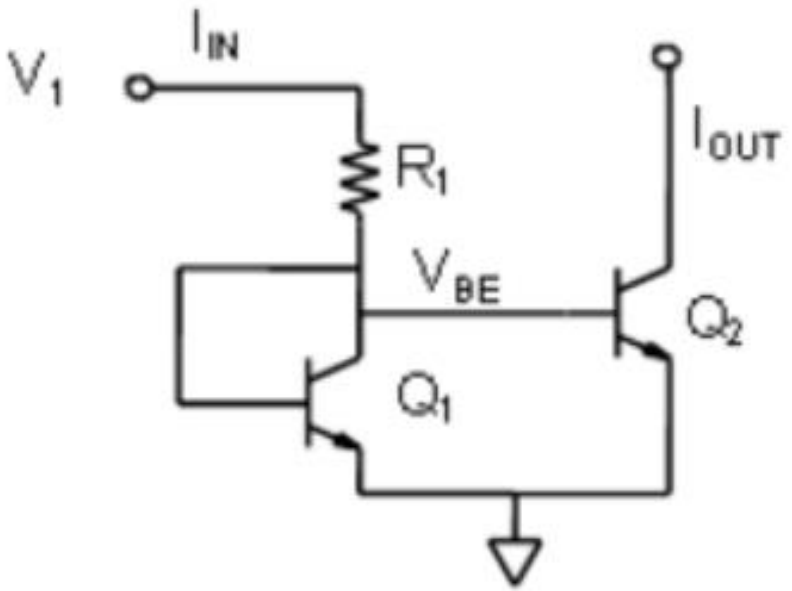
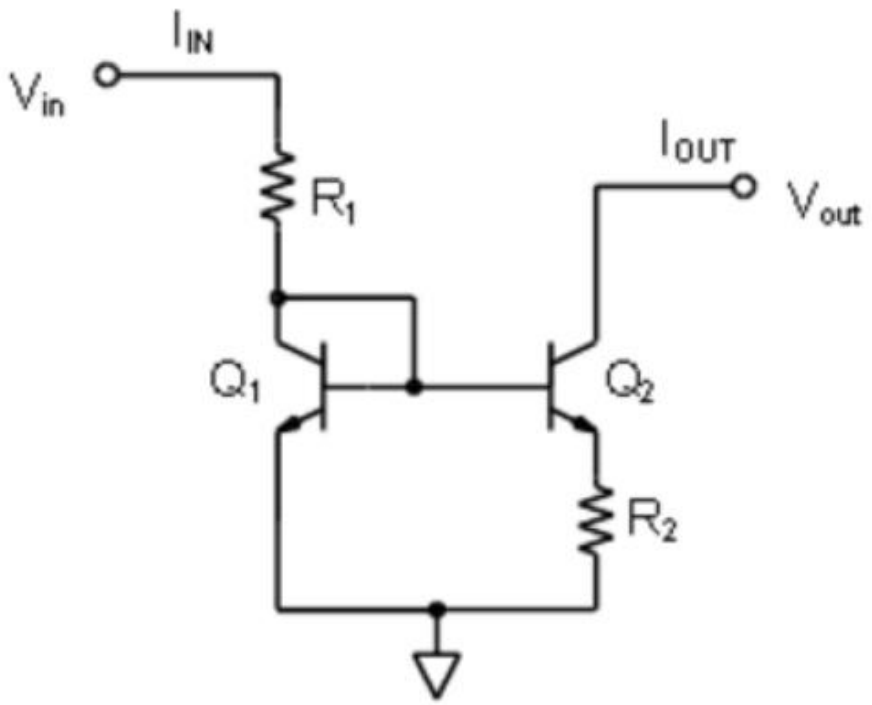
Current mirrors

[AD_ch11, Razavi]

