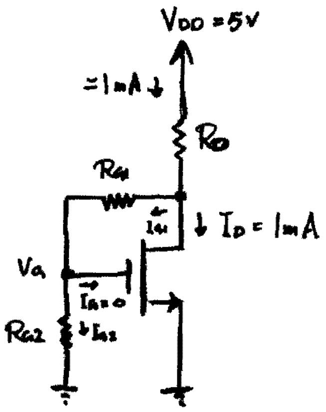
13.1 PROBLEM 7.103



$V_t = 0.8V$

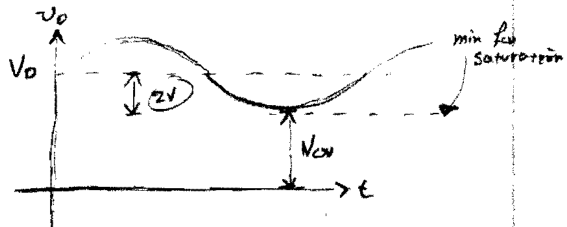
$k_n' = 8\ mA/V^2$

$\lambda = 0$

$$I_D = \frac{1}{2} k_n' V_{ov}^2$$

$$1mA = \frac{1}{2} \times 8mA/V^2 \times V_{ov}^2$$

$$V_{ov} = \underline{0.5V}$$



for Saturation $v_{GD} < V_t$ or $V_G - v_O < V_t$

$v_O > V_G - V_t = V_{ov}$

$V_O \geq V_{ov} + 2$

when $v_O < V_{ov}$

$$V_O = V_{ov} + 2$$

$$\underline{V_O = 2.5V}$$

Since $I_{G1} \ll I_D$

$$R_D \approx \frac{V_{DD} - V_O}{I_D} = \frac{5 - 2.5}{1} = 2.5\ k\Omega$$

$$V_{GS} = V_t + V_{ov} = 0.8 + 0.5 = 1.3V$$

so $V_{RG2} = 1.3V$ and $V_{RG1} = 2.5 - 1.3 = 1.2V$

that mean $R_{G2} > R_{G1}$ because $I_{G1} = I_{G2}$

$$\frac{V_O - V_G}{R_{G1}} = \frac{V_G}{R_{G2}} \longrightarrow R_{G1} = R_{G2} \cdot \frac{V_O - V_G}{V_G}$$

$$R_{G1} = R_{G2} \cdot \frac{2.5 - 1.3}{1.3}$$

if R_{G2} Selected to be $22\ M\Omega$

$$\frac{R_{G1}}{R_{G2}} = \frac{1.2V}{1.3V}$$

$$R_{G1} = \underline{20.3\ M\Omega}$$

Specifiying all resistors to two significant digits

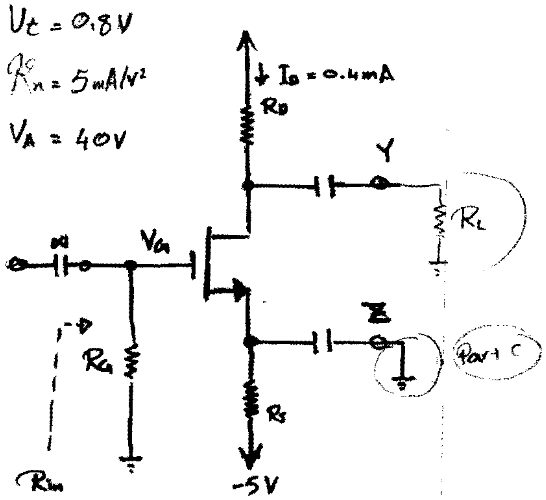
$R_D = 2.5\ k\Omega$, $R_{G1} = 20\ M\Omega$, $R_{G2} = 22\ M\Omega$

13.2 PROBLEM 7.121

$V_t = 0.8V$

$k_n' = 5mA/V^2$

$V_A = 40V$



(a)

R_{in} at gate $= R_G = 10M\Omega$

$I_D = \frac{1}{2} k_n' V_{OV}^2$

$0.4 = \frac{1}{2} \times 5mA/V^2 \times V_{OV}^2 \rightarrow \underline{V_{OV} = 0.4V}$

