EE223 Analog Integrated Circuits
Fall 2018

Lecture 12: Cascode Current Mirrors

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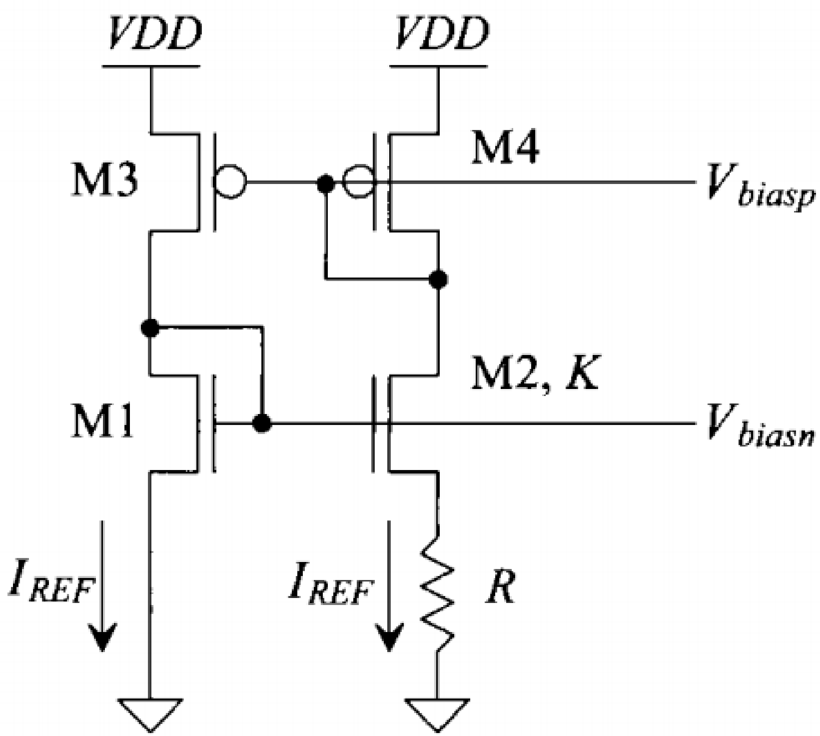
Supply Independent Biasing

Beta Multiplier Circuit



$$I_{REF} = \frac{2}{R^2 KP_n \cdot \frac{W_1}{L_1}} \left(1 - \frac{1}{\sqrt{K}}\right)^2$$

