Lecture 12: CMOS Amplifiers: The Differential Pair - Second Part

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Reference: Razavi (Fundamentals) - Chapter 10

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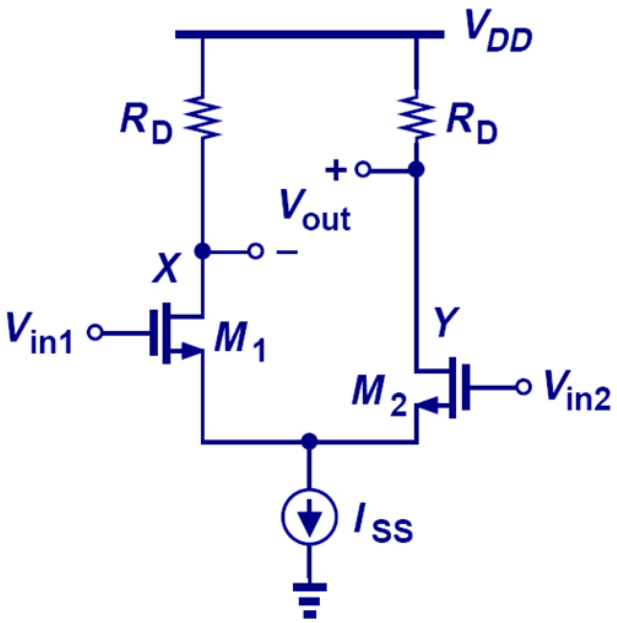
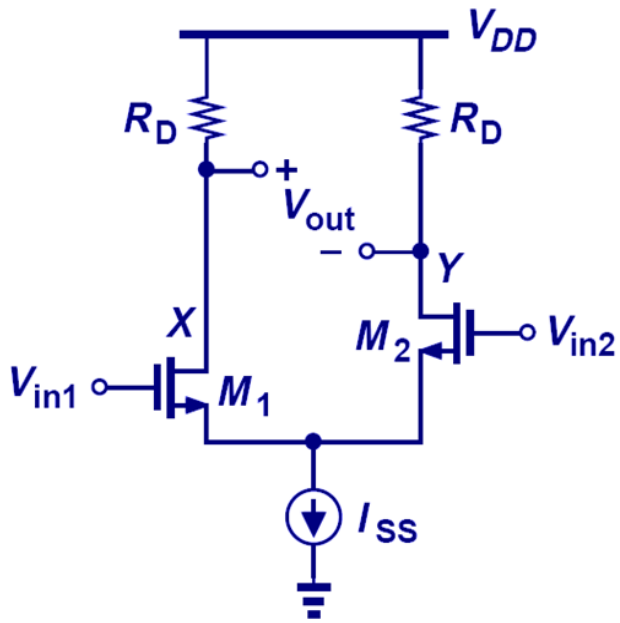
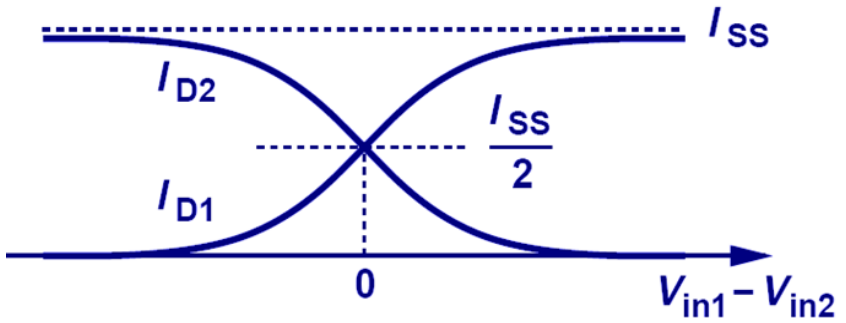
Differential Response

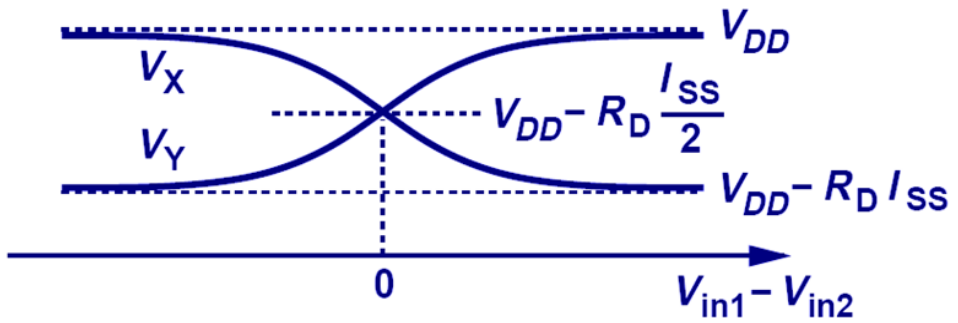


(a)



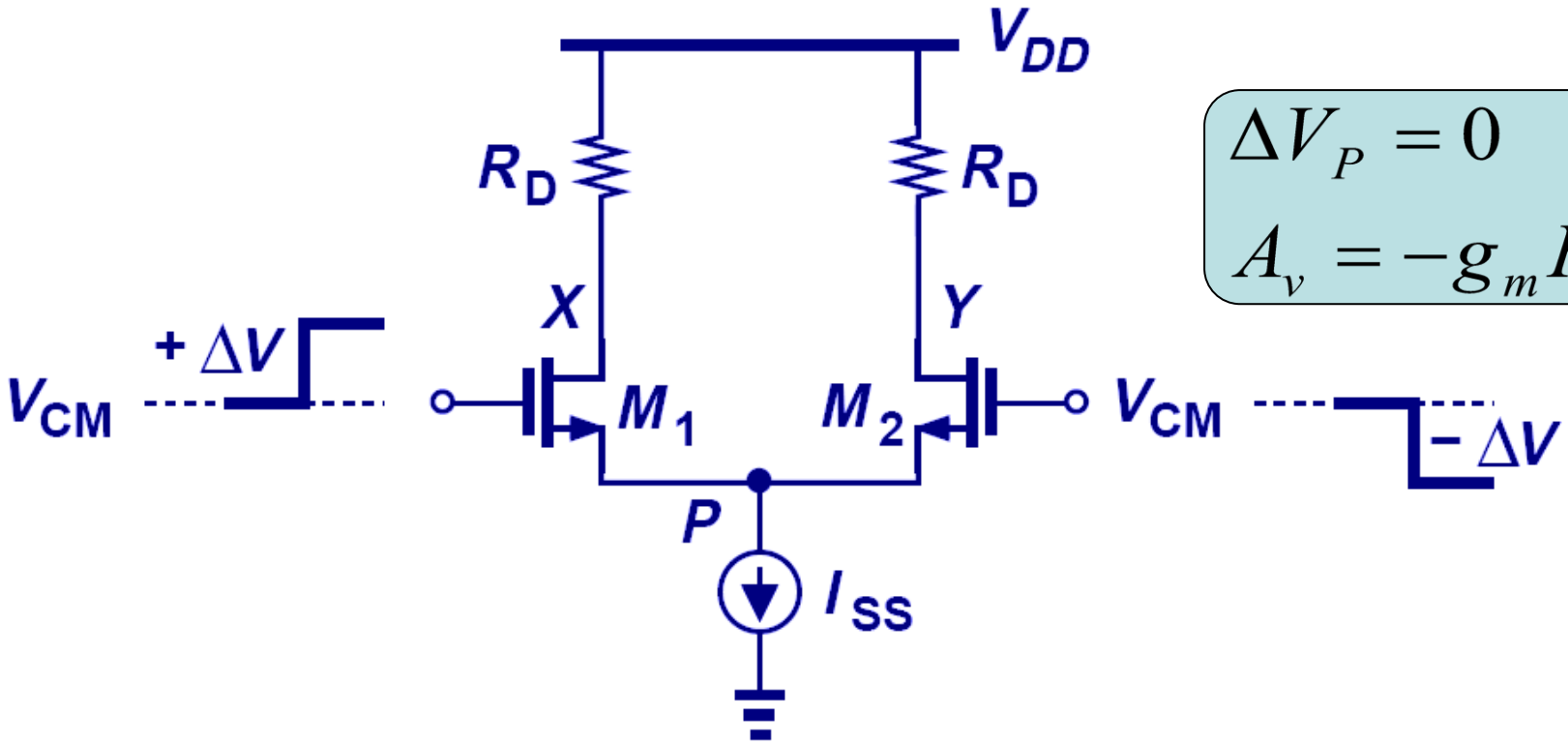
(b)





