E104. Characteristics of diodes and transistors

1. Introduction

The diode is a semiconductor element used in electrical circuits eg. due to its rectifying properties. When it is polarized in the conducting (forward) direction it starts to pass the current above a certain threshold voltage applied U_p. For germanium diodes it is approx. 0.3 V, for silicon approx. 0.65 V, and for light emitting diodes approx. 2 V. The resistance of the diode in the forward direction may be 10 Ω, while in the reverse direction it can be as high as 100 M Ω. The dependence of the current I_d flowing through diode on the applied voltage U_d is called the characteristic diode curve, $I_d=f(U_d)$. As a result of current flow the heat is dissipated on the diode (power dissipated $P=U_d \cdot I_d$). For light-emitting diode part of the dissipated energy falls within the visible region, eg. for the diodes of gallium phosphoarsenide one observes red or yellow light, while for gallium phosphide the emitted light is green.

The transistor has become an essential element of the electronic system, from simple amplifier or generator to the computer. The transistor is a semiconductor element, and is used to amplify currents. Transistors can be divided into two main categories: bipolar and field transistors. Further considerations in this exercise apply for bipolar transistors. Bipolar transistor of n-p-n or p-n-p type consists of two p-n junctions placed close to each other. The transistor has three terminals: an emitter (E), collector (C) and base (B). The term bipolar means that both electrons and holes take part in its operation. In normal operating conditions of the emitter-base junction is polarized in forward direction, while the base-collector is polarized in the reverse direction. Then, the current flowing from the emitter to the collector (I_C) is controlled by the base current (I_B). The dependence $I_C=f(I_B)$ allows to determine the amplification factor β, which is defined at a constant collector-emitter voltage as:

$$\beta = \left(\frac{\partial I_C}{\partial I_B} \right)_{U_{CE}=const.} . \qquad (1)$$

2. Apparatus and measurements

The circuits should be connected using a plexiglass plate with rows of radio outlets connected in parallel (Figure 1). The applied voltage can be connected from the measurement

console of constant 5V source or regulated in the range of 0 - 5 V. The measurement console is equipped with four channels, but only channel 1 (Kan. 1) and channel 2 (Kan. 2) are used. The measurements should be done for light-emitting diodes (red, yellow, green, blue) and silicon diode (1N4448), as well as for p-n-p transistors (TG52SII, BC177B). For the diodes the circuit shown in Figure 1 should be built, while for the p-n-p transistor – the circuit shown in Figure 2.

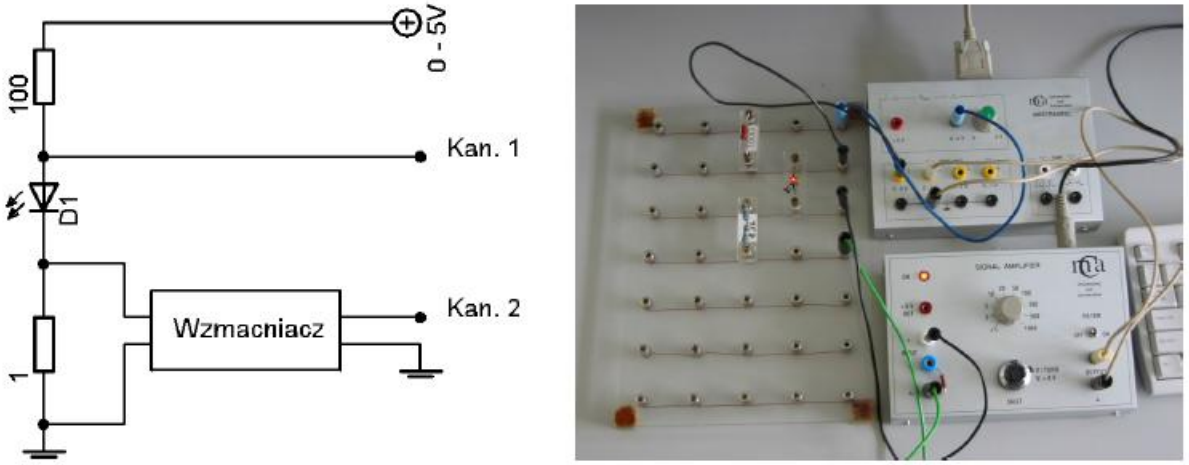

Figure 1. Scheme (and photo) of the circuit for the measurements of the diode.

