1) Drain Currents

PMOS: $I_{D1,2} = 12.5\mu A$

$I_{D5} = 25\mu A$

$I_{D3,4} = 12.5\mu A$

$I_{D3A,4A} = 12.5\mu A$

$$I_{D5} = 25 = \frac{30}{2}\left(\frac{W}{L}\right)_5 (0.1)^2$$

$$\left(\frac{W}{L}\right)_5 = \frac{2(25)}{30(0.1)^2} = 166\frac{2}{3}$$

All other PMOS are half as wide $\rightarrow 83\frac{1}{3}$

NMOS: $I_{D11,12} = 25\mu A$

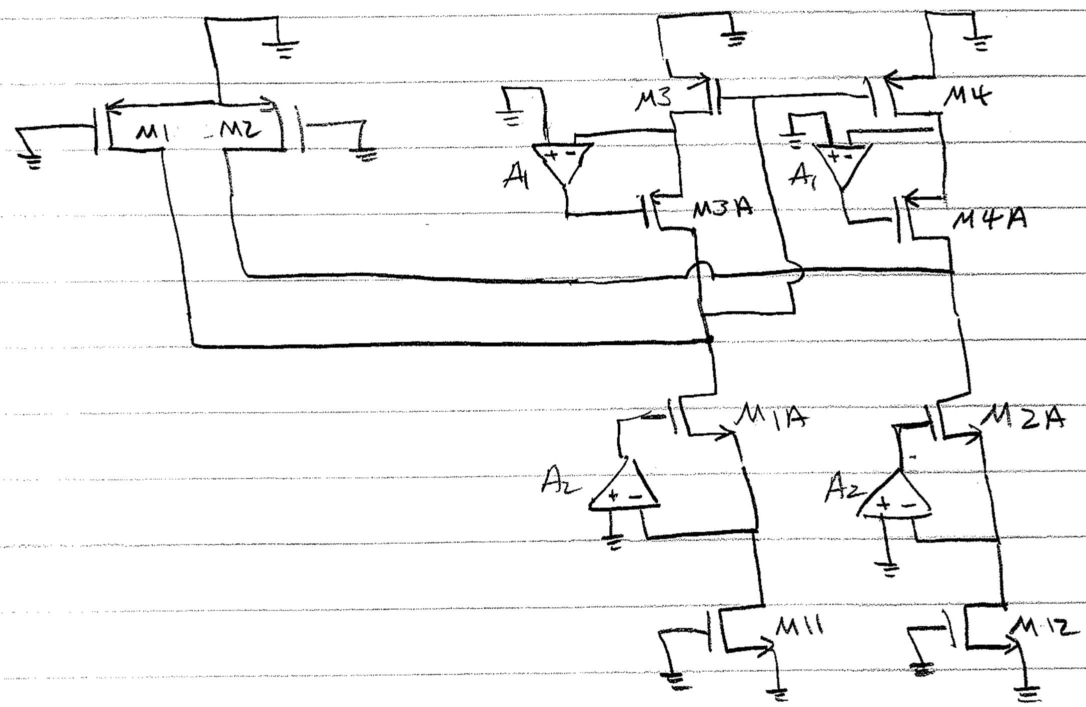
$I_{D1A,2A} = 12.5\mu A$

$$I_{D11,12} = 25 = \frac{120}{2}\left(\frac{W}{L}\right)_{11,12} (0.1)^2$$

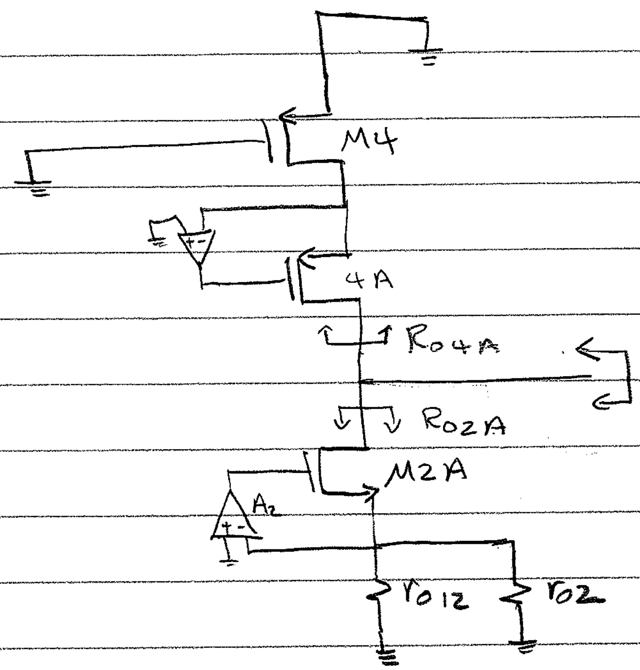
$$\left(\frac{W}{L}\right)_{11,12} = \frac{(2)25}{120(0.1)^2} = 41.\frac{2}{3}$$

All Othe NMOS are half as wide $\rightarrow 20\frac{5}{6}$

2) In the small signal analysis of output resistance, the source of transistors M1 + M2 may be considered to be small signal ground which greatly simplifies the calculation of output resistance:



2) Cont'd which can be redrawn as:



$R_o = R_{o2A} \,||\, R_{o4A}$

$$R_{o4A} = r_{o4} + \left[(A_1+1) g_{m4A} r_{o4} + 1\right] r_{o4A}$$
$$\cong \left[(A_1+1) g_{m4A} r_{o4}\right] r_{o4A}$$

$$R_{o2A} = r_{o2}||r_{o12} + \left[(A_2+1) g_{m2A} (r_{o2}||r_{o12}) + 1\right] r_{o2A}$$
$$\cong \left[(A_2+1) g_{m2A} (r_{o2}||r_{o12})\right] r_{o2a}$$

Small signal values:

$r_{o2} = \left(\frac{1}{0.2(12.5)}\right) = 0.4\ Meg\Omega$ $\quad r_{o4} = \frac{1}{0.2(12.5)}\ Meg\Omega = 0.4\ Meg\Omega$

$r_{o12} = \frac{1}{0.1(25)} = 0.4\ Meg\Omega$ $\quad r_{o4A} = 0.4\ Meg\Omega$

$r_{o2A} = \frac{1}{0.1(12.5)} = 0.8\ Meg\Omega$ $\quad g_{m4A} = \sqrt{2(12.5)30(83\tfrac{1}{3})} = 250\ \mu S$

$g_{m2A} = \sqrt{2(12.5)120(83\tfrac{1}{3})} = 500\ \mu S$

$$\frac{R_{o4A}}{R_{o2A}} \cong \frac{A_1 g_{m4A} r_{o4} r_{o4A}}{A_2 g_{m2A} (r_{o2}||r_{o12}) r_{o2A}}$$

$$A_2 = \frac{A_1 g_{m4A} r_{o4} r_{o4A}}{g_{m2A} (r_{o4}||r_{o12}) r_{o2A}}$$

$$A_2 = \frac{(100)\, 250\, (0.4)(0.4)}{500\, (0.4||0.4)\, 0.8} = 50$$

④

3) What is approx gain

$$A_V = G_m R_o$$
$$= g_{m1} R_o$$

$$R_o = R_{o2A} \,//\, R_{o4A}$$

$$R_{o4A} = R_{o2A} \cong 50(500)(0.2)\,0.8 = 4 \times 10^9\ \Omega$$

$$R_o = 4{,}000\ \text{Meg}\Omega$$
$$g_{m1} = \sqrt{2(12.5)(30)(83\tfrac{1}{3})} = 250\ \mu S$$

$$A_V = 250\,(40{,}000) = 10^6$$ Very high!