Home-Made Electronic Components Characterization System for Electronics Course at Undergraduate Level

KHAIRURRIJAL*), MIKRAJUDDIN ABDULLAH, MUHAMMAD M. MUNIR,
ASEP SUHENDI AND ARIF SURACHMAN
Physics of Electronic Materials Research Division
Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung
Jalan Ganesa 10, Bandung 40132
INDONESIA

Abstract: - A home-made and easy to use I-V meter, which consists of a programmable voltage source, a subnano-amperemeter, a test fixture where a device under test is put on, and an RS232 interface, has been developed. The I-V meter can be a tool in the laboratory to strengthen concepts delivered in lectures. In addition, the I-V meter can also make students familiar with the characteristic equations of electronic components. The I-V characteristics of high value resistor and diode have been obtained and the results have been compared to the theory.

Key-Words: - Diode, Electrometer, Electronics, I-V meter, Microcontroller, Resistor

1 Introduction

The FI2104 Electronics, which is a 3-credit unit (CU) course with a one-CU laboratory work offered in the third semester, must be taken by the undergraduate students at Physics Study Program of Institut Teknologi Bandung. This course gives a good understanding of the electrical characteristics of electronic components and their application in simple electronic circuits while the laboratory work is to strengthen concepts delivered in lectures.

Electrical characteristics of the electronic components are obtained by using current-voltage (I-V) meter, which is a primary tool in research laboratories [1,2]. However, the commercial I-V meters are not only expensive but also difficult to operate and set-up.

Here, we present a home-made I-V meter system, which is easily used by the undergraduate students to characterize electronic components in the laboratory. The obtained I-V characteristics will be discussed on the basis of theory that the students get in lectures.

2 Hardware Description

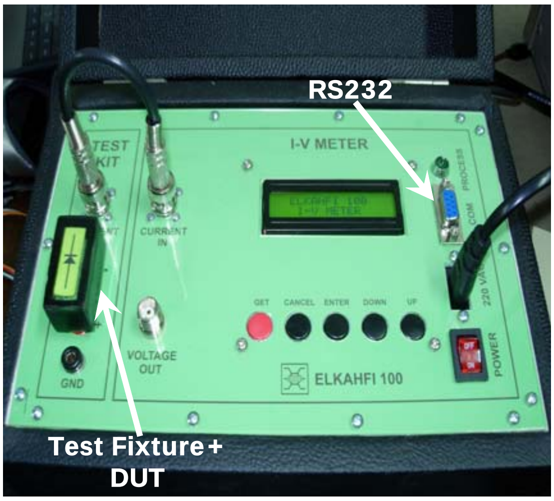
The I-V meter system depicted in Fig. 1 consists of a programmable voltage source, a subnano-amperemeter, and a test fixture where a device under test (DUT) is put on, an RS232 interface for the communication between the meter and computer. It has been realized by two main integrated circuits (ICs), i.e. the Silicon Laboratories C8051F006 and Burr-Brown LOG112 SoC (System-On-a-Chip) [3,4].

The programmable DC voltage source is formed by the microcontroller, 12-bit DAC (digital to analog converter), and signal conditioner. The 12 bit digital data provided by the microcontroller is supplied to the DAC and processed by the signal conditioner. The output of the DC voltage source is in the range of 0 to 9.6 volts.

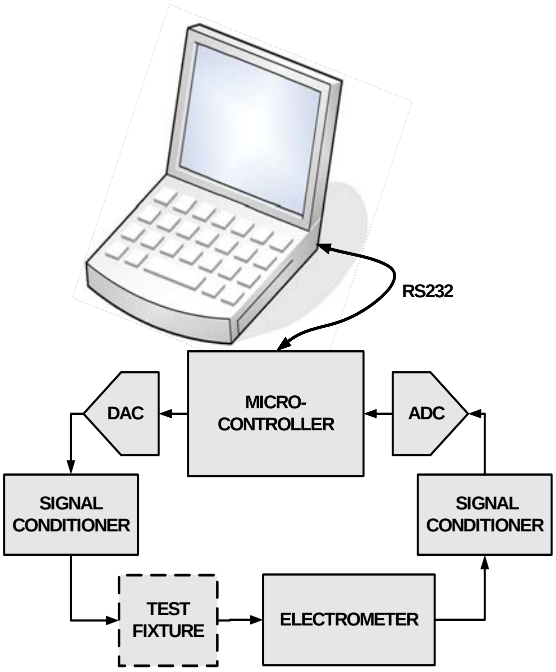
The electrometer along with the 12-bit ADC (analog to digital converter) and signal conditioner behave as a subnano-amperemeter. The subnano-amperemeter is able to measure current from 14 mA down to 100 pA.

The voltage from the voltage source and current measured by subnano-amperemeter are displayed by the LCD and stored in the high capacity memory of the I-V meter. The collected voltage and current pairs are then sent to a computer via the RS232 interface for further processing by the Microsoft Excel.

