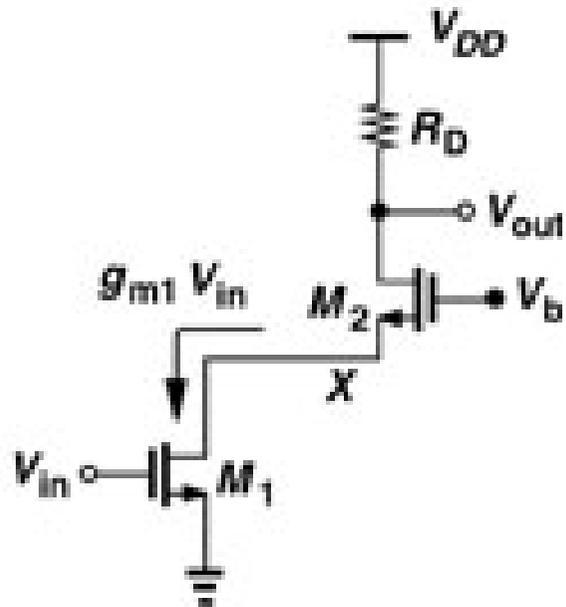


Lecture 3

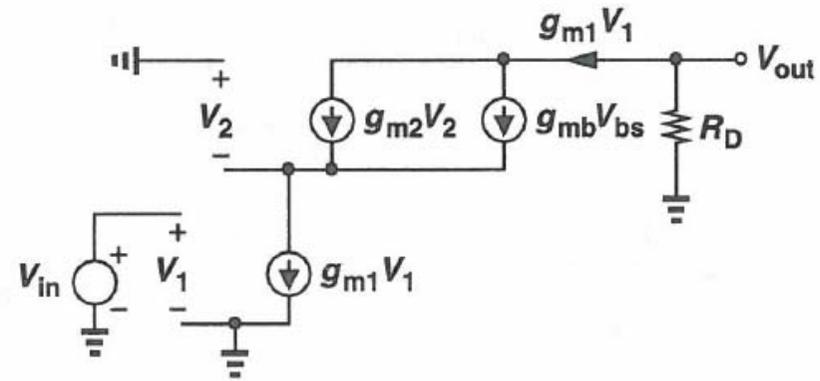
IL2218 Analog electronics, advanced course

- Chapter 3 Cascode amplifiers
- Chapter 4 Differential amplifiers
- Examples

Cascode amplifier



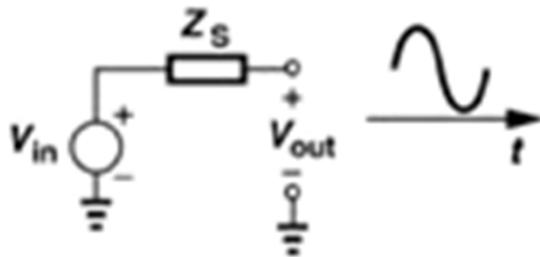
Small signal model



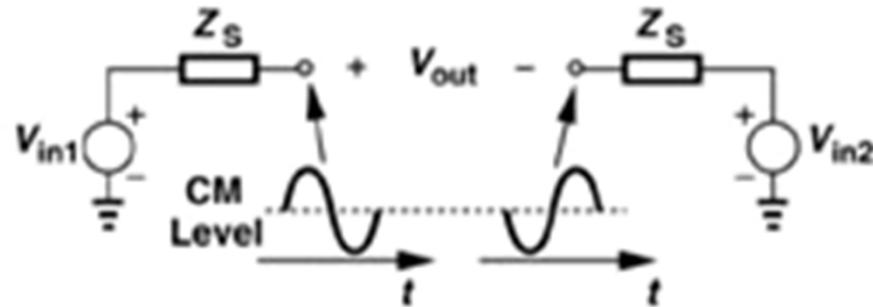
Differential amplifier

Why differential?

