TRANSISTORS: THE CORNERSTONE OF MODERN ELECTRONICS

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ABSTRACT

This study investigates the characteristics and operation of transistors, which are essential components in modern electronics. By examining the structure and types of transistors (PNP and NPN) as well as their circuit configurations (common emitter, common base, and common collector), the research highlights their diverse applications. Transistors, invented in the mid-20th century, have replaced vacuum tubes due to their compact size, low power consumption, and high reliability. These advantages enable integration into complex circuits, leading to significant advancements in computing power. The findings emphasize that transistors have been pivotal in the evolution of electronics and continue to play a vital role in the design and functionality of contemporary electronic systems. A deeper understanding of transistor features and operational principles is crucial for advancing electronic technologies and enhancing the performance of modern devices. This study contributes to the existing literature by providing insights into the fundamental role of transistors in modern electronics.

Keywords: Transistors, modern electronics, PNP and NPN configurations, circuit configurations, amplifier, switch .

Introduction

Transistors are fundamental electronic components that have enabled the remarkable development of modern electronics. They can act as switches or amplifiers and are used in a wide variety of electronic circuits and devices. Transistors were invented in the mid-20th century, replacing the bulky and power-hungry vacuum tubes that previously dominated electronics. The key advantages of transistors are their small size, low power requirements, and high reliability. This allows them to be used in complex integrated circuits, packing a large amount of computing power into a small package. The basic structure of a transistor consists of three semiconductor crystals arranged in a specific configuration, with the PNP and NPN arrangements being the most common. Transistors can be used in different circuit configurations, such as common emitter, common base, and common collector. This study examines the general characteristics and operation of transistors. This understanding is crucial for designing and working with modern electronic systems. The findings show that transistors have been key enablers of the remarkable development of electronics in the 20th century and have widespread applications in today's electronic circuits.

Before the invention of the transistor in the first half of the 20th century, electronics depended on vacuum tubes, which were bulky, expensive, and uneven, required a lot of power, and produced a lot of heat. The invention of transistors led to modern electronics, making smaller and more powerful electronic devices possible because transistors require little power, don't generate much heat, and are very reliable [1,2].

A typical transistor consists of three P-type and N-type semiconductor pieces. Small transistors can be used in complex integrated circuits, making it possible to pack a lot of computing power into a small package. There are two main types of transistors: bipolar junction transistors (BJTs) and field effect transistors (FETs) [3,4].

The construction of bipolar transistors and their structure has come a long way since the first transistors were made. Today's transistors are manufactured using complex processes, and the transistor structure enables them to have very high performance. The modern era of semiconductor electronics began with the invention of the bipolar transistor in 1947 by John Bardeen, Walter Hauser Brattin and William Shockley [5,6]. This piece, along with its field counterpart, has had a surprising impact on almost every aspect of modern life.

A BJT transistor uses electrons and electron deficiencies (as electron holes) to carry charge. When an electron leaves its current state for a higher electron, holes are left in the conducting material. These holes can move like electrons in matter and behave like positively charged particles [6,7]. When a small current is applied to one of the BJT's terminals, it effectively allows the transistor to control much more current between the emitter and the collector, which in turn allows the current to be amplified or changed.

In this tutorial, we will focus only on the bipolar junction transistor and discuss its basic structure and operation. A typical transistor (BJT) is made up of three P-type semiconductors. The arrangement of semiconductor crystals is shown in Figure 1 [8,9].

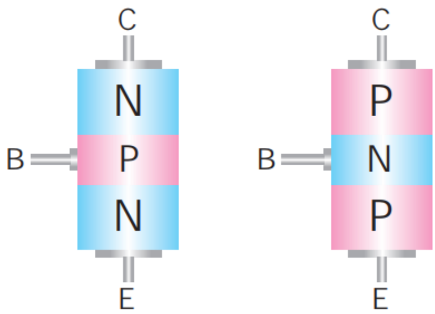

Figure 1. N and P type semiconductors in transistors

Bipolar Junction Transistor (BJT)

