Biasing methods for BJT

Transistor biasing is the process of setting a transistor DC operating voltage or current conditions to the correct level so that any AC input signal can be amplified correctly by the transistor. The term biasing appearing in the title of this chapter is an all-inclusive term for the application of dc voltages to establish a fixed level of current and voltage.

The types of transistor biasing include:

1. Fixed Base Bias or Fixed Resistance Bias
2. Emitter – Stabilized Bias Circuit
3. Collector to Base Bias Circuit
4. Voltage Divider Bias

Fixed Base Bias or Fixed Resistance Bias

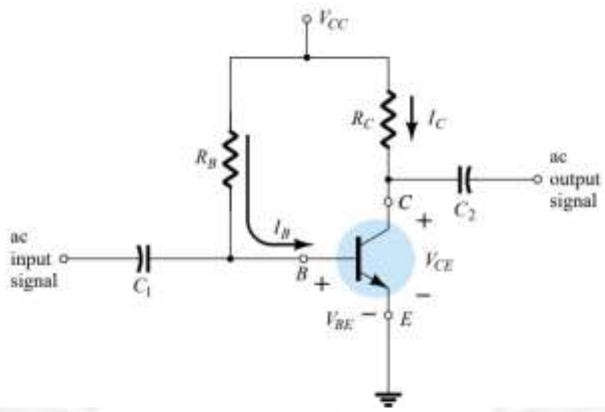

Figure 2.1.1 Fixed Bias

Diagram Electronic Tutorial

The biasing circuit shown in Fig: 2.1.1 has a base resistor R_B connected between the base and the V_{CC}. Here the base-emitter junction of the transistor is forward biased by the voltage drop across R_B, which is the result of I_B flowing through it. For the dc analysis the network can be isolated from the indicated ac levels by replacing the capacitors with an open circuit equivalent.

Consider first the base–emitter circuit loop, apply Kirchhoff's law in clockwise direction we obtain

$$-V_{CC} + I_C R_C + V_{CE} = 0$$
$$\therefore V_{CE} = V_{CC} - I_C R_C$$

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

In addition, since the supply voltage V_{CC} and the base–emitter voltage V_{BE} are constants, the selection of a base resistor, R_B, sets the level of base current for the operating point.

Collector–Emitter Loop

The collector–emitter section, the magnitude of the collector current is related directly to I_B through

$$I_C = \beta I_B$$

Apply Kirchhoff's law in clockwise direction at emitter- collector side of Fig 1, we obtain

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

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

where V_{CE} is the voltage from collector to emitter and V_C and V_E are the voltages from collector and emitter to ground respectively. But in this case, since $V_E = 0$ V, $V_{CE} = V_C$. Similarly $V_{BE} = V_B - V_E$ and V_{BE} can be written as $V_{BE} = V_B$

Emitter Stabilized bias circuit

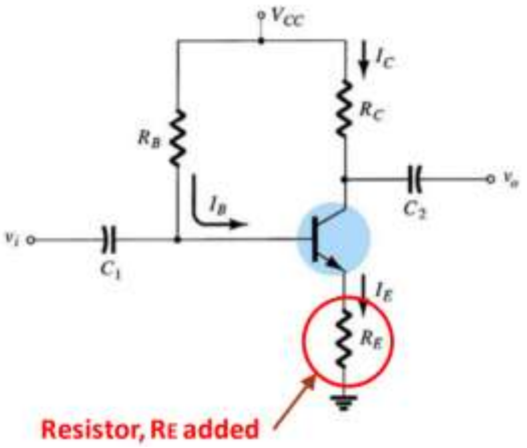

Figure 2.1.1 Emitter Stabilized bias circuit

Diagram Electronic Tutorial

The dc bias network of Fig. 2 contains an emitter resistor to improve the stability level over that of the fixed-bias configuration.

