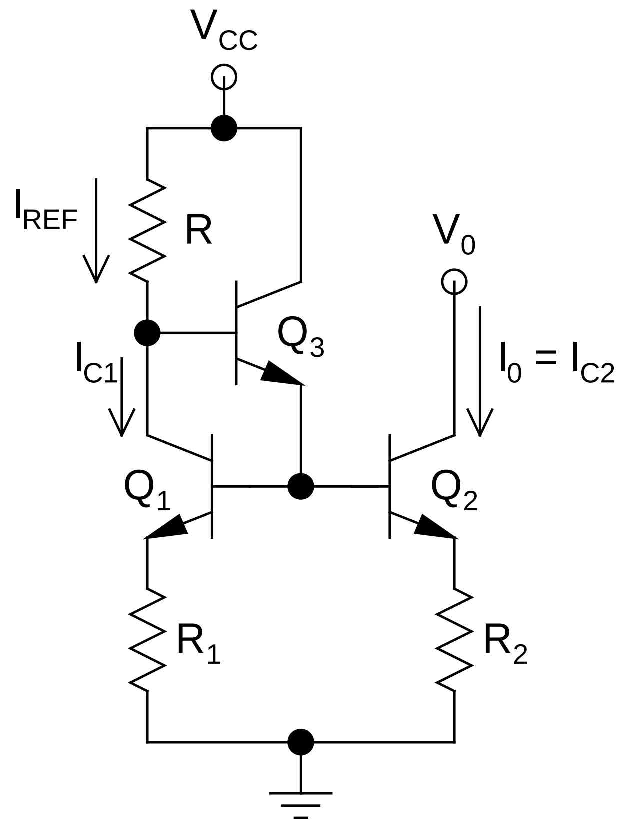
- ***npn Ratioed CM***:
  - ***Q_1-Q_2 matched pair***
  - ***Neglecting all I_B***, $I_{E1} = I_{C1} = I_{REF}$, and $I_{E2} = I_{C2} = I_0$
  - $I_{REF} = (V_{CC} - 2V_{BE})/(R + R_1)$
  - ***KVL around Q_1-Q_2 BE loop***:

$$V_{BE1} + I_{REF}R_1 = V_{BE2} + I_0R_2$$

$$\Rightarrow I_0 = (I_{REF}R_1 + \Delta V_{BE})/R_2$$

$$\Delta V_{BE} = V_{BE1} - V_{BE2} = V_T\ln(I_{REF}/I_0)$$



- ***Note the ln dependence***:
  - ***For*** $I_{REF}/I_0 = 2$, $\Delta V_{BE} = 18\ mV$
  - ***For*** $I_{REF}/I_0 = 10$, $\Delta V_{BE} = 60\ mV$

  $\Rightarrow$ ΔV_{BE} ***can be neglected if*** $I_{REF}R_1 > 10\Delta V_{BE}$

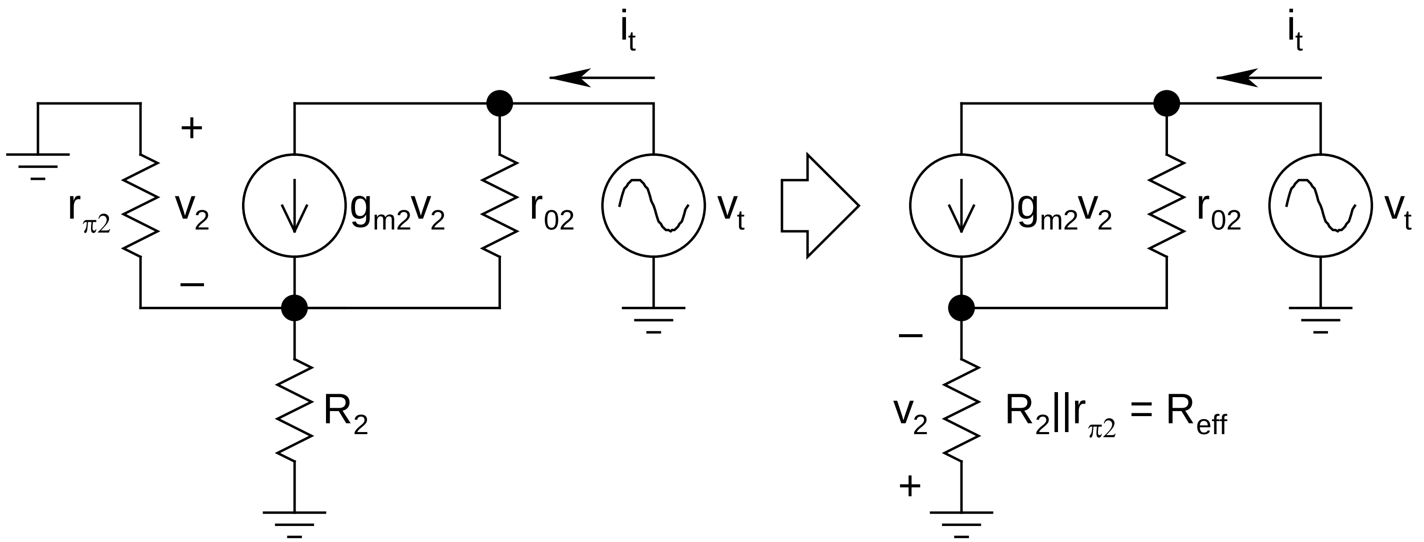
  $\Rightarrow$ $I_0 = (R_1/R_2)I_{REF}$ (***Ratioed Mirror***)
- ***Thus, by tinkering*** R_1 ***and*** R_2***, any ratio between*** I_0 ***and*** I_{REF} ***can be obtained***
  - ***Tremendous advantage***
    - ***Widely used***
- ***By inspection***:

$$V_{0,min} = V_{CE2}(SS) + I_0R_2 = 0.2 + I_0R_2$$

➢ *Calculation of R_0*:

- *Golden Rule can't be used since emitter of Q_2 is not grounded* (*R_2 present there*)
- *Needs analysis*

  ⇒ *Leads to a module that is frequently encountered*
- *Base of Q_1-Q_2 at a fixed DC potential* ⇒ *ac ground*



$$i_t = g_{m2}v_2 + (v_t + v_2)/r_{02}$$

$$= v_t/r_{02} + (g_{m2} + 1/r_{02})v_2 \simeq v_t/r_{02} + g_{m2}v_2$$

$$v_2 = -i_t R_{eff}$$

$$\Rightarrow i_t = v_t/r_{02} - g_{m2}R_{eff}i_t$$

$$\Rightarrow R_0 = v_t/i_t = r_{02}(1 + g_{m2}R_{eff})$$

- This is a ***Golden Equation***, which would be ***used frequently***
  - ***Carefully note the topology that produces this result***
- ***Exercise***: ***Reverse v_2 and show that the expression for R_0 remains invariant***