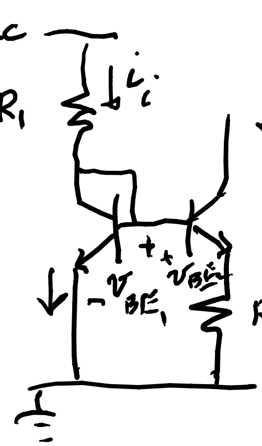
EE 303
03/05/12

Note Title 3/5/2012

Homework due W

Exam next M

p.544 : Widlar current mirror



$\downarrow i_o = \frac{V_T}{R_E} \ln\left(\frac{i_i}{i_o}\right)$

Eq (7.87)

$R_E \cdot \frac{i_o}{\alpha} = v_E$

$i_i = \frac{1}{\alpha} \cdot I_{SE}\, e^{v_{BE_1}/V_T}$

$i_o = \frac{1}{\alpha} I_{SE}\, e^{v_{BE_2}/V_T}$

$v_{BE_1} = V_T \ln\left(\frac{i_i \cdot \alpha}{I_{SE}}\right)$

$v_{BE_2} = V_T \ln\left(\frac{i_o \cdot \alpha}{I_{SE}}\right)$

$$v_{BE_1} = v_{BE_2} + \frac{R_E}{\alpha} i_o$$

$$v_{BE_1} - v_{BE_2} = V_T \ln\left(\frac{i_i}{i_o}\right) = \frac{R_E}{\alpha} i_o \Rightarrow \quad i_o = \frac{\alpha V_T}{R_E} \ln\left(\frac{i_i}{i_o}\right)$$

Without R_E, $R_E = 0$; $V_{cc} = R_1 i_i + 0.7$ with $R_E \neq 0$ can raise i_i for the same i_o

If $R_E = 0$
$0 = \alpha V_T \ln(i_i/i_o) \Rightarrow i_o/i_i = 1$

means R_1 can be smaller as still $i_i = (V_{cc} - 0.7)/R_1$

$\Rightarrow$ better for VLSI where we desire smaller resistors

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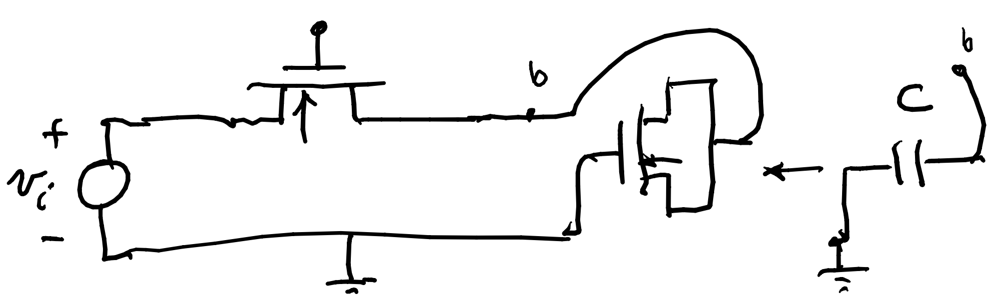
Pass transistor , p. 1155



$= C = C_{gd} + C_{gs}$

$= A_{gate} \cdot C_{ox}$

$\parallel$

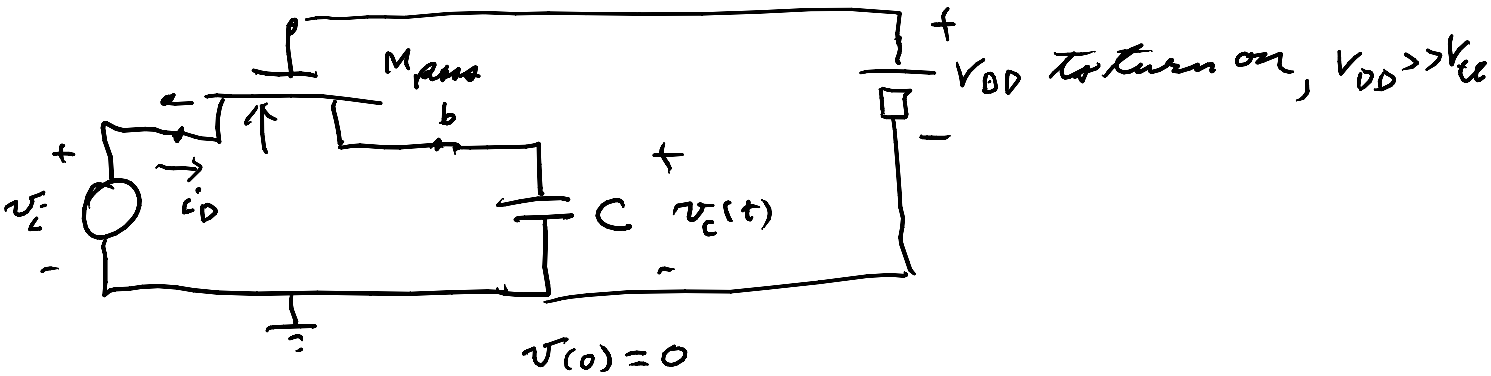
$W \times L \times \frac{\epsilon_{si\ oxide}}{t_{ox}}$

