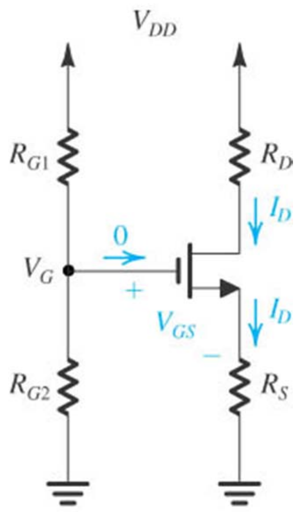
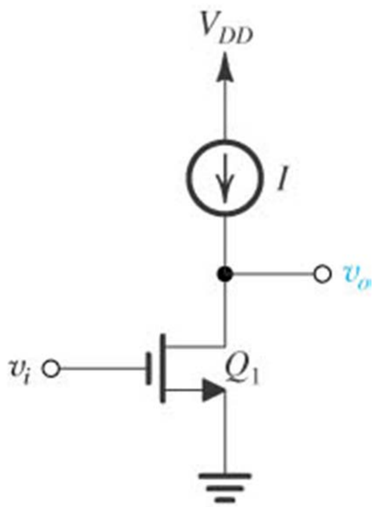
Lect. 8: Current Mirror and Cascode Amplifier

(Razavi 9.1, 9.2)

Various bias techniques for MOS circuits



(c)

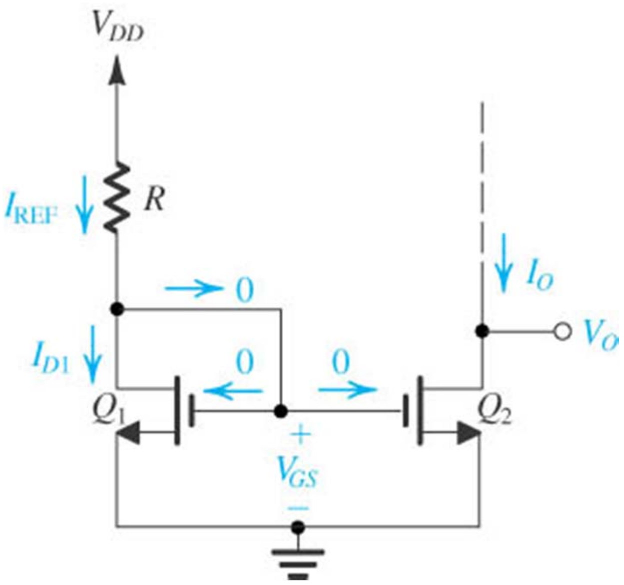


How can we make
a constant current source
with MOS?

Lect. 8: Current Mirror and Cascode Amplifier

Constant current source:

$$I_{D1} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_1 (V_{GS} - V_{TH})^2$$



$$I_{D1} = I_{REF} = \frac{V_{DD} - V_{GS}}{R}$$

$$I_O = I_{D2} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_2 (V_{GS} - V_{TH})^2$$

