Note Title 3/7/2012

EE303
03/07/12

Exam next period open book, open notes

pages in book summer, p. 66

phase shift oscillator, p. 1345

MOS inverter, p. 1070

CMOS inverter, p. 1089 – 1098

diode, p. 175,

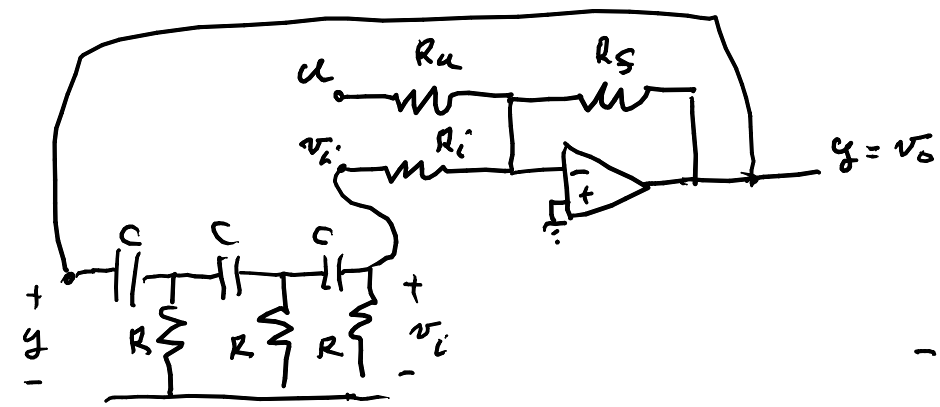
BJT, p. 367, Table 6.2

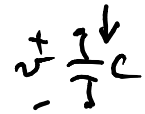
Hybrid-π, BJT, p. 708

MOS, p. 290, Table 7.A.3 = p. 558

Table 5.3

& CMOS regions + related topics as CMOS eqs.





$i = C\dfrac{dv}{dt}$

$= C s \cdot v$

$$y = -\frac{R_s}{R_u}\cdot u - \frac{R_s}{R_i} v_i$$

$$\underbrace{-\frac{R_s}{R_u}}_{} = -K_u \qquad -K = -R_s/R_i$$

$$y = -\frac{R_s}{R_u} u - \frac{R_s}{R_i}\cdot T(s)\cdot y \Rightarrow (1 + K\, T(s))\, y = -K_u \cdot u$$

$$y/u = \frac{-K_u}{1 + K\,T(s)} \quad ; \quad T(s) = \frac{(CRs)^3}{(CRs)^3 + 6(CRs)^2 + 5(CRs) + 1}$$

$p = CRs$

$$\frac{y}{u} = \frac{-K_u}{1 + \dfrac{p^3 K}{p^3 + 6p^2 + 5p + 1}} = \frac{-K_u(p^3 + 6p^2 + 5p + 1)}{(1+K)p^3 + 6p^2 + 5p + 1}$$

$$((1+K)p^3 + 6p^2 + 5p + 1)\, y = -K_u(p^3 + 6p^2 + 5p + 1)\, u$$

oscillator has $u = 0$ need $y(0)$, $y'(0)$, $y''(0)$

desire $P(p) = (1+K)p^3 + 6p^2 + 5p + 1$, to satisfy $P(p) = 0$ ~~so~~

$P(p)\,y = 0$

desire $p_0 = j\omega_0$

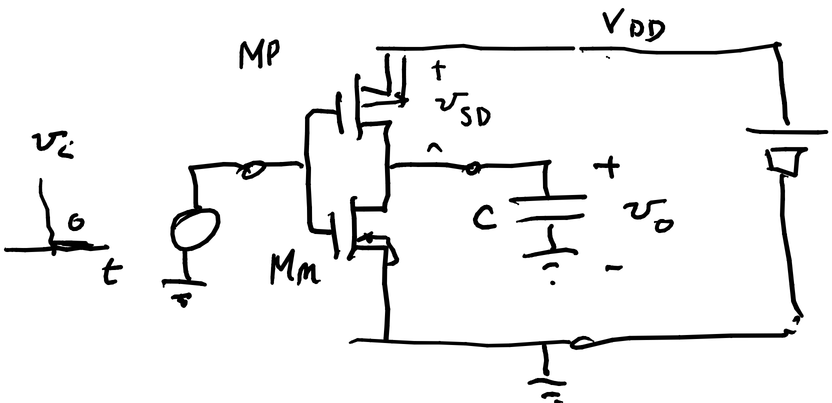
$$-j\omega^3(1+K) - 6\omega^2 + 5j\omega + 1 = 0 \Rightarrow -6\omega^2 + 1 = 0$$
$$\& \quad -\omega^2(1+K) + 5 = 0$$

