Fundamentals of Microelectronics II

فصل ۱۰- تقویت کننده های تفاضلی

(قسمت سوم- زوج تفاضلی با بار فعال)

Mohammad Ali Mansouri- Birjandi

Majid Ghadrdan

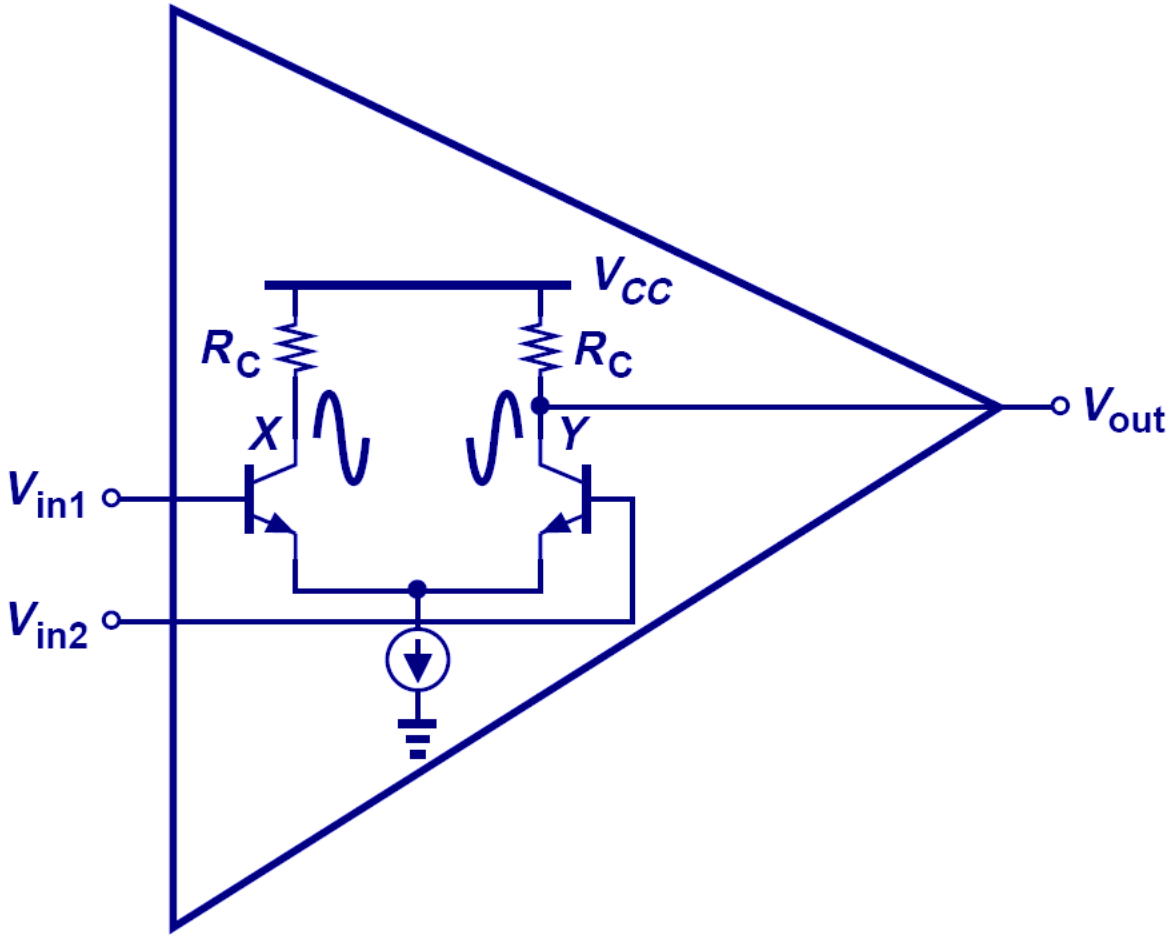
Faculty of Electrical and Computer Engineering
University of Sistan and Baluchestan (USB)