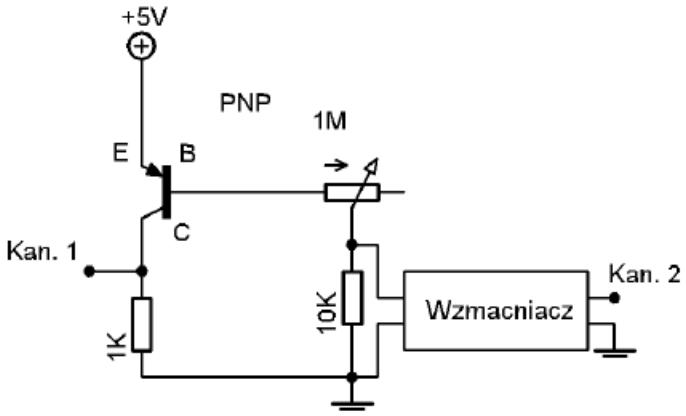

Figure 2. Scheme of the circuit for the measurements of the p-n-p transistor.

During the measurements for the diode, the applied voltage should be varied in the range from 0 to 5 V. In the case of p-n-p transistor studies, the base current should be varied by changing the value of resistance of the 1 MΩ potentiometer.

The first fold (*Pomiary*) of the program controlling the experiment (*dioda i tranzystor.exe*) is used for the measurements (Figure 3). One can set the data accumulation time (*Czas pomiaru*, about 10 seconds), the number of measurement points (*Ilość punktów*,

eg. 500) and the name of the file to which the waveform signal data will be saved (*Zapis danych do pliku*). After starting the measurement (*Start* button) the accumulated voltages in both channels are shown on the plot. One should be careful to set the optimum value of the gain in the amplifier (*Wzmacniacz*) so that the maximum signal on channel 2 does not exceed 5 V.