$$\omega_0^2 = 1/6, \quad \frac{1}{6}(1+K) = 5 \cong 30 = 1+K \Rightarrow K = 29$$

$$y(t) = c_1 e^{j\sqrt{1/6}\,t} + c_1^* e^{-j\sqrt{1/6}\,t} + c_2 e^{-\sigma_0 t}$$

$$P(p) = (30p^3 + 6p^2 + 5p + 1) = (p^2 + 1/6)(p + \sigma_0)\cdot 30$$
$$= 29p^3 + \dots + \frac{\sigma_0}{6}30 \Rightarrow 1 = \frac{\sigma_0}{6} \times 30 \Rightarrow$$
$$\sigma_0 = 1/5$$

Inverter: CMOS



$v_o(0) = 0$

$v_{SG_p}(0) = V_{DD} \rightarrow$ on all the way

$v_{GS_n}(0) = 0 \Rightarrow$ off

$v_{SD_p}(0) = V_{DD}$

check state of M_p (M_n is off) at $t=0$

$$\underset{V_{DD}}{\underset{\parallel}{v_{SD}}} \text{ vs } \underset{V_{DD}}{\underset{\parallel}{v_{SG}}} - |V_{thp}| \qquad \text{starts out in saturation}$$

$$i_D = C\frac{dv_o}{dt} = \frac{KP_p}{2}\frac{W}{L}(V_{DD} - V_{th})^2 \quad \text{(gives a linear in } t \text{ change)}$$

after awhile, eventually $v_{SD}(t) = v_o(t) < v_{SG} - V_{th} = V_{DD} - V_{th}$

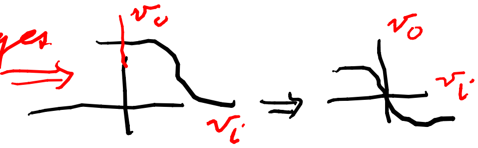
then goes into ohmic range

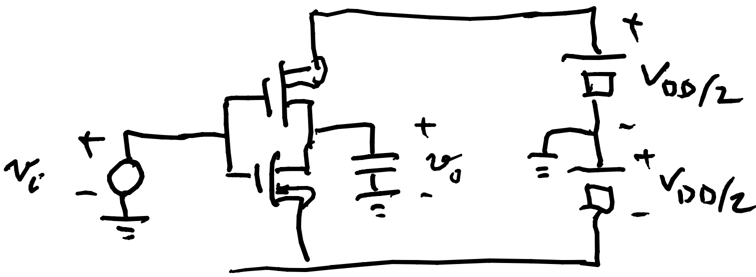
$$i_D = C\frac{dv_o}{dt} = \frac{KP_p}{2}\frac{W}{L}\left(2(V_{DD} - V_{th})v_o - v_o^2\right)$$

a Riccati equation

$\therefore$ a very nonlinear system

look at small signal behavior of this inverter shift axes by bias voltages $\Rightarrow$