$$V_{GS1} = V_{GS2} + I_{REF} \cdot R$$

$$V_{GS} = \sqrt{\frac{2I_D}{\beta}} + V_{THN}$$

$$\left(\beta = KP_n \cdot \frac{W}{L}\right)$$

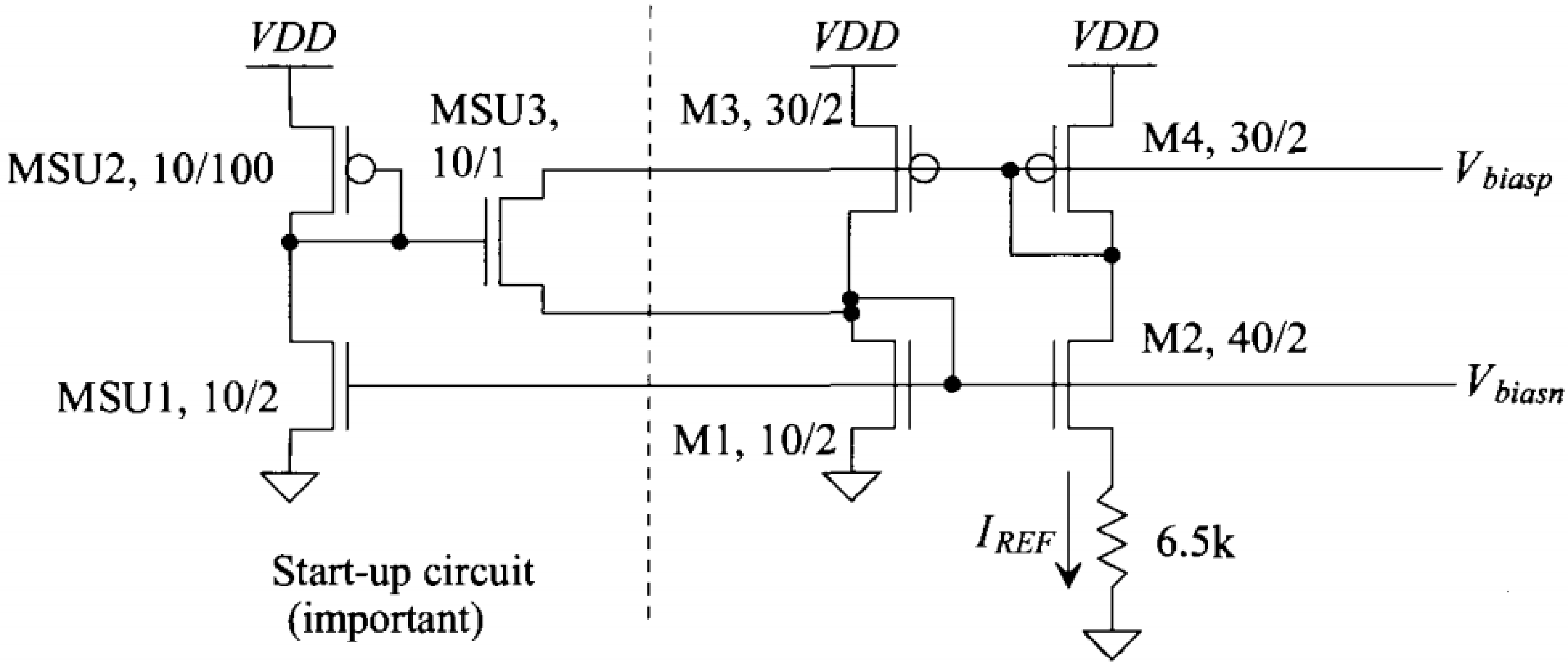
$$\beta_2 = K \cdot \beta_1$$

$$W_2 = K \cdot W_1$$

When K=4, g_m=1/R

⟶ Constant-g_m

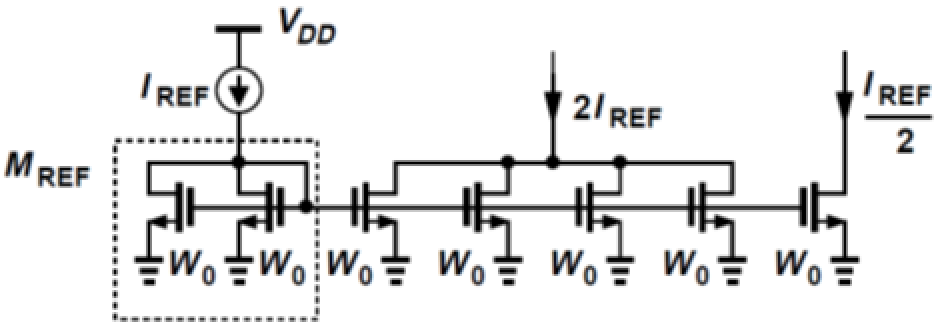
Beta-multiplier Reference with Start-up circuit



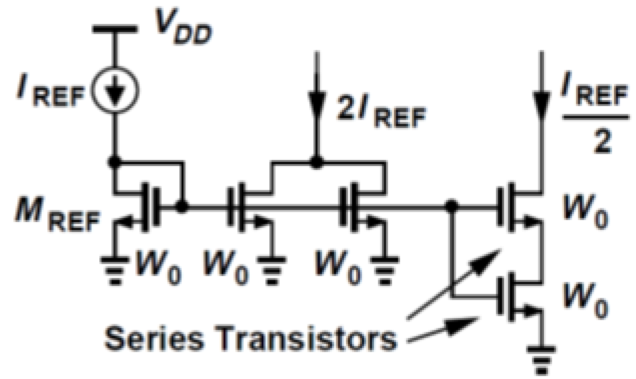
Self-biased circuit has two possible operating points.
Zero current state should be avoided -> Need a Start-up

Sizing Current Mirror

- How do we generate a current equal to $I_{REF}/2$ from I_{REF} ?



