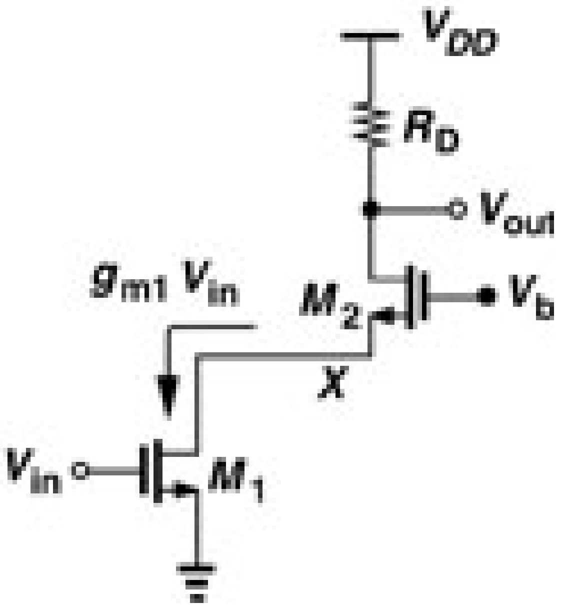
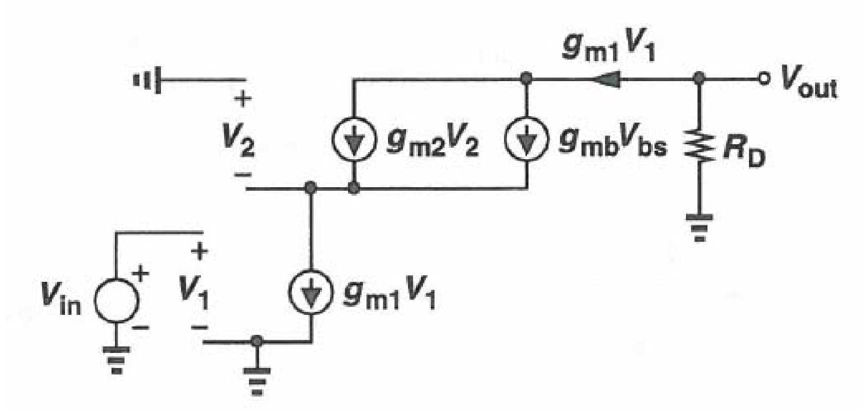
# Lecture 3
# IL2218 Analog electronics, advanced course

