EECE488: Analog CMOS Integrated Circuit Design

Set 4

Current Mirrors

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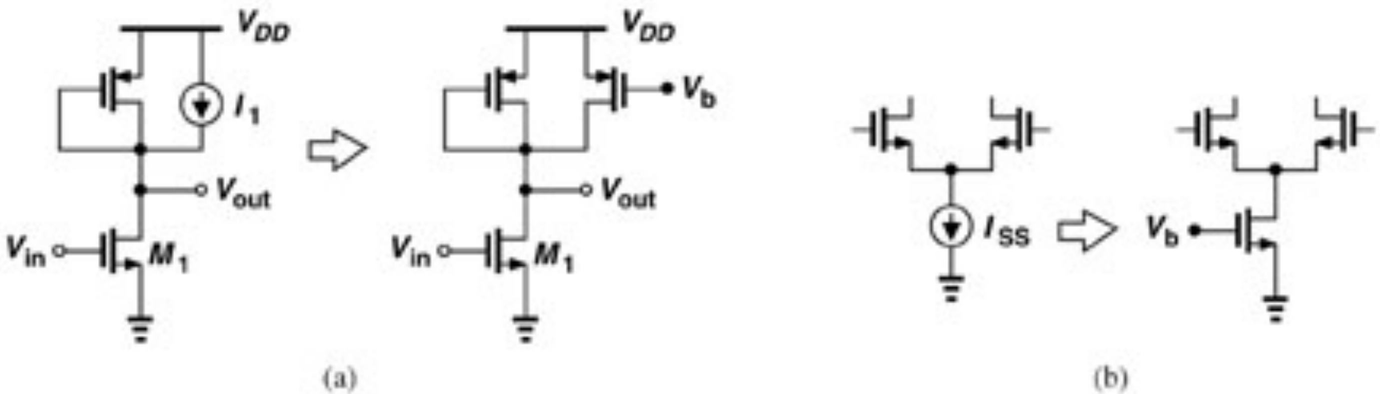
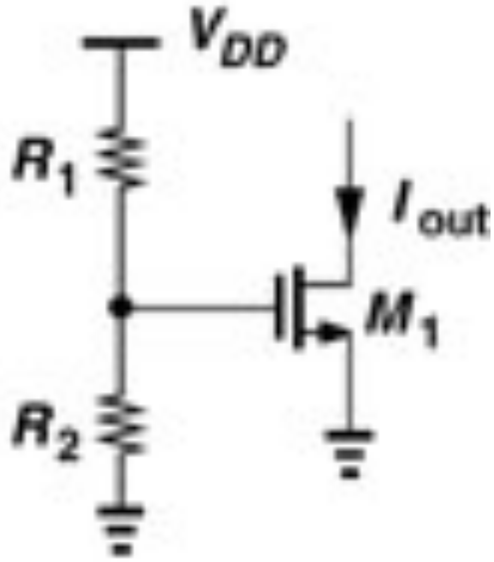
Applications of Current Sources



Simple Resistive Biasing for Current Source



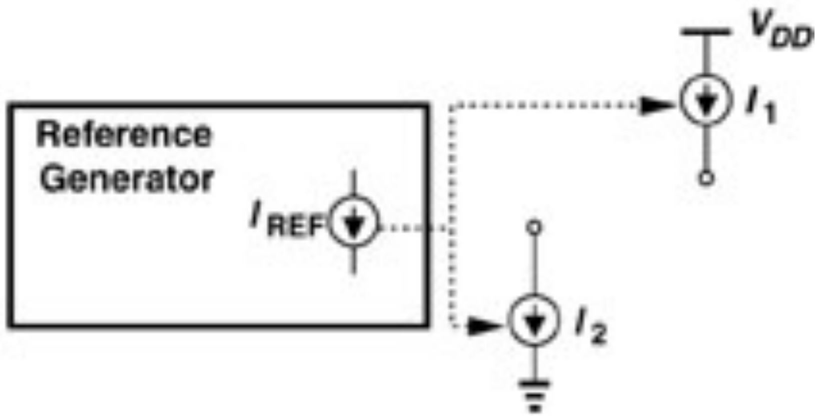
$$I_{OUT} \approx \frac{\mu_n C_{ox}}{2}\frac{W}{L}\left(\frac{R_2}{R_2+R_1}V_{DD}-V_{TH}\right)^2$$

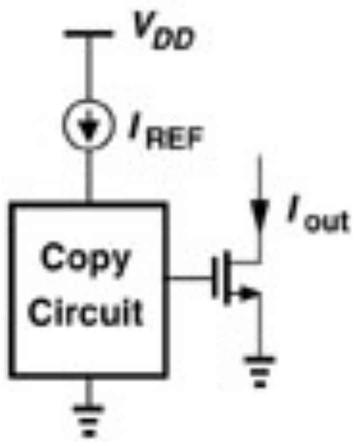
Problems

- Output current depends on:
  - Supply
  - Process
  - Temperature
- What if the bias voltage is independent of supply voltage?
- Is there a way of generating reliable currents?

Basic Idea

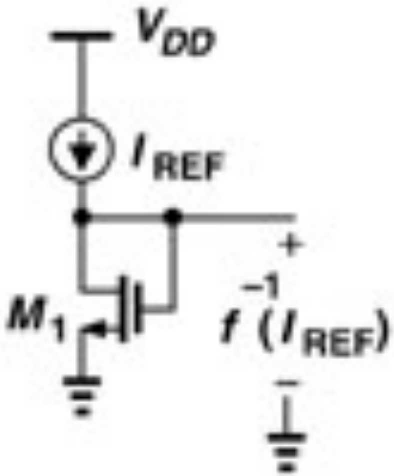
Typically we assume that one precisely defined current source is available and other current sources copy their current from this precise source.

