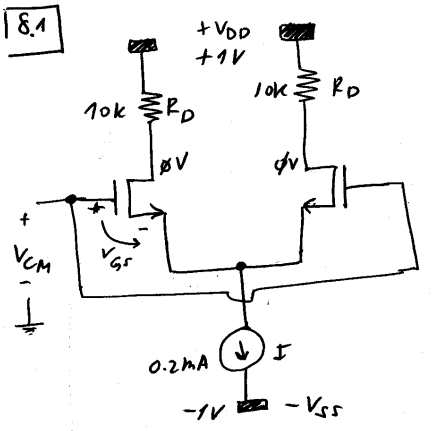
8.1



$kp = \mu_n C_{ox} = 0.4\ mA/V^2$

$W/L = 12.5$

$V_T = 0.5V$

$v_o = (v_{GS} - v_T)$

$$\frac{I}{2} = \frac{1}{2} k \left(\frac{W}{L}\right) (v_{GS} - v_T)^2$$

$$(v_{GS} - v_T) = \sqrt{\frac{I}{k\left(\frac{W}{L}\right)}} = \sqrt{\frac{0.2 \times 10^{-3}}{0.4 \times 10^{-3} \times 12.5}}$$

(a) $(v_{GS} - v_T) = 0.2\ V$; $V_{GS} = 0.7\ V$

(b) $V_{CM} = 0$; $V_S = -0.7\ V$; $V_{D1} = V_{D2} = V_{DD} - R_D I_D = 1 - 10 \times 10^3 \times 10^{-4}$

$= 1 - 1 = \phi V$

$I_{D1} = I_{D2} = 0.1\ mA$

(c) $V_{CM} = 0.3V$; $V_{GS} = 0.7 \Leftrightarrow V_G - V_S = 0.7 \Leftrightarrow V_S = V_G - 0.7$

$V_S = 0.3 - 0.7 = -0.4\ V$

(d) $V_{CM} = -0.1V$; $V_S = -0.1 - 0.7 = -0.8\ V$

(e) no channel at drain $\Rightarrow V_{GD} \leq V_T \Leftrightarrow V_G \leq V_D + V_T$

$V_G \leq 0.5\ V$

$V_{CM,MAX} = 0.5V$

(f) $V_{S,MIN} = V(I) + (-V_{SS}) = 0.2 - 1 = -0.8\ V$

$V_{CM,MIN} = V_{S,MIN} + V_T + V_{OV} = -0.8 + 0.5 + 0.2 = -0.1\ V$

8.3

$v_{G2} = 0$

$v_{G1} = v_{id}$

a) $i_{D1} = i_{D2} = 0.1 mA \Rightarrow v_{id} = 0 V$

b) $i_{D1} = 0.15 mA \qquad i_{D2} = 0.05 mA$

$$(V_{GS} - V_T) = \sqrt{\frac{2I}{k(\frac{W}{L})}} = \sqrt{\frac{2}{k(\frac{W}{L})}} \sqrt{I}$$

$$= \sqrt{\frac{2}{0.4 \times 10^{-3} \times 12.5}} \sqrt{I} = 20\sqrt{I}$$

$$V_{GS2} - V_T = 20\sqrt{I}$$

$$V_{GS2} = 20\sqrt{I} + V_T$$

$$V_{G2} - V_S = 20\sqrt{I_2} + V_T$$

$$V_S = V_{G2} - V_T - 20\sqrt{I_2}$$

$$= 0 - 0.5 - 20\sqrt{0.05 \times 10^{-3}} = -0.641 V$$

$$V_{G1} - V_S = 20\sqrt{I_1} + V_T$$

$$V_{G1} = V_S + V_T + 20\sqrt{I_1}$$

$$= -0.641 + 0.5 + 20\sqrt{0.15 \times 10^{-3}}$$

$$v_{id} = +0.104 V$$

c) $i_{d2} = 0$ (Q2 just cut off)

$v_{G2} = 0 \Rightarrow V_{GS} = V_T \Leftrightarrow V_S = -V_T = -0.5 V$

$$V_{G1} = V_S + V_T + 20\sqrt{I_1}$$

$$= -0.5 + 0.5 + 20\sqrt{0.2 \times 10^{-3}} = +0.283 V$$

d) $i_{d2} = 0.15\,mA$

$i_{d1} = 0.05\,mA$

$$V_S = V_{G2} - V_T - 20\sqrt{I2}$$

$$= 0 - 0.5 - 20\sqrt{0.15\times10^{-3}} = -0.745\,V$$

$$V_{G1} = V_S + V_T + 20\sqrt{I1}$$

$$= -0.745 + 0.5 + 20\sqrt{0.05\times10^{-3}}$$

$$= -0.104\,V$$

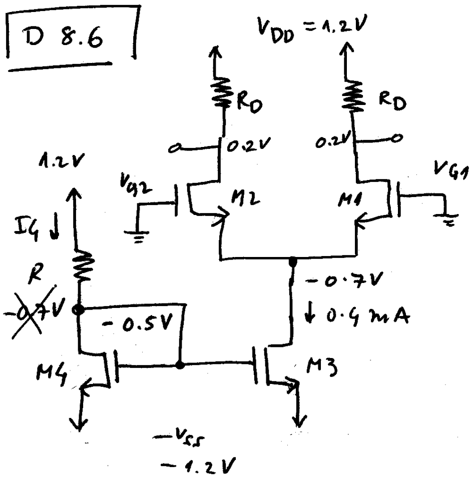
e) $i_{d1} = \varnothing$ (Q_1 just cut off)

