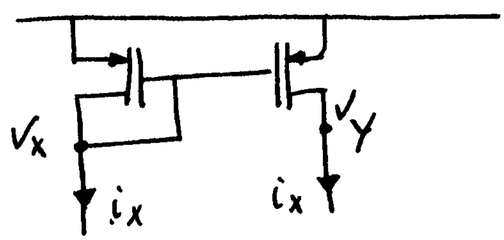
HOMEWORK #7 SOLUTION

1) • Even though the circuit topology is asymmetric, the circuit behaves symmetrically for a common mode input:

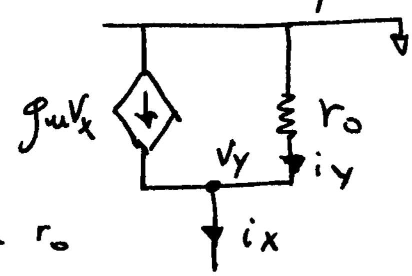


We will calculate the voltages V_x and V_y, and show that they are equal when we draw the same current i_x from both sides.

$$V_x = i_x \left[\frac{1}{g_m} // r_o\right] = \frac{i_x r_o}{1 + g_m r_o}$$

(transistor on the left is diode-connected)

Small signal equivalent circuit of the transistor on the right:



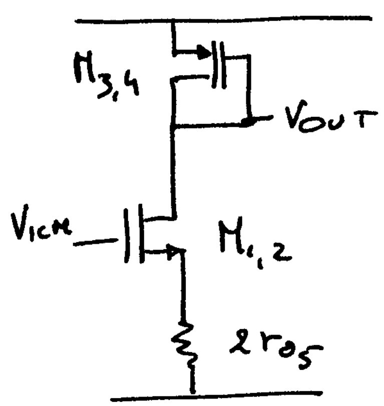
Let i_y be the current through r_o

$$\Rightarrow i_y = i_x - g_m V_x = \frac{i_x}{1 + g_m r_o}$$

$$\Rightarrow V_y = r_o i_y = \frac{i_x r_o}{1 + g_m r_o} = i_x \left[\frac{1}{g_m} // r_o\right] = V_x$$

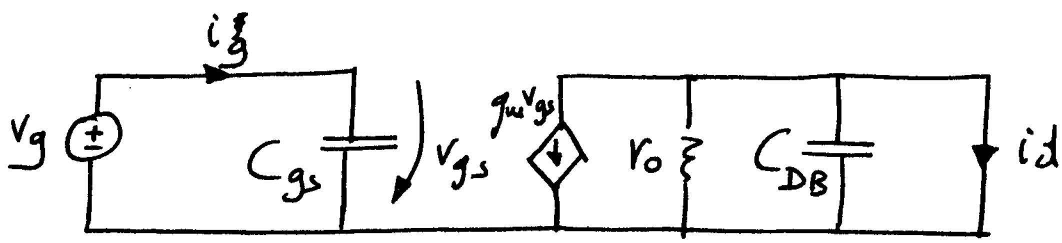
$$\Rightarrow \boxed{V_Y = V_X}$$

- Since the circuit behaves symmetrically for common mode inputs, we can draw a common-mode half-circuit



$$A_{cm} = -\frac{g_{m1,2}}{g_{m3,4}} \cdot \frac{1}{1 + g_{m1,2} \cdot 2r_{o5}}$$

2) ⓐ Small signal equivalent circuit:



$$\left.\begin{array}{l} i_g = j\omega C_{gs} V_{gs} \\ i_d = -g_m V_{gs} \end{array}\right\} \quad \frac{i_d}{i_g} = \frac{-g_m}{j\omega C_{gs}}$$

$$\left|\frac{i_d}{i_g}\right| = \frac{g_m}{\omega C_{gs}} = \frac{g_m}{2\pi f C_{gs}} = 1 \iff \boxed{f_T = \frac{g_m}{2\pi C_{gs}}}$$

(Ignoring C_{gb} and C_{gd})

ⓑ

$$f_T = \frac{g_m}{2\pi C_{gs}} = \frac{\mu_n C_{ox} W/L \, (V_{GS} - V_T)}{2\pi \, \frac{2}{3} WL \, C_{ox}}$$

$$\Rightarrow \boxed{f_T = \frac{3}{4\pi} \frac{\mu_n (V_{GS} - V_T)}{L^2}}$$