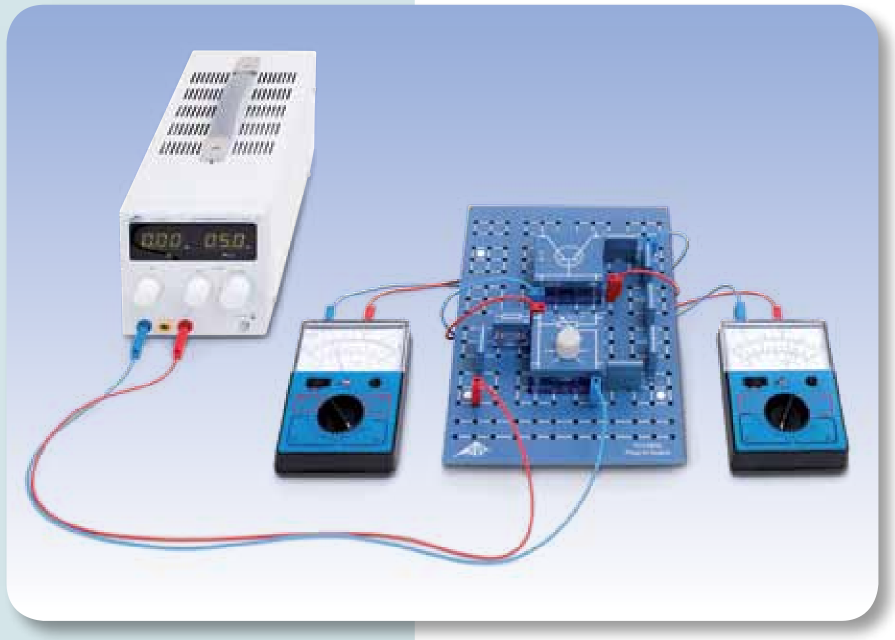
BIPOLAR TRANSISTORS



OBJECTIVE

Messung der relevanten Kennlinien eines npn-Transistors

SUMMARY

A bipolar transistor is an electronic component composed of three alternating p-doped and n-doped semiconductor layers called the base, the collector and the emitter. Depending on the sequence of the layers, the transistor may either be termed npn or pnp. The response of a bipolar transistor may be distinctively described by, for example, an input characteristic, a control characteristic and an output characteristic. In this experiment, examples of these are to be measured for an npn transistor, displayed on a graph and evaluated.

EXPERIMENT PROCEDURE

- **Measure the input characteristic, i.e. the base current I_B as a function of the base emitter voltage U_{BE}.**
- **Measure the control characteristic, i.e. the collector current I_C as a function of the base current I_B for a fixed collector-emitter voltage U_{CE}.**
- **Measure the control characteristic, i.e. the collector current I_C as a function of the collector-emitter voltage for a fixed base current I_B.**

REQUIRED APPARATUS

Quantity	Description	Number
1	Plug-In Board for Components	**1012902**
1	Set of 10 Jumpers, P2W19	**1012985**
1	Resistor 1 kΩ, 2 W, P2W19	**1012916**
1	Resistor 47 kΩ, 0.5 W, P2W19	**1012926**
1	Potentiometer 220 Ω, 3 W, P4W50	**1012934**
1	Potentiometer 1 kΩ, 1 W, P4W50	**1012936**
1	NPN Transistor, BD 137, P4W50	**1012974**
1	AC/DC Power Supply 0 – 12 V, 3 A (230 V, 50/60 Hz)	**1002776 or**
	AC/DC Power Supply 0 – 12 V, 3 A (115 V, 50/60 Hz)	**1002775**
3	Analogue Multimeter AM50	**1003073**
1	Set of 15 Experiment Leads, 75 cm 1 mm²	**1002840**

BASIC PRINCIPLES

A bipolar transistor is an electronic component composed of three alternating p-doped and n-doped semiconductor layers called the base B, the collector C and the emitter E. The base is between the collector and emitter and is used to control the transistor. In principle a bipolar transistor resembles two diodes facing opposite directions and sharing an anode or cathode. Bipolarity arises from the fact that the two varieties of doping allow for both electrons and holes to contribute to the transport of charge.

Depending on the sequence of the layers, the transistor may either be termed npn or pnp (Fig. 1). Bipolar transistors are operated as quadripoles in three basic circuits, distinguished by the arrangement of the terminals and called common emitter, common collector and common base. The names indicate which of the terminals is common to both the input and the output.

Only npn transistors are considered in the following treatment.

There are four operating modes for an npn transistor, depending on whether the base-emitter or base-collector junctions are aligned in a conducting or forward-bias direction (U_{BE}, $U_{BC} > 0$) or a non-conducting or reverse bias (U_{BE}, $U_{BC} < 0$) direction (see Table 1). In forward-bias mode, electrons from the emitter migrate into the base across the transistor's forward-biased base-emitter junction ($U_{BE} > 0$) while holes from the base move into the emitter. Since the emitter has much higher doping than the base, more electrons will migrate than holes, which minimises recombination between the two. Because the width of the base is shorter than the diffusion length of the electrons, which count as minority carriers within the base itself, the electrons diffuse through the base into the depletion layer between the base and the collector before drifting further towards the collector itself. This is because the depletion layer only forms a barrier for majority carriers. This results in a transfer current I_T from the emitter into the collector, which is the major contributor to the collector current I_C in forward-bias mode. The transistor can therefore be regarded as a voltage controlled current source whereby the I_C at the output can be controlled by the voltage U_{BE} at the input. Electrons which recombine in the base emerge from there in a base current I_B which guarantees a constant transfer current I_T, thereby ensuring that the transistor remains stable. A small input current I_B can therefore control a much greater output current I_C ($I_C \approx I_T$), which gives rise to current amplification.