$V_G = 0 \rightarrow V_S = -V_{GS}$

where $V_{OV} = V_{GS} - V_t \therefore V_{GS} = V_{OV} - V_t$

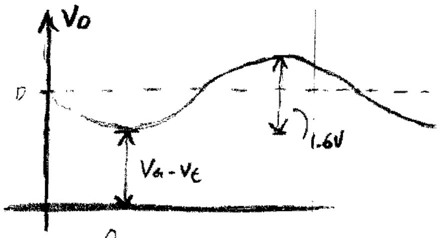
$V_{GS} = V_t + 0.4 = 0.8 + 0.4 = \underline{1.2V} \dashrightarrow V_S = \underline{-1.2V}$

$R_S = \frac{-1.2-(-5)}{0.4mA} = \underline{9.5k\Omega}$

For Saturation, minimum drain Voltage must be limited to $V_G - V_t = 0 - 0.8 = -0.8V$

So negative signal swing must have $V_D = 0V$

$R_D = \frac{5 - V_D}{I_D} = \frac{5-0}{0.4mA} = \underline{12.5k\Omega}$



for Saturation $V_{GD} < V_t$

$V_G - V_D < V_t \rightarrow V_D > V_G - V_t + V_{OV}$

$\therefore V_D > 0 - 0.8 + 0.8 = 0$

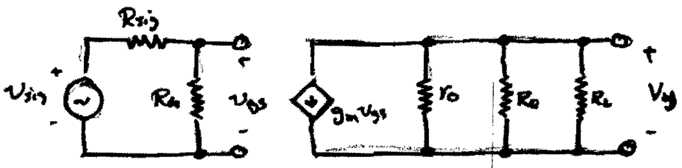
because $V_{OV} \neq V_{GS}$ in this problem.

(b)

$g_m = \frac{2I_D}{V_{OV}} = \frac{2 \times 0.4mA}{0.4V} = \underline{2mA/V}$

$r_o = \frac{V_A}{I_D} = \frac{40}{0.4} = \underline{100k\Omega}$

(c) if Z connected to ground, Circuit become CS amplifier.



$G_V = \frac{v_y}{v_{sig}} = \frac{R_G}{R_G + R_{sig}} \times -g_m (r_o \| R_D \| R_L)$

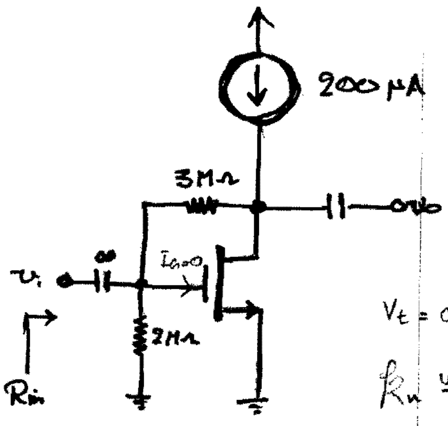
$v_y = -g_m v_{gs} (r_o \| R_D \| R_L)$ &

$v_{gs} = v_{sig} \cdot \frac{R_G}{R_G + R_{sig}}$

$= -\frac{10k}{10k+1k} \times 2\,(100k \| 12.5k \| 10k)$

$= \underline{-9.6\ V/V}$

13.3 PROBLEM 8.43



$V_t = 0.5V$

$k_n' \frac{W}{L} = 2\ mA/V^2$

$V_A = 20V$

(a)

$I_D = 200\ \mu A$

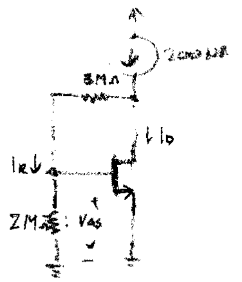
$I_D = \frac{1}{2} k_n' \left(\frac{W}{L}\right) V_{ov}^2$

