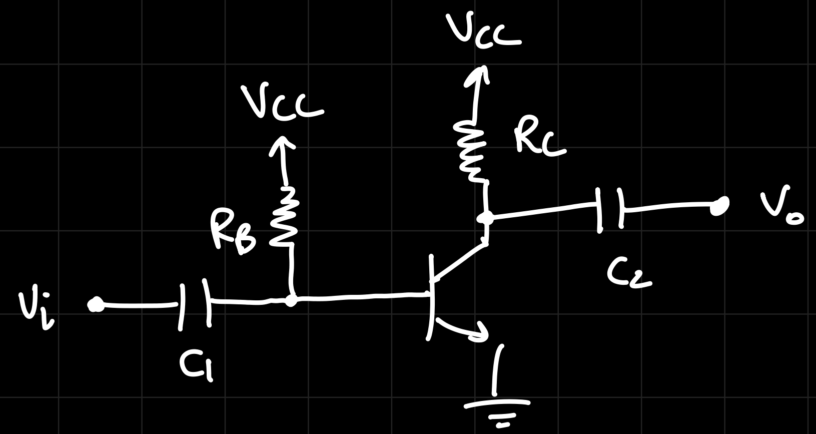
Fixed Bias

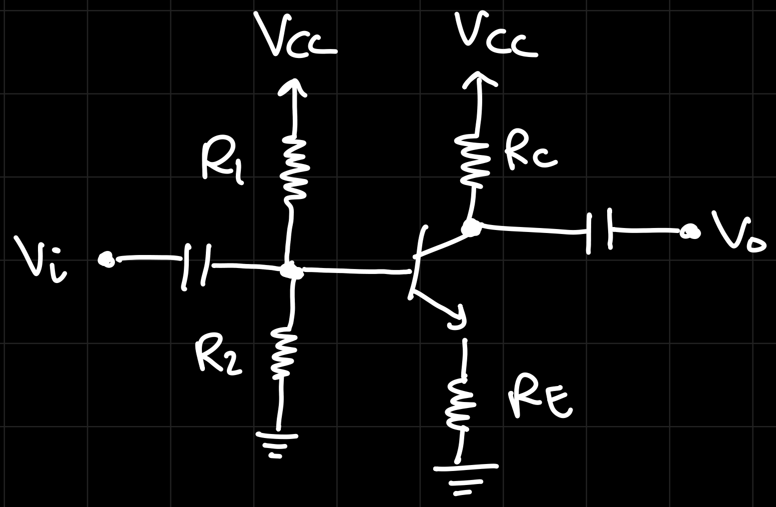


DC analysis for Q point
↳ open ckt all capacitors
↳ BE & CE loop
↳ common emitter config

Any variation in β will impact in I_c and hence will shift the Q point. Therefore this amplifier bias is not ideal

* For multiple devices where fixed bias ckt may be a subsystem (i.e. we may have multiple values of β), we may set different Q point which will result in the transistor being in indeterminant mode. We need standardized values.

Voltage Divider Bias



A dc bias voltage can be created using R_1, R_2

I_B can also be adjusted

simplified using Thevenin's Equivalent

$$-V_{Th} + I_B R_{Th} + V_{BE} + I_E R_E = 0$$

$$I_E = (\beta+1) I_B$$

$$I_B\left(R_{Th} + R_E(\beta+1)\right) = V_{Th} - V_{BE}$$

$$I_B = \frac{V_{Th} - V_{BE}}{R_{Th} + R_E(\beta+1)}$$

$$I_C = \beta I_B = \frac{\beta(V_{Th} - V_{BE})}{R_{Th} + R_E(\beta+1)}$$

due to variation in β, we have variation in I_C in the numerator but also a feedback pulling the value down in the denominator.

$$I_E = (\beta+1) I_B = \frac{V_{Th} - V_{BE}}{R_E + \frac{R_{Th}}{\beta+1}}$$

} we want
① $V_{Th} >> V_{BE}$ to not have any small signal variation

CE loop: $-V_{CC} + I_C R_C + V_{CE} + I_E R_E = 0$

$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$

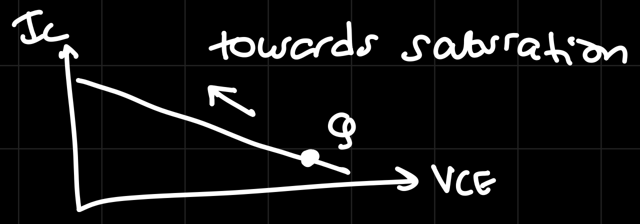
assuming $I_C \simeq I_E$

since I_C is stabilized, V_{CE} will be stabilized as well.