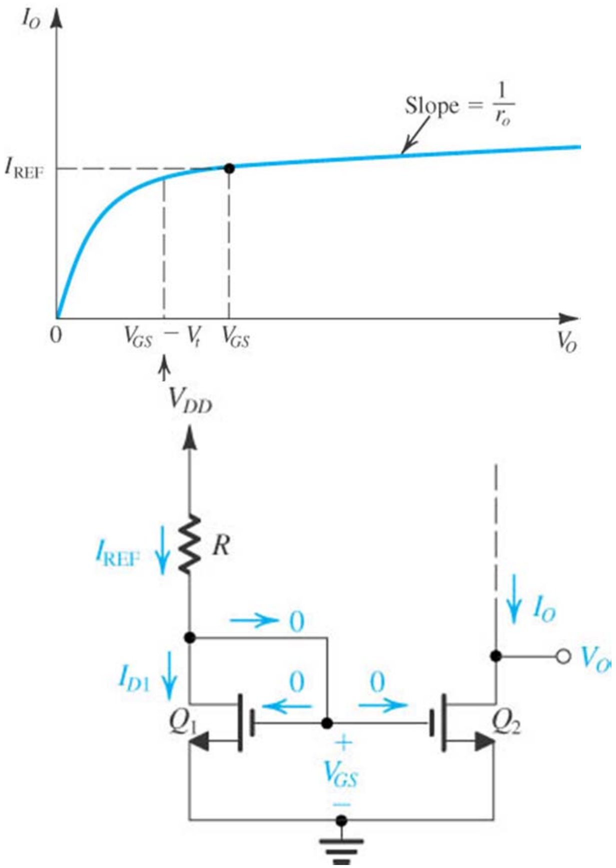
$$\frac{I_O}{I_{REF}} = \frac{(W/L)_2}{(W/L)_1}$$

➔ Current mirror

Limitation on V_o? $V_O \geq V_{GS} - V_{TH}$

Mismatches between I_{REF} and I_O

Due to channel-length modulation

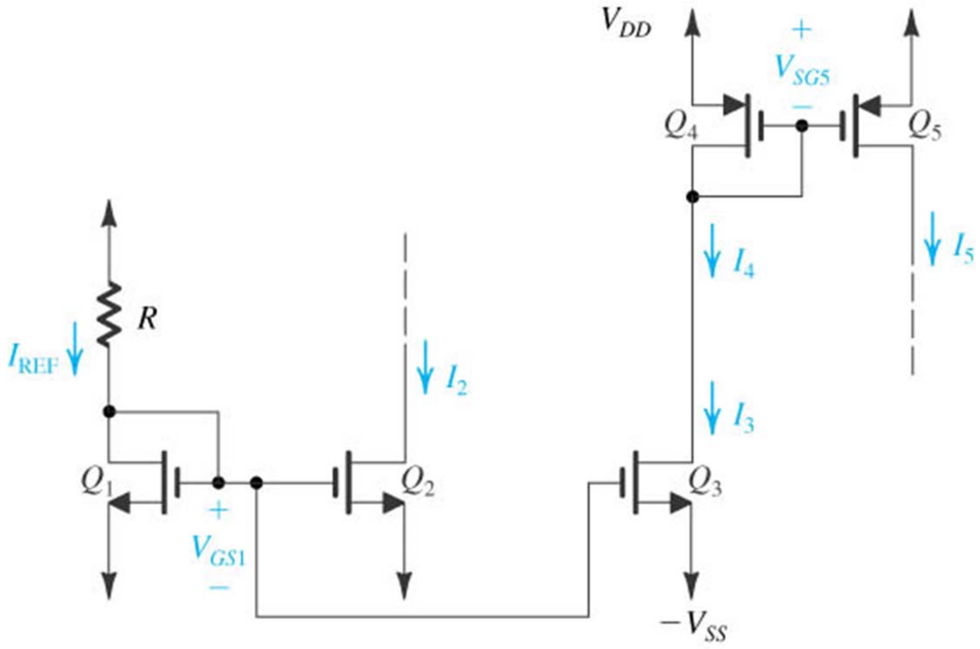


For Q_1 and Q_2
$I_O = I_{REF}$ only if $V_{DS1} = V_{DS2}$ ➔ $V_0 = V_{GS}$

As V_O increases, I_O increases from I_{REF}

$$I_O = I_{REF} + \frac{V_O - V_{GS}}{r_0}$$

Lect. 8: Current Mirror and Cascode Amplifier



(Without r_0 consideration)