$200\ \mu A = \frac{1}{2} \times 2\ mA/V^2 \times V_{ov}^2$

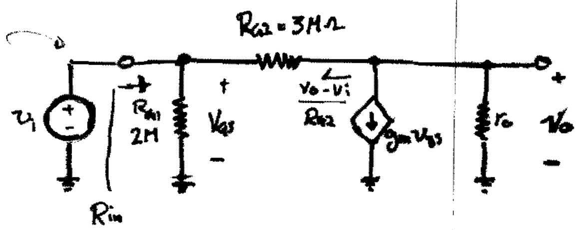
Solve for $V_{ov} = 0.45\ V$

$V_{GS} = V_t + V_{ov} = 0.5 + 0.45 = 0.95V$

$I_R = \frac{V_{GS}}{2M} = 0.475\ \mu A$ which is



(b) Replacing the MOSFET with it's hybrid-π



A kcl equation at the output node yields

$\frac{V_o}{r_o} + g_m V_{gs} + \frac{V_o - V_i}{R_{G2}} = 0$, where $V_{gs} = V_i$

$v_o\left(\frac{1}{r_o} + \frac{1}{R_{G2}}\right) = -v_i\left(g_m - \frac{1}{R_{G2}}\right)$

$\frac{v_o}{v_i} = -\left(g_m - \frac{1}{R_{G2}}\right)(r_o \| R_{G2})$

$g_m = \frac{2I_D}{V_{ov}} = \frac{2 \times 0.2}{0.45} = 0.894\ mA/V$

$r_o = \frac{V_A}{I_D} = \frac{20}{0.2} = 100\ k\Omega$ $\qquad \frac{v_o}{v_i} = -\left(0.89 - \frac{1}{3000}\right) \times (100 \| 3000) = -86.1\ V/V$

to Obtain maximum negative signal swing, first determin the dc Voltage at the output

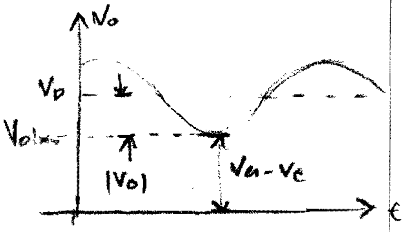
$V_o = I_R(2M\Omega + 3M\Omega) = 0.475\ \mu A \times 5M\Omega = 2.375V$

Cont. 13.3 Cont Problem 8.43

$V_{GD} \leq V_t \longrightarrow V_G - V_D \leq V_t$ or $V_D \geq V_G - V_t$

The MOSFET in Saturation limit $V_D|_{min} = V_G - V_t$ (↑ max v_G)

$v_G|_{max} = 0.5 + V_o|_{min}$



$V_{GS} + |\hat{V}_i| = 0.5 + V_{DS} - |\hat{V}_o|$

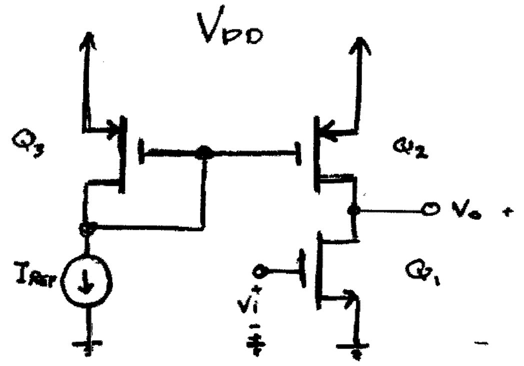
$0.95 + \frac{|\hat{v}_o|}{|A_v|} = 0.5 + 2.375 - |\hat{v}_o|$

$|\hat{V}_o| = \frac{0.5 + 2.375 - 0.95}{1 + \frac{1}{|A_v|}}$

Substituting $|A_v| = 86.5$ $\rightarrow |\hat{v}_o| = 1.9V$

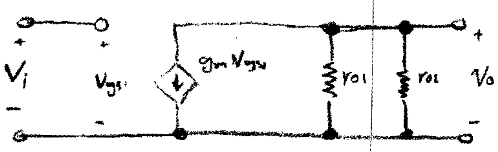
$|V_i| = \frac{|\hat{V}_o|}{|A_v|} = \frac{1.9}{86.5} = 22\,mV$

