KAZAKH BRITISH TECHNICAL UNIVERSITY

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Laboratory Work #5
First- order RL and RC circuits

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Purpose of the work laboratory work:

1. To identify the First-Order Electric circuit's response to a Constant Reference Input
2. To Check Sequential Switching
3. To Check Stability of First-Order Circuits

Brief theory

Electric circuits that consist of only one resistor and one energy storage element (an inductor or a capacitor) are termed as first-order circuits. Their response to a constant input is essential in understanding their transient and steady-state behavior.

- First-Order R-L Circuit: When a resistor and inductor are connected in series and are subjected to a step voltage, the current doesn't instantaneously reach its steady-state value due to the presence of the inductor. The inductor opposes sudden changes in current. The resulting current vs. time response can be exponential depending on the values of resistance and inductance.
- First-Order R-C Circuit: A resistor-capacitor circuit behaves similarly, but in response to a step voltage, the voltage across the capacitor doesn't change instantaneously. This is because capacitors oppose sudden changes in voltage. The resulting voltage vs. time curve is also typically exponential based on resistance and capacitance values.

Pre lab tasks

Switch was open for a long time. Find Vc, and when switch closes. Find the Vc after switch was closed for a long time. Find the time constant , and write solution to the RC circuit, and draw the solution with proper scalling. Given R1=10kOhm and C2=1microF and V=5v

1) $V_c(t) = V\left(1 - e^{-\frac{t}{RC}}\right)$

$\lim_{t\to\infty} V_c(t) = V = 5V$

This is the DC steady state of the circuit. The capacitor acts like an open circuit after it is fully charged

Time constant τ:

$\tau = R\cdot C = 10\cdot 10^3\cdot 1\cdot 10^{-6} = 0{,}01s = 10ms$

$V_c(t) = 5\left(1 - e^{-\frac{t}{0{,}01}}\right)$

2) $V_c(0) = V_3 = 5V$

$V_c(t) = V + [V_c(0) - V]\cdot e^{-t/RC}$

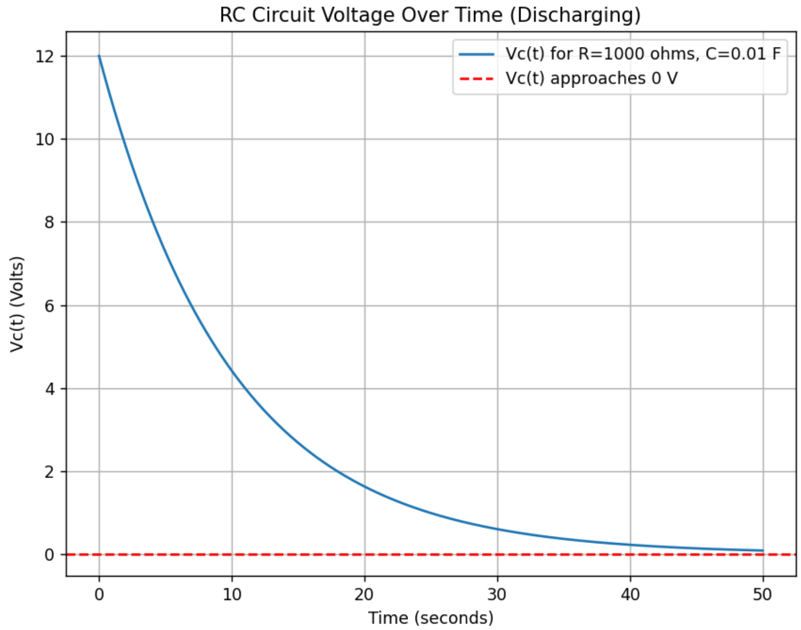
Steady state

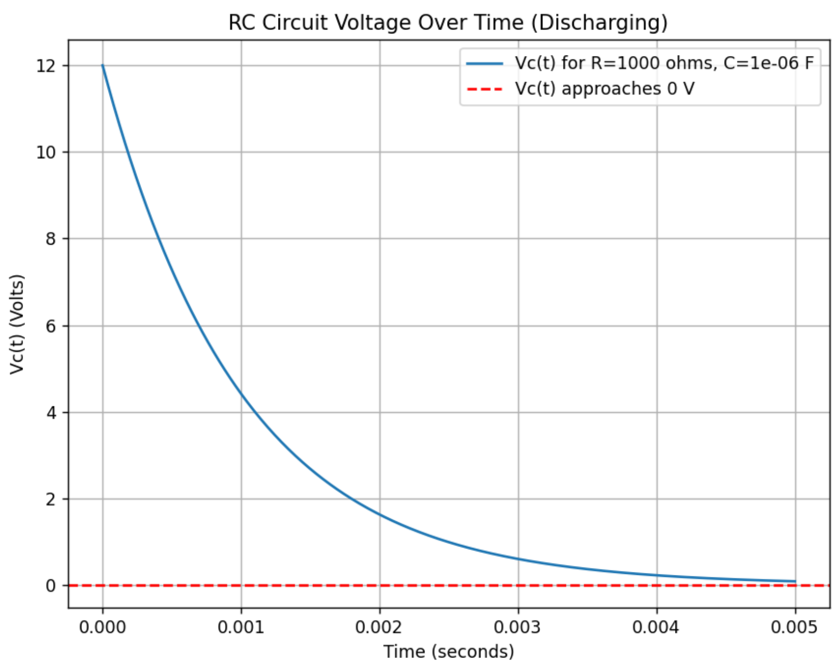
$V_c(\infty) = V = 10V$

$\tau = R \times C = 10\cdot 10^3\cdot 1\cdot 10^{-6} = 0{,}01 s = 10 ms$

$V_c(t) = 10 + [5 - 10]\cdot e^{-t/0{,}01}$

$V_c(t) = 10 - 5\cdot e^{-100t}$


RC Circuit Voltage Over Time (Discharging)
Vc(t) for R=1000 ohms, C=0.01 F
Vc(t) approaches 0 V
Vc(t) (Volts)
Time (seconds)
0
2
4
6
8
10
12
0
10
20
30
40
50


RC Circuit Voltage Over Time (Discharging)
Vc(t) for R=1000 ohms, C=1e-06 F
Vc(t) approaches 0 V
Vc(t) (Volts)
Time (seconds)
0
2
4
6
8
10
12
0.000
0.001
0.002
0.003
0.004
0.005

Calculate the Equivalent Resistance

$R_{eq} = R_1 + R_2 + R_3$

$R_{eq} = 10k\ Ohm + 20k\ Ohm + 50\ kOhm = 80\ kOhm$

Time constant τ

$\tau = R_{eq} \cdot C_1$

$\tau = 80 \cdot 10^3 \cdot 1 \cdot 10^{-6}$

$\tau = 80\,ms = 0{,}08\,s$

$V_c(t) = V \cdot \left(1 - e^{-\frac{t}{\tau}}\right)$

$V_c(t) = 12 \cdot \left(1 - e^{-\frac{t}{0{,}08}}\right)$

$V_c(\infty) = V = 12V$

104:

First two numbers: 10
Multiplier: 10^4
Resulting value: $10 \times 10^4 = 100,000$ pF, which is also 100 nF or 0.1 μF.

474:

First two numbers: 47
Multiplier: 10^4
Resulting value: $47 \times 10^4 = 470,000$ pF, which is also 470 nF or 0.47 μF.

154:

First two numbers: 15
Multiplier: 10^4
Resulting value: $15 \times 10^4 = 150,000$ pF, which is also 150 nF or 0.15 μF.

Summary:

The capacitor with "104" has a value of 0.1 μF.
The capacitor with "474" has a value of 0.47 μF.
The capacitor with "154" has a value of 0.15 μF.

Conclusion During the laboratory work on "First-order R-L and R-C circuits", we examined the transient response of these circuits when subjected to a constant reference input. Through this investigation, we learned the innate nature of inductors and capacitors in resisting sudden changes, which leads to the characteristic exponential response of first-order circuits. We also explored the importance of sequential switching. We understood that the order in which components are switched on or off can have significant impacts on the circuit behavior, especially during transients.