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EECS 42 – Introduction to Electronics for Computer Science

Spring 2003, Prof. A. R. Neureuther
Dept. EECS, 510 Cory neureuth@eecs.berkeley.edu 642-4590
UC Berkeley Office Hours (Tentative M, Tu, W, (Th), F 11
Course Web Site http://www-inst.eecs.berkeley.edu/~ee42/

Solution to Problem Set # 4 (by Farinaz Koushanfar)

4.1 Sketch/Trend. (Using C = 1pF).

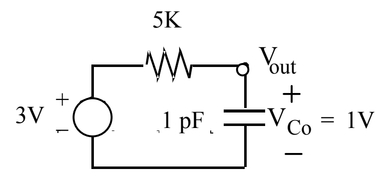
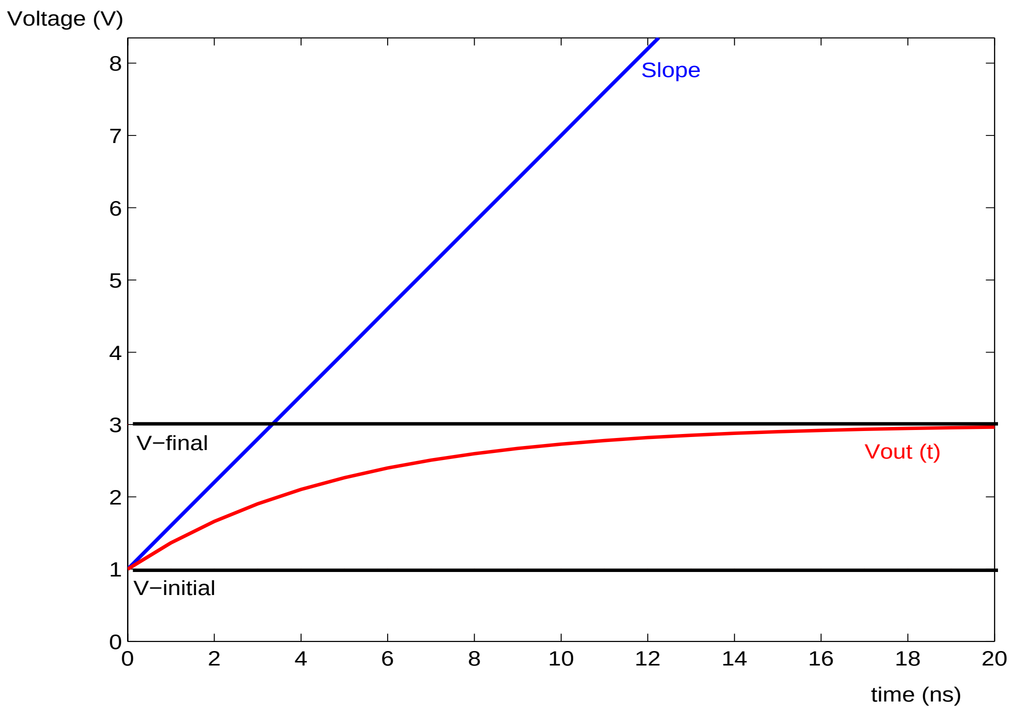


Fig. P4.1

a) As ‘t’ goes to infinity the capacitor voltage stops changing and the current goes to zero. Without current there is no voltage on the 5k resistor and $V_{out} = 3V$.
b) RC = (1pF)(5kΩ) = 5 ns.
c) The initial slope $dV/dt = (1/C)\,(V_{FINAL}-V_{INITIAL})/R = 0.6V/ns$.
d) {Show horizontal line at 0 and at 3V, line from 0 to 3V at 5 ns.}
e) refer to the graph below:



f) The slope doubles when C is cut in Half or $(V_{FINAL}-V_{INITIAL})$ doubles or R is cut in half.

4.2 General Exponential Form.

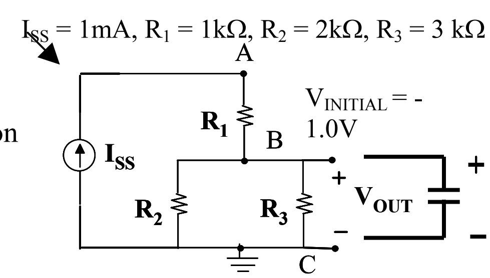


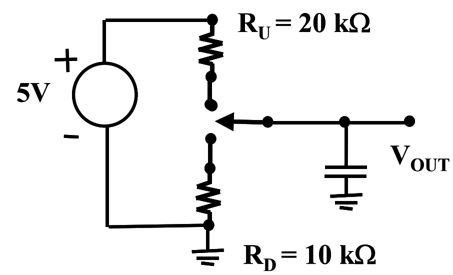
Fig. P4.3

a) $I_R = (3\text{ V} - V_0(t))/R$.
b) $I_C = C\, dV_0/dt$
c) $C\, dV_0/dt = (3\text{ V} - V_0(t))/R$
d) $C(1/\tau)B\, e^{-(t/\tau)} = (3\text{ V} - A - B\, e^{-(t/\tau)})/R$
e) $0 = \{(3\text{ V}-A)/R\} + \{[-B(C/\tau) - B/R]\}\,(e^{-(t/\tau)})$ Since this equation holds for t >0 both the constant and the exponential term coefficients must be individually zero. A = 3V and τ = RC = 1pF×5kΩ = 5 ns.
f) $V_0(0) = 0 \Rightarrow B = -A = -3V$

4.3 Nonzero levels and resistors. (Using C = 1 pF)

a) As t goes to infinity, $I_C = 0$, thus $V_0 = I_{ss}(R_2||R_3) = 1mA \times (1.2k\Omega)$ $= 1.2V$
b) Setting $I_{SS} = 0$ leaves R1 without current so $R_{TH} = (R_2||R_3) = 1.2k\Omega$
c) At t =0, $I_{OUT} = Iss - V_0/R3 - V_0/R2 = 1\ mA + 0.5mA + 0.33mA = 1.83mA$
$dV_{OUT}/dt = (1/C) \times I = (1/pF)(1.83mA) = 1.83\ V/ns$
d) a) => A = 1.2V, b) => t =RC = 1.2kΩ × 1 pF = 1.83 ns, $V_0(0) = -1$ => B = -2.2V.

4.4 Pulse shape. (Using C = 0.1 pF)



a) With switch at R_D, $V_{OUT}(t)$ goes to zero as t goes to infinity.
b) $\tau = R_DC = 10k\Omega \times 0.1\ pF = 1ns$.
$V_{OUT}(t) = 5\ e^{-(t/1ns)}$ V for t >0.
c) To decay to 50%, $e^{-(t/1ns)} = 0.5$. Taking the ln( ) of both sides gives, t =2ns, ln(2) = 0.69×(1ns) = 0.69ns.
d) $V_{OUT}(t = 1.5\ ns) = 5\ e^{-(1.5ns/1ns)} = 5\ e^{-1.5} = 1.12V$.
e) When the switch is up again $\tau = R_UC = 20k\Omega \times 0.1\ pF = 2ns$
$V_{OUT}(t) = 5V - 3.88V\ e^{-((t-1.5ns)/2ns)}$ for t > 1.5 ns.
[For fun $5V - 3.88V\ e^{-((t-1.5ns)/2ns)} = 4V$ => $3.88\ e^{-((t-1.5ns)/2ns)} = 1$ => ((t-1.5ns)/2ns) = ln(3.88), (t-1.5ns) = (1.36)(2ns) = 2.71ns => t = 1.5 ns + 2.71 ns = 4.21 ns.