13.4 PROBLEM 8.44



$I_{D1} = I_{D2}$

$R_o = 100\ k\Omega = r_{o1} \| r_{o2}$



$$r_{o1} = r_{o2} = \frac{|V_A|}{I_D} = \frac{5}{I_{REF}}$$

$$100k = \frac{1}{2} \times \frac{5}{I_{REF}}$$

$$v_o = -g_{m1} v_{gs1} (r_{o1} \| r_{o2})$$

$$v_{gs1} = v_i$$

$$A_v = \frac{v_o}{v_i} = -g_{m1} (r_{o1} \| r_{o2})$$

given, $-40 = -g_{m1} \times 100 \longrightarrow g_{m1} = 0.4\ mA/V$

but $g_{m1} = \sqrt{k_n'(\frac{W}{L})_1 I_{D1}}$ $\quad I_{REF}$

$$0.4\ mA/V = \sqrt{2 \times 0.4 (\tfrac{W}{L})_1 \times 0.025} \Longrightarrow \underline{(\tfrac{W}{L})_1 = 8}$$

$$I_{D1} = \frac{1}{2} k_n' (\tfrac{W}{L})_1 V_{ov1}^2$$

$$25 = \frac{1}{2} \times 400 \times 8 \times V_{ov1}^2 \longrightarrow V_{ov1} = 0.125V$$

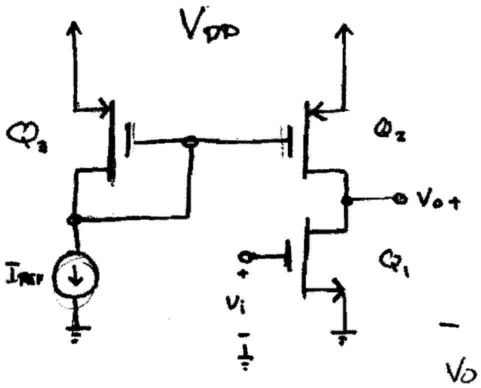
if Q_2 and Q_3 are operated at $|V_{ov}| = 0.125V$

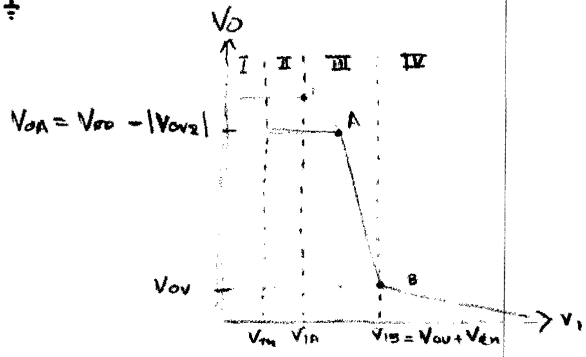
$$I_{D2} = I_{D3} = \frac{1}{2} k_p' (\tfrac{W}{L})_{2,3} |V_{ov}|^2$$

$$= \frac{1}{2} \times 100 \times (\tfrac{W}{L})_{2,3} \times 0.125^2$$

$$\underline{(\tfrac{W}{L})_{2,3} = 32}$$

13.5 PROBLEM 8.45





From 8.16(d)

in Region III is almost linear region of transfer characteristic.

$V_{IA} = 0.89\text{ V}$ and $V_{IB} = 0.935\text{ V}$

A Maximum output signal swing is achieved by biasing Q_1 at middle of this range

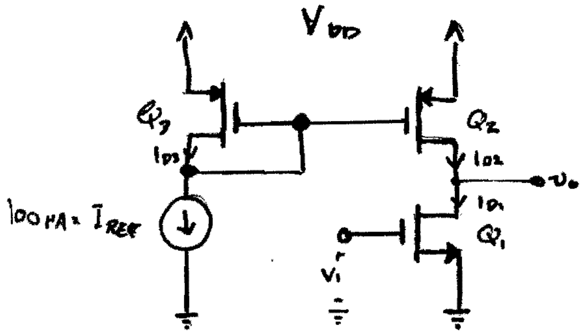
$$V_1 = \frac{V_{IA} + V_{IB}}{2} = 0.913\text{V}$$