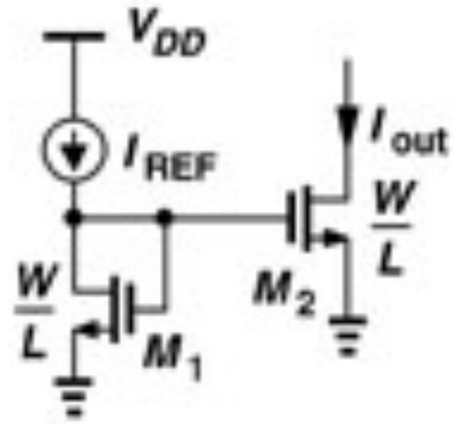




I_{out} is a function of gate-source voltage

Basic Idea





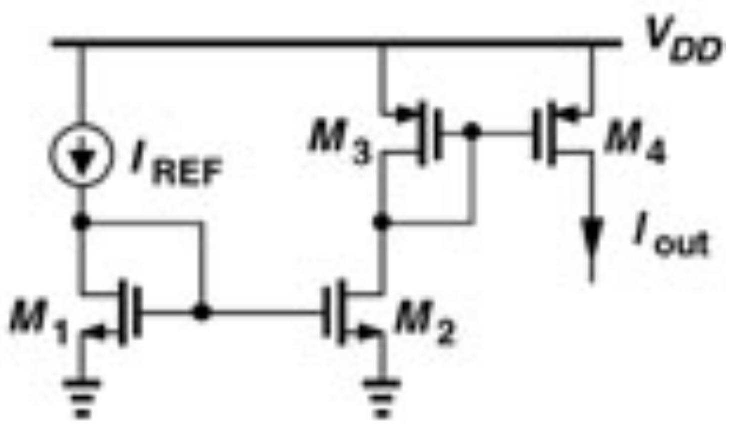
This structure is called current mirror

Question

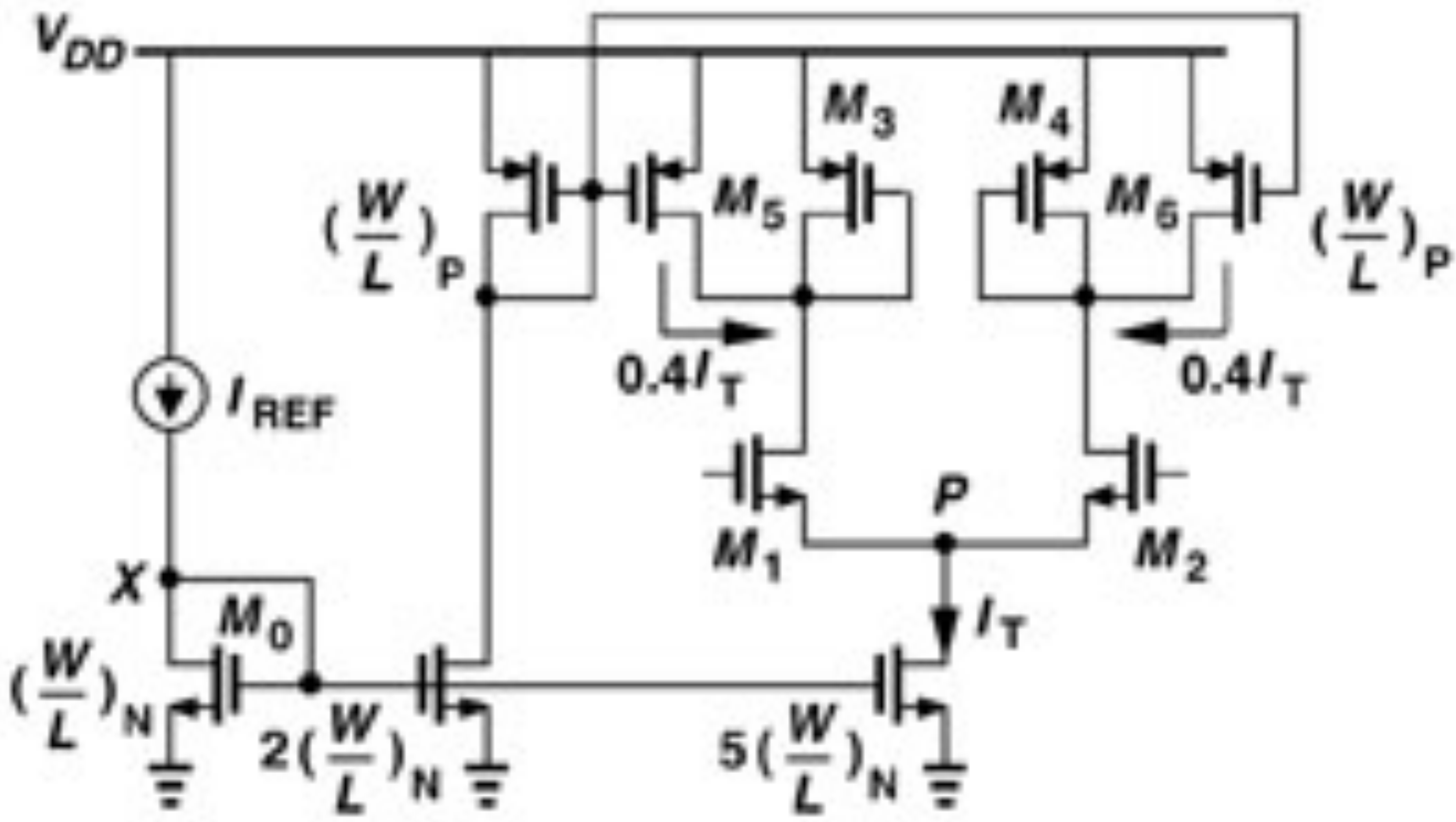
- What happens if the two transistors in the basic current mirror have different sizes?