mansouri@ece.usb.ac.ir ,
mamansouri@yahoo.com

Chapter 10 Differential Amplifiers

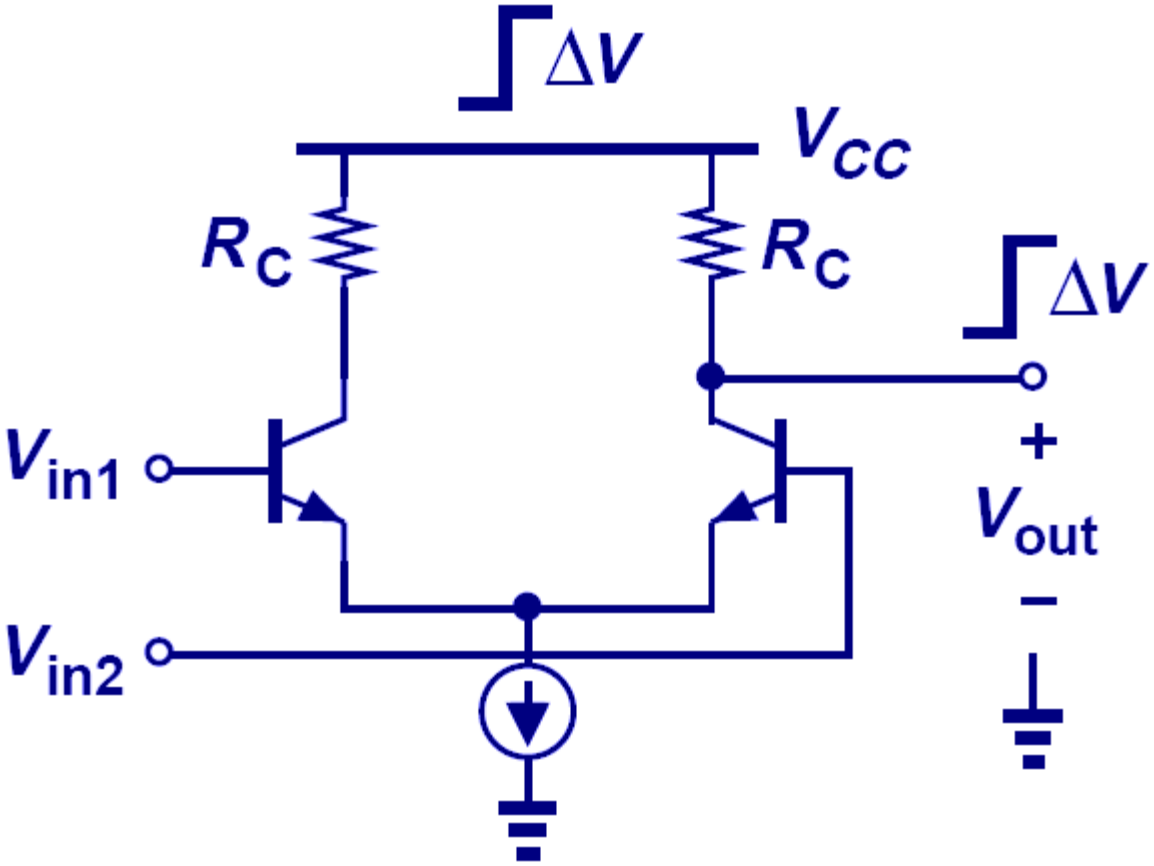
10.6 Differential Pair with Active Load

Differential to Single-ended Conversion



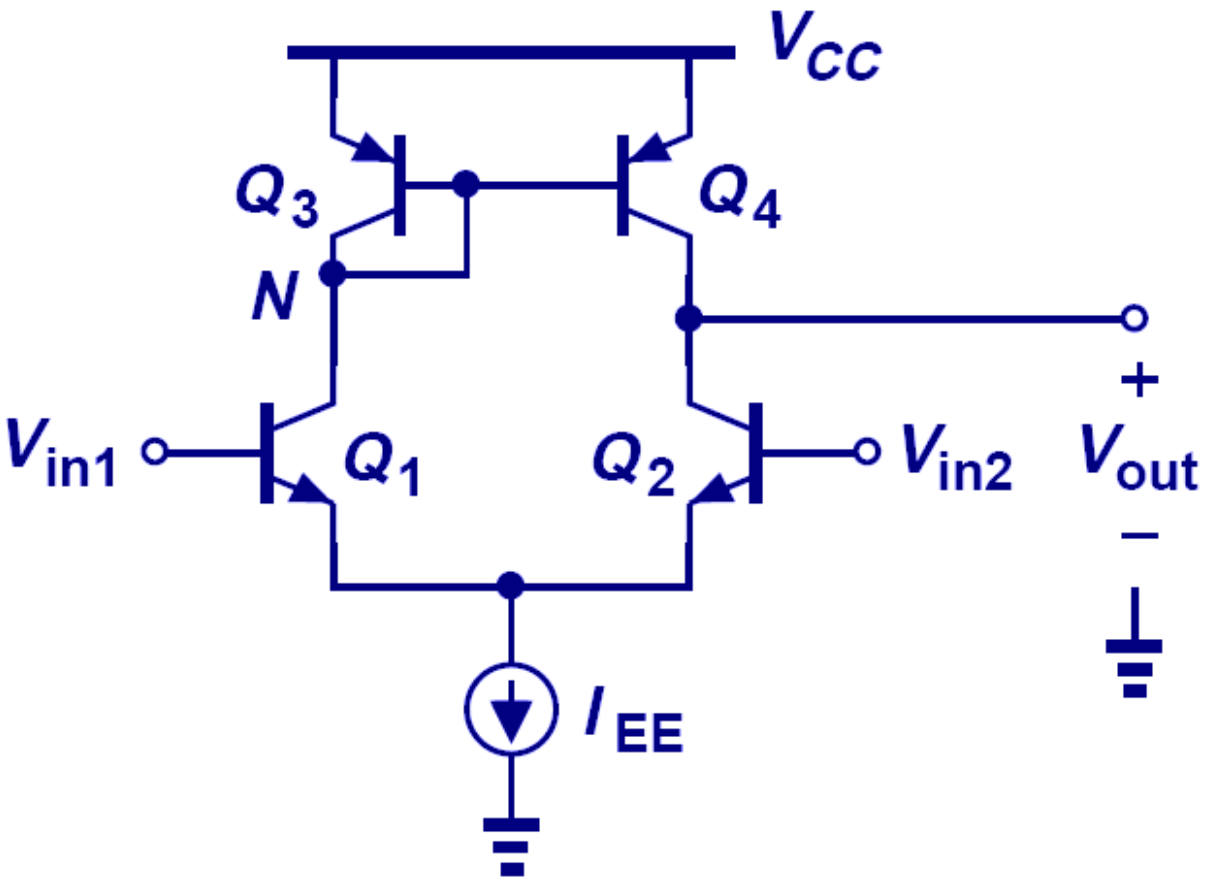
- **Many circuits require a differential to single-ended conversion, however, the above topology is not very good.**

Supply Noise Corruption



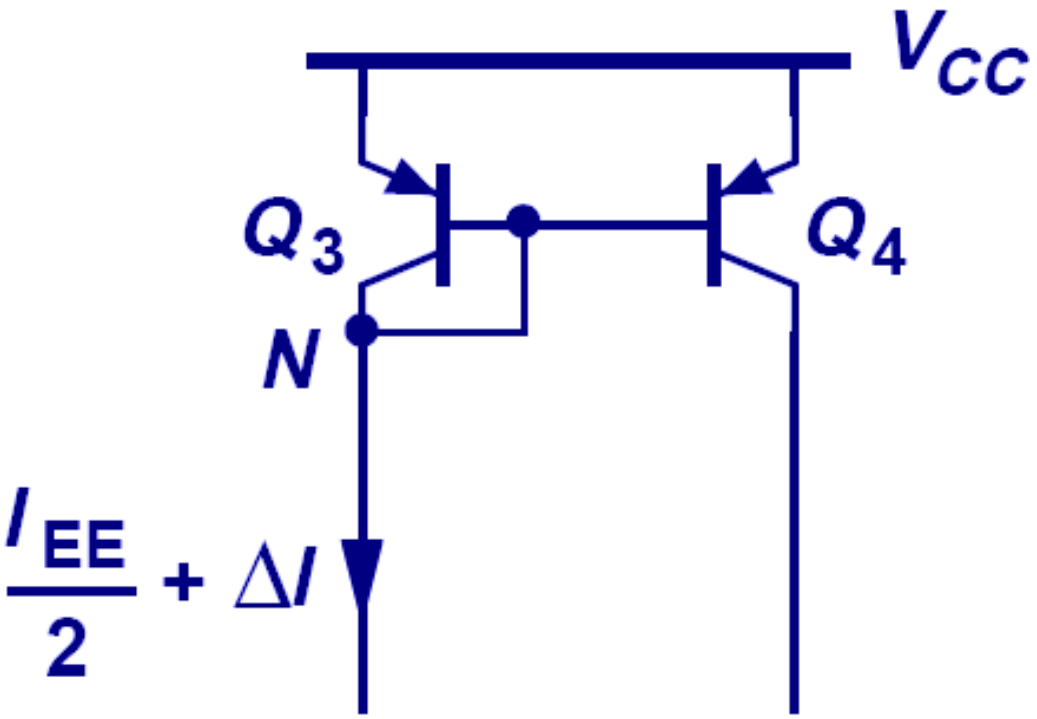
- **The most critical drawback of this topology is supply noise corruption, since no common-mode cancellation mechanism exists. Also, we lose half of the signal.**

Better Alternative



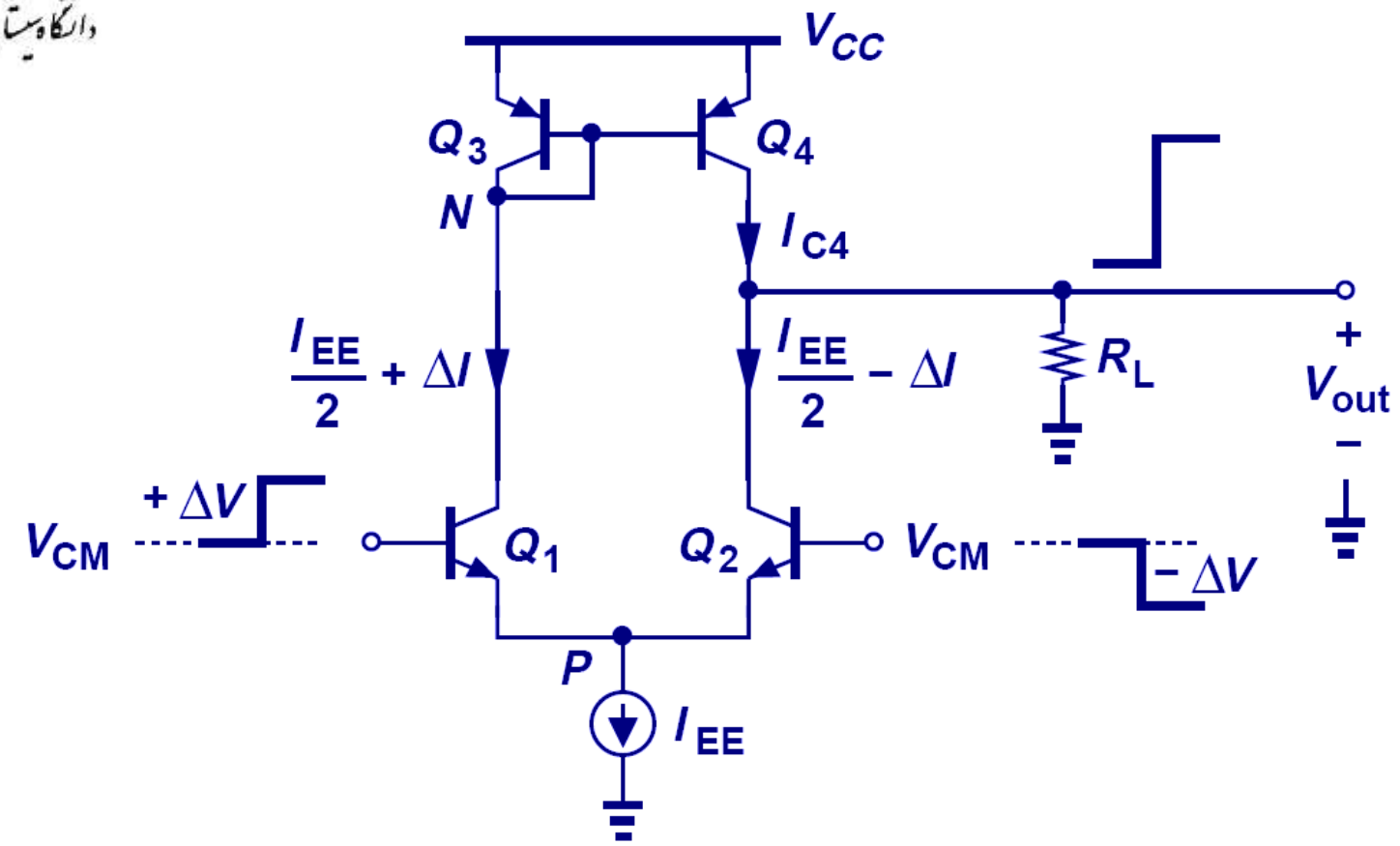
- **This circuit topology performs differential to single-ended conversion with no loss of gain.**

