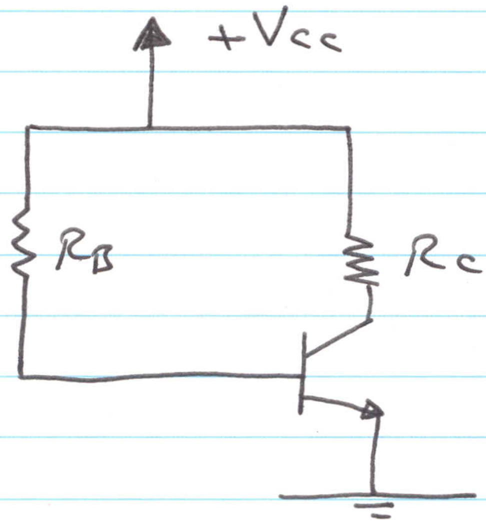
Transistor biasing Circuits

1) Fixed current bias Circuit



KVL : $V_{CC} = R_B I_B + V_{BE}$

$$\therefore I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

$$I_C = \beta I_B$$

KVL : $V_{CC} = R_C I_C + V_{CE}$

$$\therefore V_{CE} = V_{CC} - R_C I_C$$

Design a fixed current bias circuit using a Silicon transistor having

$\beta(min) = 25$, $\beta(max) = 75$

Such that $I_C = 1mA$, and $V_{CE} = 5\,V$

given $V_{CC} = 10\,V$

$$I_B = \frac{V_{cc} - 0.7}{R_B} \quad \text{———} \quad (1)$$

$$V_{CE} = V_{cc} - R_c I_c \quad \text{———} \quad (2)$$

using equation (2)

$$5 = 10 - R_c (1mA)$$

$$\therefore R_c = 5K$$

$$I_B = \frac{I_c}{\beta}$$

$$\text{Let } \beta = \frac{75+25}{2} = 50$$

$$\therefore I_B = \frac{1mA}{50} = 20\mu A$$

using equation (1)

$$I_B = \frac{10-0.7}{R_B} = 20\mu A$$

$$\therefore R_B = 465K$$

* If $\beta = 50$, $R_C = 5K$, and $R_B = 465K$

$I_C = 1mA$, and $V_{CE} = 5V$

BUT

1) when $\beta = \beta(min) = 25$

$I_B = 20\mu A$
$I_C = 0.5\,mA$
$V_{CE} = 7.5\,V$

2) when $\beta = \beta(max) = 75$

$I_B = 20\mu A$

$I_C = 1.5\,mA$

$V_{CE} = 2.5\,V$

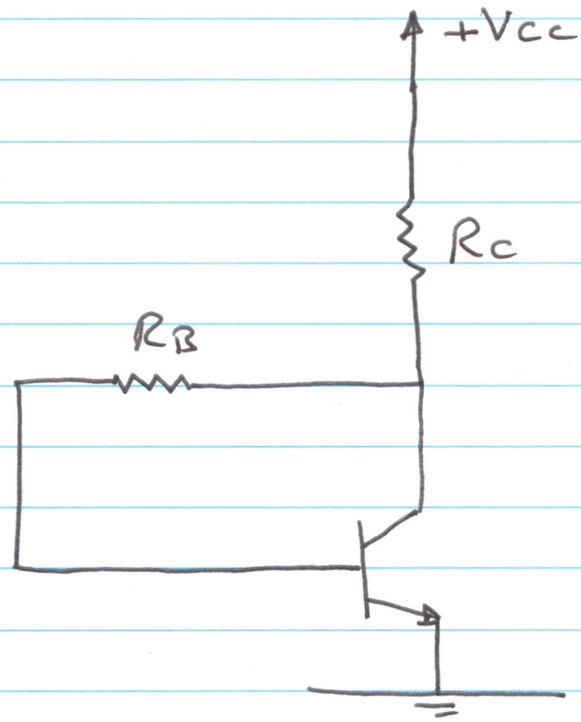
$\therefore$ For

$$75 \geq \beta \geq 25$$

$$1.5mA \geq I_C \geq 0.5mA$$

$\therefore$ The fixed current bias circuit is not a very satisfactory circuit of obtaining good bias point stability.

