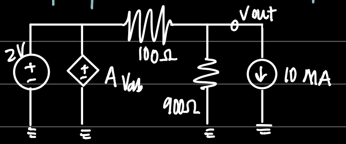
Shivani Patel 3033800943 Homework #8

1. superposition with a dependent source



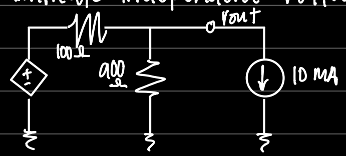
$V = IR$

$0.9 = 0.01(90)$

$R_{eq} = \frac{100 \cdot 900}{100+900} = 90\,\Omega$

$\boxed{V_{out} = 0.9\,V}$

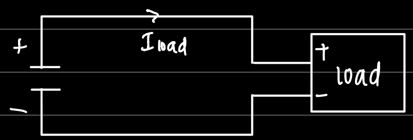
eliminate independent voltage



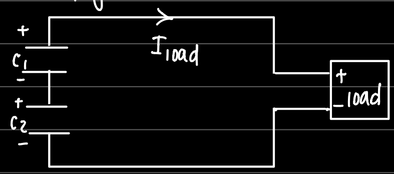
2. super capacitors

2a) Load ⟶ the load is having constant current I_{load}

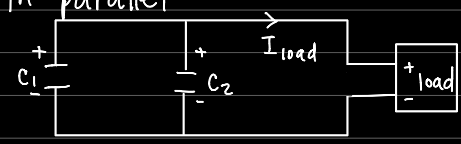
Configuration 1:



Configuration 2:



Configuration 3: Two supercapacitators connected in parallel

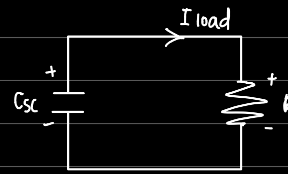


2b) Given initial voltage $= V_{init}$

$C = C_1 = C_2 = C_{sc}$

Configuration 1:

• since load is taking constant current, we can assume load as sensitive load (R_L) so the capacitor will discharge through R_L



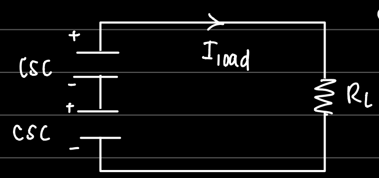
Apply KCL

$csc \frac{dv}{dt} + \frac{V}{RL} = 0 \Longrightarrow \frac{dv}{dt} = \frac{-V}{RL} \cdot csc$

V_{init} = Voltage across capacitor at time $t=0$

$\boxed{V(t) = V_{init}\, C^{-t} \mid R_L \cdot CSC}$

Configuration 2:



since 2 capacitators are connected in series

Initial voltage $= V_{init} + V_{init}$

$V_{eq} = 2\,V_{init}$

$\frac{1}{Ceq} = \frac{1}{CCS} + \frac{1}{CCS}$

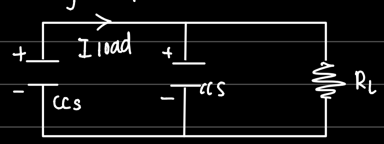
$ceq = \frac{CCS}{2}$

Equation of capacitor voltage with time:

$V(t) = Veq\, e^{-t/R_L\, ceq}$

$\boxed{V(t) = 2V_{init}\, e^{-2t/R_L \cdot ccs}}$

Configuration 3:



Two capacitors are connected in parallel

$Veq = V_{init}$

$Ceq = CCS + CCS$

$= 2Cs$

$V(t) = Veq\, e^{-t/RL\ ceq}$

$\boxed{V(t) = V_{init}\, e^{t/RL^2\, ccs}}$

2C) for device to work properly capacitor must supply at least V_{min} V. So $V(t) \doteq V_{min}$

Configuration 1 : If $V(t) = V_{min}$ $t = t_L$ (lifetime)

$V_{min} = V_{init}\, e^{-t/RL \cdot CSC}$

$\frac{t_L}{R_L \cdot CSC} = \ln\left(\frac{V_{min}}{V_{init}}\right)$

$\boxed{t_L = R_L \cdot csc \ln\left(\frac{V_{init}}{V_{min}}\right)}$

configuration 2:

$V_{min} = 2V_{init}\, e^{-2t_L/R_L C_{CS}}$

$$\boxed{t_L = \frac{R_L \cdot C_{CS}}{2} \ln\left(\frac{2V_{init}}{V_{min}}\right)}$$

configuration 3

$V_{min} = V_{init}\, e^{-t_L/R_L \cdot 2C_{CS}}$

$$\boxed{t_L = 2R_L \cdot C_{CS} \ln\left(\frac{V_{init}}{V_{min}}\right)}$$

2d) single capacitor doesn't provide sufficient lifetime, so the configuration should be selected which gives high lifetime so configuration 3 will be more suitable as it gives more lifetime as compered configuration 2 because in parallel combo. the current load get distributed between two super capacitors

2e)

$E = \frac{1}{2}C$

$$\boxed{V_C^2 = \frac{1}{2} \cdot 2C_{sc} \cdot \left(V_{init} - \frac{i_{load}}{2C_{st}} \cdot f\right)^2}$$

3. Dynamic Random Access Memory (DRAM)

$V_{init} = 1.2V$

$V_{min} = V_{bit} = 0.9V$

$Q_{bit} = V_{bit} C_{bit} \longrightarrow I_{leak} = \frac{dV_{bit}}{dt} C_{bit} \longrightarrow I_{leak} = \frac{\Delta V_{bit}}{\Delta t} C_{bit}$

$= \frac{V_{init} - V_{min}}{t_{store}} C_{bit}$

$$\boxed{I_{leak} = \frac{(1.2V - 0.9V) * 28fF}{10^{-3}s}}$$

4. It's finally Raining

4a) $C = \frac{\varepsilon A}{d}$ $\quad \varepsilon$ = permittivity of dielectric material

A = Area of plates

d = distance

applied to physical structure

$h_{tot} * W$

W = distance between the plates w

$$\boxed{\begin{aligned} C_{empty} &= \frac{\varepsilon_{air} h_{tot} W}{w} = \varepsilon h_{tot} \\ C_{full} &= \frac{\varepsilon_{H_2O} h_{tot} W}{w} = 81 \varepsilon h_{tot} \end{aligned}}$$

4b) capacitance of the two plates seperated by water

$C_{water} = \frac{\varepsilon_{H_2O} h_{H_2O} W}{w} = 81 \varepsilon h_{H_2O}$

capacitance of the two plates seperated by air

$C_{air} = \frac{\varepsilon_{air}(h_{tot} - h_{H_2O}) W}{w} = \varepsilon (h_{tot} - h_{H_2O})$

• they are in parallel ⇒ add two results

$$\boxed{C_{tank} = C_{water} + C_{air} = \varepsilon (h_{tot} + 80 h_{H_2O})}$$

4c) $V_c(t) = \frac{1}{C}\int i\,dt$

$V_c(t) = \frac{1}{C_{tank}} \int_0^t I_s\,dt$

$$\boxed{V_c(t) = \frac{I_s t}{C_{tank}}}$$

5d)

1. First disconnect C_{tank} from voltage source
2. short its terminals to ensure that $V_c(0) = 0$ (that is the initial voltage is 0)

$C_{tank} = \frac{I_s t}{V_c(t)}$

also from part ⓑ, we have

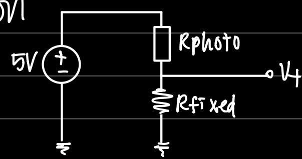
3. Then connect its terminals to the DC current source Is for time t
4. Note the V_C at the end of time interval t
5. Apply the following equations to compute C_{tank} & h_{H_2O}

$$\boxed{h_{H_2O} = \frac{C_{tank}}{\Sigma} - h_{tot}) * \frac{1}{80}}$$

5. LED Alarm circuit

5a) op-amp in companaton configuration
voltage divides configuration

$$V_+ = \left(\frac{R_{fixed}}{R_{fixed}+R_{photo}}\right) \times 5$$



5b) light conditions $\Rightarrow R_{photo} = 1k\Omega$
Dark conditions $\Rightarrow R_{photo} = 10k\Omega$
Light condition $\rightarrow V_+ = 3V$