Active Load



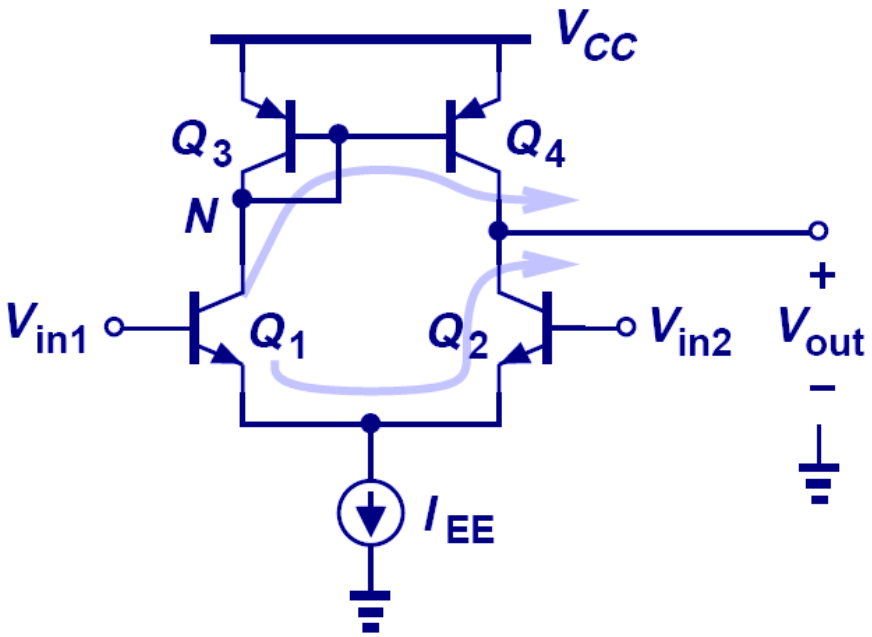
- With current mirror used as the load, the signal current produced by the Q_1 can be replicated onto Q_4.
- This type of load is different from the conventional “static load” and is known as an “active load”.

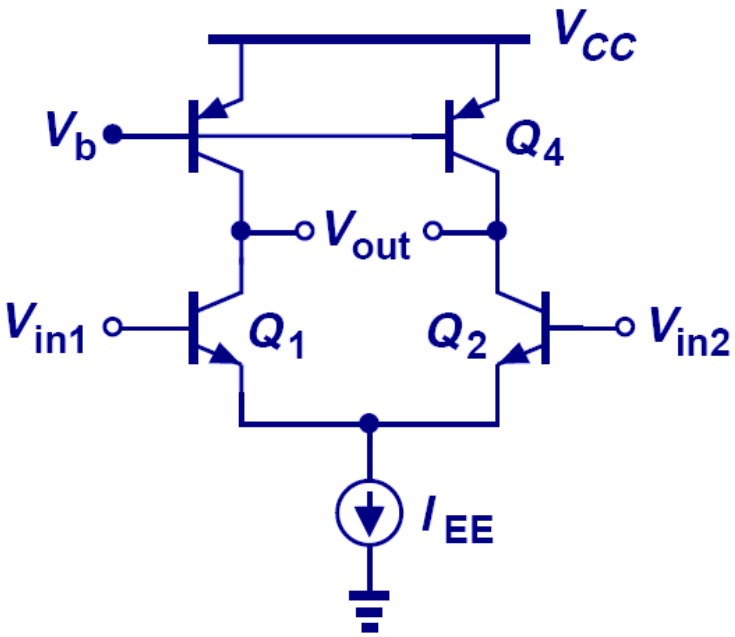
Differential Pair with Active Load



- **The input differential pair decreases the current drawn from R_L by ΔI and the active load pushes an extra ΔI into R_L by current mirror action; these effects enhance each other.**

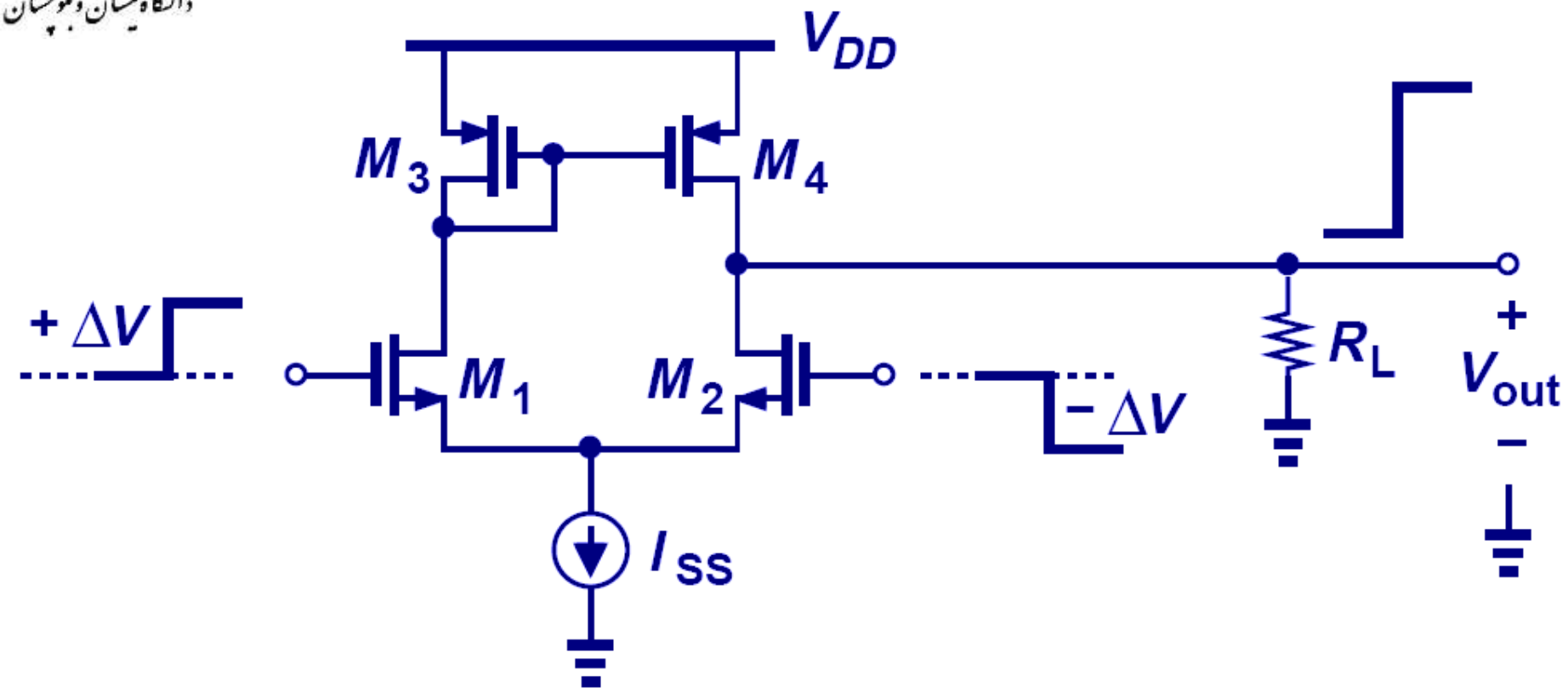
Active Load vs. Static Load





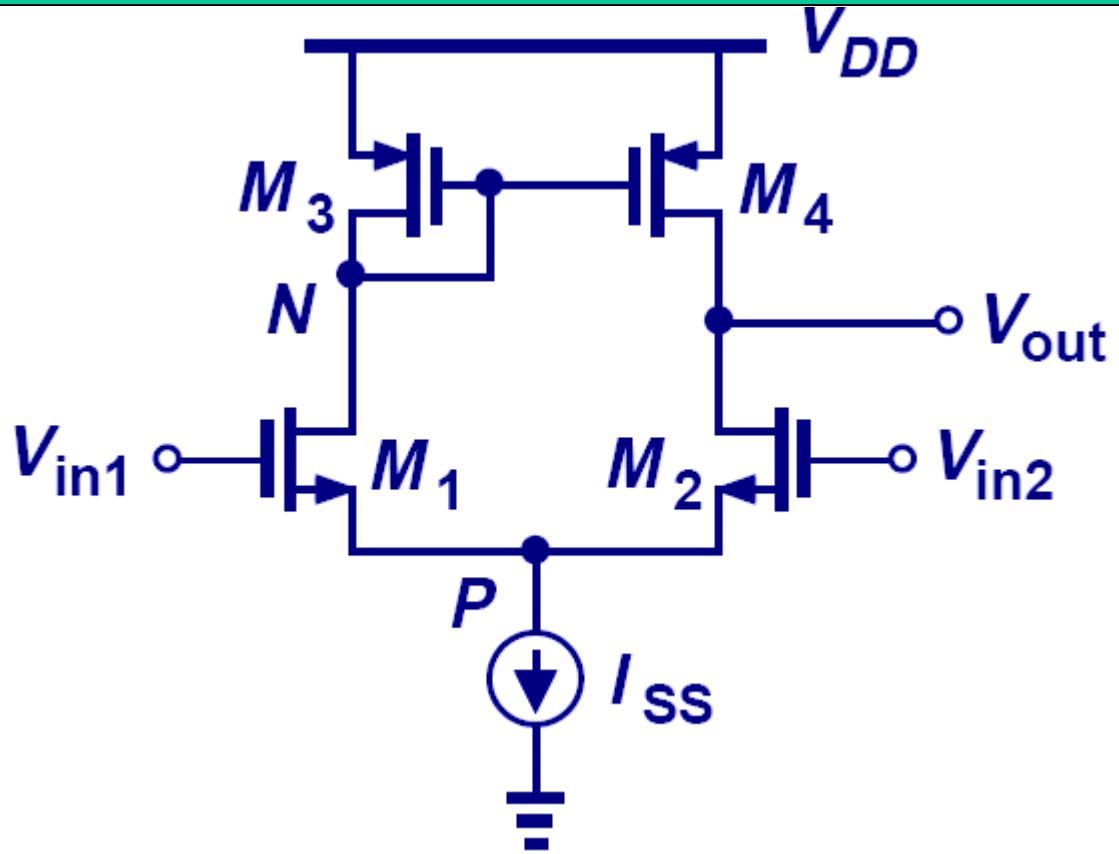
- **The load on the left responds to the input signal and enhances the single-ended output, whereas the load on the right does not.**

