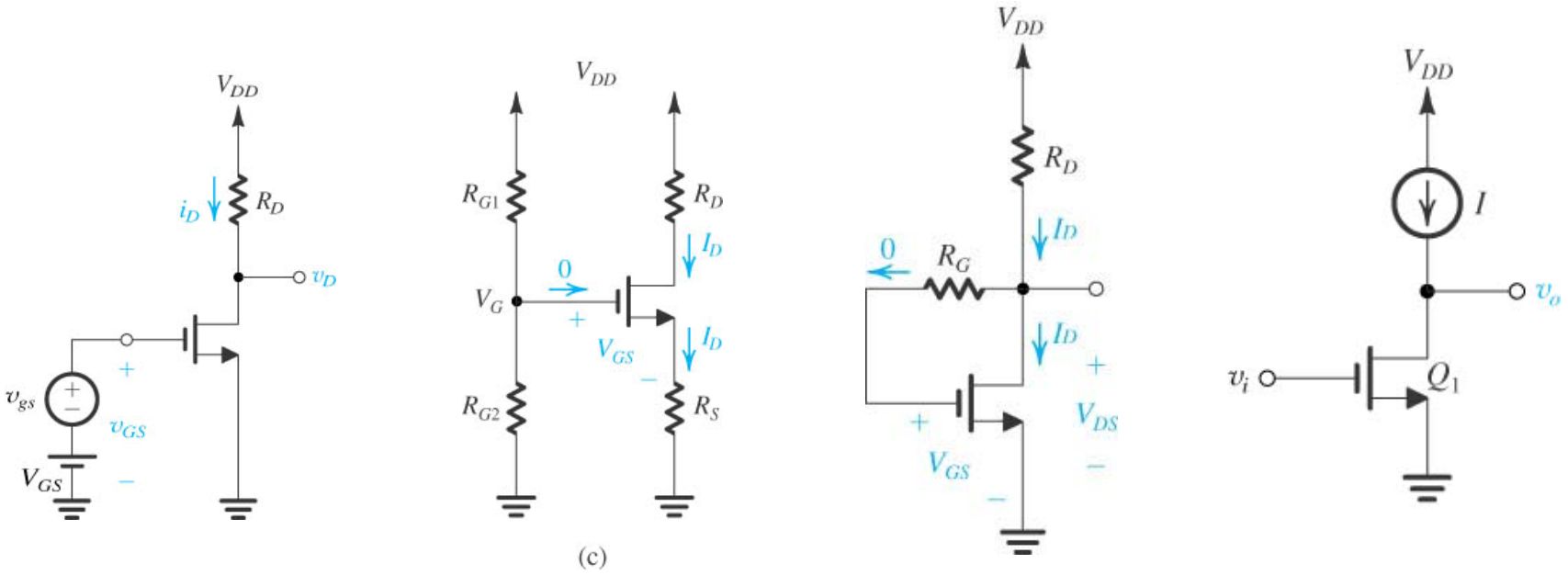
Lect. 22: MOSFET Current Mirror and CS Amplifier

Various bias techniques for MOSFET circuits



How do we make
a constant current source
with MOSFETs?

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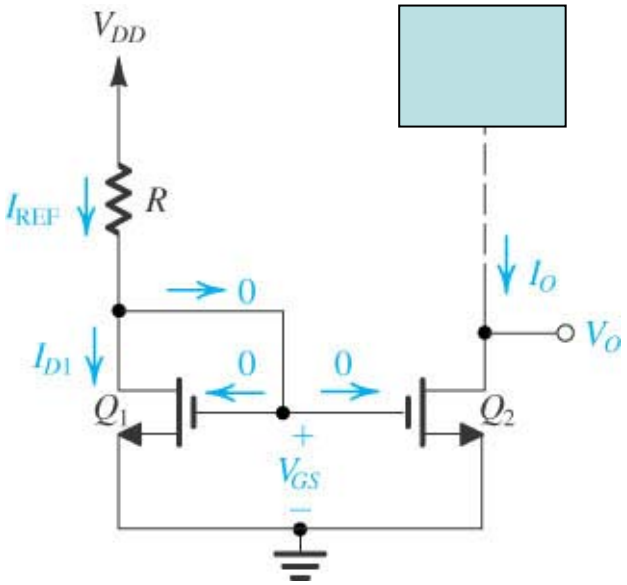
Constant current source:



(R can be outside the IC chip)

➔ Current mirror

$$I_{D1} = \frac{1}{2} k_n' \left(\frac{W}{L}\right)_1 \left(V_{GS} - V_{tn}\right)^2$$

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

Assuming Q_1, Q_2 have same properties,

$$I_O = I_{D2} = \frac{1}{2} k_n' \left(\frac{W}{L}\right)_2 \left(V_{GS} - V_{tn}\right)^2$$

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

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

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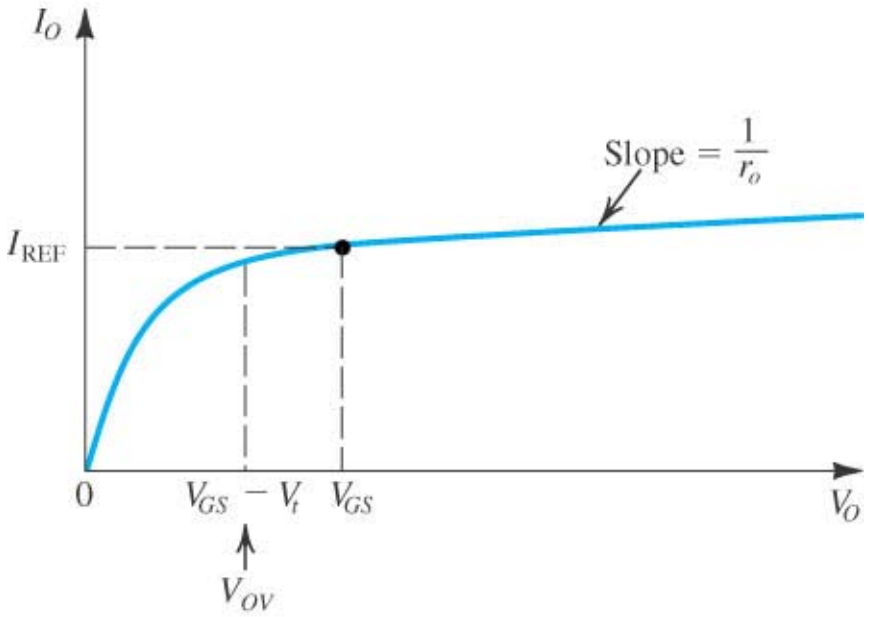
Mismatches between I_{REF} and I_O



Channel-length modulation

For two identical Q_1 and Q_2
$I_O = I_{REF}$ when $V_0 = V_{GS}$

As V_O increased, I_O increases from I_{REF}

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

$$\text{Since } r_0 \simeq \frac{V_A}{I_{REF}}$$

$$I_O = I_{REF} + \frac{V_O - V_{GS}}{V_A} \cdot I_{REF} = I_{REF}\left(1 + \frac{V_O - V_{GS}}{V_A}\right)$$