Example

Assuming all the transistors are in saturation region, find I_{out}:



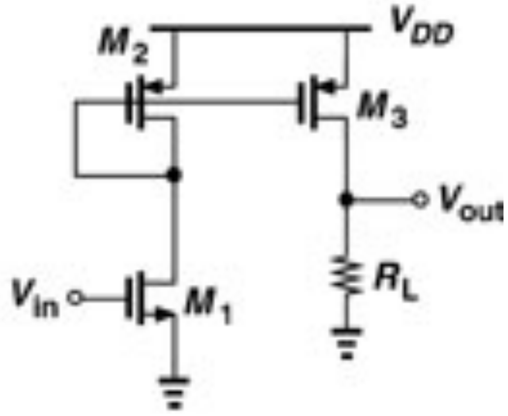
Current Mirrors: Amplifier Bias Example



Board Notes

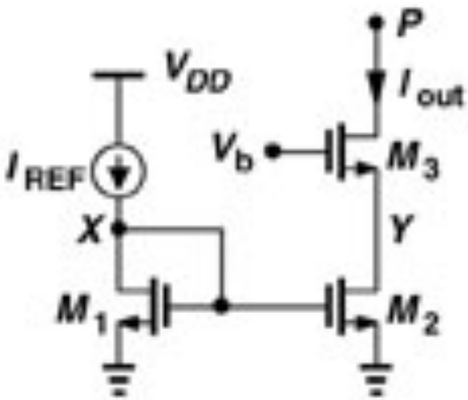
Current Mirrors: Signal Amplification Example

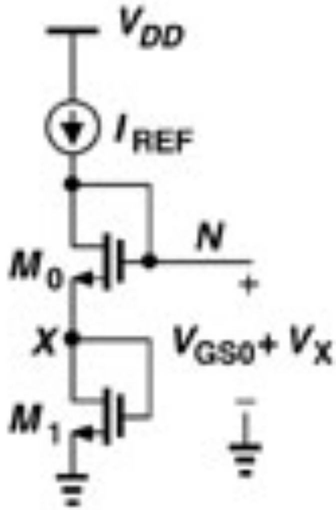
- Find the small signal voltage gain of the following circuit.

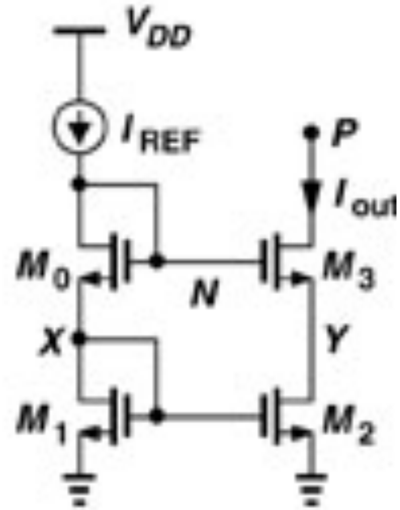


Effect of Channel Length Modulation

Cascode Current Mirror

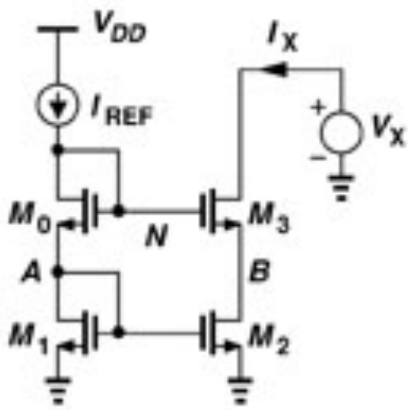




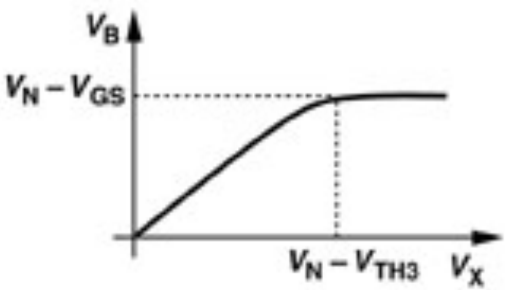


Board Notes

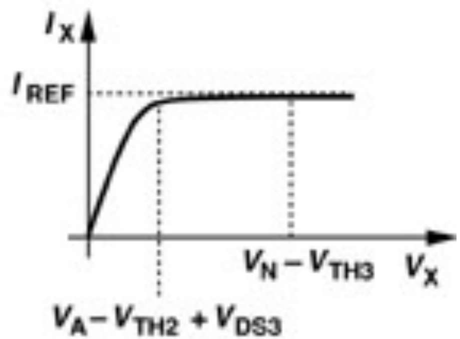
Cascode Current Mirror



(a)

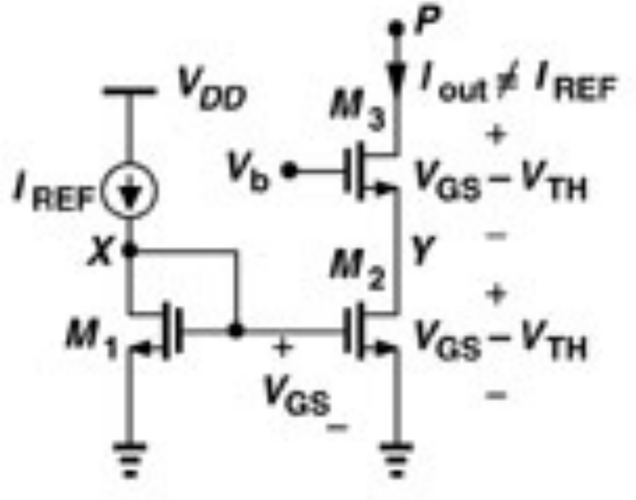


(b)



(c)

