Note Title 10/14/2014

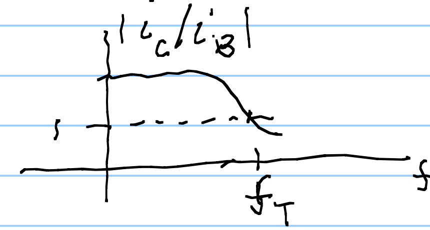
EE303H
10/14/14

CMOS inverter p. 1089 fig 13.17

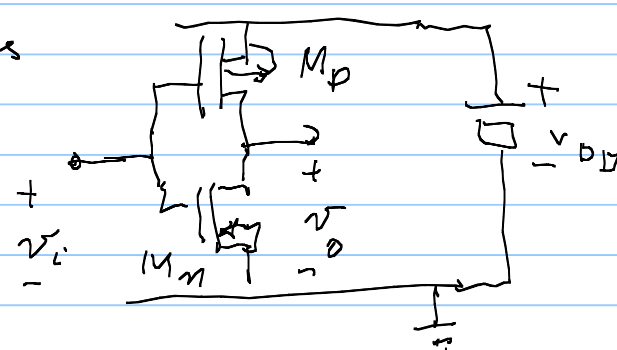
Latch p. 1205

BJT transition frequency, p. 710 ⇒ i_{sc} gain = 1

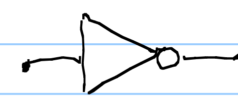
eq. 9.43 $\quad f_T = \dfrac{g_m}{2\pi(C_\mu + C_\pi)}$.

