EEC HW4 2021-16988 Jaewan Park

Exercise 10.11

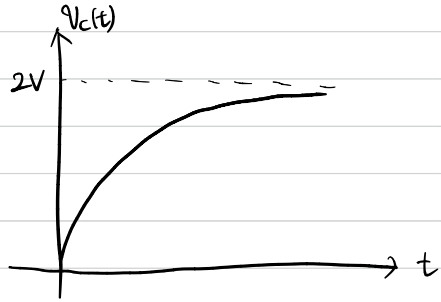
$R_{TH} = R_1 // R_2 = \frac{2}{3}\,k\Omega$

$V_{TH} = V_S \times \frac{R_2}{R_1+R_2} = \begin{cases} 0V & (t<0) \\ 2V & (t>0) \end{cases}$

$\Rightarrow v_c(0) = 0V,\ v_c(\infty) = 2V$

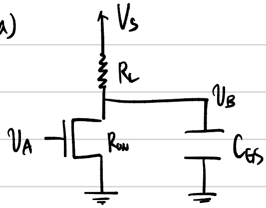
$\therefore v_c(t) = 2 + (0-2)e^{-t/\tau}\quad (\tau = R_{TH} \cdot C = \frac{20}{3}\,ms)$

$= 2 - 2e^{-\frac{3}{20}t}$



Problem 10.1

(a)



① Rise Time

$v_B(0-) = V_S \cdot \frac{R_{ON}}{R_L + R_{ON}} = v_B(0+)$ ($\because$ continuous), $v_B(\infty) = V_S$.

$\therefore v_B(t) = V_S + \left(V_S \cdot \frac{R_{ON}}{R_L+R_{ON}} - V_S\right)e^{-t/\tau_r}\quad (\tau_r = R_L \cdot C_{GS})$

$= V_S - V_S \cdot \frac{R_L}{R_L+R_{ON}}e^{-t/\tau_r}$

$v_B(t_r) = V_H \Rightarrow t_r = R_L C_{GS} \ln \frac{V_S R_L}{(V_S - V_H)(R_L + R_{ON})}$

② Fall Time.

$v_B(0-) = V_S = v_B(0+),\ v_B(\infty) = V_S \cdot \frac{R_{ON}}{R_L+R_{ON}}$

$\therefore v_B(t) = V_S \cdot \frac{R_{ON}}{R_L+R_{ON}} + \left(V_S - V_S \frac{R_{ON}}{R_L+R_{ON}}\right)e^{-t/\tau_f}\quad \left(\tau_f = R_{TH} \cdot C_{GS} = \frac{R_L R_{ON} C_{GS}}{R_L+R_{ON}}\right)$

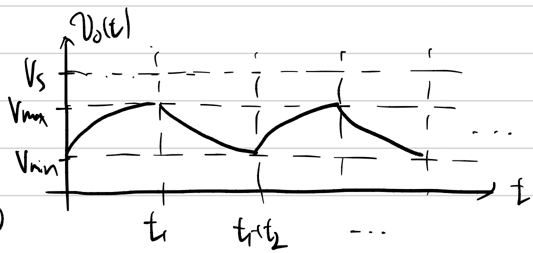
$= V_S \frac{R_{ON}}{R_L+R_{ON}} + V_S \frac{R_L}{R_L+R_{ON}}e^{-t/\tau_f}$

$v_B(t_f) = V_L \Rightarrow t_f = \frac{R_L R_{ON} C_{GS}}{R_L+R_{ON}} \ln \frac{V_S R_L}{V_L(R_L+R_{ON}) - V_S R_{ON}}$

(b) $t_r \simeq 8.2ns,\ t_f \simeq 1.9ns$

$\therefore$ propagation delay $= 8.2ns$

Problem 10.12



$0 \le t \le t_1:\ v_o(t) = V_S + (V_{min} - V_S)e^{-t/RC}$

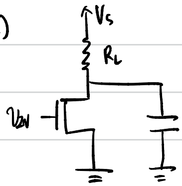
$t_1 \le t \le t_1+t_2:\ v_o(t) = 0 + (V_{max} - 0)e^{-(t-t_1)/RC}$

Average voltage: $V_S = \frac{V}{2} +$ (square wave between $\frac{V}{2}, -\frac{V}{2}$)

$\Rightarrow$ Average $v_o = \frac{V}{2}$

Exercise 11.1

(a)



When $v_{IN}=0$, $P_{steady-state}=0$

(b) When $v_{IN}=1$, $P_{steady-state} = V_S \cdot i_D = V_S \cdot \frac{V_S}{R_L+R_{ON}} = \frac{V_S^2}{R_L+R_{ON}}$

