EE105 – Fall 2015
Microelectronic Devices and Circuits

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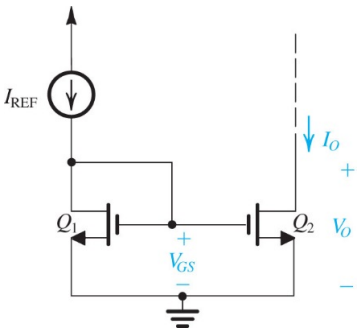
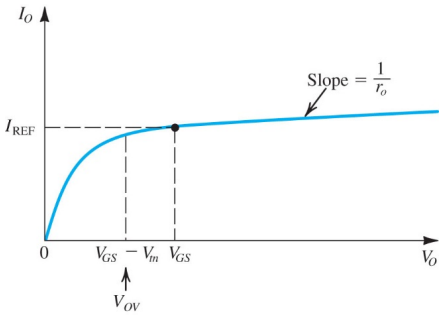
Discrete vs Integrated Circuits

Discrete Circuits	IC
• Resistors and capacitors are frequently used	• Use mostly transistors – Resistors and capacitors occupy too much areas
• AC coupled with coupling capacitors	• Mostly DC coupled (without capacitors)
• Large DC power supply voltage	• Low DC power supply voltage (~ 1V)
• Transistor choice limited to available parts	• Can vary device size
• Mostly BJT, some MOS	• Predominantly CMOS – BiCMOS provides BJT

Current Mirrors





Neglecting channel length modulation

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

$$V_{GS1} = V_{GS2}$$

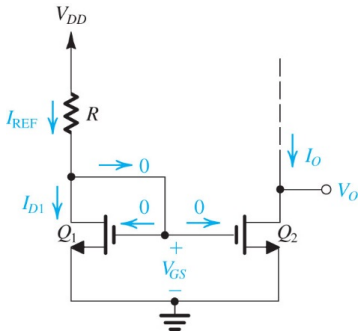
Q_1 and Q_2 are matched (same k_n' and V_{tn})

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

If considering channel length modulation, I_O vary slightly with V_O

Output resistance $R_o = \frac{\Delta V_O}{\Delta I_O} = r_{o2}$

Example Current Mirror with Reference Current Source



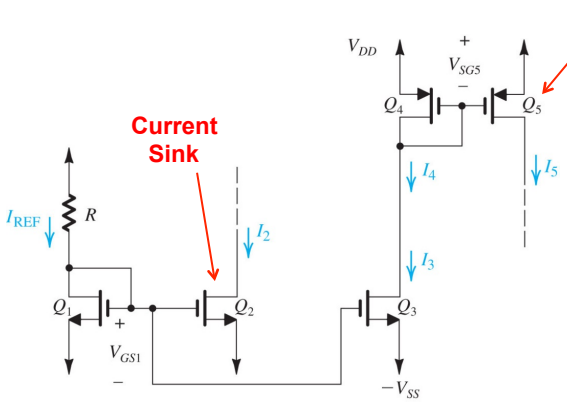
Neglecting channel length modulation

$$I_{D1} = \frac{k_n'}{2}\left(\frac{W}{L}\right)(V_{GS1} - V_{tn})^2 = \frac{V_{DD} - V_{GS1}}{R}$$

Solve the quadratic equation for V_{GS1}

$$I_{REF} = I_{D1} = \frac{k_n'}{2}\left(\frac{W}{L}\right)(V_{GS1} - V_{tn})^2$$

MOS Current Steering Circuits



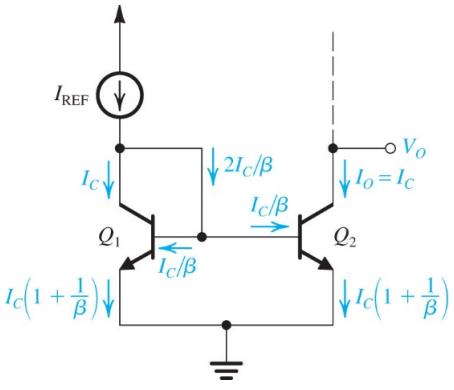
$$I_2 = I_{REF}\frac{(W/L)_2}{(W/L)_1}$$

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

$$I_4 = I_3$$

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

BJT Current Mirror



Neglecting Early effect

$I_C = I_S e^{\frac{V_{BE}}{V_T}}$ (Remember, $I_S \propto$ Emitter Area)

$V_{BE1} = V_{BE2}$

For Q_1 and Q_2 with matched emitter areas

$$I_{REF} = I_C + 2I_B = I_C + \frac{2I_C}{\beta}$$

$$I_O = I_C$$

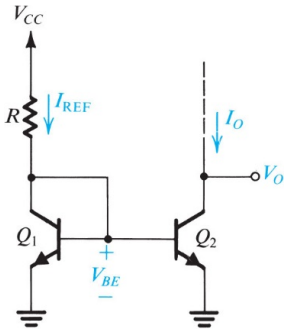
$$\frac{I_O}{I_{REF}} = \frac{1}{1+\frac{2}{\beta}}$$

If Q_2 emitter is m times larger than Q_1's

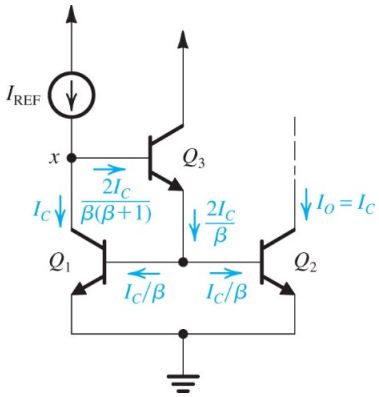
$$\boxed{\frac{I_O}{I_{REF}} = \frac{m}{1+\frac{m+1}{\beta}}}$$

Example BJT Current Source

$$I_{REF} = \frac{V_{CC} - V_{BE}}{R}$$



Current Mirror with Base Current Compensation



Add BJT Q_3 to supply base currents of Q_1 and Q_2

$$I_{REF} = I_C + I_{B3} = I_C + \frac{2I_C}{\beta(\beta+1)}$$

$$I_O = I_C$$

$$\frac{I_O}{I_{REF}} = \frac{1}{1+\frac{2}{\beta(\beta+1)}} \approx \frac{1}{1+\frac{2}{\beta^2}}$$

Small-Signal Model

Small-signal current modulation at I_{D1}

$$R_{in} = r_{o1} \parallel \frac{1}{g_{m1}} \quad , \quad R_o = r_{o2}$$

$$A_{is} = \frac{g_{m2}}{g_{m1}}$$