(c)

Small-Signal Response

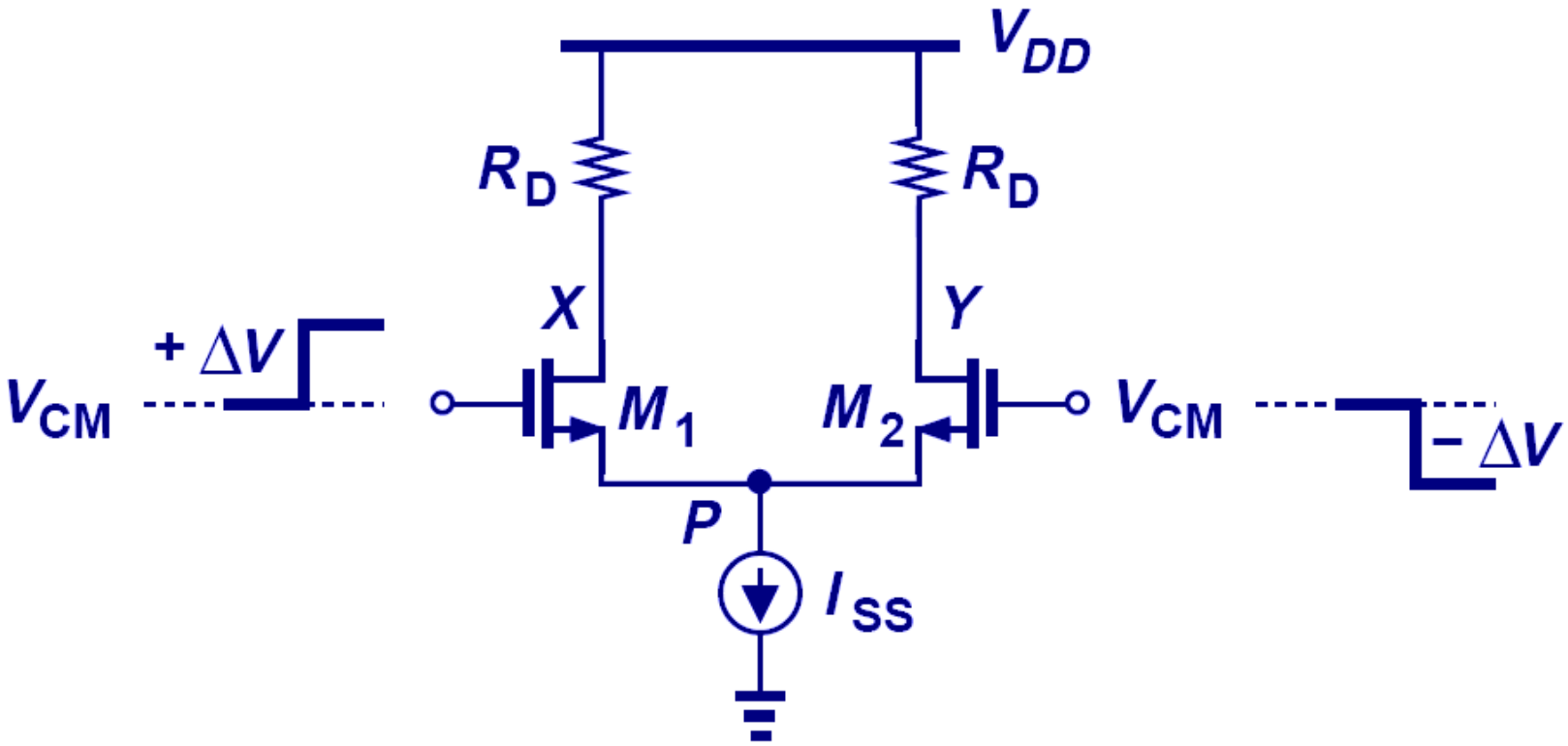


$$\Delta V_P = 0$$

$$A_v = -g_m R_D$$

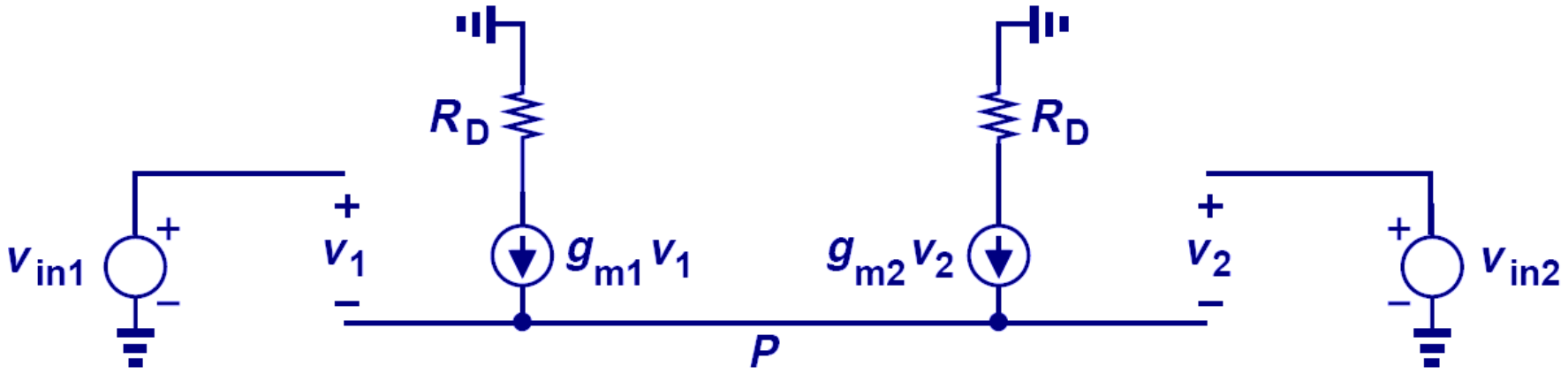
- **Similar to its bipolar counterpart, the MOS differential pair exhibits the same virtual ground node and small signal gain.**