A typical transistor consists of three P and N type semiconductor pieces. The difference between PNP and NPN BJT is in the bias, which is the direction of current allowed to flow. In a PNP BJT, there are two positively charged regions - the collector and the emitter - each with additional holes. The depletion region in between the two is negatively charged because it has extra electrons. Boundaries between regions are called links. The base-emitter junction is reverse biased and the base junction is collected is forward A small voltage is applied to the base region. In an NPN BJT, there are two negatively charged regions - the collector and the region Emitter - each with extra electrons. The discharge region is positively charged because it has extra holes. In an NPN BJT, the base-emitter junction is forward-biased and the base-collector junction is reverse-biased. A small voltage is applied to the base Region [2,6]. The transistor which is made of two P-type semiconductor pieces and one N-type semiconductor piece is called PNP transistor and the transistor which includes two P-type semiconductor pieces and one P-type semiconductor piece is called NPN transistor. Figure 2 shows two types of NPN and PNP transistors and their symbols [7,9].

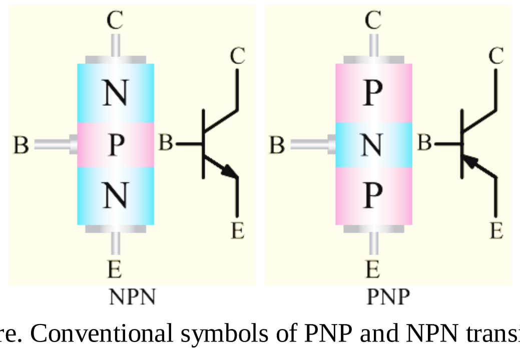

Figure. Conventional symbols of PNP and NPN transistors

The bases of the transistor are called emitter (E), base (B) and collector C. Figure 4 shows the names of transistor bases [3,6].

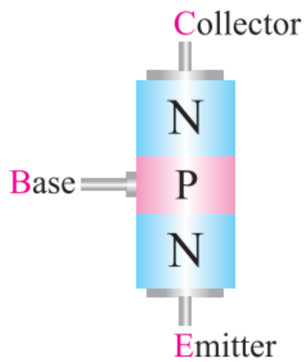

Figure3. Names of transistor bases

Equivalent to PNP and NPN transistor diodes

Each P-N connection is equivalent to a diode, so the diode equivalent of NPN and PNP transistors is drawn in Figure. [8].

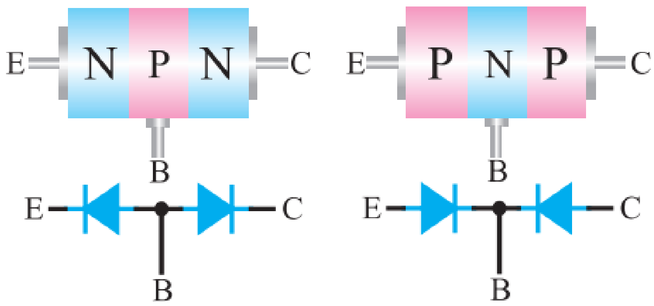

Figure.4 Equivalent of NPN and PNP diode transistors

How to bias the transistor in the active region

In the active region, it is necessary to place the base-emitter diode in the positive bias and the base-collector diode in the opposite bias so that currents are established in the transistor. Figure 5 shows how to bias an NPN transistor in the active region [2,6].

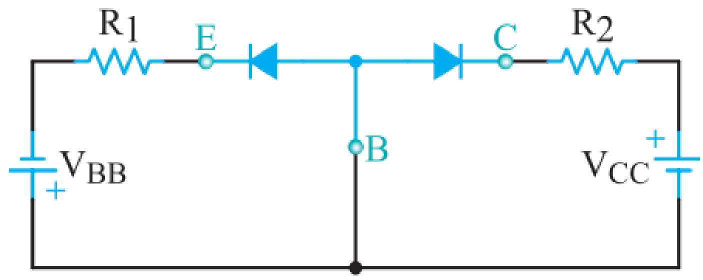

Figure5. NPN transistor bias in the active region

BJTs under Varying Voltages

A transistor's functions depends on the voltages applied and the polarity of the current. The following formulas show the function of the transistor in various scenarios. The subscripts refer to the base (VB), the collector (VC), and the emitter (VE).

- If $VE < VB < VC$, then the transistor acts as an amplifier.