MOS Differential Pair with Active Load



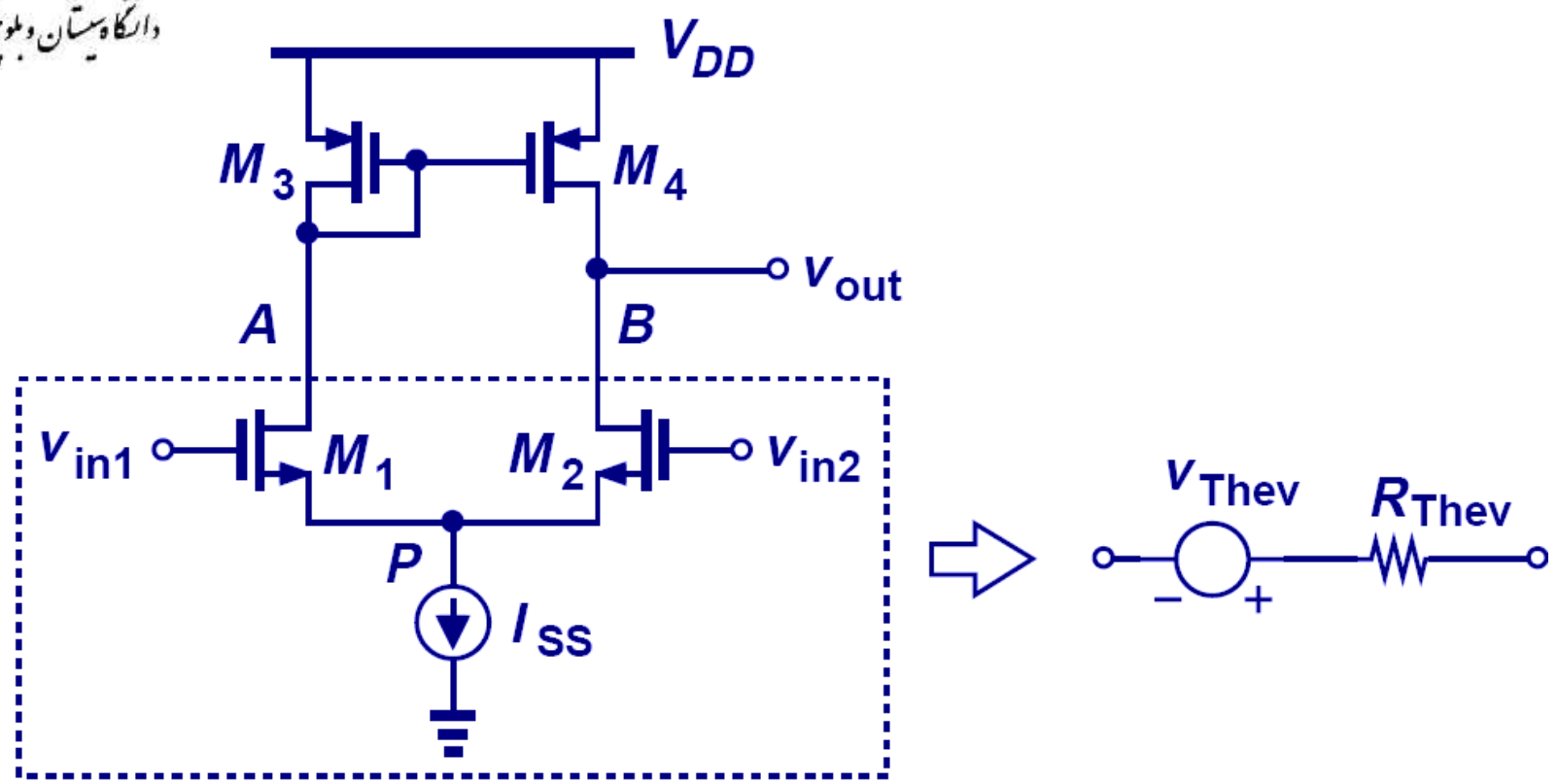
- **Similar to its bipolar counterpart, MOS differential pair can also use active load to enhance its single-ended output.**

Asymmetric Differential Pair



- **Because of the vastly different resistance magnitude at the drains of M_1 and M_2, the voltage swings at these two nodes are different and therefore node P cannot be viewed as a virtual ground.**