Power and Gain Tradeoff



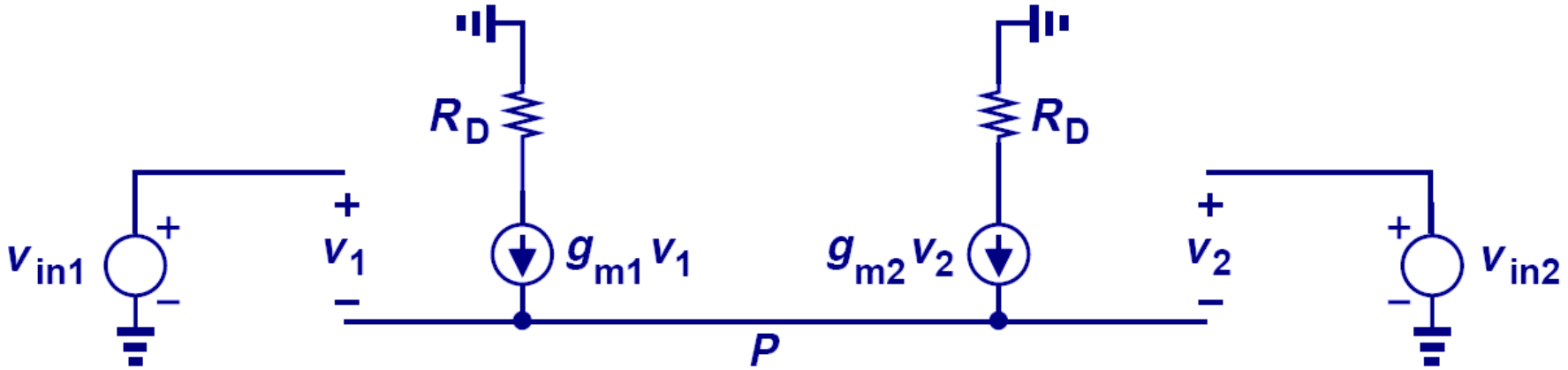
- **In order to obtain the source gain as a CS stage, a MOS differential pair must dissipate twice the amount of current. This power and gain tradeoff is also echoed in its bipolar counterpart.**

Small-Signal Analysis of MOS Differential Pair

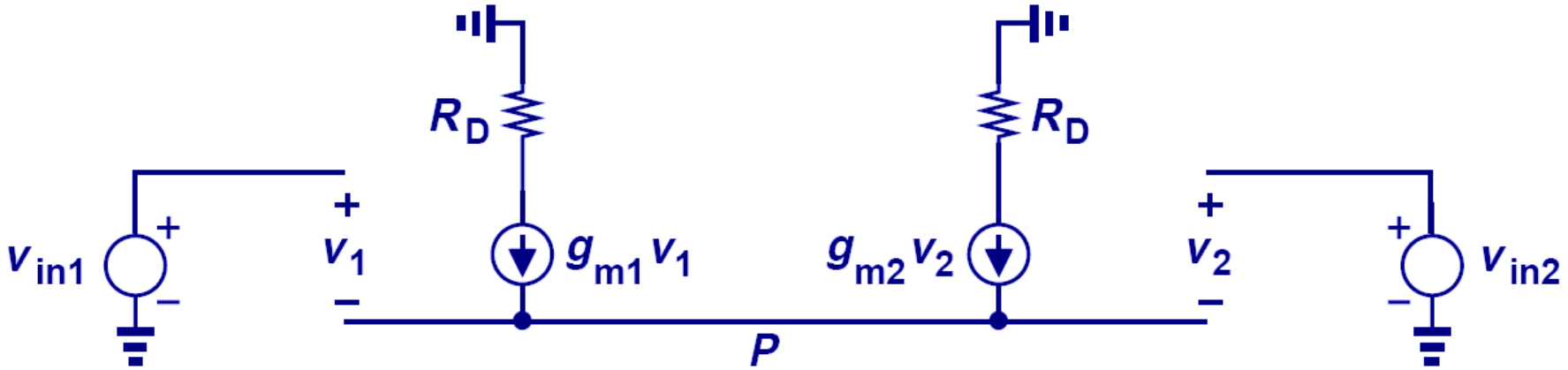


- When the input differential signal is small compared to $4I_{SS}/\mu_n C_{ox}(W/L)$, the output differential current is linearly proportional to it, and small-signal model can be applied.

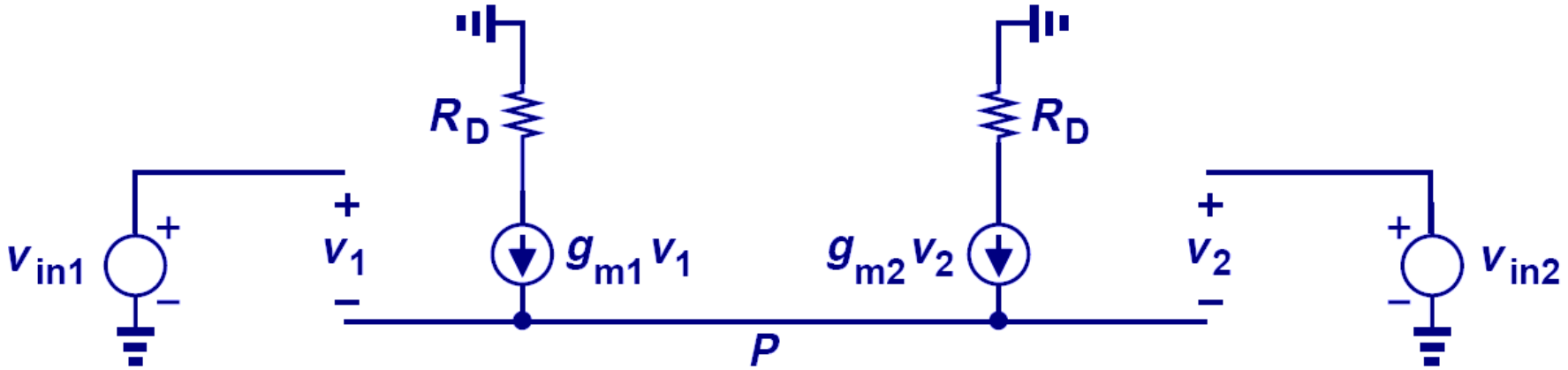
Small-Signal Analysis of MOS Differential Pair