$$I_2 = I_{REF} \frac{(W/L)_2}{(W/L)_1}$$

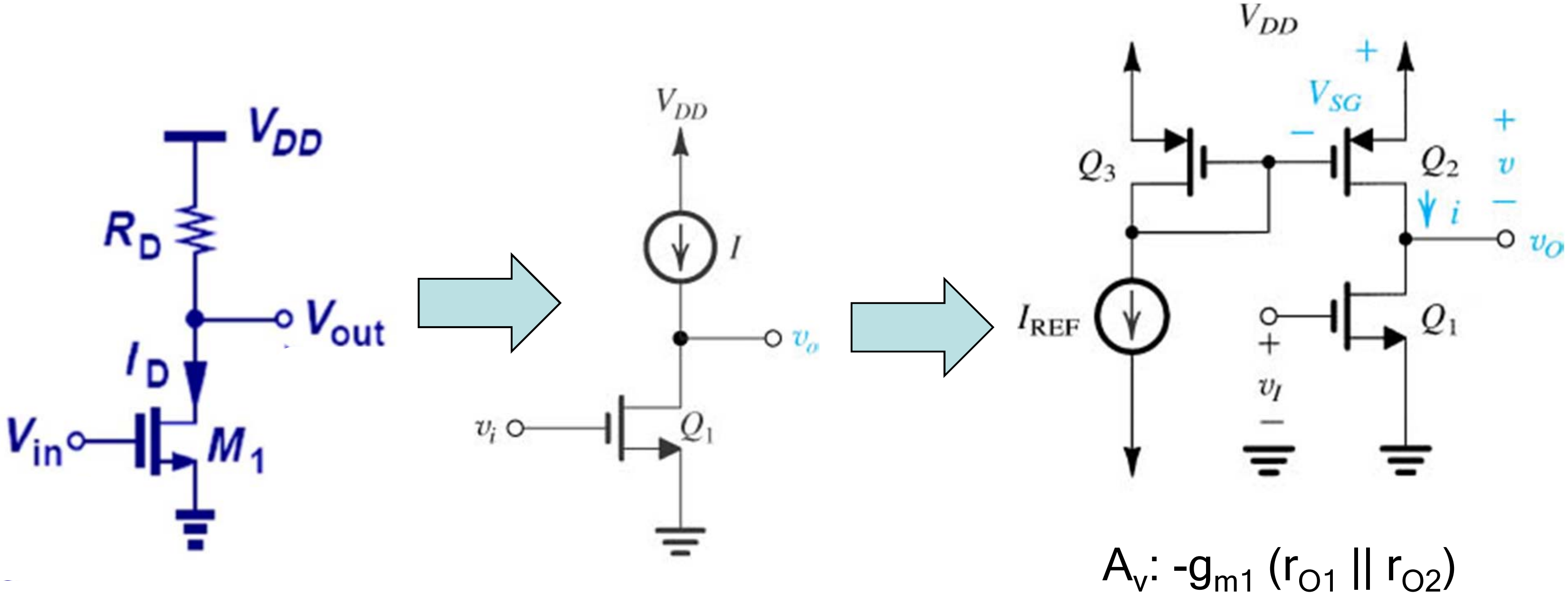
$$I_3 = I_{REF} \frac{(W/L)_3}{(W/L)_1}$$

