Lecture 20

BJT

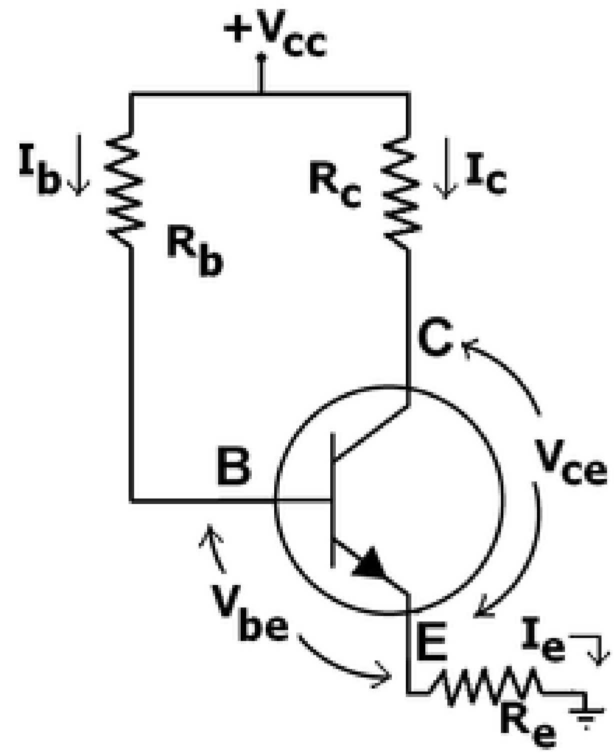
TRANSISTOR BIASING

&

STABILIZATION

Fixed bias with emitter resistor

The fixed bias circuit is modified by attaching an external resistor to the emitter. This resistor introduces negative feedback that stabilizes the Q-point.



Merits:

• The circuit has the tendency to stabilize operating point against changes in temperature and β-value.

Demerits:

• As β-value is fixed for a given transistor, this relation can be satisfied either by keeping R_E very large, or making R_B very low.

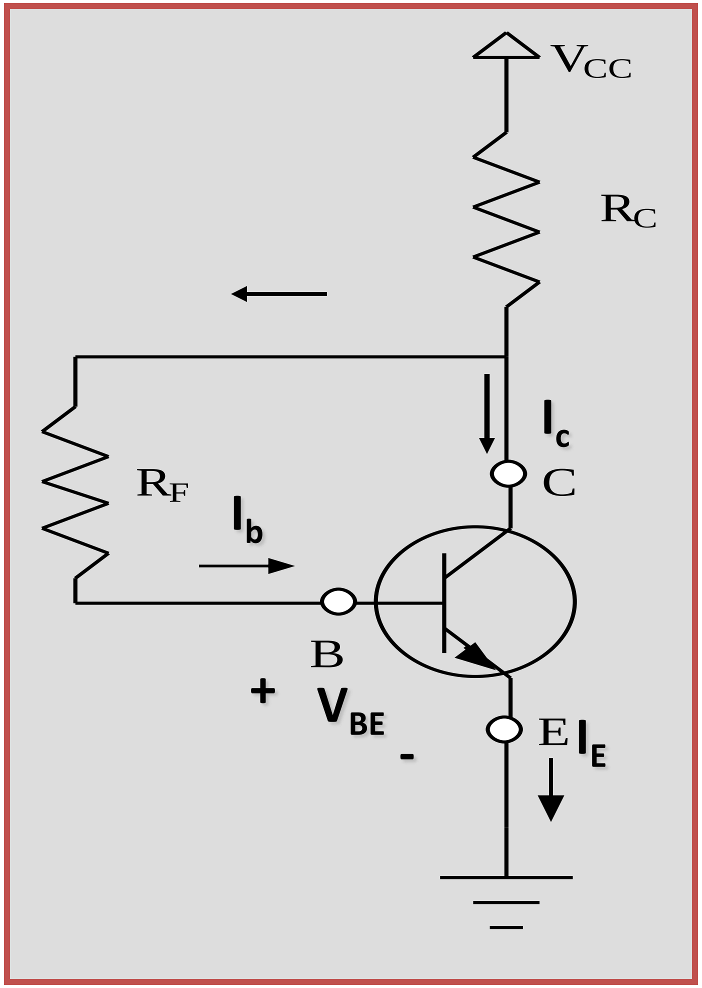
- If R_E is of large value, high V_{CC} is necessary. This increases cost as well as precautions necessary while handling.
- If R_B is low, a separate low voltage supply should be used in the base circuit. Using two supplies of different voltages is impractical.