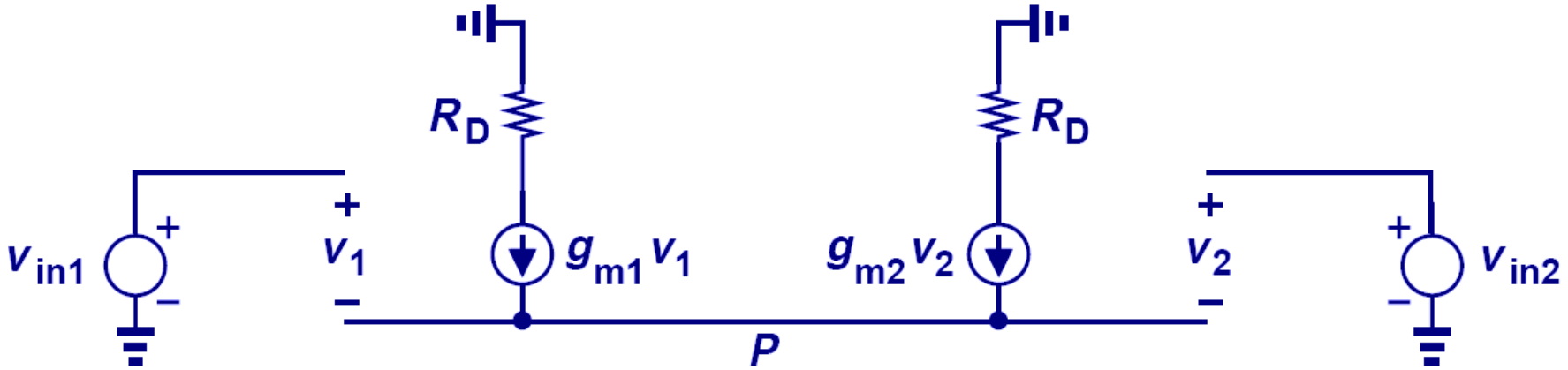
Small-Signal Analysis of MOS Differential Pair



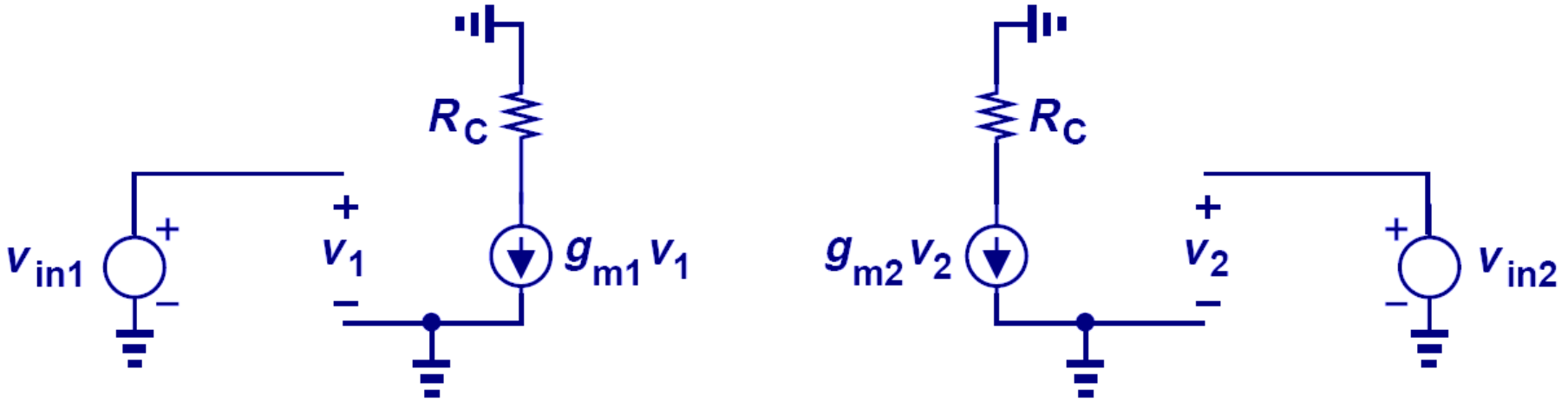
Small-Signal Analysis of MOS Differential Pair



Small-Signal Analysis of MOS Differential Pair



Virtual Ground and Half Circuit

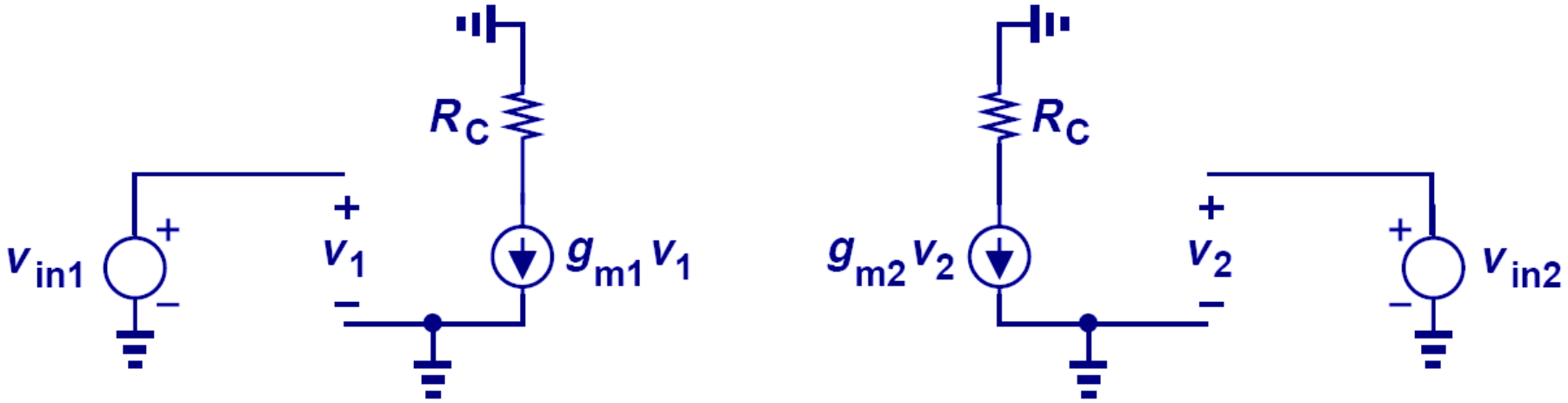


$$\Delta V_P = 0$$

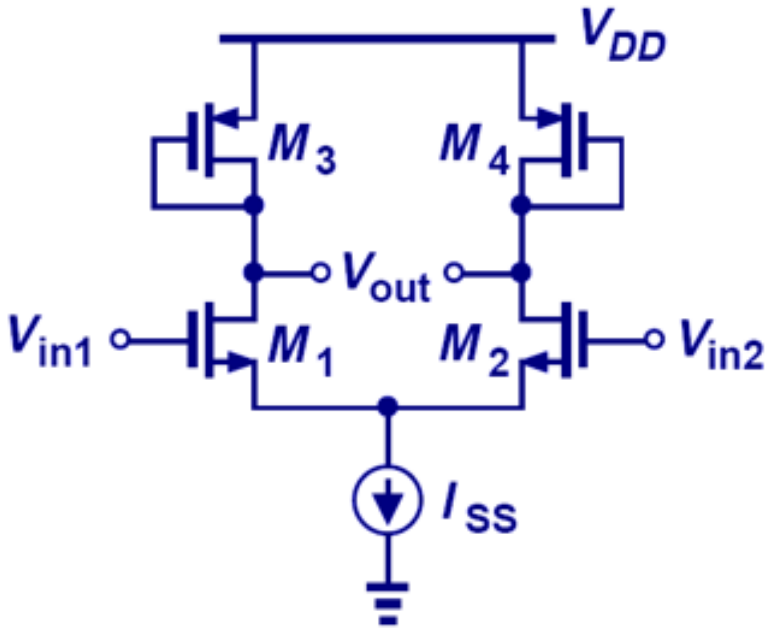
$$A_v = -g_m R_C$$

- **Node P will not move for small input signals and the concept of half circuit can be used to calculate the gain.**

