DESIGNING AN OPTOELECTRONIC CHARACTERIZATION SYSTEM FOR AN EDUCATIONAL LABORATORY

Todor Stoyanov Djamiykov

Faculty of Electronics and Technologies, Technical University of Sofia, Studenstki Grad, TU-Sofia, block 1, room 1428, 1797, Sofia, Bulgaria, e-mail: tsd@tu-sofia.bg

This paper describes a simple, cost-effective parameter analysis system, built of low-cost data acquisition module, easily obtainable components and programmed using a graphical programming environment. The system is designed for educational purpose and can be used for static characterization of optoelectronic devices, sensors and other semiconductors. In the presented paper is considered some topics concerning the connectivity between data acquisition board and integrated parametric measure unit. Such considerations are important in order to achieve accurate I-V characteristics of investigated optoelectronic devices. The designed system's hardware is powerful and capable of performing a more of the tests required for the laboratory experiments.

Keywords: Data acquisition, I-V characteristics, Optoelectronic, Parametric Measure Unit, Virtual instrumentation

1. INTRODUCTION

Study and investigation of almost all electronic components always begins with the characterization of its DC performance. Instead of power supplies and voltmeters parametric measure unit (PMU) with source-measure capability can be used. This allows to fully characterizing the device under test (DUT) from fempto-Ampere up to its maximum current, and in all four quadrants [1, 2]. In other words forward and reverse currents and voltages are measured with the same PMU unit. Usually, in case of a device with four terminals, all of them (including substrate) are connected to individual PMUs in order to avoid recabling during the forward and reverse measurements.

In this paper is suggested a simple, low cost parameter analysis system, dedicated for optoelectronic educational laboratory.

To address the needs of this high throughput laboratory, the optoelectronic characterization system had to meet several requirements:

• It had to be relatively inexpensive.

• It had to allow students to determine I–V curves of optoelectronic devices (LEDs, Photodiodes, Photoresistors, optocouplers, and other sensors devices).

• It had to make measurements on devices in voltage range from 1mV to 10V and current range 5 nA to 500 mA.

• The results it generated should correlate well with those obtained using more sophisticated systems.

• It should allow students to minimize the time invested in learning how to make measurements so they can spend more time analyzing the results of those measurements. The system must be fully automated to make this possible.

• It had to provide a simple method of data export so that results can be included in laboratory reports, so the system had to be capable of linking to a file server.

• To simplify system maintenance and upgrades, a simple, well-established, high level programming language had to be used to create the application software.

2. I-V CHARACTERISTICS OF OPTOELECTRONIC DEVICES

As electrical component the Light Emitting Diode (LED) is described by a number of characteristics and parameters. I-V characteristic is of great importance in order to understand the property of any LED. Fig 1 shows typical connections and instruments needed to measure I-V characteristic of the LED point by point.

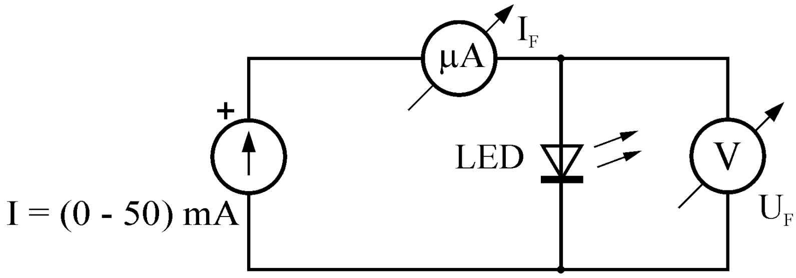

Fig. 1 Base test circuit for I-V characteristic measurement of a LED

The current source, from the figure 1 generates current flowing into LED and voltage drop across diode is measure for each current change. In order to measure most popular power LED it is necessary to use current source with output current up to 1A and voltage 4V. On the other hand the used voltmeter must be capable to measure voltage in range 0 to 5V and ammeter must be capable to measure current in range 0 to 1A.

The other popular optoelectronic device is photodiode. The most common circuit to measure its I-V characteristic is shown in the circuit diagram in fig.2. The photodiode is exposing to illumination generated by light reference (et-source). This light reference can be controlled by supply current.

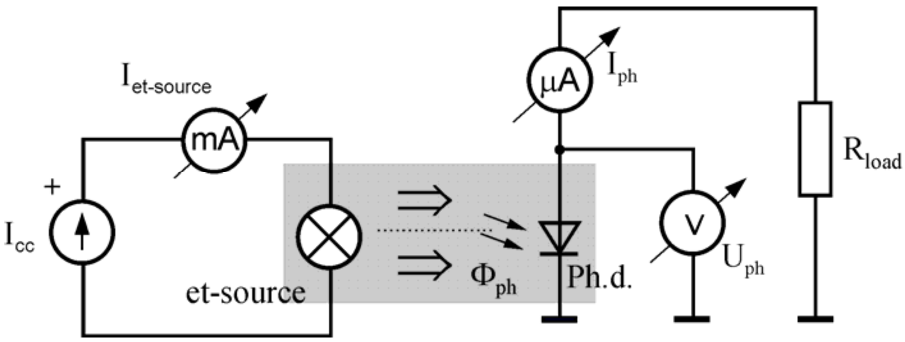

Fig. 2 Electrical and physical configuration of test circuit for I-V characteristic measurement of a photodiode.

Electrical parameters of photodiode can be measured with microammeter with current range from 1 μA to 10 mA and voltmeter with up to 10V voltage range.