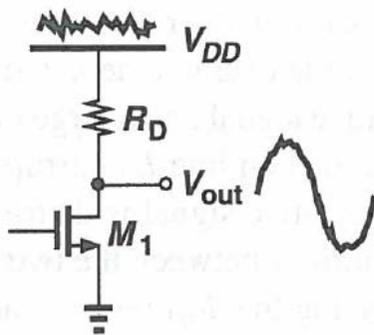
Single ended output



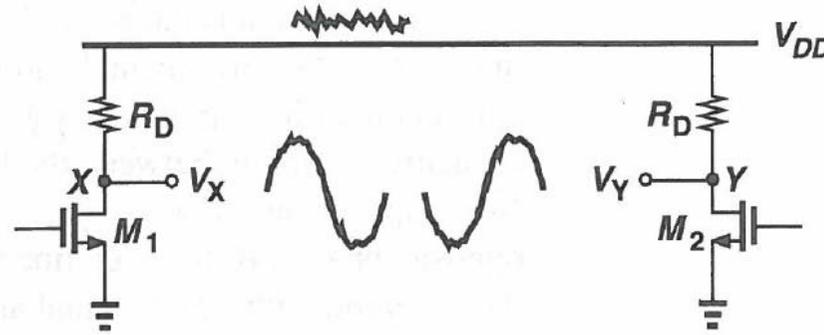
Differential output



Noisy V_{DD}

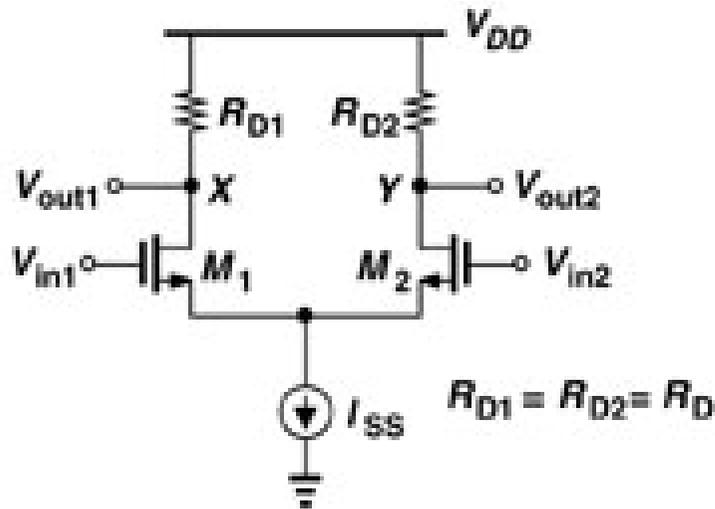


Noise reduction



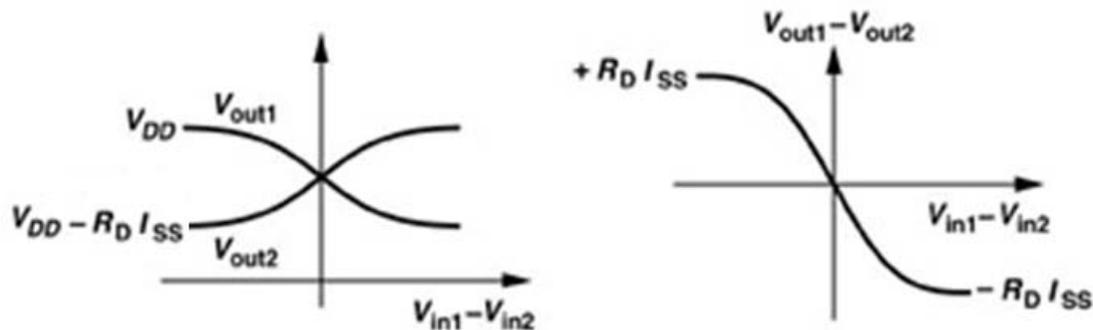
What is wrong in this picture?

