Lab Report: Experiment 2

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Experiment:
Studying the transient
and steady state response
of an RC Circuit
with Square Wave Input

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Objective

To analyze the transient and steady-state responses of an RC circuit to a square wave input $(0 - 5V)$ in three cases:

1. $RC << T$

2. $RC = T$

3. $RC >> T$

where T is the time period of the input square wave.

Equipment Used

- Function generator
- Resistor R
- Capacitor C
- Oscilloscope
- Wires
- Breadboard

Theory

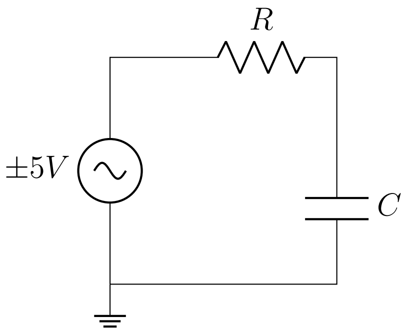


Figure 1: RC Circuit

Governing equation of the above RC circuit is,

$$iR + V_c = V(t) \tag{1}$$

$$C\frac{dV_c}{dt}R + V_c = V(t) \tag{2}$$

$$\frac{dV_c}{dt} = \frac{1}{RC}(V(t) - V_c) \tag{3}$$

Now we can apply any of the known methods for numerically solving differential equations (such as Euler's Method, Backward Euler's Method, Runge-Kutta Method, Trapezoidal Rule). Here, we have chosen to use Trapezoidal rule.

$$\int_{x_n}^{x_{n+1}} dV_c = \frac{1}{RC}(\int_{x_n}^{x_{n+1}} V(t)dt - \int_{x_n}^{x_{n+1}} V_c dt) \tag{4}$$

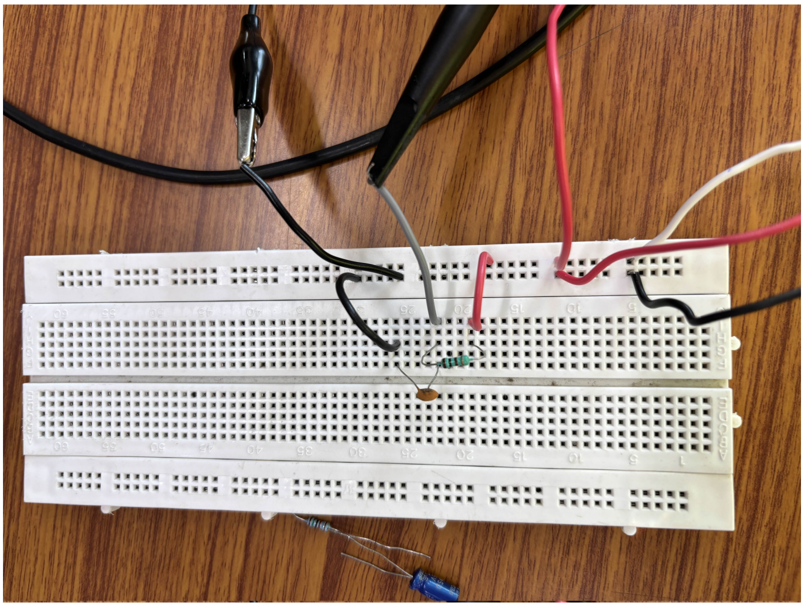
$$V_c(t_{n+1}) - V_c(t_n) = \frac{1}{RC}\left(\frac{h}{2}(V(t_{n+1} + V(t_n))) + \frac{h}{2}(V_c(t_{n+1}) + V_c(t_n))\right) \tag{5}$$

This simplifies to be,

$$V_c(t_{n+1}) = V_c(t_n)\left(\frac{2RC - h}{2RC + h}\right) + \frac{h}{2RC + h}(V(t_{n+1}) + V(t_n)) \tag{6}$$

Procedure

Connecting Circuit



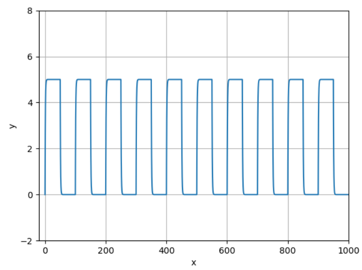
1. Construct the circuit as shown in the above figure.
   (a) Connect the positive end of the function generator in series with a resistor
2. Set the function generator to output a square wave with $5V$ amplitude (Peak Voltage $5V$, Minimum Voltage $0V$) and a time-period T. Select the type of cycle as *N-CYCLES*.
3. Connect the second channel of the function generator to the second channel of the oscilloscope. Set the waveform for this as a square wave with the same conditions as in the first channel. This will allow us to compare output voltage across capacitor with input square wave.
4. This configuration enables the generation of a square wave with a predefined number of cycles when the trigger button is pressed on the function generator. On the oscilloscope, press the *SINGLE* button. This ensures that the next event captured by the oscilloscope is displayed and then the display pauses automatically.
5. Trigger the burst mode manually on the function generator to generate the single pulse or event.
6. Observe and record the captured waveforms on the oscilloscope.