- If $VE < VB > VC$, then the transistor is a conductor.
- If $VC > VB < VE$, then the transistor is an open switch and cuts off the flow.

Think of positive voltages as being greater than zero, or $+V > 0$, and negative voltages as being less than zero, or $-V < 0$. This will make working through these formulas easier [6].

Power BJTs

The n-p-n bipolar junction transistor, BJT in short, is shown in Figure 6 The collector (C) to emitter (E) path serves as the switch, conducting or interrupting the main current, while the base (B) is the control electrode. In contrast to thermistors, the collector current, I_C, can be continuously controlled by the base current, I_B, as

$$I_C = \beta I_B$$

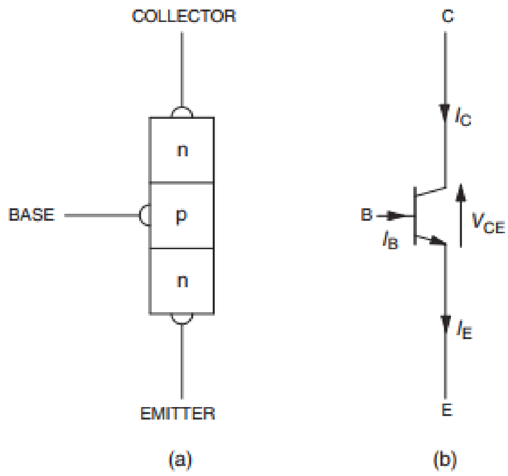

Figure 6. BJT: (a) semiconductor structure, (b) circuit symbol.

Where β denotes a dc current gain of the transistor. In high-power $BJTs$, the current gain is low, on the order of 10. The emitter current, I_E, is a sum of the collector and base currents. The voltage–current characteristics of the BJT, specifically the collector current, I_C, versus collector–emitter voltage, V_{CE}, relations for various values of the base current, I_B, are shown in Figure 7 The conduction power loss, P_c, is given by [3,6,8].

$$P_c = V_{CE} I_C$$

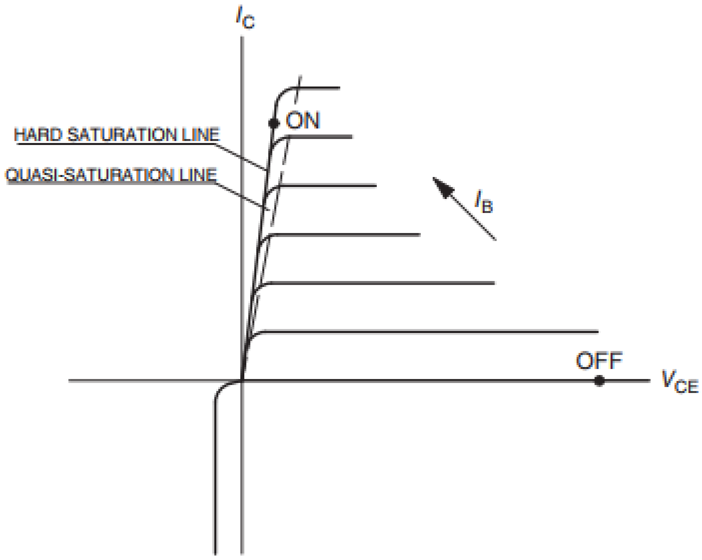

Figure 7. Voltage–current characteristics of the BJT

Conclusion

This study has explored the critical characteristics and operational principles of transistors, which are fundamental components of modern electronics. The investigation into PNP and NPN configurations, along with circuit arrangements such as common emitter, common base, and common collector, highlights the versatility and wide-ranging applications of transistors. Since their introduction in the mid-20th century, transistors have effectively replaced vacuum tubes, thanks to their compact size, low power consumption, and high reliability. These advantages have enabled the integration of transistors into complex circuits, leading to remarkable advancements in computing power and electronic performance. The findings emphasize that transistors are pivotal to the ongoing evolution of electronic technology, playing a vital role in contemporary system design and functionality. Understanding their operational principles is crucial for driving future innovations in electronic technologies. Overall, this study reaffirms the significance of transistors as the cornerstone of modern electronics.

References

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