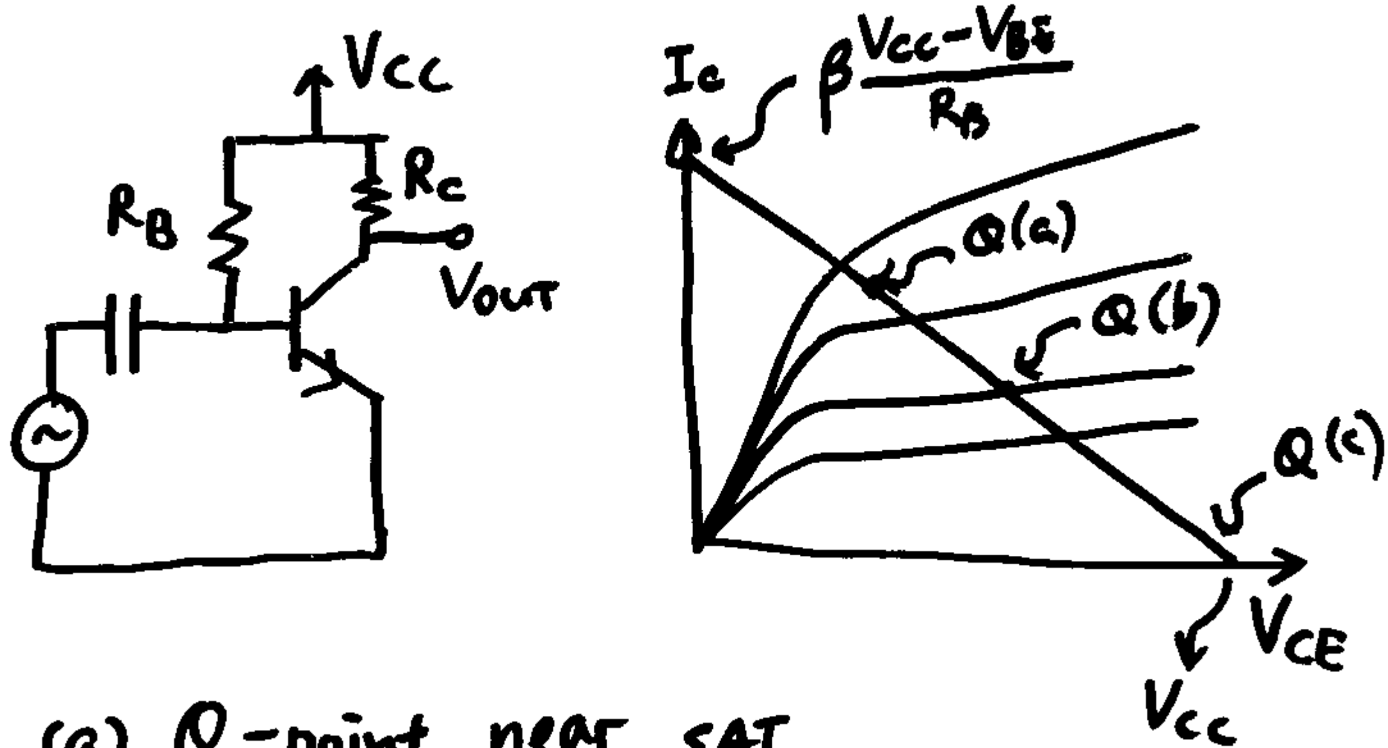
BJT Bias Circuits



(a) Q-point near SAT

AC signal leads to fluctuation of V_{BE}

⇒ Changes in I_B

⇒ Pushes device into SAT $I_B \neq \frac{I_c}{\beta}$

⇒ Output not (linearly) controlled by input

(c) Pushes device into cut-off

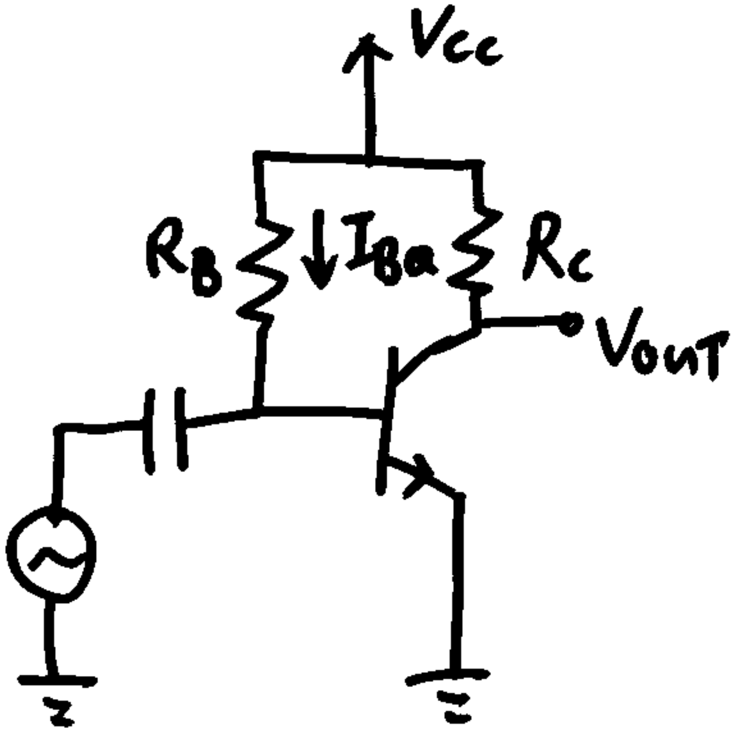
⇒ Input cannot control output

(b) I_B fluctuations lead to (linearly) proportional I_c fluctuations

Biasing

- Between the extremes of SAT. and cut-off for max. swing in both directions about Q-point
- A production circuit must be stable with respect to β
- Base-current bias method
  - not practical
  - Quiescent output voltage a strong function of β.
- Emitter-bias stage
  - Good stability with changes in β and temperature