(a) half-width device

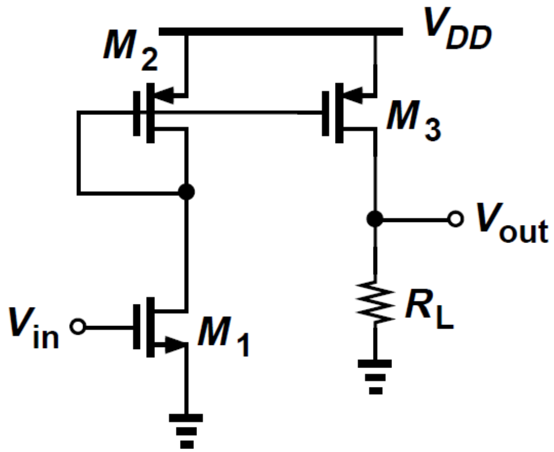


(b) series transistors

- Approach (b) preserves an effective length of ($L_{drawn}-2L_D$) for each unit, yielding an equivalent length of $2(L_{drawn} - 2L_D)$
- Current mirrors can process signals as well, example next slide.

Current Mirror to Process Signal

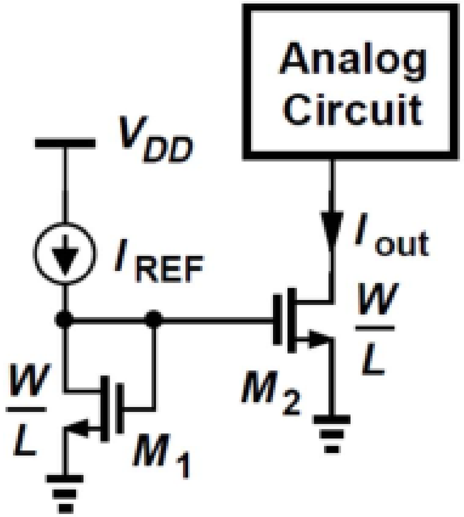
- Calculate the small-signal voltage gain of the circuit



$$
\begin{aligned}
I_{D2} &= I_{D1} \\
I_{D3} &= I_{D2}(W/L)_3/(W/L)_2
\end{aligned}
$$

- Gain = $g_{m1}R_L(W/L)_3/(W/L)_2$

Accuracy of Simple Current Mirror



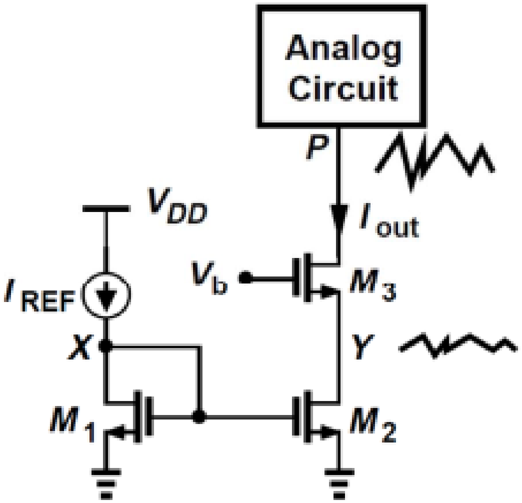
$$I_{D1} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_1 (V_{GS} - V_{TH})^2(1+\lambda V_{DS1})$$

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

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

- While $V_{DS1}=V_{GS1}=V_{GS2}$
  - V_{DS2} may not be equal to V_{DS1}
  - This cause an error in the mirroring ratio
- To improve accuracy,
  - Reduce λ
  - Force V_{DS2} to be equal to V_{DS1} (Cascode Current Mirror)