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

# Cascode amplifier

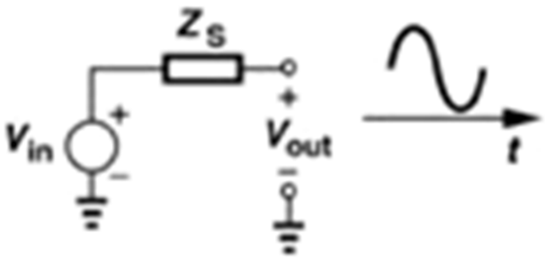



Small signal model

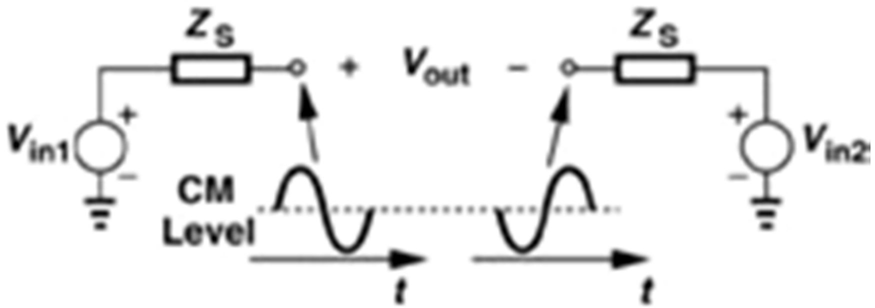


# Differential amplifier
# Why differential?

Single ended output

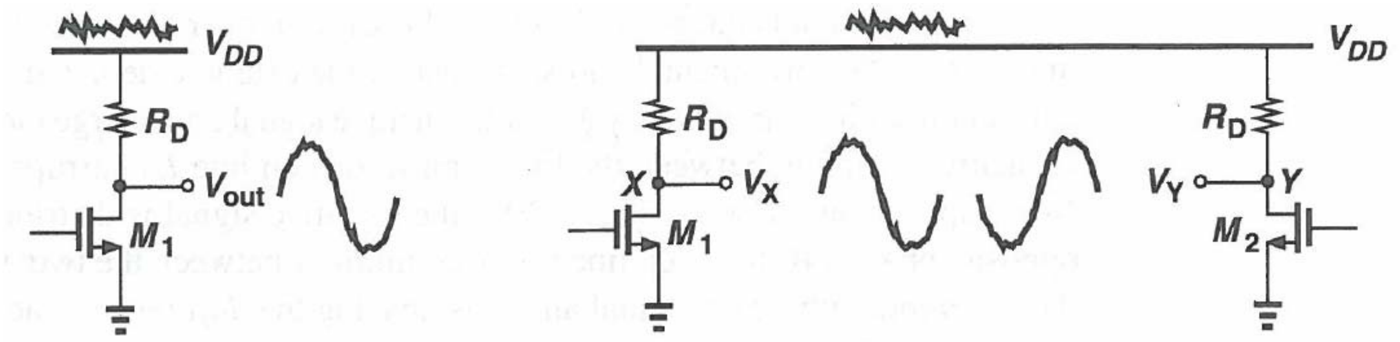



Differential output



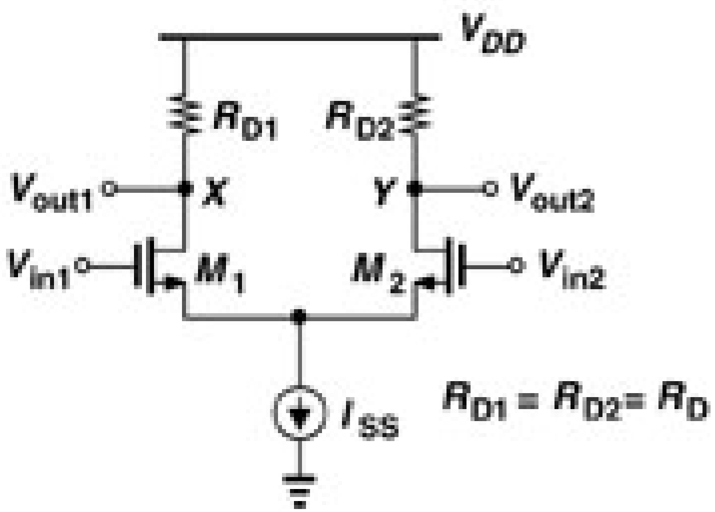

Noisy $V_{DD}$

Noise reduction



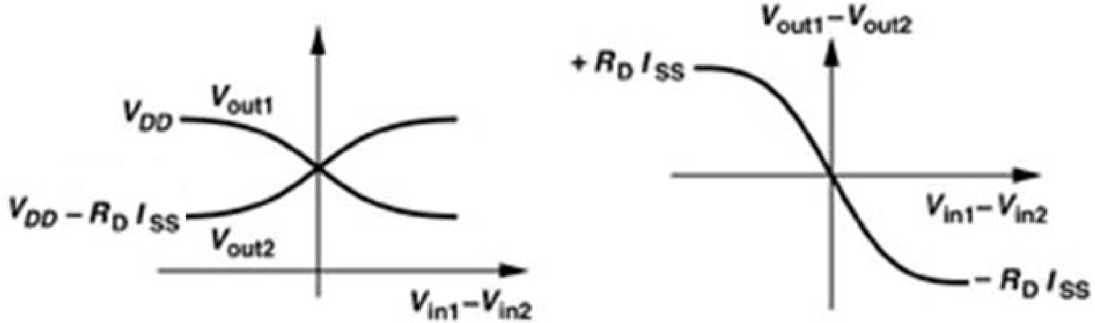

What is wrong in this picture?

