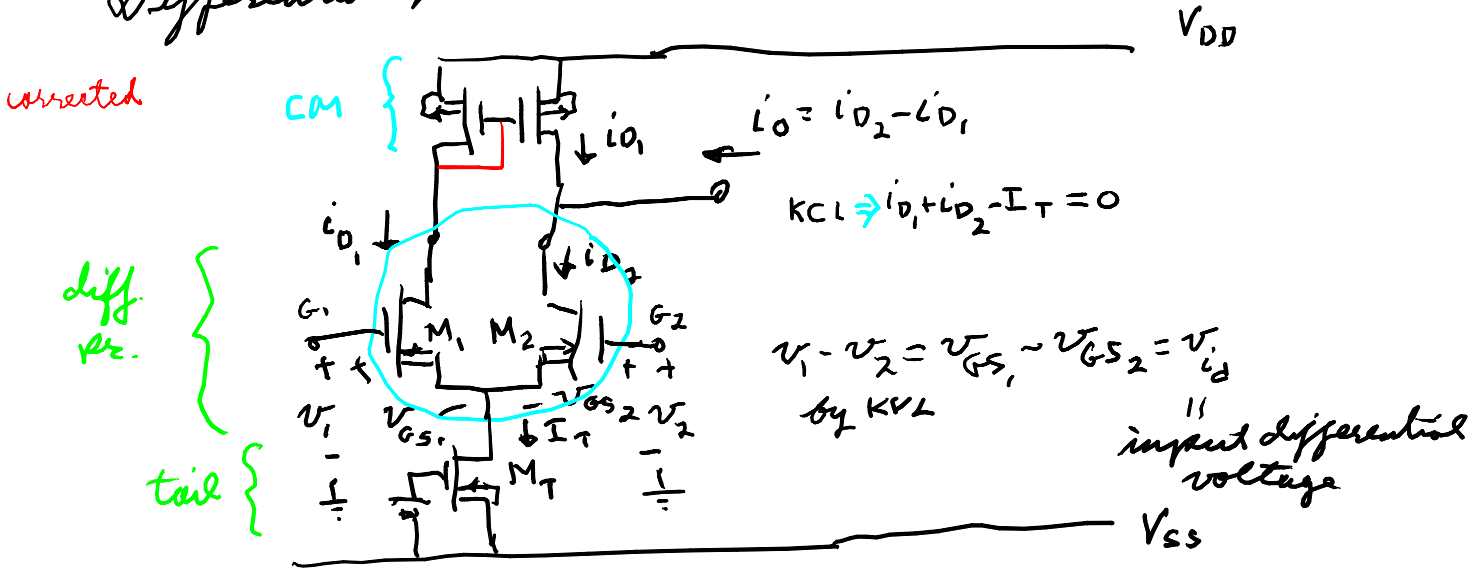
Note Title

EE303H
10/04/11
corrected

10/4/2011

Differential pair



assume $M_1 = M_2$ are in saturation & $\lambda = 0$

$$i_{D_1} = \frac{KP}{2} \cdot \frac{W}{L} (v_{GS_1} - V_{th})^2 = \beta (v_{GS_1} - V_{th})^2$$

both $V_{th_1} = V_{th_2} = V_{th}$

$$i_{D_2} = \frac{KP}{2} \cdot \frac{W}{L} (v_{GS_2} - V_{th})^2 = \beta (v_{GS_2} - V_{th})^2$$

$$+\sqrt{\frac{i_{D_1}}{\beta}} = v_{GS_1} - V_{th} \quad , \quad +\sqrt{\frac{i_{D_2}}{\beta}} = v_{GS_2} - V_{th}$$

