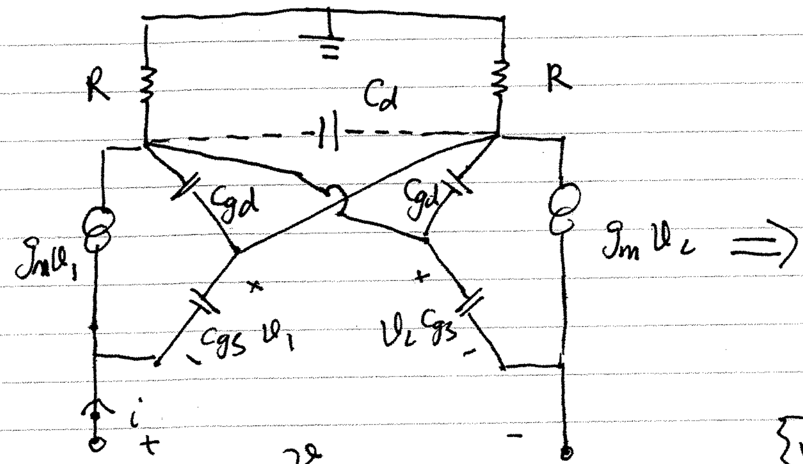
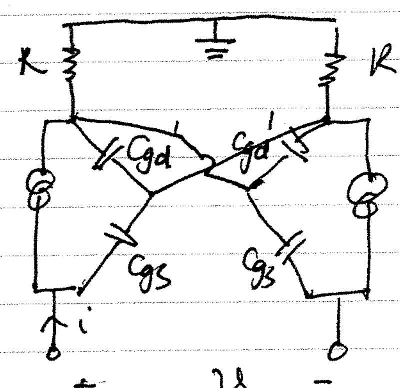
ENEE 610 HW#2 09/27/04

Problem 2: adding capacitor C_d between two transistor Drains





with $C_{gd}' = C_{gd} + \frac{1}{2} C_d$

The two transitors' gate-drain Capacitor C_{gd} are parellel, they are also parallel to the added Capacitor C_d

use result from Lecture (09/15/04)

$$Z(s) = \frac{V}{i} = \frac{2[(1-g_mR) + sR(4C_{gd}+C_{gs})]}{(g_m+sC_{gs})(1+s\cdot 4RC_{gd})}$$

replacing C_{gd} with $C_{gd}' = C_{gd} + \frac{1}{2} C_d$

$$Z(s) = \frac{2[(1-g_mR) + sR(4C_{gd}+2C_d+C_{gs})]}{(g_m+sC_{gs})[1+s\cdot 4R(C_{gd}+\frac{1}{2}C_d)]}$$

For $R=1$, $C_{gd}=C_{gs}=C_d=1$

$$Z(s) = \frac{2[(1-g_m)+7s]}{(g_m+s)(1+6s)} = \frac{16g_m-2}{6g_m+1}\cdot\frac{1}{s+g_m} - \frac{6g_m+1}{3(6g_m+1)}\frac{1}{(s+\frac{1}{6})}$$

∴ Impulse response:

$$V(t) = \left[\frac{16g_m-2}{6g_m+1}\cdot e^{-g_mt} - \frac{6g_m+1}{3(6g_m+1)}\, e^{-t/6}\right] u(t)$$

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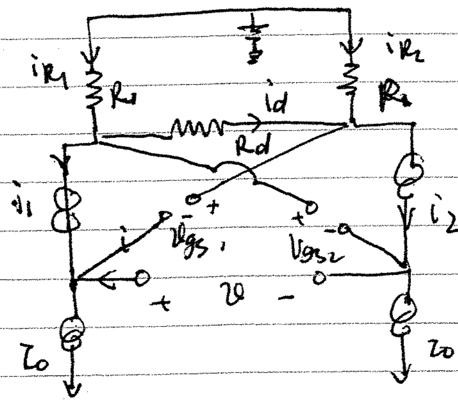
Problem 3.



$$\begin{cases} i_1 = I_0 - i = \beta(V_{gs1} - V_{th})^2 & \text{①} \\ i_2 = I_0 + i = \beta(V_{gs2} - V_{th})^2 & \text{②} \end{cases}$$

$$\Rightarrow \begin{cases} V_{gs1} = V_{th} + \sqrt{\frac{I_0}{\beta}}\left(1 - \frac{i}{I_0}\right)^{\frac{1}{2}} & \cdots \text{③} \\ V_{gs2} = V_{th} + \sqrt{\frac{I_0}{\beta}}\left(1 + \frac{i}{I_0}\right)^{\frac{1}{2}} & \cdots \text{④} \end{cases}$$

$$V_{gs1} - V_{gs2} = -\sqrt{\frac{I_0}{\beta}}\left(\sqrt{1+\frac{i}{I_0}} - \sqrt{1-\frac{i}{I_0}}\right) \quad \cdots \text{⑤}$$

$$g_m = 2\sqrt{\beta I_0}, \quad V_{gs1} - V_{gs2} = -\frac{2I_0}{g_m}\left(\sqrt{1+\frac{i}{I_0}} - \sqrt{1-\frac{i}{I_0}}\right) \cdots \text{⑥}$$

KLV: $v + V_{gs1} + i_d R_d - V_{gs2} = 0 \quad \cdots \text{⑦}$

$$\therefore \quad i_d = -\frac{1}{R_d}\cdot(V_{gs1} - V_{gs2}) - \frac{1}{R_d} v \quad \cdots \text{⑧}$$

KVL: $v + V_{gs1} + i_{R_2} R - i_{R_1} R - V_{gs2} = 0 \cdots \text{⑨}$

$$v + (V_{gs1} - V_{gs2}) + (i_{R_2} - i_{R_1}) R = 0 \quad \cdots \text{⑩}$$

$$\begin{cases} i_{R_1} = i_1 + i_d & \text{⑪} \\ i_{R_2} = i_2 - i_d & \text{⑫} \end{cases} \Rightarrow i_{R_2} - i_{R_1} = -(i_1 - i_2) - 2i_d \cdots \text{⑬}$$

from ① & ② $\Rightarrow i_1 - i_2 = -2i \quad \therefore \quad i_{R_2} - i_{R_1} = 2i - 2i_d \cdots \text{⑭}$

plug ⑧ into ⑭ $i_{R_2} - i_{R_1} = 2i + \frac{2}{R_d}(V_{gs1} - V_{gs2}) + \frac{2}{R_d} v \cdots \text{⑮}$

plug ⑮ in ⑩ solve v in term of $(i\ V_{gs1} - V_{gs2})$

$$v = -(V_{gs1} - V_{gs2}) - \frac{2R}{1 + \frac{2R}{R_d}} i \quad \cdots \text{⑯}$$ plug ⑥ in ⑯

$$\boxed{v = \frac{2I_0}{g_m}\left(\sqrt{1+\frac{i}{I_0}} - \sqrt{1-\frac{i}{I_0}}\right) - \frac{2R}{1+\frac{2R}{R_d}} i \quad \text{⑰}}$$

for small i: $v \approx \left(\frac{2}{g_m} - \frac{2R}{1 + \frac{2R}{R_d}}\right) i$

$R = R_d = 1$, $v = 2\left(\frac{1}{g_m} - \frac{1}{3}\right) i$ for small i.