# Basic differential pair




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

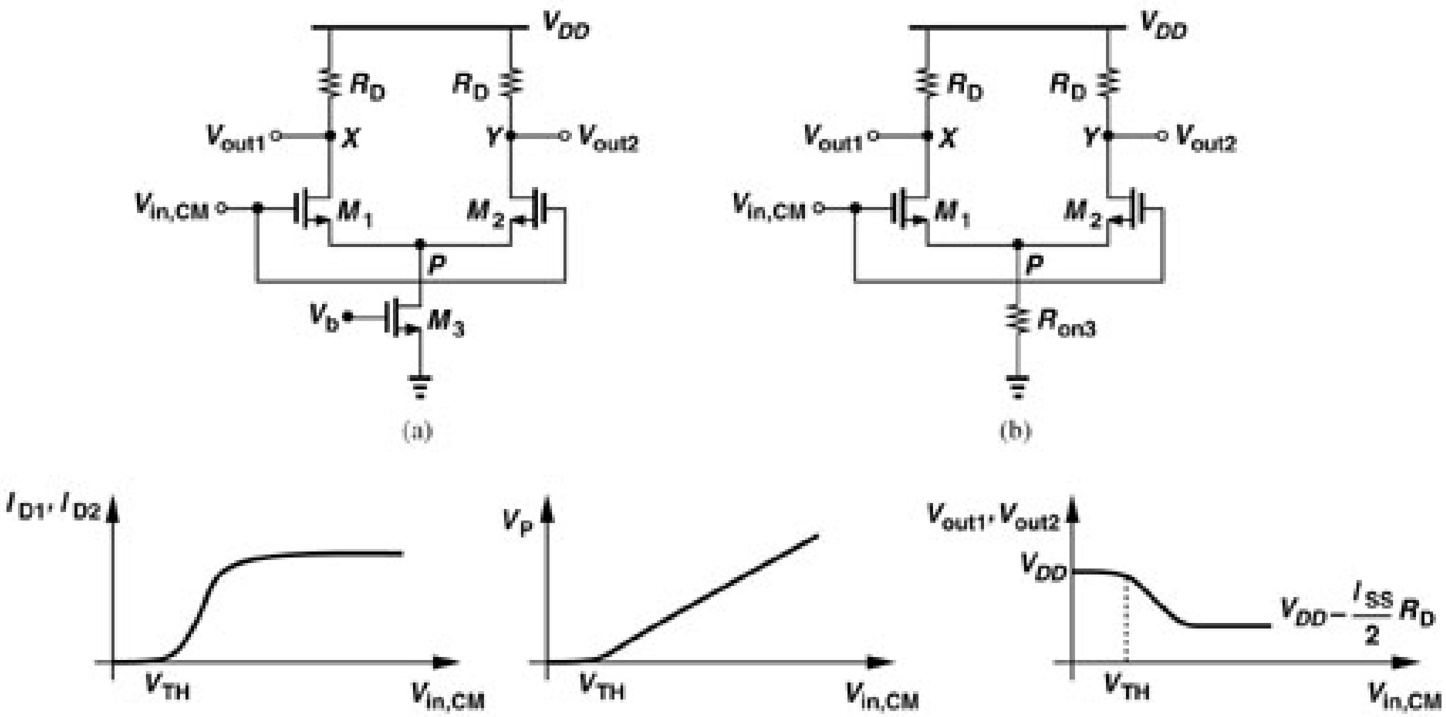
What will happen if $V_{in1}$= $V_{in2}$ and the input voltage is increasing?