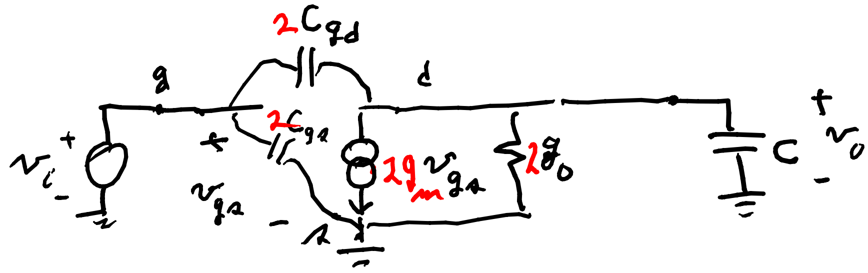


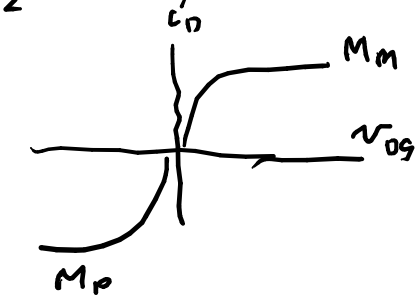


biases the transistors at $V_{GS_n} = -V_{GS_p} = V_{DD}/2$

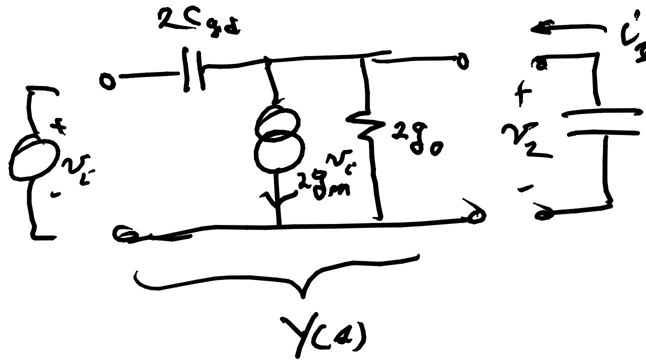
for small signals replace transistors by their linear equivalent circuits

here at the bias point $\underset{\frac{V_{DD}}{2} - V_{th}}{V_{GS} - V_{th}} < \underset{V_{DD}/2}{V_{DS}} \Rightarrow M_n$ in saturation (also M_p " ")





Find v_o/v_i

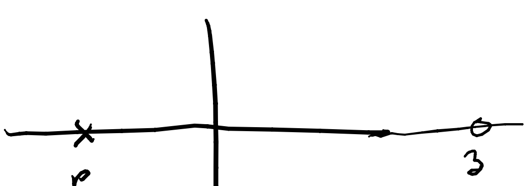


$i_2 = -i_C = -sCv_2$

$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} Y(s) = \begin{bmatrix} 2sC_{gd} & -2C_{gd}s \\ g_m - 2sC_{gd} & 2g_o + 2sC_{gd} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

$$i_2 = (g_m - 2sC_{gd})v_i + (2g_o + 2sC_{gd})v_2 = -sCv_2$$

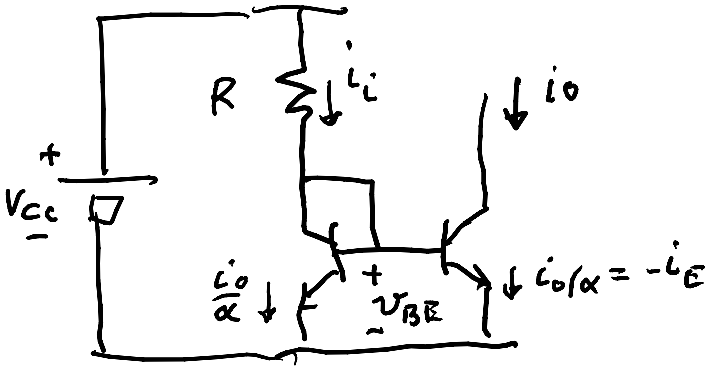
$$\Rightarrow \quad \frac{v_2}{v_i} = \frac{(g_m - 2sC_{gd})}{-s(2C_{gd} + C) - 2g_o} = -\frac{(g_m - 2sC_{gd})}{2g_o + s(2C_{gd} + C)}$$

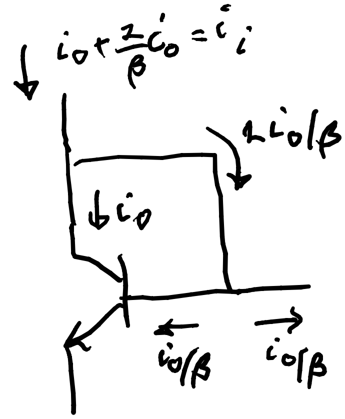


$$\text{pole} = p_1 = -\frac{2g_o}{2C_{gd} + C}$$

$$\text{zero} = z_1 = +\frac{g_m}{2C_{gd}}$$

Biasing for a current source, npn or pnp





$$i R = V_{cc} - v_{BE}$$

$$\frac{i_0}{\alpha} \approx I_S \left(e^{v_{BE}/V_T} \underbrace{-1}_{\text{ignore if } i_0 > 0}\right) = I_S e^{v_{BE}/V_T}$$

$$v_{BE} = V_T \ln\left(\frac{i_0/\alpha}{I_S}\right) \approx V_T \ln\left(i_0/I_S\right)$$

for Q 2n3904, $I_S = 650.5 \times 10^{-18}$

if $i_0 = 6.5\ mA$ then $\frac{i_0}{I_s} = \frac{6.5 \times 10^{-3}}{6.5 \times 10^{-16}} = 10^{+13}$

$$v_{BE} = 26 \times 10^{-3} \times \ln 10^{13} = 26 \times 10^{-3} \times (6 \times \ln 100 + \ln 10)$$