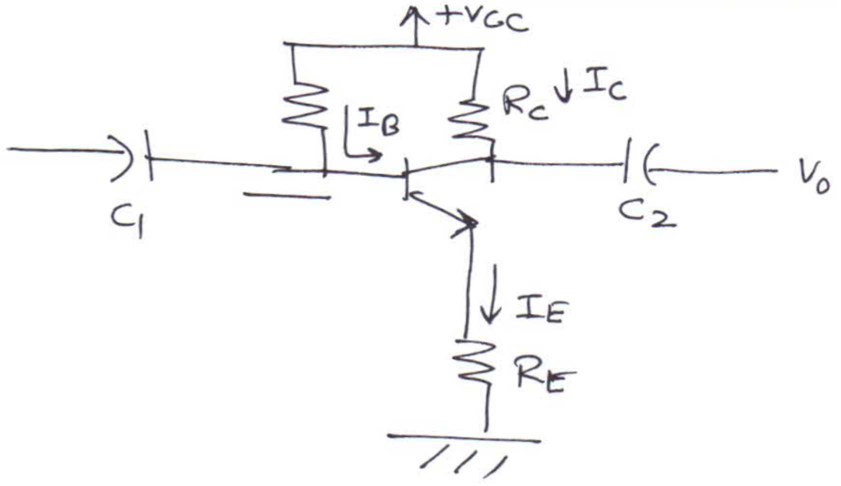
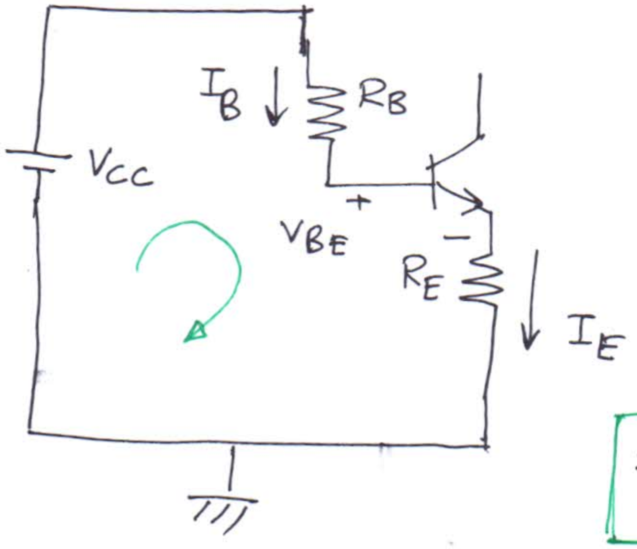
Emitter Stabilized Bias ckt



BJT Bias ckt with Emitter resistor

Base Emitter Loop



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

$$I_E = I_C + I_B$$
$$= (\beta+1) I_B \quad (2)$$

$$\boxed{\text{Substitute} \quad I_E = (\beta+1) I_B}$$

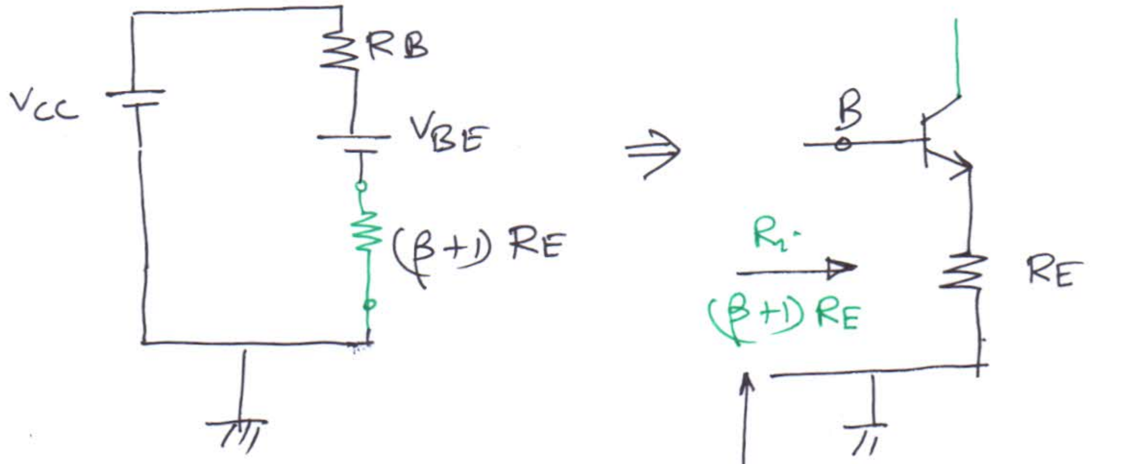
$$I_B R_B + (\beta+1) I_B R_E = V_{CC} - V_{BE} \quad (3)$$

