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EECS 42 – Introduction to Electronics for Computer Science

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Solution Problem Set # 3 (by Farinaz Koushanfar)

3.1 Capacitance.

a) Charge accumulation rate x time = Q(t) = $(9\times10^{5}$m/hr)(1/3600 s/hr)(10^{17}e/m)(-1.6×10^{-19}C/e)t = 4t C.

b) V(t) =$(1/C_{PLANE})$Q(t) = $10^{+3}\times 4t = 4.0\times10^{3}t$ V.

c) 100 KV/(4.0 x 10^{3} V/s) = 25 s

d) $(1/2)CV^2 = (1/2)(10^{-3})(10^{5})^2$ = 5.0 MJ

3.2 Capacitance and voltage versus time.

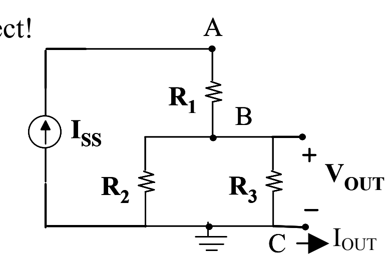
a) From 0 to 2 μs, v(t) = V(t=0) + (1/C)i(t)t = 0 + $(1/10^{-12})(1\times10^{-6})$t = 0 +1t (V)
From 2 to 4 μs, v(t) = V(t=2) + (1/C)i(t)(t-2us) = 2 + $(1/10^{-12})(2\times10^{-6})$ (t - 2μs)
= 2 +2 (t - 2μs) (V)
From 4 to 7 μs, v(t) = V(t=4) + (1/C)i(t)(t-4μs) = 6 + $(1/10^{-12})(-4\times10^{-6})$ (t - 2μs) = 6 –4(t– 4μs) (V)
If v(t)=0 ⇒ 6 –4(t– 4μs) = 0 ⇒ 22-4t=0 ⇒ t = 5.5μs

b) $$E = \int_{v=V_{Initial}}^{v=V_{Final}} Cv\,dv = \frac{1}{2}CV_{Final}^{2} - \frac{1}{2}CV_{Initial}^{2} = (1/2)\times10^{-12}\times(4\text{-}0) = 2\text{ pJ}$$

c) $$E = \int_{v=V_{Initial}}^{v=V_{Final}} Cv\,dv = \frac{1}{2}CV_{Final}^{2} - \frac{1}{2}CV_{Initial}^{2} = -(1/2)(10^{-12})2^2 + (1/2)(10^{-12})6^2 = 16\text{ pJ}$$

d) $E = \frac{1}{2}C(V_{Final} - V_{Initial})^2$ = $(1/2)(10^{-12})(6-2)^2$ = 8 pJ which is **NOT** correct!
Since $(V_{Final} - V_{Initial})^2$ is not the solution to the integral

$$E = \int_{0}^{\infty} i(t(.v(t).dt$$



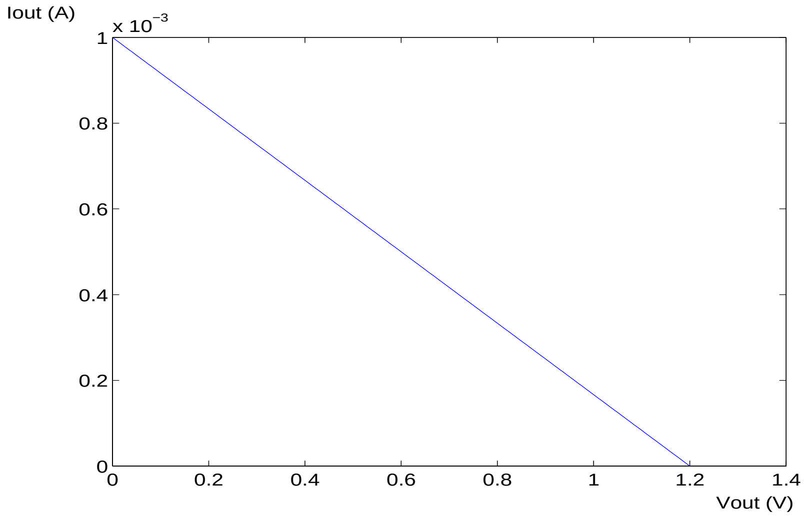
I_{SS} = 1mA, R_1 = 1kΩ, R_2 = 2kΩ, R_3 = 3 kΩ
Fig. P3.3