Cascode Current Mirror



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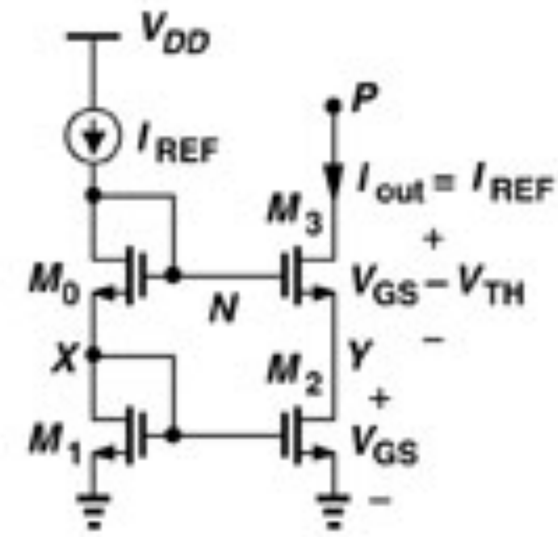
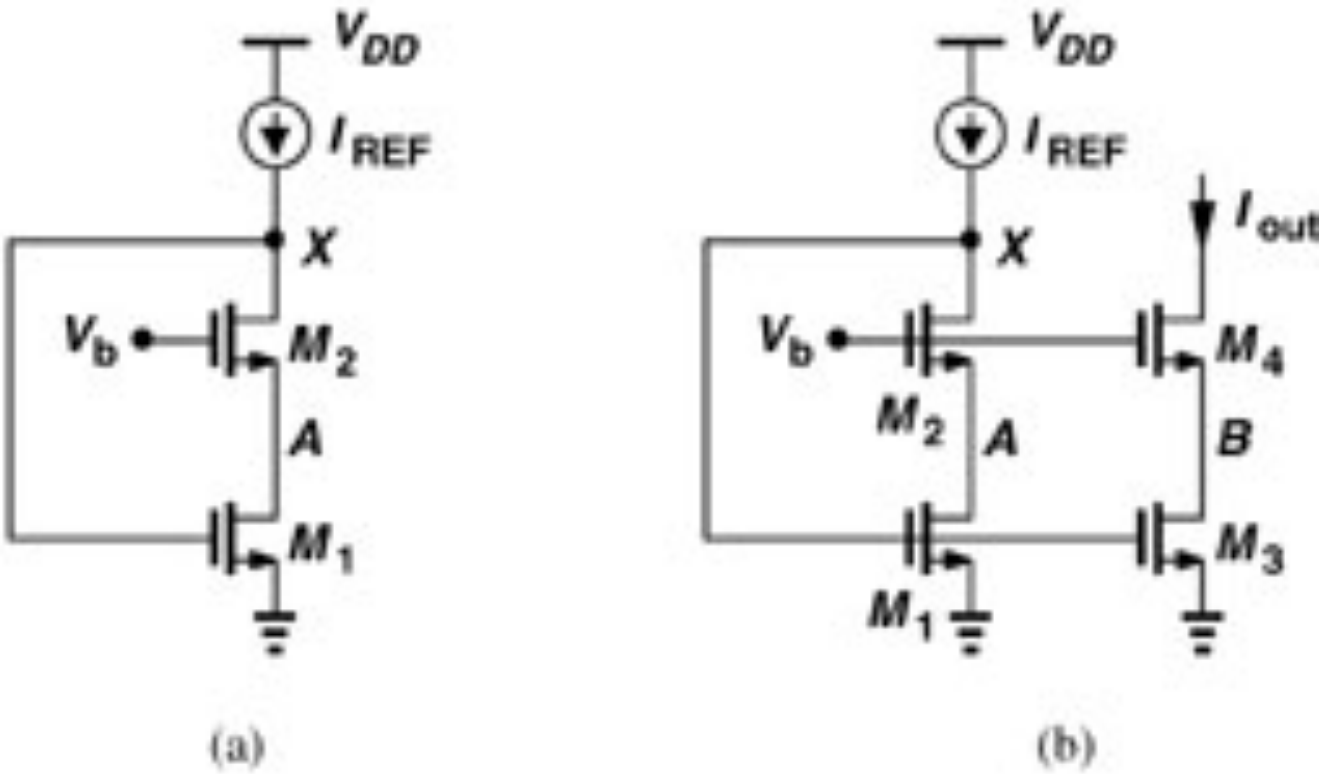


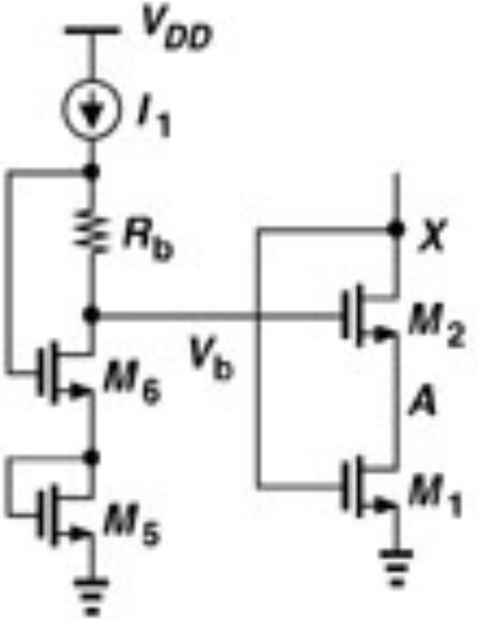
(b)

