BAŞKENT UNIVERSITY
ENGINEERING FACULTY
ELECTIC-ELECTRICAL ENGINEERING

EEM214 ELECTRONICS I
LAB REPORT

LAB V:
BIPOLAR JUNCTION TRANSISTOR

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CONTENTS

THEORY

Transistors are electronic components that are used to amplify or switch electronic signals. They are made of semiconductor materials, such as silicon, and consist of three layers of material: an emitter, a base, and a collector. The base of the transistor acts as a control terminal, while the emitter and collector serve as input and output terminals. When a small current is applied to the base, it controls a larger current that flows between the emitter and collector. This amplification effect allows transistors to be used in a wide range of electronic devices, such as radios, televisions, and computers. Additionally, transistors can be used as switches, where a small current into the base can turn a larger current on or off between the collector and emitter. Transistors are considered one of the most important inventions in the history of electronics, and they have played a crucial role in the development of modern technology.

A bipolar junction transistor (BJT) is a type of transistor that consists of three doped semiconductor regions: an emitter, a base, and a collector. The base is sandwiched between the emitter and the collector, and the transistor can be either an NPN or a PNP type. When a small current flows into the base of an NPN transistor, it allows a larger current to flow from the collector to the emitter. In a PNP transistor, a small current flow out of the base, which allows a larger current to flow from the emitter to the collector. BJTs are used as amplifiers and switches in electronic circuits. When used as an amplifier, a small input signal is applied to the base, which controls a larger output signal at the collector. When used as a switch, a small input signal can turn the transistor on or off, allowing a larger current to flow or stopping it completely. BJTs are widely used in a variety of electronic devices, such as radios, televisions, computers, and power supplies. They are relatively simple to manufacture and can operate at high frequencies, making them useful for a range of applications.

The DC behavior of a bipolar junction transistor (BJT) refers to its characteristics in a steady state or under a constant bias condition. In the forward active region, which is the normal operating mode for a BJT, the base-emitter junction is forward-biased, while the collector-base junction is reverse-biased. In this region, the BJT behaves like an amplifier, with a small input current at the base controlling a larger output current at the collector. The amount of amplification is determined by the current gain of the transistor, which is the ratio of the collector current to the base current. The DC behavior of a BJT can be analyzed using the Ebers-Moll model, which describes the transistor as two diodes back-to-back. The model takes into account the voltage drops across the base-emitter and collector-base junctions, as well as the current gain of the transistor. The DC current-voltage (I-V) characteristics of a BJT can be represented by a load line, which is a graphical representation of the relationship between the collector current and the collector-emitter voltage. The load line intersects the transistor's I-V curve at a single point, which represents the operating point of the transistor.

Ultimately, the DC behavior of a BJT involves the analysis of its steady-state characteristics, such as its current gain, voltage drops across the junctions, and load line analysis. These characteristics are important for designing and analyzing electronic circuits that use BJTs.