$$I_3 = I_4$$

$$I_5 = I_4 \frac{(W/L)_5}{(W/L)_4}$$

Lect. 8: Current Mirror and Cascode Amplifier

CS with Current Source as an active load

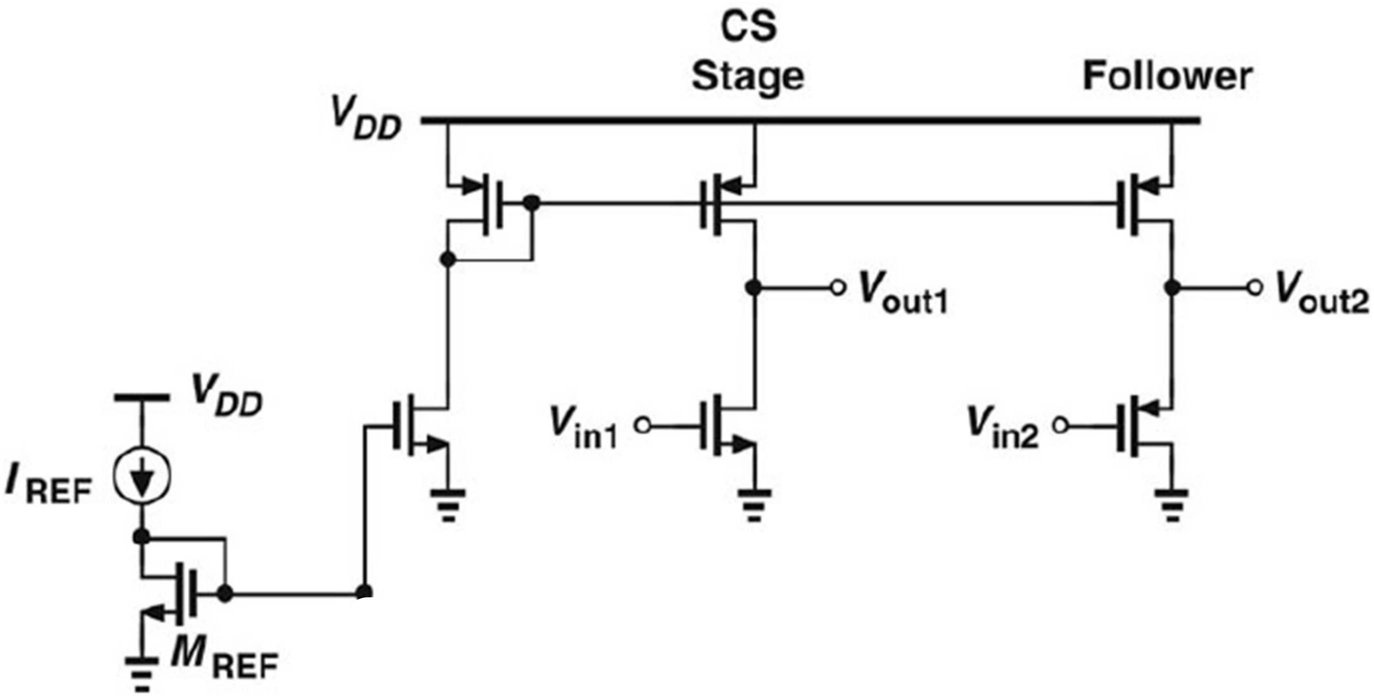


A_v: $-g_{m1} (r_{O1} \| r_{O2})$

PMOS current mirror provides bias and large resistance (Active Load) as well as bias current!

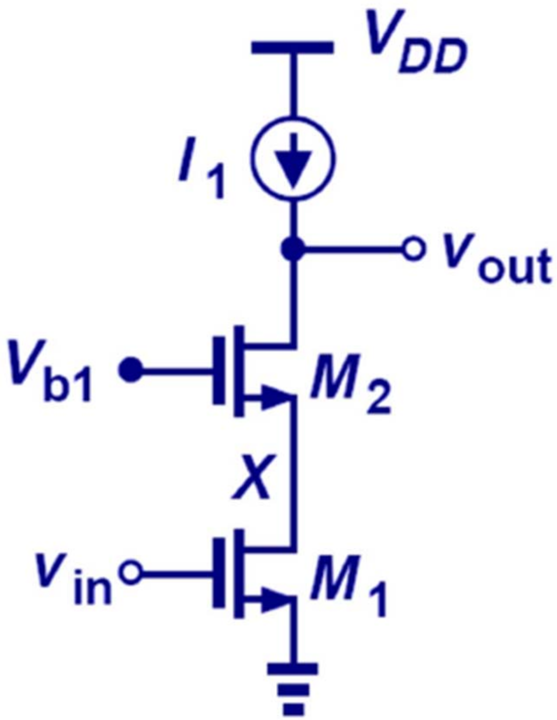
➔ Good for IC!