• In addition to the above, R_E causes ac feedback which reduces the voltage gain of the amplifier.

Usage:

The feedback also increases the input impedance of the amplifier when seen from the base, which can be advantageous. Due to the above disadvantages, this type of biasing circuit is used only with careful consideration of the trade-offs involved.

The Collector to Base Bias Circuit



This configuration employs negative feedback to prevent thermal runaway and stabilize the operating point. In this form of biasing, the base resistor R_F is connected to the collector instead of connecting it to the DC source V_{CC}. So any thermal runaway will induce a voltage drop across the R_C resistor that will throttle the transistor's base current.

Applying KVL through base circuit

we can write $(I_b + I_C) R_C + I_b R_f + V_{be} = V_{cc}$

Diff. w. r. t. I_C we get

$$(\partial I_b / \partial I_c) = - R_C / (R_f + R_C)$$

Therefore, $$S_{Ico} = \frac{(1+\beta)}{1 + [\beta R_C / (R_C + R_f)]}$$

Which is less than $(1+\beta)$, signifying better thermal stability

Merits:

- Circuit stabilizes the operating point against variations in temperature and β (i.e. replacement of transistor)

Demerits:

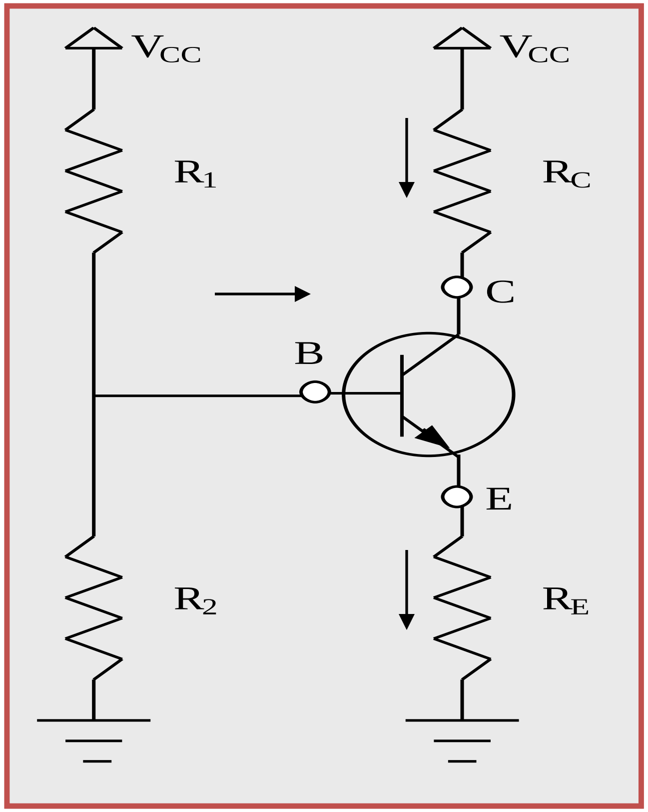
- As β -value is fixed (and generally unknown) for a given transistor, this relation can be satisfied either by keeping R_c fairly large or making R_f very low.
  - If R_c is large, a high V_{cc} is necessary, which increases cost as well as precautions necessary while handling.
  - If R_f is low, the reverse bias of the collector–base region is small, which limits the range of collector voltage swing that leaves the transistor in active mode.
  - The resistor R_f causes an AC feedback, reducing the voltage gain of the amplifier. This undesirable effect is a trade-off for greater Q-point stability.

Usage: The feedback also decreases the input impedance of the amplifier as seen from the base, which can be advantageous. Due to the gain reduction from feedback, this biasing form is used only when the trade-off for stability is warranted.

The Potential Divider Bias Circuit

This is the most commonly used arrangement for biasing as it provide good bias stability. In this arrangement the emitter resistance 'R_E' provides stabilization. The resistance 'R_E' cause a voltage drop in a direction so as to reverse bias the emitter junction. Since the emitter-base junction is to be forward biased, the base voltage is obtained from R_1-R_2 network. The net forward bias across the emitter base junction is equal to V_B- dc voltage drop across 'R_E'. The base voltage is set by Vcc and R_1 and R_2. The dc bias circuit is independent of transistor current gain. In case of amplifier, to avoid the loss of ac signal, a capacitor of large capacitance is connected across R_E. The capacitor offers a very small reactance to ac signal and so it passes through the condensor.