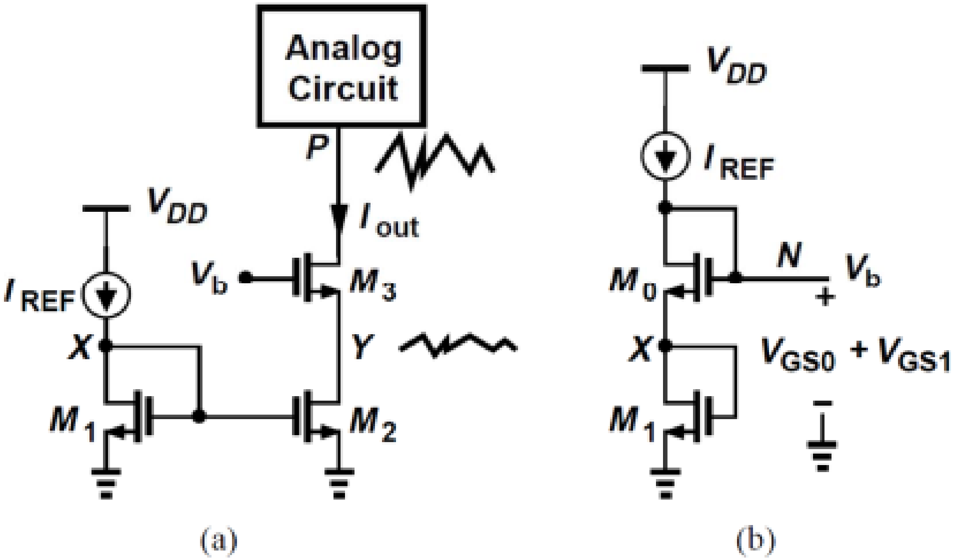
Cascode Current Mirror



(a)

- A cascode device can shield a current source, thereby reducing the voltage variations across it.
- But, how do we ensure that $V_{DS2} = V_{DS1}$?
- We can generate V_b such that $V_b - V_{GS3} = V_{DS1}(=V_{GS1})$ with a stacked diode connected transistor

Cascode Current Mirror



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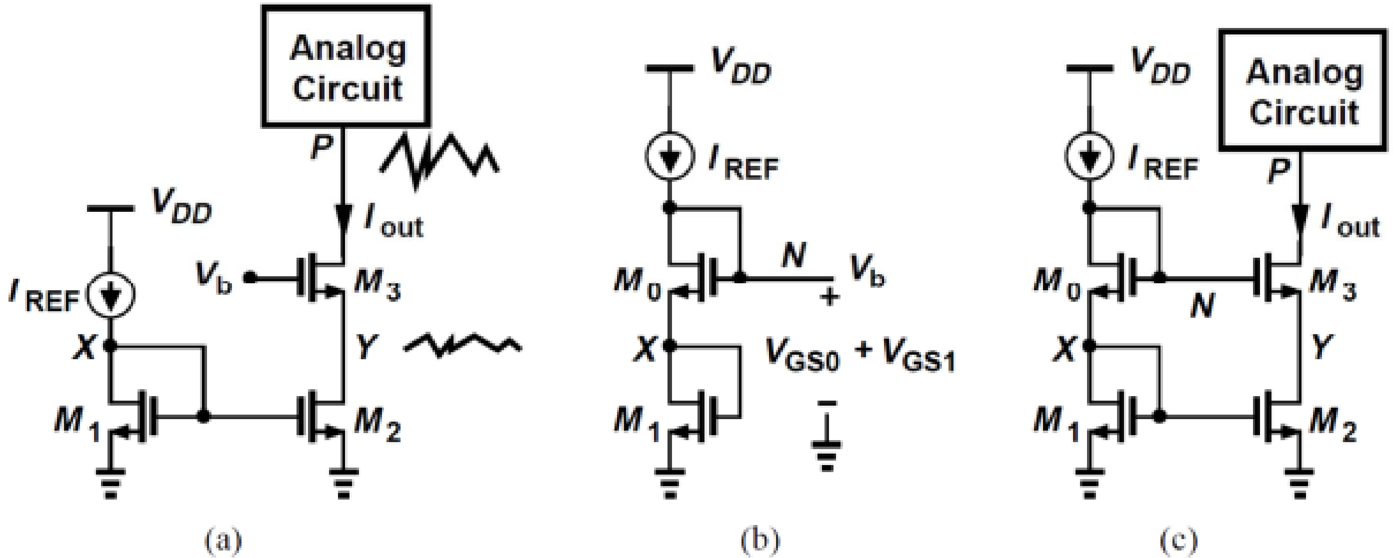

