Current Mirrors

- ***Basic Current Mirrors***
- ***Cascode Current Mirrors***

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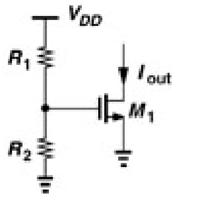
References

- **B. Razavi, "Design of Analog CMOS Integrated Circuits", McGraw-Hill, 2001.**

Copying Currents

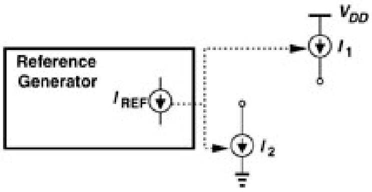
- **Definition of current by a resistive divider**

$$I_{out} \approx \frac{\mu_n C_{ox}}{2} \frac{W}{L} \left(\frac{R_2}{R_1 + R_2} V_{DD} - V_{TH} \right)^2$$



- **I_{out} depends upon supply, process and temperature.**

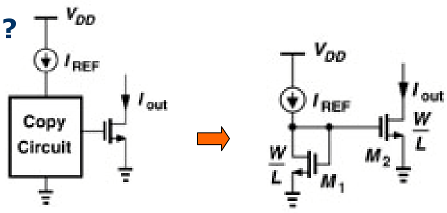
- **A relatively complex circuit is used to generate a stable reference current I_{REF}**



- **I_{REF} is then copied to the different current sources of the system.**

Basic Current Mirror

- **How to guarantee that $I_{out} = I_{REF}$?**



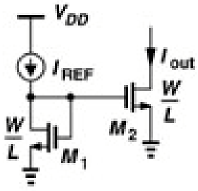
- **2 identical MOS devices that have equal gate-source voltages and operating in saturation carry equal currents (assuming λ=0).**

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

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

$$\Rightarrow \quad I_{out} = \frac{(W/L)_2}{(W/L)_1} I_{REF}$$

Taking channel Length modulation into account



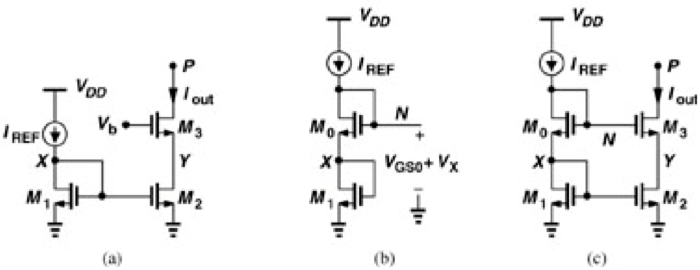
$$I_{D1} = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_1 (V_{GS} - V_{TH})^2 (1 + \lambda V_{DS1})$$

$$I_{D2} = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_2 (V_{GS} - V_{TH})^2 (1 + \lambda V_{DS2})$$

$$\Rightarrow \quad \frac{I_{D1}}{I_{D2}} = \frac{(W/L)_2}{(W/L)_1}\frac{(1+\lambda V_{DS2})}{(1+\lambda V_{DS1})}$$

$$If \quad V_{DS1} \neq V_{DS2} \quad \Rightarrow \quad I_{D1} \neq I_{D2}$$

Cascode Current Mirror



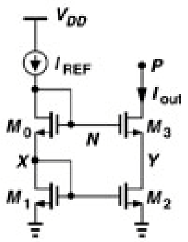
$$V_{GS0} + V_X = V_{GS3} + V_Y$$

$$if \quad \frac{(W/L)_3}{(W/L)_0} = \frac{(W/L)_2}{(W/L)_1}$$

$$Then \quad V_{GS3} = V_{GS0}$$

$$and \quad V_Y = V_X$$

Limited Voltage Swing



(c)

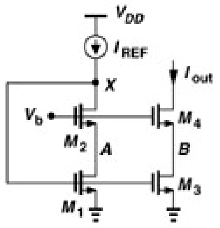
$$V_{DS3} = V_{GS3} - V_{TH}$$

$$V_{P\min} - V_Y = V_N - V_Y - V_{TH}$$

$$V_{P\min} = V_N - V_{TH}$$

$$V_{P\min} = V_{GS1} + V_{GS0} - V_{TH}$$

$$V_{P\min} = (V_{GS1} - V_{TH}) + (V_{GS0} - V_{TH}) + V_{TH}$$



(b)

- **Low Voltage Cascode Current Mirror:**

$$V_{P\min} = (V_{GS3} - V_{TH}) + (V_{GS4} - V_{TH})$$