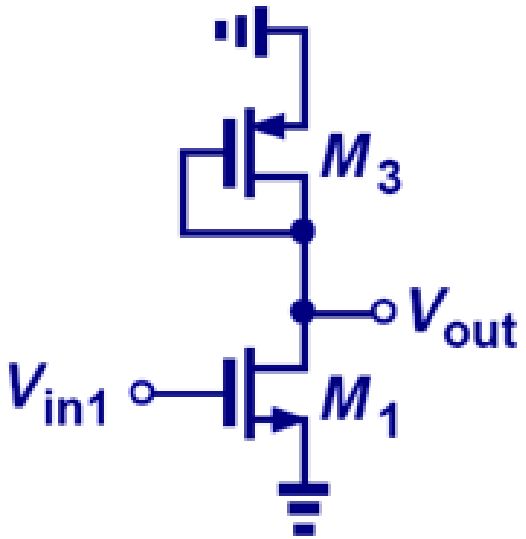
Virtual Ground and Half Circuit



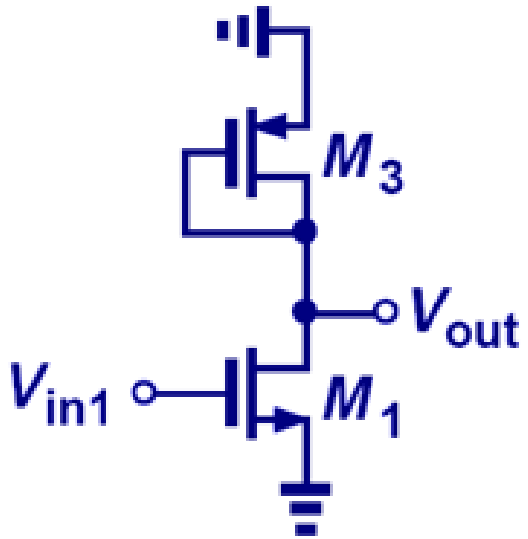
MOS Differential Pair Half Circuit Example I



MOS Differential Pair Half Circuit Example I



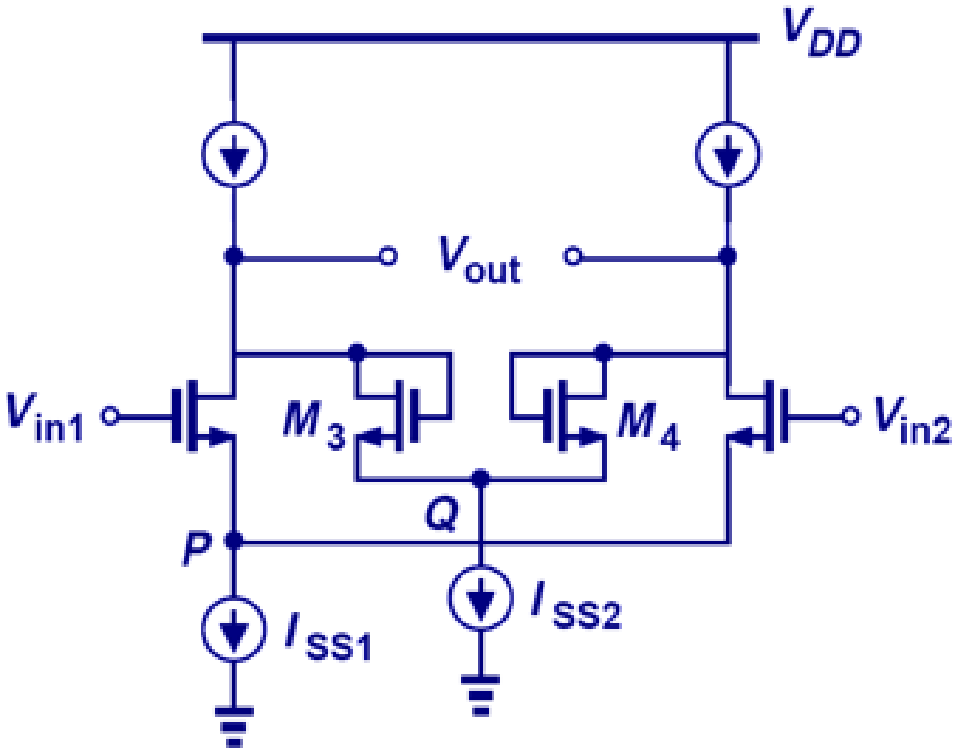
MOS Differential Pair Half Circuit Example I



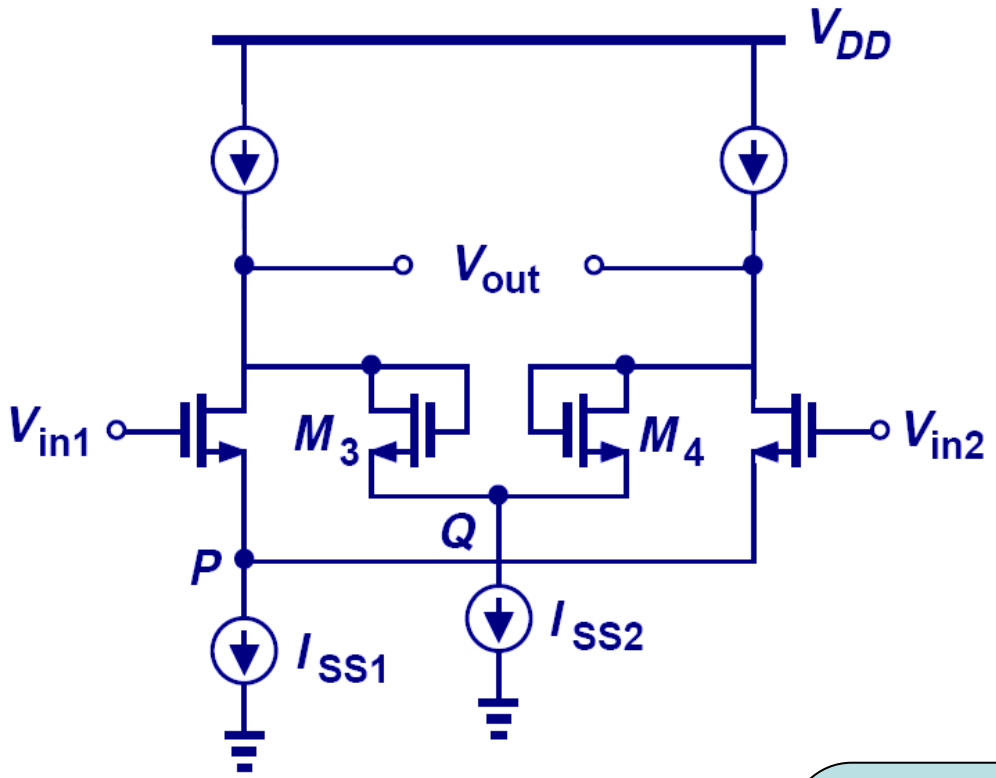
$$\lambda \neq 0$$

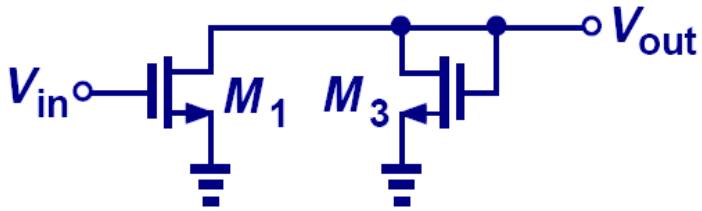
$$A_v = -g_{m1}\left(\frac{1}{g_{m3}} \| r_{O3} \| r_{O1}\right)$$

