7.21 $K = 40 = g_{m2} r_{O2} = \dfrac{V_A}{V_{OV/2}}$

so that

$$V_A = \frac{K V_{OV}}{2} = \frac{40(0.2V)}{2} = 4 \text{ V}$$

If $V_A' = 5 \text{ V}/\mu\text{m}$,

$$L = \frac{V_A}{V_A'} = \frac{4 \text{ V}}{5 \text{ V}/\mu\text{m}} = 0.8 \ \mu\text{m}$$

7.24 $g_{m1} = \dfrac{2I_D}{V_{OV}}$, so,

$$I_D = \frac{g_{m1} V_{OV}}{2} = \frac{1 \text{ mA/V}(0.2 \text{ V})}{2} = 100 \ \mu\text{A}$$

$R_O = (g_{m2} r_{O2}) r_{O1}$

However, if we make $g_{m1} = g_{m2} = g_m$

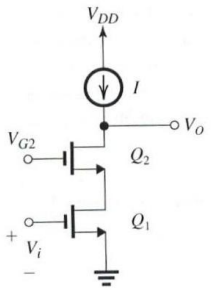
and $r_{O1} = r_{O2} = r_O$, we can say

that $400 \text{ k}\Omega = 1 \text{ mA/V} \cdot r_O^2$

$$r_O^2 = \frac{400 \text{ k}\Omega}{1 \text{ mA/V}} \Rightarrow r_O = 20 \text{ k}\Omega$$

since $r_O = \dfrac{V_A' L}{I_D}$,

$$L = \frac{I_D r_O}{V_A'} = \frac{100 \ \mu\text{A}(20 \text{ k}\Omega)}{5 \text{ V}/\mu\text{m}} = 0.4 \ \mu\text{m}$$



$g_m = \sqrt{2 \mu_n C_{ox} (W/L)} \cdot \sqrt{I_D}$ so that

$$\frac{W}{L} = \frac{g_m^2}{2 \mu_n C_{ox} I_D}$$

$$= \frac{(1000 \ \mu\text{A/V})^2}{2(400 \ \mu\text{A/V}^2)(100 \ \mu\text{A})} = 12.5$$

For maximum negative excursion at the output, we want the MOSFETs to be biased so that each transistor can reach $V_{DS} = V_{OV} = 0.2$ V.

$\therefore$ Set $V_{G2} = V_{tn} + V_{OV} + V_{OV}$

$= 0.5 + 0.2 + 0.2 = 0.9$ V

minimum output voltage will be

$2 V_{OV} = 0.4$ V

7.27 Refer to Fig. 7.10.

$$I_{D_3} = I_{D_4} = I = \frac{1}{2} \mu_P C_{ox} \left(\frac{W}{L}\right) V_{OV}^2$$

$$\frac{W}{L} = \frac{2I}{\mu_P C_{ox} V_{OV}^2}$$

$$= \frac{2(100 \ \mu\text{A})}{(60 \ \mu\text{A/V}^2)(0.2 \text{ V})^2} = 83.3$$

For V_{G_4}, $V_{G_4} = V_{DD} - |V_{tp}| - |V_{OV}|$

$= 3.3 \text{ V} - 0.8 \text{ V} - 0.2 \text{ V} = 2.3$ V

For maximum swing,

$V_{SD \min} = |V_{OV}| = 0.2$ V

so, V_{D4} would be

$V_{DD} - |V_{OV}| = 3.3 - 0.2 = 3.1$ V

$\therefore V_{G3}$ must be

$V_{D4} - |V_{tp}| - |V_{OV}| = 3.1 - 0.8 - 0.2 = 2.1$ V

The highest allowable output will be

$V_{DD} - |V_{OV}| - |V_{OV}| = 3.3 - 0.4 = 2.9$ V

From Fig. 7.10, $R_O = (g_{m3} r_{O3}) r_{O4}$

$$r_{O3} = r_{O4} = r_O = \frac{|V_A|}{|I_D|} = \frac{5 \text{ V}}{0.1 \text{ mA}} = 50 \text{ k}\Omega$$

$$g_m = \frac{|I_D|}{|V_{OV}|/2} = \frac{0.1 \text{ mA}}{0.2 \text{ V}/2} = 1 \text{ mA/V}$$

$$R_O \simeq (1 \text{ mA})(50 \text{ k})^2 = 2.5 \text{ M}\Omega$$

7.46 Reffering to Fig 7.22, $V_{DD} = 1.8$ V,

$I_O = I_{ref} = 100 \ \mu\text{A}$,

$L = 0.5 \ \mu\text{m}$, $W = 4 \ \mu\text{m}$,

$V_A' = 10 \text{ V}/\mu\text{m}$, $V_t = 0.5$ V,

$k_n' = 400 \ \mu\text{A/V}^2$

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

$$V_{OV} = \sqrt{\frac{2I_D}{k_n' \left(\frac{W}{L}\right)}} = \sqrt{\frac{2(100 \ \mu\text{A})}{(400 \ \mu\text{A/V}^2)\left(\frac{4}{0.5}\right)}}$$

$= 0.25$ V

$V_{DS} = V_{GS} = V_t + V_{OV} = 0.5 + 0.25 = 0.75$ V

$$R = \frac{V_{DD} - V_{GS}}{I_{ref}} = \frac{1.8 - 0.75}{0.1 \text{ mA}} = 10.5 \text{ k}\Omega$$

The lowest V_O will be when

$V_{DS2} = V_{OV} = 0.25$ V

$$R_O = r_O = \frac{V_A' L}{I_D} = \frac{10 \text{ V}/\mu\text{m}(0.5 \ \mu\text{m})}{100 \ \mu\text{A}}$$

$= 50 \text{ k}\Omega$

$$\Delta I_D \approx \frac{\Delta V_O}{r_O} = \frac{0.5 \text{ V}}{50 \text{ K}} = 10 \ \mu\text{A}$$