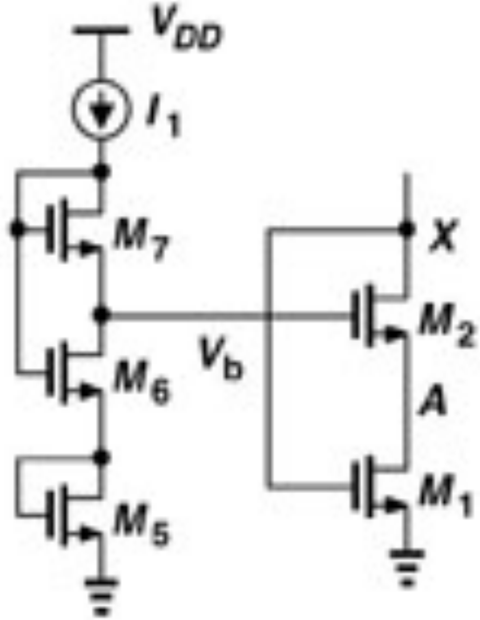
Cascode Current Mirror



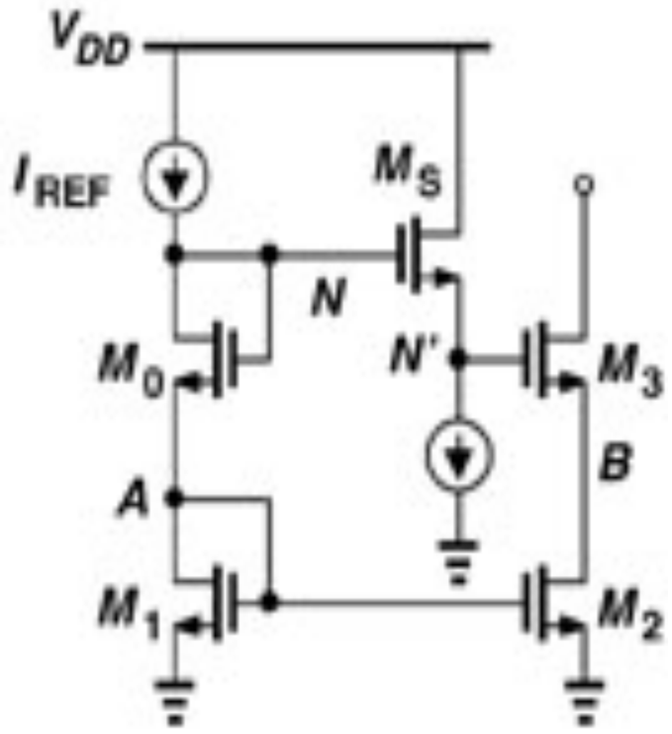
Board Notes

Cascode Current Mirror Biasing

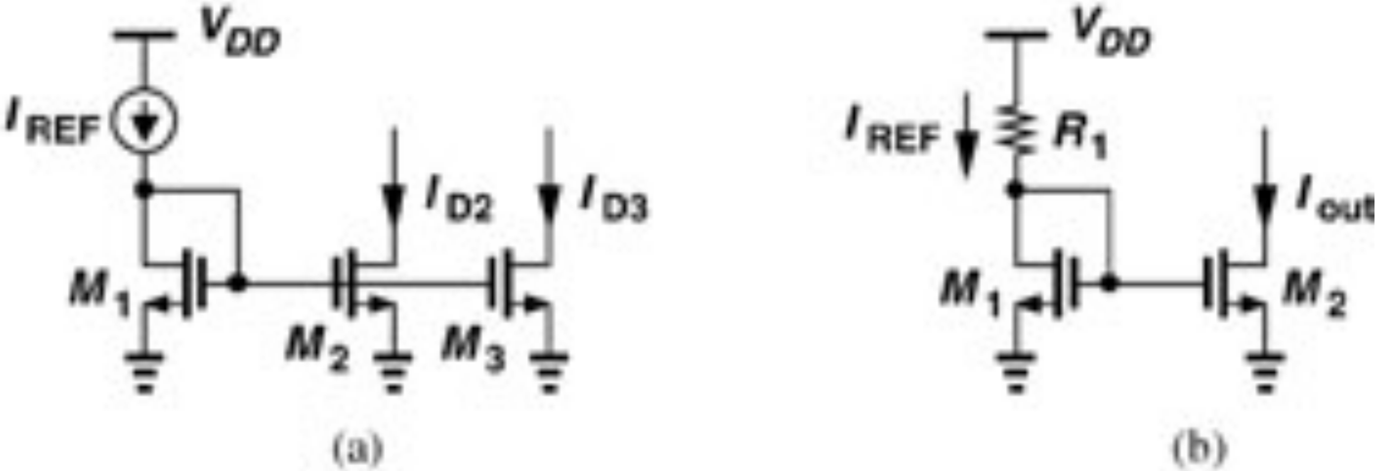




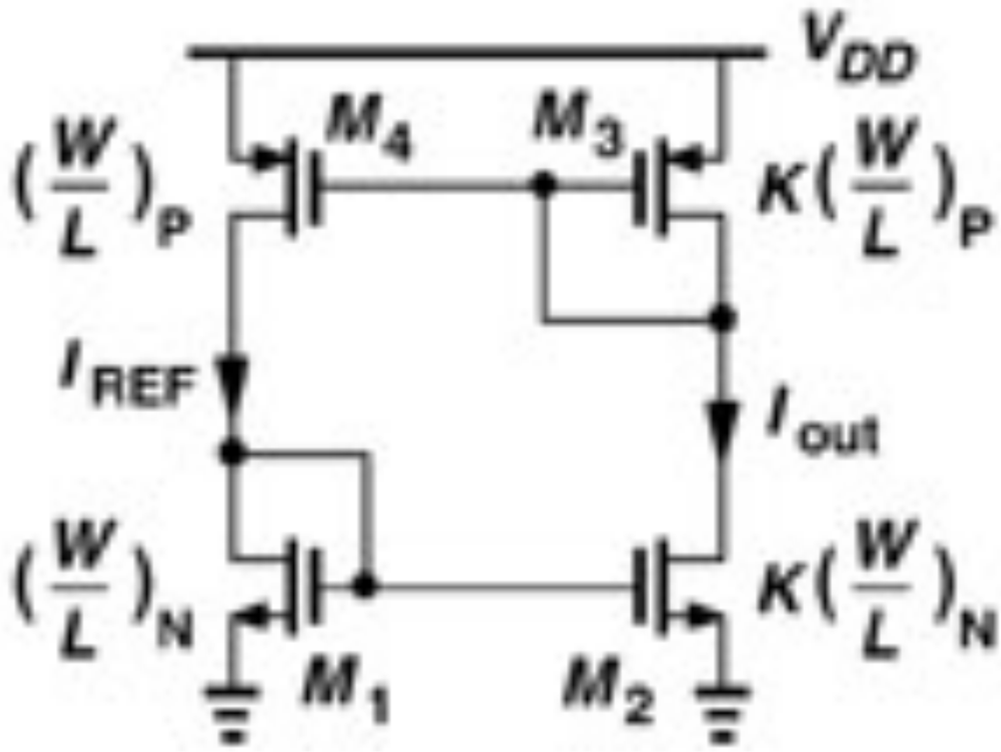
Cascode Current Mirror Biasing



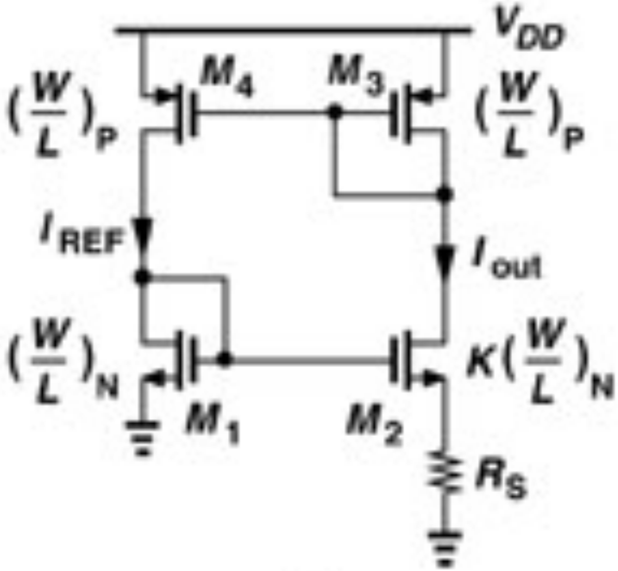