<u>Base–Emitter Loop</u>

The base–emitter loop of the network can be redrawn as shown in Fig. 2. Writing Kirchhoff's voltage law around the indicated loop in the clockwise direction will result in the following equation

$V_{CC} – I_B R_B – V_{BE} - I_E R_E$

we know that

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

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

Grouping terms will then provide the following:

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

Multiplying through by (-1) we have

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

with

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

and solving for I_B gives

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

<u>Collector–Emitter Loop</u>

The collector–emitter loop, writing Kirchhoff's voltage law for the indicated loop in the clockwise direction will result in

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

Substituting $I_E \cong I_C$ and grouping terms gives

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

and

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

The single-subscript voltage V_E is the voltage from emitter to ground and is determined by

$$V_E = I_E R_E$$

while the voltage from collector to ground can be determined from

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

and

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

or

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

The voltage at the base with respect to ground can be determined from

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

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

VOLTAGE-DIVIDER BIAS

There are two methods that can be applied to analyse the voltage divider configuration.

a) Exact method

b) Approximate method

Exact Analysis

The input side of the network of as shown in Fig. 2.1.3 for the dc analysis. The Thevenin equivalent network for the network to the left of the base terminal can then be found in the following manner

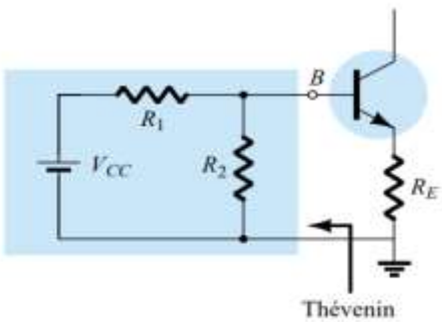

Figure 2.1.3 Emitter Stabilized bias circuit

Diagram Electronic Tutorial

R_{Th}: The voltage source is replaced by a short-circuit equivalent as shown in Fig. 2.1.4

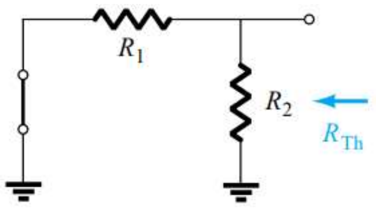

Figure 2.1.4 Thevenin Equivalent Circuit

Diagram Electronic Tutorial

Determining R_{Th}

R_{Th} = R1||R2

E_{Th}: The voltage source V_{CC} is returned to the network and the open-circuit Thévenin voltage of Fig. 5 determined as follows: Applying the voltage-divider rule

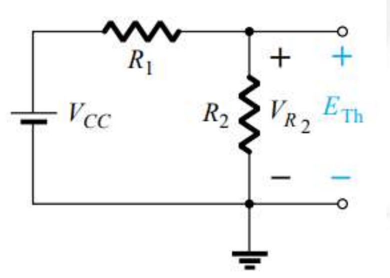

Figure 2.1.4 Thevenin Equivalent Circuit

Diagram Electronic Tutorial

Determining E_{Th}

$$E_{Th} = V_{R_2} = \frac{R_2 V_{CC}}{R_1 + R_2}$$

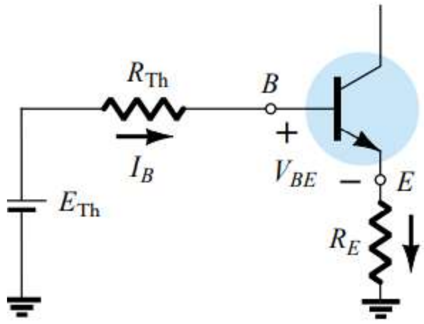

Figure 2.1.4 Inserting the Thevenin Equivalent Circuit

Diagram Electronic Tutorial

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

Substituting $I_E = (\beta + 1)I_B$ and solving for I_B yields

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

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

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

BIAS STABILIZATION

The stability of a system is a measure of the sensitivity of a network to variations in its parameters. In any amplifier employing a transistor the collector current IC is sensitive to each of the following parameters:

1. β increases with increase in temperature
2. VBE: decreases about 7.5 mV per degree Celsius (°C) increase in temperature
3. ICO (reverse saturation current): doubles in value for every 10°C increase in temperature

Stability Factors, $S(I_{CO})$, $S(V_{BE})$, and $S(\beta)$

A stability factor, S, is defined for each of the parameters affecting bias stability as listed below:

$$S(I_{CO}) = \frac{\Delta I_C}{\Delta I_{CO}}$$

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

$$S(\beta) = \frac{\Delta I_C}{\Delta \beta}$$