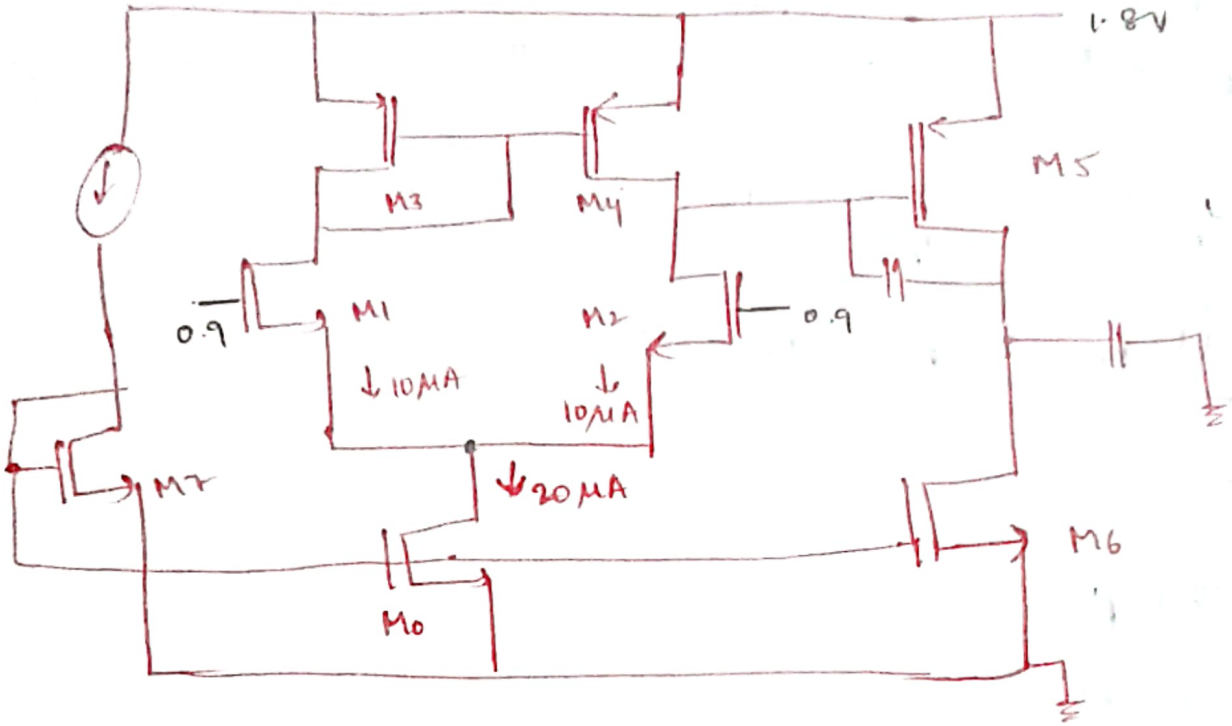

Given:

$(V_{th})_n = 0.37V$

$(V_{th})_p = 0.39V$

$\mu_n C_{ox} = 230\ \mu A/V^2$

$\mu_p C_{ox} = 80\ \mu A/V^2$

$L_{min} = 0.18\mu m$

$W_{min} = 0.27\mu m$

initial $V_{gs} - V_{th} = 200\ mV$

M0

$$I_D = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_{th})^2$$

$$20 = \frac{1}{2} \times 230 \times \left(\frac{W}{L}\right)(0.2)^2$$

$$\left(\frac{W}{L}\right)_{M0} = 4.35$$

$$g_m = \frac{2I_D}{V_{gs}-V_{th}}$$

$$= \frac{2 \times 20\mu}{0.1} = 200\mu$$

$$r_o = \frac{1}{\lambda I_D} = \frac{1}{0.1 \times 20\mu} = 500\ K\Omega$$

M1 and M2

$M_1 \rightarrow$ saturation

$V_{gs} - V_{th} > 0$

$V_g - V_s > 0.37$

$0.9 - V_s > 0.37$

$V_s < 0.53$

let $V_s = 0.5$

then

$$10\mu = \frac{1}{2} \times 230\mu \left(\frac{W}{L}\right)(0.9-0.5-0.37)^2$$

$$\left(\frac{W}{L}\right) = 96.666$$

$$g_m = \frac{2I_D}{(V_{gs}-V_{th})^2} = \frac{2\times 10\mu}{0.03} \doteq 666.66$$

$$r_o = \frac{1}{\lambda I_D} = \frac{1}{0.1\times 10\mu} = 1000\ k\Omega$$

$$\boxed{(r_o)_{M_1} = (r_o)_{M_2} = 1000\ k\Omega}$$

M3 and M4

$(V_{sg}) > (V_{th})_p$

$1.8 - V_g > 0.34$

$V_g < 1.41$

$V_g = V_d \quad V_d < 1.41$ → with this V_d → M_1 Saturation

$(V_{ds})_1 > V_{gs_1} - (V_{th})_n$

$V_d > 0.9 - 0.37$

$V_d > 0.53$

$\therefore V_d \in (0.53, 1.41)$

let $\boxed{V_d = 1.3V}$

$$10\mu = \frac{1}{2}\times 10\mu\times\left(\frac{W}{L}\right)(1.8 - 1.3 - 0.39)^2$$

