# <u>24 Fall ECEN 704: VLSI Circuit Design</u>

# <u>Design Pre-lab Report</u>

## Lab7: Frequency Response of Inverting Amplifiers

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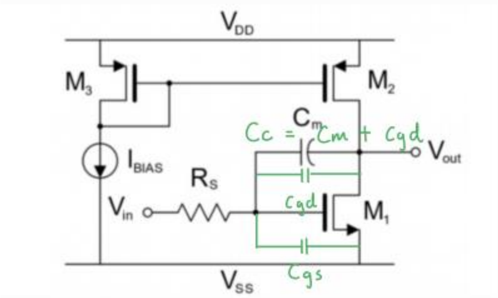
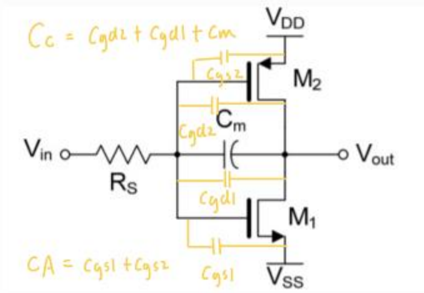
1.

| | gain (M) | Rin | Rout | linearity |
|---|---|---|---|---|
| current mirror load | $-g_{m1} \times (r_{ds1} // r_{ds2})$ medium | $\infty$ same | $r_{ds1} // r_{ds2}$ good | middle |
| digital cmos | $-(g_{m1} + g_{m2}) \times (r_{ds1} // r_{ds2})$ good | $\infty$ " | $r_{ds1} // r_{ds2}$ good | worse |
| self-bias pmos | $-g_{m1} \times (\frac{1}{g_{m2}} // r_{ds1})$ worse | $\infty$ " | $r_{ds1} // \frac{1}{g_{m2}}$ worse | good |
| self-bias cmos | $-g_{m1} \times (r_{ds1} // \frac{1}{g_{m2}})$ worse | $\infty$ " | $r_{ds1} // \frac{1}{g_{m2}}$ worse | midde |

2.



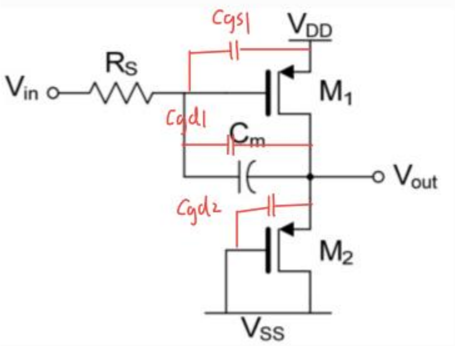



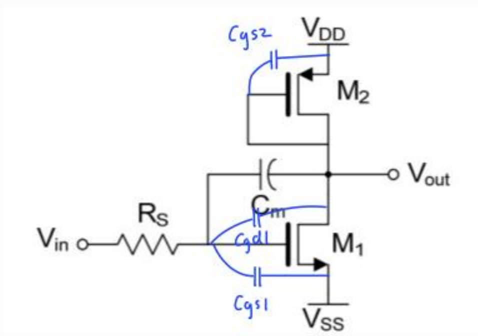

$$R_{out} = R_B // (C_B + \frac{1}{1-M} C_c)$$

$$H(s) = \frac{V_o}{V_i} = \frac{C_A + (1-M) C_c}{R_{in}} \times M \times R_{out}$$

$$R_{in} = R_A + (C_A + (1-M) C_c)$$

| | $R_A$ | $C_A$ | $C_c$ | $R_B$ | $C_B$ |
|---|---|---|---|---|---|
| current mirror load | $R_s$ | $C_{gs1}$ | $C_{gd1} + C_m$ | $r_{o1} // r_{o2}$ | $C_{bd1} + C_{bd2}$ |
| digital cmos | $R_s$ | $C_{gs1} + C_{gs2}$ | $C_{gd1} + C_{gd2} + C_m$ | $r_{o1} // r_{o2}$ | $C_{bd1} + C_{bd2}$ |
| self-bias pmos | $R_s$ | $C_{gs1}$ | $C_{gd1} + C_m$ | $r_{o1} // \frac{1}{g_{m2}}$ | $C_{bd1} + C_{bd2} + C_{gs2}$ |
| self-bias cmos | $R_s$ | $C_{gs1}$ | $C_{gd1} + C_m$ | $r_{o1} // \frac{1}{g_{m2}}$ | $C_{bd1} + C_{bd2} + C_{gs2}$ |



3.