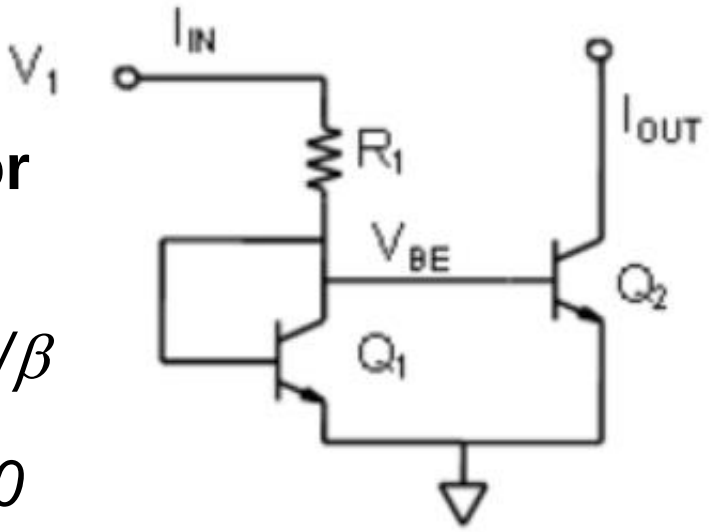
Basic mirror



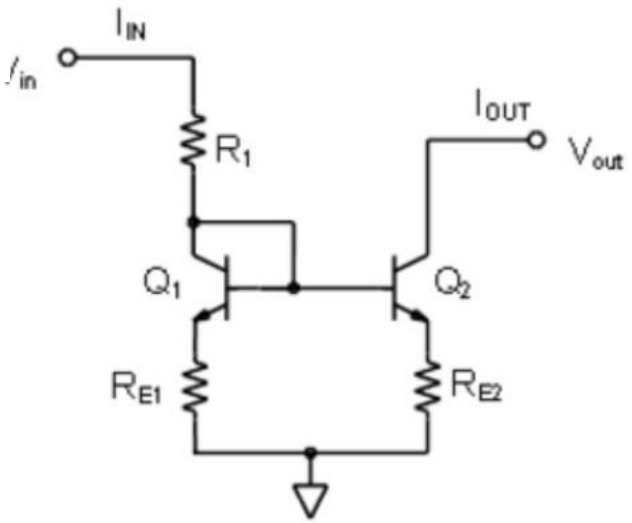
For low currents: Widlar mirror



Imperfections of the basic mirror

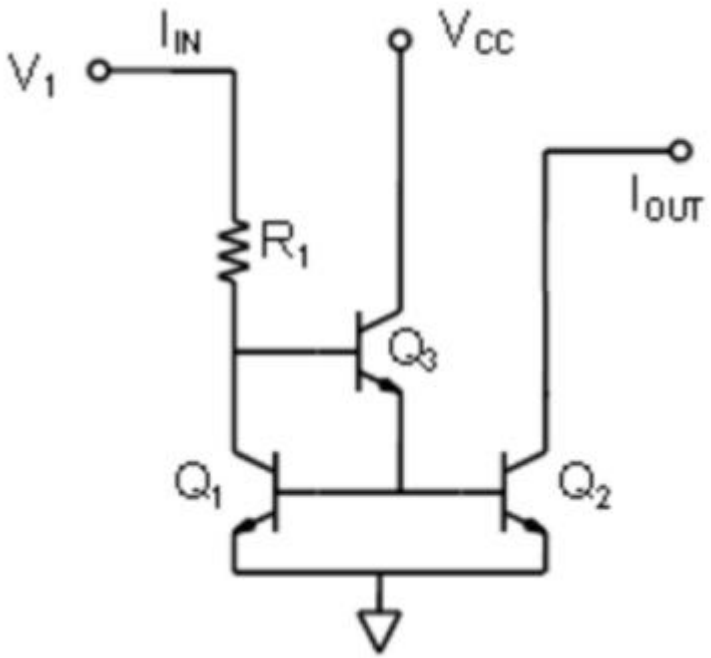


- *Gain error*: $I_{OUT} = I_{IN} - 2\,I_B$
  - the relative error is around $2/\beta$
- Q_2 must not saturate, i.e. $V_{CB} \geq 0$
- $V_{CB1}=0$ is different from V_{CB2} (and $V_{CE1} \neq V_{CE2}$)
  - for the Early effect, $I_{C2} \neq I_{C1}$ and dependent on V_{CB2}
  - $R_{out} \neq \infty$
  - it may be found that $r_O = \dfrac{V_{CB} + V_A}{I_C}$
  - R_{out} can be improved by adding an R_E on the Q_2 emitter