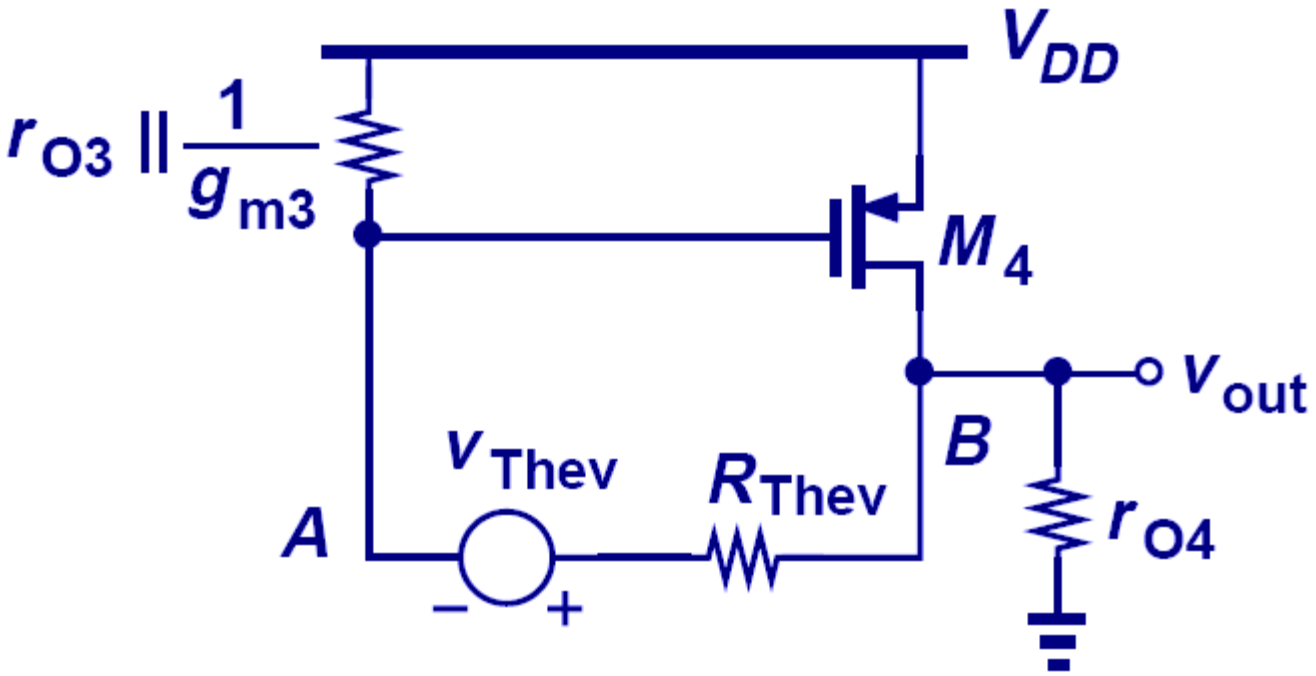
Thevenin Equivalent of the Input Pair



$$v_{Thev} = -g_{mN} r_{oN} (v_{in1} - v_{in2})$$

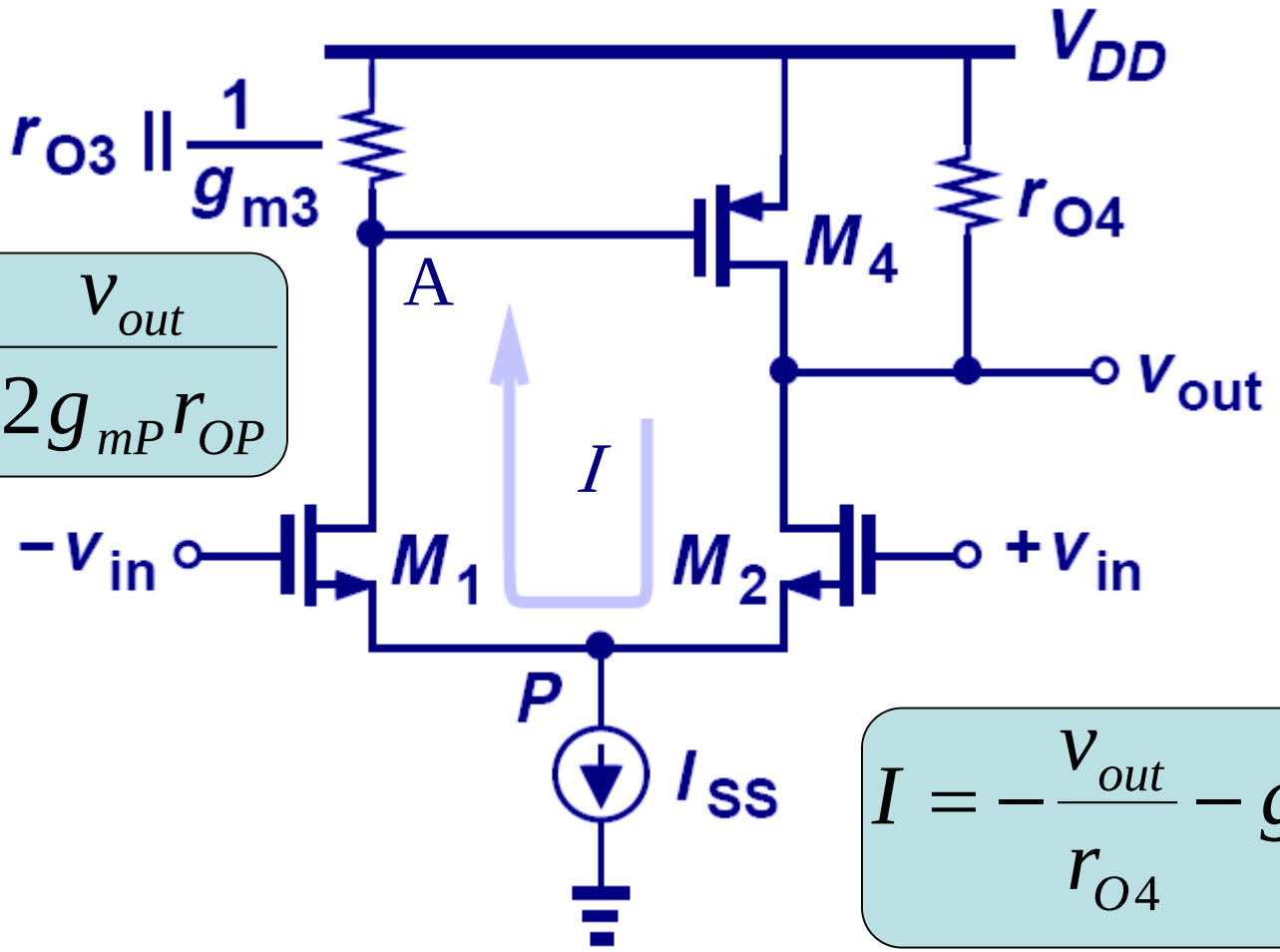
$$R_{Thev} = 2r_{oN}$$

Simplified Differential Pair with Active Load



$$\frac{v_{out}}{v_{in1} - v_{in2}} = g_{mN}(r_{ON} \| r_{OP})$$

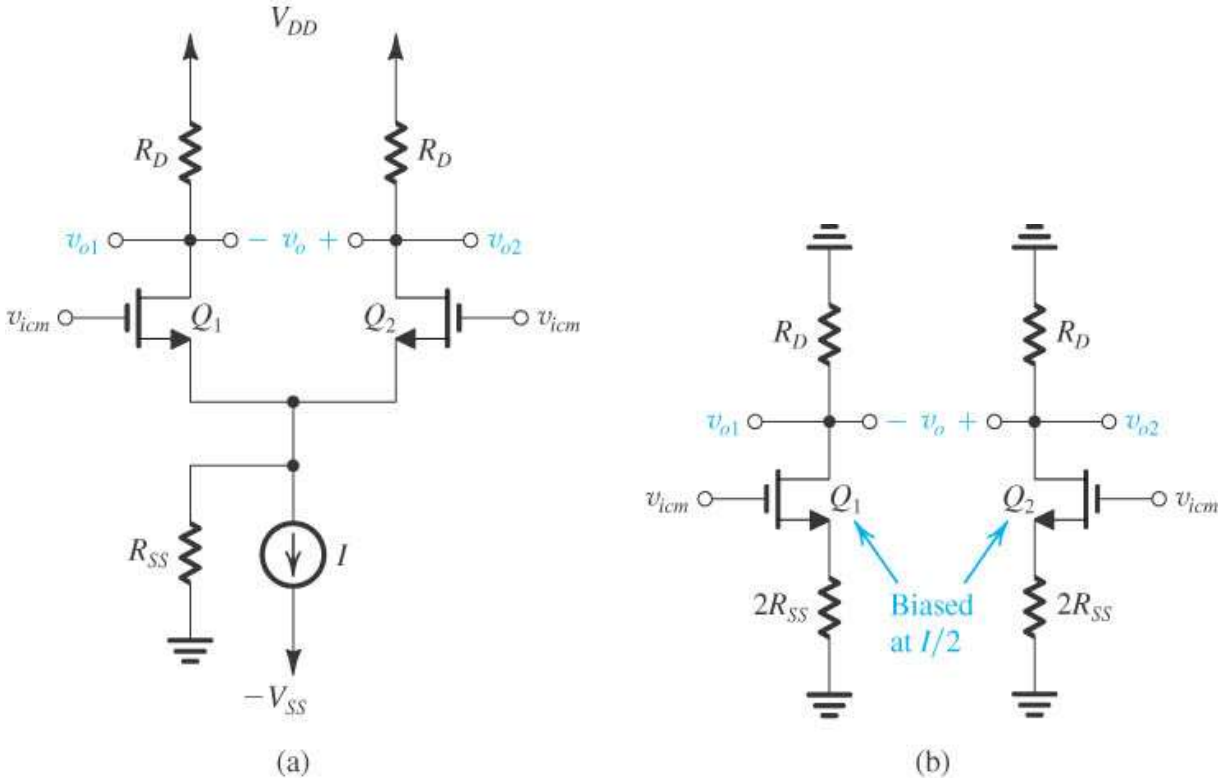
Proof of $V_A << V_{out}$



$$v_A \approx -\frac{v_{out}}{2g_{mP}r_{OP}}$$

$$I = -\frac{v_{out}}{r_{O4}} - g_{m4}v_A$$

Common-mode input signal

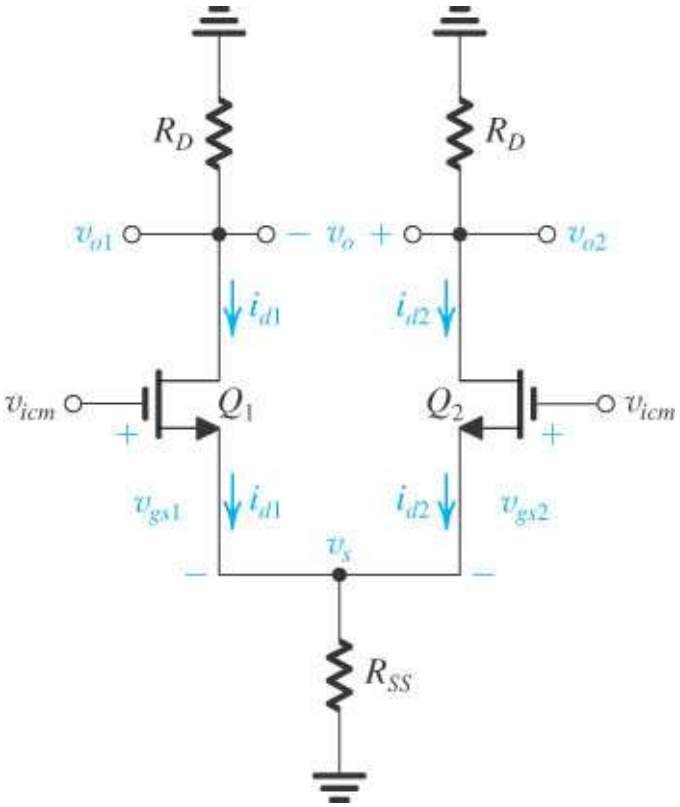


(a) The MOS differential amplifier with a common-mode input signal v_{ic}

(b) Equivalent circuit for determining the common-mode gain (with r_o ignored).