2) Collector-to-base feedback bias circuit



KVL : $V_{CC} = R_C I + R_B I_B + V_{BE}$

$I = I_C + I_B$

$$\therefore I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1) R_C} \quad \text{— ①}$$

$$I_C = \beta I_B$$

KVL : $V_{CC} = R_C (I_C + I_B) + V_{CE}$

$$\therefore V_{CE} = V_{CC} - R_C (I_C + I_B) \quad \text{— ②}$$

Design :

Let $\beta = \beta(typical) = 50$

$$\therefore I_B = \frac{I_c}{\beta} = 20\mu A$$

using equation ②

$$V_{cc} = V_{CE} + R_c (I_c + I_B)$$

$$\therefore R_c \cong 4.9K$$

using equation ①

$$I_B = \frac{V_{cc} - 0.7}{R_B + R_c(\beta+1)}$$

$$\therefore R_B = 215K$$

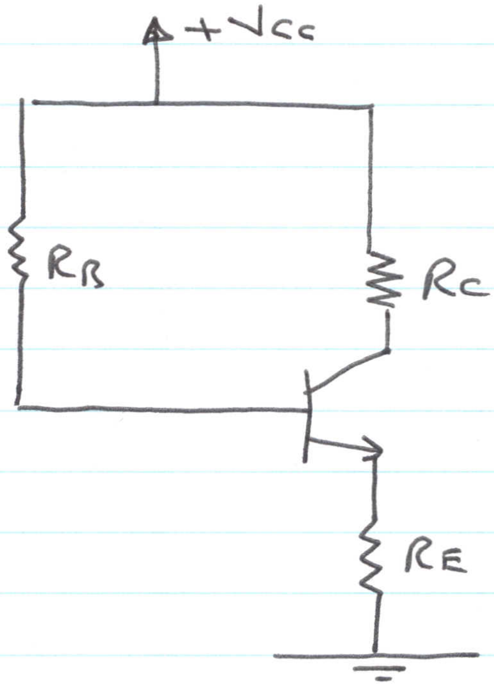
Proof that

$$75 \geq \beta \geq 25$$

$$1.19mA \geq I_c \geq 0.68mA$$

$\therefore$ There is an improvement over the fixed current bias circuit

3) Biasing Circuit with stabilization resistance [R_E]



KVL : $V_{cc} = R_B I_B + V_{BE} + R_E I_E$

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

$$\therefore I_B = \frac{V_{cc} - V_{BE}}{R_B + (\beta+1) R_E} \quad \text{—— (1)}$$

$$I_c = \beta I_B$$

KVL : $V_{cc} = R_c I_c + V_{CE} + R_E I_E$

$$\therefore V_{CE} = V_{cc} - R_c I_c - R_E I_E \quad \text{— (2)}$$

Design :

In this Circuit we have 3 unknowns (R_B, R_C, and R_E).