MOS Differential Pair Half Circuit Example II



MOS Differential Pair Half Circuit Example II

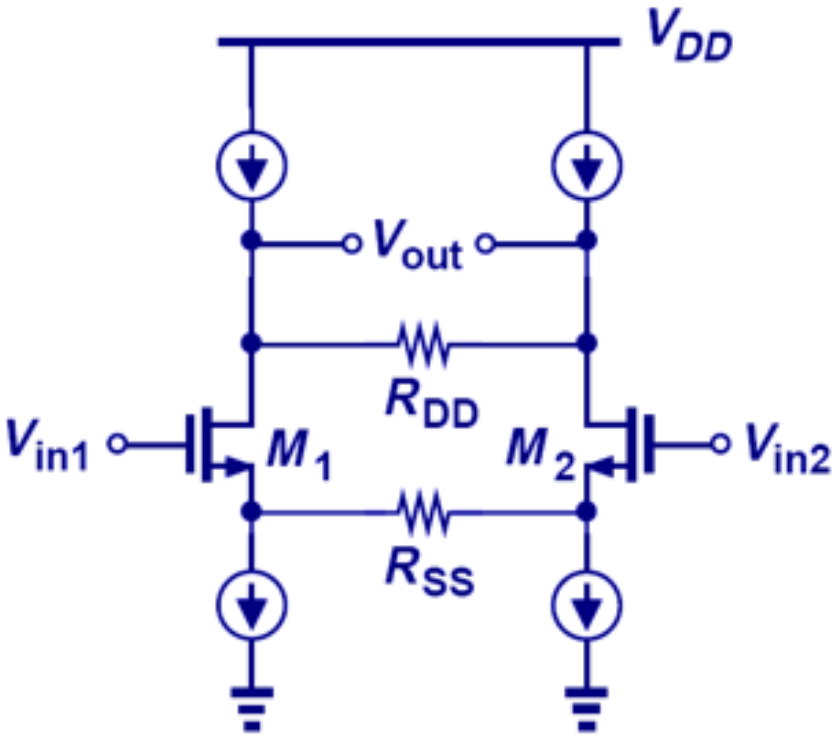




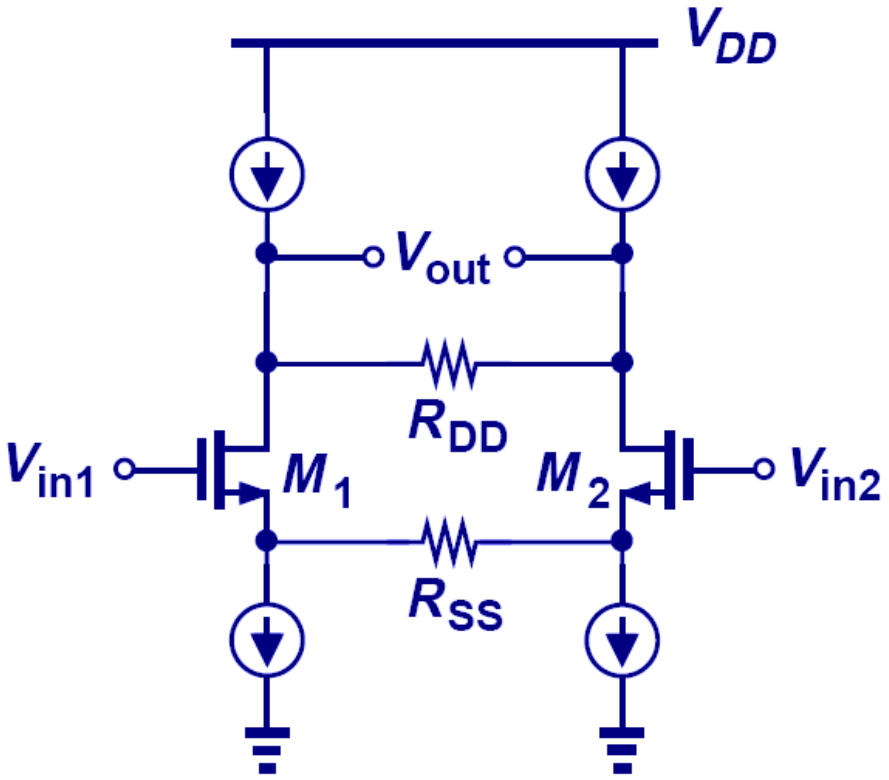
$$\lambda = 0$$

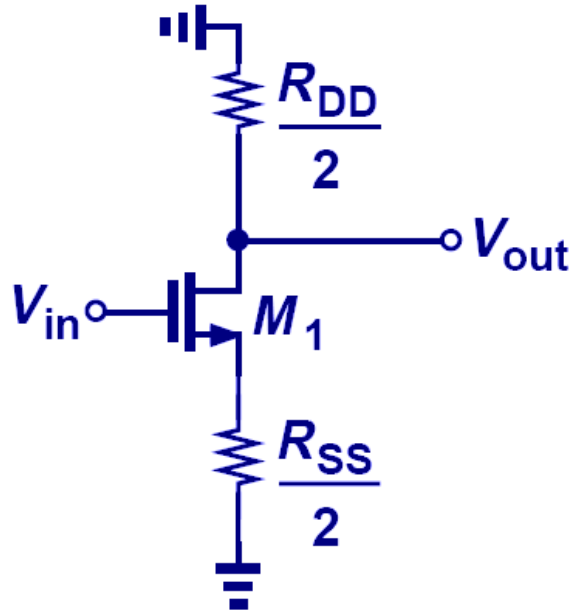
$$A_v = -\frac{g_{m1}}{g_{m3}}$$

