Course Name: Electrical Science- II
Course Code: 15B11EC211

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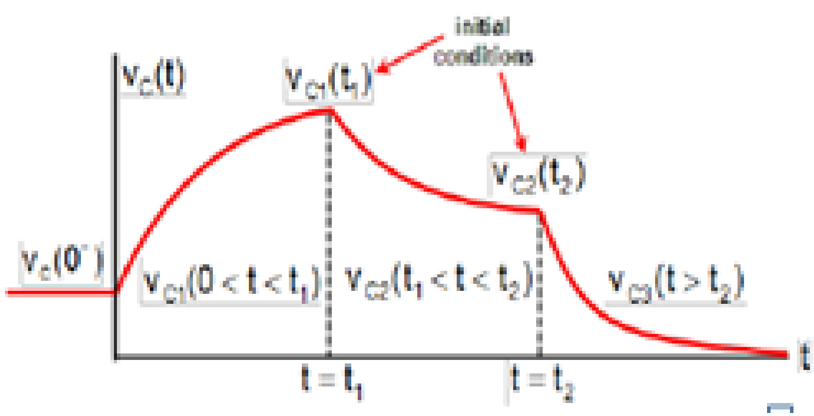
Sequential Switching

- Sequential switching occurs when a circuit contains two or more switches that change state at different instants [1]

- When a series of sequential switches are thrown at various times, as series of sequential charge-ups or discharges will occur with the capacitor. Of course, every time a new circuit is created with the throwing of a switch, it creates new time constants and new complete responses [1,2].



$$\begin{cases} \text{Initial steady state} & t=0^- \\ \text{Circuit-1 with } \tau_1 & t=0^+ \\ \text{Circuit-2 with } \tau_2 & t=t_1 \\ \text{Circuit-3 with } \tau_3 & t=t_2 \\ \quad\vdots & \end{cases}$$

Sequential Switching

Mathematically what do we expect?
Circuit 1: The switch is closed at t=0$^-$ and steady state is established. The complete response of circuit-1 is

$$V_{c1}(0 < t < t_1) = V_{oc1} + [V_c(0^+) - V_{oc1}]e^{-t/\tau_1}$$

Circuit 2: When the switch is thrown at t=t1, a second RC circuit is created that requires its own complete response and new time constant τ_2. However , there are two new things that have to be accounted for.

- The discharging of the capacitor starts at t=t1 and therefore, its complete response is time shifted: t is replaced by t-t1.
- The capacitor's initial voltage is the final steady state value of the previous circuit -1 at time t=t1.

With these modifications, the discharging behavior of the capacitor then looks like

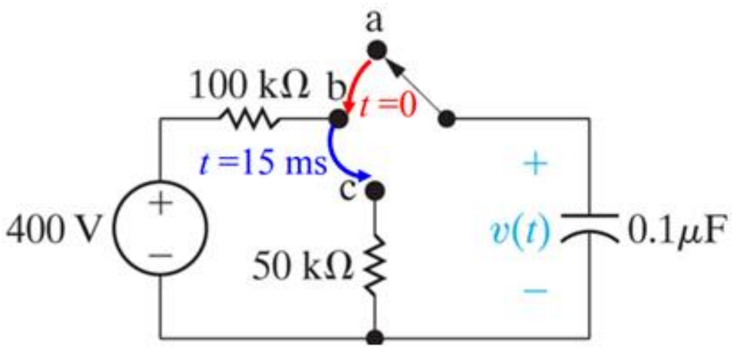
$$V_{c2}(t_1 < t < t_2) = V_{oc2} + [V_{c1}(t_1) - V_{oc2}]e^{-(t-t_1)/\tau_2}$$