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

This term is new here.

Note: The Difference w.r.t. Fixed bias is the inclusion of term $(\beta+1) R_E$.

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta+1)R_E} \quad \ldots \quad (4)$$



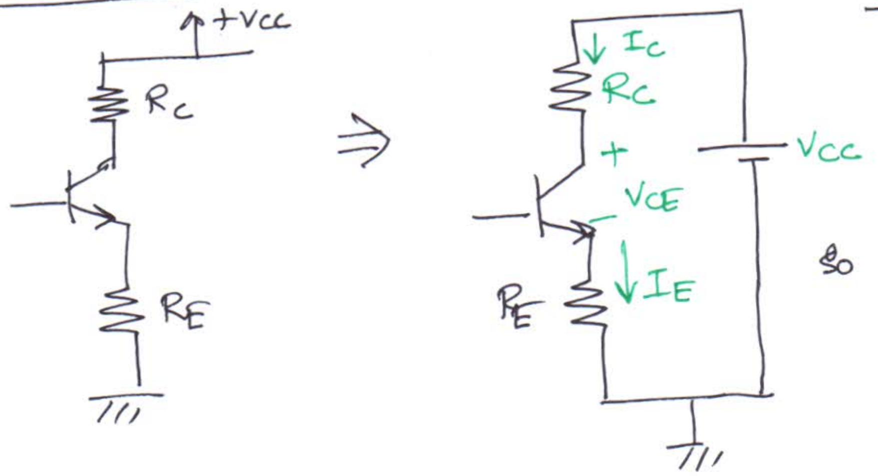
Equivalent network of Eqn (4)

Reflected impedance of R_E

The emitter resistance R_E which is part of the collector emitter Loop 'appears as' $(\beta+1)R_E$ in the base emitter Loop.

$$\boxed{R_i = (\beta+1)R_E} \quad \ldots \quad (5)$$

Collector Emitter Loop



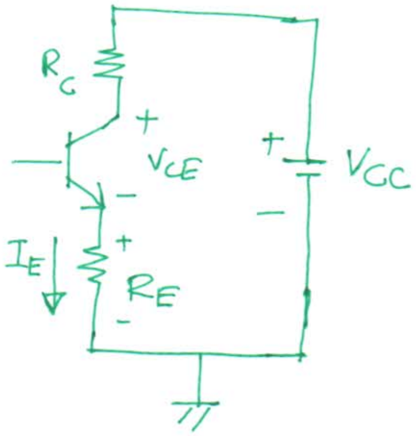
$$-V_{CC} + I_C R_C + V_{CE} + I_E R_E = 0$$