Basic differential pair



Constant tail current I_{SS}
 We can increase the current at one side if it is decreased at the other side $I_{D1} = -I_{D2}$

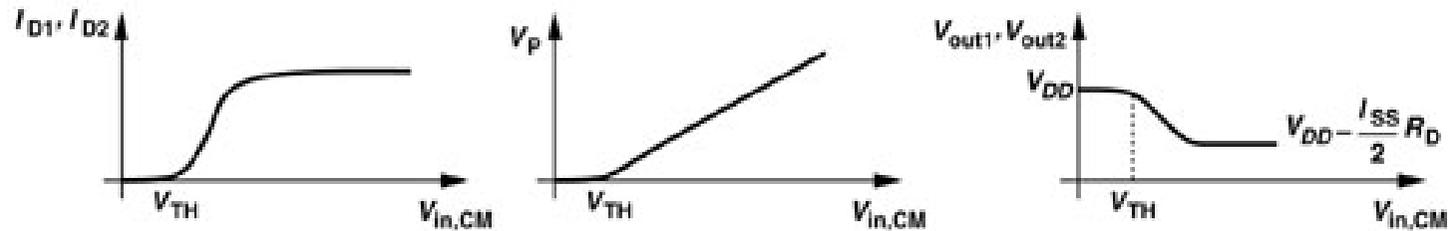
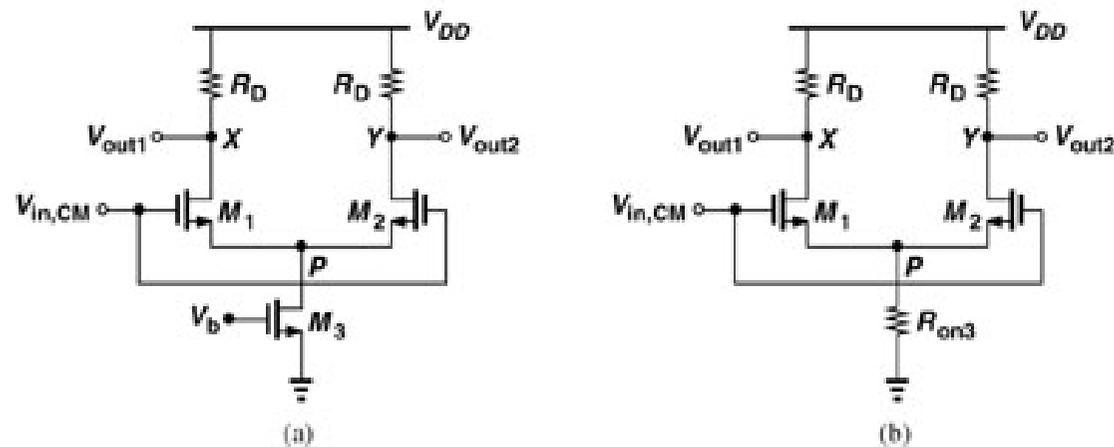
What will happen if $V_{in1} = V_{in2}$ and the input voltage is increasing?



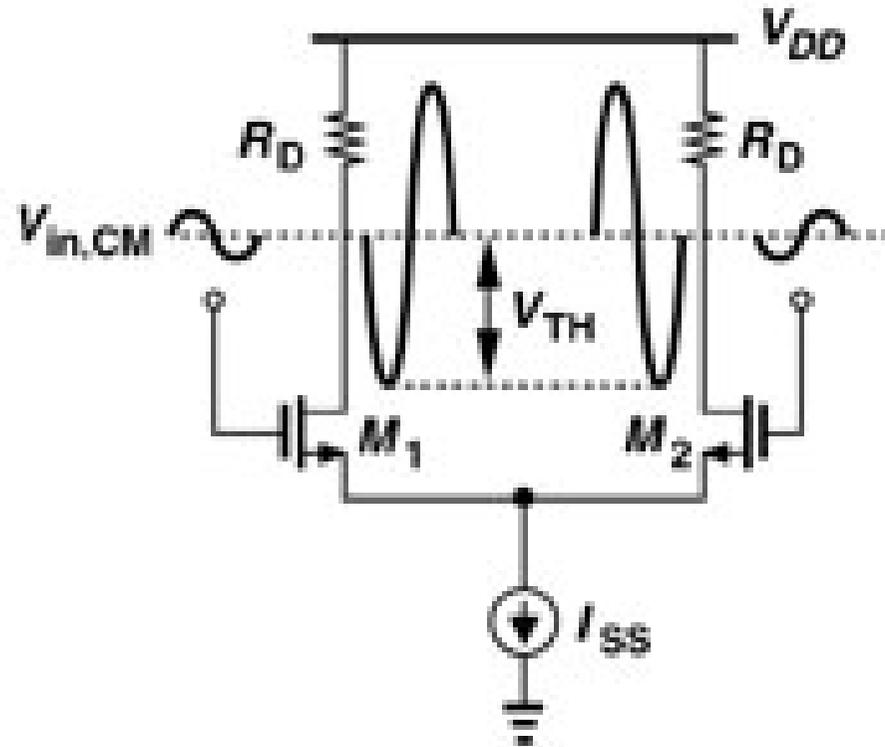
Input-output characteristics of a differential pair