(c) $P_{static} = \frac{V_S^2}{2(R_L+R_{ON})}$

$P_{dynamic} = C_L f \cdot \left(\frac{R_L V_S}{R_L+R_{ON}}\right)^2 = \frac{C_L}{2T} \cdot \left(\frac{R_L V_S}{R_L+R_{ON}}\right)^2$

(d) (i) $\times \frac{1}{2}$

(ii) $\times \frac{1}{4}$

(iii) $\times \frac{1}{2}$

(e) For $V_{OL}^* \le V_{OL}$, $V_S \cdot \frac{R_{ON}}{R_L+R_{ON}} \le V_L$, $R_L \ge R_{ON}\left(\frac{V_S}{V_L}-1\right)$

$\bar{P} = P_{static} + P_{dynamic}$, and $P_{static} \gg P_{dynamic}$, so

$R_L \uparrow \iff \bar{P} \downarrow$.

$\therefore$ We should increase R_L as much as possible, satisfying the static discipline

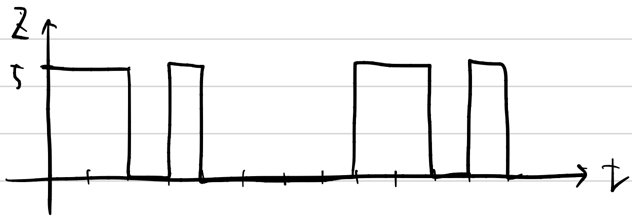
No upper limit exists, $\therefore R_L = \infty$

Problem 11.1

(a) The truth table is as the following. $(Z = A\bar{B})$

A	B	Z
0	0	0
0	1	0
1	0	1
1	1	0

$\Rightarrow$



(b) $P_{static} = \begin{cases} \frac{V_s^2}{R_L} & (0 \le t \le T_1) \\ \frac{2V_s^2}{R_L} & (T_1 \le t \le T_2) \\ \frac{V_s^2}{R_L} & (T_2 \le t \le T_3) \\ \frac{V_s^2}{R_L} & (T_3 \le t \le T_4) \end{cases}$

$$\therefore \overline{P_{static}} = \frac{T_1}{T_4} \cdot \frac{V_s^2}{R_L} + \frac{T_2 - T_1}{T_4} \cdot \frac{2V_s^2}{R_L} + \frac{T_3 - T_2}{T_4} \cdot \frac{V_s^2}{R_L} + \frac{T_4 - T_3}{T_4} \cdot \frac{V_s^2}{R_L}$$

$$= \frac{T_4 + T_2 - T_1}{T_4} \cdot \frac{V_s^2}{R_L}$$

(c) $C_G, C_L \Rightarrow$ once, twice charge & discharge each

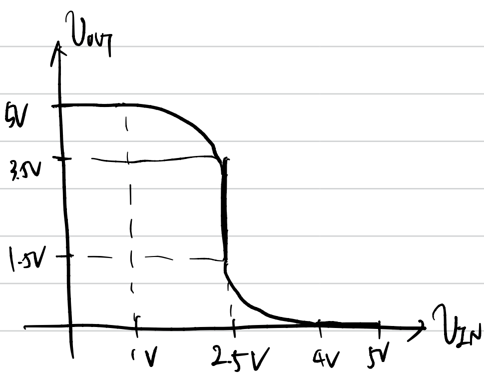
$$\therefore \overline{P_{dynamic}} = \frac{C_G V_s^2}{T_4} + \frac{2C_L V_s^2}{T_4}$$

$$= \frac{(C_G + 2C_L)V_s^2}{T_4}$$

(d) $\overline{P_{static}} = 2.9\,mW$

$\overline{P_{dynamic}} = 87.5\,nW$

(c)



Previous Exam

(a) $P_{dynamic} = C \cdot \frac{f}{2} \cdot V_D^2 = 1.25W$

(b). Both saturated

$\Rightarrow i_{DN} = i_{DP}, \quad 0.1(V_{IN} - 1)^2 = 0.1(5 - V_{IN} - 1)^2$

$\therefore V_{IN} = 2.5V$

For saturation, we have

$V_{IN} \ge V_{TN} \quad V_{IN} - V_{OUT} < V_{TN}, \quad V_{IN} - 5 \le V_{TP}, \quad V_{IN} - V_{OUT} > V_{TP}$

$\therefore 1.5V < V_{OUT} < 3.5V$ (when $V_{IN} = 2.5V$)