

Optoelectronic Devices Characterization Using Low Cost Data Acquisition System

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Abstract – Development of a simple and cost-effective system dedicated for optoelectronic device characterization is reported in present paper. The system consists of low-cost data acquisition module and graphical programming environment. Designed with education in mind, the presented system is a comprehensive tool for teaching the base characteristics of optoelectronic devices.

Keywords – Data Acquisition System, I-V characteristics, LabVIEW, Optoelectronic, Virtual instrumentation

I. INTRODUCTION

Optoelectronics has become an important part of human lives. Examples include light-emitting diodes in various appliances, photodetectors in elevator doors and digital cameras, and laser diodes that transmit phone calls through glass fibers. Such optoelectronic devices take advantage of sophisticated interactions between electrons and light [4]. For these reasons recently growing number of courses and educational laboratories are developed in this area. The need for enhanced laboratory teaching aids is obvious for better understanding of basic optoelectronic concepts to students. Although there are currently a number of powerful educational products in the market, they are often very expensive and are sometimes inappropriate for low budget educational institutions [1, 7].

On the other hand I-V measurements are made by many various types of customers. Many engineering and physics research facilities use these systems regularly to further measurement theory and component theory. Almost all educational facilities use these systems as a tool to further understanding and research. The applications of these tests are almost limitless. It may seem strange that something seemingly insignificant like the slope of a curve can lead to such incredible conclusions, but the interpretation of the test results is the key to relating this information to something useful. Traditionally, these measurements have been dominated by large rack-mounted measurement systems. These instruments came with a several thousand dollars price tag [7]. The measurement parameters were not nearly as flexible as a computer-based solution. The measurement industry sold these high cost systems each year by providing only small upgrades, but still raising the price with each new version. Today, it is common to see LabVIEW used to

automate all these expensive systems. With the combination of low cost hardware and graphical software, a PC-based measurement system could be built that could compete with many of the traditional measurement systems.

The present paper describes an automated system for optoelectronic devices characterization. The system encompasses a personal computer, a set of inexpensive hardware tools for data acquisition and control and graphical programming environment in order to make learning for students attractive and innovative.

The purpose of the laboratory is to invoke student interest by exposing them to various modern tools in comparison to very conventional as well as boring existing optics laboratories. The use of this scientific graphical programming software will help in performing various measurements and calculations with ease. The automation of the experiments will also save great amount of experimentation time and procurement of costly equipments dedicated to each experiment thus providing an efficient way to carry out studies with reduced financial constraints.

II. LED BASIC ELECTRICAL PROPERTIES

Light Emitting Diodes (LEDs) are the most widely used optical sources for optical communication and relevant studies. A light emitting diode works on the principle of spontaneous emission. The regions of operation of LEDs can be identified by studying the two most important characteristics, device current vs. device voltage (I-V) characteristics and optical output power vs. device current (P-I) characteristics.

LEDs are monochromatic devices. The color is determined by the bandgap of the semiconductor used to make them. Red, green, yellow and blue LEDs are fairly common. White light contains all colors and cannot be directly created by a single LED. The most common form of white LED really isn't white. It's an Indium Gallium Nitride blue LED coated with a phosphor that, when excited by the blue LED light, emits a broad range spectrum that in addition to the blue emission makes a fairly white light.

The current-voltage (I-V) characteristic of a p-n junction was first developed by Shockley and the equation describing the I-V curve of a p-n junction diode is therefore referred to as the Shockley equation [4]. The Shockley equation for a diode with cross-sectional area A is given by:

$$I = eA \left(\sqrt{\frac{D_P}{\tau_P}} \frac{n_i^2}{N_D} + \sqrt{\frac{D_N}{\tau_N}} \frac{n_i^2}{N_A} \right) \left(e^{\frac{eV}{kT}} - 1 \right) \quad (1)$$

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where e is elementary charge, k is Boltzmann constant, T is absolute temperature in K , N_A and N_D are the acceptor and donor concentration, respectively, n_i is the intrinsic carrier concentration of the semiconductor, $D_{n,p}$ and $\tau_{n,p}$ are the electron and hole diffusion constants and the electron and hole minority carrier lifetimes, respectively.

Under reverse bias conditions, the diode current saturates and the saturation current is given by the factor preceding the exponential function in the Shockley equation. Under typical forward bias conditions, the diode voltage is $V \gg kT/e$, and thus [4]:

$$I = I_S e^{\frac{eV}{MkT}} \quad (2)$$

where M is the ideality factor of the diode. For a perfect diode, the ideality factor has a value of unity. For real diodes, the ideality factor assumes values of typically $M = 1.1 - 1.5$. However, values as high as $M = 2.0$ have been found for III-V arsenide and phosphide diodes. Values as high as $M = 6.0$ have been found for GaN/GaInN diodes. [4]

In addition a diode has unwanted or parasitic resistances. A series resistance can be caused by excessive contact resistance or by the resistance of the neutral regions. A parallel resistance can be caused by any channel that bypasses the p-n junction. This bypass can be caused by damaged regions of the p-n junction or by surface imperfections [2, 5].

