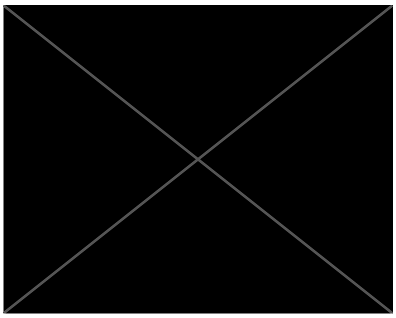
Santiago del Estero, 29 de mayo del 2025

Ingeniería eléctrica

TP N° 4: Operating Point or Q-point (Quiescent)

Electronica II



- Chevauchey Clément

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Objetives

- Find the Q-point at which to operate the transistor.

Introduction

In amplifier circuits with bipolar junction transistors (BJT), the analysis of the operating point or Q-point (quiescent) is essential to guarantee stable and linear operation of the device. This point represents the current and voltage conditions of the transistor in the absence of input signal, and it is determined by the circuit bias.

The NPN transistor can operate in three different regions, according to the values of and :

Active region

This occurs when > 0.65–0.7 V and > (sat). In this region the transistor functions as a linear amplifier, allowing small variations of the input signal to be reflected proportionally at the output. It is the desired operating region for most analog applications.

Saturation region

This happens when both the base–emitter junction and the base–collector junction are forward biased. This implies that is very low (< 0.2 V). The transistor is fully on and behaves like a closed switch.

Cutoff region

This is present when < 0.65–0.7 V, which means there is no significant collector current. The transistor is off (it interrupts the flow of current), and . It is the state opposite to saturation.

To ensure operation in the active region, the Q-point is defined so that the transistor remains within safe limits of voltage and current, even in the presence of varying signals. Proper bias places the Q-point approximately in the center of the active region, allowing a symmetric excursion of the amplified signal without clipping.

Data and calculations

Case A: Active region

- $R_B = 33\,\Omega$
- $R_C = 1\,K\Omega$
- $V_{CC} = 12\,V$
- $V_{BB} = 4\,V$
- $\beta = 75$

$$I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{4 - 0{,}7}{33K} = 0{,}1\,mA$$

$$I_C = \beta \cdot I_B = 75 \cdot 0{,}1 = 7{,}5\,mA$$

$$V_{CE} = V_{CC} - I_C \cdot R_C = 12 - 7{,}5 = 4{,}5\,V$$

Case B: Active region

- $R_1 = 300\,K\Omega$
- $R_2 = 200\,K\Omega$
- $R_C = 22\,K\Omega$
- $V_{CC} = 18\,V$
- $V_{BB} = 4\,V$
- $\beta = 12$

$$V_B = V_{CC} \cdot \frac{R_2}{R_1 + R_2} = 7{,}2\,V$$

$$I_B = \frac{V_{BB} - V_{BE}}{R_1 // R_2} = \frac{6{,}5}{120K} = 54{,}2\,\mu A$$

$$I_C = \beta \cdot I_B = 12 \cdot 54{,}2\,\mu A = 0{,}65\,mA$$

$$V_{CE} = V_{CC} - I_C \cdot R_C = 18 - 0{,}65\,mA \cdot 22K$$
$$= 3{,}7\,V$$

Case C: Saturation region

- $R_1 = 400\,K\Omega$
- $R_2 = 200\,K\Omega$
- $R_C = 1\,K\Omega$
- $R_E = 100\,\Omega$
- $V_{CC} = 25\,V$
- $\beta = 100$
- $V_{BE} = 0{,}7\,V$

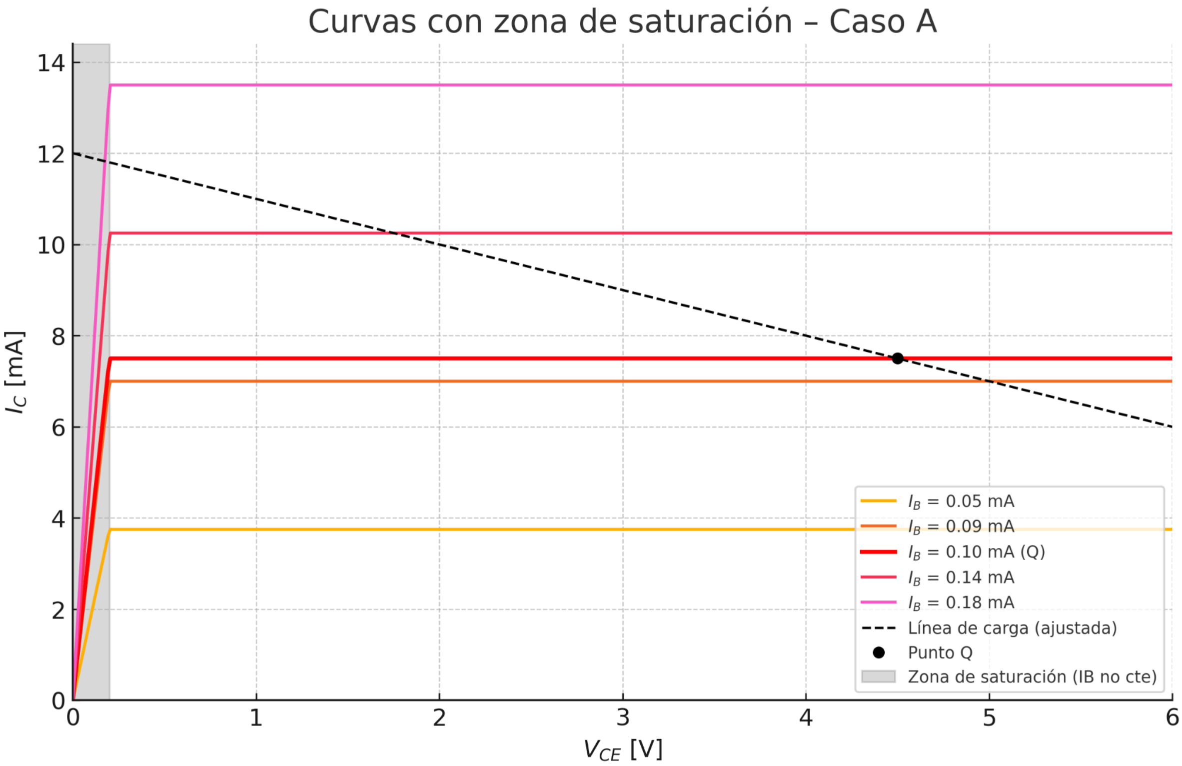
$$V_{BB} = V_{CC} \cdot \frac{R_2}{R_1 + R_2} = 8{,}33\,V$$

