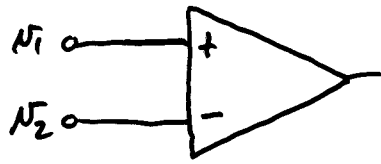
Differential Amplifiers



$$v_{out} = A_{Nd}(v_1 - v_2) \pm A_{cm}\left(\frac{v_1 + v_2}{2}\right)$$

$$= A_{dd}(v_{id}) \pm A_{cm}(v_{cm})$$

where, $v_{id} \equiv v_1 - v_2$ and $v_{cm} \equiv \frac{v_1 + v_2}{2}$

v_{id}: Differential signal

v_{cm}: Common (average) signal

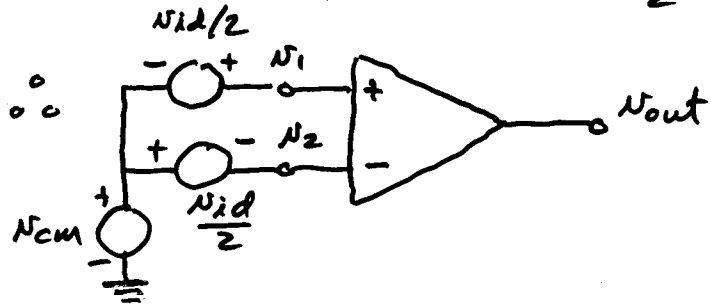
A good differential amplifier rejects the average signal and amplifies the difference signal.

Note: $v_{id} = v_1 - v_2$

$$2v_{cm} = v_1 + v_2$$

$$v_{id} + 2v_{cm} = 2v_1 \rightarrow v_1 = v_{cm} + \frac{v_{id}}{2}$$

Similarly, $v_2 = v_{cm} - \frac{v_{id}}{2}$



Types of analysis:

1.) Differential mode ($v_{cm} = 0$)

2.) Common mode ($v_{id} = 0$)

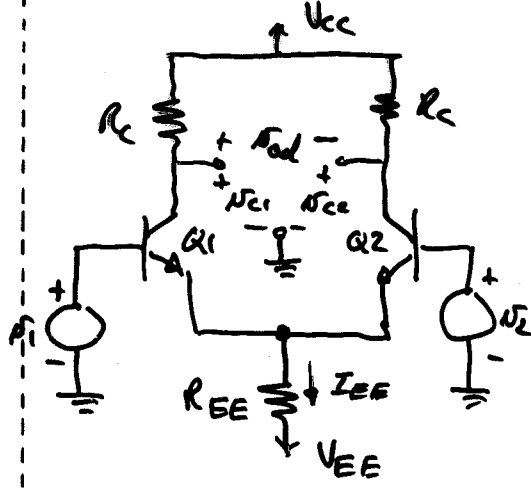
Much easier than trying to do the whole analysis.

Common Mode Rejection Ratio (CMRR):

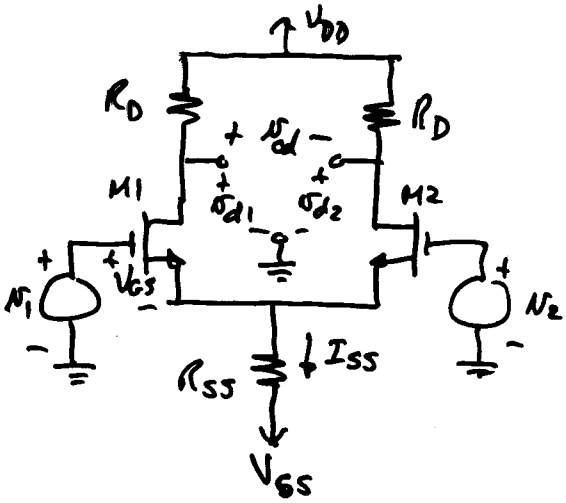
$$CMRR \equiv \frac{|A_{Nd}|}{|A_{cm}|} \quad \text{Ideal} \rightarrow \infty$$

Different Amplifier Circuits

BJT:



MOSFET:



DC Analysis (Assume $V_{i1} = V_{i2} = 0$)

$$I_{EE} = \frac{|V_{EE}| - V_{BE}}{R_{EE}}$$

$$I_{E1} = I_{E2} = \frac{I_{EE}}{2}$$

$$I_{C1} = I_{C2} = \alpha \frac{I_{EE}}{2}$$

Guessing V_{BE} gives I_{EE}.

$$I_{SS} = \frac{|V_{SS}| - V_{GS}}{R_{SS}}$$

$$I_{D1} = I_{D2} = \frac{I_{SS}}{2}$$

$V_{DD} = 5$, $V_{SS} = -5V$, $R_{SS} = 10K$, $R_D = 10K$

$K_N = 1mA/V^2$ & $V_{TN} = 1V$

$$|V_{SS}| = V_{GS} + I_{SS} R_{SS}$$

$$I_{SS} = 2I_D = 2\frac{K_n}{2}(V_{GS} - V_T)^2$$

$$|V_{SS}| = V_{GS} + R_{SS} K_n (V_{GS} - V_T)^2$$

$$V_{GS}^2 - 1.9 V_{GS} + 0.5 = 0$$

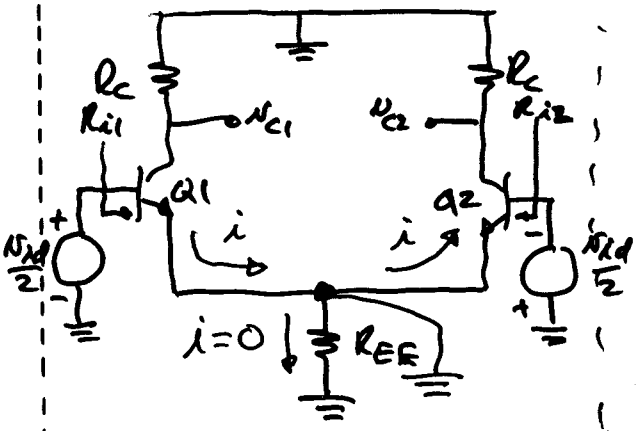
$$V_{GS} = 1.542V$$

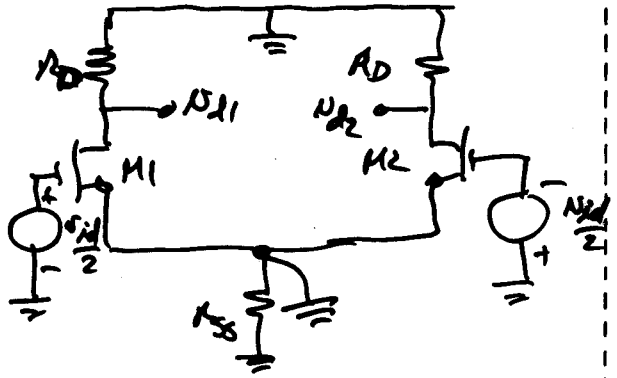
$\therefore I_{DS} = 171mA$

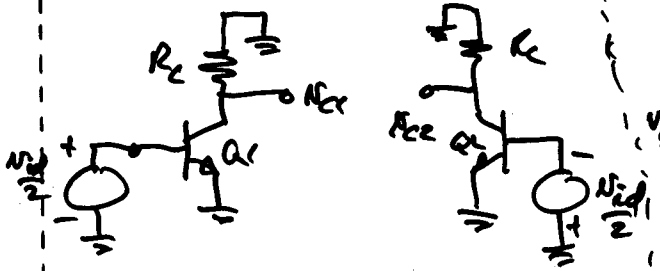
$V_{DS} = 4.276V$

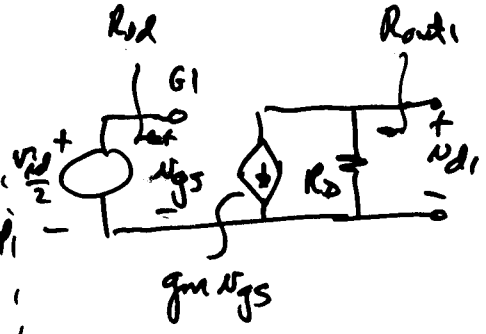
$\therefore$ saturated

Differential Mode Analysis (Small-signal)