Current Mirror Biasing



Basic Circuit to Generate Supply Independent Current



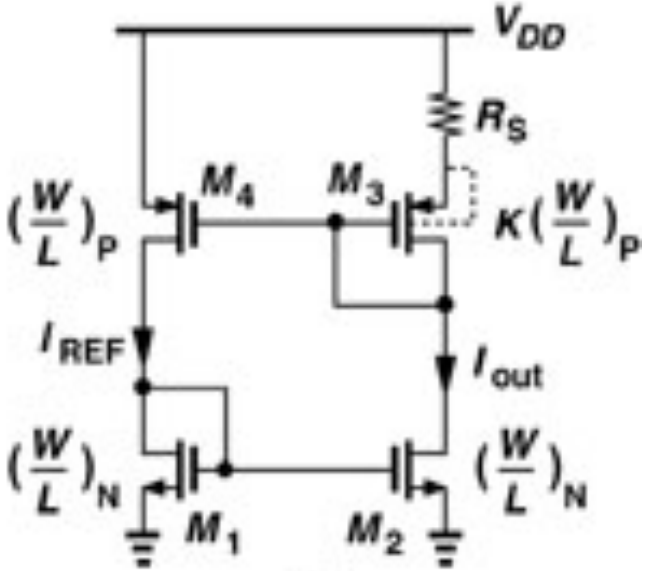
Supply Independent Current



(a)

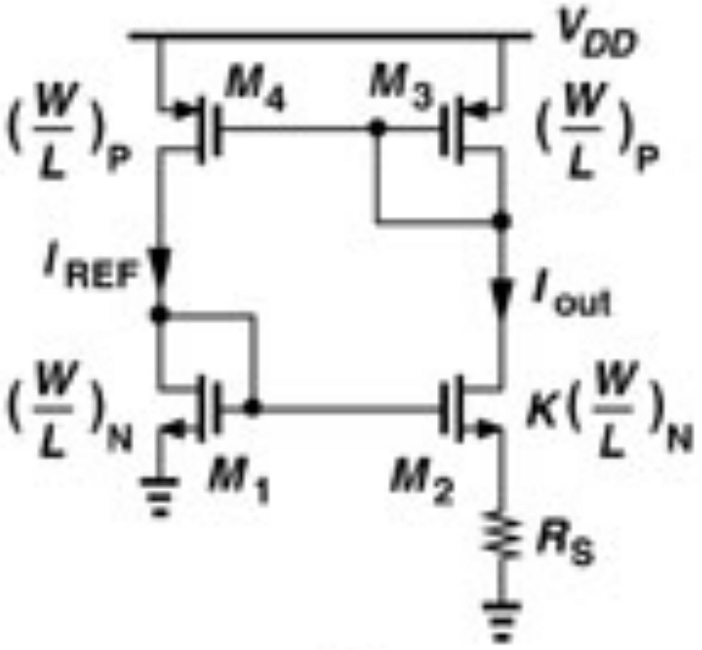
Board Notes

Supply Independent Current



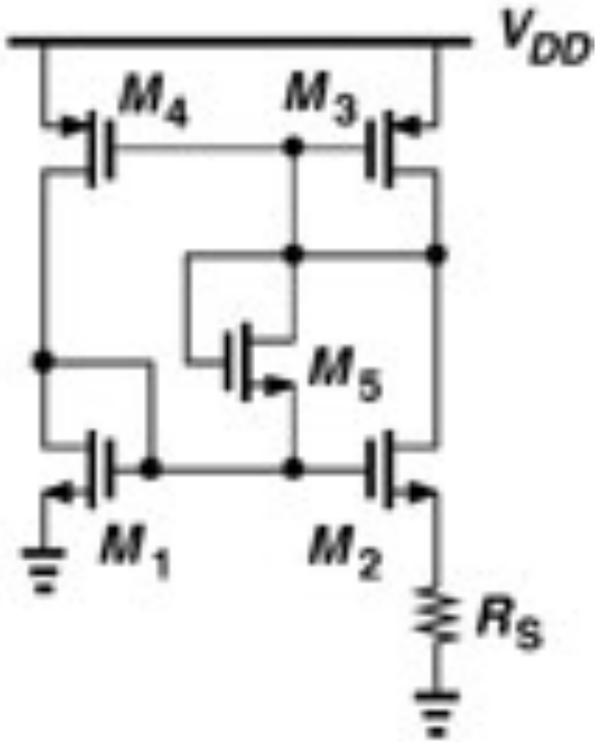
(b)

Start-up Problem



(a)

