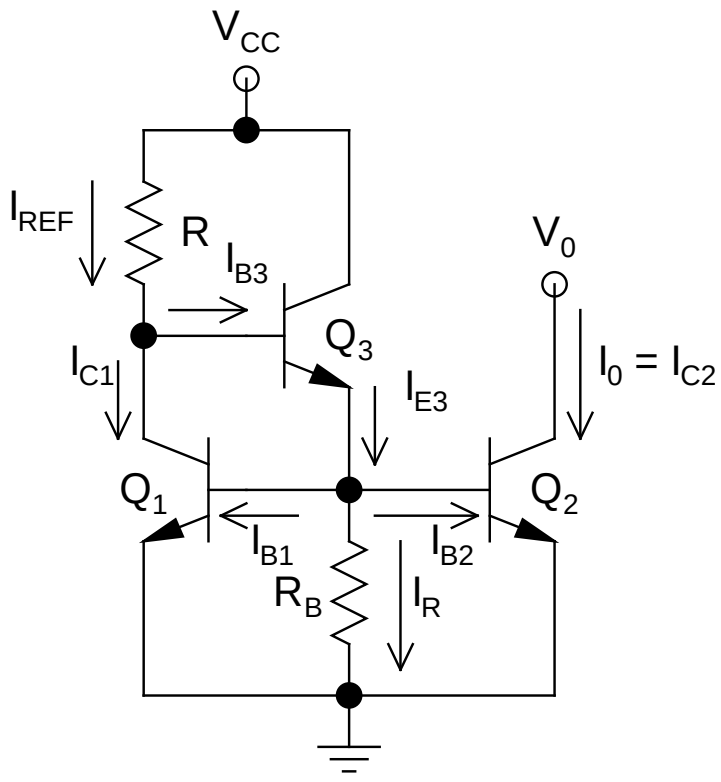
- ***npn CM With Better β Insensitivity***:
  - $I_{REF} = (V_{CC} - 2V_{BE})/R$
  - Neglecting I_{B3}:

    $I_{C1} = I_{REF}$
  - ***If Q_1 and Q_2 are matched***:

    $I_0 = I_{C2} = I_{C1} = I_{REF}$

    $\Rightarrow$ ***Simple CM***
  - ***The actual advantage of the circuit lies elsewhere***!



- First, assume ***R_B is absent***

$$\Rightarrow I_{E3} = I_{B1} + I_{B2} = I_{C1}/\beta_1 + I_{C2}/\beta_2 = 2I_0/\beta_1$$

(***assuming $\beta_1 = \beta_2$***)

$$\Rightarrow I_{B3} = \frac{I_{E3}}{\beta_3 + 1} = \frac{2I_0}{\beta_1(\beta_3 + 1)}$$

$$I_{REF} = I_{C1} + I_{B3} = I_0\left[1 + \frac{2}{\beta_1(\beta_3 + 1)}\right]$$

$$\Rightarrow I_0 = \frac{I_{REF}}{1 + \dfrac{2}{\beta_1(\beta_3 + 1)}}$$

- Now, if $\beta_1 = \beta_3 = \beta$, and $\beta >> 1$:

  $I_0 \approx I_{REF}(1 - 2/\beta^2)$
- Compare with that of simple CM:

  $I_0 \approx I_{REF}(1 - 2/\beta)$
- ***The advantage is obvious***!
- ***Further Insights***:
  - I_{E3} (= $I_{B1} + I_{B2}$) ~ ***few 10s of μA***
  - ***At such a low current, β drops significantly from its nominal value***
  - ***Thus, full advantage of the circuit can't be exploited***

- ***Here comes the role of R_B***:
  - ***It drains a constant current*** (= V_{BE}/R_B), ***which gets added to*** ($I_{B1} + I_{B2}$), and ***boosts*** I_{E3} (and, thus, I_{C3})
  - ***Thus, β_3 gets pulled up to its nominal value***
  - ***This resistor has a special name***: ***Keep Alive***, ***since it keeps Q_3 alive***!
- ***However, it creates some issues as well***:
  - ***Additional power drain due to the additional current flowing through R_B***
  - ***If $I_{E3} \uparrow$, so would I_{B3}***

    $\Rightarrow$ I_{C1} may depart from I_{REF}
  - ***Design optimization needed***

- ***Now, for R_0***:
  - ***Looking at C_2***
  - ***E_2 grounded***
  - ***No connection between C_2 and B_2*** (***no feedback***)
  - ***Therefore, by inspection***:

    $R_0 = r_{02} = V_{A2}/I_0$

- ***Also, by inspection***:

  $V_{0,min} = V_{CE2}(SS) = 0.2\ V$

- ***There is no MOS counterpart for this circuit for obvious reasons***!