$$V_{G1} = -0.283\,V$$

	i_{d1}	i_{d2}	V_{G1}	V_{G2}	V_{D1}	V_{D2}	$(V_{D2} - V_{D1})$
a	0.1 mA	0.1 mA	+0.0	0	0	0	0
b	0.15 mA	0.05 mA	+0.1	0	−0.5	+0.5	1
c	0.2 mA	0	+0.283	0	−1	+1	2
d	0.05 mA	0.15 mA	−0.1	0	+0.5	−0.5	−1
e	0	0.2 mA	−0.283	0	+1	−1	−2

WARNING: TRANSISTOR GOES INTO LINEAR REGION !

D 8.6



$V_{OV} = (V_{GS} - V_T) = 0.2\,V$

$V_T = 0.5\,V$

$\mu_n C_{ox} = 250\,\mu A/V^2$

R

$$R_D = \frac{V_{DD} - V_D}{I_D} = \frac{1.2 - 0.2}{0.2\,mA} = 5\,k\Omega$$

$(W/L)_{M1}$

$(W/L)_{M2}$ $\quad (W/L)_1 = (W/L)_2$

$(W/L)_{M3}$

$(W/L)_{M4}$

$$V_{GS2} = 0.2 + V_T = 0.7$$

$$V_{G2} - V_{S2} = 0.7 \Leftrightarrow V_{S2} = V_{G2} - 0.7 = -0.7\,V$$

$V_{GS4} = -0.7 - (-1.2) = 0.5\ V$ no overdrive voltage!

with $V_{OV4} = 0.2\ V$

$(V_{GS4} - V_T) = 0.2\ V$

$V_{GS4} = 0.2 + V_T = 0.7$

$V_{G4} - V_{S4} = 0.7$

$V_{G4} = 0.7 + V_{S4} = 0.7 + (-1.2) = -0.5$

Design decision : $I_4 = 0.4\ mA$

then $\left(\frac{W}{L}\right)_4 = \left(\frac{W}{L}\right)_3$

$$R = \frac{V_{DD} - V_{G4}}{I_4} = \frac{1.2 - (-0.5)}{0.4 \times 10^{-3}} = \frac{1.7}{0.4 \times 10^{-3}} = 4.25\ K\Omega$$

Calculo de $(W/L)_1$ e de $(W/L)_2$

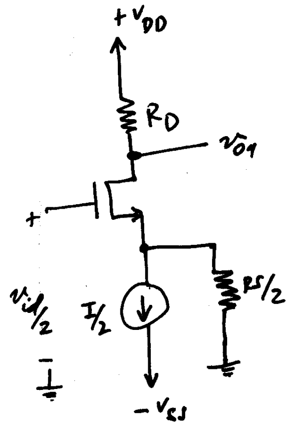
$$I_D = \frac{1}{2} kp \left(\frac{W}{L}\right) (V_{GS} - V_T)^2$$

$$\left(\frac{W}{L}\right)_{1,2} = \frac{2\ I_D}{kp\ V_{OV}^2} = \frac{2 \times 0.2 \times 10^{-3}}{250 \times 10^{-6} \times 0.04} = 40$$

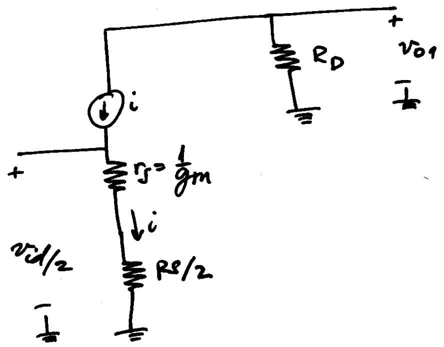
$$\left(\frac{W}{L}\right)_{3,4} = \frac{2 \times 0.4 \times 10^{-3}}{250 \times 10^{-6} \times 0.04} = 80$$

8.21

HALF - CIRCUIT:



small signal equivalent:



$$A_d \equiv \frac{v_{o2} - v_{o1}}{v_{id}} = \frac{v_{o2}}{v_{id}} + \frac{v_{o1}}{(-v_{id})} = 2\frac{v_{o1}}{(-v_{id})}$$

$$v_{o1} = -R_D \, i$$

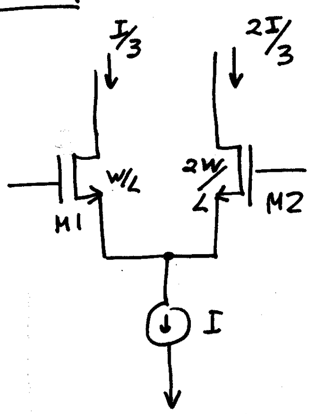
$$i = \frac{v_{id}/2}{\frac{1}{g_m} + R_S/2}$$

$$\therefore \quad v_{o1} = -\frac{R_D}{\frac{1}{g_m} + \frac{R_S}{2}} \frac{v_{id}}{2}$$