Base-Current Bias



$R_C = 5k\Omega$

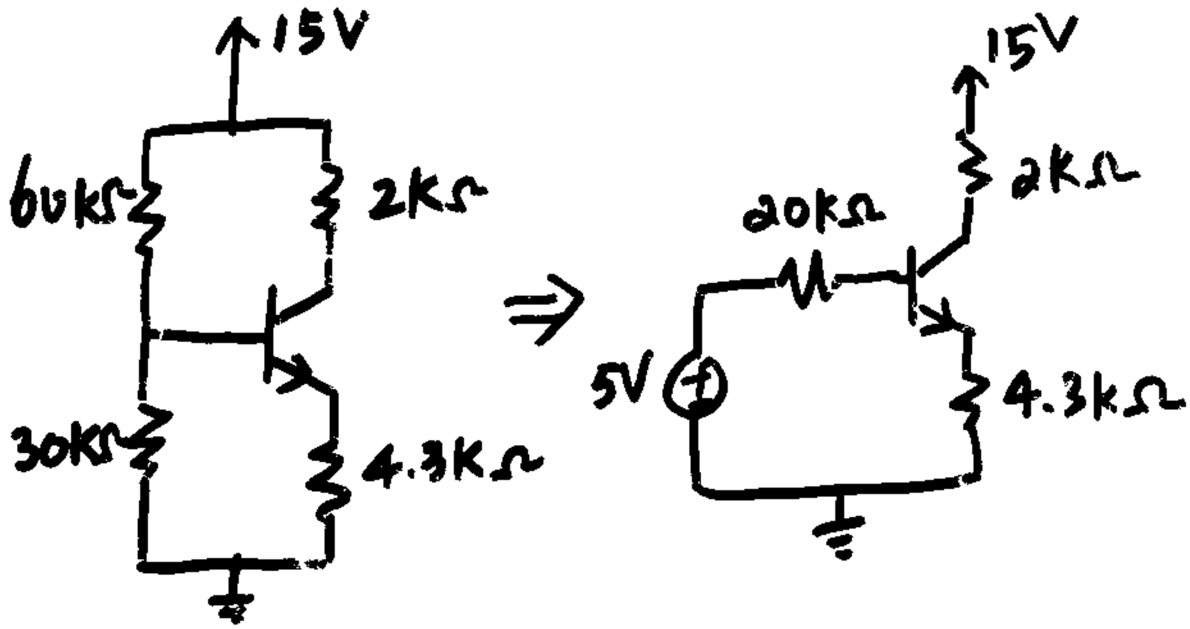
$\beta = 120$

$V_{CC} = 20V$

Find R_B?

How about

$\beta = 60$ or 200?



$\beta = 100$ $\quad I_c$?

$\beta = 200$ $\quad I_c$?

$\beta \to \infty$ $\quad I_c$?

$$I_{BQ} = \frac{V_{TH} - V_{BE}}{R_{TH} + (1+\beta)R_E}$$

$$V_{CQ} = V_{CC} - R_C \beta \frac{V_{TH} - V_{BE}}{R_{TH} + (1+\beta)R_E}$$

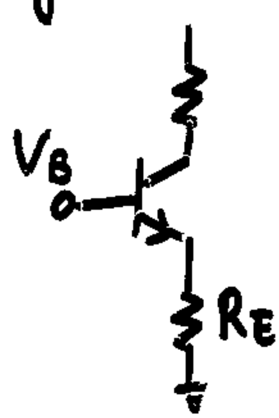
If $R_{TH} << (1+\beta) R_E$

$$V_{CQ} = V_{CC} - \frac{\beta R_C}{(1+\beta) R_E} [V_{TH} - V_{BE}]$$

$$= V_{CC} - \alpha \frac{R_C}{R_E} [V_{TH} - V_{BE}]$$

LARGE variations in $\beta \Rightarrow$ 1~2% variations in α.

Why stable?