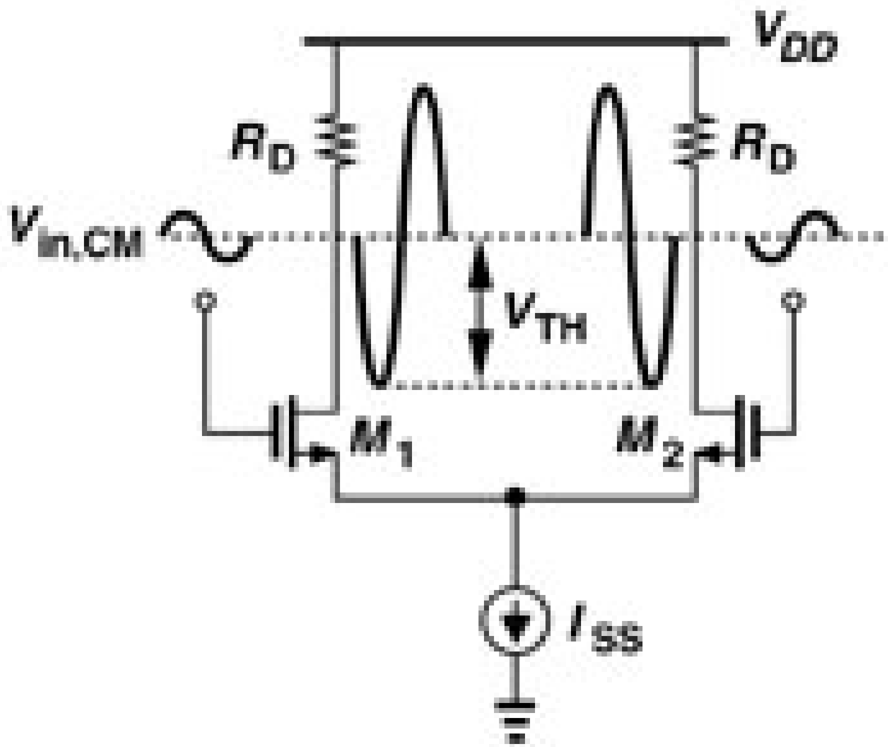

Input-output characteristics of a differential pair

# Common mode response

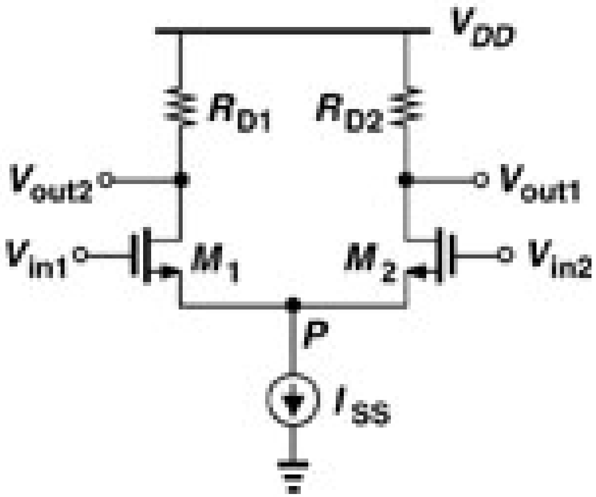
Tail current source with finite output resistance