we also want → ② $R_E >> \frac{R_{Th}}{\beta+1}$ to make

I_E and I_C β invariant

$V_{Th} \uparrow \rightarrow I_E \uparrow \rightarrow I_C \uparrow \rightarrow V_{CE} \downarrow$



but if $V_{Th} \downarrow$, $I_E \downarrow$, $I_c \downarrow$, $V_{CE} \uparrow$

towards cutoff

So, we need to maintain V_{Th} such that transistor remains in active mode

Rule of thumb →

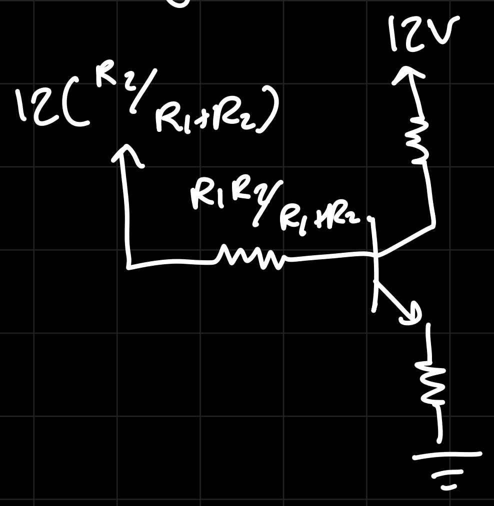
$$\boxed{\begin{gathered} V_{Th} = \frac{1}{3} V_{cc} \\ V_{CB} = \frac{1}{3} V_{cc} \\ \text{(or } V_{BE}\text{)} \\ I_c R_c = \frac{1}{3} V_{cc} \end{gathered}}$$

*

$$I_1 / I_2 = (0.1 - 1) \times I_E$$

Q) $I_E = 1mA$ $V_{CC} = 12V$

$\beta = 100$



$\frac{1}{3}V_{CC}$ for R_C ; $\frac{1}{3}V_{CC}$ for R_2 ; rest $\frac{1}{3}$ for possible negative signal swing

as per rule of thumb →

$$V_B = \frac{1}{3}V_{CC} = \underline{4V}$$

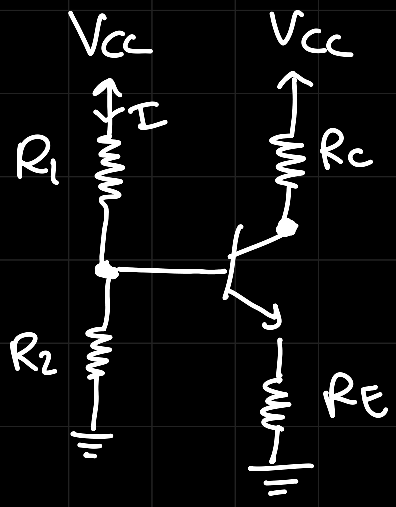
$$V_C = \frac{2}{3}V_{CC} = \underline{8V}$$

$$V_E = V_B - V_{BE} = \underline{3.3V}$$

$$R_E = \frac{V_E}{I_E} = 3.3K\Omega$$

assume, $I_B \simeq 0$ → $I = \frac{V_{CC}}{R_1+R_2}$ → I can be $[I_E, 0.1 I_E]$

Case 1 : $I = 0.1 I_E = 0.1mA = \frac{12}{R_1+R_2} \rightarrow \underline{R_1+R_2 = 12\times10^4}$ ①



$$V_B = \frac{V_{CC} \times R_2}{R_1+R_2}$$

$$V_B = \frac{12 R_2}{12\times10^4}$$

$4\times10^4 = R_2 \rightarrow \quad R_2 = 40k\Omega$

$R_1 = 80k\Omega$

$$I_E = \frac{V_{BB} - V_{BE}}{R_E + \frac{R_B}{\beta+1}} \quad , \quad R_B = \frac{320\cancel{0}}{12\cancel{0}} \Rightarrow \frac{80}{3}\Omega$$

$$I_E = \frac{\frac{1\times4\cancel{0}K}{1\cancel{0}\cancel{K}} - 0.7}{R_E + \frac{32\cancel{00}\cancel{K}}{12\cancel{0}K}} = \frac{3.3}{R_E + \frac{80}{303}}$$