Common mode response

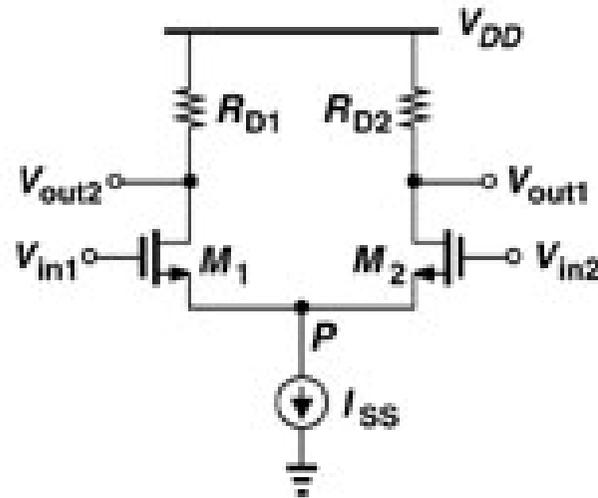
Tail current source with finite output resistance



Common mode, output swing



Differential gain



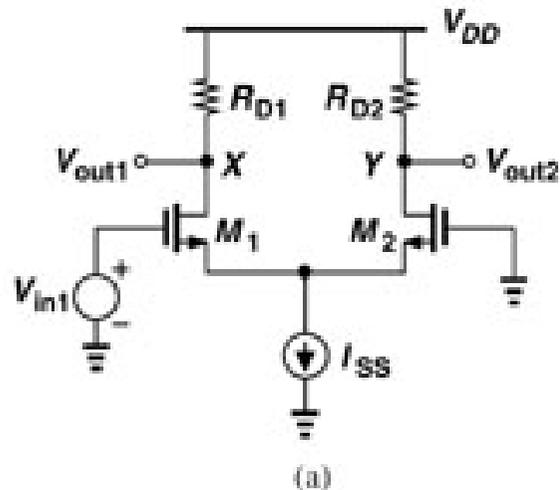
Differential gain

$$A_v = \frac{V_{out1} - V_{out2}}{V_{in1} - V_{in2}} = g_m R_D$$

Single ended output

$$A_v = \frac{g_m}{2} R_D$$

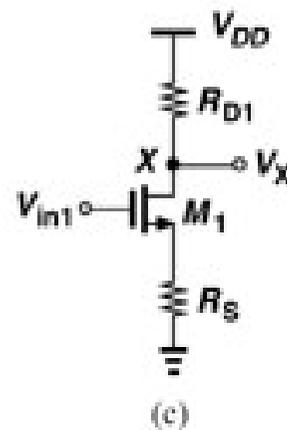
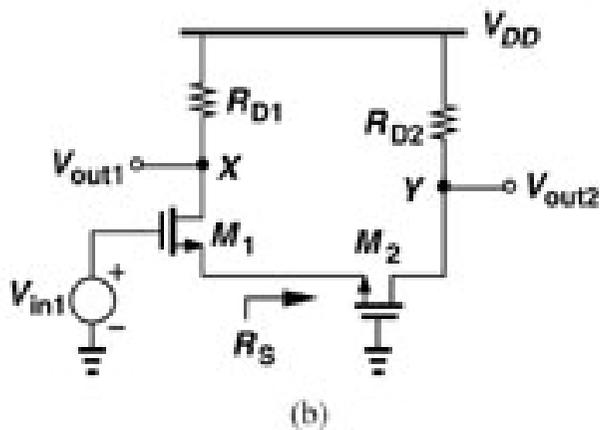
Differential mode gain



