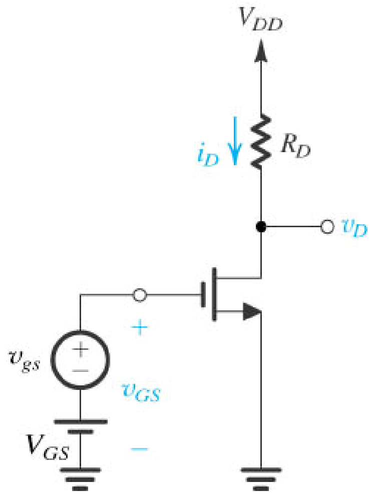
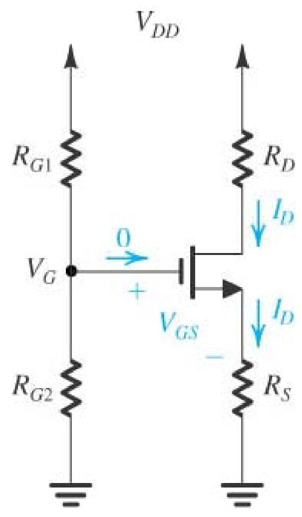
Lect. 23: MOSFET Current Mirror and Active Load

Various bias techniques for MOSFET circuits





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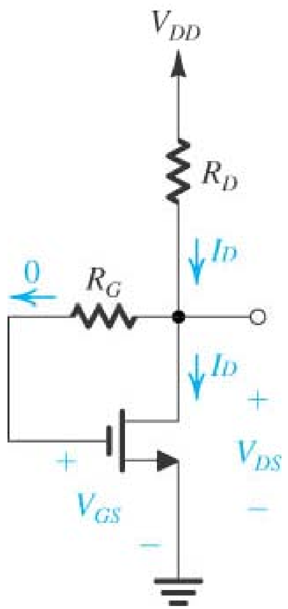

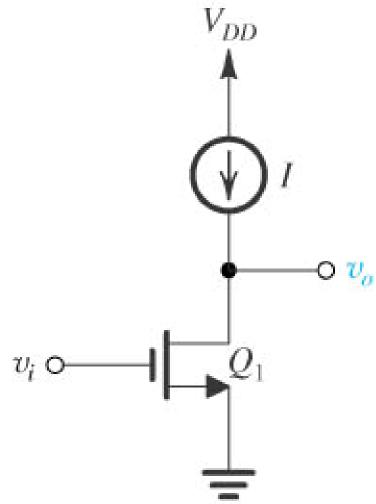

How do we make
a constant current source
with MOSFETs?

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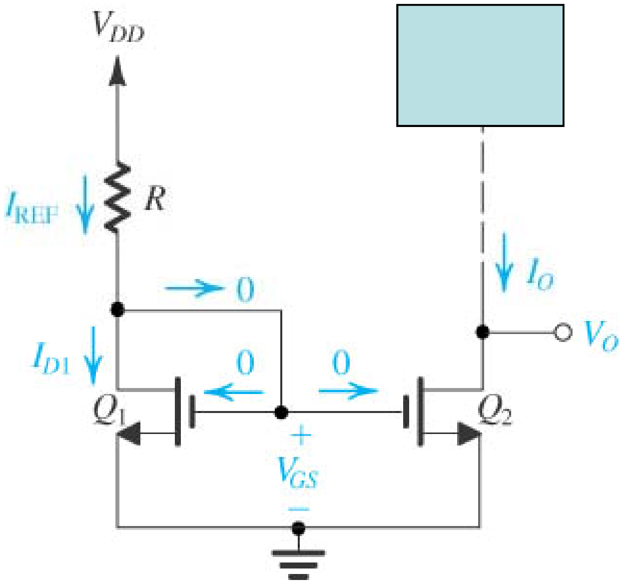
Constant current source:



➔ Current mirror

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

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

Assuming Q_1, Q_2 have same properties (k_n'),

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

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

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

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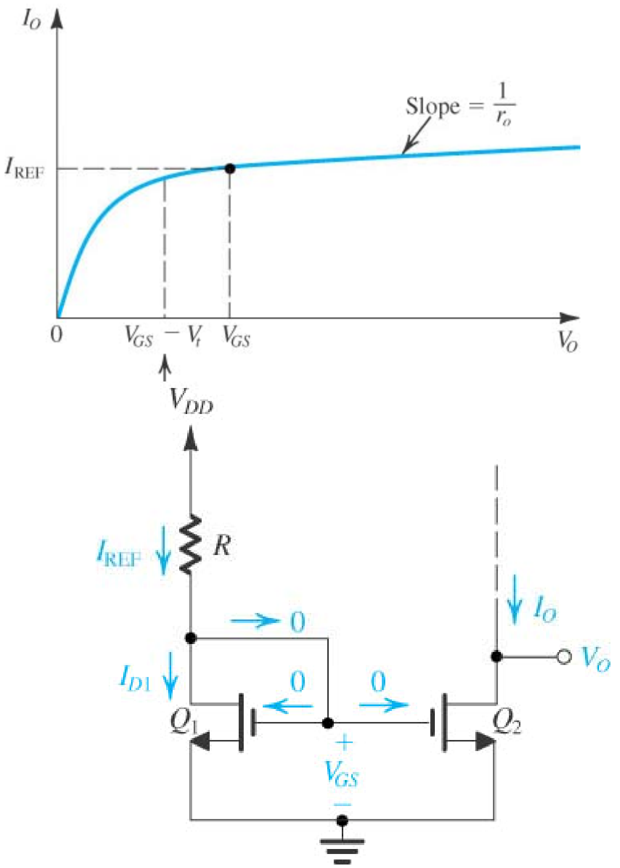
Mismatches between I_{REF} and I_O

Due to channel-length modulation



For two Q_1 and Q_2

$I_O = I_{REF}$ only if $V_{DS1} = V_{DS2}$ ➔ $V_0 = V_{GS}$

As V_O increased, I_O increases from I_{REF}

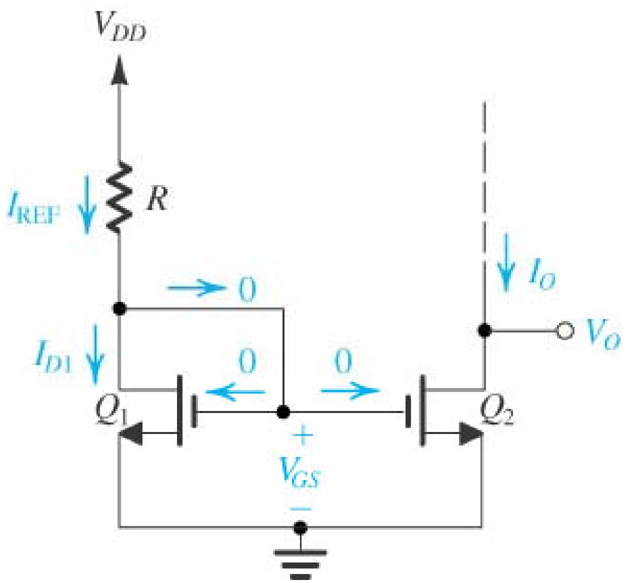
$$I_O = I_{REF} + \frac{V_O - V_{GS}}{r_0}$$

Comparison with BJT current mirror?