p.236 $\epsilon_{SiO_2} = \epsilon_r \cdot \epsilon_o = 3.9\epsilon_o = 3.45\times10^{-11}\ Fd/m$

if $t_{ox} = 4\,nm \Rightarrow C_{ox} = 8.6\times10^{-3}\ Fd/m^2$

if $W = L = 10\,um \Rightarrow A_{gate} = (10\times10^{-6})^2 = 10^2\times10^{-12} = 10^{-10}\,m^2$

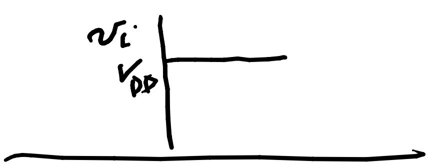
$C_{MOS\ transistor} = 8.6\times10^{-3}\times10^{-10} = 8.6\times10^{-13} = 86\,f\,Fd$



$v(0) = 0$

$v_i(t) = V_{DD}\,1(t)$

$1(t)$: unit step



at $t=0$, $a = D$, $b = S$; $v_{GS} = V_{DD} - v_c = V_{DD} - 0$

$v_{DS} = V_{DD} - 0$ @ $t=0$

if $a = D$, $b = S$

$v_{GS} = V_{DD} - v_c$

$v_{DS} = V_{DD} - v_c \Rightarrow v_{DS} > v_{GS} - V_{th}$

$\Rightarrow M_{pass}$ is in saturation

$$i_D = \beta(v_{GS} - V_{th})^2 = \beta(V_{DD} - v_c - V_{th})^2 = C\frac{dv_c}{dt} = C\frac{d(v_c - V_{DD} + V_{th})}{dt}$$

let $x = v_c - V_{DD} + V_{th} \Rightarrow \beta x^2 = C\frac{dx}{dt}$, $x(0) = -V_{DD} + V_{th}$

$\beta = \frac{KP}{2}\frac{W}{L}$

a Riccati ODE

$$\frac{\beta}{C}dt = \frac{dx}{x^2} \Rightarrow \int_0^t \frac{\beta}{C}d\tau = \int_{x(0)}^{x(t)} \frac{dy}{y^2}$$

$$\frac{\beta}{C}\cdot t = -\frac{1}{y}\Big|_{y=x(0)}^{x(t)} = -\frac{1}{x(t)} + \frac{1}{x(0)} \Rightarrow \frac{1}{x(t)} = \frac{1}{x(0)} - \frac{\beta t}{C}$$

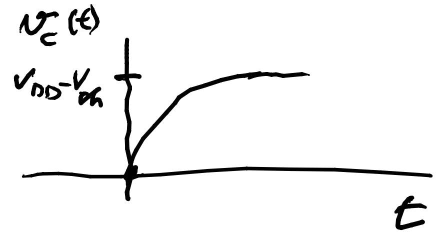
$$x(t) = \frac{1}{\frac{1}{x(0)} - \frac{\beta}{C}t} = \frac{x_0}{1-\frac{\beta}{C}t}$$ is $= x(0) = x_0$ at $t=0$

$t_0 = C/\beta$ = finite escape time

$$v_C(t) = x(t) + V_{DD} - V_{th}$$

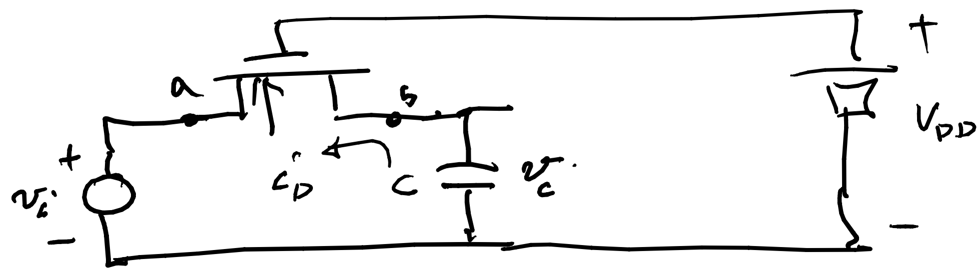
$$= \frac{-V_{DD}+V_{th}}{1-\frac{\beta}{C}t} + V_{DD} - V_{th}$$

