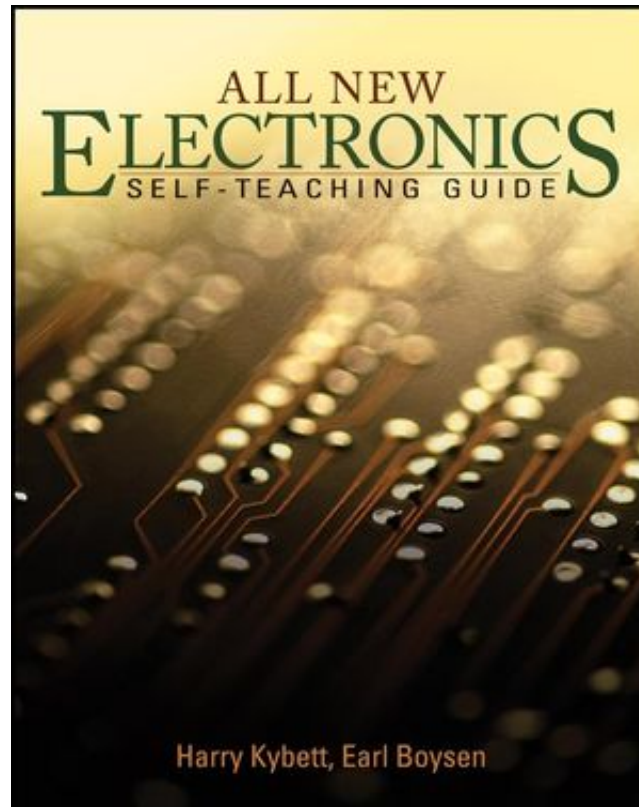


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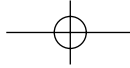
Extract: The Transistor Experiment



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- D. 1.5 mA
 - E. 6 mA
-

The Transistor Experiment

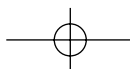
20 The objective of the following experiment is to find β of a particular transistor by measuring several values of base current with the corresponding values of collector current. Next, divide the values of collector current by the values of the base current to determine β . The value of β will be almost the same for all the measured values of current. This demonstrates that β is a constant for a transistor.

While the circuit is set up, measure the collector voltage for each current value. This demonstrates (experimentally) some points that are covered in future problems. As you perform the experiment, observe how the collector voltage V_c drops toward 0 V as the collector current increases.

If you do not have the facilities for setting up the circuit and measuring the values, just read through the experiment. If you do have the facilities, you will need the following equipment and supplies.

- One 9 V transistor radio battery (or a lab power supply).
- One multimeter set to measure current on a scale that will measure at least 100 μA .
- One multimeter set to measure current on a scale that will measure at least 10 mA.
- One multimeter set to measure voltage, on a scale that will measure at least 10 V.
- One resistor substitution box, or a 1 M Ω potentiometer, or assorted resistors with the values listed in the following table. If you use a potentiometer, you'll need another multimeter to read its resistance after each adjustment.

R_B
1 M Ω
680 k Ω
470
330



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R_B
270
220
200
180
160
150
120
110
100

- One 1 k Ω resistor.
- One transistor, preferably NPN.
- One breadboard.

Almost any small commercially available transistor will do for this experiment. The measurements given in this book were obtained using a 2N3643. If only a PNP is available, then simply reverse the battery voltage and proceed as described.

Set up the circuit shown in Figure 3-19 on the breadboard. Using breadboards allows you to easily connect components in a circuit that you can then disassemble when testing is complete. You can then use the components and breadboard in the construction of your next circuit.

