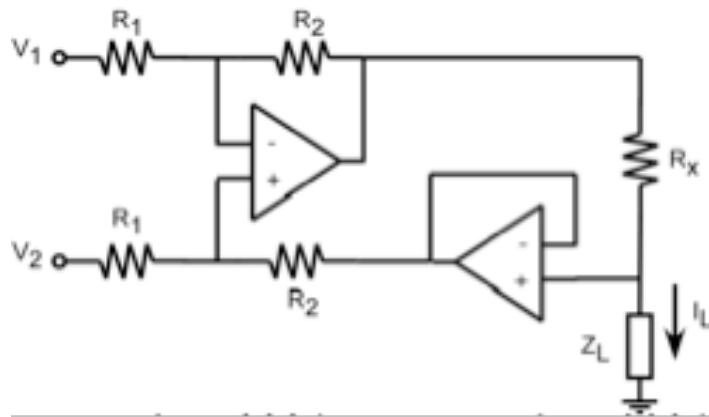


Examen 3

Discusión

INEL4202 - Diciembre 2009



I. Assuming ideal operation of the amplifiers ($A_v = \infty$), find the expression for I_L in terms of the differential voltage $v_2 - v_1$ and the resistors R_x , R_1 , and R_2

$$v_+ = V_L + \frac{v_2 - v_L}{R_1 + R_2} R_2 = \frac{R_1}{R_1 + R_2} v_L + \frac{R_2}{R_1 + R_2} v_2$$

$$i_{R1} = \frac{v_1 - v_-}{R_1} = \frac{v_1}{R_1} - \frac{1}{R_1 + R_2} v_L - \frac{R_2}{R_1} \frac{1}{R_1 + R_2} v_2$$

$$v_{OA1} = v_- - i_{R1} R_2$$

$$= \frac{R_1}{R_1 + R_2} v_L + \frac{R_2}{R_1 + R_2} v_2 - \frac{R_2}{R_1} v_1 + \frac{R_2}{R_1 + R_2} v_L + \frac{R_2}{R_1} \frac{R_2}{R_1 + R_2} v_2$$

$$= v_L + \left(1 + \frac{R_2}{R_1}\right) \frac{R_2}{R_1 + R_2} v_2 - \frac{R_2}{R_1} v_1$$