The Peak to Peak amplitude at the output will be

$$(V_{OA} - V_{OB}) = 2.47 - 0.335 = \underline{2.135\text{V}}$$

$$\text{Peak amplitude} = \frac{1}{2}(2.135) = \underline{1.07\text{V}}$$

13.6 **Ex 8.8**



Since Q_2 and Q_3 have the same $\frac{W}{L}$ and R_e so $I_{D3} = I_{D2} = I_{REF}$ and

$$I_{D1} = I_{D2} = I_{REF} = 100\mu A$$

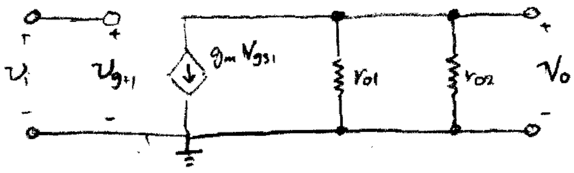
$$\frac{W}{L} = \frac{7.2\mu m}{0.36\mu m}$$

From (7.41) $g_{m1} = \sqrt{2 k_n' \left(\frac{W}{L}\right)} \sqrt{I_{D1}}$

$$= \sqrt{2 \cdot (387\,\mu A/V^2)\left(\frac{7.2}{0.36}\right)(100\mu A)} = \underline{1.24\, mA/V}$$

From (7.37) $r_{o1} = \frac{|V_{An}'| L_1}{I_{D1}} = \frac{5\,V/\mu m\,(0.36\mu m)}{0.1\,mA} = \underline{18\,k\Omega}$

$$r_{o2} = \frac{|V_{Ap}'| L_2}{I_{D2}} = \frac{6\,V/\mu m\,(0.36\mu m)}{0.1\,mA} = \underline{21.6\,k\Omega}$$



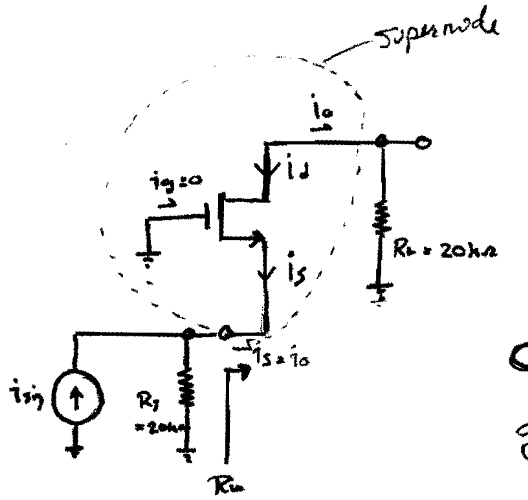
$v_o = -g_{m1} v_{gs1} \cdot (r_{o1} \| r_{o2})$, $V_{gs1} = V_i$

$$\therefore A_v = \frac{v_o}{v_i} = -g_{m1}(r_{o1} \| r_{o2})$$

$$= -(1.24\, mA/V)(18k\Omega \| 21.6k\Omega)$$

$$= -\underline{12.2\ V/V}$$

13.7 **PROBLEM 8.52**



CG Amplifiers

$g_m = 2\ mA/V$

$r_o = 20\ k\Omega$

FROM (8.53)

$$R_{in} = \frac{r_o + R_L}{1 + g_m r_o} = \frac{20k + 20k}{1 + 2\,mA/V \times 20k} = \underline{980\ \Omega}$$

Since $i_s = i_o$ From Supernode

$$\frac{i_o}{i_{sig}} = \frac{R_s}{R_s + R_{in}} = \frac{20k}{20k + 980} = \underline{0.95\ A/A}$$

if R_L is increase by factor of 10, $R_{in} = \frac{20k + 200k}{1 + 2\,mA/V \times 20k} = \underline{5.37\ k\Omega}$

and Current gain become

$$\frac{i_o}{i_{sig}} = \frac{20k}{20k + 5.37'} = \underline{0.79\ A/A}$$

When R_L increase by factor of 10, Current gain decrease, by -17%, This indicates that the CG amplifier function as an effective current buffer.