Student Corner

The Transistor

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Transistor the building block of the modern processor was invented by Physicists John Bardeen, Walter Brattain, and William Shockley in 1947 at Bell Laboratories, USA. Considering the importance of the invention, the inventors were awarded the Nobel Prize in Physics in 1956 . In the original patent application, the device was named as semiconductor amplifier and later it was renamed as the transistor abbreviating trans-resistor. Without the invention of the transistor, a computer with the capabilities of a typical desktop computer would have been of a size of a three storied building, and laptops/ mobile phone are just science fictions.

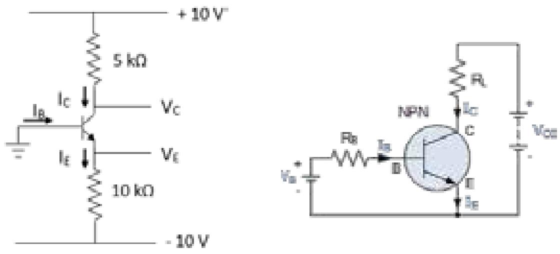
In general, there are two main types of transistor namely Bipolar Junction Transistors (BJTs) and Field Effect Transistors (FETs) that are in use today. The design of both transistor types is different from the original point contact transistor. Today, the semiconductor device manufacturing industry is capable of fabricating billions of transistors in a single silicon chip. For example, Qualcomm Snapdragon 850 System-on-chip (SOC) which is used by Android Flagships, contains over 5.3 billion transistors.

Let's take a glance at the action of a Bipolar Junction Transistor or BJT. BJTs are made by fabricating two pn junctions, side by side. This arrangement can be realized by having two n regions on either side of a central p region or vice versa. Hence, there can be two types of BJTs possible, which are called npn and pnp. The two pn junctions in a BJT can be biased in different modes namely, cutoff, active, and saturation. Active and cutoff modes are used when BJT is used as a switch, and when it is in active mode it works as a current amplifier. The current flow convention of an npn transistor is shown in Figure 1. Considering the conservation of current flow through the transistor, the following equation can be derived.

$$I_E = I_B + I_C \qquad [1]$$

When a transistor operates in active mode, the DC current gain (β) of the device is defined as IC/IB, and the ratio of the current at the Collector terminal to that at the Emitter terminal, IC/IE, is called α. Relationship between α and β can be derived with the help of the equation (1) as follows

$$\alpha=\beta/(\beta+1) \quad \text{or} \quad \beta=\alpha/(1-\alpha)$$



A B

Figure 1: Circuit diagrams of use of npn transistor in common Emitter configuration. Note that standard convention of current flow is also marked

Table 1 gives a summary of the properties of the Si BJT in different modes of operation.

Table 1: Certain properties of BJT in different modes of operation

	BE junction	BC junction	Currents	Voltages
Cutoff	Reverse biased	Reverse biased	$I_B=I_C=0$	
Active	Forward biased	Reverse biased	$I_C = \beta I_B$	$V_{BE} = 0.7$ V (for Si)
Saturation	Forward biased	Forward biased	$I_C < \beta I_B$	$V_{BE} = 0.7$ V, $V_{CE}=0.1$ V (for Si)

Common emitter configuration of the BJTs is the most widely used configuration due to its flexibility and high current and voltage gains.

Consider the example circuit given in Figure 1 (A), where the voltage at the emitter VE is given as −0.7 V and β=50. Let's find I_E, I_C, I_B and V_C assuming the device is in active mode.

Analysis

1. VE is given as -0.7 V. So the potential drop across 10 k resistor is (-0.7 – (-10)) V = 9.3 V. Hence the current(IE) through 10 k resistor is given by IE = 9.3 V / 10 k = 0.93 mA
2. Using $I_C = \alpha I_E$, $\alpha=\beta/(\beta+1)$
   $\alpha = 50 /(50+1) = 50/51$
   $I_C = \alpha$ IE → $I_C = 50/51 \times 0.93$ mA = 0.912 mA
3. From equation 1 →$I_E= I_B + I_C$ → IB = $I_E - I_B$ = 0.93 – 0.912 = 0.18 mA
4. Since the current through the 5 k resistor is IC, the potential drop through the resistor can be written as, (10 V – V_C) = I_C × RC = 0.912 × 10^{-3} A × 5 kΩ = 4.56 V
   10 V – V_C = 4.56 V → V_C = 5.44 V

The example circuit given in Figure 1 (B), where V_{CC} = 5 V, V_B = 5 V, R_B = 100 Ω, R_L = 200 Ω, β = 100 and transistor operates in saturation mode. Let's find IB, I_C and V_C.

1. Since the transistor is in saturation mode, B_E junction is forward biased and V_{BE} = 0.7 V (see Table 1). So, the potential at point B is 0.7 V. Hence the potential drop across the R_B resistor is (5 V – 0.7 V) =4.3 V; So current though the resistor, I_B = 4.3 V /100 Ω = 43 mA
2. Since transistor is in the saturation mode V_{CE} = 0.1 V. So, the potential drop across the resistor R_L is (V_{CC} - V_C) = (5 V – 0.1 V) = 4.9 V. Hence current through the resistor RL , I_C = 4.9 V/ 200 Ω = 245 mA

References

1. B. Labs, "1956 Nobel Prize in Physics: The Transistor," Bell Labs, [Online]. Available: https://www.bell-labs.com/about/recognition/1956-transistor/. [Accessed 18 August 2019].
2. I. Cutress, "Qualcomm Snapdragon 8cx wafer on 7nm," 06 December 2018. [Online]. Available: https://www.anandtech.com/show/13687/qualcomm-snapdragon-8cx-wafer-on-7nm. [Accessed 18 Augut 2019].

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Chirality of Molecules

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Chirality is the existence of different configurations (three dimensional arrangements) of a substance with an identical chemical formula. The word **Chirality** is derived from the Greek word *chéri* meaning hand. A chiral object has a handedness, hence is not superimposable on its mirror image (Figure 1). These non-superimposable mirror images are called optical isomers or enantiomers. When an organic molecule has a tetrahedral centre, bonded to four different atoms or groups, it is called a chiral centre or a stereogenic centre.

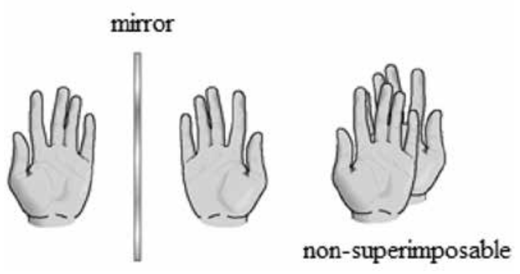

Figure 1: Left and right hands are mirror images, but they are not identical, or superimposable.

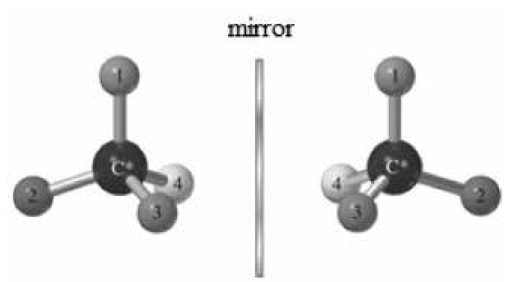

Figure 2: Ball-and-stick representation of an enantiomeric pair.

In contrast, achiral objects such as a plain round ball, a nail, etc. do not have handedness. The chirality of an object is related to its symmetry. If an object possesses a plane, a line or a point in or through it, about which a rotation or reflection leaves the object in a configuration, indistinguishable from the original, it must be achiral.

To distinguish one enantiomer from the other,