$$I_E \simeq I_C$$

so $$V_{CC} - V_{CE} = I_C(R_C + R_E) \quad \ldots \quad (6)$$

$$V_{CE} = V_{CC} - I_C(R_C + R_E) \quad \ldots \quad (6)$$

$$V_E = I_E \cancel{R_E} = I_E R_E$$



$$V_{CE} = V_C - V_E$$

$$\boxed{V_C = V_{CC} - I_C R_C}$$

$$\boxed{V_C = V_{CE} + V_E}$$

voltage at the base w.r.t ground

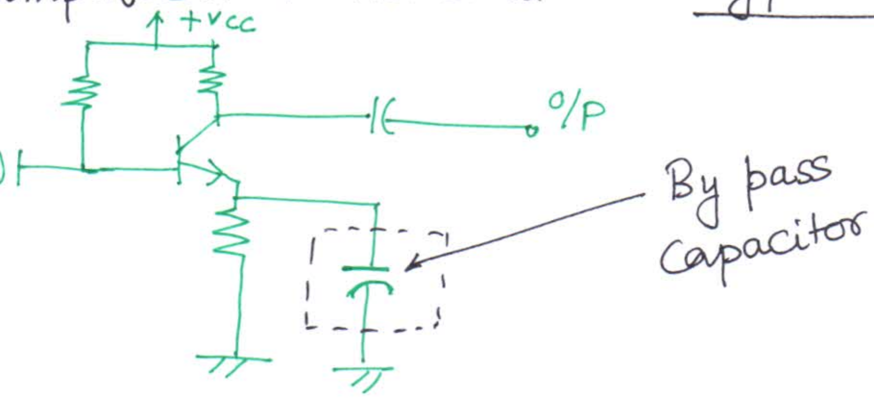
$$\boxed{V_B = V_{CC} - I_B R_B}$$

$$\boxed{V_B = V_{BE} + V_E}$$

The d.c. resistance R_E improves the stability

But it ~~d~~ reduces the voltage gain for small a.c. signal.

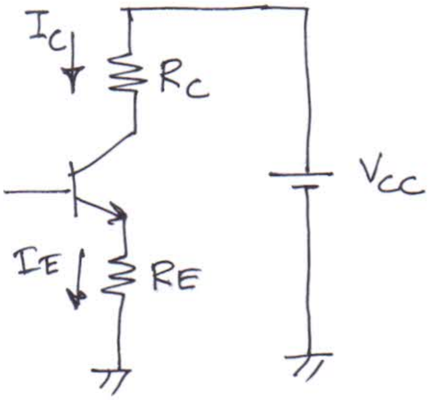
Thus the resistance R_E is desired for d.c. bias (to improve stability) but not desired for AC amplification. Hence it is bypassed by a Capacitor



For Emitter stabilized Bias ckt

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

$$\approx \frac{V_{CC}}{R_B + \beta R_E}$$



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

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

$$I_E = I_C + I_B$$

⇒ For input base emitter Loop

$$V_{CC} - V_{BE} = I_B(R_B + R_E) + I_C R_E$$

or $$0 = \frac{dI_B}{dI_C}(R_B + R_E) + R_E$$

or. $$\boxed{\frac{dI_B}{dI_C} = -\frac{R_E}{R_B + R_E}}$$

$$I_C = \beta I_B + (\beta+1) I_{CO}$$

$$1 = \beta \frac{dI_B}{dI_C} + (\beta+1)\frac{dI_{CO}}{dI_C} \qquad \frac{dI_C}{dI_{CO}} = S$$

$$= \beta \frac{dI_B}{dI_C} + \frac{(\beta+1)}{S}$$

or. $$\boxed{S = \frac{(\beta+1)}{1 - \beta \frac{dI_B}{dI_C}} = \frac{(\beta+1)}{1 + \beta \frac{R_E}{R_B + R_E}}}$$