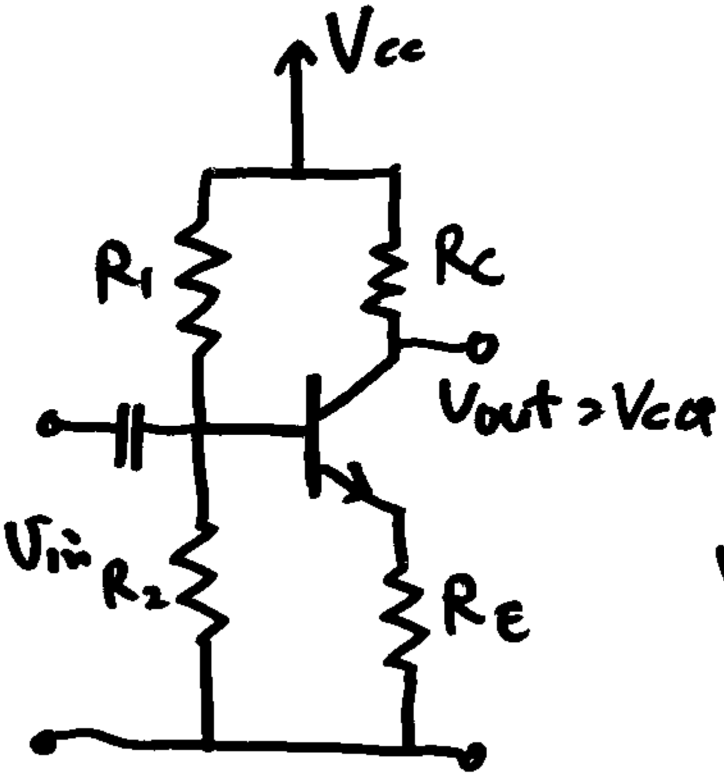


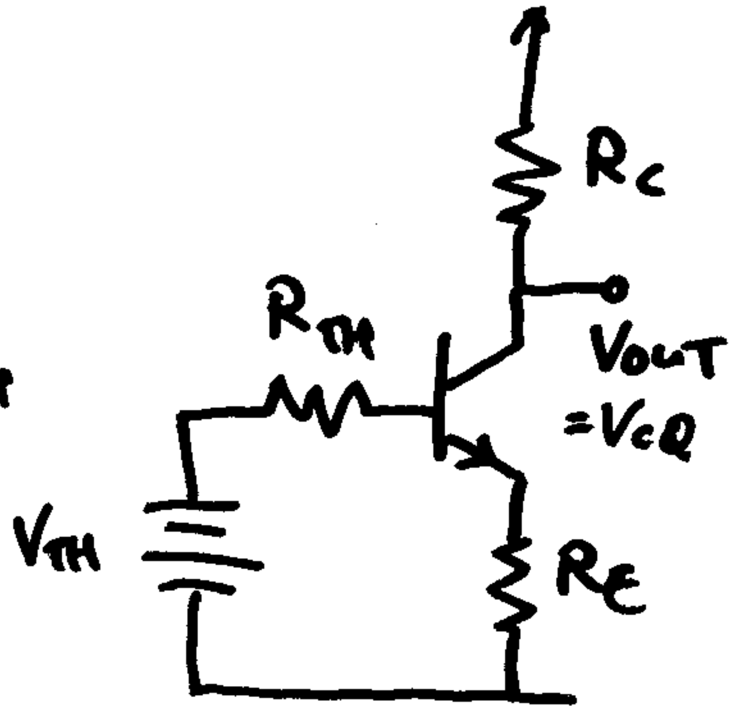
$I_C \uparrow \Rightarrow V_E \uparrow \Rightarrow V_{BE} \downarrow \Rightarrow I_C \downarrow$