7. To capture steady state, switch from burst mode to continuous mode and capture steady state.
8. Set the sweep to normal from auto.
9. Make sure that the probe and the oscilloscope both are $1X$ or $10X$.

Results and Verification

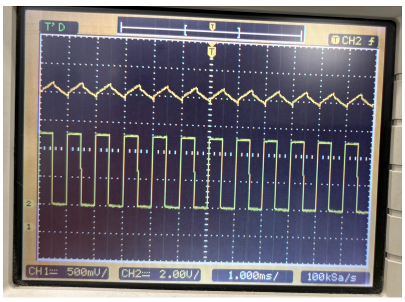
Case 1: $RC << T$

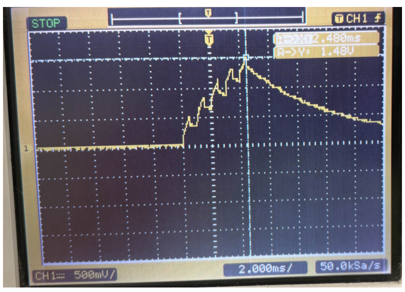
When RC, i.e., time constant, is very less than T, the capacitor takes very less time to charge and discharge making the voltage across it almost similar to the input square wave.

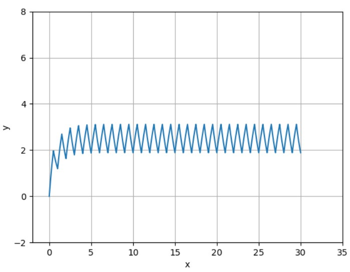


Case 2: $RC = T$

When RC = T, the capacitor charges and discharges as the input wave alternates between 5 to 0V.

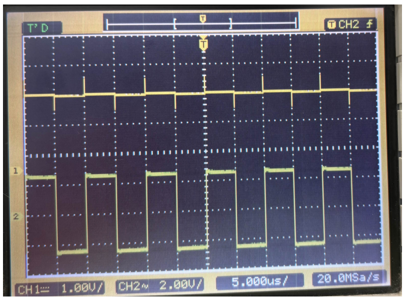


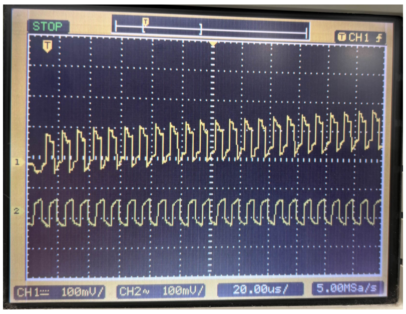


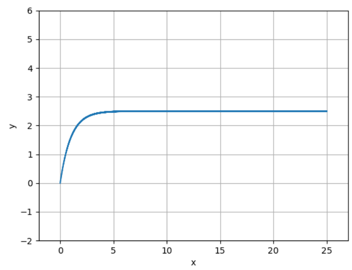


Case 3: $RC >> T$

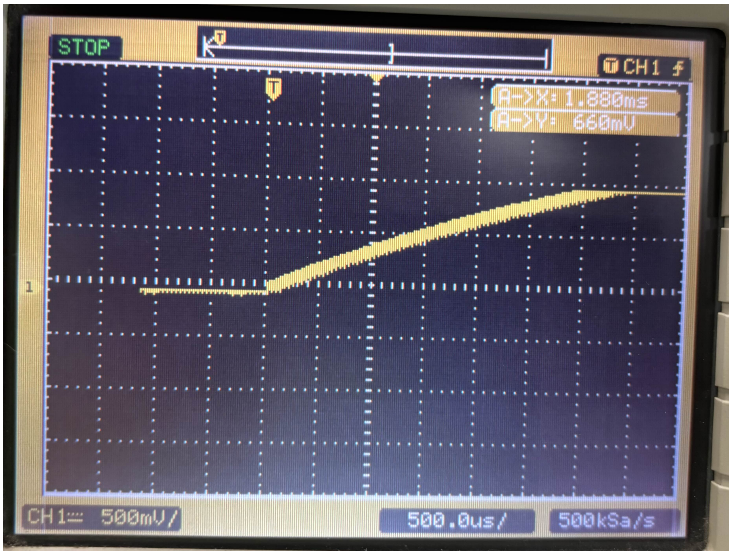
When RC is very large than T, the capacitor charges and discharges very slowly making the graph very smooth and almost like a response to a DC input. Here, we have plotted more than 5 cycles of square wave as it better shows the increasing nature of the potential difference across capacitor. For







an infinite number of cycles of square wave, output comes out to be,



Python code verification of obtained graphs:
`https://github.com/ArjunPavanje/EE1200/tree/main/Experiment_2/codes`

Conclusion

We have successfully found and verified the effect (output) of a square wave on a series RC circuit.