Stability Factor for Emitter resistor ckt

$$S(I_{co}) = \frac{(\beta+1)}{1+\beta \cdot \frac{R_E}{(R_B+R_E)}}$$

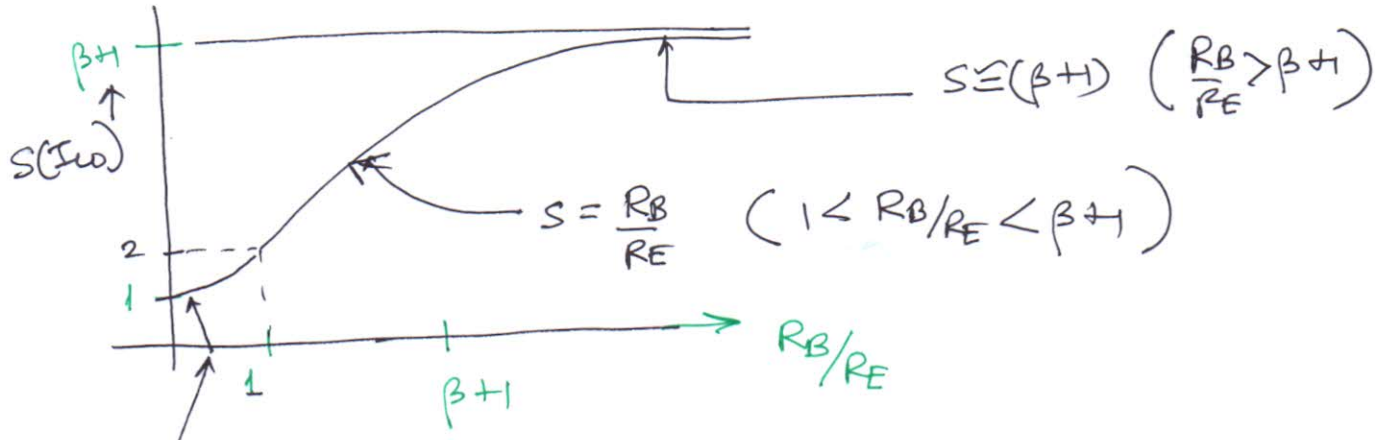
$$= (\beta+1) \cdot \frac{R_B+R_E}{R_B+(\beta+1)R_E}$$

$$= (\beta+1)\left[\frac{1+R_B/R_E}{(1+\beta)+R_B/R_E}\right]$$

$$\boxed{\frac{R_B}{R_E} \gg (\beta+1)}$$

$$\boxed{S(I_{co}) = (\beta+1)}$$

Same as fixed bias



$S \cong 1 \; \left(\frac{R_B}{R_E} < 1\right)$

$$\frac{R_B}{R_E} \ll 1$$

$$S(I_{co}) = (\beta+1) \cdot \frac{1}{(\beta+1)} \approx 1$$

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

$$I_C = \beta I_B + I_{CEO}$$

$$S(V_{BE}) = \frac{\partial I_C}{\partial V_{BE}}$$

$$= -\beta\left(\frac{1}{R_B + (\beta+1)R_E}\right)$$

$$= -\frac{\beta/R_E}{\frac{R_B}{R_E} + (\beta+1)}$$

$$(\beta+1) \gg \frac{R_B}{R_E} \qquad = -\frac{\beta/R_E}{(\beta+1)} \cong \frac{-\beta}{R_E \cdot \beta}$$

$$\simeq \frac{-1}{R_E}$$

$$S(V_{BE}) = -1/R_E$$

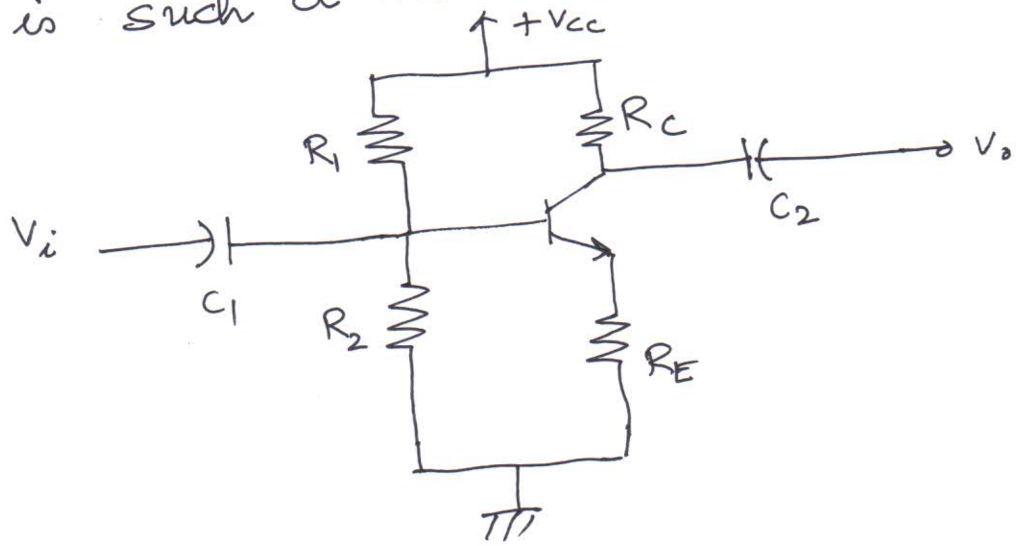
Larger 'R_E' will ensure higher stability.