# Common mode, output sving



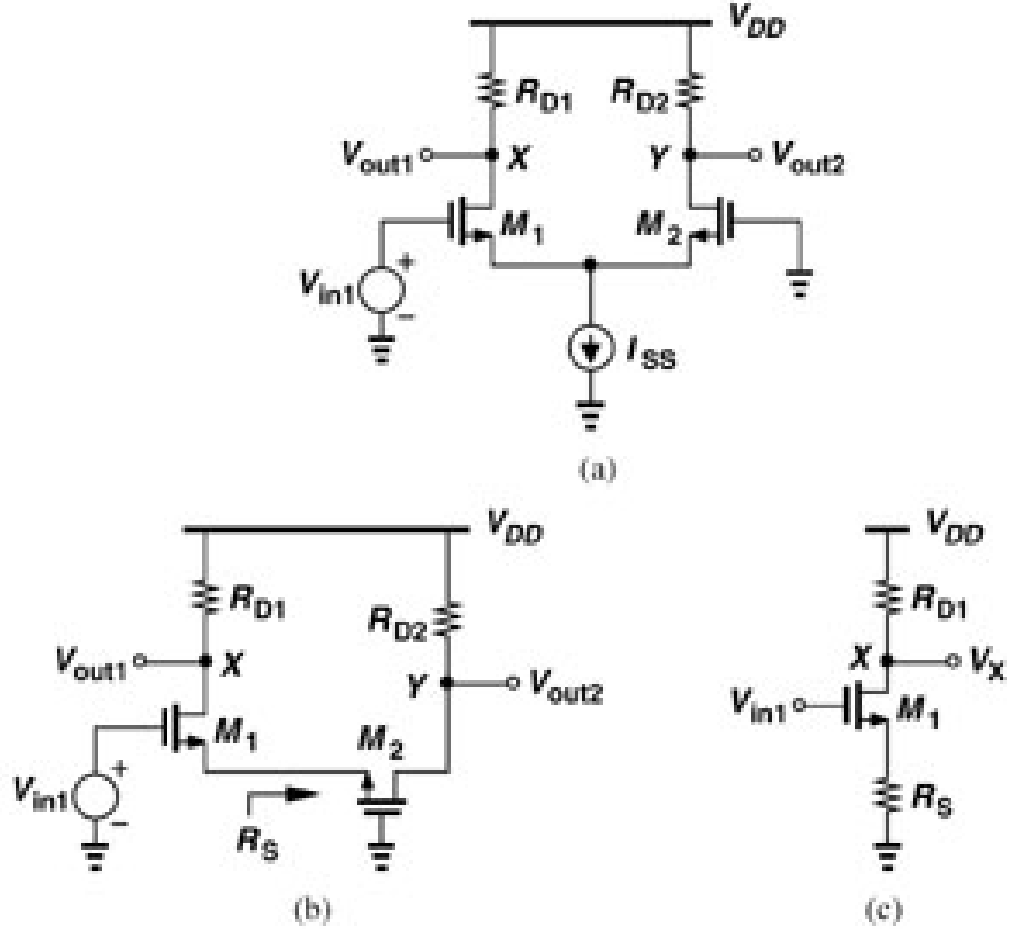
# Differential gain




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

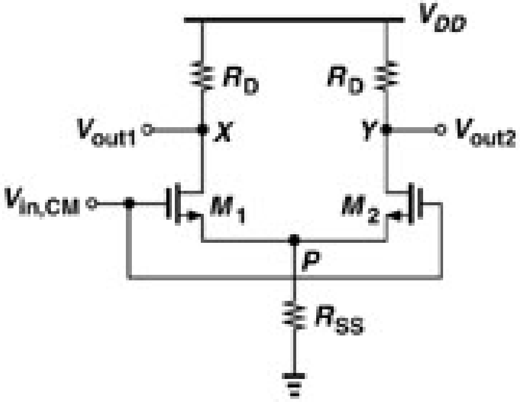
$$A_v = -\frac{g_m R_D}{1 + g_m R_S}$$

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

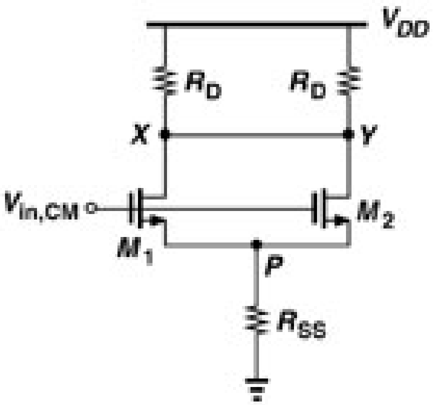
Differential gain

$$A_v = g_m R_D$$

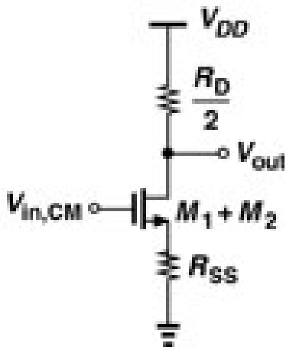
# Common mode gain




(a)