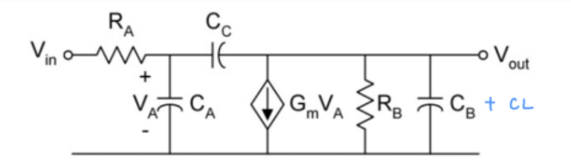
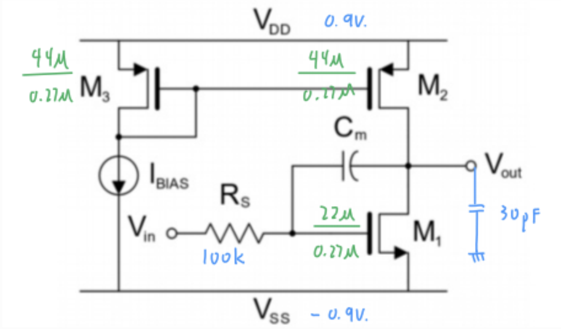



**Figure 7-2:** Generic Inverting Amplifier Small-Signal Model




$$GBW = A_{vo} \times f_{p1} \Rightarrow 1M = 32 \times f_{p1} \qquad \underline{f_{p1} = 31.25k}$$

$$f_{p2} \geq \sqrt{3}\ GBW \qquad \underline{f_{p2} \geq \sqrt{3}\ MHz}$$

$$\omega_{p1} = 2\pi f_{p1} = \frac{-1}{|A_{vo}|\, R_s\, C_m} \Rightarrow 196.3125k = \frac{-1}{32 \times 100k \times C_m} \qquad \underline{C_m = 1.59pF}$$

$$\omega_{p2} = \frac{-G_m}{C_B} = \frac{-g_{m1}}{30pF} \geq 2\pi \times 1M \times \sqrt{3} \qquad \underline{g_{m1} \geq 326\mu}$$

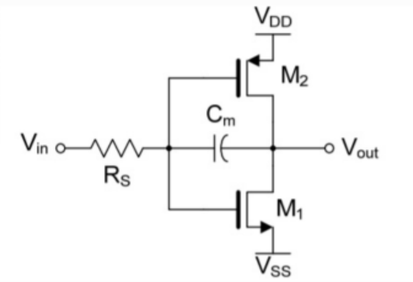
$$A_{vo} = -G_m R_{out} \qquad (\lambda = 0.15)$$

$$= -g_{m1} \times (r_{ds1} \parallel r_{ds2}) = 32 = -g_{m1} \times \frac{1}{2\lambda I_D} = 32$$

$$\underline{I_{bias} = 33.95\mu A} = I_D$$

$$g_{m1} = \sqrt{2 \mu_n C_{ox} \frac{W}{L} I_D} \Rightarrow 10.62\mu = 0.12866 \frac{W}{L} \qquad \frac{W}{L_n} = 82.5 = \frac{22\mu}{0.27\mu}$$

$$\frac{W}{L_p} = \frac{44\mu}{0.27\mu}$$



$GBW = A_{vo} \times f_{p1} \Rightarrow 1M = 32 \times f_{p1}$ $\quad \underline{f_{p1} = 31.25k}$

$f_{p2} \geq \sqrt{3}\ GBW$ $\quad \underline{f_{p2} \geq \sqrt{3}\ MHz}$

$$\omega_{p1} = 2\pi f_{p1} = \frac{-1}{|A_{vo}| R_s C_m} \Rightarrow 196.3125k = \frac{-1}{32 \times 100k \times C_m} \quad \underline{C_m = 1.59pF}$$