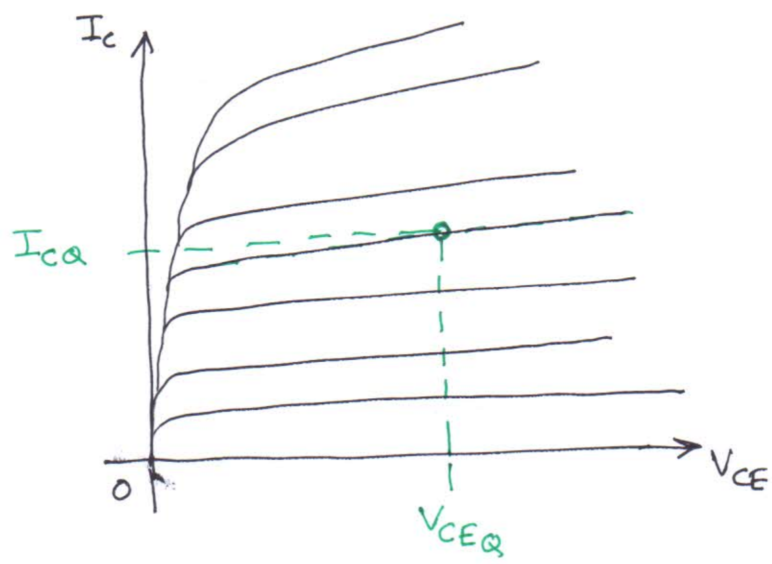
Voltage Divider Bias

- In the previous configurations, the bias ct I_{CQ} and voltage V_{CEQ} were a function of current gain (β). of the transistor.

- However, since β is temperature sensitive, particularly for Si transistors and actual value of β is not usually well defined, it would be desirable to develop a bias ckt that is less dependent, or infact, independent of transistor β.

The voltage-divider bias config of Fig below is such a network.