$+\sqrt{\ }$ as M_1 & M_2 assumed on in sat

0): $\sqrt{\frac{i_{D_2}}{\beta}} - \sqrt{\frac{i_{D_1}}{\beta}} = v_{id}$

desire i_o vs v_{id}

1): $i_o = i_{D_2} - i_{D_1}$ 2): $I_T = i_{D_1} + i_{D_2}$

2)+1) = 3): $I_T + i_o = 2 I_{D_2}$ 2)−1) = 4): $I_T - i_o = 2 I_{D_1}$

$\sqrt{3)}$ = 5): $\sqrt{\frac{i_{D_2}}{\beta}} = \sqrt{\frac{I_T + i_o}{2\beta}}$ $\sqrt{4)}$ = 6): $\sqrt{\frac{i_{D_1}}{\beta}} = \sqrt{\frac{I_T - i_o}{2\beta}}$

0) = 6) − 5) ⇒ 7): $v_{id} = \sqrt{\frac{I_T + i_o}{2\beta}} - \sqrt{\frac{I_T - i_o}{2\beta}}$

$7)^2$ = 8): $v_{id}^2 = \frac{I_T + i_o}{2\beta} + \frac{I_T - i_o}{2\beta} - 2\sqrt{\frac{I_T^2 - i_o^2}{4\beta^2}} = \frac{I_T}{\beta} - \sqrt{\frac{I_T^2 - i_o^2}{\beta^2}}$

rearrange $\sqrt{\frac{I_T^2 - i_o^2}{\beta}} = \frac{I_T}{\beta} - v_{id}^2$

$8)^2 = 9)$: $\frac{I_T^2 - i_0^2}{\beta^2} = \left(\frac{I_T}{\beta}\right)^2 + v_{id}^4 - 2\frac{I_T}{\beta} v_{id}^2$

rearrange & cancel $(I_T/\beta)^2$

$10)$: $\frac{i_0^2}{\beta^2} = 2\frac{1}{\beta} I_T v_{id}^2 - v_{id}^4$

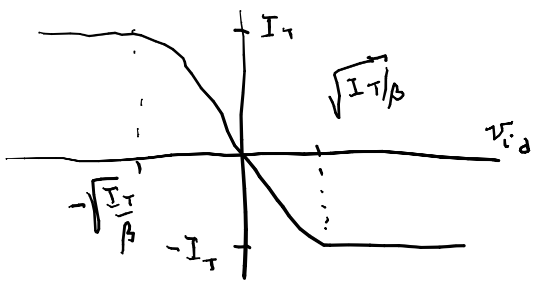
$\sqrt{10)} = 11)$: $i_0 = \pm \beta v_{id} \sqrt{2\frac{I_T}{\beta} - v_{id}^2}$ — when M_1 & M_2 saturated; needs − sign as $i_0 \uparrow$ as $v_1 \uparrow$

i_0 becomes max @ $\frac{di_0}{dv_{id}} = 0$;

$12)$: $\frac{di_0}{dv_{id}} = -\beta \sqrt{2\frac{I_T}{\beta} - v_{id}^2} - \beta v_{id} \cdot \frac{1}{2} \cdot \frac{-2v_{id}}{\sqrt{2\frac{I_T}{\beta} - v_{id}^2}} = \frac{-2I_T + \beta(v_{id}^2 + v_{id}^2)}{\sqrt{2\frac{I_T}{\beta} - v_{id}^2}}$

$= 0 \Rightarrow v_{id}^2 = \frac{I_T}{\beta} \Rightarrow i_0 = \beta\sqrt{\frac{I_T}{\beta}}\sqrt{2\frac{I_T}{\beta} - \frac{I_T}{\beta}} = I_T$

$\therefore$ all current is one of the transistors which turns the other off for $v_{id}^2 > \frac{I_T}{\beta}$



$i_0 = -\beta v_{id}\sqrt{2\frac{I_T}{\beta} - v_{id}^2}$, $v_{id}^2 \le \frac{I_T}{\beta}$

$= +I_T$ for $v_{id} < -I_T/\beta$

$= -I_T$ for $v_{id} > I_T/\beta$