Problem

Investigate how to use a transistor to realize both switching states of a switch.

Equipment

Plug-in board	06033.00	1
On/off switch	39139.00	1
Lamp holder E10	17049.00	1
Filament lamp, 4 V/0.04 A, E10, 1 pc.	06154.03	(1)
Resistor, 1 kΩ	39104.19	1
Potentiometer, 250 Ω	39109.05	1
Transistor BC337	39127.20	1
Wire building block	39120.00	6
Connecting cables, 25 cm, red	07360.01	1
Connecting cables, 25 cm, blue	07360.04	1
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. Set direct voltage on power supply unit to 4 V and switch on power supply unit.

— Beginning from the left, turn dial on potentiometer just far enough that the filament lamp lights up to maximum brightness and the collector current no longer increases.

— Measure collector current I_C and voltage U_{CE} between collector and emitter. Enter measurements in Table 1.

— Switch connection of voltmeter to the collector over to the base and measure the voltage U_{BE} between base and emitter. Note measurements.

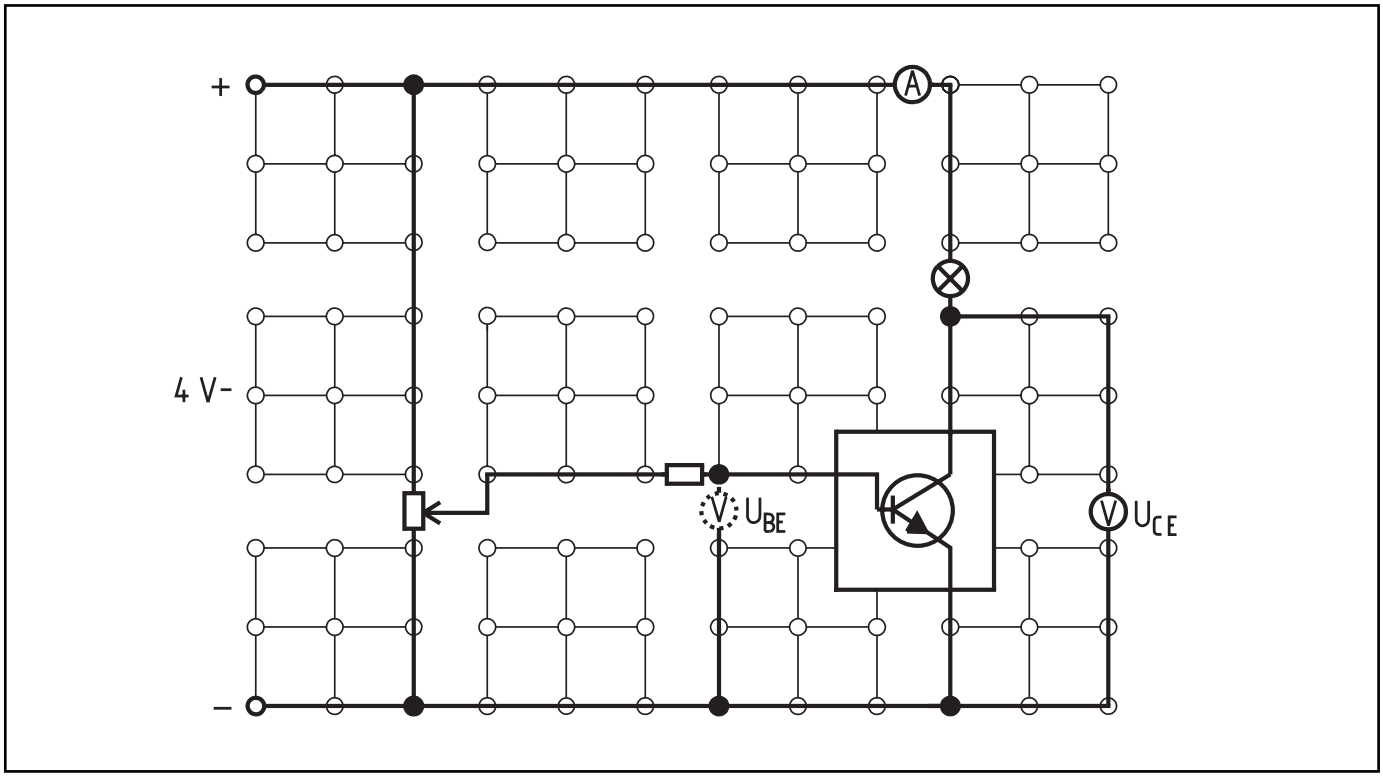
— Turn the dial on the potentiometer just far enough that the filament lamp goes out.

— Measure collector current, collector-emitter voltage, and base-emitter voltage as previously. Note measurements (Table 1, right column).

— Switch power supply unit off and change experiment set-up as shown in Fig. 2.

— Switch power supply unit back on and toggle on/off switch back and forth. Measure base current I_B for both switching states. Note measurements (bottom line in Table 1).

