DEPARTMENT OF ELECTRONICS AGH UST

LABORATORY
OF
ELECTRONICS ELEMENTS

Bipolar Junction Transistor

(DC parameters)

REV. 0.2

1. THE GOAL OF THE EXERCISE

- Determination of basic npn bipolar junction transistor parameters:
  - α_N, β_N , α_R, β_R
  - U_a Early voltage,
  - Parameters of the equations describing Ebers-Moll model of bipolar transistor

2. THE UTILIZED MODELS AND ELEMENTS

During the exercise following components will be used:

- NI ELVIS Prototyping Board (ELVIS) connected with PC,
  - Virtual measurement devices:
  - `Virtual Instruments (VI):`
  - `Digital Multimeter (DMM),`
  - `Two-Wire Current-Voltage Analyzer (2-Wire)`
  - `Variable Power Supplies (VPS)`
- Agilent multimeter
- Laboratory power supply
- Set of electronics elements listed in Table 1.

Table 1. Values of electronic elements required to perform the exercise

Resistors	1x100 Ω, 1x10kΩ, 1x100kΩ,
Capacitors	1x100nF,
Transistors	1xBD441, BD283 (or eq.)

3. PREPARING THE DRAFT

3.1. Structure and principle of operation of bipolar transistor.

3.2. Draw the output, input and transfer characteristics of npn bipolar transistor for normal and inverse connection. In order to verify the prepared characteristics present the method of characteristics verification with the use of NI ELVIS Prototyping Board (ELVIS).

Which conditions need to be fulfilled while measuring the bipolar transistor in inverse mode?

3.3. Ebers-Moll equation, physical meaning of particular bipolar transistor model parameters.

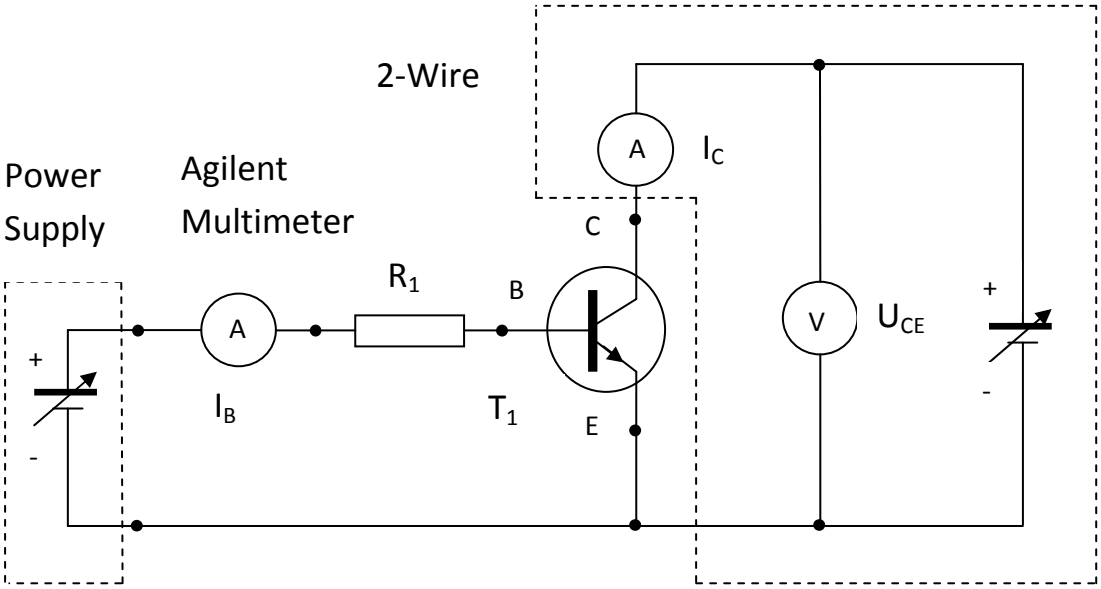


Fig. 3.1. Schematic of measurement setup utilized to determine output characteristics of npn bipolar transistor in normal connection.

