What effect do base current and collector voltage have on the collector current of a transistor?

EEP 13.6 **S**

Problem

1. Investigate the collector current of a npn transistor as a function of the base current at a constant collector voltage of 5 V.
2. Investigate collector current as a function of collector voltage for various values of base current.

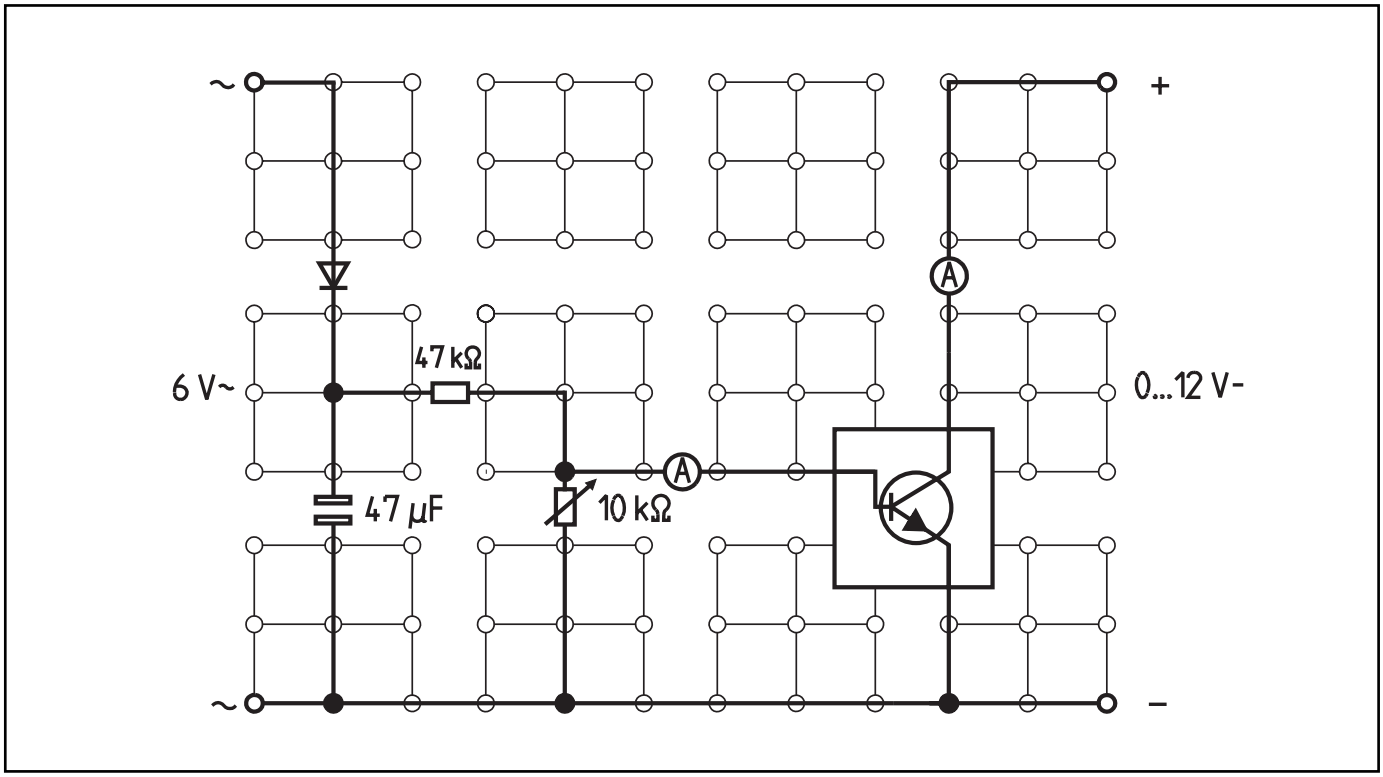
Equipment

Plug-in board	06033.00	1
Resistor, 47 kΩ	39104.38	1
Adjustable resistor 10 kΩ	39108.03	1
Electrolytic capacitor, 47 μF, bipolar	39105.45	1
Silicone diode 1N4007	39106.02	1
Transistor BC337	39127.20	1
Short-circuit plug, black	06027.05	3
Connecting cables, 25 cm, red	07360.01	2
Connecting cables, 25 cm, blue	07360.04	2
Connecting cables, 50 cm, red	07361.01	2
Connecting cables, 50 cm, blue	07361.04	2
Multi-range meter	07028.01	2
Power supply, 0...12 V-, 6 V~, 12 V~	13505.93	1

Set-Up and Procedure

— Set up experiment as shown in Fig. 1. Make sure that the meters are set to the correct measurement ranges (measurement range for base current 50 μA, for collector current 30 mA) and that the polarity is correct.
— Switch on power supply unit. Set voltage on power supply unit to 5 V-.
— Increase base current in increments of 10 μA using the 10 kΩ adjustable resistor and enter measurements for collector current in Table 1.
— Set base current to 10 μA. Increase collector voltage in increments of 1 V, take the measurement for collector current, and enter in Table 2. Check the base current each time after changing the collector voltage and correct, if necessary.
— Increase base current (see Table 2) and, again, measure collector current as a function of collector voltage.
— Switch power supply unit off.