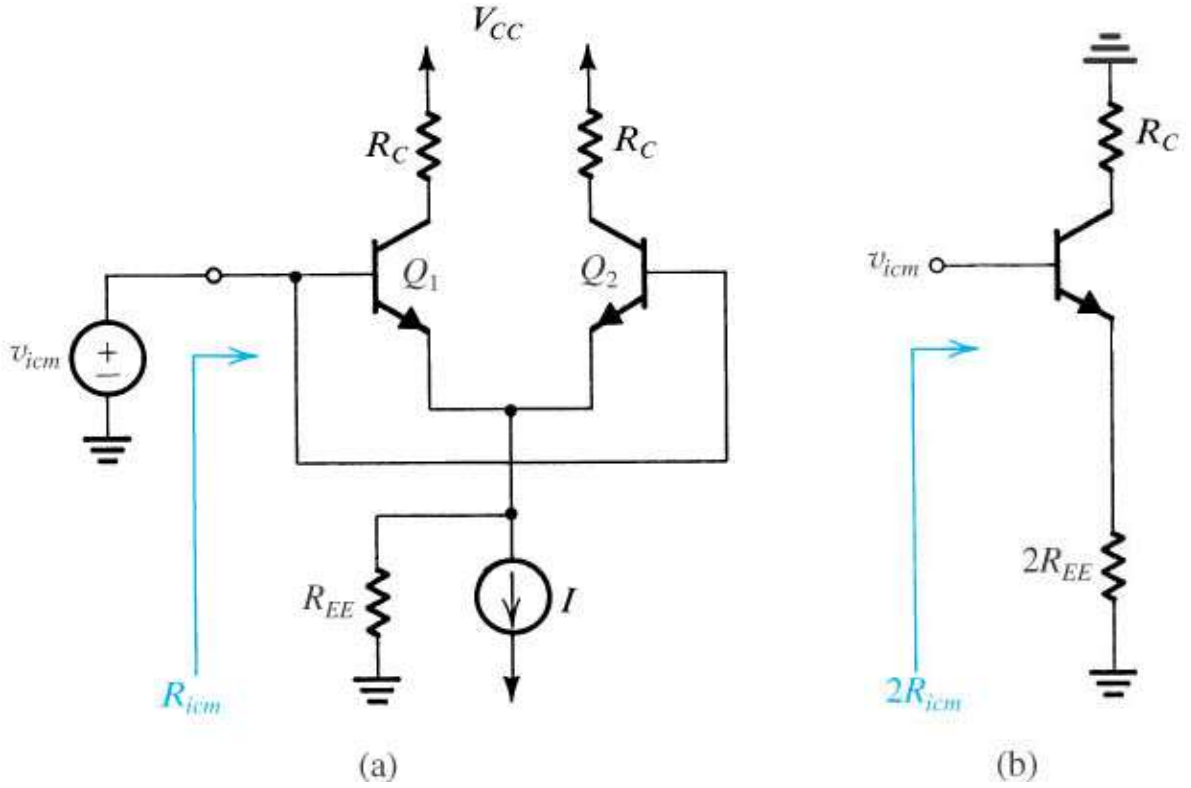
Each half of the circuit is known as the "**common-mode half-circuit**."

Common-Mode Gain



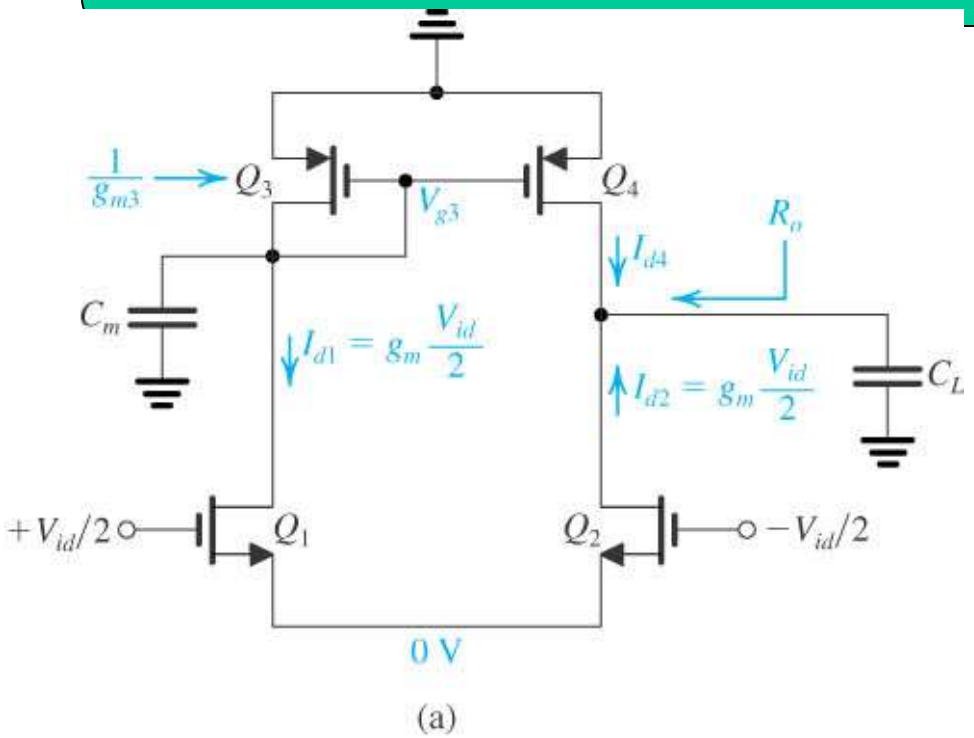
Analysis of the MOS differential amplifier to determine the common-mode gain resulting from a mismatch in the g_m values of Q_1 and Q_2.

input common-mode resistance R_{icm}

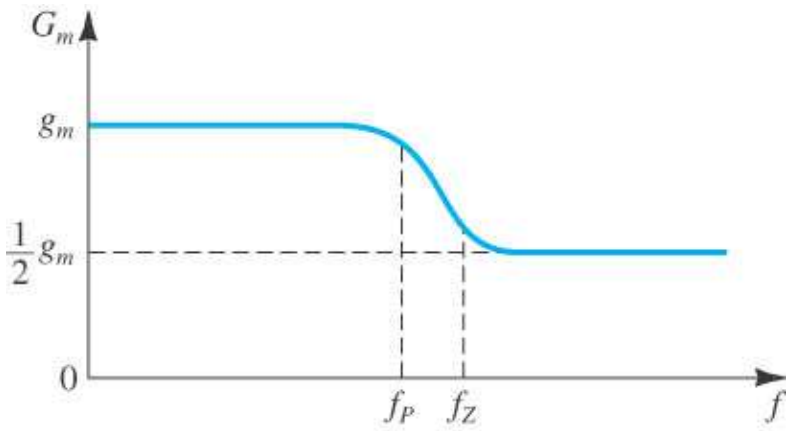


(a) Definition of the input common-mode resistance R_{icm}.

(b) The equivalent common-mode half-circuit.



(a)

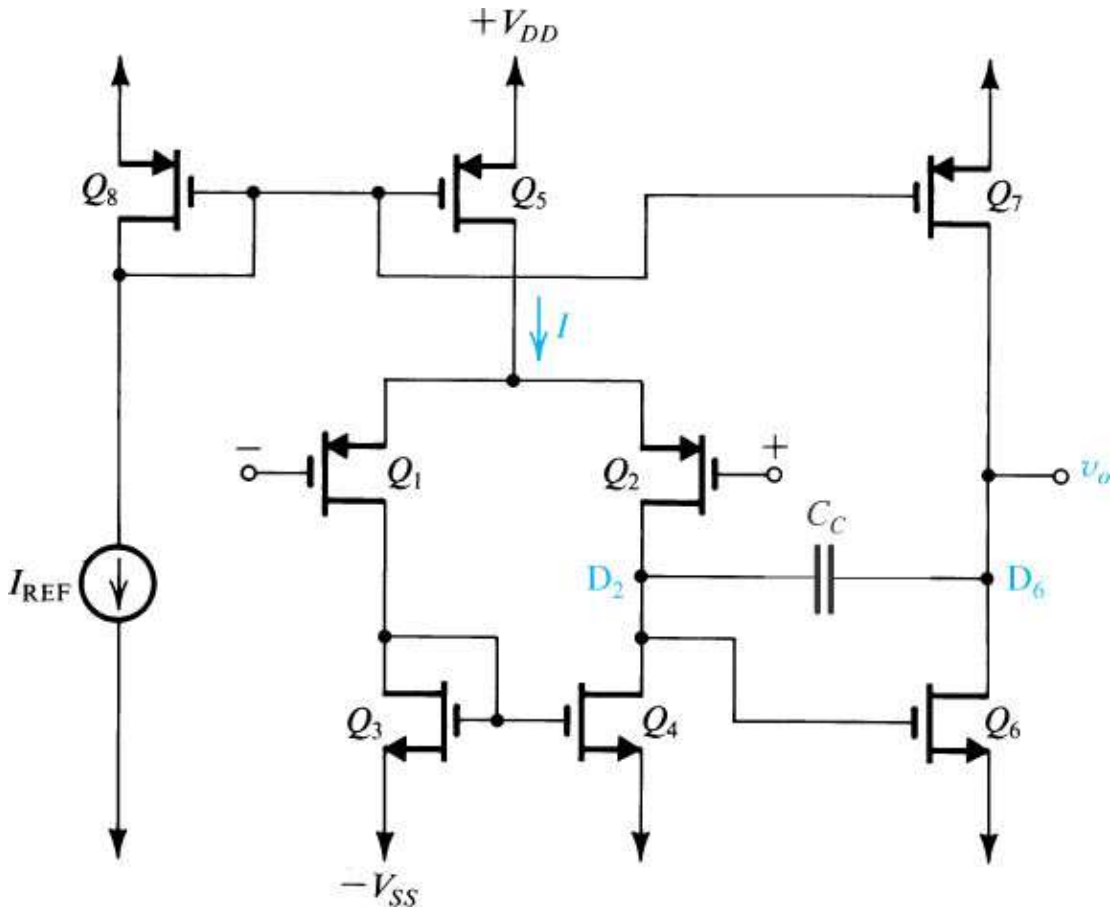


(b)