III. HARDWARE SET-UP OF THE VIRTUAL SYSTEM

The automated characterization system is built using LabVIEW and its compatible Data Acquisition (DAQ) card, NI USB-6008 for interfacing. The experimental set-up and its working for the different characteristic studies are explained in following section.

The National Instruments USB-6008 provides basic data acquisition functionality for applications such as simple data logging, portable measurements and academic lab experiments. It is affordable for student use, but powerful enough for more sophisticated measurement applications [6].

The NI USB 6008 uses last achievement in technology to deliver high-performance and reliable data acquisition capabilities to meet a wide range of application requirements. This device has 12-bit performance on 8 singled-end analogue inputs. The module features digital triggering capability, as well as one 24-bit, 20 MHz counter/timers, and 12 digital I/O lines. It also features two 12-bit analogue outputs.

The experimental set-up is shown in Fig. 1. This schematic shows the test circuit for the two terminal I-V measurement. There are only two components, the device under test (LED in this example) and the load resistor.

Analog Output Channel (AO0) of the NI USB 6008 module is used to supply voltage to the DUT in user defined steps. Volts and the corresponding device voltage is read using Analog Input Channel 0 (AI0). The difference in the two voltages is then used to calculate the current flowing through the series resistor, R which is same as the device current in this case. This current is plotted with respect to the voltage read from AI0 thus generating the I-V characteristic curve for

the DUT. The value of the load resistor should be known as accurately as possible for accurate measurements.

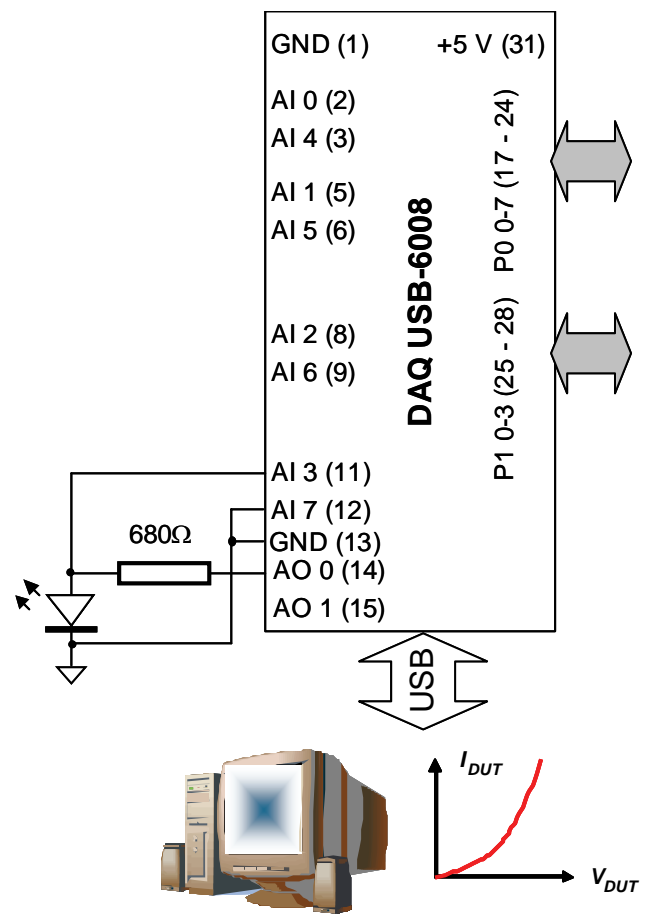


Fig. 1. The components of virtual system

It is known that LabVIEW is a highly productive graphical programming environment that combines easy-to-use graphical development with the flexibility of a powerful programming language. It offers an intuitive environment, tightly integrated with measurement hardware, for engineers and scientists to quickly produce solutions for data acquisition, data analysis and data presentation [3].

One of the more power features of LabVIEW is the build in connection with DAQmx data acquisition device drivers. It is a new type of drivers which architectural changes and new features allow DAQmx to deliver increased ease-of-use and improved performance over the traditional driver. This approach saves development time and improves the performance of data acquisition applications [3]. One of the ways DAQmx saves development time is by providing only a small number of functions to expose. This means that all of the functionality of a multifunction device is programmed with the same set of functions. In LabVIEW, this is possible because polymorphic software component accepts multiple data types for one or more input and output terminals. Another significant feature of the DAQmx architecture is measurement multithreading which means that multiple data acquisition operations can occur simultaneously.

