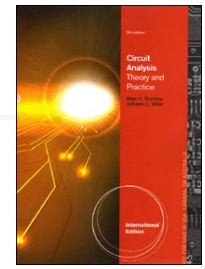

Chapter 11

Capacitors Charging, Discharging, Simple Waveshaping Circuits

Capacitor Charging

When switch is closed at beginning state, $t = 0+$

- Capacitor voltage cannot change **instantaneously**
- When switching, the capacitor looks like a short circuit
- **Capacitor voltage begins at zero**
- **Capacitor current instantaneously jumps to E/R**

Capacitor Charging

When switch is closed at transient state, $t \geq 0$

- **Capacitor voltage** begins at zero and **exponentially increases to E volts**
- **Capacitor current** instantaneously jumps to E/R and **exponentially decays to zero**

t=0s, v_c = 0V, $i_c = (E - v_c)/10 = (10 - 0)/10$ = 1A
t=1s, v_c = 6.3V, $i_c = (E - v_c)/10 = (10 - 6.3)/10$ = 0.37A
t=3s, v_c = 9.5V, $i_c = (E - v_c)/10 = (10 - 9.5)/10$ = 0.05A
t=5s, v_c = 10V, $i_c = (E - v_c)/10 = (10 - 10)/10$ = 0A
t=6s, v_c = 10V, $i_c = (E - v_c)/10 = (10 - 10)/10$ = 0A

Steady State Conditions

When switch is closed at steady state, $t \geq 5RC$

- Capacitor voltage and current reach their final values and **stop changing**
- Capacitor **has voltage** across it, but **no current** flows through the circuit. **Capacitor looks like an open circuit.**

Capacitor Discharging

When switch is closed at beginning state, $t = 0+$

- **Capacitor voltage** has E volts across it when it begins to discharge
- **Capacitor current** will instantly jump to $-E/R$
- Both voltage and current will **decay exponentially to zero**

t=0s, v_c = 10V, i_c = -(v_c)/10 = -(10)/10 = -1A
t=1s, v_c = 3.7V, i_c = -(v_c)/10 = -(3.3)/10 = -0.37A
t=3s, v_c = 0.5V, i_c = -(v_c)/10 = -(0.5)/10 = -0.05A
t=5s, v_c = 0V, i_c = -(v_c)/10 = (0)/10 = 0A
t=6s, v_c = 0V, i_c = -(v_c)/10 = (0)/10 = 0A

The Time Constant

The functions $e^{-t/\tau}$ and $1-e^{-t/\tau}$

$$v_C = E\left(1 - e^{-t/RC}\right)$$

t =0RC=0τ, e^{-0} = 1 , $E(1-e^{-0})= 0$
t =1RC=1τ, e^{-1} = 0.368 , $E(1-e^{-1})= 0.632\times E$
t =2RC=2τ, e^{-2} = 0.135 , $E(1-e^{-2})= 0.865\times E$
t =3RC=3τ, e^{-3} = 0.050 , $E(1-e^{-3})= 0.950\times E$
t =4RC=4τ, e^{-4} = 0.018 , $E(1-e^{-4})= 0.982\times E$
$t \geq$5RC=5τ, e^{-5} = 0.007 , $E(1-e^{-5})= 0.993\times E$

Kernel abilities

1. Can understand the meanings of beginning state, transient state, and steady state during a capacitor charging and discharging.
2. Can draw the voltage waveforms of a capacitor charging and discharging.
3. Can calculate the voltage and current at a time of a capacitor charging and discharging.
4. Can understand that the time constant RC will affect the voltage and current during a capacitor charging and discharging.