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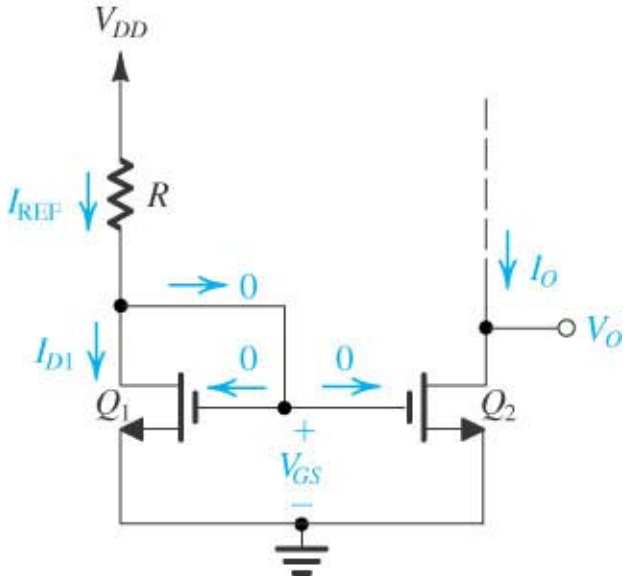
Example 6.5

V_{DD}=3V, Q_1 and Q_2 are identical with
L= 1μm, W=100μm, V_t=0.7V, k_n'=200μA/V^2,
V_A' (Early voltage per L) =20V/μm

1. Determine R for I_O=100μA.
2. What is the lowest value for V_O?
3. How much I_O changes when V_O changes 1V?



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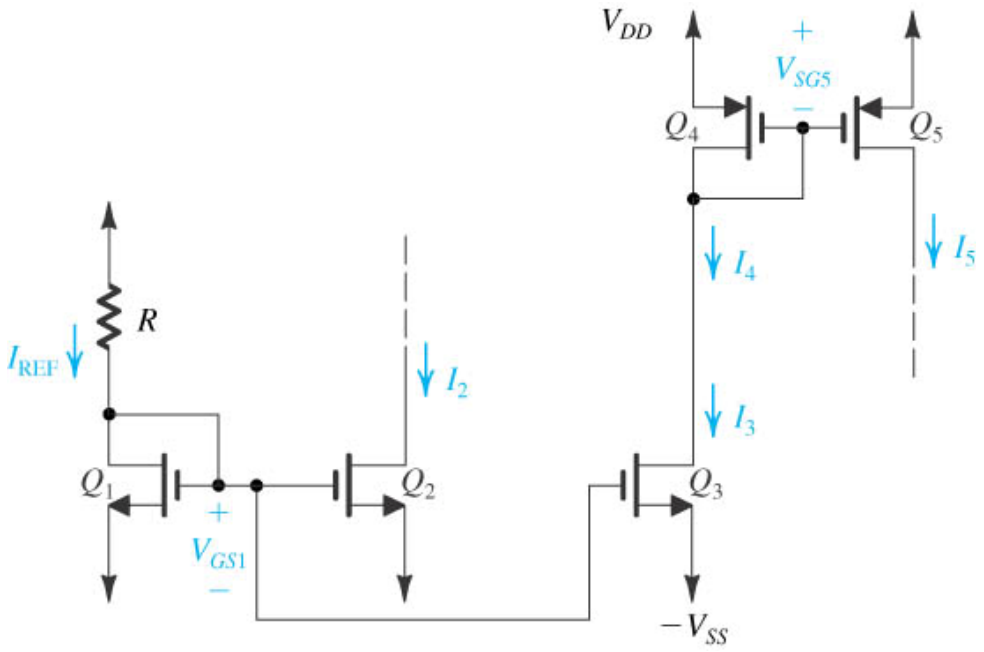