Fig. 1



Measurement Results
Table 1

I_B/μA	I_C/mA
0	
10	
20	
30	
40	
50	

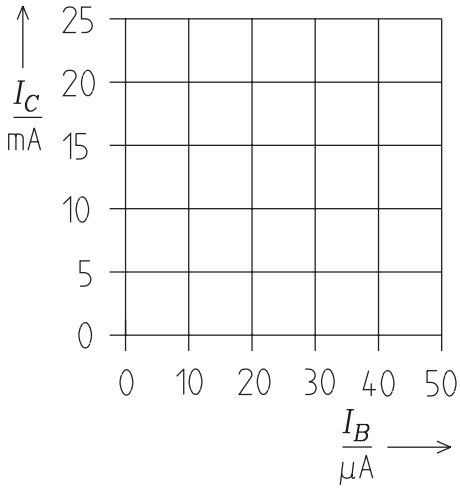


Fig. 2

Table 2
Collector current I_C in mA as a function of voltage with various base currents.

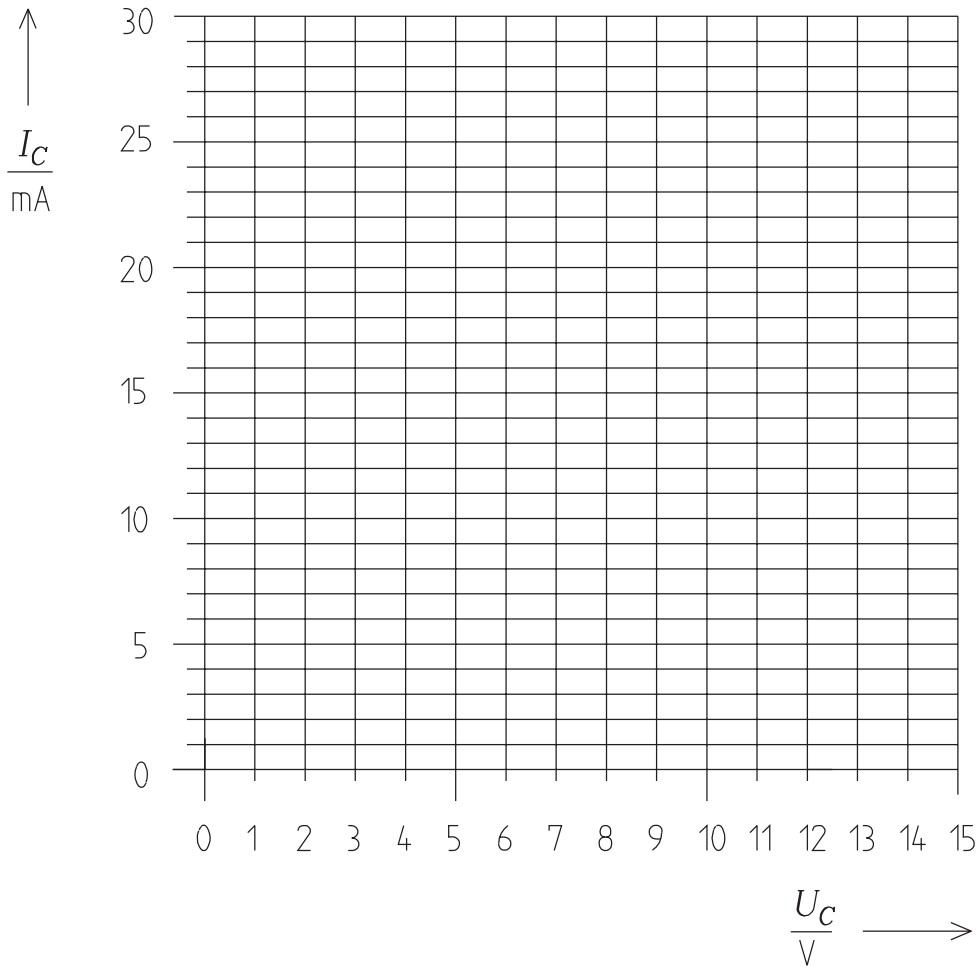
U /V \ I_B/μA	10	20	30	40	50
0					
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					

Evaluation
1. Graph the pairs of values from Table 1 in Fig. 2.
2. By how much does the collector current change when the base current is increased by 10 μA?

3. The ratio of the change in collector current to the change in base current is called the current gain β of the transistor. Determine the value for current gain $\beta = \Delta I_C/\Delta I_B$ for the transistor in this experiment. Don't forget that the currents have different units.