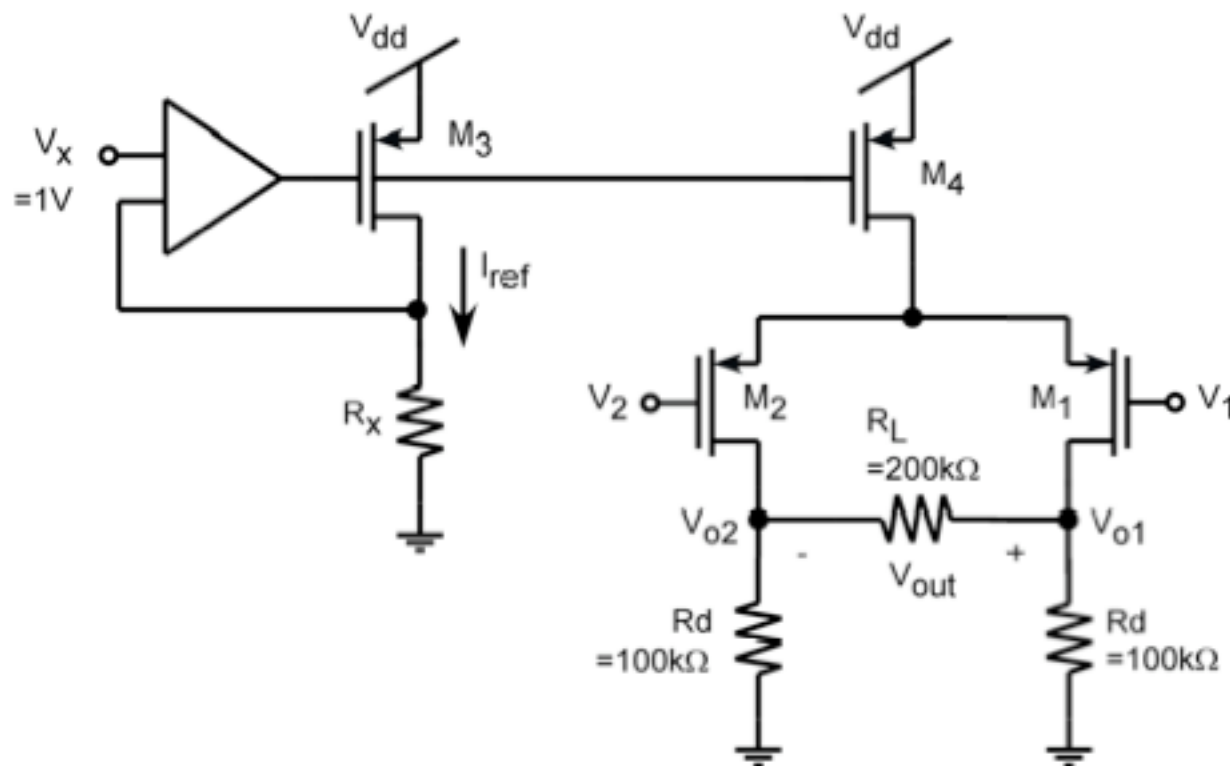
$$= v_L + \frac{R_2}{R_1} (v_2 - v_1)$$

$$i_L = \frac{v_{OA1} - v_L}{R_x} = \boxed{\frac{R_2}{R_x R_1} (v_2 - v_1)}$$

II. For the following circuit, where V_x is DC bias voltage:

- determine the correct polarity of the amplifier terminals so that it works properly with negative feedback
- determine the value of the resistor R_x for a reference current of $10\mu\text{A}$
- find the differential mode gain $A_d = V_{\text{out}}/V_{\text{id}}$ (use $I_{\text{ref}} = 10\mu\text{A}$)
- determine the common mode gain $A_{\text{cm}} = V_{\text{o1}}/V_{\text{cm}}$ (use $I_{\text{ss}} = 10\mu\text{A}$)

Assume: Ideal Amplifier ($A_v = \infty$), $K_p = 500\mu\text{A}/\text{V}^2$, $K_{p4}/K_{p3} = 2$, $\lambda_{p1} = \lambda_{p2} = 0$, $\lambda_{p4} = 0.01\text{V}^{-1}$



a) $v_2 = +; v_1 = -$

b) $R_x = 1\text{V} / 10\mu\text{A} = 100\text{k}\Omega$

$$\begin{aligned}
 \text{c)} \quad R'_d &= 100k\Omega \parallel \frac{200k\Omega}{2} = 50k\Omega \\
 A_d &= \frac{v_{OUT}}{v_{id}} = g_m R'_d = 2\sqrt{500\mu A/V^2 \times 10\mu A} \times 50k\Omega \\
 &= 2 \times 70.7\mu A/V \times 50k\Omega = \boxed{7V/V}
 \end{aligned}$$

$$\begin{aligned}
 \text{d)} \quad r_{O4} &= \frac{1}{\lambda_{P4} I_{Q4}} = \frac{100V}{20\mu A} = 5M\Omega \\
 A_{CM} &= \frac{g_{m1} R_d}{1 + 2g_{m1} r_{O4}} = \frac{2 \times 70.7\mu A/V^2 \times 100k\Omega}{1 + 2 \times 2 \times 70.7\mu A/V^2 \times 5M\Omega} = \frac{14.14}{1415} \\
 A_{CM} &\simeq \boxed{.01V/V}
 \end{aligned}$$