Thus

$$A_d = \frac{2\, v_{o1}}{(-v_{id})} = \frac{R_D}{\frac{1}{g_m} + \frac{R_S}{2}} = \frac{g_m R_D}{1 + g_m \frac{R_S}{2}}$$

8.25



$V_{GS1} = V_{GS2}$

$$I_{D1} = \frac{1}{2}\mu C_{ox}\frac{W}{L}(V_{GS_1}-V_T)^2$$

$$I_{D2} = \frac{1}{2}\mu C_{ox}\frac{2W}{L}(V_{GS_2}-V_T)^2$$

Thus $I_{D2} = 2 I_{D1}$

$$g_{m1} = \frac{2(\frac{1}{3}I)}{V_{ov}} \quad ; \quad g_{m2} = \frac{2(\frac{2}{3}I)}{V_{ov}}$$

$$\frac{v_{o1}}{v_{id}/2} = -g_{m1} R_D \quad ; \quad \frac{v_{o2}}{(-v_{id}/2)} = -g_{m2} R_D$$

$$A_d \equiv \frac{v_{o2}-v_{o1}}{v_{id}} = \frac{1}{2}\left(\frac{2\times\frac{2}{3}I}{V_{ov}} + \frac{2\times\frac{1}{3}I}{V_{ov}}\right) R_D$$

$$= \frac{I}{V_{ov}} R_D$$

8.73

$\mu C_{ox} = 250\,\mu A/V^2$

$$\frac{I}{2} = \frac{1}{2}\mu C_{ox}\frac{W}{L}(V_{GS}-V_T)^2 \Rightarrow V_{ov} = V_{GS}-V_T = \sqrt{\frac{I}{\mu C_{ox}(W/L)}} = 0.2V$$

$$V_{o1} = (I/2)\,R_D$$

$$V_{o2} = (I/2)(R_D+\Delta R_D)$$

$$\Rightarrow \Delta V_o = V_{o2}-V_{o1} = \frac{I}{2}\Delta R_D$$

$$\Delta V_{IN} = \frac{\Delta V_o}{A_d} = \frac{I/2\ \Delta R_D}{I/V_{ov}\ R_D}$$

$$= \frac{\Delta R_D}{2R_D} V_{ov}$$

$$V_{O1} = (I/2)\ R_D$$

$$V_{O1} = \frac{1}{2} \times \frac{1}{2} \mu C_{ox} \frac{W}{L} V_{OV}^2 R_D$$

$$V_{O2} = \frac{1}{2} \times \frac{1}{2} \mu C_{ox} \frac{(W + \Delta W)}{L} V_{OV}^2 R_D$$

$$\Delta V_O = \frac{1}{2} \times \frac{1}{2} \mu C_{ox} \frac{\Delta W}{L} V_{OV}^2 R_D$$

$$\Delta V_{in} = \frac{\Delta V_O}{A_d} = \frac{\frac{1}{2} \times \frac{1}{2} \mu C_{ox} \frac{\Delta W}{L} V_{OV}^2 R_D}{\frac{1}{2} \mu C_{ox} \frac{W}{L} V_{OV}^2 R_D} V_{OV}$$

$$= \frac{1}{2} \frac{\Delta W}{W} V_{OV}$$

(simple solution)

$$V_{IN1} = V_{GS} - V_T$$

$$V_{IN2} = V_{GS} - (V_T + \Delta V_T)$$

$$\Delta V_{IN} = V_{IN2} - V_{IN1} = \Delta V_T$$

(more complicated)

$$I_1 = \frac{1}{2} \mu C_{ox} \frac{W}{L} (V_{GS} - V_T)^2$$

$$I_2 = \frac{1}{2} \mu C_{ox} \frac{W}{L} (V_{GS} - V_T + \Delta V_T)^2$$

$$I_2 = \frac{1}{2}\mu C_{ox}\frac{W}{L}(V_{GS}-V_T)^2$$

$$+ \frac{1}{2}\mu C_{ox}\frac{W}{L}\left(2(V_{GS}-V_T)\Delta V_T\right)$$

$$+ \frac{1}{2}\mu C_{ox}\frac{W}{L}\Delta V_T^2$$

$$(v_{o2}-v_{o1}) = 2\,\frac{1}{2}\mu C_{ox}\frac{W}{L}(V_{GS}-V_T)^2\,\frac{\Delta V_T}{V_{GS}-V_T}\,R_D$$

$$= 2\,I\,\frac{\Delta V_T}{V_{GS}-V_T}\,R_D$$

$$A_D = g_m R_D = \frac{2I}{(V_{GS}-V_T)}R_D$$

$$V_{OFFSET} = \Delta V_{in} = \frac{v_{o2}-v_{o1}}{A_D} = \Delta V_T$$