4. Graph the values from Table 2 in Fig. 3

Fig. 3



5. The product of collector voltage and collector current is the dissipation power $P_D = U_C \cdot I_C$. It is transformed into heat by the transistor. Its maximum value for the transistor used in this experiment is 300 mW. Calculate the dissipation power of the transistor at a collector voltage of 5 V and a base current of 30 μA and check whether the result is less than the maximum allowable value for P_D.

6. The ratio $\Delta U_{CE}/\Delta I_C$ is the output resistance of the transistor for a certain operating point. Using the characteristic curve for a base current of 30 μA, determine the change in collector current ΔI_C when the collector voltage is increased ΔU_{CE} from 5 V to 10 V and calculate the output resistance of the transistor.

(What effect do base current and collector voltage have on the collector current of a transistor?)

A prerequisite for a deeper understanding of the processes related to a transistor amplifier or switching stage is the knowledge of the characteristics of a transistor. Of the four characteristics (the output, control, input, and reverse voltage transfer ratio characteristics), the output and control characteristics are particularly important. Therefore, this experiment is limited to the recording of the characteristic curves for control and output. The other characteristic curves can be determine by slightly altering the experiment set-up.

Since two voltage sources are required to determine the characteristic curve of controllable components such as the transistor, the base direct current necessary for controlling is produced through rectification of the alternating current from the power supply unit.

We recommend spending some class time after the experiment going over the characteristic curves the students recorded. The operating lines graphed in the output characteristic field can be used to deepen their understanding of the control process. For example, you can explain voltage gain as a function of load resistance, the oppositional nature of output and input voltage, the achievable output power, and the influence of the position of the operating point on signal clippings.

Notes on Set-Up and Procedure

Aside from making sure the polarity of the connections to the meters and the diode is correct, there should be no major problems with setting up the circuit.

Since the change in the collector voltage influences the strength of the base current, the students should check the base current each time after changing the voltage and correct it, if necessary.

Make sure that the maximum dissipation power of the transistor does not exceed P_D = 300 mW. As long as the collector current is less than 30 mA, there should be no problem here, either.

Measurement Results

Table 1

$I_B/\mu A$	I_C/mA
0	0
10	3.8
20	8.2
30	13
40	18
50	22.5

Table 2: Collector current I_C in mA as a function of voltage with various base currents.

U /V \ $I_B/\mu A$	10	20	30	40	50
0	0	0	0	0	0
1	3.2	7.0	11.0	15.2	17.0
2	3.5	7.1	11.8	16.0	20.8
3	3.5	7.2	12.0	16.2	21.2
4	3.5	7.8	12.5	16.5	21.8
5	3.6	7.8	12.5	16.8	22.4
6	3.6	8.0	12.7	17.2	23.0
7	3.3	8.0	12.8	17.6	23.6
8	3.7	8.0	13.0	18.0	24.2
9	3.7	8.2	13.4	18.5	24.6
10	3.8	8.3	13.8	19.0	25.0
11	3.8	8.4	13.8	19.2	25.2
12	3.8	8.5	14.0	19.2	25.4

(What effect do base current and collector voltage have on the collector current of a transistor?)

Evaluation

1. See Fig. 2.
2. When the base current is increased by 10 μA, the collector current increases by 5.2 mA.
3. The current gain of the transistor is

$$\beta = \Delta I_C/\Delta I_B = 520.$$

4. See Fig. 3.
5. When the collector voltage is 5 V, the collector current is 12.5 mA. The dissipation power of the transistor in this operating point is

$$P_V = U_C \cdot I_C = 62.5 \text{ mW}.$$

   It is less than the maximum admissible value of 300 mW.
6. The output resistance of the transistor is

$$R = \Delta U_C/\Delta I_C = 5 \text{ V}/1.5 \text{ mA} = 3.3 \text{ k}\Omega.$$

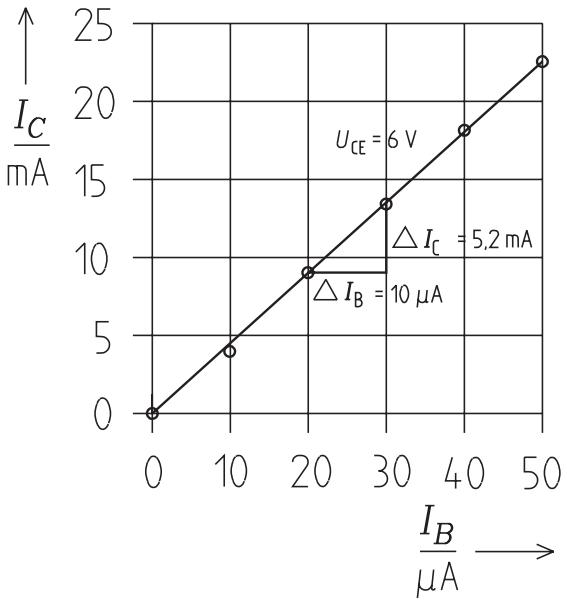


Fig. 2

Fig. 3