MOS Differential Pair Half Circuit Example III



MOS Differential Pair Half Circuit Example III

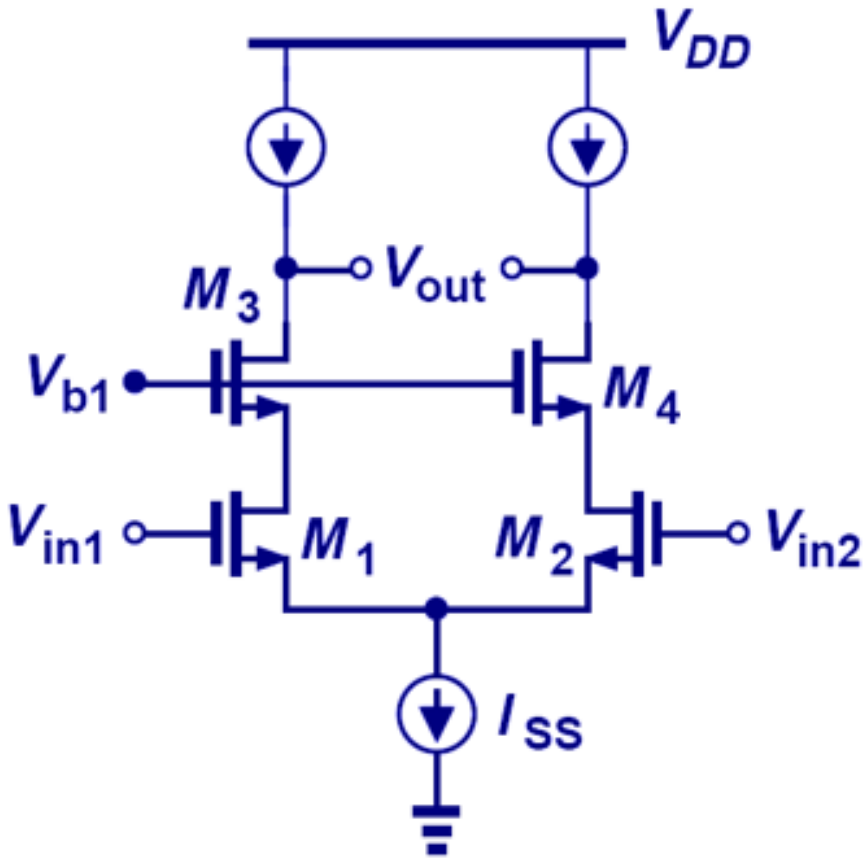




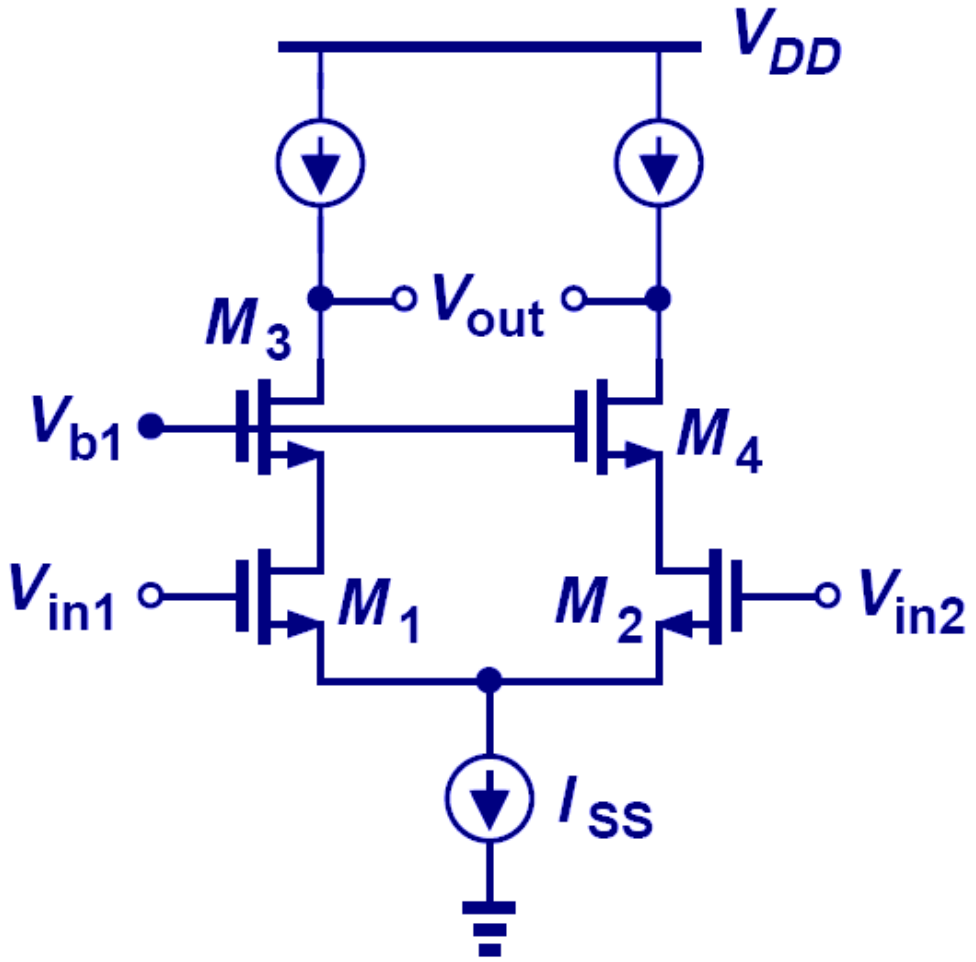
$$\lambda = 0$$

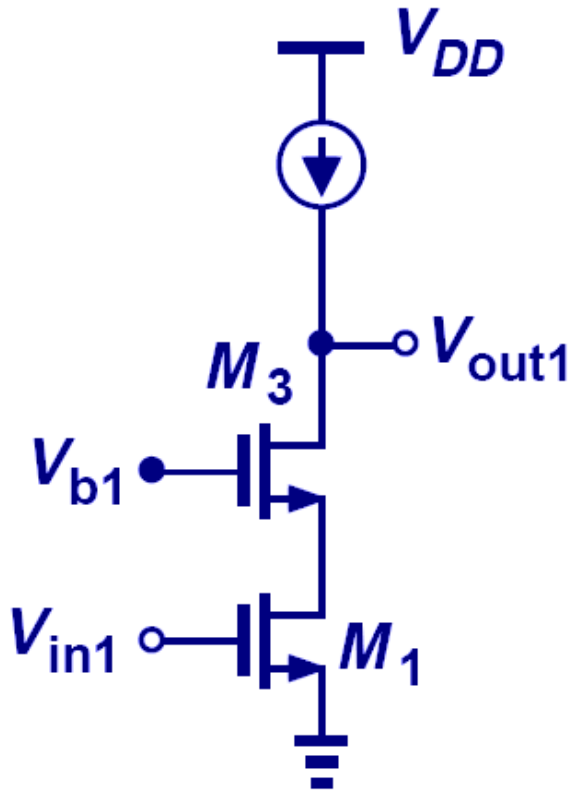
$$A_v = -\frac{R_{DD}/2}{R_{SS}/2 + 1/g_m}$$