$$I_2 = I_{REF}\frac{(W/L)_2}{(W/L)_1}$$

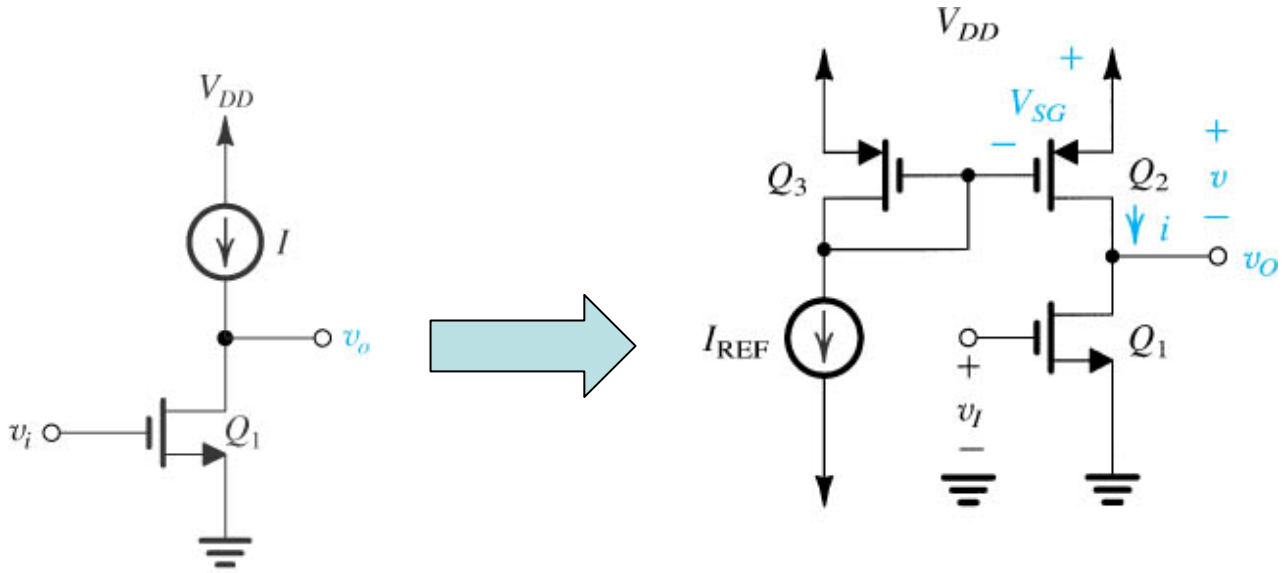
$$I_3 = I_{REF}\frac{(W/L)_3}{(W/L)_1}$$

$$I_3 = I_4$$

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

Current-steering circuits, current source (Q_5), current sink (Q_2)

Lect. 22: MOSFET Current Mirror and CS Amplifier



CS amplifier

Where is R_D ?

Current mirror as a resistor ➔ Active load

(Remember Q_2 has $r_{O)}$

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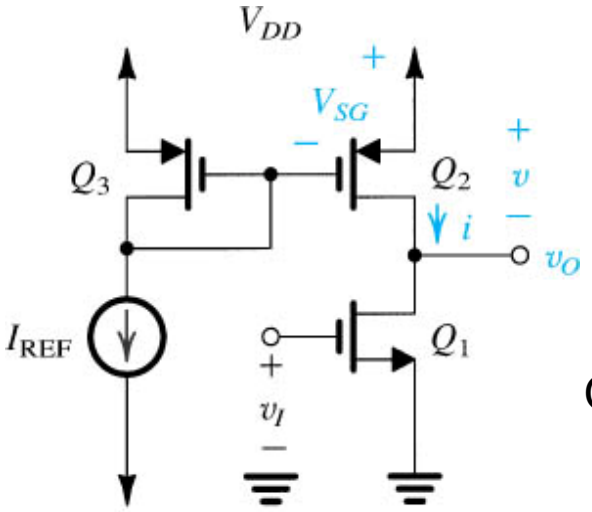
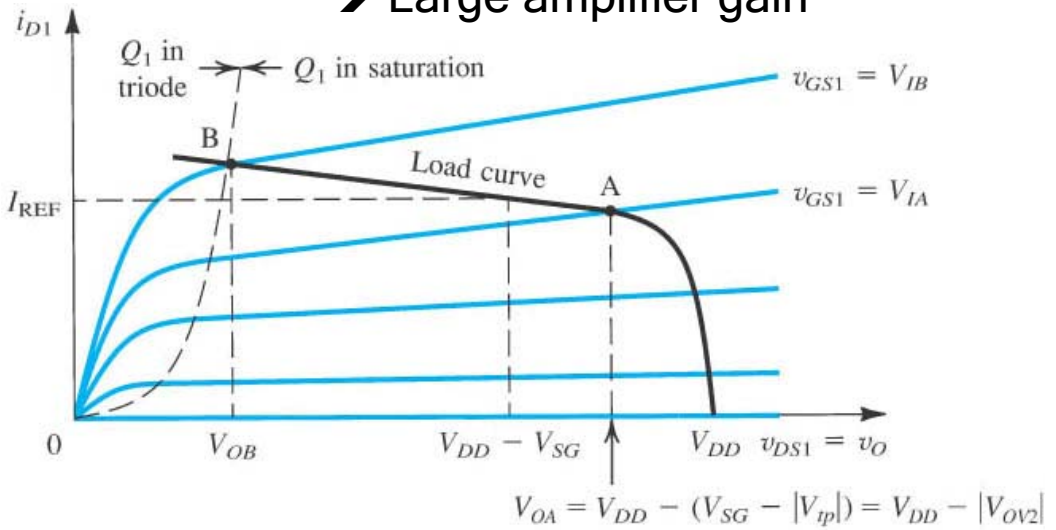
Large change in v_O with v_I change!
➔ Large amplifier gain