$I_E = 0.925mA \simeq 0.93mA$

now reduce R_E by $\frac{R_B}{101}$

$$R_E' = R_E - \frac{R_B}{101} = 3.3k - 0.267^k = 3.03k\Omega$$

$$I_E' = \frac{4-0.7}{3.03k + \frac{80}{303}} \simeq 1.0018\,mA$$

<u>case2</u> : $I = I_E = 1mA$

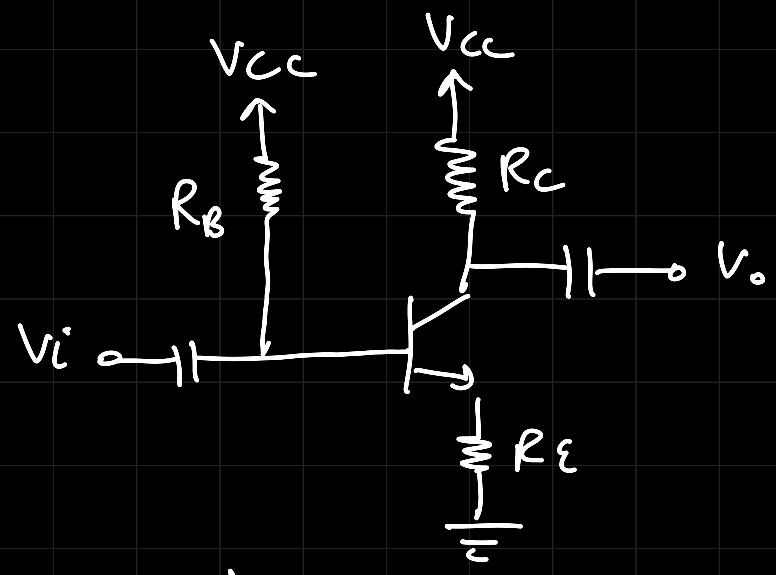
$$\frac{V_{cc}}{R_1+R_2} = 1mA$$

$$R_1+R_2 = 12k\Omega$$

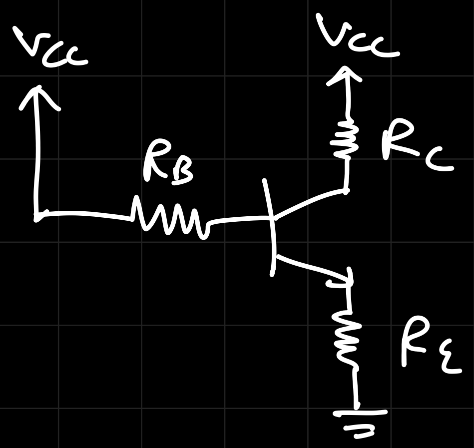
$$\left(\frac{R_2}{R_1+R_2}\right)V_{cc} = 4V \Rightarrow \begin{array}{l} R_2 = 4k\Omega \\ R_1 = 8k\Omega \end{array}$$

$$I_E = \frac{3.3}{3.3 + \left(\frac{8}{3}\right)/101} = 0.992mA \simeq 1mA$$

Emitter stabilized circuit



DC analysis



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

$$I_B = \frac{I_E}{(\beta+1)}$$

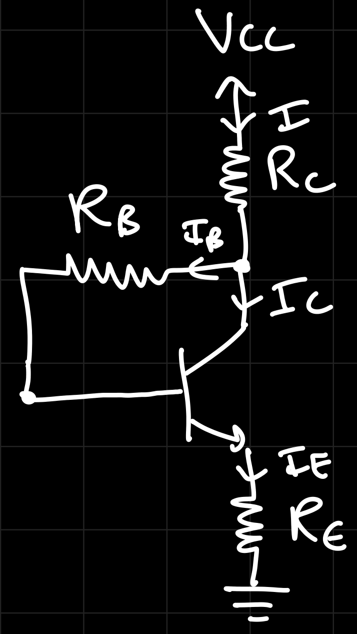
$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta+1) R_E}$$

$$I_C = \frac{\beta (V_{CC} - V_{BE})}{R_B + (\beta+1) R_E}$$

Note: we have control/feedback unlike fixed bias

$$V_{CE} = V_{CC} - I_C R_C - I_E R_E$$

DC bias with voltage Feedback



$-V_{CC} + IR_C + I_B R_B + V_{BE} + I_E R_E = 0$

assuming $I_B << I_C$

$-V_{CC} + I_C R_C + I_B R_B + V_{BE} + I_E R_E = 0$

$$-V_{CC} + I_B(\beta R_C + R_B + (\beta+1) R_E) + V_{BE} = 0$$

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

assuming $I_C \simeq I_E$

$$\text{So, } I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta(R_C + R_E)}$$

$$I_C = \beta I_B = \frac{V_{CC} - V_{BE}}{\frac{R_B}{\beta} + R_C + R_E}$$

much better & robust as compared to emitter stabilized bias

| What is the tradeoff ? |

amplifier design → adequate gain

prevents distortion in output ← stabilize Q point

infinite input resistance

low output impedance

linear amplification

CE : V amp → out of phase by 180°

CB : V amp → in phase

CC : buffer amp