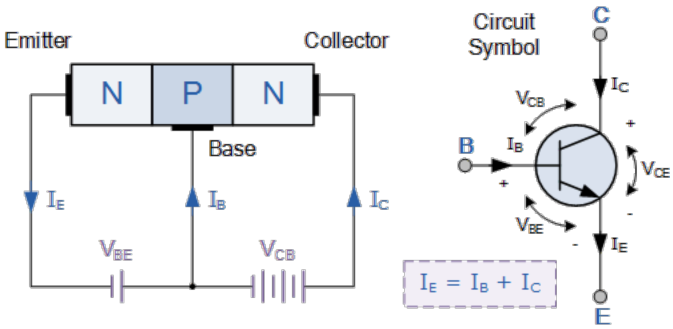
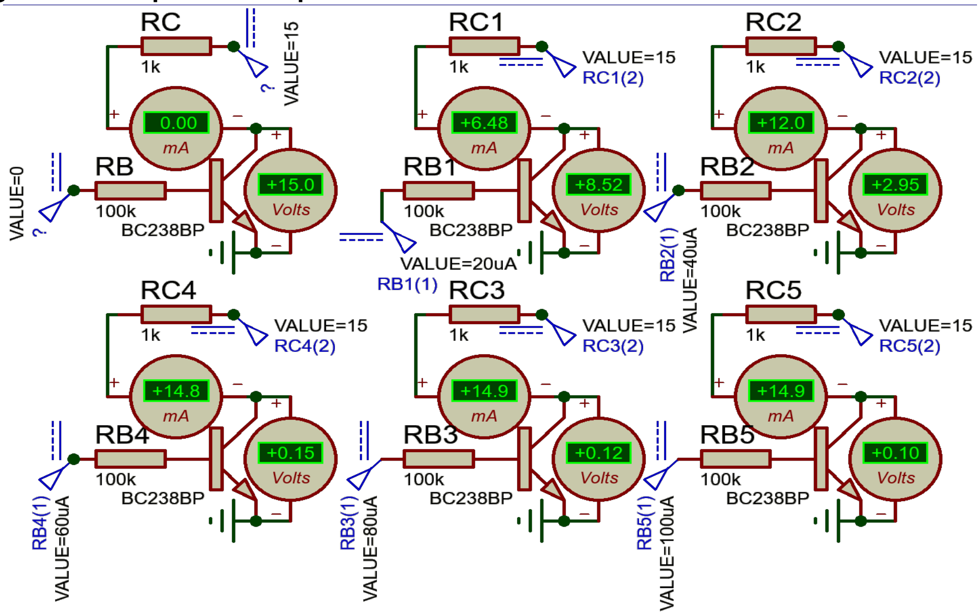


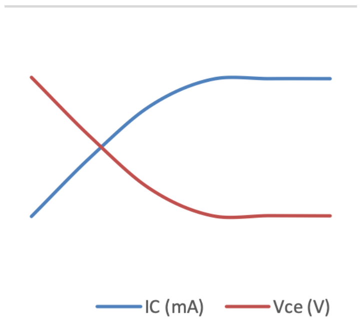
Figure 1. NPN Transistor

QUESTIONS, OUTPUTS & COMMENTS

1. Construct the circuit given in Fig.3 using RC = 1k. Set VCC = 15V.. Set IB 0 to 100 μA, measure the IC and VCE fill the table with your results. Why Ic stops increasing at some point? Explain in detail.



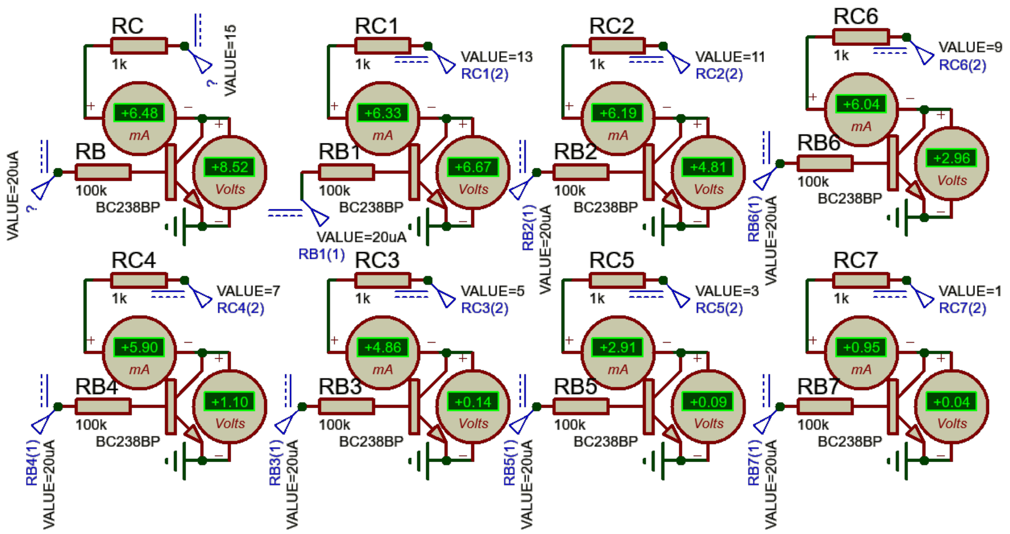
I_B	I_C (mA)	V_{ce} (V)
0 μA	0	15
20 μA	6.48	8.52
40 μA	12	2.95
60 μA	14.8	.15
80 μA	14.9	.12
100 μA	14.9	.10