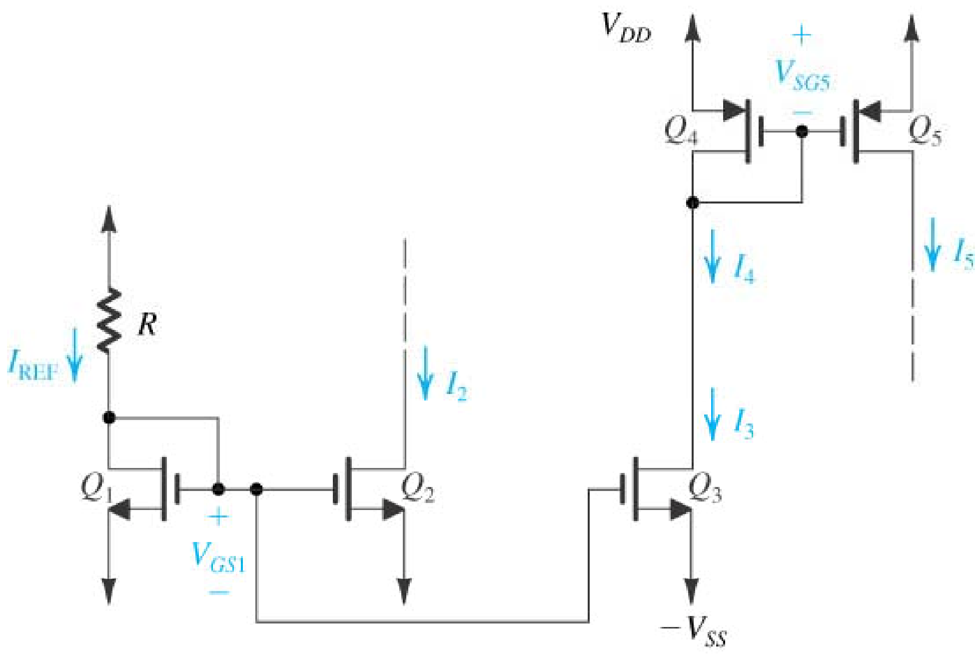
Lect. 23: MOSFET Current Mirror and Active Load

V_{DD}=3V, Q_1 and Q_2 are identical with
L= 1μm, W=100μm, V_t=0.7V, k_n'=200μA/V^2,
r_o = 200kΩ

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?



Lect. 23: MOSFET Current Mirror and Active Load



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

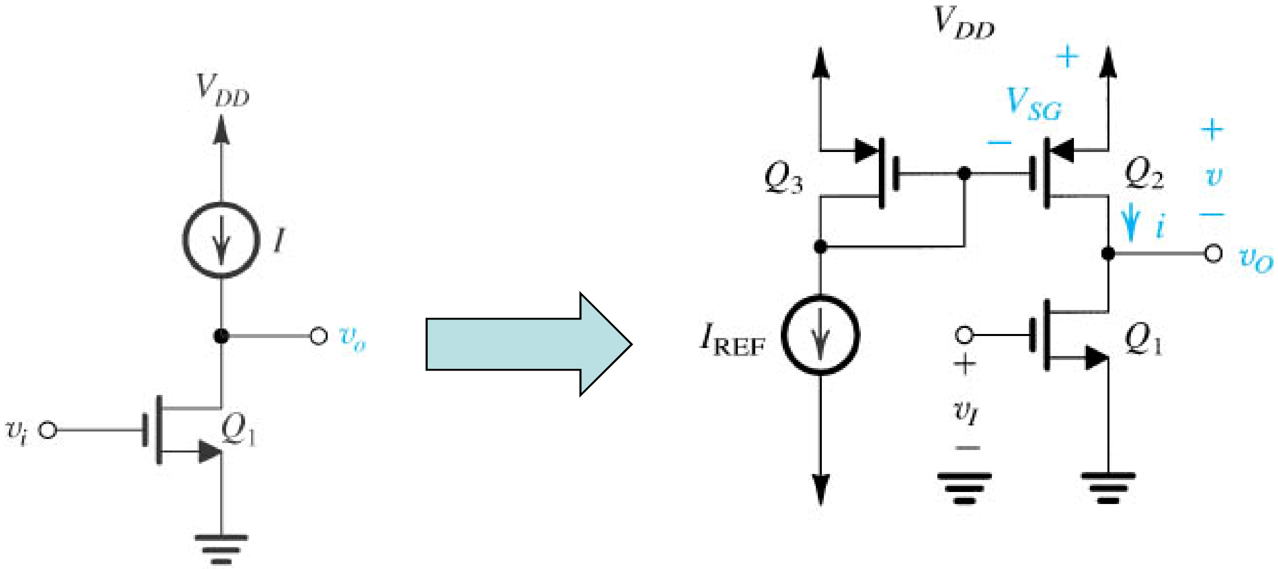
$$I_3 = I_{REF} \frac{(W/L)_3}{(W/L)_1}$$