$$V_+ = \left(\frac{R_{fixed}}{R_{fixed}+R_{photo}}\right) * 5$$

under light conditions $3 = \frac{R_{fixed}}{R_{fixed}+1k\Omega} \times 5$

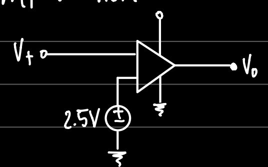
$3(R_{fixed}+1k\Omega) = 5R_{fixed}$

$3k\Omega - 5 R_{fixed} - 3R_{fixed}$

$$\boxed{R_{fixed} = 3/2\ k\Omega}$$

5c) op-amp as comparaton

$$V_0 = \begin{cases} V_{cc} ; V_+ > V_- \\ 0 ; V_+ < V_- \end{cases}$$



on

$$V_0 = \begin{cases} 5V; & V_+ > 2.5V \\ 0; & V_+ < 2.5V \end{cases}$$

5d) $V_+ \left(\frac{R_{fixed}}{R_{fixed}+R_{photo}}\right) \times 5V$

$R_{fixed} = 3/2\ k\Omega$ from part ⓑ

$$V_+ = \left(\frac{R_{fixed}}{3/2k + R_{photo}}\right) * 5V$$

conditions $V_+ > 2.5V \longrightarrow V_0 = 5V$

$$\frac{5 \times 3/2\ k}{R_{photo}+3/2\ k} > 2.5$$

$15/2 k > 2.5 R_{photo} + 3.75 k$

$+3.75k > 2.5 R_{photo}$

$R_{photo} < +1.5k\Omega$

For $V_0 = 5V \rightarrow R_{photo} < 1.5k\Omega$

For $V_0 = 0V$ $<2.5V$ $R_{photo} > 1.5k\Omega$

$$V_0 \begin{cases} 5V; R_{photo} < 1.5k\Omega \\ 0; R_{photo} > 1.5k\Omega \end{cases}$$

5e) From LED portion of the circuit

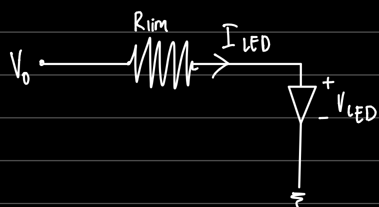
$V_{LED} = V_0 - R_{lim} \cdot I_{LED}$

$V_f = 3V$ (LED to act)

I_{LED} recommend $= 20mA$

$3V = 5V - R_{lim} \times 20mA$

↓
V_0

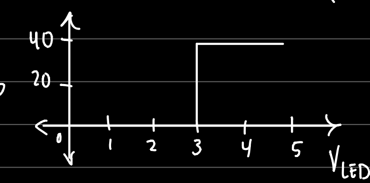


when light conditions

$3 = 5 - R_{lim} \times 20 \times 10^{-3}$

$\Rightarrow R_{lim} \times 2 \times 10^{-2} = 2$

$\therefore R_{lim} = 100\Omega$



6. DC-DC voltage Divider

6a) $C_{eq} = \frac{C_1 \cdot C_2}{C_1 + C_2}$

$$V_{C1} = \frac{\frac{C_1 \cdot C_2}{C_1+C_2} \cdot V_{in}}{C_1}$$

$Q_{C1} = \frac{C_1 \cdot C_2}{C_1+C_2} \cdot V_{in}$

$Q_{eq} = C_{eq} V_s$

$Q_{eq} = \frac{C_1 \cdot C_2}{C_1+C_2} \cdot V_{in}$

$V = Q/C$

$$V_{C2} = \frac{\frac{C_1 \cdot C_2}{C_1+C_2} \cdot V_{in}}{C_2}$$

$Q_{C_2} = \frac{-C \cdot C_2}{C_1+C_2} \cdot V_{in}$

6b)

$$\boxed{V_{in} - \frac{\frac{C_1 \cdot C_2}{C_1+C_2} \cdot V_{in}}{C_1}}$$

6c) output voltage $= V_{in}/2$; Efficiency: $E = 1/2\, C_1 V_{C_1}^2$

$E_{total} = 1/2 \left(\frac{C_1 \cdot C_1}{C_1+C_1}\right) V_{in}^2 - (C_1)\left(\frac{\frac{C_1 \cdot C_1}{C_1+C_1} \cdot V_{in}}{C_1}\right)^2$

8 Homework process & study Group

I worked with Sadia (3034541667) but mostly by myself. This took me 6 hours. 1 hour with Sadia & 5 hours on my own