The Potential Divider Bias Circuit

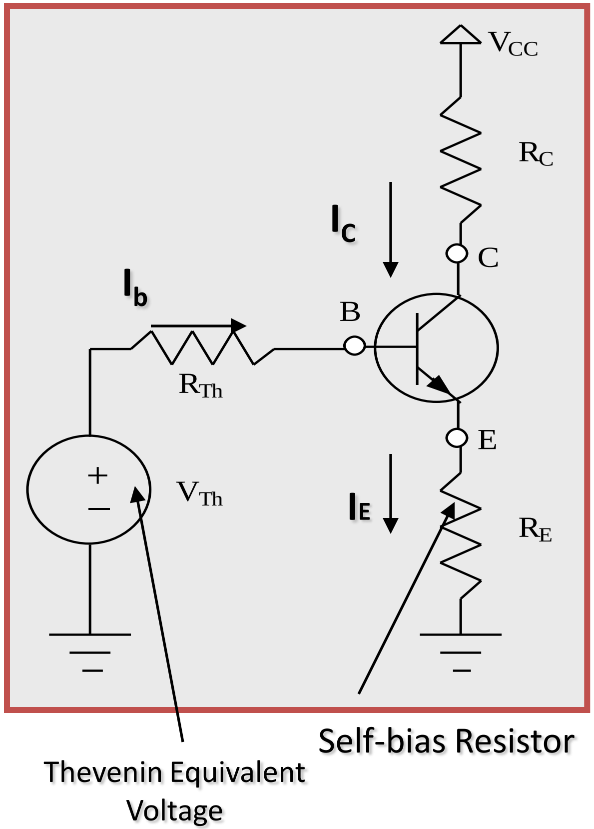


To find the stability of this circuit we have to convert this circuit into its Thevenin's Equivalent circuit

$$R_{th} = \frac{R_1 * R_2}{R_1 + R_2} \quad \& \quad V_{th} = \frac{Vcc\ R_2}{R_1 + R_2}$$

The Potential Divider Bias Circuit

Thevenin Equivalent Ckt



Applying KVL through input base circuit

we can write $I_b R_{Th} + I_E R_E + V_{be} = V_{Th}$

Therefore, $I_b R_{Th} + (I_C + I_b) R_E + V_{BE} = V_{Th}$

Diff. w. r. t. I_C & rearranging we get

$$(\partial I_b / \partial I_c) = - R_E / (R_{Th} + R_E)$$

Therefore,

$$S_{Ico} = \frac{1+\beta}{1+\left[\beta \frac{R_E}{R_E + R_{Th}}\right]}$$

This shows that S_{Ico} is inversely proportional to R_E and It is less than $(1+\beta)$, signifying better thermal stability

Merits:

- Operating point is almost independent of β variation.
- Operating point stabilized against shift in temperature.

Demerits:

- As β-value is fixed for a given transistor, this relation can be satisfied either by keeping R_E fairly large, or making R1||R2 very low.
  - If R_E is of large value, high V_{CC} is necessary. This increases cost as well as precautions necessary while handling.
  - If R1 || R2 is low, either R1 is low, or R2 is low, or both are low. A low R1 raises V_B closer to V_C, reducing the available swing in collector voltage, and limiting how large R_C can be made without driving the transistor out of active mode. A low R2 lowers Vbe, reducing the allowed collector current. Lowering both resistor values draws more current from the power supply and lowers the input resistance of the amplifier as seen from the base.
  - AC as well as DC feedback is caused by RE, which reduces the AC voltage gain of the amplifier. A method to avoid AC feedback while retaining DC feedback is discussed below.

Usage:

The circuit's stability and merits as above make it widely used for linear circuits.

Summary

- The Q-point is the best point for operation of a transistor for a given collector current.
- The purpose of biasing is to establish a stable operating point (Q-point).
- The linear region of a transistor is the region of operation within saturation and cutoff.
- Out of all the biasing circuits, potential divider bias circuit provides highest stability to operating point.