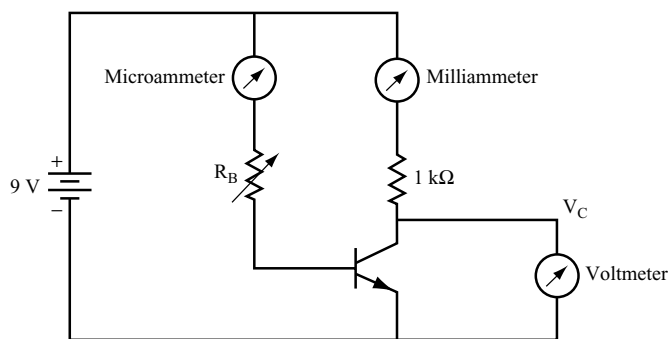


Figure 3-19

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Check the numbers in your table to make sure you got a consistent pattern. Then compare your measurements with the ones shown in the following table.

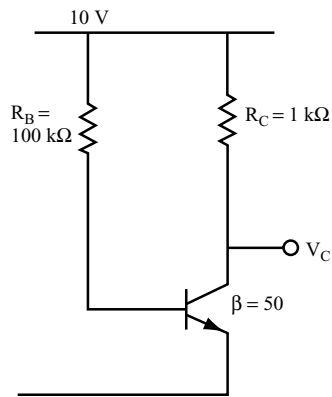
R_B	I_B	I_C	V_C	β
1 M Ω	9 μ A	0.9 mA	8.1 volts	100
680 k Ω	13	1.3	7.7	100
470	19	1.9	7.1	100
330	27.3	2.8	6.2	103
270	33.3	3.3	5.7	99
220	40	4.1	5.0	103
200	45	4.5	4.5	100
180	50	5	4.0	100
160	56	5.6	3.4	100
150	60	6	3	100
120	75	7.5	1.5	100
110	82	8.0	1.0	98
100	90	9	0.3	100

The measurements shown here were obtained by conducting this experiment very carefully. Precision resistors and a commercial 2N3643 transistor were used. With ordinary ± 5 percent tolerance resistors and a transistor chosen at random, you could get different results. Don't worry if your results are not as precise as those listed here.

Calculation of β results in values at or very close to 100 for each measurement, which agrees with the manufacturer's specification of $\beta = 100$.

For each value of I_B and its corresponding value of I_C in your experiment, calculate the value of β ($\beta = I_C/I_B$). The values will vary slightly but will be close to an average. (Excessively low and high values of I_B may produce values of β , which will be quite different. Ignore these for now.) Did you get a consistent β ? Was it close to the manufacturer's specifications for your transistor?

21 In the experiment, you measured the voltage level at the collector (V_C) and recorded your measurements. Now, examine how to determine the voltage at the collector, when it's not possible to measure the voltage level.

**Figure 3-20**

Use the values shown in the circuit in Figure 3-20 to complete these steps.

1. Determine I_C .
2. Determine the voltage drop across the collector resistor R_C . Call this V_R .
3. Subtract V_R from the supply voltage to calculate the collector voltage.

Here is the first step:

1. To find I_C , you must first find I_B .

$$I_B = \frac{10\text{ V}}{100\text{ k}\Omega} = 0.1\text{ mA}$$

$$I_C = \beta \times I_B = 50 \times 0.1\text{ mA} = 5\text{ mA}$$

Now, perform the next two steps.

Questions

2. $V_R =$ _____
3. $V_C =$ _____

Answers

2. To find V_R :

$$V_R = R_C \times I_C = 1\text{ k}\Omega \times 5\text{ mA} = 5\text{ V}$$
3. To find V_C :

$$V_C = V_S - V_R = 10\text{ V} - 5\text{ V} = 5\text{ V}$$

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22 Determine parameters for the circuit shown in Figure 3-20, using the value of $\beta = 75$.