NEGATIVE FEEDBACK

$$R_{TH} \leq 0.1 (\beta+1) R_E$$

Emitter Bias





$$V_{TH} = \frac{R_2}{R_1 + R_2} V_{cc}$$

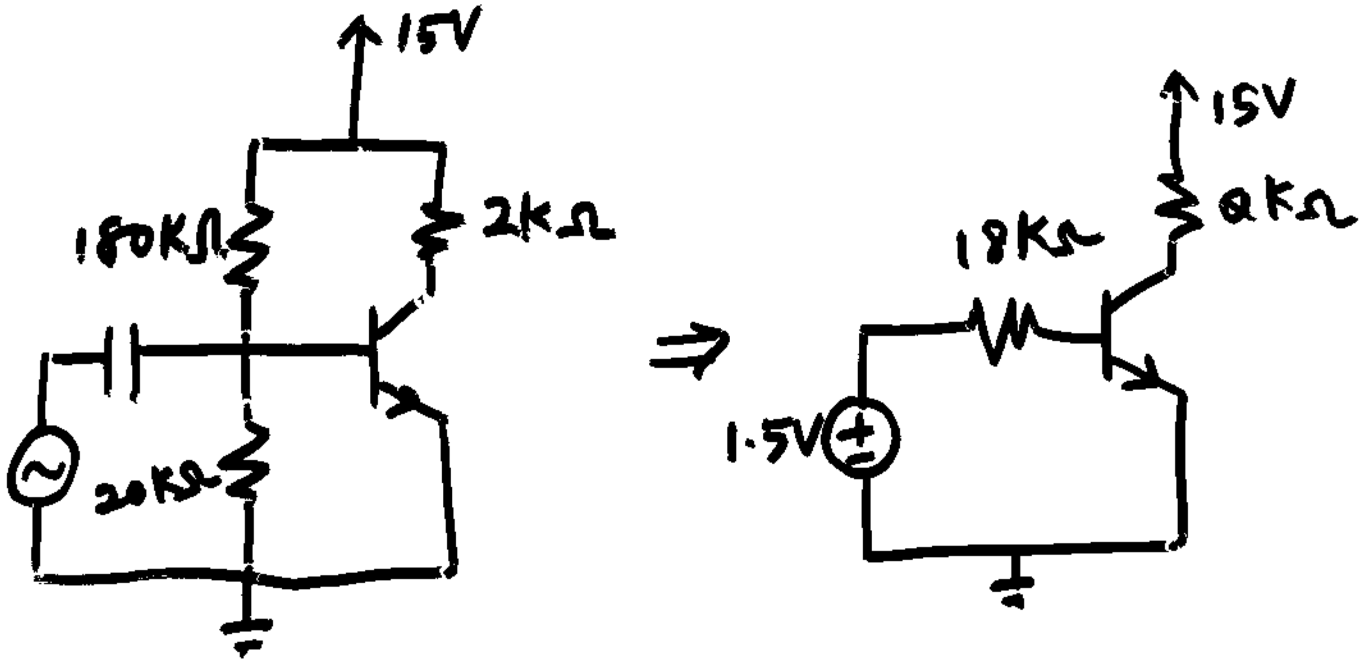
$$R_{TH} = R_1 \| R_2$$

$$V_{TH} = R_{TH} I_B + V_{BE} + R_E I_E$$

$$= R_{TH} I_B + V_{BE} + R_E (1+\beta) I_B$$

$$I_{BQ} = \frac{V_{TH} - V_{BE}}{R_{TH} + (1+\beta) R_E}$$

$R_E = 0 \Rightarrow$ Base current bias
unstable w.r.t. β



$$I_B = \frac{1.5-0.7}{18K\Omega} = 44\mu A$$

$\beta = 100 \Rightarrow$

$\beta = 200 \Rightarrow$

Where is the center of active region?

$V_{CMAX} = V_{CC}$ (cut-off)

$$V_{CMIN} = \frac{R_E}{R_E + R_C} V_{CC}$$

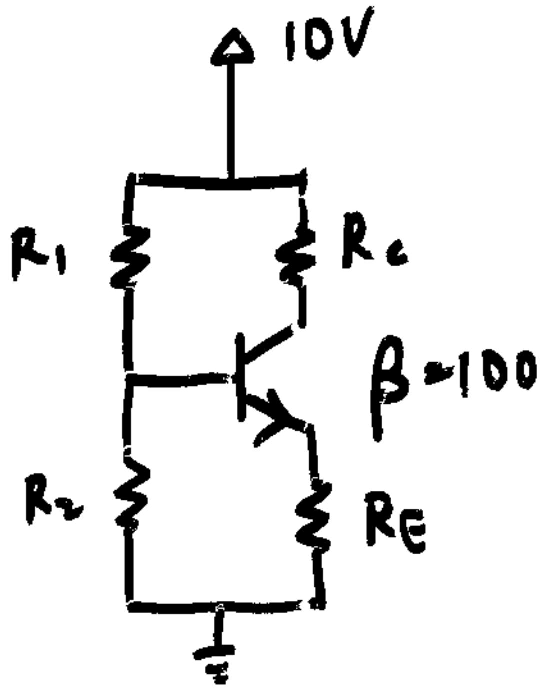
$$V_{CQ} = \frac{V_{CMAX} + V_{CMIN}}{2} = \frac{V_{CC}}{2}\left(1 + \frac{R_E}{R_E + R_C}\right)$$

$$\Rightarrow V_{CE} = \frac{V_{CC}}{2}$$

Design pointers:

① Choose $R_2 = 10 \sim 20 \times R_E$

② Choose R_E s.t. $V_{R_E} = V_{BE(ON)}$



$I_c = 1mA$