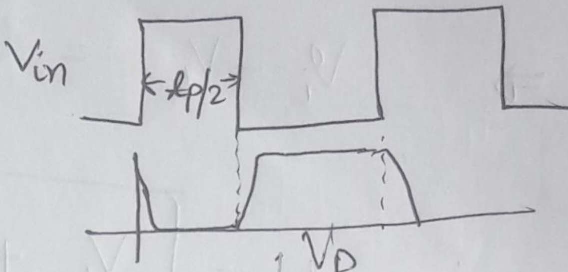
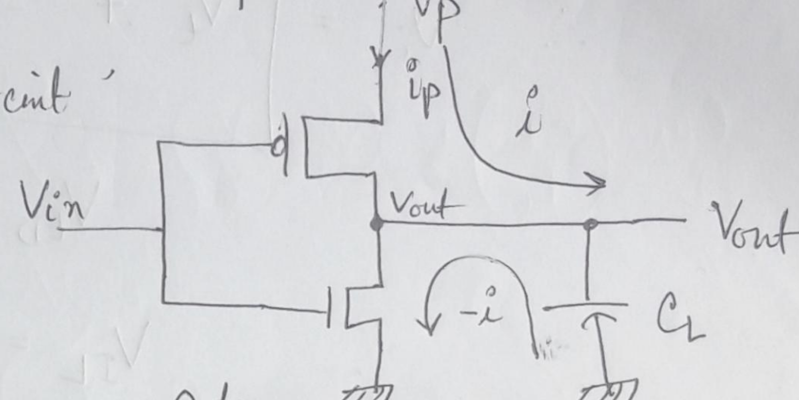
Static Power Dissipation

$$P_s = \sum_{1}^{n} \left(\text{leakage current} \times \text{supply voltage}\right)$$



Dynamic Power Dissipation

During 2-3, it is short circuit
Otherwise, P_d (dynamic)



$$P_d = \frac{1}{t_p}\int_0^{t_p/2} i_n(t)\, V_0\, dt + \frac{1}{t_p}\int_{t_p/2}^{t_p} i_p(t)\left(V_p - V_0\right) dt$$

$$\boxed{i_n(t) = C_L \frac{dV_0}{dt}}$$

$$\cancel{\frac{1}{t_p}\int -i\, V_0\, dt} = \frac{C_L}{t_p}\left[\int_{V_p}^{0} -V_0\, dV_0 + \int_0^{V_p} \left(V_p - V_0\right) dV_0\right]$$

$$= \frac{C_L}{t_p} \int_0^{V_p} V_0\, dV_0 + \int_0^{V_p} \left(V_p - V_0\right) dV_0$$

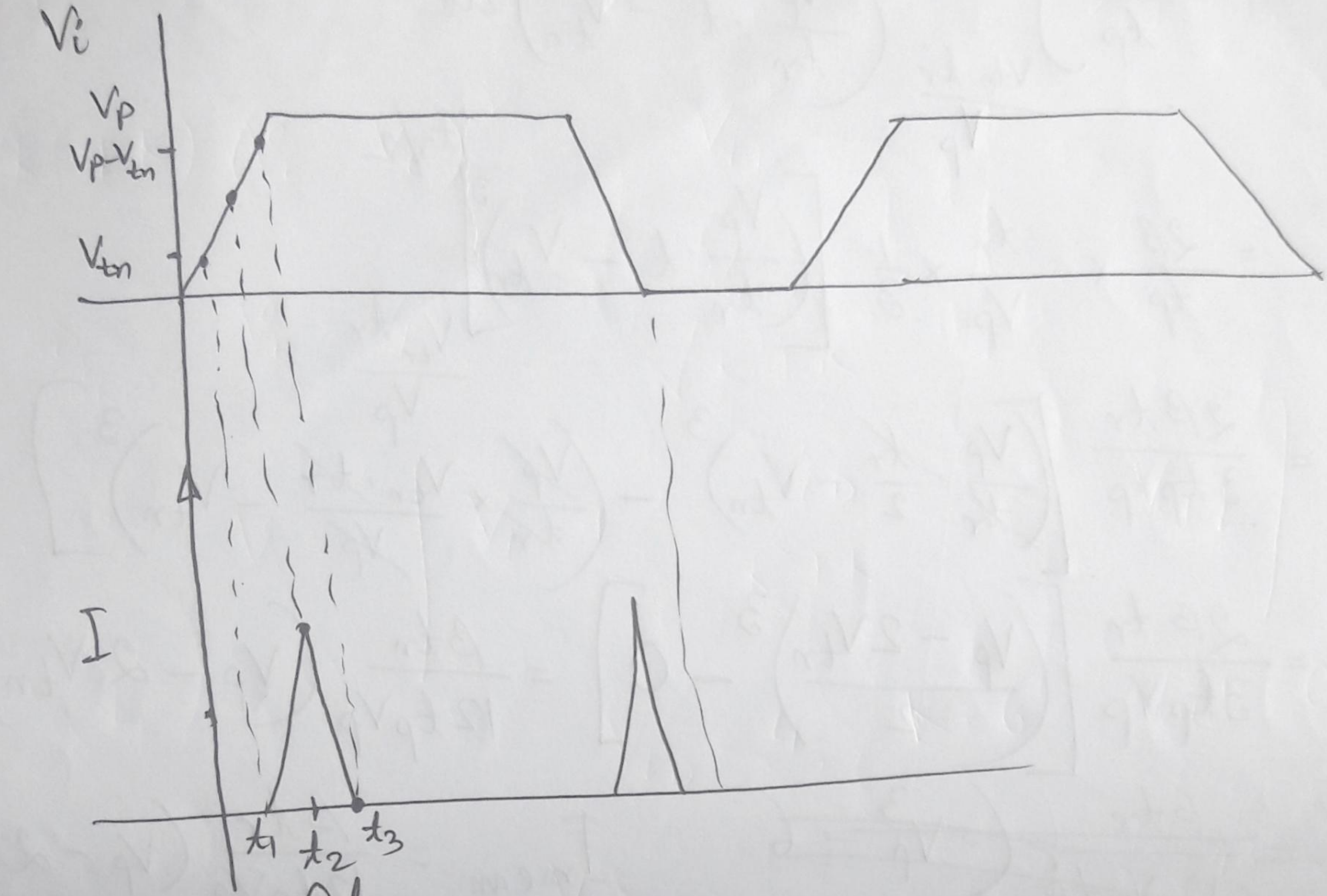
$$= \frac{C_L}{t_p} \int_0^{V_p} \left(\cancel{V_0} + V_p - \cancel{V_0}\right) dV_0$$

