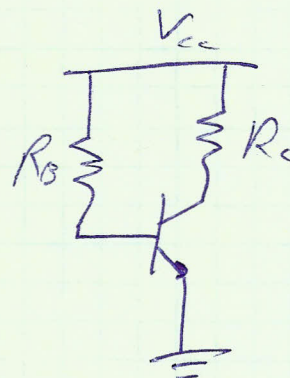


BJT fixed bias

V_{cc} supplies both the collector and the base

$$\begin{aligned} \text{BE-KVL} \left\{ \begin{aligned} V_{cc} &= I_B R_B + V_{BE} \rightarrow I_B = \frac{V_{cc} - V_{BE}}{R_B} \\ * I_C &= \beta I_B = \beta \frac{V_{cc} - V_{BE}}{R_B} \end{aligned} \right. \end{aligned}$$



$$\begin{aligned} \text{CE-KVL} \left\{ \begin{aligned} V_{cc} &= I_C R_C + V_{CE} \rightarrow V_{CE} = V_{cc} - I_C R_C \\ * V_{CE} &= V_{cc} - \beta \frac{R_C}{R_B} (V_{cc} - V_{BE}) \end{aligned} \right. \end{aligned}$$

* We can solve these equations to get the Q-point

Design example find R_C, R_B so that $I_C = 25\text{mA}$, $V_{CE} = 7.5\text{V}$
for $\beta = 100$, $V_{cc} = 15\text{V}$

BJT is active ($V_{CE} = 7.5\text{V} > V_{be}$)

$$\rightarrow I_B = I_C / \beta = 0.25\text{mA}$$

$$\text{BE-KVL: } V_{cc} - R_B I_B - V_{BE} = 0 \rightarrow R_B = \frac{15\text{V} - 0.7\text{V}}{0.25\text{mA}} = 57\text{k}\Omega$$

$$\text{CE-KVL: } V_{cc} - I_C R_C + V_{CE} = 0 \rightarrow R_C = \frac{15\text{V} - 7.5\text{V}}{25\text{mA}} = 300\Omega$$

• What happens if $\beta \rightarrow 200$?

$$I_B = \frac{V_{cc} - V_{BE}}{R_B} = 0.25\text{mA} \rightarrow \text{no change}$$

$$I_C = \beta I_B = 50\text{mA} \quad (\times 2)$$

$$V_{CE} = V_{cc} - I_C R_C \rightarrow V_{CE} = 15 - 300 \times 50 \times 10^{-3} = 0$$

$\rightarrow$ transistor is in saturation

β can change due to:

- Manufacturing tolerances
- Temperature variations
 - changes by 9% per $^{\circ}\text{C}$
 - for 10°C rise, I_c will roughly double

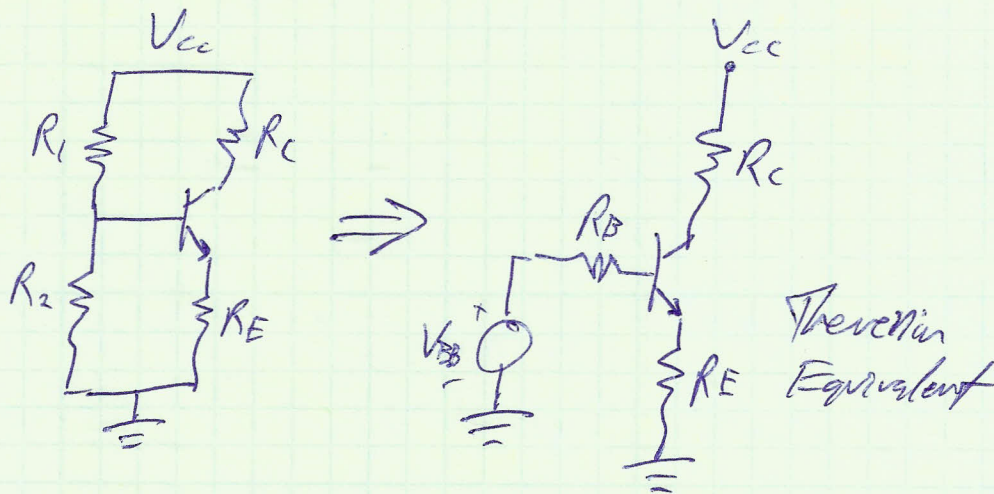
Positive feedback

- Temperature increase makes I_c rise
- I_c rising makes transistor hotter etc.