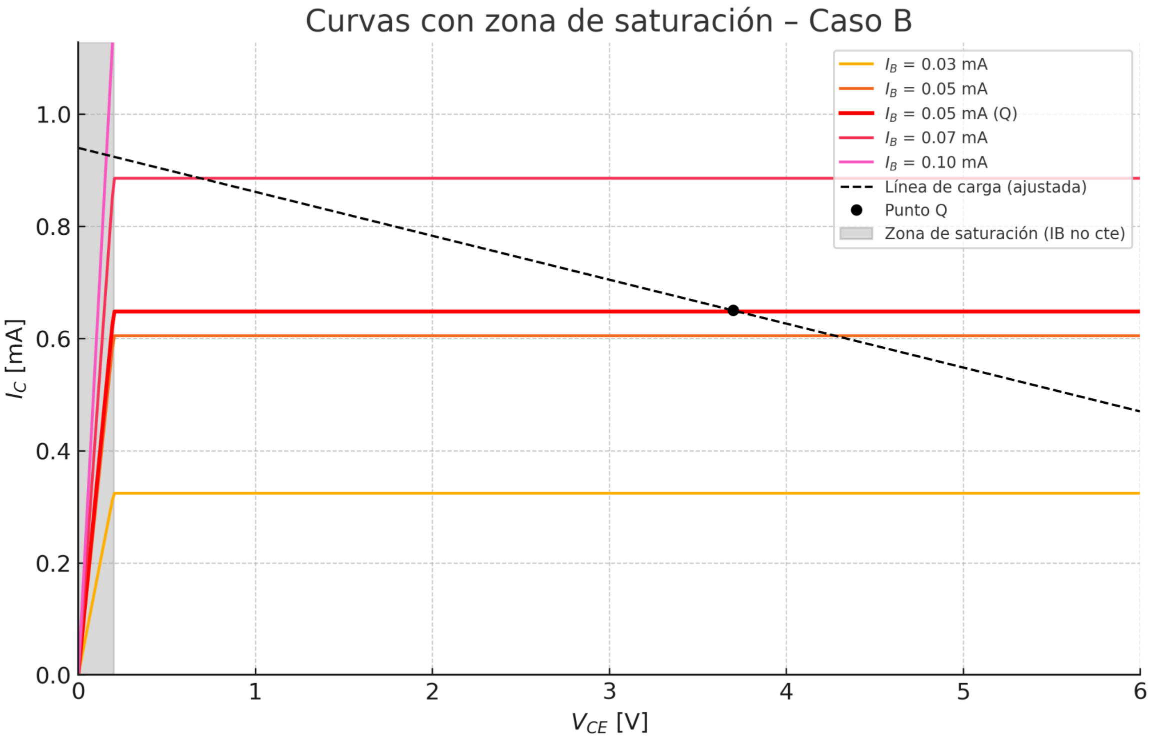
$$I_B = \frac{V_{BB} - V_{BE}}{R_{B(eq)} + \beta \cdot R_E} = \frac{8{,}33 - 0{,}7}{133333 + 10100}$$
$$= 53\,\mu A$$