Single ended output

$$A_v = -\frac{g_m R_D}{1 + g_m R_S}$$

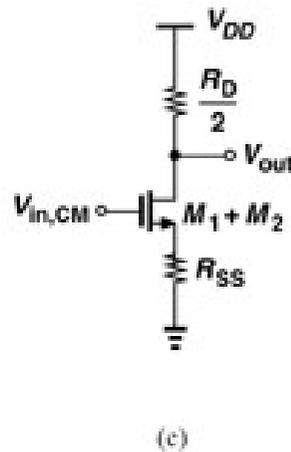
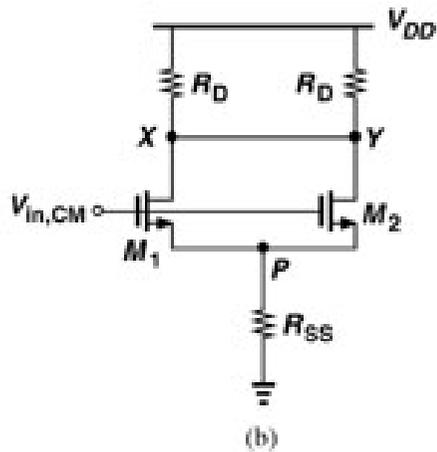
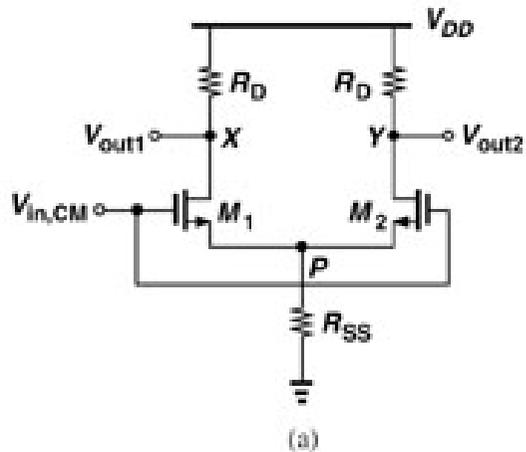
$$= -\frac{g_m}{2} R_D$$



Differential gain

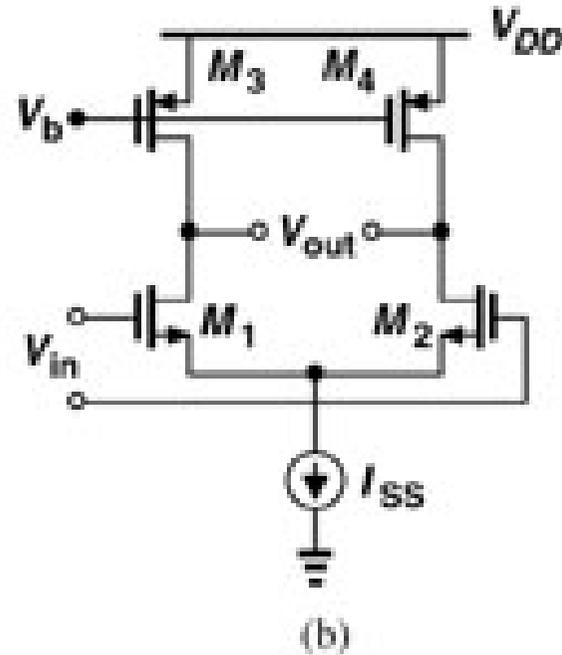
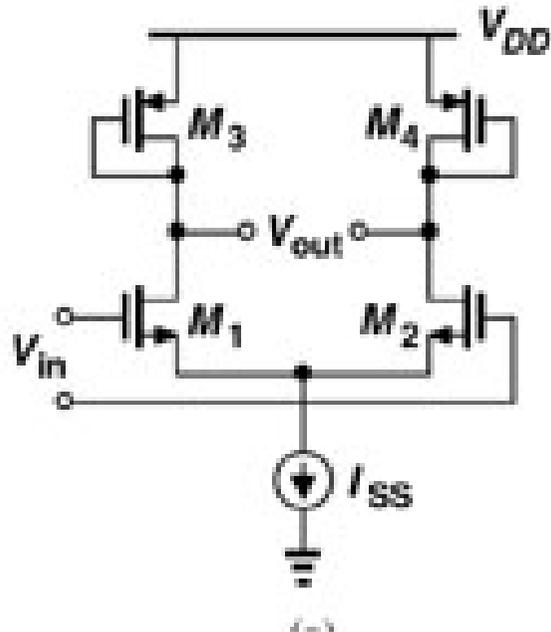
$$A_v = g_m R_D$$