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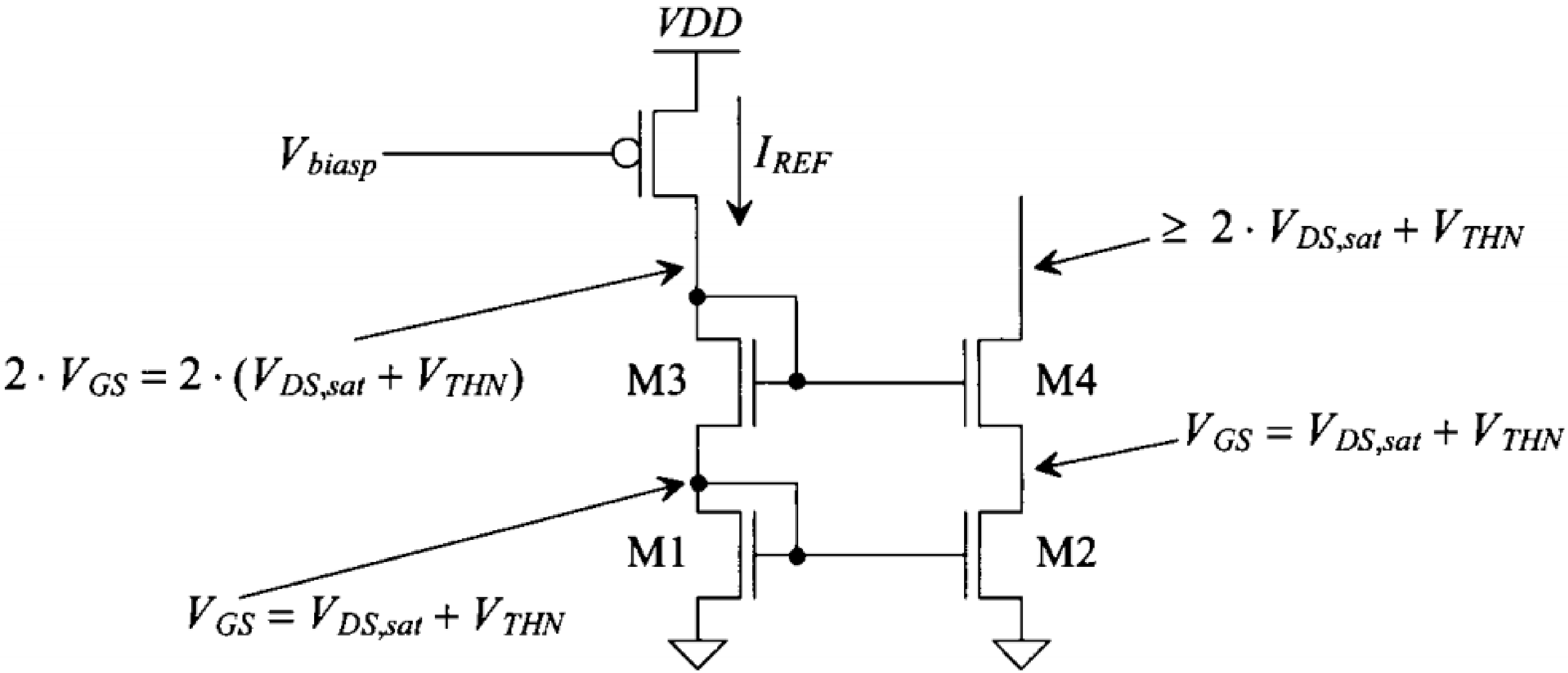
Cascode Current Mirror Compliance Voltage



(a) Regular cascode structure