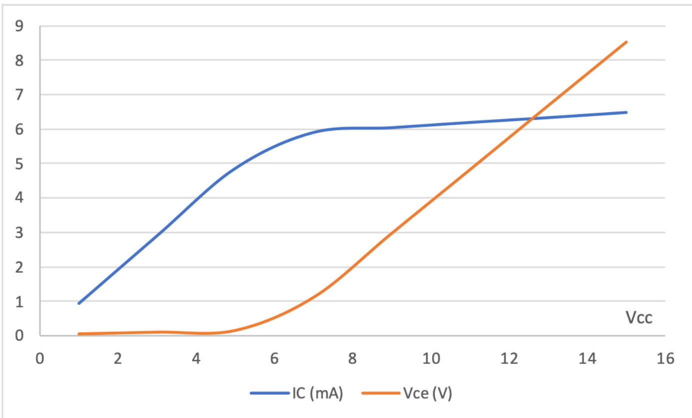
When the base current (IB) increases, the collector current (IC) usually increases proportionally. This is because the transistor operates in its active region, and the relationship between IC and IB is given by:
IC = β x IB. Where β is the current gain (also known as hFE) of the transistor. However, as IB continues to increase, there comes a point when the transistor cannot increase IC any further. This point is called saturation, and it occurs because the transistor has reached its maximum capacity to conduct current. In this region, increasing IB does not result in any further increase in IC. The reason for this saturation behavior is that the voltage across the collector-emitter junction (VCE) approaches a minimum value, typically around 0.2V for silicon transistors. When VCE reaches this minimum value, the transistor is considered to be in saturation. In this state, the transistor acts like a closed switch, and the collector current is limited by the external resistors (RC and R) and the supply voltage (VCC).

In summary, IC stops increasing at some point because the transistor reaches saturation, where VCE is at its minimum value and the transistor behaves like a closed switch. The external resistors and supply voltage limit the maximum collector current in this state.

2. You will now trace the transistor iC–VCE characteristics at a constant base current of IB = 20 µA. This can be done by changing VCC from 15V to 1V. Measure IC and VCE at each point. Why Ic stops increasing at some point. Explain in detail.