$$\left(\frac{W}{L}\right) = \frac{1}{5(0.11)^2} = 16.53$$

$$g_m = \frac{2I_D}{V_{sg}-V_{thp}} = \frac{2(10)\mu}{0.11} = 181.81\mu$$

$(r_o)_{M3}$ and $(r_o)_{M4} = 1000\ k\Omega$ $\quad \boxed{V_x > 1.55}$

M5

let current = 60 μA

$V_{sd4} > V_{sg4} - (V_{th})_p$

V_x → M_2, M_4, M_5 → Saturation

$V_g + V_{tp} > V_x$

$(V_{sg})_5 > (V_{th})_p \quad 1.8 - V_x > 0.39$

$V_x < 1.3 + 0.39$

$\boxed{V_x < 1.41}$ $\quad \boxed{V_x < 1.69}$

$\therefore V_x \in (0.53, 1.41)$

let $V_x = 1.3$

$$I_D = \frac{1}{2}\mu_p C_{ox}\left(\frac{W}{L}\right)_5 (1.8 - 1.3 - 0.39)^2$$

$$60\mu = \frac{1}{2} \times \overset{5}{10}\mu \times \left(\frac{W}{L}\right)_5 (0.11)^2$$

$$\left(\frac{W}{L}\right)_5 = \frac{1.2}{0.0121} = 99.174$$

$$g_{m5} = \frac{2 \times 60\mu}{0.11} = 1091\,\mu$$

$$(r_{o6}) = (r_{o5}) = \frac{1}{\lambda I_D} = \frac{1}{0.1 \times 60\mu} = 0.1667\ M\Omega$$

$$= 166.7\ K\Omega$$

M7:

$$\frac{(I_D)_7}{\left(\frac{W}{L}\right)_7} = \frac{(I_D)_{M0}}{\left(\frac{W}{L}\right)_{M0}} \quad \text{(same overdrive)}$$

$$\frac{2\mu}{\left(\frac{W}{L}\right)_7} = \frac{\overset{10}{20}\mu A}{4.35} \qquad \left(\frac{W}{L}\right)_7 = \frac{4.35}{10} = 0.435$$

$$(V_{gs} - V_{th})_7 = 0.2$$

$$V_g - 0 - 0.37 = 0.2$$

$$V_g = 0.57$$

$$g_m = \frac{2 \times 2\mu}{0.2} = 20\,\mu$$

$$r_o = \frac{1}{\lambda I_D} = \frac{1}{0.1 \times 2\mu} = 5\ M\Omega$$

M6:

$$60\mu = \frac{1}{2} \times 230\mu \times \left(\frac{W}{L}\right) \times (0.2)^2$$

$$\left(\frac{W}{L}\right)_6 = \frac{2 \times 6}{23 \times 0.04} = 13.04$$

$$V_{gs} - V_{th} = 0.57 - 0.37 = 0.2$$

$$(g_m)_6 = \frac{2 \times 60\mu}{0.1} = 600\mu \qquad r_6 = \frac{1}{0.1 \times 60\mu} = 166.7K\Omega$$

$\left(\frac{W}{L}\right)_{M_0} = 4.35$ $\quad g_m = 200\mu$ $\quad r_0 = 500K\Omega$

$\left(\frac{W}{L}\right)_{M_1, M_2} = 96.66$ $\quad g_m = 666.66$ $\quad r_0 = 1M\Omega$

$\left(\frac{W}{L}\right)_{M_3, M_4} = 16.53$ $\quad g_m = 181.81\mu$ $\quad r_0 = 1M\Omega$

$\left(\frac{W}{L}\right)_{M_5} = 99.174$ $\quad g_m = 1091\mu$ $\quad r_{oM_5} = 166.7K\Omega$

$\left(\frac{W}{L}\right)_{M_6} = 13.04$ $\quad g_m = 600\mu$ $\quad r_0 = 166.7K\Omega$

$\left(\frac{W}{L}\right)_{M_7} = 0.435$ $\quad g_m = 20\mu$ $\quad r_0 = 5M\Omega$

Theoretical gain

$$1^{st} \text{ stage} = g_m (r_{on} \parallel r_{op})$$

$$= 666.66 \times (1M\Omega \parallel 1M\Omega) = 666.66 \times \frac{1}{2} \times 10^6 \times 10^{-6}$$

$$= 333.33$$

$$2^{nd} \text{ stage} = 1091 \times 10^{-6} \left(\frac{166.7 \times 10^3}{2}\right) = 90.93 = 91$$

Overall gain $= 333.33 \times 91 = 30333.03$