Questions

Calculate the following:

- A. $I_C =$ _____
 B. $V_R =$ _____
 C. $V_C =$ _____

Answers

- A. $I_B = \frac{10\text{ V}}{100\text{ k}\Omega} = 0.1\text{ mA}$
 $I_C = 75 \times 0.1\text{ mA} = 7.5\text{ mA}$
 B. $V_R = 1\text{ k}\Omega \times 7.5\text{ mA} = 7.5\text{ V}$
 C. $V_C = 10\text{ V} - 7.5\text{ V} = 2.5\text{ V}$

23 Determine parameters for the same circuit, using the values of $R_B = 250\text{ k}\Omega$ and $\beta = 75$.

Questions

Calculate the following:

- A. $I_C =$ _____
 B. $V_R =$ _____
 C. $V_C =$ _____

Answers

- A. $I_B = \frac{10\text{ V}}{250\text{ k}\Omega} = \frac{1}{25}\text{ mA}$
 $I_C = 75 \times \frac{1}{25}\text{ mA} = 3\text{ mA}$
 B. $V_R = 1\text{ k}\Omega \times 3\text{ mA} = 3\text{ V}$
 C. $V_C = 10\text{ V} - 3\text{ V} = 7\text{ V}$

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24 From the preceding problems, you can see that you can set V_C to any value by choosing a transistor with an appropriate value of β , or by choosing the correct value of R_B .

Now, consider the example shown in Figure 3-21. The objective is to find V_C . Use the steps outlined in problem 21.

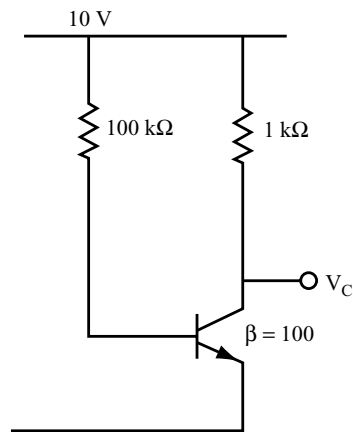


Figure 3-21

Questions

Calculate the following:

- A. $I_B =$ _____
 $I_C =$ _____
- B. $V_R =$ _____
- C. $V_C =$ _____

Answers

Your results should be as follows:

- A. $I_B = \frac{10\text{ V}}{100\text{ k}\Omega} = 0.1\text{ mA}$
 $I_C = 100 \times 0.1\text{ mA} = 10\text{ mA}$
- B. $V_R = 1\text{ k}\Omega \times 10\text{ mA} = 10\text{ V}$
- C. $V_C = 10\text{ V} - 10\text{ V} = 0\text{ V}$.

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Here, the base current is sufficient to produce a collector voltage of 0 volts and the maximum collector current possible, given the stated values of the collector resistor and supply voltage. This condition is called *saturation*.

25 Look at the two circuits shown in Figure 3-22 and compare their voltages at the point labeled V_C .

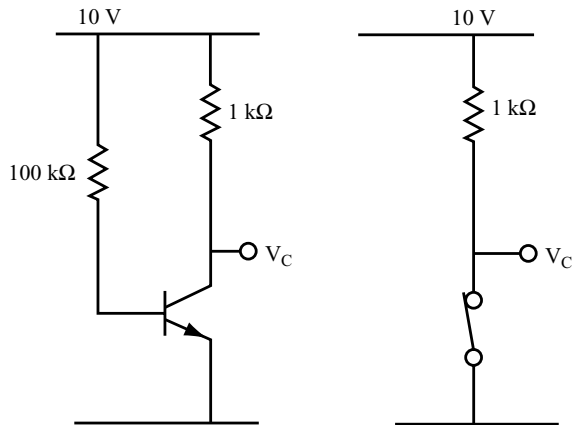


Figure 3-22

Consider a transistor that has sufficient base current and collector current to set its collector voltage to 0 V. Obviously, this can be compared to a closed mechanical switch. Just as the switch is said to be ON, then the transistor is also said to be “turned on,” or just ON.

Questions

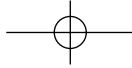
A. What can you compare a turned on transistor to?

B. What is the collector voltage of an ON transistor?

Answers

A. A closed mechanical switch

B. 0 V



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26 Now, compare the circuits shown in Figure 3-23.