$$\frac{V_{c1}}{V_{ic}} = -g_m R_L \qquad \frac{V_{c1}}{V_{id}} = -\frac{g_m R_L}{2}$$

$$R_{id1} = r_{\pi 1} \qquad R_{id2} = r_{\pi 2}$$

$$R_{out1} = R_C \qquad R_{out2} = R_C$$

$$R_{id} = 2r_\pi$$

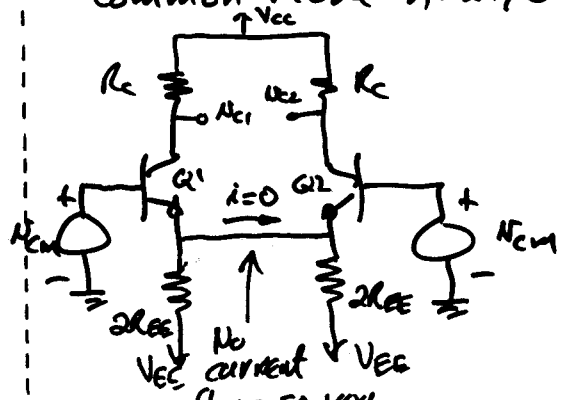
$$R_{od} = 2R_C$$

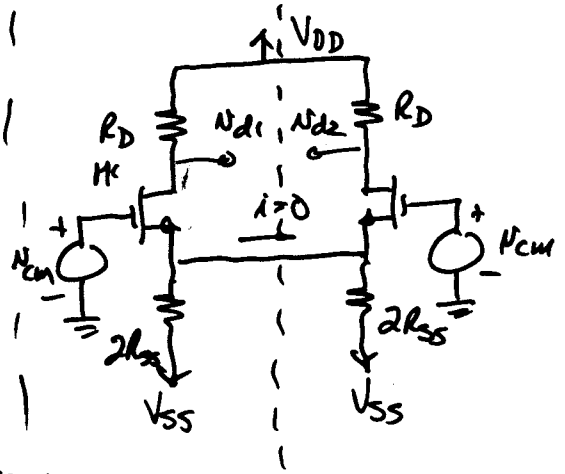
$$\frac{V_{d1}}{V_{id}} = -\frac{1}{2} g_m R_D$$

$$R_{id1} = \infty \qquad R_{out1} = R_D$$

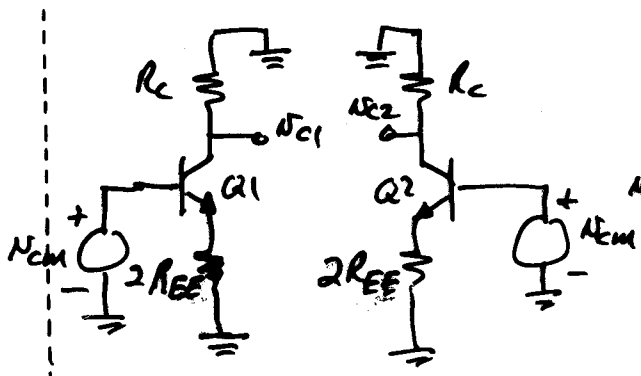
$$R_{id} = \infty \qquad R_{od} = 2R_D$$

Common Mode Analysis

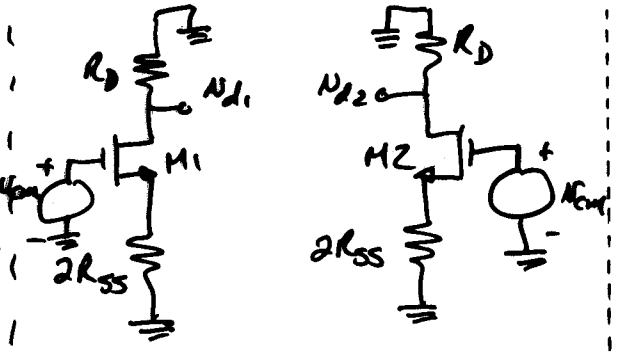




Eq. ckt. for cm analysis:



Analyze either one



Analyze either one

Note: The cm analysis is essentially a common nothing circuit.