Principally, the present measuring system is the same as that explained elsewhere [5]. However, some improvements in the hardware as well as software have been performed so that the present I-V meter has increased performance. Calibration of the I-V meter was done by employing the Fluke 5100B series calibrator [6]. Its performance was evaluated by comparing I-V curves obtained from the present I-V meter and Keithley 617 Programmable Electrometer [7]. It was found that the curves are comparable.



(a)



(b)

Fig.1. (a) A home-made I-V meter and (b) its block diagram.

3 Characterization Results and Discussion

In the lecture portion of the course, the students have studied the theory of electronic components such as resistor and diode. After the students have done laboratory works on characterization of resistor and diode, they become familiar with equations representing current-voltage relationship of the electronic components.

The I-V meter is very useful when characterizing high value resistors because the measured current can be down to several hundreds pA. In addition, the I-V meter can show very low diode current in the range of several nA to the students.

Putting a resistor or diode as a DUT on the test fixture and applying a voltage from the programmable voltage source to the DUT, a current will flow through the DUT and the subnano-amperemeter will measure the current. Pairs of applied voltage and measured current sent to the computer are then processed by Microsoft Excel to get I-V curves.

Figure 2 depicts the electrical characteristic of high value resistor 99 MΩ ± 10%. For the applied voltage less than 9 volts, the measured current is lower than 9×10^{-8} A. It is also found that the I-V curve of the resistor fits very well Eq. (1).

$$I = 10^{-8}\, V \,, \qquad (1)$$

with a high linear regression coefficient R^2 of 0.9995.

Noting that the Ohm law gives the relation

$$I = \frac{V}{R}\,, \qquad (2)$$

where R is the resistance of a resistor under test, the I-V curve in Fig. 2 produces the resistance of 100 MΩ. The obtained resistance is therefore still in the range of 99 MΩ ± 10%.

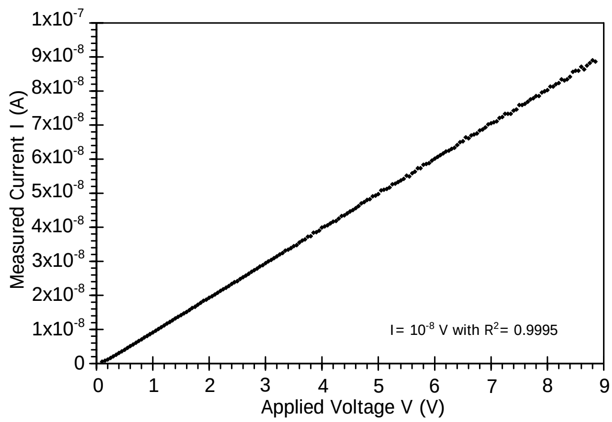
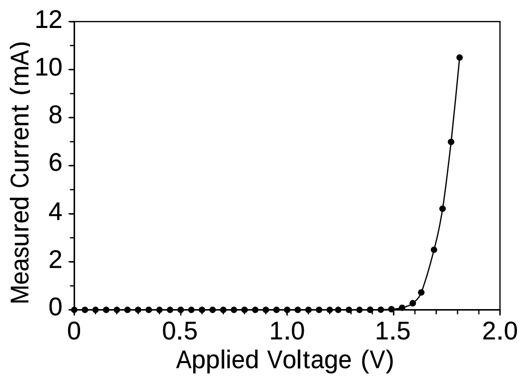


Fig. 2. An I-V curve of a high value resistor of 99 MΩ ± 10%.

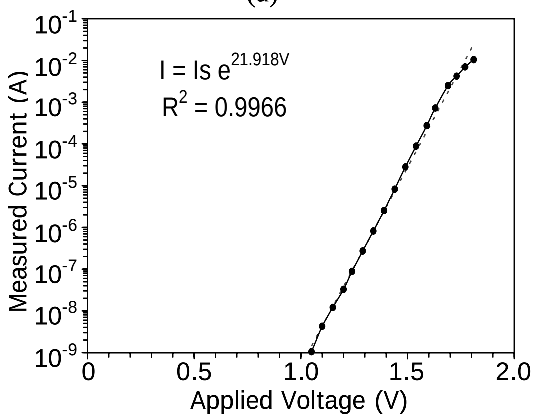
The I-V characteristic of a light emitting diode (LED) under forward bias is shown Fig. 3. It is given in Fig. 3(b) that the I-V curve is represented very well by the equation of $I = I_s \exp(21.918V)$. Since the diode equation for $V/V_T >> 1$ is written as [8,9]

$$I = I_0 \exp(V / V_T)\,, \qquad (3)$$

where I_o is the saturation current and V_T is the thermal voltage, the LED has the thermal voltage V_T of 0.045 V. The saturation current I_o, which is got from the I-V curve of the diode under reverse bias, is to be around 10^{-10} A.



(a)



(b)

Fig. 3. I-V characteristics of a LED under forward bias. (a). linear plot and (b) semilog plot.

4 Conclusion

We have built a home-made and easy to use I-V meter that can be a students' tool in the laboratory to strengthen concepts that they have got after attending lectures and to get familiar with the characteristic equations of electronic components. The I-V characteristics of high value resistor and diode have been obtained by the home-made I-V meter and the results have been discussed on the basis of theory delivered in lecture.

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