Improved current mirrors: emitter follower augmented CM

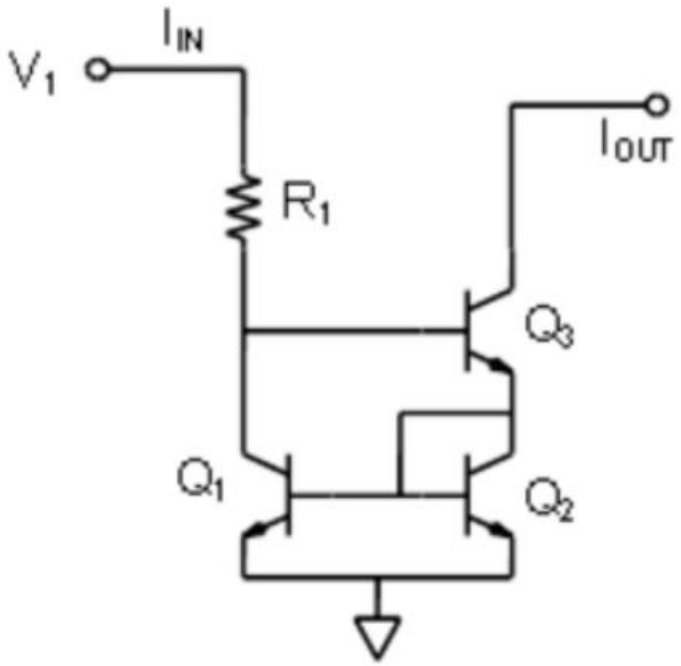
The current gain of Q_3 reduces the gain error



Improved current mirrors: Wilson CM

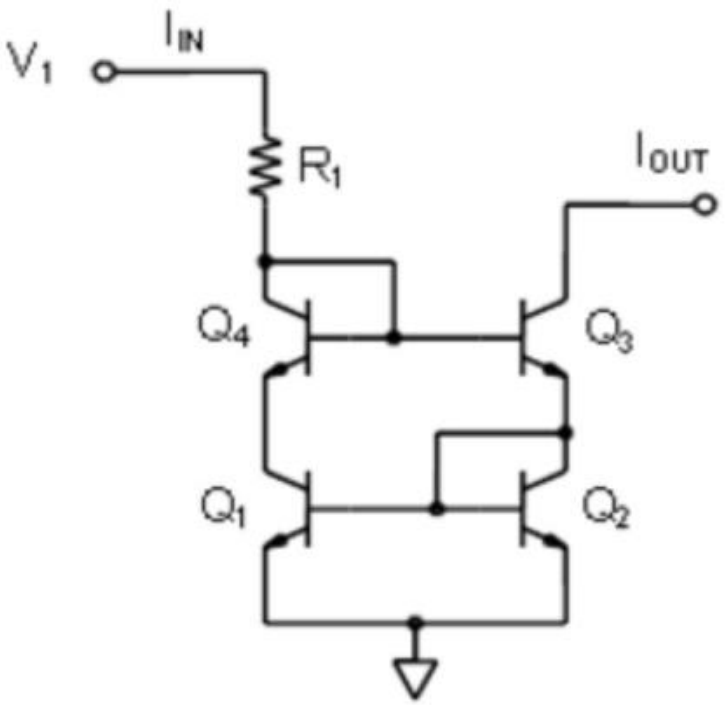
Advantages:

- base current mismatch (and so gain error) virtually eliminated
- very high output impedence
  - Q_3 has a current source at its emitter!