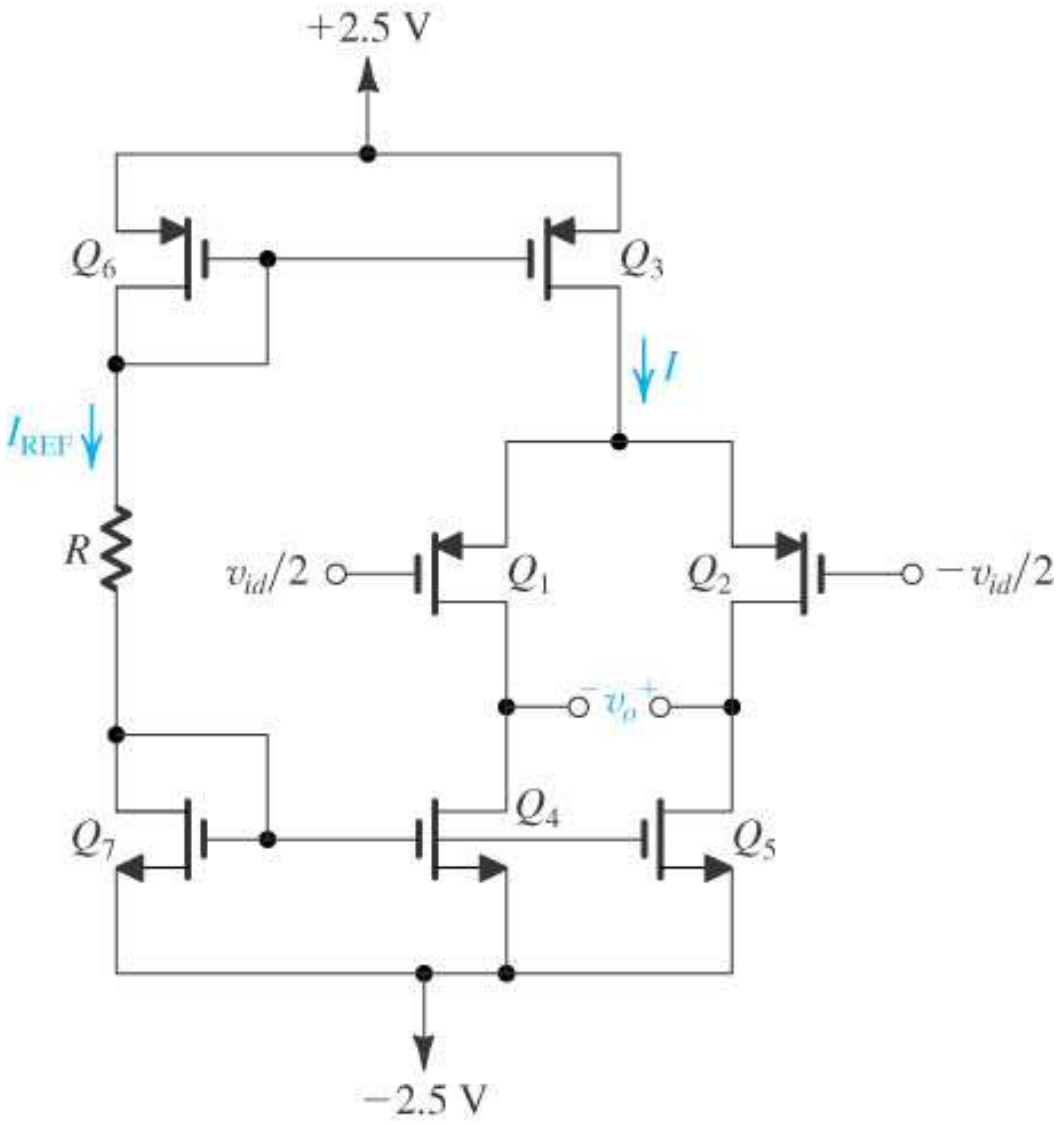
(a) Frequency-response analysis of the active-loaded MOS differential amplifier.

(b) The overall transconductance G_m as a function of frequency.

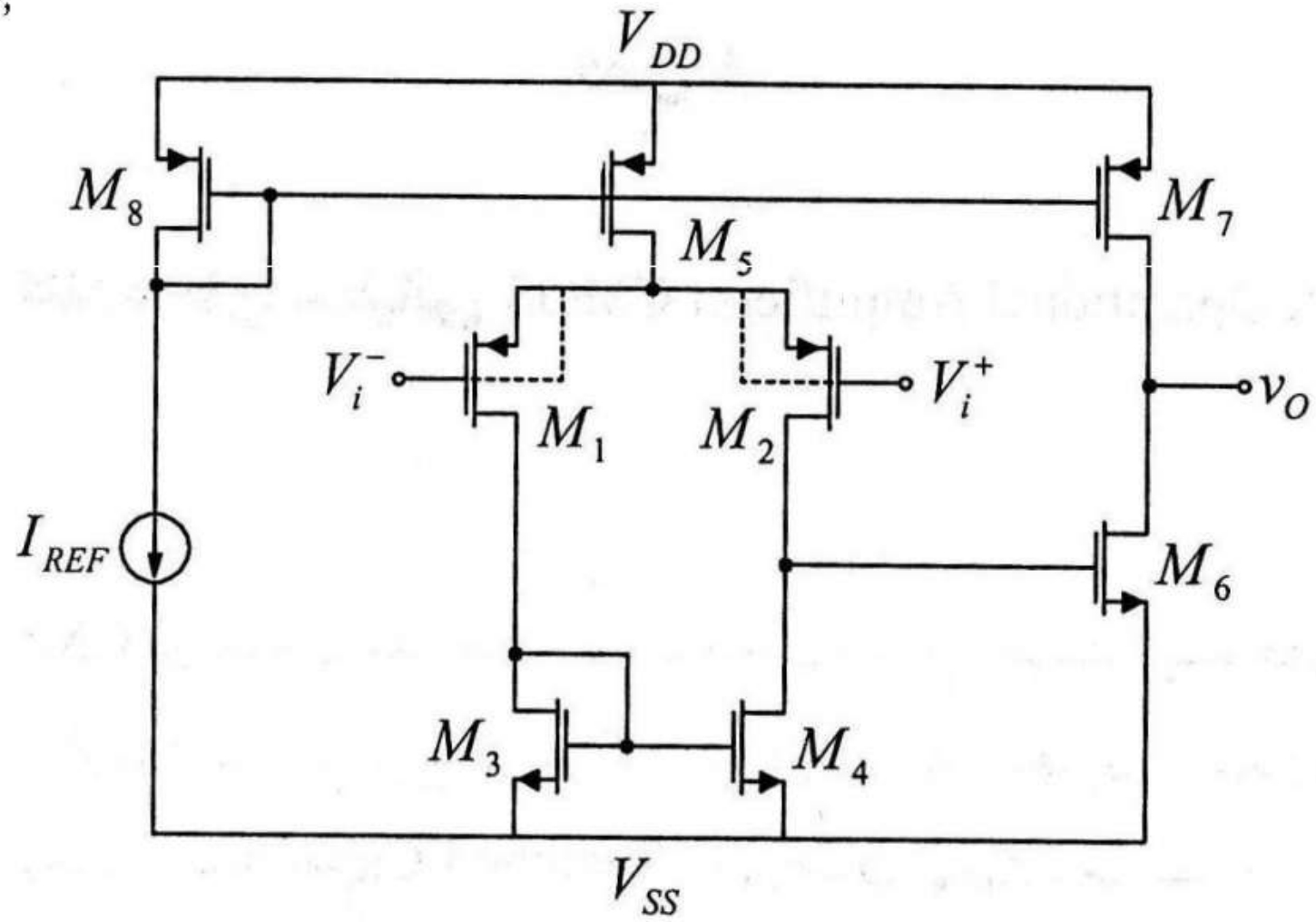
Two-stage CMOS op-amp configuration.