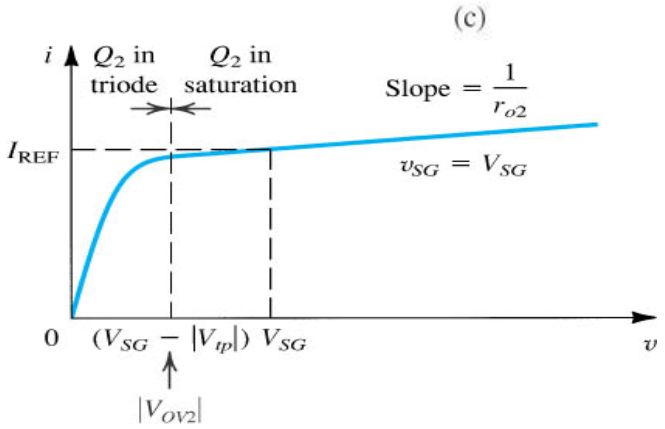
Load-line analysis



Q1



Q2



$v = V_{DD} - v_o$

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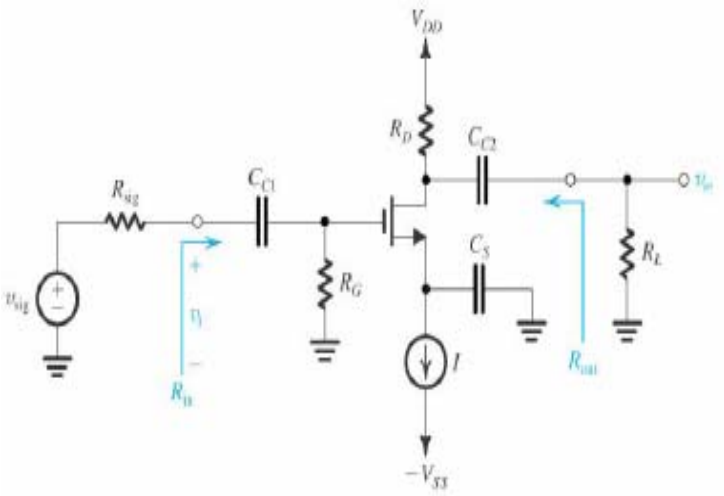
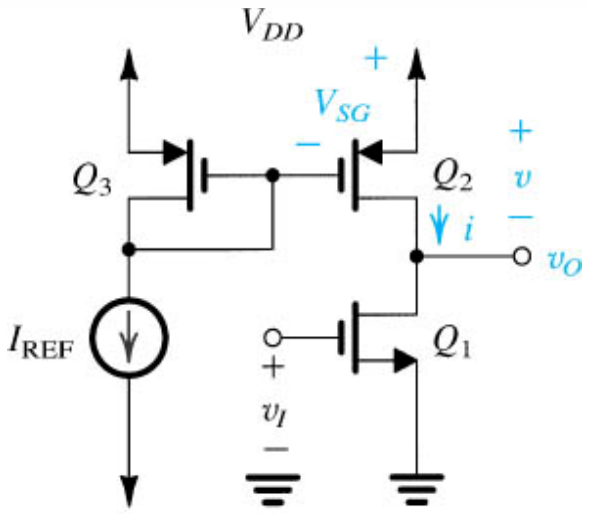