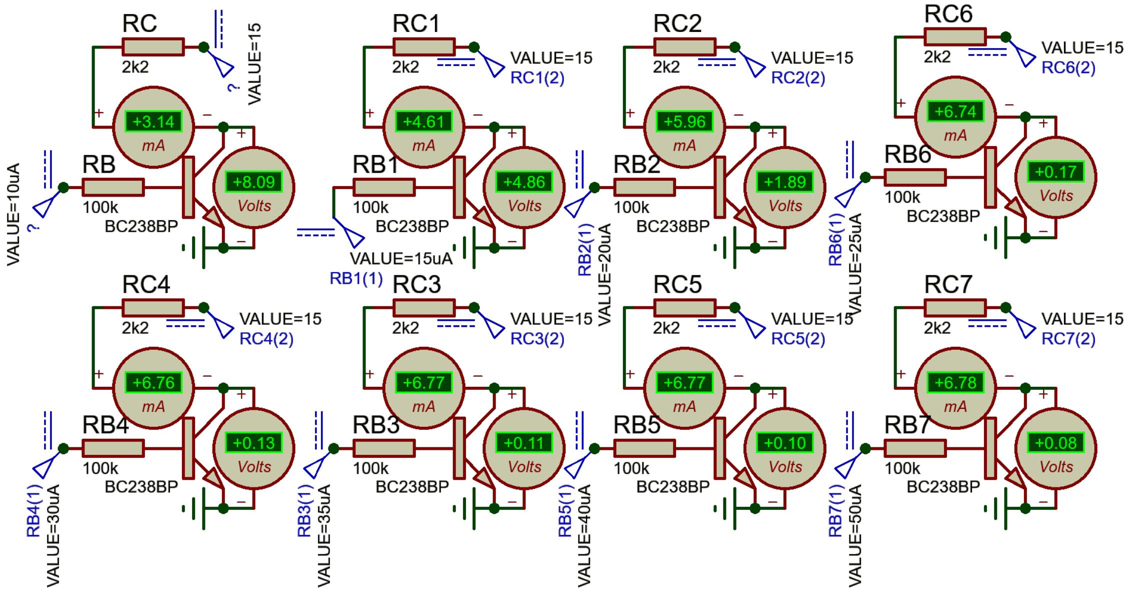
V_{CC} (V)	I_C (mA)	Vce (V)
15	6.48	8.52
13	6.33	6.67
11	6.19	4.81
9	6.04	2.96
7	5.90	1.10
5	4.86	.14
3	2.91	.09
1	.95	.04



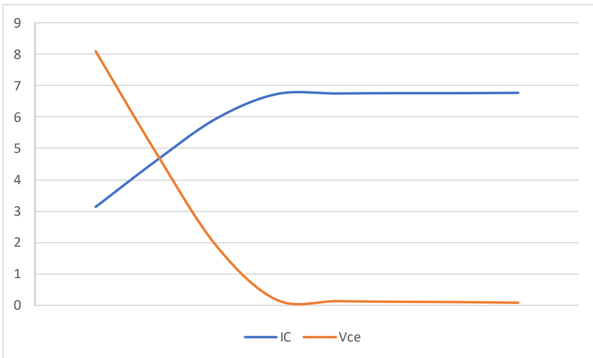
After 9-11 Volts, increasing rate of Ic decreases significantly, at some point we observe it as almost no change. This is due to the saturation region of the transistor. In the saturation region, both the base-emitter junction and the base-collector junction are forward-biased, and the transistor is in its "ON" state. When the transistor is in saturation, any further increase in VCE will not result in an increase in IC. This is because the transistor is already operating at its maximum current capacity, and the additional voltage will only cause the base-collector junction to become more forward-biased. The transistor is essentially acting as a closed switch, and the current is limited by the external load connected to it.

In summary, IC stops increasing at some point when the transistor enters the saturation region. In this region, the transistor is fully "ON," and any additional increase in VCE will not result in an increase in IC, as the transistor is already operating at its maximum current capacity.

3. Vcc = 15V was taken as it was not specified in the question.
You will now investigate how changing the slope of the load line by changing RC affects the circuit. Replace RC with a 2.2kΩ resistor. Set IB=5µ to 70µ in 5µA steps. For each value of I^B, measure IC and VCE, and determine the state of the transistor.



IB	IC	Vce
10 µA	3.14	8.09
15 µA	4.61	4.86
20 µA	5.96	1.89
25 µA	6.74	.17
30 µA	6.76	.13
35 µA	6.77	.11
40 µA	6.77	.10
50 µA	6.78	.08



The results of this experiment demonstrate the importance of the RC resistor value in determining the transistor's operation, as it directly affects the load line slope. A higher RC value would result in a steeper load line, while a lower RC value would result in a less steep load line. The slope of the load line has a significant impact on the transistor's operating point (Q-point), which determines the transistor's amplification and distortion characteristics.

4. How does changing RC influence the IB value?

The main relationship between RC and the circuit's performance is through the collector current (IC) and the collector-emitter voltage (VCE).