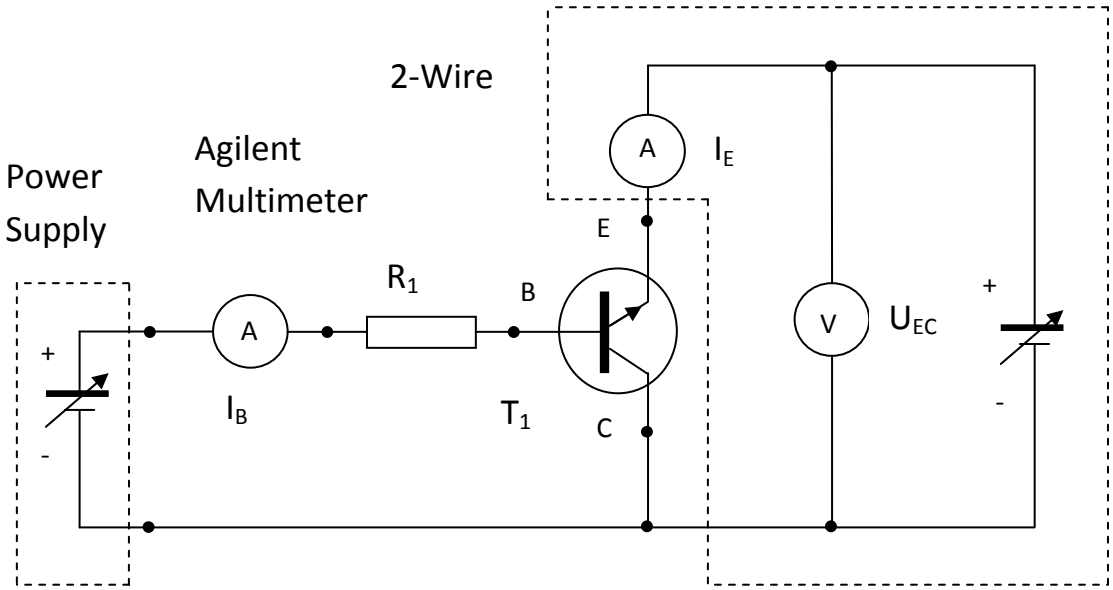


Fig. 3.2. Schematic of measurement setup utilized to determine output characteristics of npn bipolar transistor in inverse connection.

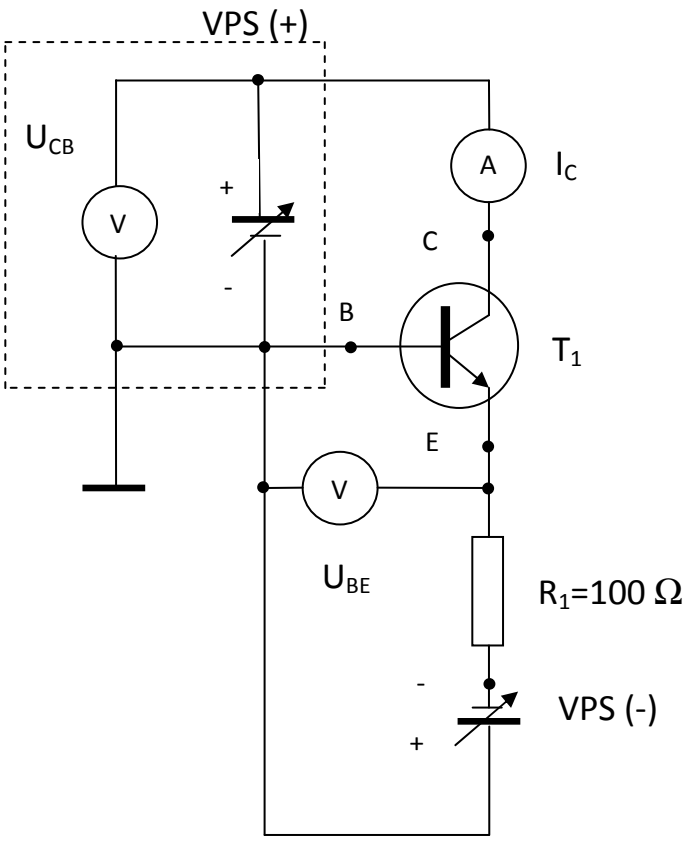


Fig. 3.3. Schematic of measurement setup utilized to determine current-voltage characteristics of emitter diode.

