Experiment 02

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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.

1 Objective

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

1. RC = T
2. RC >> T
3. RC << T

2 Apparatus

- Oscilloscope
- Two channel function generator
- Connecting wires and probes
- Unpolarised capacitor (0.1μF)
- Resistors(100Ω, 1kΩ, 10kΩ, 1MΩ)

3 Theory

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

$$V(t) = RC\frac{dV_C}{dx} + V_C \tag{1}$$

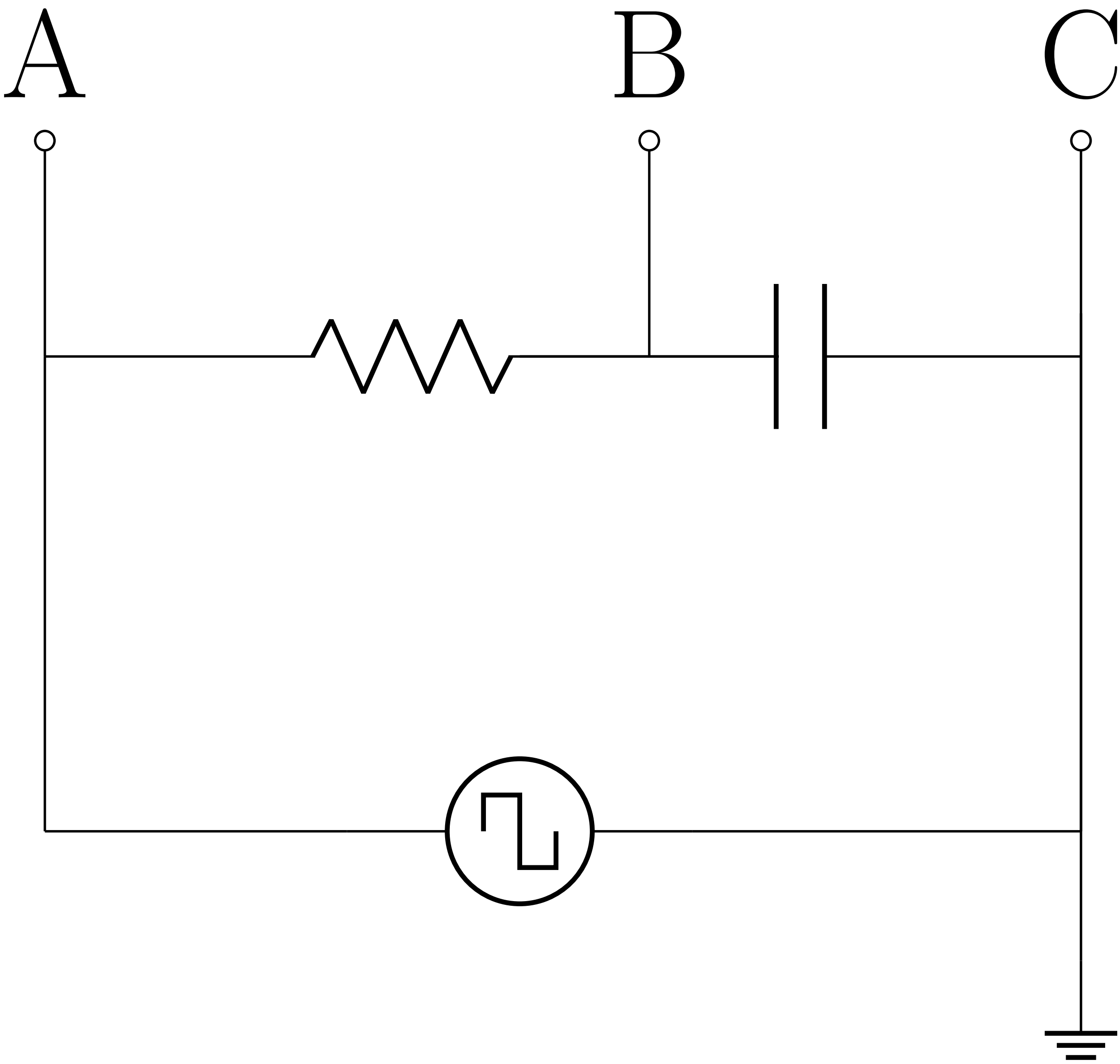
$$\Rightarrow \frac{dV_C}{dt} = \frac{1}{RC}(V(t) - V_C) \tag{2}$$

This can be solved numerically using trapezoidal rule,

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

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

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 tree 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.