MOS Cascode Differential Pair



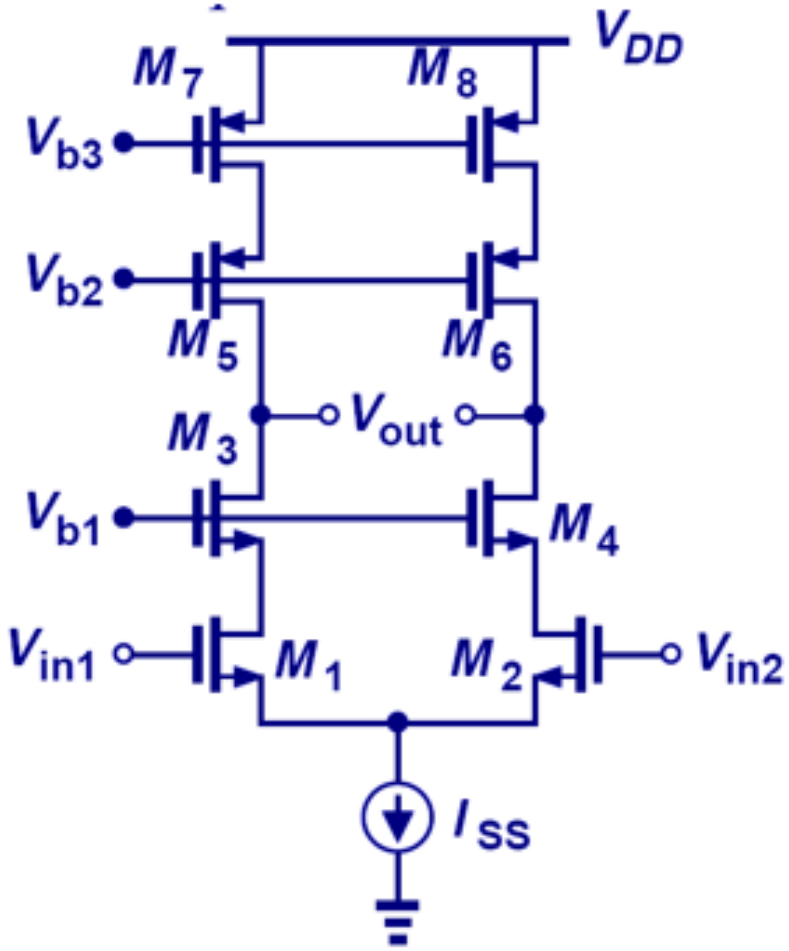
MOS Cascode Differential Pair



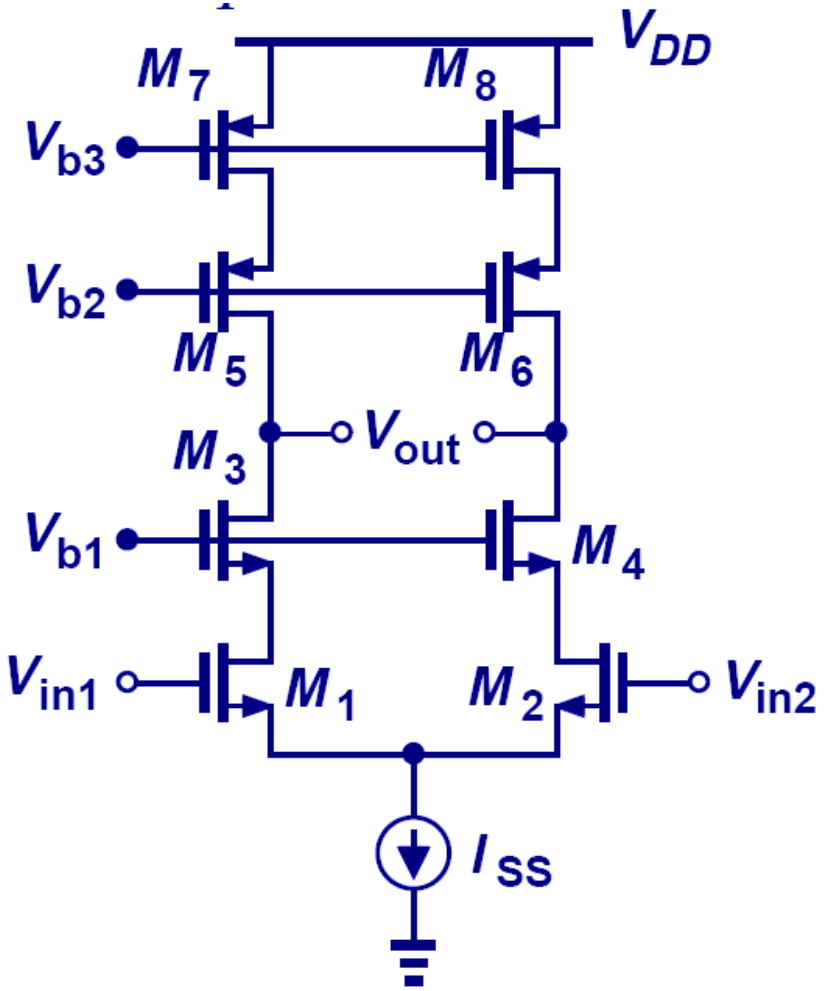


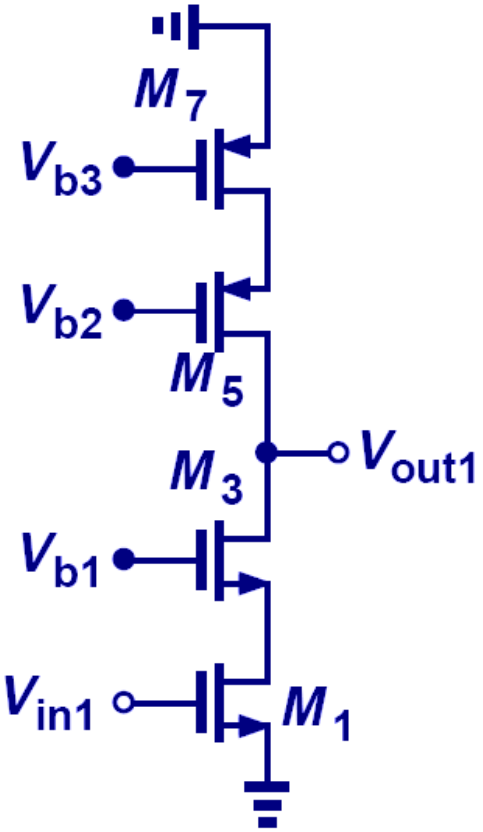
$$A_v \approx -g_{m1} r_{O3} g_{m3} r_{O1}$$

MOS Telescopic Cascode



MOS Telescopic Cascode





Thanks

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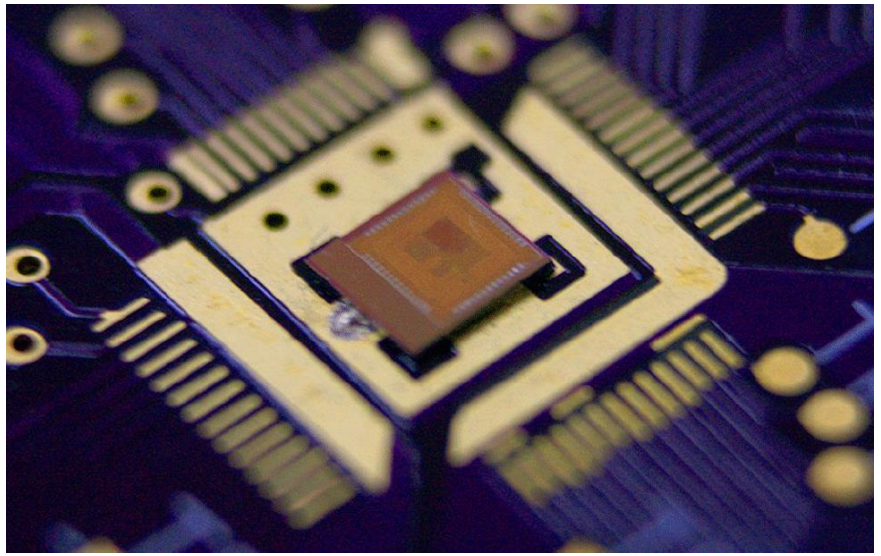

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