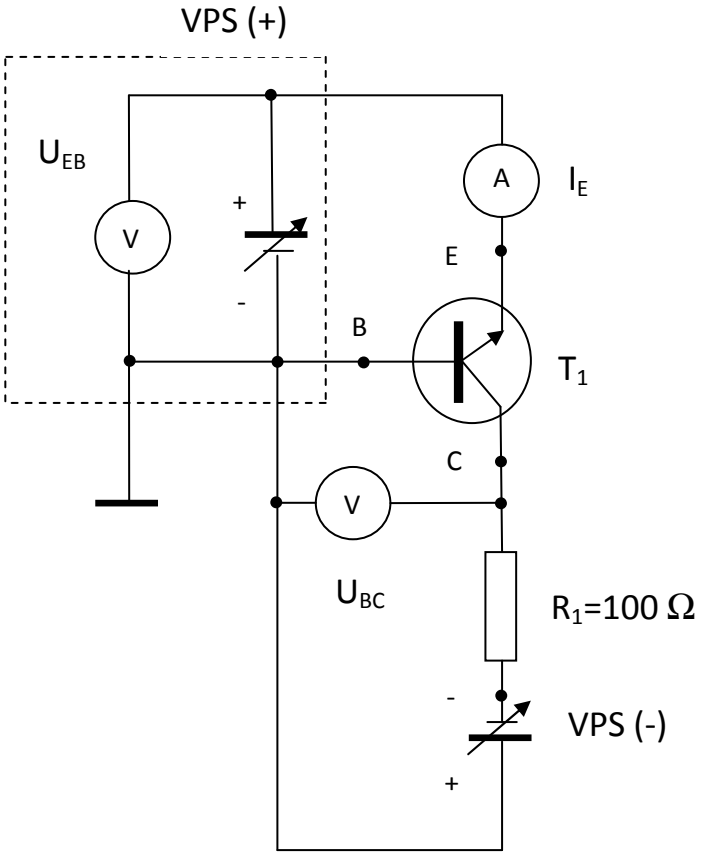


Fig. 3.4. Schematic of measurement setup utilized to determine current-voltage characteristics of collector diode.

4. THE COURSE OF THE EXERCISE

4.1. Construct the measurement setup from Fig.3.1. Use virtual multimeter (DMM) or Agillent multimeter to measure the base current. Use laboratory power supply as a power supply polarizing base-emitter circuit. Elements values equal to: R_1=100 kΩ, transistor T1 chosen by the teacher. Draw the output npn bipolar transistor characteristic in normal connection for the U_{CE} voltage within 0-10 V range, changing the voltage by 0.1 V, for fixed base current. The base current I_B should be changed from the starting value 10 μA with the step of 10 μA in the range chosen by the teacher (for example 10, 20, 30, 40, 50 μA). Base current value is adjusted by setting the proper voltage at the output of power supply in a base circuit.

4.2. Construct the measurement setup from Fig.3.2. Use virtual multimeter (DMM) or Agillent multimeter to measure the base current. Use laboratory power supply as a power supply polarizing base-emitter circuit. Elements values equal to: R_1=10 kΩ, transistor T1 (use the same transistior as in 4.1). Draw the output npn bipolar transistor characteristic for inverse connection for the U_{EC} voltage within **0-5 V** range, changing the voltage by 0.1 V, for fixed base current. The base current I_B should be changed from the starting value 100 μA with the step 100 μA in the range chosen by the teacher (for example 100, 200, 300, 400, 500 μA). Base current value is adjusted by setting the proper voltage at the output of power supply in a base circuit.

4.3. Construct the measurement setup from Fig.3.3. Use Agillent multimeter to measure the collector current. Use virtual power supply VPS(-) as a power supply polarizing base-emitter circuit. Elements values equal to: R_1=100 Ω, transistor T1 (use the same transistior as in 4.1). Measure the current-voltage characteristics of the npn bipolar transistor emitter diode for fixed U_{BC} voltage within the **0-5 V** range (current limitation +20 mA), by noting I_C current value and U_{BE} voltage value (3 measurements per decade current change, from 1 μA to 10 mA). Values of I_C current are adjusted by setting the proper voltage at the output of VPS, in analogous way to measurements of semiconductor diode characteristic.

