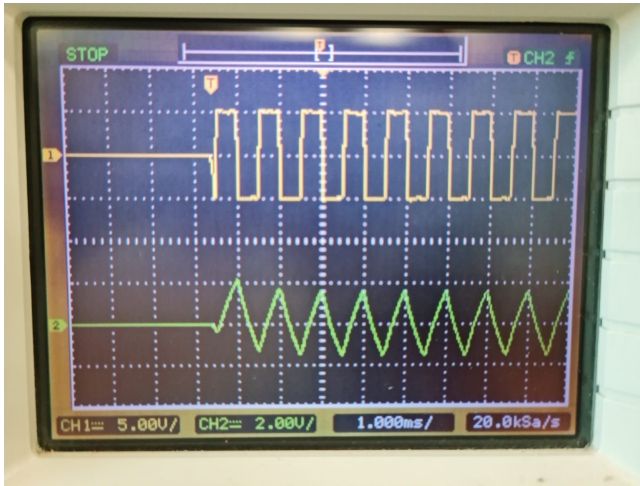
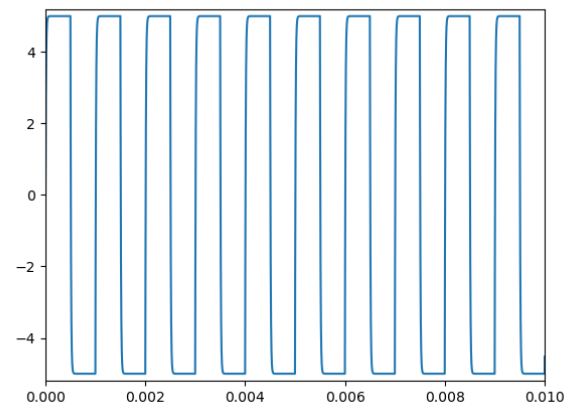
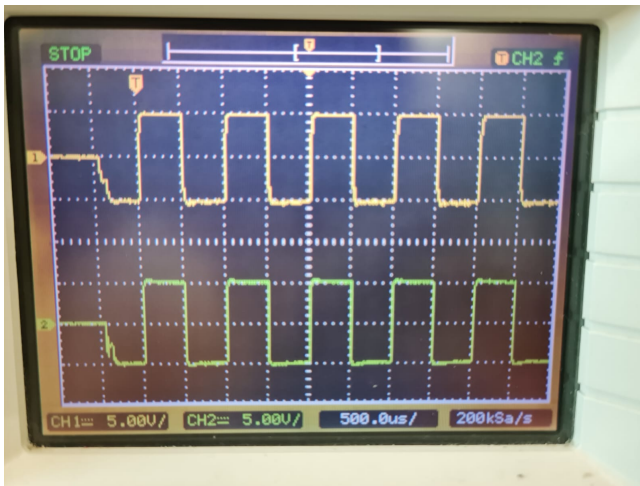
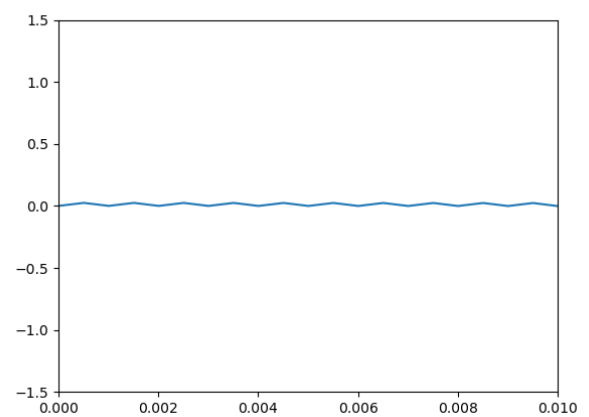
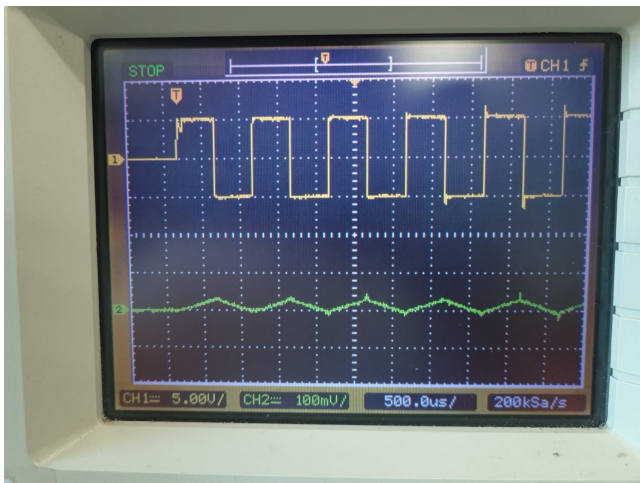
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import matplotlib.pyplot as plt
import numpy as np

def V(t, T, A):
    if t % T <= T/2:
        return A
    else :
        return 0

h = 1e-6
V_0 = 0
t_0 = 0
def f(R, C, V, t, A, T):
    return V(t, A, T)/(R * C) - V/(R*C*C)
R = 1e4
C = 1e-7
A = 5
T = 1
print("T = ", T)
print("RC = ", R*C)
time = list()
V_vals = list()
num_points = 1000000
for _ in range(num_points):
    time.append(t_0)
    V_vals.append(V_0)
    V_0 = V_0 * (2*R*C - h)/(2*R*C + h) + h/(2*R*C + h) * (V(t_0, T, A) + V(t_0 + h, T, A))
    t_0 += h
plt.plot(time, V_vals)
plt.xlim(0, 0.1)
plt.ylim(-5.2, 5.2)
plt.savefig("RC=T.png")
plt.show()
```

By following the procedure for different values R and C, we produced the following verified them using the previously mentioned code. The parameters for the signals used are present in the pictures.

## 6 Results

Figure 1:  $RC = T$ Figure 2:  $RC = 0.01T$ Figure 3:  $RC = 100T$

## 7 Conclusion

1.  $RC = T$ : The capacitor charges to a peak value in the positive half cycle and in the negative half cycle, the initially charged capacitor can be seen as an uncharged capacitor with a series voltage source( $CV_0$ ) acting in series with the square wave input with same polarity, so it will charge to a negative charge on the capacitor. This process repeats untill a steady state is reached.
2.  $RC = 0.01T$ : Since the time constant is much smaller than the time period of input signal, it will charge to peak voltages very quickly and as a result the response closely imitates the input voltage signal.
3.  $RC = 100T$ : In the positive half cycle, the capacitor will charge to a very small value, and in the negative half cycle it will charge approximately to 0 (slightly less than zero). This process repeats till steady state is reached.