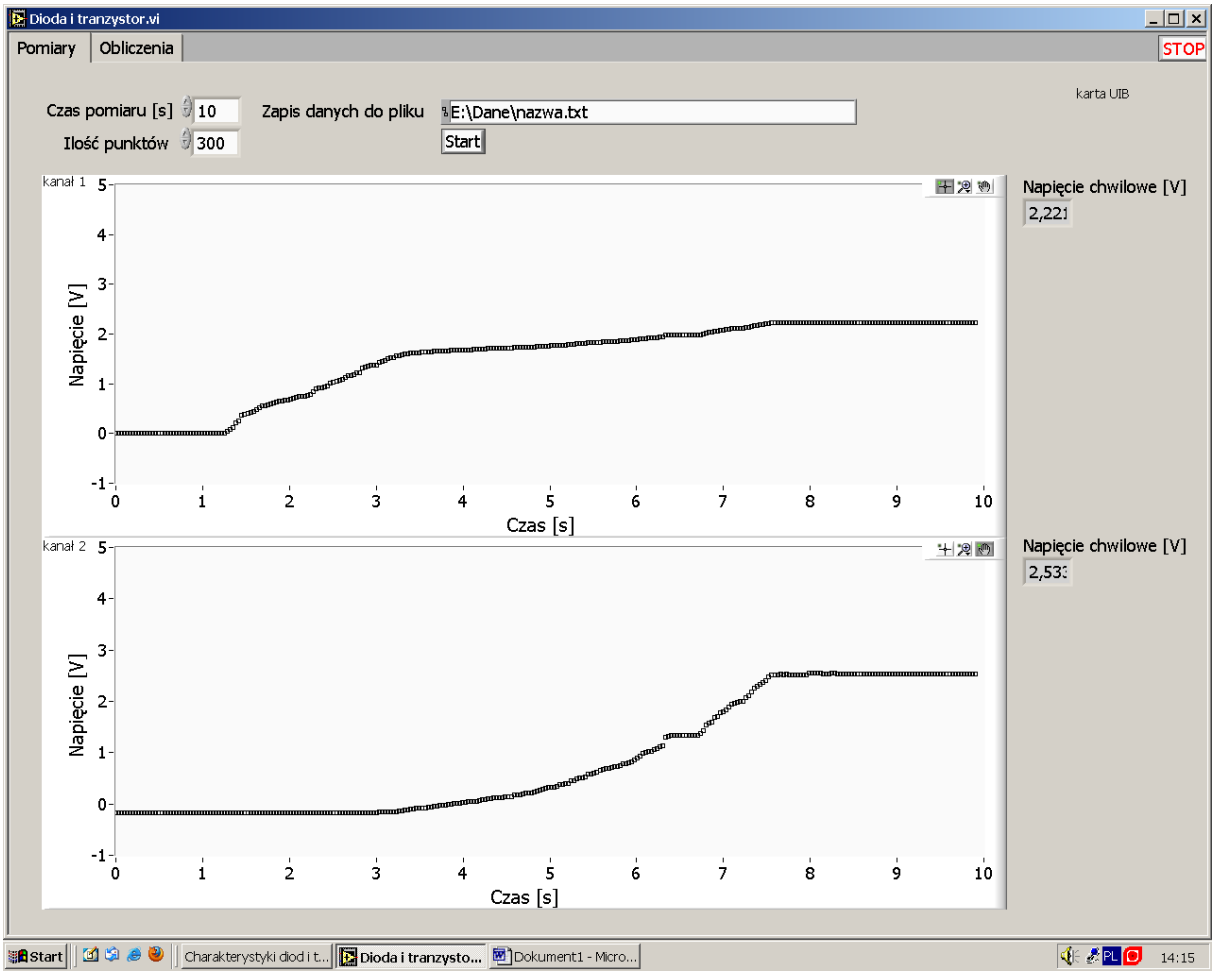

Figure 3. Front panel of the fold for the measurements.

Next, the analysis of the measured curves should be done in the fold *Obliczenia* (Figure 4). It presents the $I_d=f(U_d)$characteristics for the diode or $I_C=f(I_B)$ characteristics for the transistor. Before, for the correct calculations of the currents and voltages, the user has to choose the type of the circuit used (*diody* for diodes, *tranzystor p-n-p* for p-n-p transistor), the source of the data (*Z bieżącego pomiaru* for the recently measured data), and the gain *k* used in channel 2 (*Podaj współczynnik wzmocnienia*), see dialog boxes in Figure 5.