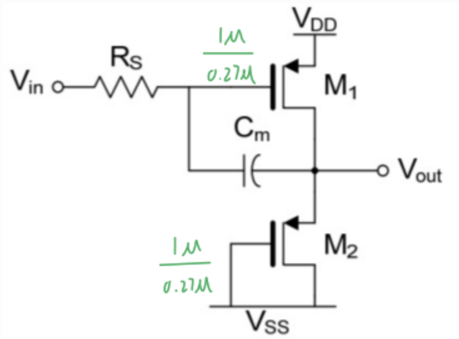
$$\omega_{p2} = \frac{-G_m}{C_B} = \frac{-g_{m1}+g_{m2}}{30pF} \geq 2\pi \times 1M \times \sqrt{3} \quad g_{m1}+g_{m2} \geq 326\mu$$

$$g_{m1} = g_{m2} = 163\mu$$

$$\times 2\left(\frac{k_N\ (\frac{W}{L})_N}{k_p\ (\frac{W}{L})_p}\right)^{\times 2} = 1 \quad I_D \text{ same}$$

$$k_n \left(\frac{W}{L}\right) = \frac{g_{m1}}{V_{DD}-V_T} \quad \left(\frac{W}{L}\right)_n \simeq \frac{1\mu}{0.27\mu} \quad \left(\frac{W}{L}\right)_p = \frac{2\mu}{0.27\mu}$$

3.5



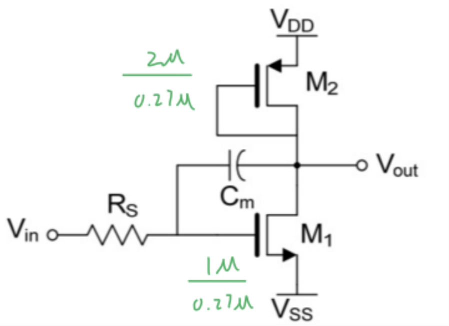

$GBW = A_{vo} \times f_{p1} \Rightarrow 1 \times f_{p1}$ $\quad \underline{f_{p1} = 1MHz}$

$f_{p2} \geq \sqrt{3}\ GBW$ $\quad \underline{f_{p2} \geq \sqrt{3}\ MHz}$

$$\omega_{p1} = 2\pi f_{p1} = \frac{-1}{|A_{vo}| R_s C_m} \Rightarrow 3.14M = \frac{-1}{100k \times C_m} \quad \underline{C_m = 3.18pF}$$

$$f_{p2} = \sqrt{3}\ GBW = \sqrt{3}MHz \times 2\pi = \frac{g_{m1}}{C_B = 30\ pF} \quad g_{m1} = 326\mu = g_{m2}$$

$$\sqrt{2K_p \left(\frac{W}{L}\right)_1 I_D} = \sqrt{2K_p \left(\frac{W}{L}\right)_2 I_D}$$




$GBW = A_{vo} \times f_{p1} \Rightarrow 1 \times f_{p1}$ $\qquad$ $\underline{f_{p1} = 1MHz}$

$f_{p2} \geq \sqrt{3}\ GBW$ $\qquad$ $\underline{f_{p2} \geq \sqrt{3}\ MHz}$

$\omega_{p1} = 2\pi f_{p1} = \dfrac{-1}{|A_{vo}|\, R_s\, C_m} \Rightarrow 3.14M = \dfrac{-1}{100k \times C_m}$ $\qquad$ $\underline{C_m = 3.18pF}$

$f_{p2} = \sqrt{3}\ GBW = \sqrt{3}MHz \times 2\pi = \dfrac{g_{m1}}{C_B = 30\ pF}$ $\qquad$ $g_{m1} = 326\mu = g_{m2}$

$$\sqrt{2K_p \left(\frac{W}{L}\right)_1 I_D} = \sqrt{2K_p \left(\frac{W}{L}\right)_2 I_D}$$

$\frac{W}{L} = \frac{5\mu}{0.27\mu} \Rightarrow$ get $I_D$