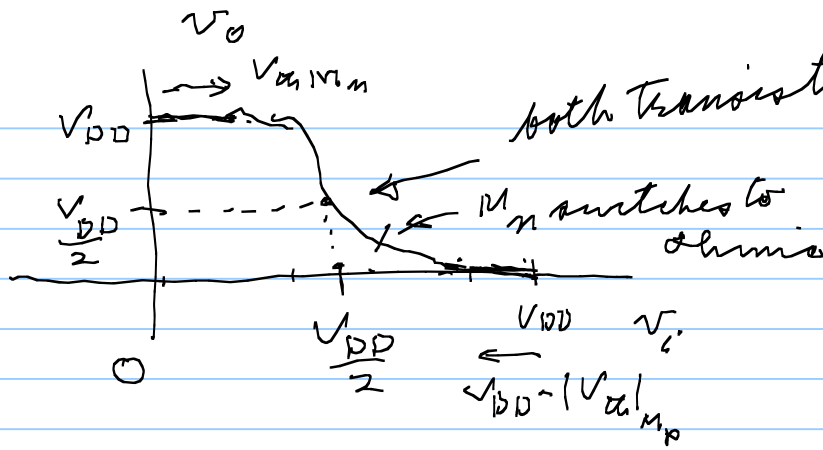


CMOS inverter

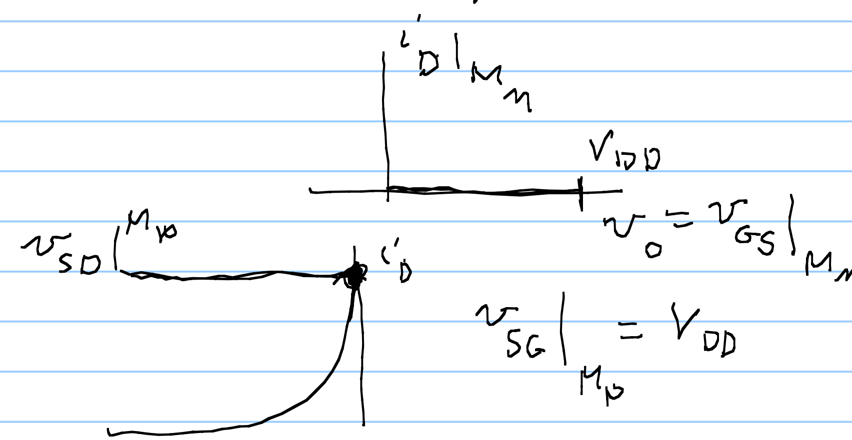


⇒





@ $v_i = 0$, $v_{GS}|_{M_n} = 0$



when both in saturation, @ $v_i = v_O$
$= V_{DD}/2$

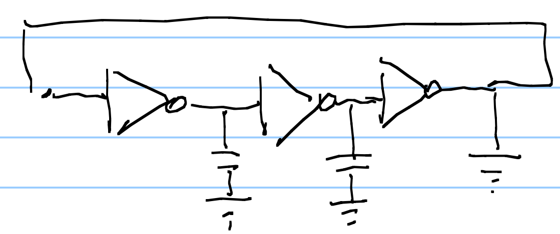
$i_{D_n} = -i_{D_p}$ if $|v_{BS}|$ turns transistor bulk diodes off
(does in standard connection)

$$i_{D_n} = \frac{KP_n}{2}\left(\frac{W}{L}\right)_n \left(\frac{V_{DD}}{2} - V_{TO_n}\right)^2 \left(1 + \lambda_n \frac{V_{DD}}{2}\right)$$

$$= \frac{KP_p}{2}\left(\frac{W}{L}\right)_p \left(\frac{V_{DD}}{2} - |V_{TO_p}|\right)^2 \left(1 + \lambda_p \frac{V_{DD}}{2}\right)$$

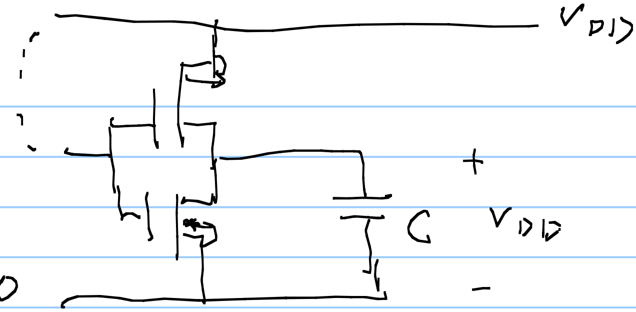
allows choice of $(W/L)_p$ for fixed everything else.

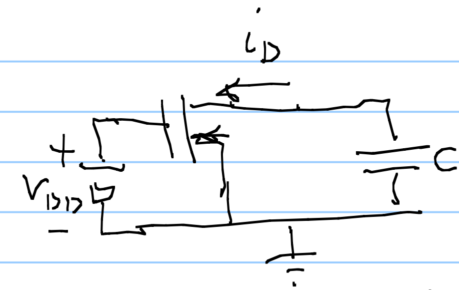
Ring oscillator



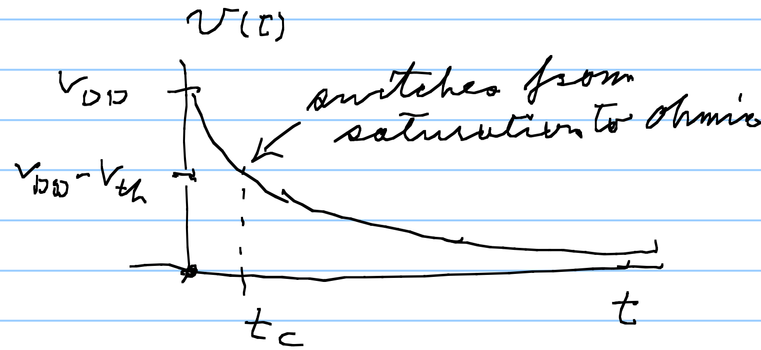
p. 1100, Fig 13.22 discharging

at $t=0$ → $v_i = V_{DD}$ switched from $v_i = 0$





v ; $v(0) = V_{DD}$



$$-C\frac{dv}{dt} = i_D(v) = \begin{cases} 0 \text{ if } V_{GS}=0 \\ \text{saturation value if } v > V_{DD}-V_{th} \\ \text{ohmic value if } v < V_{DD}-V_{th} \end{cases}$$