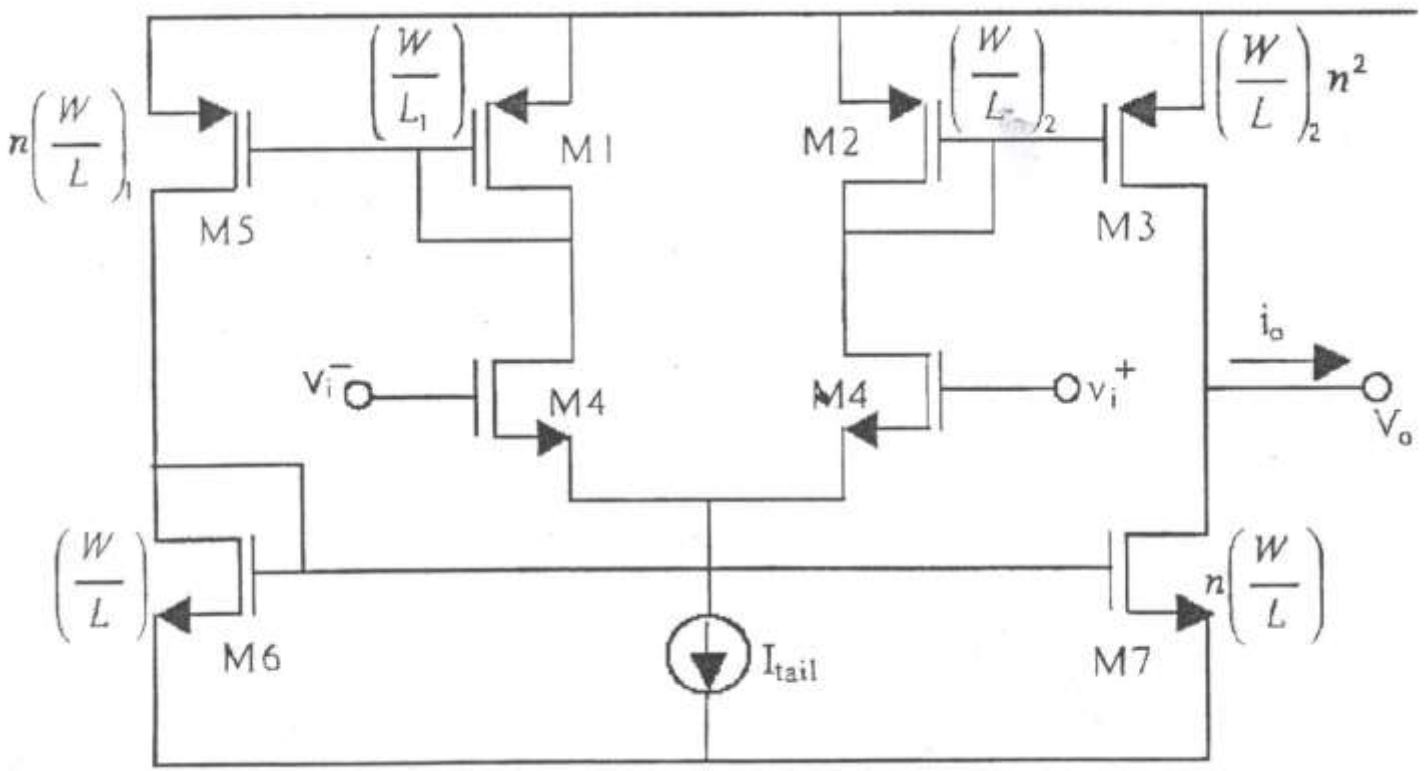
MOS Differential Amplifier



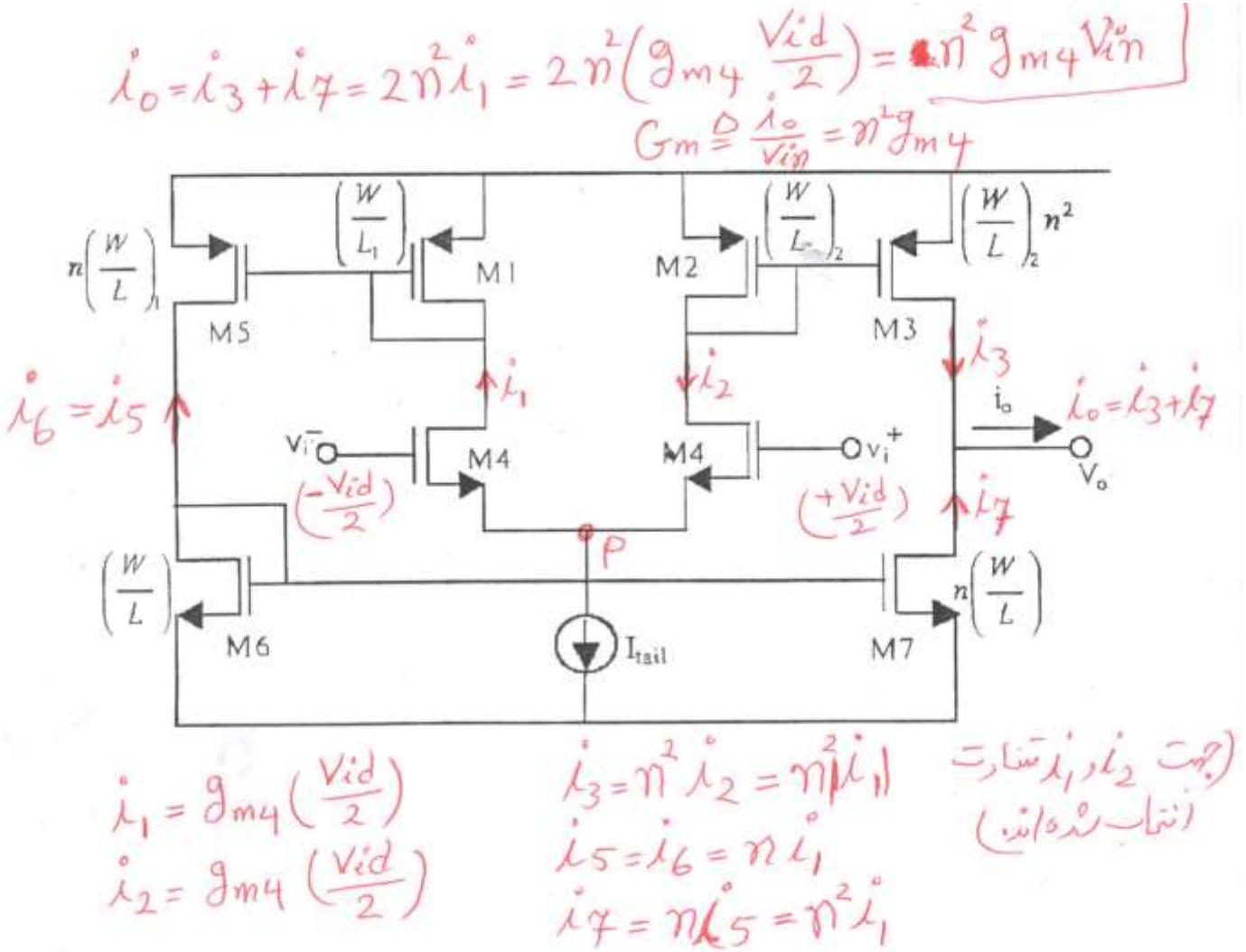
MOS Differential Amplifier



Example: Gm =?


$n\left(\frac{W}{L}\right)_1$
$\left(\frac{W}{L_1}\right)$
M1
M2
$\left(\frac{W}{L}\right)_2 n^2$
M5
M3
i_o
v_i^-
M4
M4
v_i^+
V_o
$\left(\frac{W}{L}\right)$
$n\left(\frac{W}{L}\right)$
M6
I_{tail}
M7

Example: Gm =?


$i_o = i_3 + i_7 = 2n^2 i_1 = 2n^2\left(g_{m4}\frac{V_{id}}{2}\right) = n^2 g_{m4} V_{in}$
$G_m \triangleq \frac{i_o}{V_{in}} = n^2 g_{m4}$
$n\left(\frac{W}{L}\right)_1$
$\left(\frac{W}{L_1}\right)$
M1
M2
$\left(\frac{W}{L}\right)_2$
$\left(\frac{W}{L}\right)_2 n^2$
M5
M3
$i_6 = i_5$
i_1
i_2
i_3
i_o
$i_o = i_3 + i_7$
v_i^-
M4
M4
v_i^+
V_o
$\left(-\frac{V_{id}}{2}\right)$
$\left(+\frac{V_{id}}{2}\right)$
i_7
P
$\left(\frac{W}{L}\right)$
M6
I_{tail}
M7
$n\left(\frac{W}{L}\right)$
$i_1 = g_{m4}\left(\frac{V_{id}}{2}\right)$
$i_2 = g_{m4}\left(\frac{V_{id}}{2}\right)$
$i_3 = n^2 i_2 = n^2 i_1$
$i_5 = i_6 = n i_1$
$i_7 = n i_5 = n^2 i_1$
(جهت i_2 و i_1 عکس شده‌اند)