Common mode gain



$$A_v = \frac{V_{out}}{V_{in,CM}} = - \frac{R_D / 2}{1 / (2g_m) + R_{SS}}$$

MOS loads

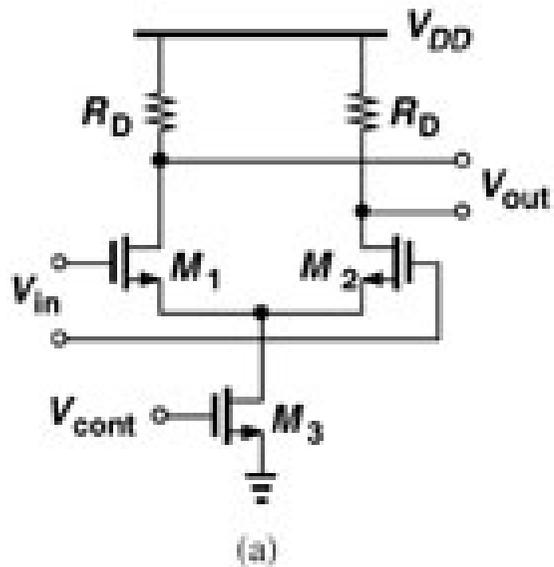


$$A_v = -g_{mN} \left(\frac{1}{g_{mP}} \parallel r_{oN} \parallel r_{oP} \right)$$