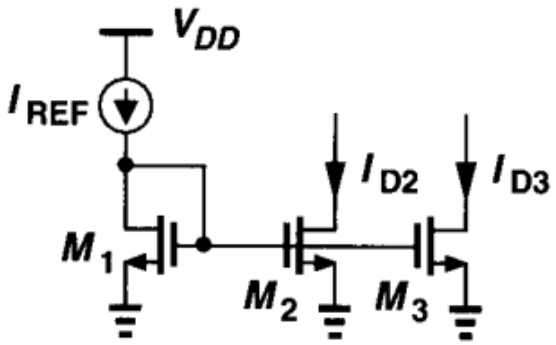
Improved current mirrors: full Wilson

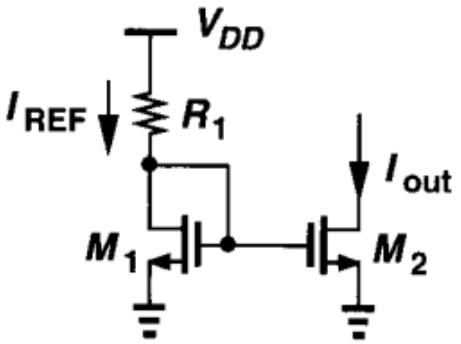
$V_{CE1}=V_{CE2}=V_{BE}$



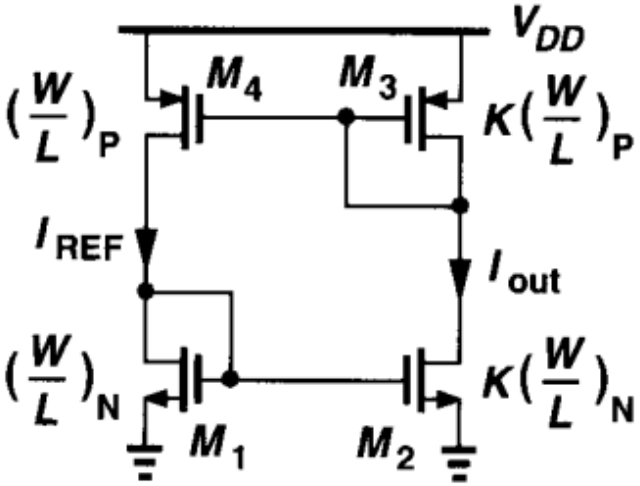
Current mirrors: how to have I_{ref} not dependent on V_{DD} ?

- If I_{REF} is generated using a resistor, it depends on V_{DD}



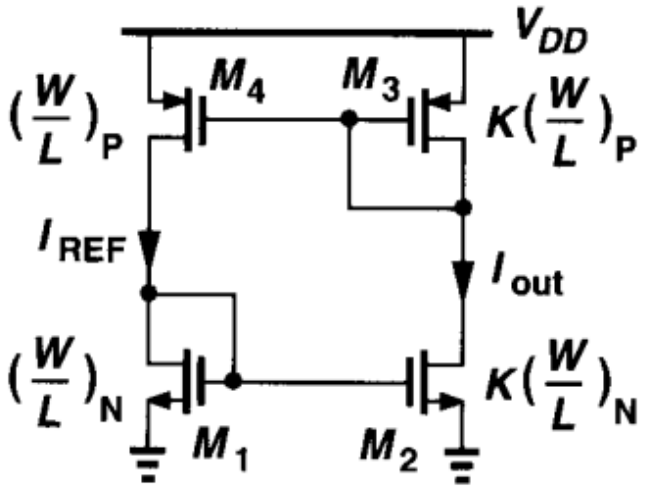


- The idea is that the circuit has to bias itself
  - I_{REF} is a replica of I_{out}
- here, $I_{out} = K\, I_{REF}$
- Since each diode-connected device feeds from a current source, both currents are (almost) independent on V_{DD}



Current mirrors: how to have I_{ref} not dependent on V_{DD} ?

- The circuit is governed only by $I_{out} = K I_{REF}$
- hence can support any current!



- To uniquely define a current, we add another constraint
- here, R_s decreases I_{D2}, while $I_{D4}=I_{D3}$ as they have the same dimensions
- from $V_{GS1}=V_{GS2}+R_S I_{D2}$ it may be found

$$I_{out} = \frac{2}{\mu_n C_{ox}(W/L)_N} \cdot \frac{1}{R_S^2}\left(1 - \frac{1}{\sqrt{K}}\right)^2$$

- I_{out} independent on V_{DD} (but not on process and T)!!