3.3 Equivalent Circuits.

a) For V_{OUT} = 1.2V, we know from last weeks HW that this is the open circuit voltage and so I_{OUT} = 0. This means that there is really no external element and the circuit to the left of V_{OUT} can be analyzed by itself. I_{SS} x R2||R3= 1.2V as expected.
For V_{OUT} = 0.6V the current through R1 plus through R2 is:
(0.6V/2kΩ) + (0.6V/3kΩ) = 0.3 mA+ 0.2 mA= 0.5mA ⇒ I_{OUT} = 1 mA – 0.5 mA = 0.5mA.
For V_{OUT} = 0V there is no voltage drop on R2 or R3 ⇒ there is no current through them. This greatly simplifies the circuit to the left by removing R1 and R2 and I_{OUT} = 1.0 mA.

b) The short circuit case V_{OUT} = 0V was easiest followed by the open circuit case V_{OUT} = 1.2V. The solution technique for V_{OUT} = 0.6V is completely general and could be used for any output voltage.

c) $I_{OUT} = 1\text{mA} - V_{OUT}/(R2||R3) = (1-V_{OUT}/(1.2\text{K}\Omega))$



d) Slope = $10^{-3}/1.2$ (A/V). The inverse of the slope gives 1.2kΩ and the voltage is 1.2V.

e) Show that $R_T = -V_{OC}/I_{SC} = -(1.2\text{V}/-1\text{mA}) = 1.2\text{k}\Omega$.

f) This value is $R_2||R_3$. Turning the current source to zero makes $I_{SS} = 0$ and there is no current path through I_{SS}. Thus only R_2 and R_3 are in the circuit in this case.

3.4 Equivalent Circuits and Ideal Supplies.

$V_{AA} = 1\text{V}$, $I_{SS} = 1\text{mA}$, $R_1 = 1\text{k}\Omega$, $R_2 = 2\text{k}\Omega$

a) $V_{OC} = V_{AA} = 1\text{V}$ as there is no current through R_2.

b) In the book I_{SC} flows into the output. $I_{SC} = (-V_{AA}/R_2) = (-1\text{V}/2\text{k}\Omega) = -0.5$ mA.

c) $I_N = -I_{SC} = 0.5\text{mA}$. $R_N = R_{TH} = -(V_{OC}/I_{SC}) = -(1\text{V}/(-0.5\text{mA})) = 2\text{k}\Omega$.

d) $V_{SS} = I_{SS} \times R_1 + V_{AA} = 1\text{mA} \times 1\text{k}\Omega + 1\text{V} = 2\text{V}$.

e) $I_{AA} = I_{SS}$ - Current through $R_2 = 1\text{mA} - V_{AA}/R_2$
$= 1\text{mA} - 1\text{V}/2\text{k}\Omega = 0.5$ mA.

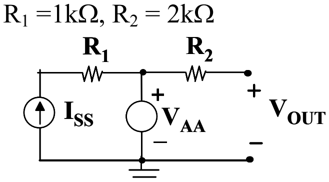


Fig. P3.4

3.5 Nonlinear Load and Power. Use a graphical method to find the solution for the following loads when attached to V_{OUT} in Fig. P3.3. For a) The answer is around 0.9V and 0.225 mA with 0.20 mW into the load. For b) it is about 0.7V, 0.4mA and 0.28mW. For c) it is at about 1.35V, -0.2mA and 0.3mW.