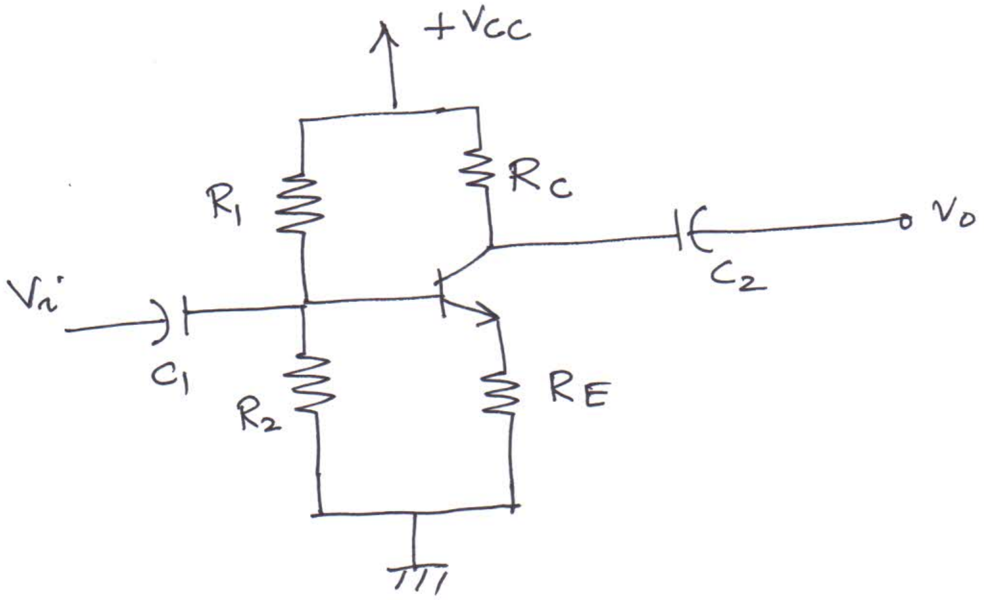




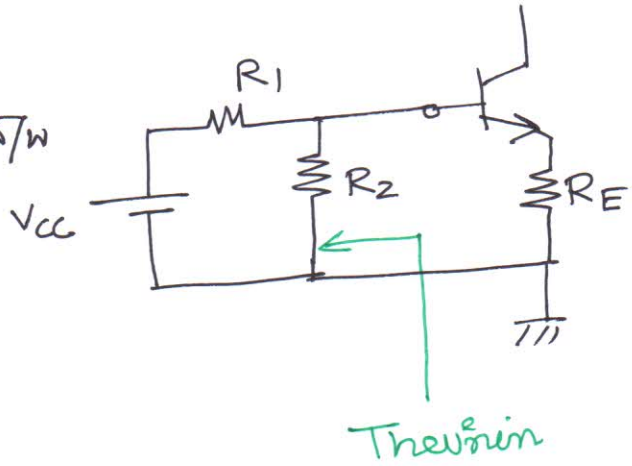
Sensitivity to changes in β is small

By proper choice of circuit parameters, resulting level of I_{CQ} and V_{CEQ} can be made totally independent of β.

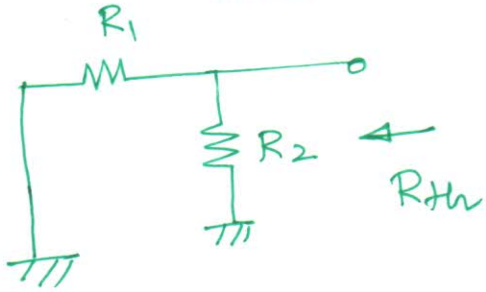
The level of I_{BQ} will change with change in β, but the operating point on the characteristics defined by I_{CQ} and V_{CEQ} can remain fixed.