The response of a bipolar transistor is described by four characteristics, the input characteristic, the control or base characteristic, the output characteristic and the feedback characteristic (see Table 2). This experiment involves measuring, by way of example, input, control and output characteristics for an npn transistor and plotting them as a graph.

Tab. 1: Four operating modes of an npn transistor

U_{BE}	U_{BC}	Operating mode
> 0	< 0	Normal mode
> 0	> 0	Saturation
< 0	> 0	Inverse mode
< 0	< 0	Off state

Tab. 2: Four characteristics of an npn transistor in normal mode

Name	Dependency	Parameter
Input characteristic	$I_B(U_{BE})$	
Control characteristic	$I_C(I_B)$	U_{CE} = const.
Output characteristic	$I_C(U_{CE})$	I_B = const.
Feedback characteristic	$U_{BE}(U_{CE})$	I_B = const.

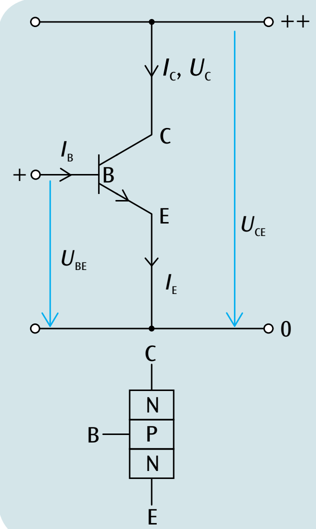


Fig. 1: Design of an npn transistor in principle, including accompanying circuit symbol plus indications of voltage and current

EVALUATION

The threshold voltage U_{Th} can be found from the input characteristic and the gain can be found from the control characteristic

$$B = \frac{\Delta\ I_C}{\Delta\ I_B}$$

The power dissipation can be found from the output characteristic $P = U_{CE} \cdot I_C$.

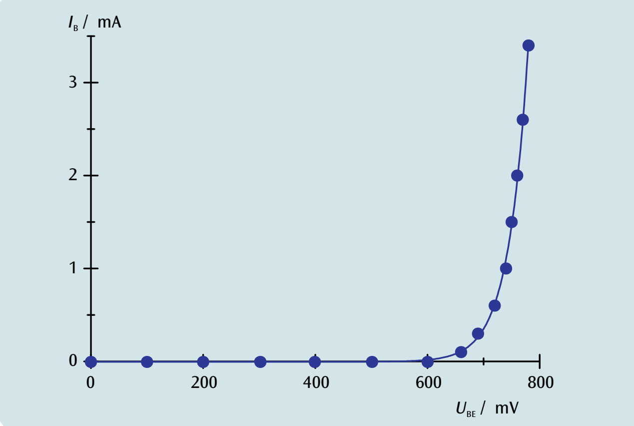


Fig. 2: Input characteristic

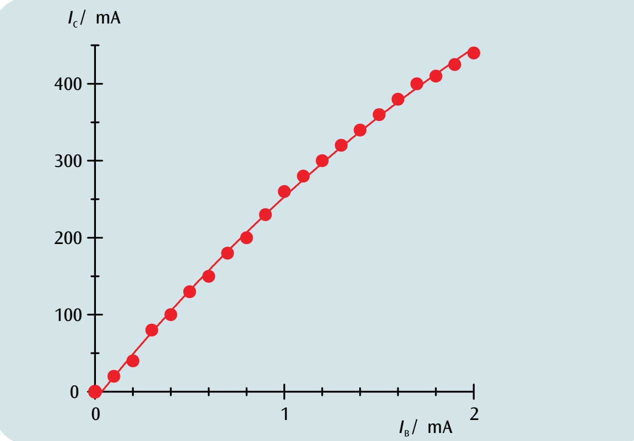


Fig. 3: Control characteristic for U_{CE} = 5.2 V

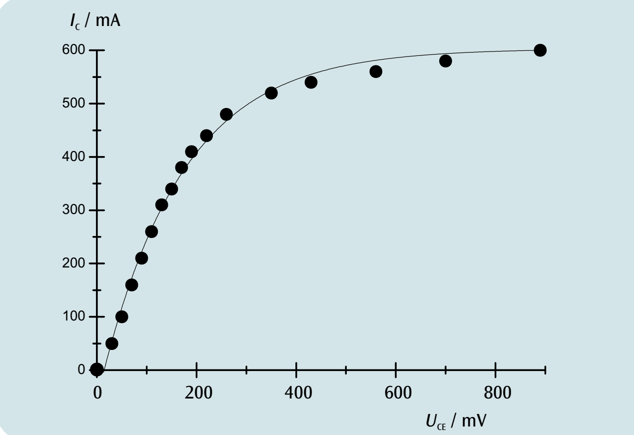


Fig. 4: Output characteristic for I_B = 4.2 mA