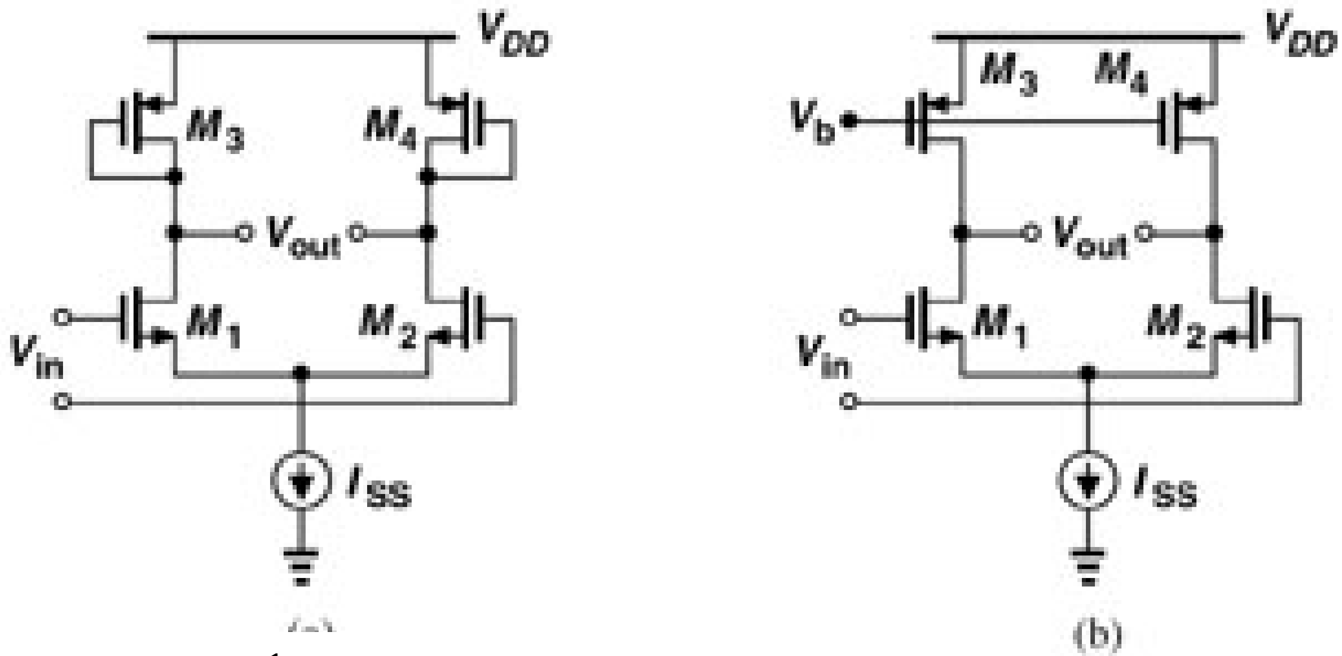

(b)




(c)