$\Rightarrow$ Need a biasing scheme that makes Q point independent of β .

BJT "emitter degeneration" bias with voltage divider

- Emitter resistor provides negative feedback



$$V_{BB} = \frac{R_2}{R_1 + R_2} V_{CC}, \quad R_B = R_1 \parallel R_2$$

Emitter resistor R_E gives negative feedback

- If I_C increases, $V_E = R_E I_E$ increases
 - BE-KVL shows I_B will decrease
 - I_C will go back down
 - This bias scheme is stable, independent of β .

$$I_C = \beta I_B, \quad I_E = (\beta + 1) I_B$$

$$\text{BE-KVL: } V_{BB} + R_B I_B - V_{BE} - I_E R_E = 0$$

$$\rightarrow I_B = \frac{V_{BB} - V_{BE}}{R_B + (1 + \beta) R_E}$$

$$\text{CE-KVL: } V_{CC} - I_C R_C - V_{CE} - I_E R_E = 0$$

$$\rightarrow V_{CE} = V_{CC} - I_C \left[R_C + \frac{1 + \beta}{\beta} R_E \right]$$

* choose $R_B \ll (1 + \beta) R_E$

→ necessary for feedback to be effective

→ need I_B to be very responsive to voltage changes → small R_B

$$\rightarrow I_B \approx \frac{V_{BB} - V_{BE}}{(1 + \beta) R_E}, \quad I_C \approx I_E \approx \frac{V_{BB} - V_{BE}}{R_E}$$

$$V_{CE} \approx V_{CC} - \frac{R_C + R_E}{R_E} (V_{BB} - V_{BE})$$

* note both I_C and V_{CE} are independent of β

Another look at Emitter Degeneration

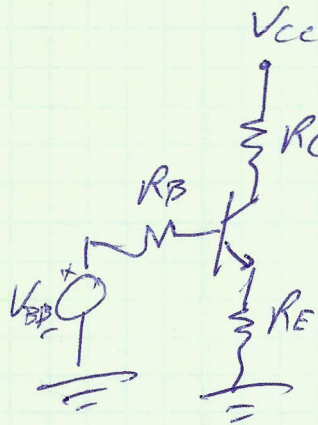
Consider BE KVL

$$V_{BB} - I_B R_B - V_{BE} - I_E R_E = 0$$

Choose $R_B \ll (1+\beta)R_E$

$$\approx \frac{I_E}{I_B} R_E$$

$$\text{or } I_B R_B \ll I_E R_E$$



$$I_E R_E \approx V_{BB} - V_{BE}$$

* I_E is constant, independent of β . I_C also constant ($\approx I_E$)

This circuit forces I_E to be fixed, and changes I_B accordingly

* Note: V_{BE} not constant - can vary from 0.6 to 0.8 V for Si BJT

→ need $I_E R_E$ much larger than changes in V_{BE}

$$I_E R_E \gg 0.1 \text{ V or } \sim 10 \times 0.1 \text{ V}$$

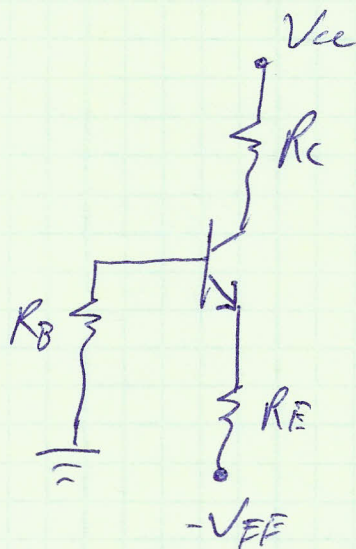
$$\text{or } V_E \gg 1 \text{ V}$$

* Note why R_2 is needed:

- If only one resistor R_B supplied by V_{CC} , it would not be possible to have a small R_D

Students should go through design example on page 4-9

BJT Emitter Degeneration Bias with 2 sources



Same basic idea as with base
stable if $R_B \ll (1+\beta)R_E$

- R_B can be zero if connected directly to signal (DC Amplifier)
- If coupling capacitor is used, base would be open
- resistor is needed then