as $t \to \infty \Rightarrow V_{DD} - V_{th}$



note has a V_{th} loss

Look at passing from C to a short v_i



$$v_C(0) = V_{DD}$$

$v_i(t) \equiv 0$

here $a = S$, $b = D \Rightarrow v_{GS} = V_{DD}$, $v_{DS} = v_C \le V_{DD}$

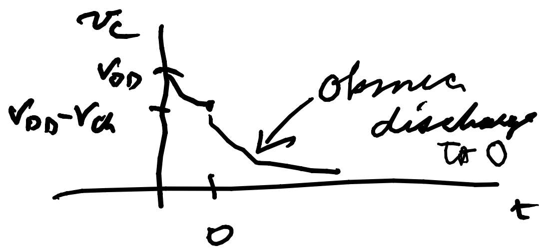
for a small time $v_{GS} - V_{th} = V_{DD} - V_{th} < v_C$ as $v_C(0) = V_{DD}$

starts in sat.

after $v_C \le V_{DD} - V_{th}$ then

$v_{GS} - V_{th} = V_{DD} - V_{th} \ge v_C$

changes to ohmic region



$$-C\frac{dv_C}{dt} = i_D = \beta\left(2(V_{DD}-V_{th})v_C - v_C^2\right) = \beta\left(2(V_{DD}-V_{th}) - v_C\right)v_C$$

a new Ricati eq.

$$-\frac{\beta}{C}dt = \frac{dv_C}{(2(V_{DD}-V_{th})-v_C)v_C} = \frac{dx}{(a-x)x}$$ $a = 2(V_{DD}-V_{th})$, $x = v_C$

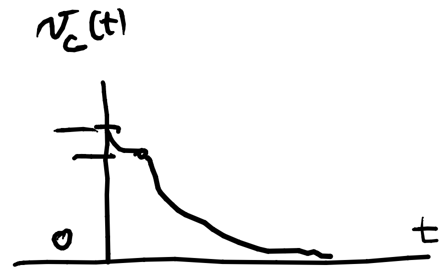
$$= dx\left[\frac{k_0}{x} + \frac{k_a}{x-a}\right]$$ via partial fraction expansion

$k_0 = \frac{x}{(a-x)x}\Big|_{x=0} = 1/a$, $k_a = \frac{(x-a)}{(a-x)x}\Big|_{x=a} = -1/a$

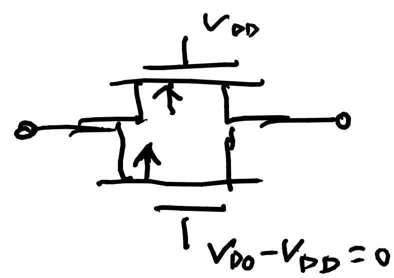
$$-\frac{\beta}{c} t = \int_{x_0}^{x(t)} \frac{dy}{a}\left[\frac{1}{y} + \frac{-1}{y-a}\right] = \frac{1}{a}\left[\ln y - \ln(y-a)\right]\Big|_{x_0}^{x(t)}$$

$$= a \ln \frac{y}{y-a}\Big|_{x_0}^{x(t)}$$

as $t \to \infty$, $\ln(1) \to 0$

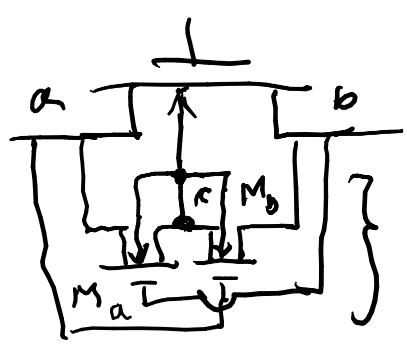


∴ to pass all the way in both directions



here if tie Bulk to one side then passes bulk current when that side is the drain

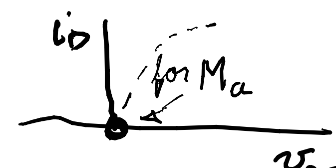
Look for a bulk bias circuit to tie the bulk to the source. Put on something like an inverter



bulk bias circuit

if $v_b > v_c \geq v_a$ then M_b is off as $v_{GS} < V_{th}$

M_a is fully on but with no drain current (as M_b is off)



$\Rightarrow v_c = v_a$

$\Rightarrow$ bulk tied to S of M_{pass}

same result of $v_c = v_b$ if $v_b < v_a$

∴ can pass without bulk current