When the RC value changes, it affects the collector current (IC) and the collector-emitter voltage (VCE) according to Ohm's law:

IC = (Vcc - VCE) / RC
Where Vcc is the supply voltage.

As the collector current (IC) changes, it also affects the base current (IB) through the transistor's current gain (β), also known as the base current amplification factor:

IC = β * IB
From these equations, we can see that changing the RC value indirectly affects the base current (IB) through its impact on the collector current (IC) and the collector-emitter voltage (VCE).

However, it's essential to note that the base current (IB) is primarily determined by the base-emitter circuit and the transistor's current gain (β). The change in RC may not have a significant impact on the base current (IB) in some cases, especially if the transistor is operating in the active region, where the base-emitter junction is forward-biased, and the collector-emitter junction is reverse-biased.

In summary, changing the RC value (resistor at the collector side) may indirectly influence the base current (IB) through its effect on the collector current (IC) and collector-emitter voltage (VCE). However, the base current (IB) is primarily determined by the base-emitter circuit and the transistor's current gain (β).

RESULTS

The result section presents the findings of a series of experiments conducted to investigate the behavior of a transistor circuit. The circuit consists of an NPN transistor connected to a resistor and a voltage source, as shown in figure. Brief interpretations given below:

1. As the IB increases, the IC also increases, but eventually, the IC stops increasing and becomes constant. This happens because the transistor reaches saturation, and further increases in the base current do not result in a proportional increase in the collector current. At saturation, the transistor behaves like a closed switch, and the collector voltage drops to a minimum value, resulting in a constant IC.

2. Similar to the first experiment, the IC increases with an increase in VCC. However, the maximum IC value is limited by the collector voltage, which decreases as VCC decreases. Eventually, the collector voltage drops to a point where the transistor enters saturation, and the IC becomes constant.

3. Experiment 3 investigated how changing the value of the collector resistor affects the behavior of the transistor. The results showed that as the value of the base current was increased in steps from 10 µA to 50 µA, the collector current increased, but at a decreasing rate. This is due to the fact that as the collector current increases, the voltage drop across the collector resistor also increases, which reduces the effective voltage available for the transistor. This causes the transistor to enter into the saturation region, where further increases in base current produce only small increases in collector current. The results also showed that as the value of the collector resistor was increased from 1kΩ to 2.2kΩ, the slope of the load line decreased, resulting in a smaller range of collector-emitter voltage values for a given base current. This suggests that the choice of collector resistor value is an important design parameter that affects the operating point of the transistor and the range of base current values that can be used to keep the transistor in the active region.

4. The value of the RC affects the slope of the load line, which is the line connecting the Q-point to the saturation and cut-off regions on the IC-VCE graph. The slope of the load line determines the range of VCE values that can be obtained for a given IB. A smaller value of RC results in a steeper load line, which means that the range of VCE values for a given IB is smaller. As a result, a smaller value of RC leads to a smaller range of IB values that can be used to keep the transistor in the active region. Conversely, a larger value of RC leads to a wider range of IB values that can be used to keep the transistor in the active region. However, a larger value of RC also results in a smaller IC value for a given IB, as seen in the results of the third experiment. Therefore, the choice of RC should be made based on the desired operating point of the transistor and the load requirements of the circuit.

BIBLIOGRAPHY

[1] Boylestad, R. L., & Nashelsky, L. (2018). Electronic Devices and Circuit Theory. Pearson Education.

[2] Sedra, A. S., & Smith, K. C. (2018). Microelectronic Circuits. Oxford University Press.

[3] https://physics.uncg.edu/hellen/research_links/ebers-moll.html
Access Date: Mar 29,23.

[4] https://www.electronics-tutorials.ws/transistor/tran_2.html
Access Date: Mar 29,23.

[5] http://web.mit.edu/6.012/www/SP07-L17.pdf
Access Date: Mar 30, 23.

[6] (Motorola, 1996.) https://sametbayat.me/datasheets/BC238B.pdf
(Datasheet of transistor used in experiment.)