Gain for CS amplifier with R_D:

$-g_m (r_O \| R_D \| R_L)$



Gain for CS amplifier with PMOS current mirror

$-g_m (r_{O1} \| r_{O2} \| R_L)$

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

➔ Good for IC!

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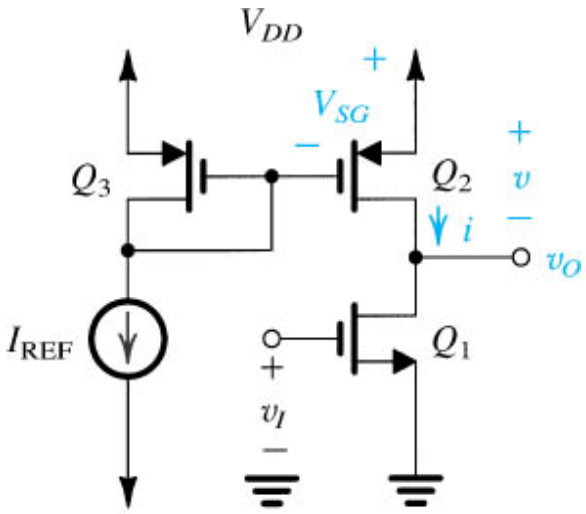
Example 6.8

V_{DD}=3V, V_{tn}=|V_{tp}|=0.6V, k_n'=200μA/V², k_p'=65μA/V²,
L=0.4μm, W=4μm, V_{An}=20V, |V_{Ap}|=10V, I_{REF}=100μA.

1. What is the small-signal voltage gain, v_O/v_I?
2. What is the maximum v_O for which the above is valid?



$$1.\ A_v = -g_{m1}(r_{o1} \,\|\, r_{o2})$$

$$g_{m1} = \sqrt{2k_n'\left(\frac{W}{L}\right)_1 I_{REF}} = \sqrt{2\times 200\times\frac{4}{0.4}\times 100} = 0.63\,\text{mA/V}$$

$$r_{o1} = \frac{V_{An}}{I_{D1}} = \frac{20\text{V}}{0.1\text{mA}} = 200\text{k}\Omega$$

$$r_{o2} = \frac{|V_{Ap}|}{I_{D2}} = \frac{10\text{V}}{0.1\text{mA}} = 100\text{k}\Omega$$

$$\therefore A_v = -0.63(\text{mA/V})\cdot(200\,\|\,100)(\text{k}\Omega) = -42$$

$$2.\ \text{For } Q_3,\ I_{REF} = \frac{1}{2}k_p'\left(\frac{W}{L}\right)_3\left(V_{SG}-|V_{tp}|\right)^2\left(1+\frac{V_{SD,3}}{|V_{Ap}|}\right)$$

$$100 = \frac{1}{2}\times 65\left(\frac{4}{0.4}\right)(V_{SG}-0.6)^2\left(1+\frac{V_{SG}}{10}\right)$$

$$\therefore V_{SG} = 1.13V$$

$$\text{For } v_{O,\max},\ V_{SD2,\min} = V_{SG}-|V_{tp}| = 1.13-0.6 = 0.53V$$

$$\therefore v_{O,\max} = V_{DD}-V_{SD2,\min} = 2.47V$$

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Homework: Do your design project: Part 1 and 2 (No need to hand it in)