$$= \frac{V_p C_L}{t_p} \int_0^{V_p} 1 \cdot dV_0 = \frac{V_p^2 C_L}{t_p}$$

$$P_d = \frac{C_L V_p^2}{t_p} = f_p C_L V_p^2$$

$$\therefore P_d \propto f_p,\ C_L$$

Short Ckt Power dissipation



$$I_{mean} = \frac{1}{t_p}\int_0^{t_p} I(t)\,dt$$

$$= \frac{2}{t_p}\int_{t_1}^{t_3} I(t)\,dt = \frac{4}{t_p}\int_{t_1}^{t_2} I(t)\,dt$$

$$= \frac{4}{t_p}\left(\frac{\epsilon \mu_n}{D}\times\frac{W}{L}\right)\times\frac{1}{2}\int_{t_1}^{t_2}\left(V_{gs}(t) - V_{tn}\right)^2 dt$$

$$= \cancel{\frac{4}{t_p}\times\frac{\beta}{2}}$$

$$\left[V_i(t) = \frac{V_p}{t_r}\times t\right]$$

$$= \frac{4}{t_p}\times\frac{\beta}{2}\int_{\frac{V_{tn}\cdot t_r}{V_p}}^{t_r/2}\left(\frac{V_p}{t_r}\cdot t - V_{tn}\right)^2 dt$$

$t_2 = t_r/2$

when $t = t_1$

$V_i(t) = V_{tn} = \frac{V_p}{t_r}\times t_1$

$\therefore t_1 = \frac{V_{tn}\cdot t_r}{V_p}$

$$= \frac{2\beta}{t_p} \int_{\frac{V_{tn} t_r}{V_p}}^{t_r/2} \left(\frac{V_p}{t_r} \cdot t - V_{tn} \right)^2 dt$$

$$= \frac{2\beta}{t_p} \times \frac{t_r}{V_p} \times \frac{1}{3} \left[\left(\frac{V_p}{t_r} \cdot t - V_{tn} \right)^3 \right]_{\frac{V_{tn} t_r}{V_p}}^{t_r/2}$$

$$= \frac{2\beta t_r}{3 t_p V_p} \left[\left(\frac{V_p}{\cancel{t_r}} \cdot \frac{\cancel{t_r}}{2} - V_{tn} \right)^3 - \left(\frac{\cancel{V_p}}{\cancel{t_r}} \times \frac{V_{tn} \cdot \cancel{t_r}}{\cancel{V_p}} - V_{tn} \right)^3 \right]$$

$$= \frac{2\beta t_r}{3 t_p V_p} \left[\left(\frac{V_p - 2V_{tn}}{2} \right)^3 - 0 \right] = \frac{\beta t_r}{12 t_p V_p} \left(V_p - 2 V_{tn} \right)^3$$

$$= \cancel{\frac{\beta t_r}{12 V_p t_p} \left(V_p^3 - 6 \right.}$$

$$I_{mean} = \frac{\beta t_r}{12 t_p V_p} \left(V_p - 2 V_{tn} \right)^3$$

$$P_{sc} = V_p \cdot I_{mean}$$

$$\boxed{P_{sc} = \frac{\beta t_r}{12 t_p} \left(V_p - 2 V_{tn} \right)^3}$$

$$P_{sc} \propto \beta, t_r$$