Circuit 3: Following the same ideas as with circuit-2's complete response, we write

$$V_{c3}(t_2 < t < \infty) = V_{c2}(t_2)e^{-(t-t_1-t_2)/\tau_3}$$

Problem-1

Q. For the given network, find v(t) for t>0 [1]



Sol. For t<0, capacitor is disconnected to rest of the circuit, Hence

$$V(0^-) = V(0^+) = 0$$

For $0 < t \leq 15$ ms, the 400 V source charges the capacitor via the 100 KΩ resistor, therefore final value of capacitor voltage is $V_f = 400$ V, τ=RC=10 ms, then capacitor voltage is given as

$$v_1(t) = V_f + [V(0^+) - V_f]e^{-t/\tau} = 400 - 400e^{-100t} V$$

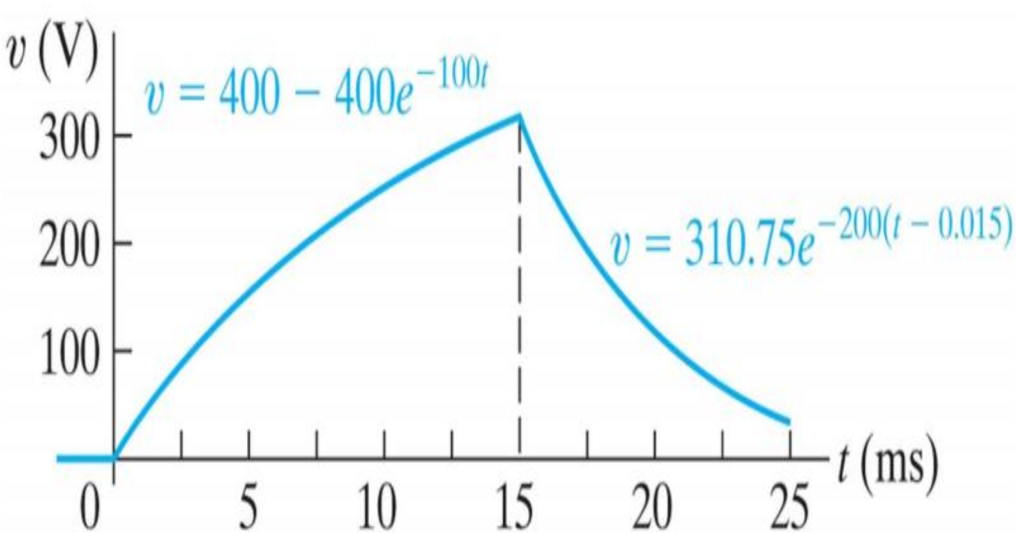
Problem-1 Continues

For t>15 ms, the capcitor is disconnected from the 400 V source and is discharged via the 50 KΩ
Resistor, therefore,

V(0)=v1(15ms)=310.75 V

Vf=0; τ=RC=5 ms, then capacitor voltage is given as

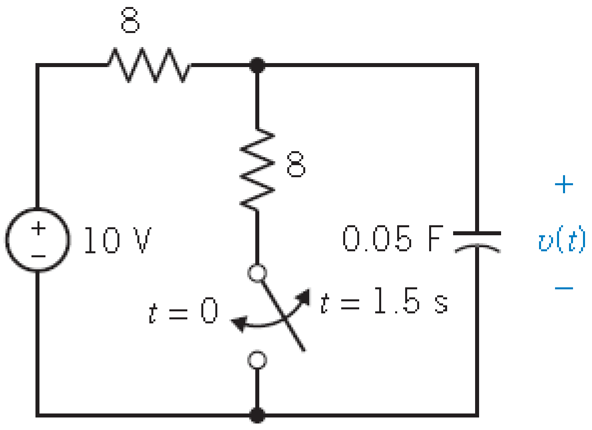
$$v_1(t) = V_f + [V(0^+) - V_f]e^{-(t-t_o)/\tau} = 310.75e^{-200(t-0.015)}V$$



$$v(t) = \begin{cases} 0 & t < 0 \\ 400 - 400e^{-100t}V & 0 < t \le 15ms \\ 310.75e^{-200(t-0.015)}V & t > 15ms \end{cases}$$

Practice Problem

Q. The circuit shown in Fig. is at steady state before the switch closes at time t=0. The switch remains closed for 1.5s and then opens. Determine the capacitor voltage for t>0. [1]



Ans

$$v(t)=\begin{cases}10 & t<0\\ 5+5e^{-5t}V & 0<t\le 1.5s\\ 10-5e^{-2.5(t-1.5)}V & t>1.5s\end{cases}$$

References

[1] R.C. Dorf and J. A. Svoboda, “Introduction to Electric Circuits”, 9th ed, John Wiley & Sons, 2013.

[2] W. H. Hayt, J. E. Kemmerly and S. M. Durbin, “ Engineering Circuit Analysis,” New York: McGraw-Hill,2006