III. For the following CMOS amplifier, where V_{b1} and V_{b2} are DC voltages for proper operation of the circuit:

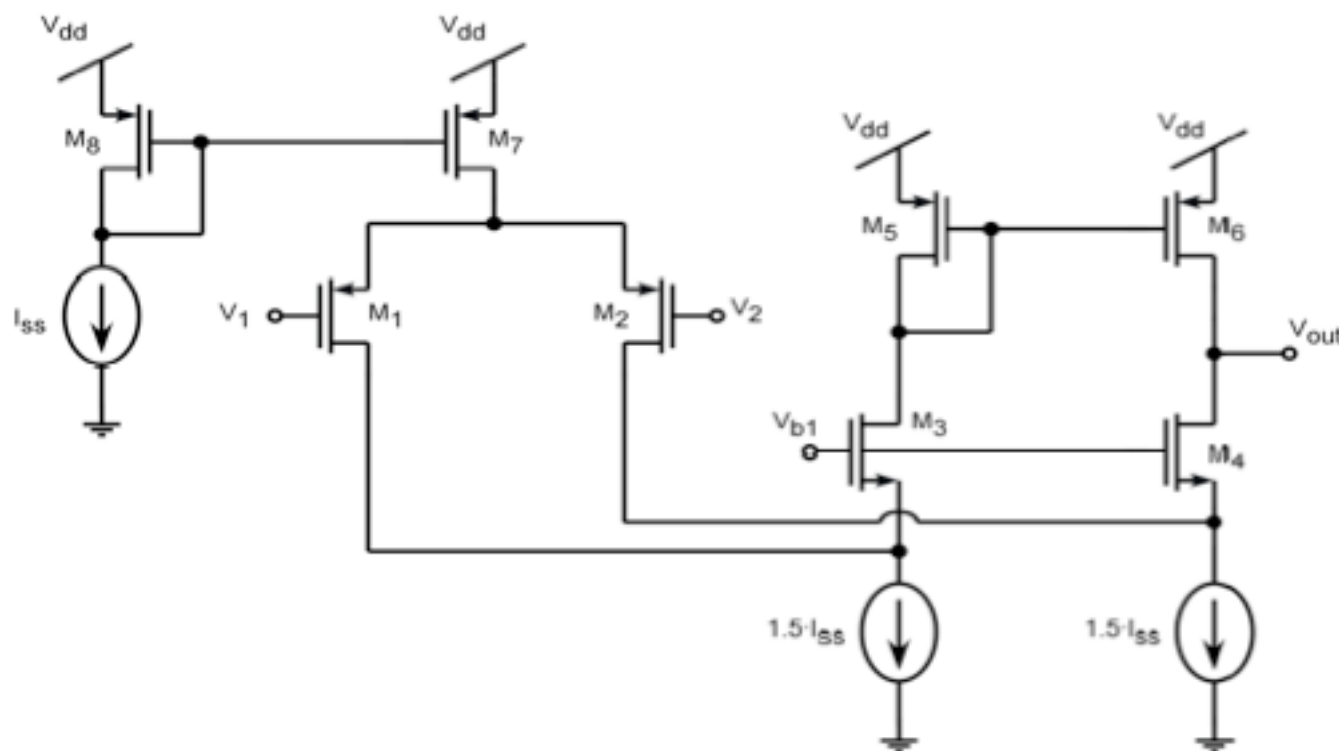
- identify the negative and the positive terminals
- find the expression for the differential gain $A_{id} = V_{out}/V_{id}$
- find the expression for the differential input resistance R_{ind}
- find the expression for the output resistance R_{out}

Assume: I_{ss} = ideal current source

a)

$$v_1 \uparrow \Rightarrow i_{d1} \uparrow \Rightarrow i_{d5} \downarrow \Rightarrow i_{d6} \downarrow$$

$$\therefore v_1 \text{ is } + ; v_2 \text{ is } -$$



$$\begin{aligned}
 \text{b)} \quad A_{id} &= \frac{v_{OUT}}{v_{id}} = g_{m1} R_O \\
 R_O &= r_{O6} \parallel r_{O4} (1 + g_{m4} r_{O2}) \\
 g_{m1} &= 2\sqrt{K_P I_{SS}/2} & g_{m4} &= 2\sqrt{K_N I_{SS}} \\
 r_{O6} &= \frac{1}{\lambda_{P6} I_{SS}} & r_{O2} &= \frac{2}{\lambda_{P2} I_{SS}} \\
 r_{O4} &= \frac{1}{\lambda_{N4} I_{SS}}
 \end{aligned}$$

$$\text{c)} \quad R_{ind} = \infty$$

$$\begin{aligned}
 \text{d)} \quad R_O &= r_{O6} \parallel r_{O4} (1 + g_{m4} r_{O2}) \\
 g_{m1} &= 2\sqrt{K_P I_{SS}/2} & g_{m4} &= 2\sqrt{K_N I_{SS}} \\
 r_{O6} &= \frac{1}{\lambda_{P6} I_{SS}} & r_{O2} &= \frac{2}{\lambda_{P2} I_{SS}} \\
 r_{O4} &= \frac{1}{\lambda_{N4} I_{SS}}
 \end{aligned}$$