square laws

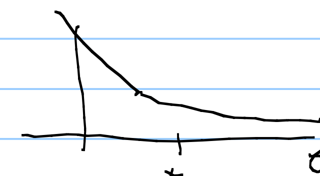
⇒ nonlinear ODE

for $0 \leq t \leq t_{change} = t_c$ = time to switch from saturation

$$-C\frac{dv}{dt} = k(V_{DD} - V_{TO})^2 \quad ; \quad v(0) = V_{DD}$$

$$v = -\frac{k}{C}\int_0^t (V_{DD}-V_{TO})^2\, d\tau + v(0)$$

$$= V_{DD} - \frac{k}{C}(V_{DD}-V_{TO})^2 \cdot t$$



$$-t_c = \frac{(V_{DD}-V_{TO}) - V_{DD}}{\frac{k}{C}(V_{DD}-V_{TO})^2} = \frac{-V_{TO}\times C}{k(V_{DD}-V_{TO})^2}$$

then switch to

$$-C\frac{dv}{dt} = k\left[2(V_{DD}-V_{TO})v - v^2\right] \quad ; \quad v(t_c) = V_{DD}-V_{TO}, \quad t_c < t < \infty$$

$$\frac{dv}{dt} - \frac{k}{C}v^2 + \frac{2k}{C}(V_{DD}-V_{TO})v = 0 \qquad \text{a Riccati equation}$$

$$\frac{dv}{v^2 - 2(V_{DD}-V_{TO})v} = \frac{k}{C} \cdot dt \Rightarrow \int_{v(t_c)}^{v(t)} \frac{dx}{x(x - 2(V_{DD}-V_{TO}))} = \int_{t_c}^{t} \frac{k}{C}\, d\tau$$

partial fraction expansion of , $a = 2(V_{DD} - V_{TO})$

$$\frac{1}{x(x-a)} = \frac{k_0}{x} + \frac{k_1}{x-a} = \qquad k_0 = \left.\frac{1}{x-a}\right|_{x=0} = -1/a$$

$$= \frac{-1/a}{x} + \frac{1/a}{x-a} \qquad k_1 = \left.\frac{1}{x}\right|_{x=a} = 1/a$$

$$\int_{v(t_c)}^{v(t)} \left[\frac{-1/a}{x}\, dx + \frac{1/a}{x-a}\, dx \right] = -\frac{1}{a} \ln x \Big|_{v(t_c)}^{v(t)} + \frac{1}{a} \ln(x-a) \Big|_{v(t_c)}^{v(t)}$$

$$= \frac{1}{a}\left[-\ln v(t) + \ln v(t_c) + \ln(v(t)-a) - \ln(v(t_c)-a) \right]$$

$$= 1/a \left[\ln\left(v(t_c)/v(t) \right) + \ln\left(\frac{v(t)-a}{v(t_c)-a} \right) \right]$$

$$= \frac{1}{a} \ln \left[\frac{v(t_e) \times (v(t) - a)}{v(t) \times (v(t_e) - a)} \right] = \frac{k}{c}(t - t_e)$$

$\Rightarrow$ take $e^{\ln x} = x$ $\Rightarrow$

$$\frac{v(t_e)(v(t) - a)}{v(t) \times (v(t_e) - a)} = e^{a\frac{k}{c}(t - t_e)}$$

$$\Rightarrow \quad v(t_e) v(t) = a \cdot v(t_e) + v(t)[v(t_e) - a] e^{\frac{ak}{c}(t - t_e)}$$

$$v(t) = \frac{a\, v(t_e)}{\left(v(t_e) - [v(t_e) - a] e^{\frac{ak}{c}(t - t_e)}\right)}, \quad t_e < t, \quad v(t)\Big|_{t = t_e} = v(t_e)$$

decreases to 0 as $t \to \infty$ somewhat like $e^{-\frac{ak}{c}t}$.