Lect. 8: Current Mirror and Cascode Amplifier



Lect. 8: Current Mirror and Cascode Amplifier

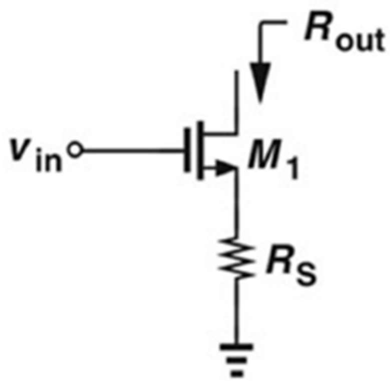
Cascode Amplifier



Assume ideal current source for simplicity

- R_{in}?

- R_{out}?



(From CS with Degeneration in Lect 5)

R_{out}: $(1 + g_m r_O)R_s + r_O$

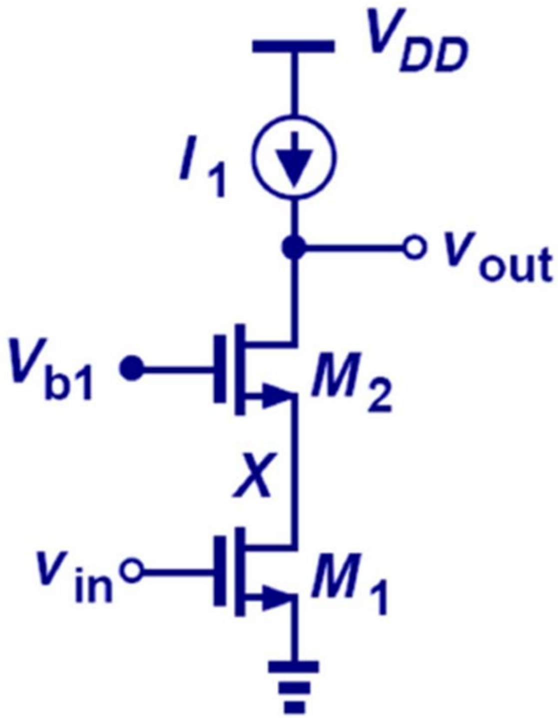
➔ $g_m r_O R_s$

- R_{out} for cascode: $g_{m2} r_{O2} r_{O1}$

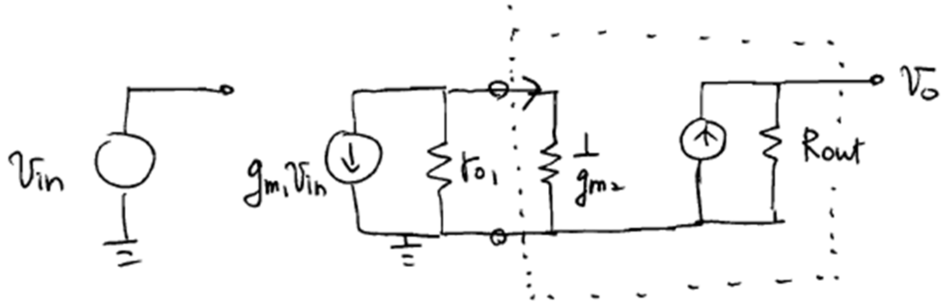
Cascoding MOS transistors enhances impedance by factor or $g_m r_0$

