#1. a) For M_{in} $V_{DS} = V_{GS} = -V_{SS} = 5v$

$$\Rightarrow \quad I_D = \frac{KP_n}{2} \cdot \frac{W}{L} \cdot (V_{GS} - V_{TO_n})^2 (1 + \lambda_n V_{DS})$$

$$= \frac{10^{-4}}{2} \cdot 1\,(5-1)^2 (1 + 0.01 \times 5) = \tfrac{1}{2} \times 10^{-4} (16)(1.05) = 8.4 \times 10^{-4}$$

$$= 0.84\,mA$$

$$R_{in} = V_{dd}/I_d = \frac{5}{0.84} \times 10^3 = 5.95 \times 10^3 \approx 6\,k\Omega$$

b) $R_{out} = \frac{5.95}{2}\,k\Omega \Rightarrow 3\,k\Omega$

M_{out} is in saturation since $V_{DS_{Mout}} > V_{DS_{Min}}$ & $V_{GS_{Mout}} = V_{GS_{Min}}$ and M_{in} is in saturation, so $V_{DS_{Mout}} > V_{DS_{Min}} > V_{GS_{Min}} - V_{TO_n}$

$$\therefore \quad I_{D_{Mout}} = \frac{KP}{2} W/L \,(V_{GS_{Min}} - V_{TO_n})^2 (1 + \lambda_n V_{DS_{Mout}})$$

$$= I_{D_{Min}} \cdot \left(\frac{1 + \lambda_n V_{DS_{Mout}}}{1 + \lambda_n V_{DS_{Min}}} \right) = \frac{0.84 \times 10^{-3}}{(1.05)} \times (1 + \lambda_n V_{DS_{Mout}})$$

$$= 0.8 \times 10^{-3} (1 + 0.01 \times V_{DS_{Mout}})$$

$$= (V_{R_{out}} / R_{out}) = (10 - V_{DS_{Mout}}) / 3 \times 10^3$$

gives $2.4 + 0.01 \times 2.4\, V_{DS_{Mout}} = 10 - V_{DS_{Mout}}$

$$\Rightarrow \quad 1.024\, V_{DS_{Mout}} = 10 - 2.4 = 7.6 \Rightarrow V_{DS_{Mout}} = 7.42V$$

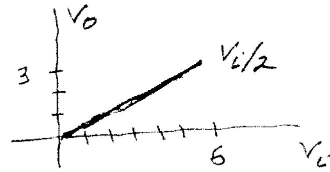
$$\Rightarrow \quad I_{D_{Mout}} = 0.8 \times 10^{-3} (1 + 0.0742) = 0.859 \times 10^{-3}$$

$$\approx 0.86\,mA$$

#2. a) as the transistors are completely complementary and

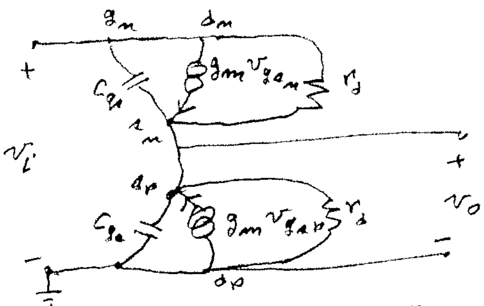
$$V_i = V_{GS_n} + V_{SG_p} = 2V_{GS_n} \Rightarrow V_{GS_n} = V_{SG_p} = V_i/2$$

as $V_O = V_{SG_p} \Rightarrow V_O = V_i/2$



This is not an inverter! It is a linear amplifier of gain 1/2 (even for $V_i < 0$)

b) For small signals



where
$V_i = 3 \Rightarrow V_{GS_n} = V_{SG_p} = 3/2$

$V_O = \frac{V_i}{2} = \frac{3}{2} = V_{SD_p} = V_{DS_n} > V_{GS_n} - V_{TO_n}$
$> V_{SG_p} - |V_{TO}|_p$

$\Rightarrow$ M_{n_3} & M_{p_3} are in saturation

$$g_m = \frac{\partial |I_D|}{\partial |V_{GS}|} = \frac{2|I_D|}{(|V_{GS}| - |V_{TO}|)} = 2\frac{10^{-4}}{2} \times 1 \times \frac{(3/2 - 1)^2}{(3/2 - 1)}(1 + 0.01 \times 3/2) = 10^{-4} \times \frac{1}{2} \times (1.015)$$

$$= 50.75 \times 10^{-6}\ \mho$$

$$g_d = \frac{\partial |I_D|}{\partial |V_{DS}|} = \frac{\lambda |I_D|}{(1 + \lambda |V_{DS}|)} = 0.01 \times \frac{10^{-4}}{2} \times 1 \times \left(\frac{3}{2} - 1\right)^2 = \frac{0.01}{8} \times 10^{-4} = \frac{10^{-6}}{8}$$

$$\Rightarrow r_d = 8 \times 10^{+6}\ \Omega$$

c) as the two portions of the circuit are identical v_i splits in half by voltage division. So

$$\frac{v_o}{v_i}(s) = \frac{1}{2}$$

There are no poles or zeros; this is an "entire" function