4.4. Construct the measurement setup from Fig.3.4. Use Agillent multimeter to measure the emitter current. Use virtual power supply VPS(-) as a power supply polarizing base-collector circuit. Elements values equal to: R_1=100 Ω, transistor T1 (use the same transistior as in 4.1). Measure the current-voltage characteristics of the npn bipolar transistor collector diode for the fixed U_{BE} voltage within the **0-5 V** range (the same value as in 4.3) (current limitation +20 mA) by noting I_E current value and U_{BC} voltage value (3 measurements per decade current change, from 1 μA to 10 mA). Value of I_E current is adjusted by setting the proper voltage at the output of VPS, in analogous way to measurements of semiconductor diode characteristic.

ATTENTION: In the case of instability of the measurement setup, 100nF monolithic capacitor should be placed between the base and collector of the measured T_1 transistor.

5. THE COURSE OF THE EXERCISE, DATA ANALYSIS

5.1. Based on the registered data in 3.1, draw the output characteristics of T_1 bipolar transistor operating in common emitter configuration.

5.2. Based on the registered data in 3.1, draw the transfer characteristic for the voltage U_{CE} given by the teacher, determine β_N and I_{CE0} of T_1 bipolar transistor operating in common emitter configuration. Calculate α_N.

5.3. Based on the registered data in 3.1, determine the Early voltage value of bipolar transistor T_1 operating in common emitter configuration.

5.4. Based on the registered data in 3.2, draw the output characteristics of bipolar transistor T_1 operating in common emitter configuration for inverse connection.

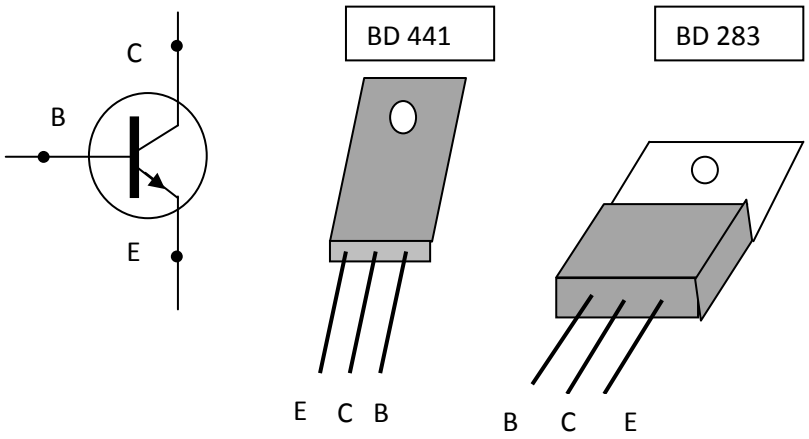
5.5. Based on the registered data in 3.2, draw the transfer characteristic for the voltage U_{EC} given by the teacher, determine β_R and I_{EC0} of T_1 bipolar transistor operating in common emitter configuration for inverse connection. Calculate α_R.

5.6. Based on the registered data in 3.1, determine the Early voltage value of bipolar transistor T_1 operating in common emitter configuration for inverse connection.

5.7. Based on the registered data in 3.3, draw the graph presenting emitter diode current in function of U_{BE}/U_T, determine from the graph the non-ideality coefficient of emitter junction *n* and the value of the current I_{E0}.

5.8. Based on the registered data in 3.4 draw the graph presenting collector diode current in function of U_{BC}/U_T, determine from the graph the non-ideality coefficient of collector junction *m* and the value of the current I_{C0}.

5.9. Basing on the determined parameters, write the Ebers-Moll equations for the measured T_1 bipolar npn transistor.



6. LITERATURE

[1] Lecture (P. Dziurdzia)

[2] Behzad Razavi „Fundamentals of Microelectronics”

[3] W. Marciniak “Przyrządy półprzewodnikowe”