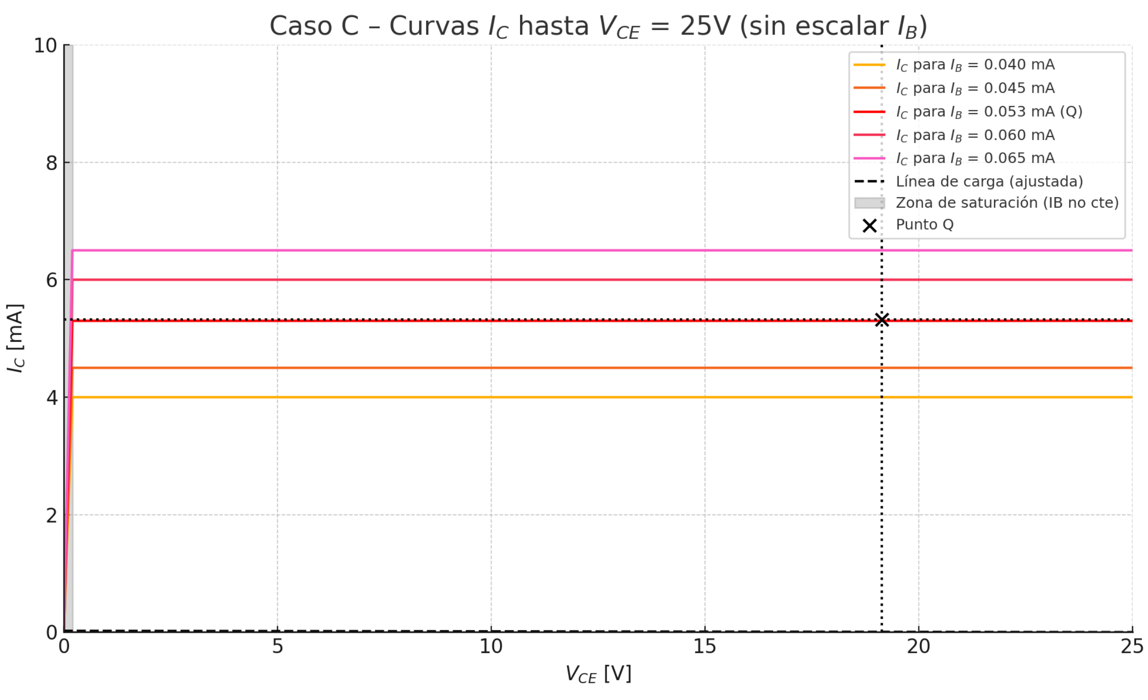
$$I_C = \beta \cdot I_B = 5{,}322\,mA$$

$$I_E = I_B + I_C = 5{,}375\,mA$$

$$V_{CE} = V_{CC} - I_C \cdot R_C - I_E \cdot R_E = 19{,}141\,V$$


Curvas con zona de saturación – Caso A
I_C [mA]
V_{CE} [V]
I_B = 0.05 mA
I_B = 0.09 mA
I_B = 0.10 mA (Q)
I_B = 0.14 mA
I_B = 0.18 mA
Línea de carga (ajustada)
Punto Q
Zona de saturación (IB no cte)


Curvas con zona de saturación – Caso B
I_C [mA]
V_{CE} [V]
I_B = 0.03 mA
I_B = 0.05 mA
I_B = 0.05 mA (Q)
I_B = 0.07 mA
I_B = 0.10 mA
Línea de carga (ajustada)
Punto Q
Zona de saturación (IB no cte)


Caso C – Curvas I_C hasta V_{CE} = 25V (sin escalar I_B)
I_C [mA]
V_{CE} [V]
I_C para I_B = 0.040 mA
I_C para I_B = 0.045 mA
I_C para I_B = 0.053 mA (Q)
I_C para I_B = 0.060 mA
I_C para I_B = 0.065 mA
Línea de carga (ajustada)
Zona de saturación (IB no cte)
Punto Q

Conclusion

In this work three different BJT transistor bias configurations in amplifier mode were analyzed, called Case A, B, and C. For each one, their respective operating points (Q) were determined based on the given resistance and voltage values. Subsequently, the load lines and the transistor characteristic curves were plotted, incorporating the saturation region as well as the behavior of the base current .

Case A

In this configuration, the calculated Q-point was located appropriately in the active region, and the load line showed a typical slope for a circuit with moderate .

Case B

Bias by voltage divider was used without an emitter resistor. Although it improves stability compared to fixed bias, it is still sensitive to variations of , and the Q-point was located within the active region, as shown by the calculations and the graphs.

Case C

In this case a resistive divider (R1 and R2) was introduced to set the base voltage, which allows greater independence with respect to variations of . However, with the values given in the statement (R1 = 400 kΩ, R2 = 200 kΩ), the base current turned out to be very low, which also resulted in a small . Consequently, the equivalent resistance of the circuit was very high, and the load line was practically vertical.

This phenomenon was corrected graphically so that the Q-point coincided with the corresponding curve.

Final reflection

The comparison among the three configurations makes it possible to highlight the technical advantages of using emitter resistors and voltage dividers versus fixed bias. Each topology offers a trade-off between simplicity and precision in the operating point. The correct determination and representation of the Q-point, together with the and curves, is fundamental to guarantee efficient linear operation of the amplifier in the active region of the transistor. The generated graphs complemented the theoretical analysis and allowed a clear visualization of the operating regions and their limitations.

References

Boylestad, R. L., & Nashelsky, L. (2012). *Electronic Devices and Circuit Theory* (11.ª ed.). Prentice Hall.

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