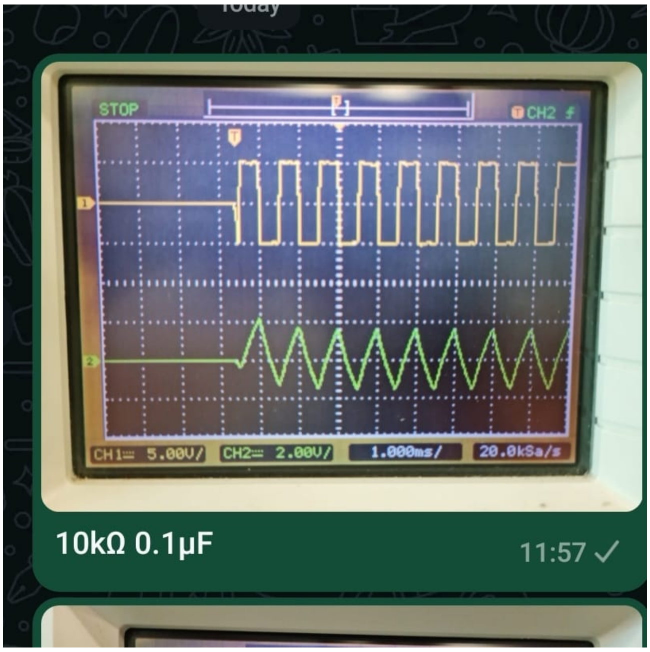
5 Justification

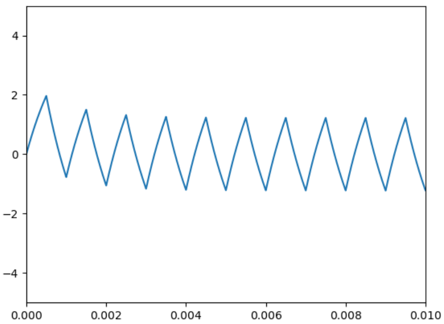
We will be using Python along with Matplotlib and Numpy libraries to verify our experiment's results. The following code plots out the theoretical response of the RC circuit to the input square wave using the numerical solution shown above.

```
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,
    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()
```

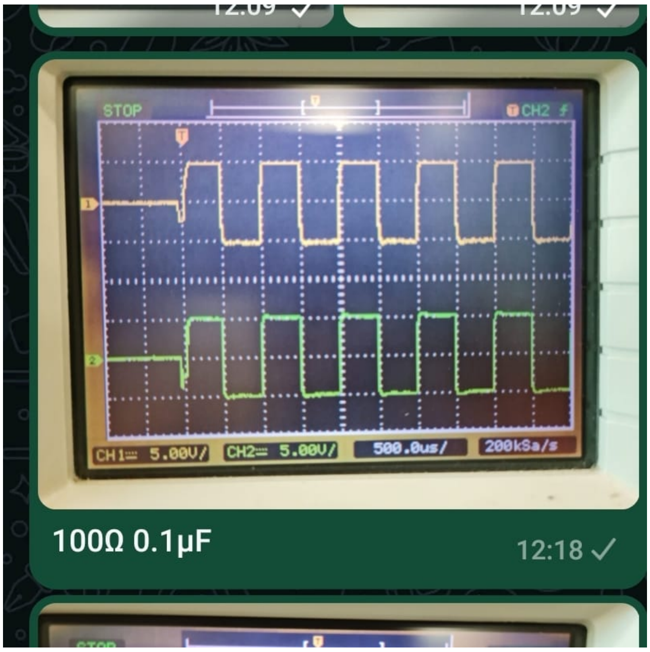
By following the procedure for different values R and C, we produced the following verified them using the previously mentioned code. The parameters for the signals used are present in the pictures of the function generator menu.

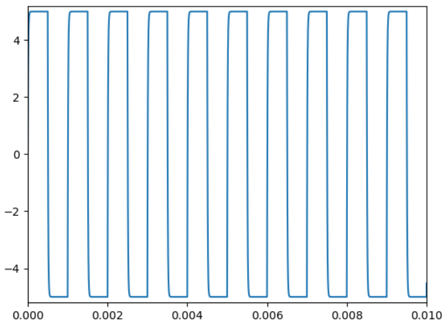
5.1 1.



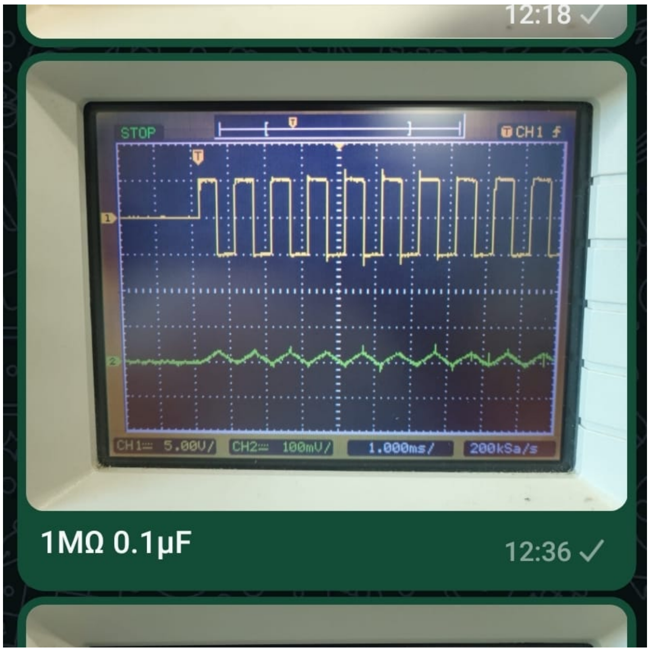


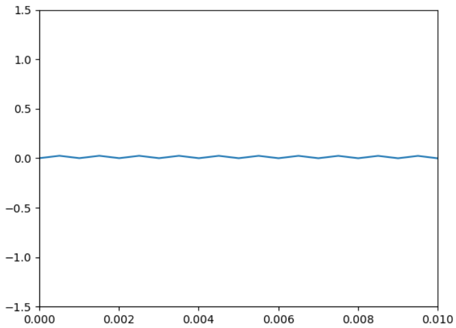
5.2 2.


STOP
CH2
CH1 5.00V/
CH2 5.00V/
500.0us/
200kSa/s
100Ω 0.1μF
12:18


4
2
0
−2
−4
0.000
0.002
0.004
0.006
0.008
0.010

5.3 3.





6 Conclusion

We generated simple sinusoidal signals and made Lissajous figures with them, observing patterns emerging from the frequency ratios, symmetry, phase differences; and verified them using code.