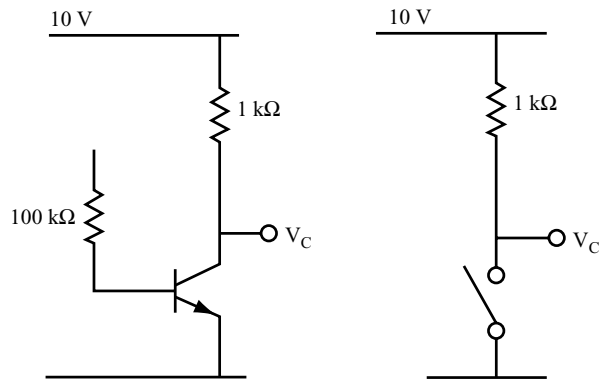


Figure 3-23

Because the base circuit is broken (that is, it is not complete), there is no base current flowing.

Questions

A. How much collector current is flowing?

B. What is the collector voltage?

C. What is the voltage at the point V_C in the mechanical switch circuit?

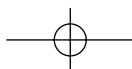
Answers

A. None.

B. Because there is no current flowing through the $1\text{ k}\Omega$ resistor, there is no voltage drop across it, so the collector is at 10 V .

C. 10 V , because there is no current flowing through the $1\text{ k}\Omega$ resistor.

27 From problem 26, it is obvious that a transistor with no collector current is similar to an open mechanical switch. For this reason, a transistor with no collector current and its collector voltage at the supply voltage level is said to be “turned off,” or just OFF.



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Question

What are the two main characteristics of an OFF transistor?

Answer

It has no collector current, and the collector voltage is equal to the supply voltage.

23 Now, calculate the following parameters for the circuit in Figure 3-24 and compare the results to the examples in problems 26 and 27. Again, the objective here is to find V_C .

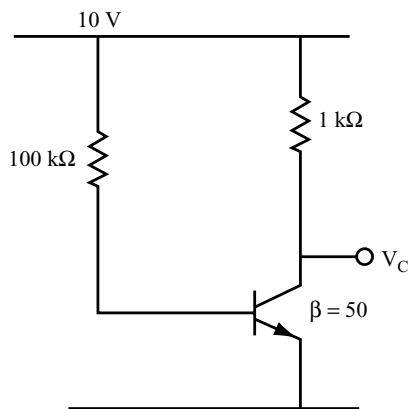


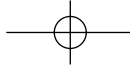
Figure 3-24

Questions

- A. $I_B =$ _____
 $I_C =$ _____
- B. $V_R =$ _____
- C. $V_C =$ _____

Answers

A. $I_B = \frac{10\text{ V}}{100\text{ k}\Omega} = 0.1\text{ mA}$



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$$I_C = 50 \times 0.1 \text{ mA} = 5 \text{ mA}$$

B. $V_R = 1 \text{ k}\Omega \times 5 \text{ mA} = 5 \text{ V}$

C. $V_C = 10 \text{ V} - 5 \text{ V} = 5 \text{ V}$

NOTE The output voltage in this problem is exactly half the supply voltage. This condition is very important in AC electronics and is covered in Chapter 8.

The Junction Field Effect Transistor

29 Up to now, the only transistor described was the bipolar junction transistor (BJT). Another common transistor type is the junction field effect transistor (JFET). The JFET, like the BJT, is used in many switching and amplification applications. The JFET is preferred when a high input impedance circuit is needed. The BJT has a relatively low input impedance as compared to the JFET. Like the BJT, the JFET is a three terminal device. The terminals are called the source, drain, and gate. They are similar in function to the emitter, collector, and base, respectively.

Questions

- A. How many terminals does a JFET have, and what are these terminals called?
- _____
- B. Which terminal has a function similar to the base of a BJT?
- _____

Answer

- A. Three, called the source, drain, and gate.
- B. The gate has a control function similar to that of the base of a BJT.
-

30 The basic design of a JFET consists of one type of semiconductor material with a channel made of the opposite type of semiconductor material running through it. If the channel is N material, it is called an N-channel JFET; if it is P material, it is called a P-channel. Figure 3-25 shows the basic layout of N and P materials, along with their circuit symbols. Voltage on the gate controls the current flow through the drain and source by controlling