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

# MOS loads

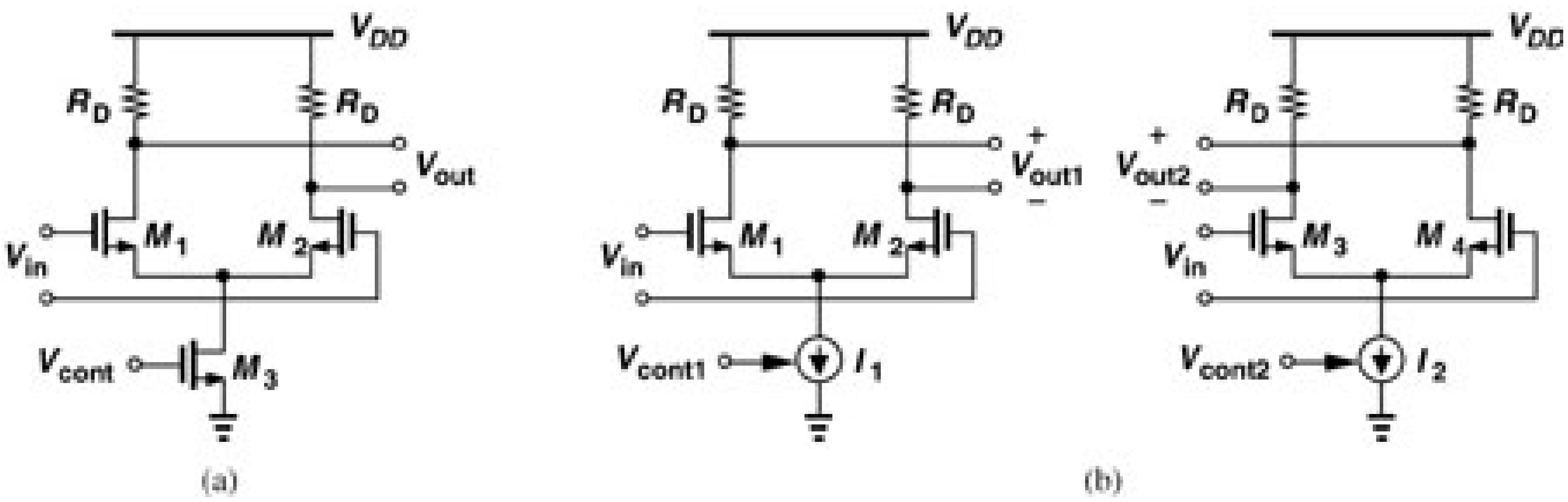



$$A_v = -g_{mN}\left(\frac{1}{g_{mP}} // r_{oN} // r_{oP}\right)$$

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

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

# Variable gain

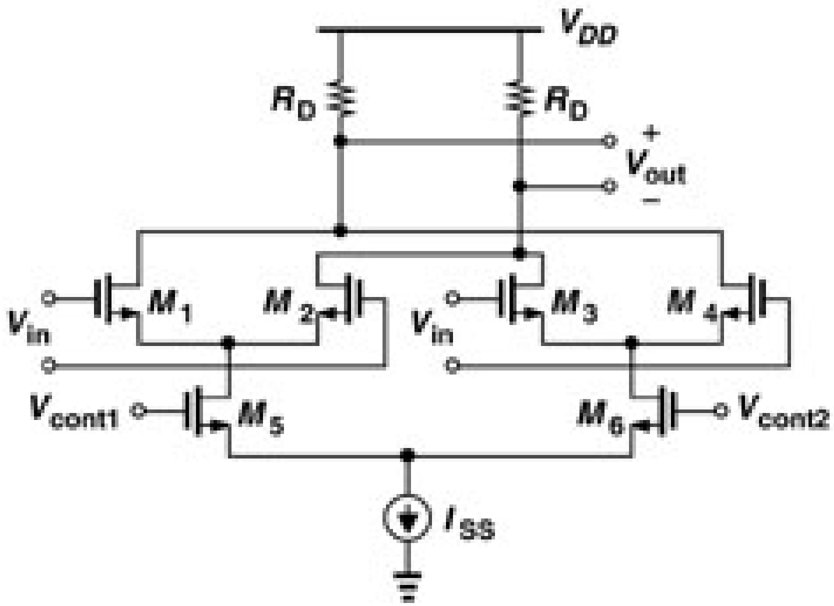


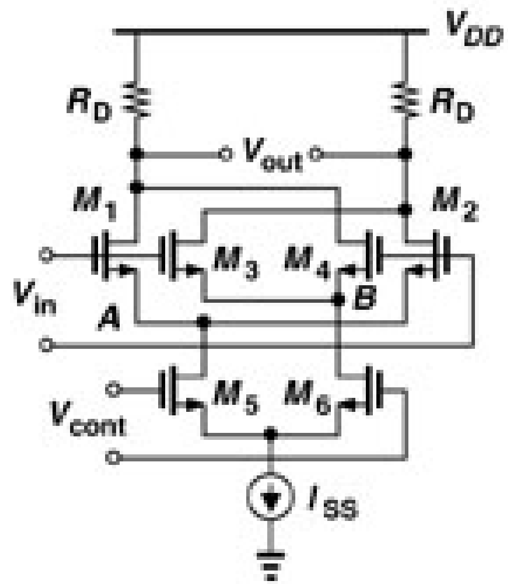

Gain varied by control voltage $V_{cont}$

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

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

# Gilbert cell




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

Widely used in radio circuits as mixer and phase detector