BJT & Biasing for Beginners

Saikat Mohanta
Independent Citizen Researcher
Email: saikatmohantabkp@gmail.com

June 24, 2020

Abstract

This article introduces Bipolar Junction Transistors (BJTs) with an emphasis on modes of operation and biasing techniques. Theoretical equations, load line analyses, and practical examples are included to help beginners understand the concepts clearly.

1 Introduction

A Bipolar Junction Transistor (BJT) is a three-terminal semiconductor device used in amplification and switching applications. It operates in three distinct modes:

- **Linear (Active) Mode** – for amplification
- **Saturation Mode** – acts as a closed switch
- **Cut-off Mode** – acts as an open switch

2 How to Determine BJT Mode

To analyze BJT circuits:

1. Assume linear mode and analyze.
2. If base current $I_B < 0$, the transistor is in **cut-off**.
3. If $I_B > 0$, compute V_{CE}:
   - If $V_{CE} > 0.2$ V, it's in **linear mode**.
   - If $V_{CE} \leq 0.2$ V, it's in **saturation mode**.

3 Class A Biasing Techniques

3.1 Fixed Biasing

$$P_{max} = V_{CC} \cdot I_{C(\max)} \quad \Rightarrow \quad I_B = \frac{I_C}{\beta}$$

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

3.2 Fixed Bias with Emitter Resistance

$$V_{CC} = I_B R_B + V_{BE} + I_E R_E \quad \text{with } I_E \approx I_C$$

Operating point:

$$V_{CE} = \frac{1}{2} V_{CC}, \quad V_C = \frac{3}{4} V_{CC}, \quad V_E = \frac{1}{4} V_{CC}$$

3.3 Collector-to-Base Feedback Bias

$$R_B = \frac{V_{CC} - V_{BE}}{I_B} \quad \text{from KVL: } V_{CC} = I_C R_C + V_{CE}$$

3.4 Voltage Divider Biasing

From Thevenin's theorem:

$$V_{BB} = \frac{R_2}{R_1 + R_2} V_{CC}, \quad R_B = \frac{R_1 R_2}{R_1 + R_2}$$

$$V_{CC} = I_B R_B + V_{BE} + I_E R_E \quad (\text{use } I_E \approx (1+\beta) I_B)$$

4 Example A: Linear Mode

Given:

$$\beta = 50, \quad V_{CC} = 12\,V, \quad R_B = 400\,k\Omega, \quad R_C = 2\,k\Omega$$

$$I_B = \frac{12 - 0.7}{400 \times 10^3} \approx 28.25\,\mu A$$

$$I_C = \beta I_B = 1.413\,mA \quad \Rightarrow \quad V_{CE} = 12 - (1.413 \cdot 2) = 9.17\,V$$

Since $V_{CE} > 0.2\,V$, BJT is in **linear mode**.

Power Dissipation

$$P = V_{CE} \cdot I_C \approx 9.17 \cdot 1.413 = 13\,mW$$

5 Example B: Saturation Mode

$$V_{CE} = 0.2\,V \Rightarrow \text{Saturation} \quad \Rightarrow \quad I_C = \frac{V_{CC} - V_{CE(SAT)}}{R_C} = \frac{12 - 0.2}{8.5\,k\Omega} = 1.388\,mA$$

6 Example C: Cut-off Mode

If $I_B = 0$ and $V_E > V_B - 0.7$, BJT is in **cut-off**:

$$I_B = 0, \quad I_C = 0$$

7 Load Line and Q-Point

For faithful amplification, the Q-point should be centered:

$$V_{CE(Q)} = \frac{1}{2} V_{CC}, \quad I_{C(Q)} = \frac{V_{CE(Q)}}{R_C}$$

8 Summary

- BJTs are analyzed based on their modes.
- Several biasing techniques allow proper setting of the Q-point.
- Load line analysis helps define operating region for amplifiers.

References

This work is based on handwritten notes by Saikat Mohanta, Bongaon (2020). For further reference on BJT modeling, consult:

- Sedra and Smith, *Microelectronic Circuits*
- Millman and Halkias, *Integrated Electronics*