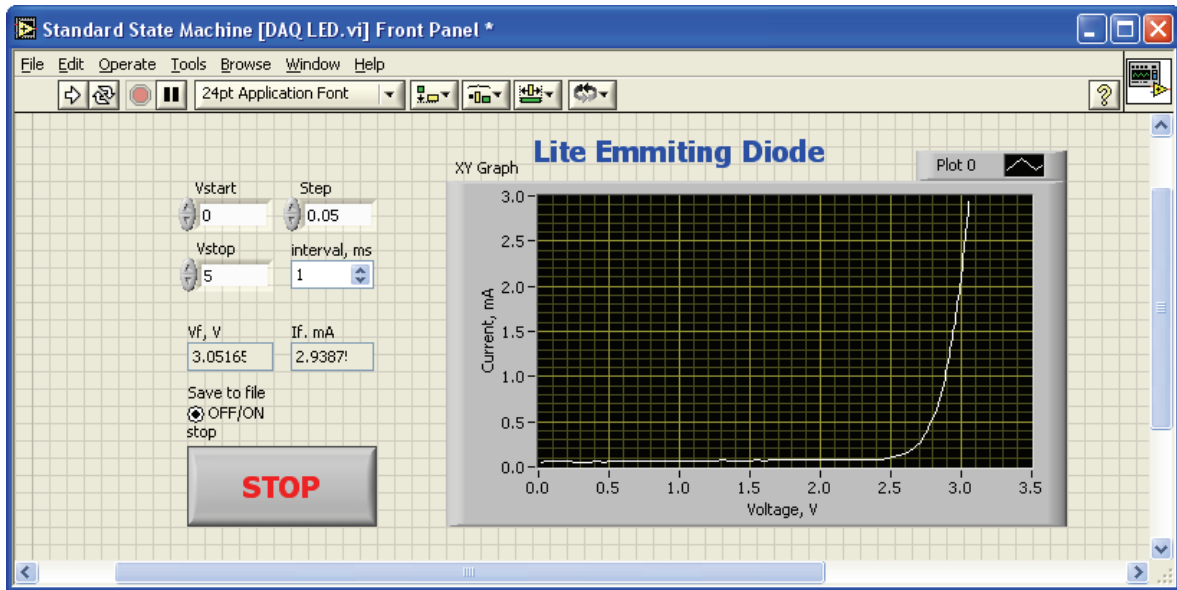


Fig. 3. The I-V characteristic of white LED

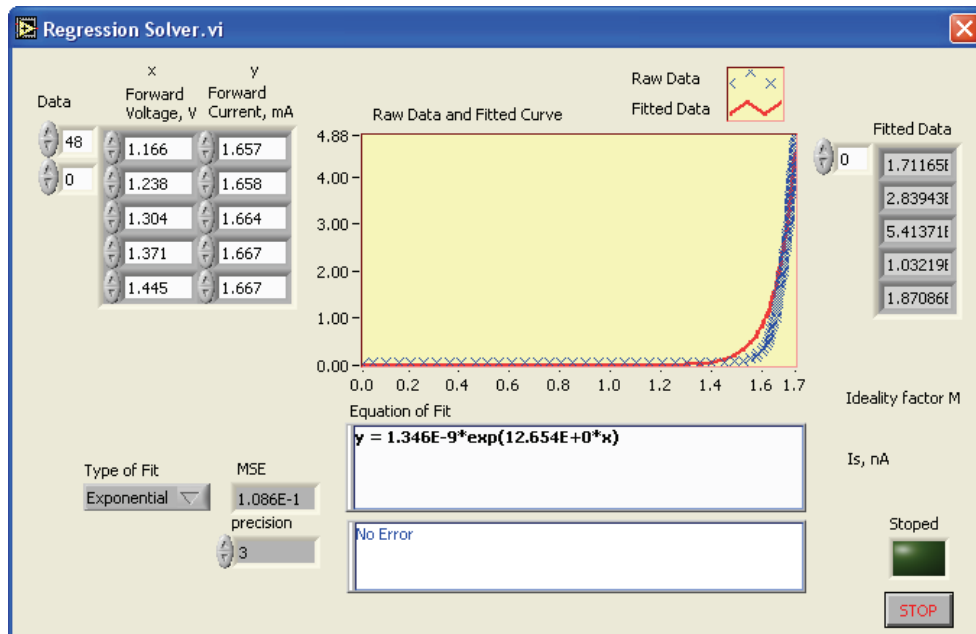


Fig. 4. Front panel of virtual instrument for exponential regression

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