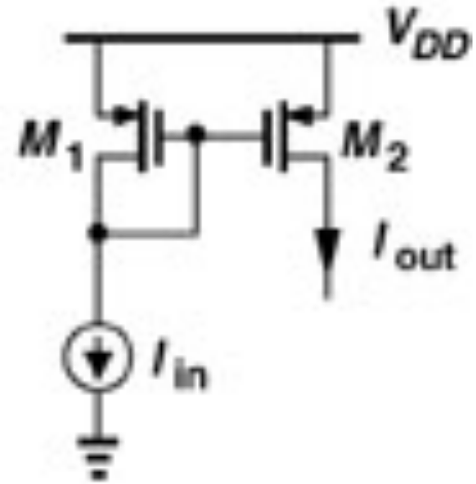
Start-up Problem



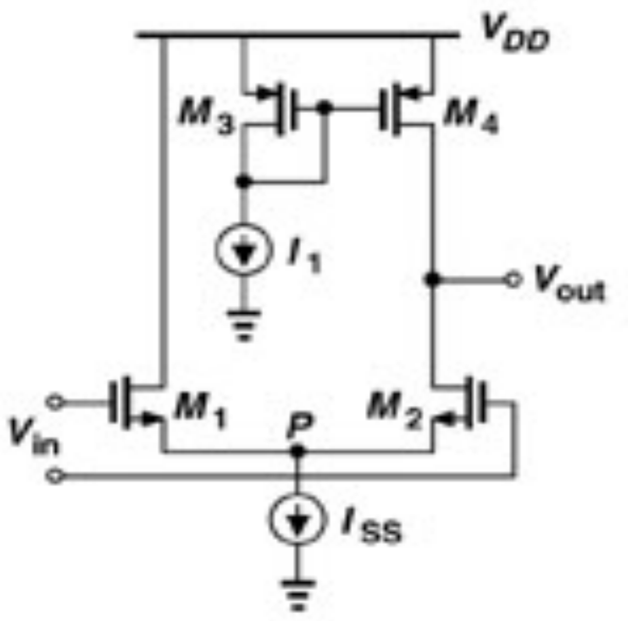
$$V_{TH1} + V_{TH5} + \left|V_{TH3}\right| < V_{DD} \qquad and \qquad V_{GS1} + V_{TH5} + \left|V_{GS3}\right| > V_{DD}$$

Board Notes

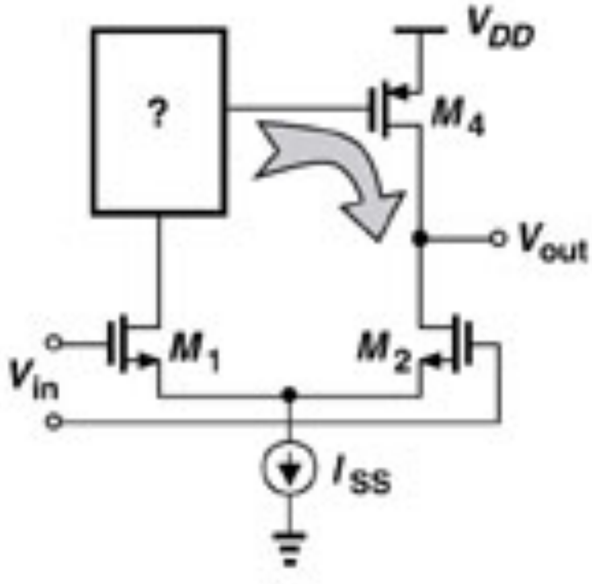
Active Current Mirrors



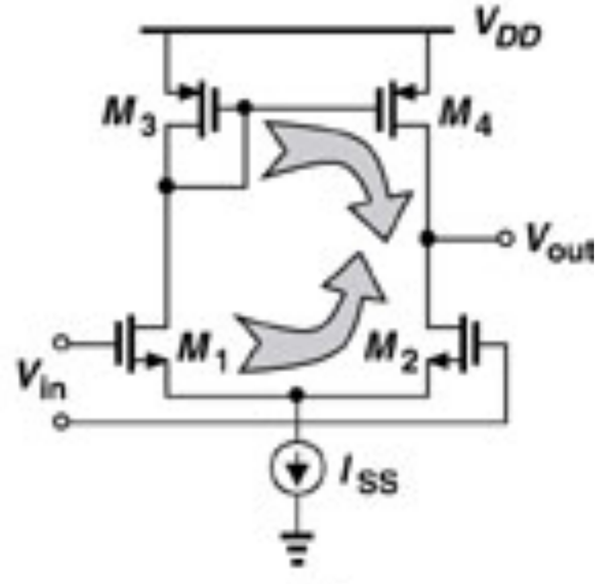
Active Current Mirrors in Differential to Single-Ended Amplifiers



Differential to Single-Ended Amplifiers

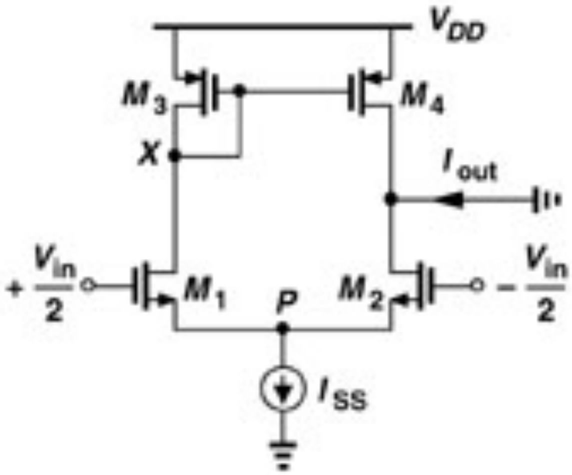


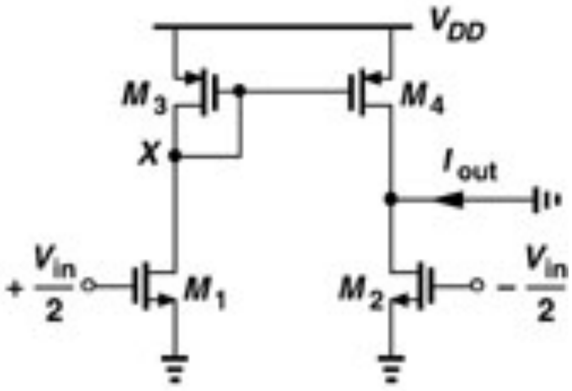
(a)



(b)