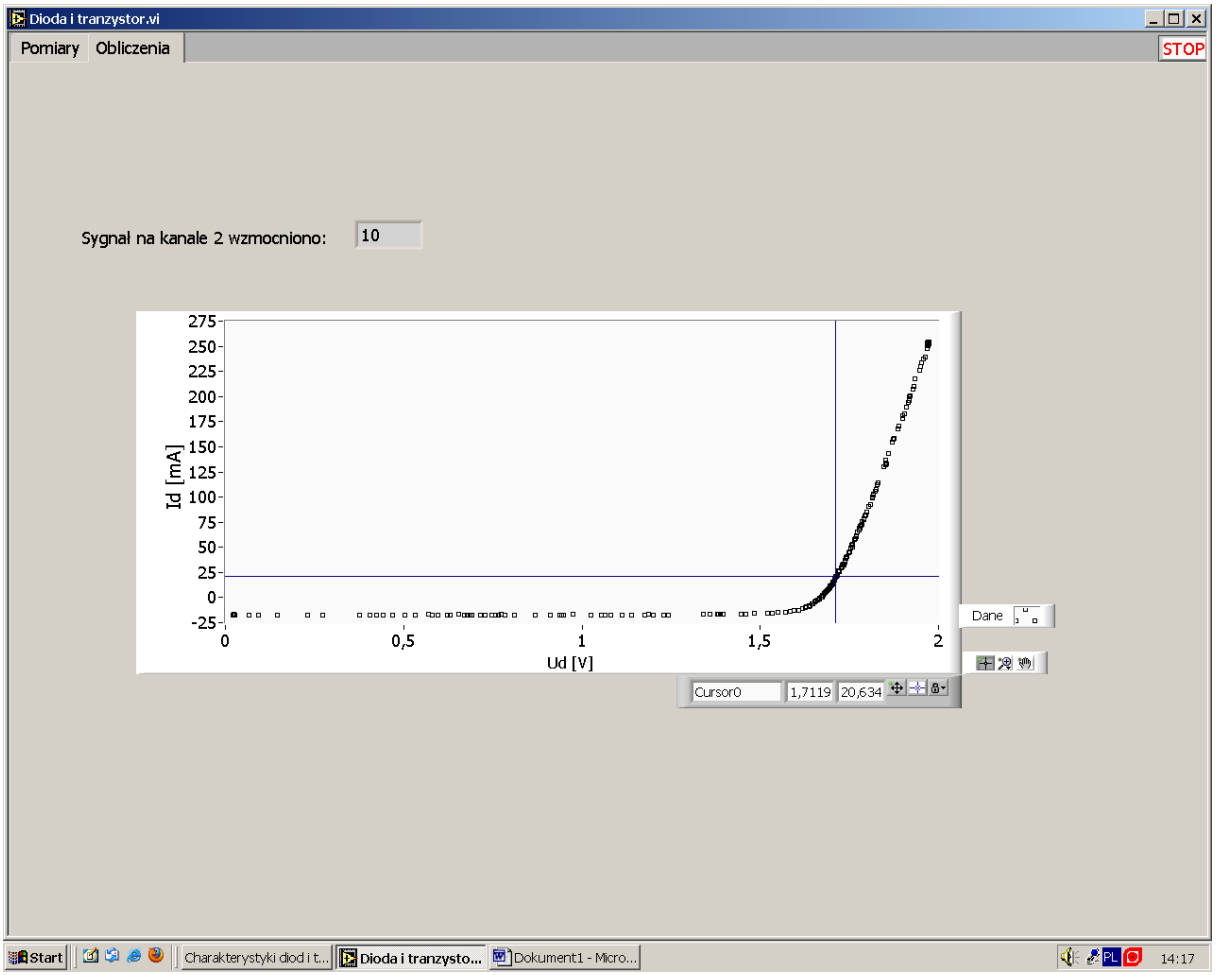

Figure 4. Front panel of the fold for the analysis for the diode.

The analysis for the diodes is based on the determination, using cursors on the plot (Figure 4), of the threshold voltage $U_d$for which the diode starts to pass the current. The discussion of these values for different diodes should be done. The aim of the analysis for the transistor is to determine the amplification factor β (equation 1) by fitting the straight line to the $I_C=f(I_B)$ plot (red line in Figure 6). After setting the proper line slope and intercept values, remember to press STOP button before next measurements.

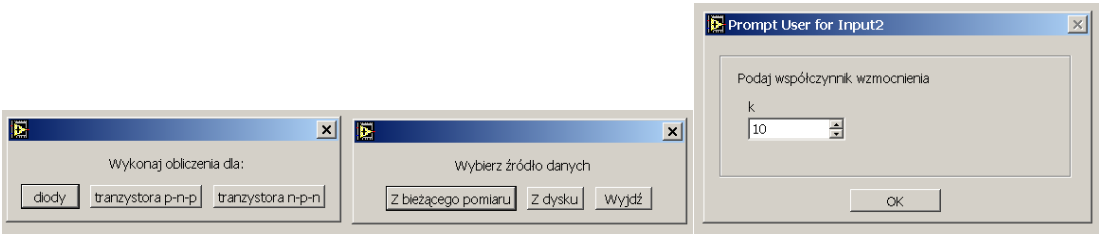

Figure 5. Dialog windows that appear before activating the analysis fold.

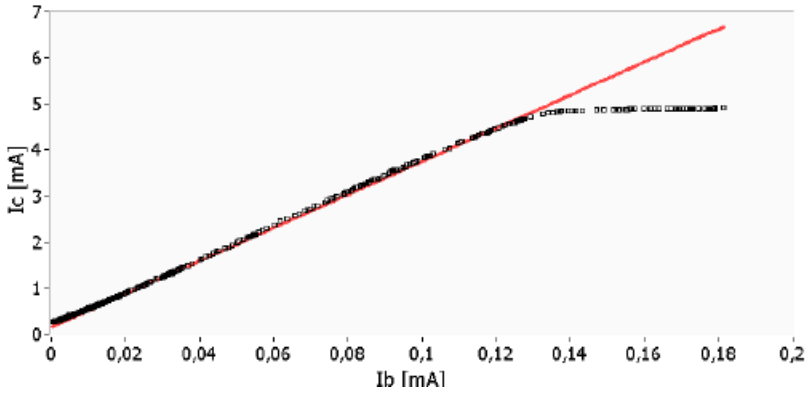

Figure 6. An example of $I_C=f(I_B)$ characteristic for p-n-p transistor.