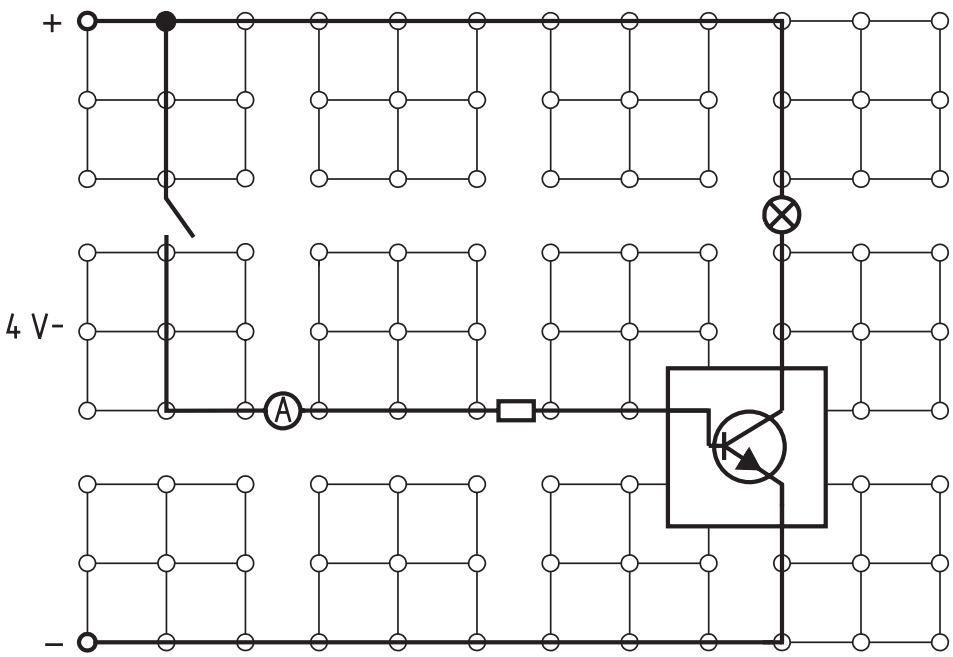
Fig. 1



Measurement Results
Table 1

	Lamp lighted	Lamp not lighted
Collector current I_C/mA		
Collector-emitter voltage U_{CE}/V		
Base-emitter-voltage U_{BE}/V		
Base current I_B/mA		

Fig. 2



Evaluation

1. List the conditions that must be fulfilled for a transistor
   a) to switch a circuit on

   b) to interrupt a circuit.

2. The power switched on and off by the transistor is nearly equal to the product of connected operating voltage $U_O = 4V$ and the collector current when the filament lamp is shining at maximum brightness:
   $P_S \approx U_O \cdot I_C$
   Compare this power with the control power $P_{CO} = U_{BE} \cdot I_B$ necessary to trigger the switching process.

3. How does a transistor switch differ from a mechanical switch?

4. Where could transistors be put to practical use as switches?

(Can transistors be used as switches?)

The development of computer engineering and the increasing digitalization in the transmission and processing of information are accompanied by increased use of transistors in switching functions.
This experiment should demonstrate the basic principle of a transistor functioning as an electronic switch. The instructor should discuss the differences between mechanical and electronic switches and the advantages of electronic switches with the students. In particular, discuss the minimal control power necessary for switching, the absence of contacts (which wear out with time), very brief switching times in the nanosecond range, and their small size, allowing them to be included in integrated electronic circuits.

Notes on Set-Up and Procedure
The 1 kΩ resistor limits the base current to a level that guarantees safe switching to the conductive state even with a small current gain factor.
If there are not enough multi-range meters for each experiment group to have two, the students can also take the measurements one after another. A short-circuit plug must be put in place of the second current meter.

Measurement Results
See Table 1

Evaluation
1.a) A transistor switches a circuit on when a voltage of $U_{BE} \geq 0.7$ V is connected to the base. A small base current flows in this case.

b) A transistor interrupts a circuit when there is no base-emitter voltage. Neither base nor collector current flows in this case.

2. The power P_S switched on and off by the transistor is

$$P_S \approx U_O \cdot I_C = 4\ V \cdot 38\ mA = 152\ mW.$$

The control power necessary at the base to trigger the switching process is

$$P_{CO} = U_{BE} \cdot I_B = 0.75\ V \cdot 2.2\ mA = 1.65\ mW$$

Transistors can be used to switch large operating powers with a minimal control power.

3. A transistor switch has no contacts which can wear out or corrode. The switching process is not triggered by mechanical movement but rather by a small electrical voltage. Transistors are smaller than mechanical switches.
4. Transistors are most useful as switches in situations where the switching process must be very fast and where many switches must be fit into a minimum of space. This is true in computer engineering and control technique, and automatic control.

Notes
The transmission of audio and video signals is being digitalized more and more. Large quantities of electronic switches are used in this area as well.

Table 1

	Lamp lighted	Lamp not lighted
Collector current I_C/mA	38	0
Collector-emitter voltage U_{CE}/V	0.02	3.9
Base-emitter voltage U_{BE}/V	0.75	0
Base current I_B/mA	2.2	0

(Can transistors be used as switches?)

Room for notes