Calculation of G_m

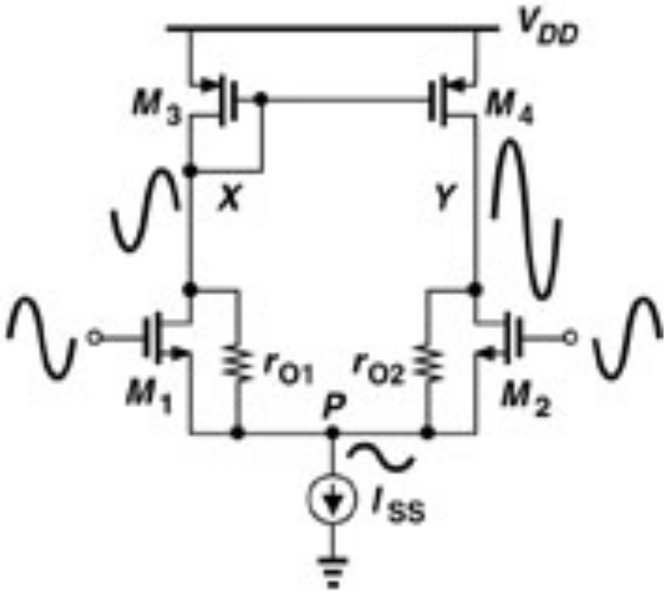




$$I_{D1} = I_{D3} = I_{D4} = g_{m1,2} V_{in} / 2 \qquad I_{D2} = -g_{m1,2} V_{in} / 2$$

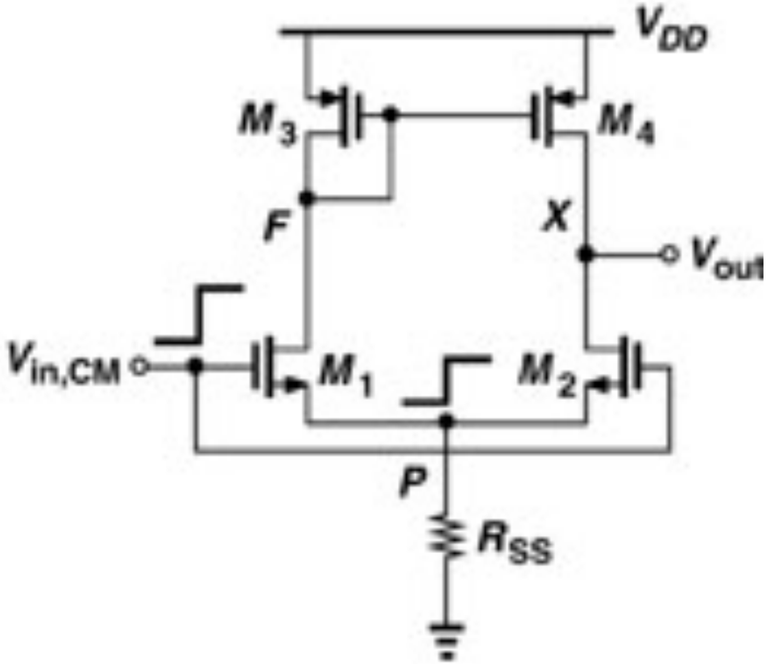
$$I_{out} = I_{D2} - I_{D4} = -g_{m1,2} V_{in} \;, \Rightarrow G_m = g_{m1,2}$$

Small-Signal Gain



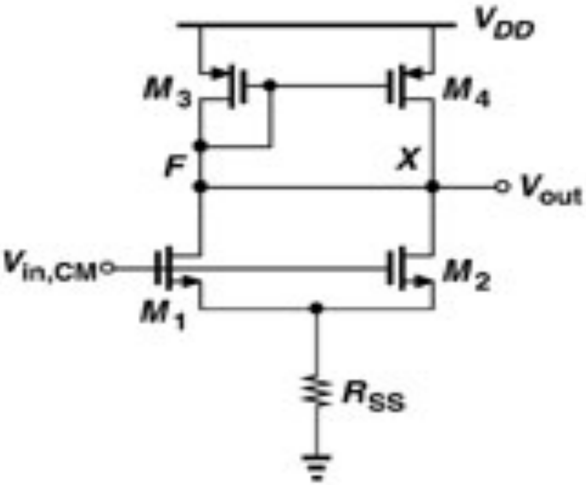
$$A_v \approx g_{m1,2}(r_{o2} \| r_{o4})$$

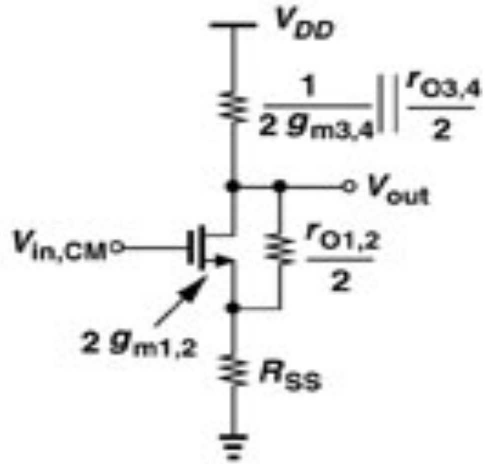
Common Mode Characteristics



$$A_{CM} = \frac{\Delta V_{out}}{\Delta V_{in,CM}}$$

Common Mode





$$A_{CM} \approx \frac{-\dfrac{1}{2g_{m3,4}} \| \dfrac{r_{o3,4}}{2}}{\dfrac{1}{2g_{m1,2}} + R_{SS}} = \frac{-1}{1+2g_{m1,2}R_{SS}} \frac{g_{m1,2}}{g_{m3,4}}$$

Common Mode

$$CMRR = \left| \frac{A_{DM}}{A_{CM}} \right|$$

$$= g_{m1,2}(r_{o1,2} \parallel r_{o3,4}) \frac{g_{m3,4}(1 + 2g_{m1,2}R_{SS})}{g_{m1,2}}$$

$$= g_{m3,4}(r_{o1,2} \parallel r_{o3,4})(1 + 2g_{m1,2}R_{SS})$$