$$I_3 = I_4$$

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

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

Lect. 23: MOSFET Current Mirror and Active Load



CS amplifier

Where is R_D ?

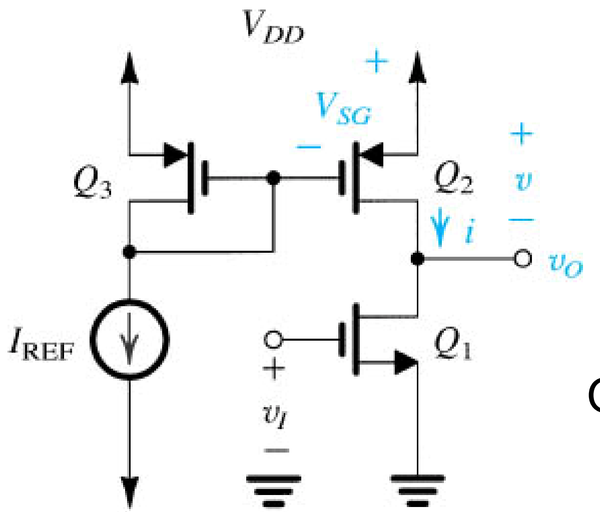
Current source as a resistor ➔ Active load

(Remember Q_2 has r_O)

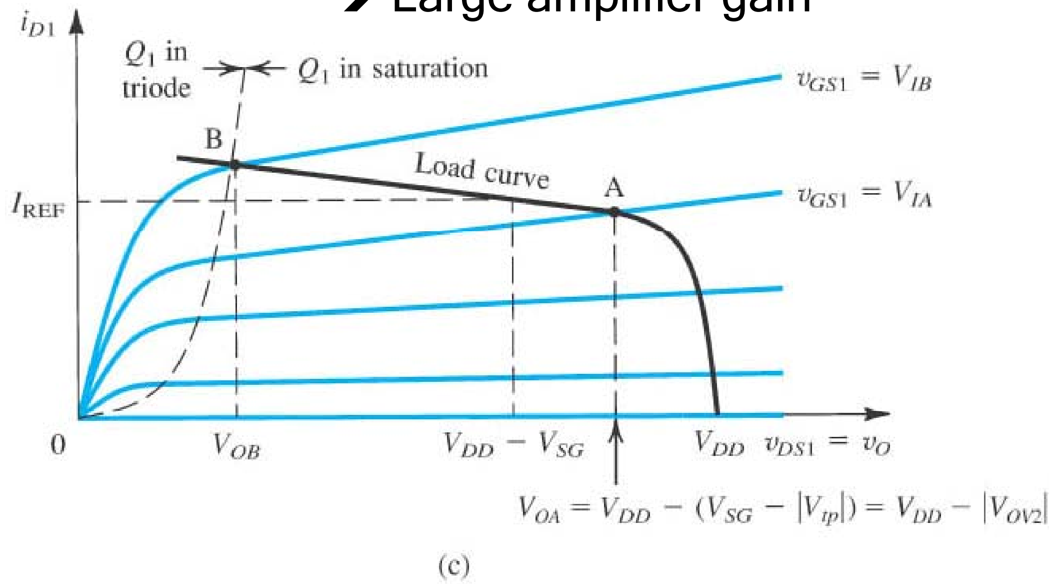
Lect. 23: MOSFET Current Mirror and Active Load