we have two equations

$\therefore$ we must make a new assumption

$$\frac{V_{cc}}{5} \geq V_{RE} \geq \frac{V_{cc}}{10}$$

and $\beta = \beta(\text{typical}) = 50$

$\therefore$ Let $V_{RE} = \frac{V_{cc}}{5} = 2V$

$\therefore R_E = \frac{V_{RE}}{I_E} \simeq \frac{2V}{1mA} = 2K$

using equation ②

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

$\therefore R_C = 3K$

using equation ①

$$I_B = \frac{V_{cc} - V_{BE}}{R_B + (\beta+1) R_E} = 20\mu A$$

$\therefore \quad R_B = 365\ K$

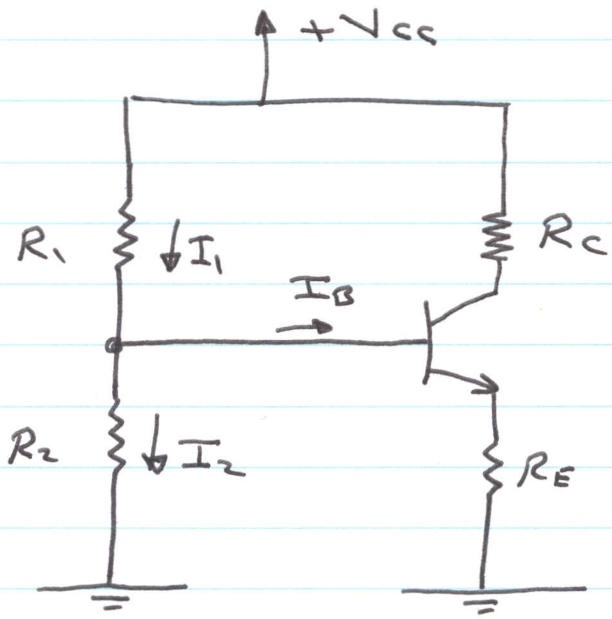
Proof

$$75 \geq \beta \geq 25$$

$$1.349\,mA \geq I_C \geq 0.55755\ mA$$

$\therefore$ There is an improvement over the fixed current bias circuit

4) Voltage Divider Bias Circuit



a) Approximate method

I_B very small $\longrightarrow$ $I_B \simeq 0$

$\therefore \quad I_2 = I_1$

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

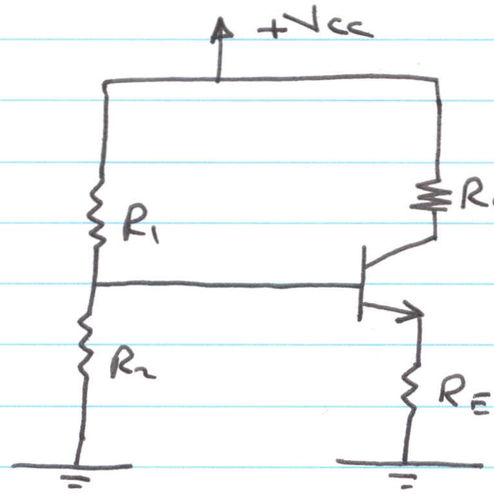
$$V_E = V_B - V_{BE}$$

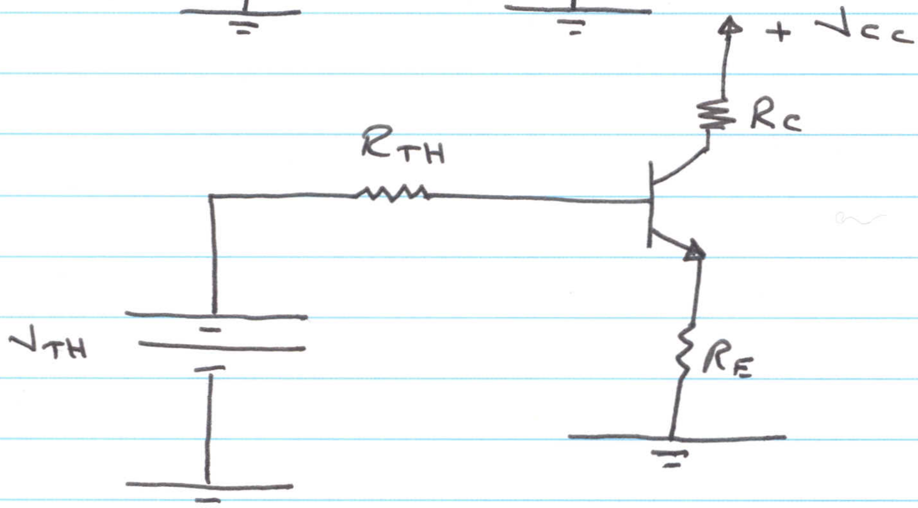
$$I_{E_1} = \frac{V_E}{R_E}$$

$$I_C = \alpha I_E \simeq I_E$$

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

b) Exact method





$$R_{TH} = \frac{R_1 R_2}{R_1 + R_2}$$

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

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

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

$$\therefore \quad I_{E_2} = \frac{V_{TH} - V_{BE}}{\frac{R_{TH}}{\beta + 1} + R_E}$$

using the approximate method, we get

$$I_{E_1} = \frac{V_B - V_{BE}}{R_E}$$

where $V_B = \frac{R_2}{R_1 + R_2} V_{cc}$

using the exact method, we get

$$I_{E_2} = \frac{V_{TH} - V_{BE}}{\frac{R_{TH}}{\beta+1} + R_E}$$

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

To make $I_{E_2} \cong I_E$

$$\frac{R_{TH}}{\beta+1} + R_E \cong R_E$$

$$\frac{R_{TH}}{\beta+1} << R_E$$

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

$\therefore$ let

$$R_{TH} = \frac{(\beta+1) R_E}{10, 20, 30, \ldots}$$

Design :

Let $V_{RE} = \frac{V_{cc}}{10} = 1\,\underline{V}$

$\therefore R_E = \frac{V_{RE}}{I_E} \cong 1K$

Let $R_{TH} = \frac{\beta R_E}{50} = 1K$; $\beta = 50$

KVL : $V_{cc} = R_C I_C + V_{CE} + R_E I_E$

$10 = R_c(1mA) + 5\underline{V} + (1K)(1.02\,mA)$

$\therefore R_c = 4K$

To find R_1 and R_2, we need to find

R_{TH}, and V_{TH}

using $I_E = \dfrac{V_{TH} - 0.7}{\frac{R_{TH}}{\beta+1} + R_E}$

we get $V_{TH} = 1.72\,\underline{V}$

$R_{TH} = \frac{R_1 R_2}{R_1 + R_2}$

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

$\therefore R_1 = 5.8K$, and $R_2 = 1.2K$

If $R_1 = 5.8K$, $R_2 = 1.2K$, $R_C = 4K$, and

$R_E = 1K$, $\beta = 50$

$I_{CQ} = 1mA$, and $V_{CE} = 5V$

But

$$75 \geqslant \beta \geqslant 25$$

$$1.0067mA \geqslant I_C \geqslant 0.982\,mA$$