Lect. 8: Current Mirror and Cascode Amplifier

A_v for Cascode Amplifier



- Can be viewed as CS+CG



A_V : $- g_{m1} g_{m2} r_{O2} r_{O1}$

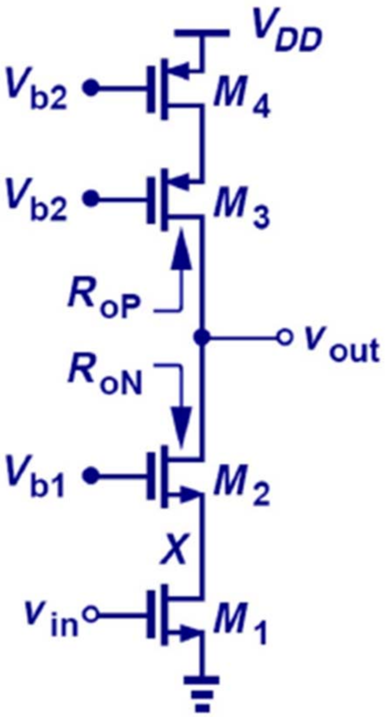
➔ Effectively CS amplifier with $R_{out} = g_{m2} r_{O2} r_{O1}$

Larger gain or faster for the same gain

Less V_{out} range

Lect. 8: Current Mirror and Cascode Amplifier

With cascoded PMOS transistors for the current source



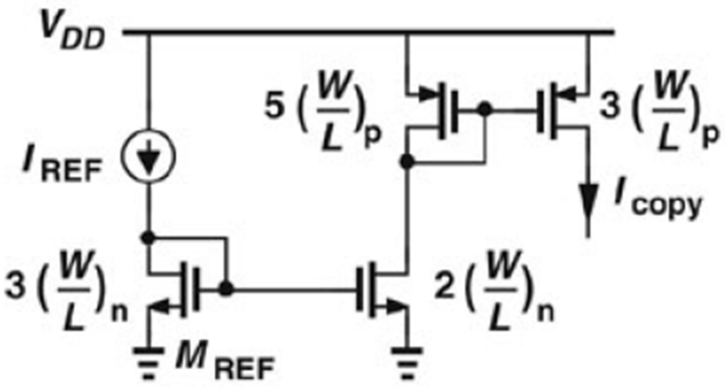
$$R_{on} \approx g_{m2} r_{O2} r_{O1}$$

$$R_{op} \approx g_{m3} r_{O3} r_{O4}$$

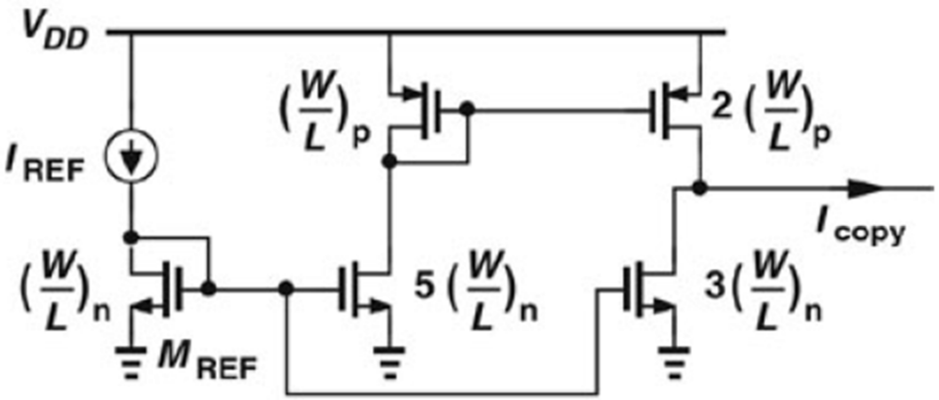
A_V : $- g_{m1} (g_{m2} r_{O2} r_{O1} \,||\, g_{m3} r_{O3} r_{O4})$

Homework(1)

Determine I_{copy} in following circuits. Assume all MOS transistors are in saturation and the influence of r_0 can be ignored.



(a)



(b)

W.-Y. Choi

Lect. 8: Current Mirror and Cascode Amplifier

Homework(2)

Determine the output impedance of circuits shown below. All transistors are in saturation and $g_m r_O >> 1$