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

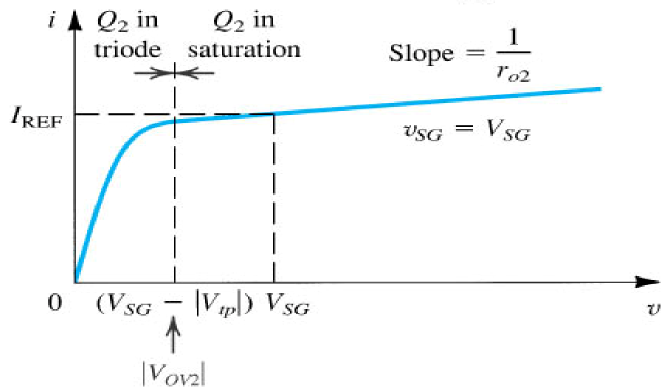
Load-line analysis



Q1



Q2



$v = V_{DD} - v_o$

$v_o = V_{DD} - v$

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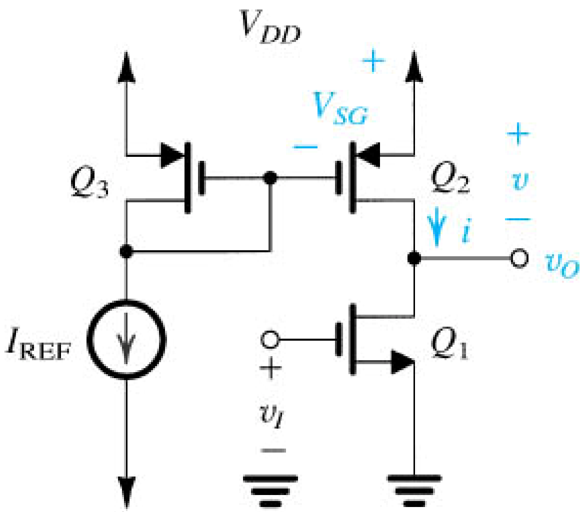


Gain for CS amplifier with PMOS current mirror

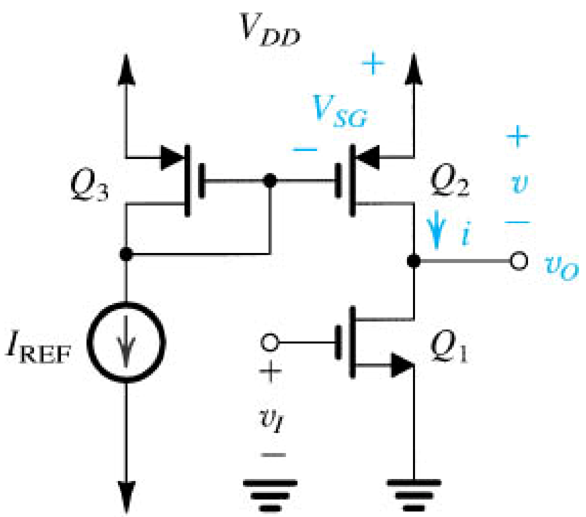
$-g_m\,(r_{O1}\,||\,r_{O2})$

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

➔ Good for IC!

V_{DD}=3V, V_{tn}=|V_{tp}|=0.6V, k_n'=200μA/V^2, k_p'=65μA/V^2,
L=0.4μm, W=4μm, r_{o1}=200kΩ, $r_{o2,3}$ = 100kΩ,
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. $A_v = -g_{m1}(r_{o1} \| r_{o2})$

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

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

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

$$100 = \frac{1}{2}\times 65\left(\frac{4}{0.4}\right)(V_{SG} - 0.6)^2 + \frac{V_{SG,3}}{100K}$$

$$\therefore V_{SG} \sim 1.12V$$

For $v_{O,\max}$, $V_{SD2,\min} = V_{SG} - |V_{tp}| = 1.12 - 0.6 = 0.52V$

$$\therefore v_{O,\max} = V_{DD} - V_{SD2,\min} = 2.48V$$