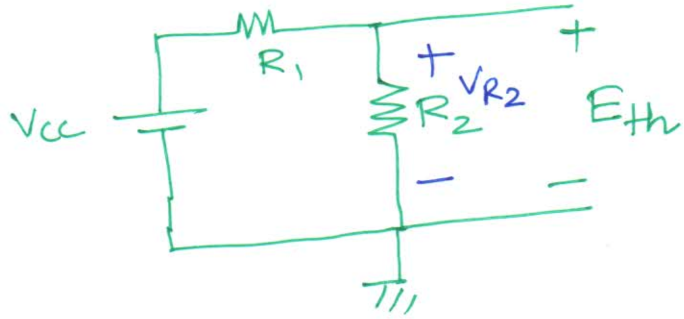
i/p side of the n/w

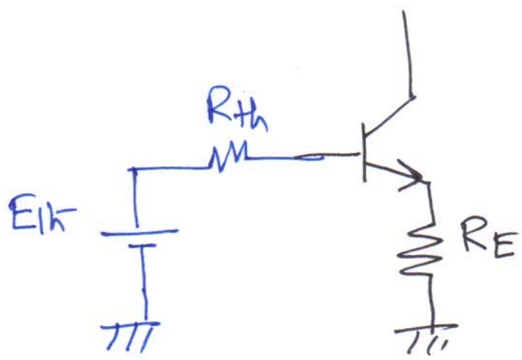


$$R_{th} = R_1 \| R_2$$



$$E_{th} = V_{R_2} = \frac{V_{CC} \cdot R_2}{(R_1 + R_2)}$$





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

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

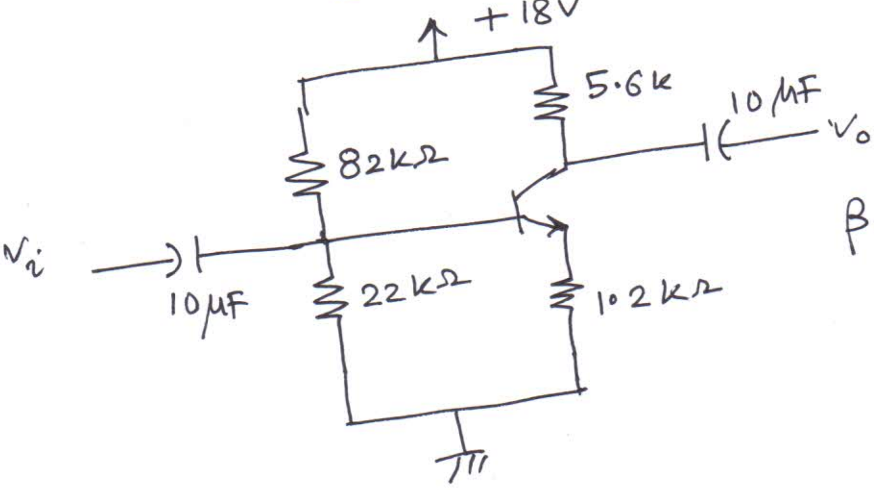
$$\boxed{I_B = \frac{E_{th} - V_{BE}}{R_{th} + (\beta+1) R_E}}$$

Once I_B is known, the remaining quantities of the network can be found in the same manner as developed for the emitter-bias config.

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

or $$I_C = \frac{V_{CC} - V_{CE}}{R_C + R_E}$$

Example



$\beta = 50$

$$R_{th} = R_1 \| R_2 = 82 \| 22 = 17.35\ k\Omega$$

$$E_{th} = \frac{18 \times 22}{82 + 22} = 3.81V$$

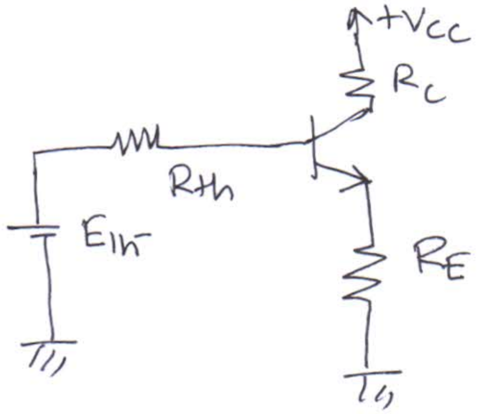
$$I_B = \frac{E_{th} - V_{BE}}{R_{th} + R_E(1+\beta)} = \frac{3.81 - 0.7}{17.35 + 1.2 \times 51} = 39.6\ \mu A$$

$$I_{C_Q} = \beta I_B = 50 \times 39.6\ \mu A = 1.98\ mA$$

$$V_{CE_Q} = V_{CC} - I_C(R_C + R_E)$$
$$= 18 - 1.98(5.6 + 1.2) = 4.54V$$

Voltage Divider Bias

Equivalent ckt.



Following the same approach of Emitter stabilized Bias ckt, we obtain

$$S(I_{CO}) = (\beta+1)\,\frac{(1 + R_{th}/R_E)}{(\beta+1) + R_{th}/R_E}$$

Now for Emitter stabilized Bias, we have greatest stability when $\frac{R_B}{R_E} < 1$ or $R_E > R_B$ $\quad S \approx 1$

Similarly here $S \approx 1$ when $\boxed{R_E > R_{th}}$

For voltage divider bias, R_{th} can be much less than the corresponding R_B of the emitter-bias configuration, and still have an effective design.

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

$$I_C = \beta I_B + I_{CEO}$$

$$S(V_{BE}) = \frac{\partial I_C}{\partial V_{BE}}$$

$$= \beta \left(- \frac{1}{R_{TH} + (\beta+1) R_E} \right)$$

$$= - \frac{\beta / R_E}{\frac{R_{TH}}{R_E} + (\beta+1)}$$

$$\frac{R_{TH}}{R_E} \ll (\beta+1) \qquad = - \frac{\beta/R_E}{(\beta+1)}$$

$$\text{or. } (\beta+1) \gg \frac{R_{TH}}{R_E} \qquad = - \frac{\beta/R_E}{\beta} = -1/R_E$$

$$\boxed{S(V_{BE}) = -1/R_E}$$

Larger the resistance R_E, Lower the stability factor, and more stable the system.