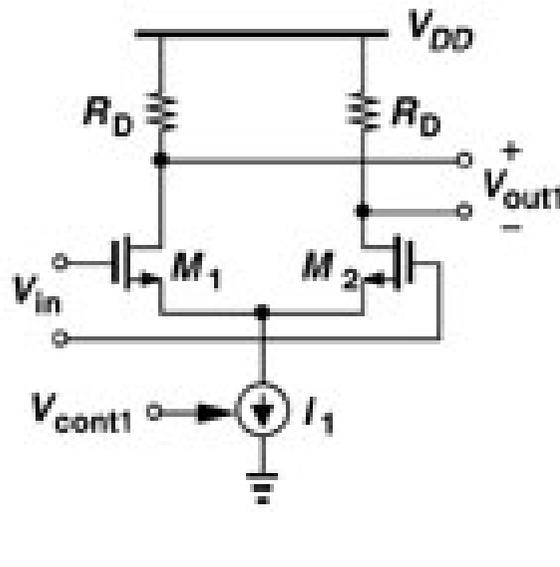
$$\approx -\frac{g_{mN}}{g_{mP}}$$

$$A_v = -g_{mN} (r_{oN} \parallel r_{oP})$$

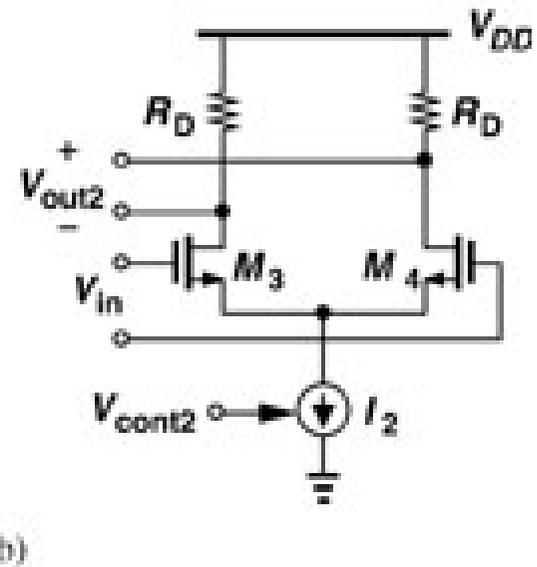
Variable gain



Gain varied by control voltage V_{cont}

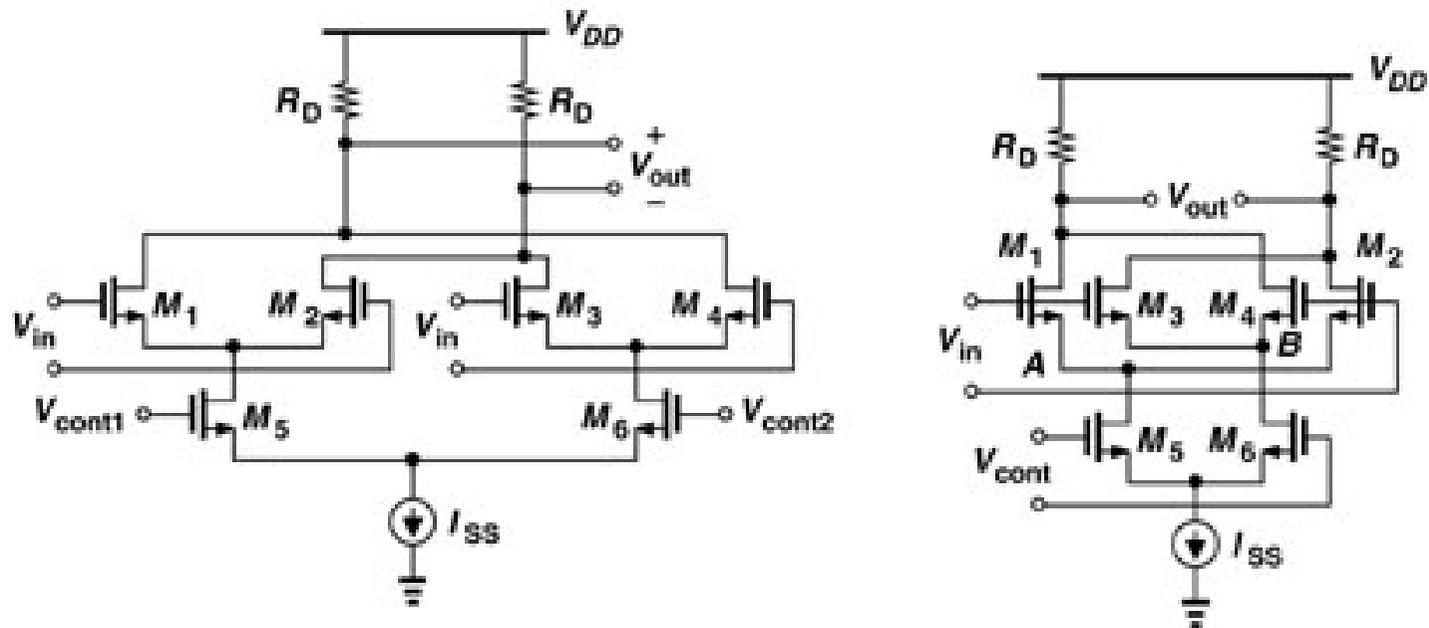


$$\frac{V_{out1}}{V_{in}} = -g_m R_D$$



$$\frac{V_{out2}}{V_{in}} = +g_m R_D$$

Gilbert cell



$$V_{OUT} = kV_{in} V_{cont}$$

Widely used in radio circuits as mixer and phase detector