In similar way are measured and investigated I-V characteristics of other optoelectronic devices. All test circuits can be grouped in general circuit containing current ore voltage source and one ammeter or voltmeter connected directly to device under test.

3. SYSTEM DESCRIPTION

The block diagram of designed virtual system for static characteristic of optoelectronic devices is shown in fig. 3. The system includes a modular DAQ controlled by computer platform (PC) via USB two parametric measurement units (PMU1 and PMU2) and a set of additional electronic components. Two PMU is involved in order to test various devices with four terminals.

Because the low cost modular DAQ has only two analog outputs it is necessary to multiplex these outputs to eight. This can be done with two sample and hold amplifiers SMP04 produced from Analog Devices [4]. In order to achieve output voltage from -10V to +10V additional operational amplifiers is used.

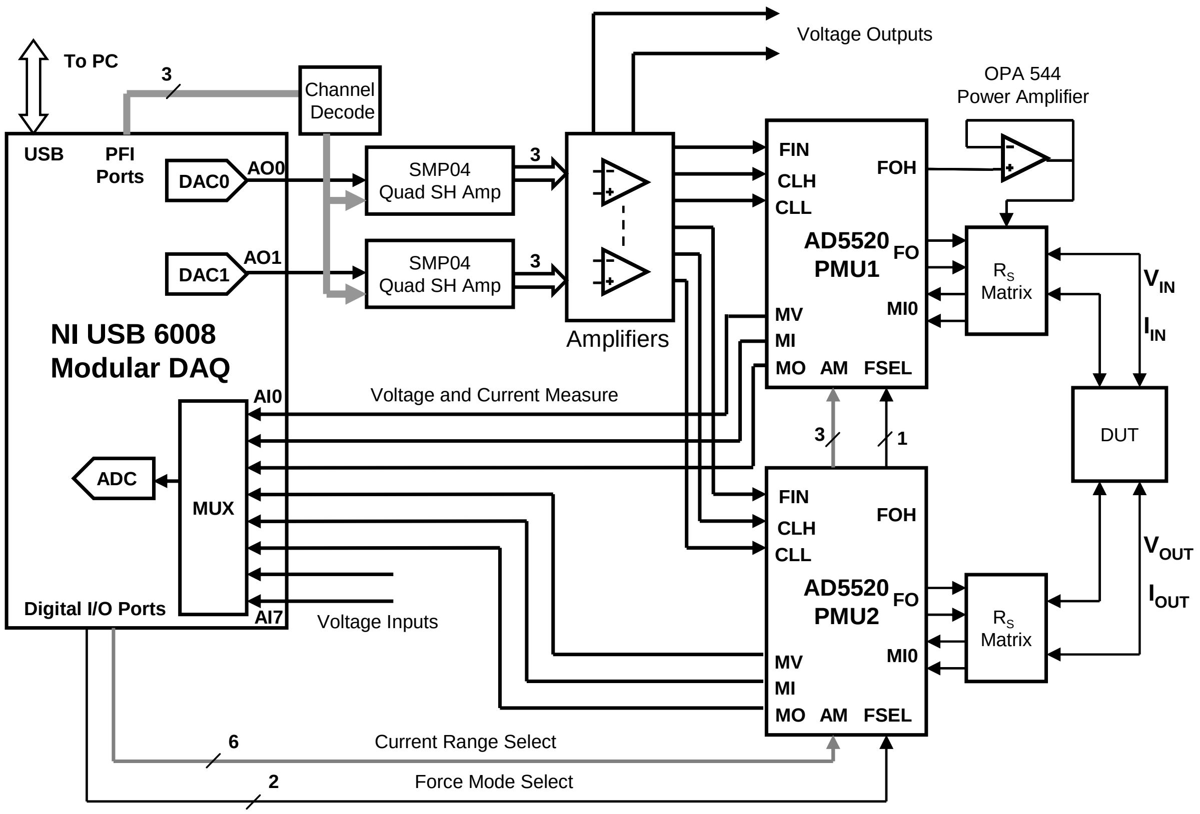

Fig. 3 Block diagram of designed system

One of the more important functions of the presented block diagram is fulfilled by integrated circuit AD5520. The AD5520 is a single-channel, Parametric Measurement Unit (PMU) for use in semiconductor test and measurement equipment and instrumentation. This circuit contains programmable modes to force a voltage and measure the corresponding current, or force a current and measure the voltage [5]. The AD5520 can force or measure voltage over a ±11 V range. In addition, this circuit can force or measure currents up to ±6 mA with its on-board force amplifier over four distinct ranges according to selected external sense resistors. An external power amplifier is required for additional two wider current ranges. In this development as high power amplifier is selected OPA544 capable to drive current up to ±4 A.

The presented system supports two modes of operation: force current/measure voltage and force voltage/measure current. FSEL is an input that determines whether the PMU itself forces a voltage or current.

In the force voltage mode, the voltage at analog input FIN is mapped directly to the voltage forced at the DUT. In these modes, the maximum voltage applied to the input corresponds to the maximum current outputs.

In force current mode, the voltage at FIN is now converted to a current through the following relationship:

$$I_{DUT} = \frac{V_{FIN}}{16R_S}, \quad (1)$$

where I_{DUT} is current flowing into investigated device, V_{FIN} is voltage applied to FIN input and R_S is sense resistor (actually there are six sense resistors for different current ranges labeled in fig. 3 as R_S matrix).

Clamp circuitry, which is also included on-chip AD5520, clamps the force amplifier's output if the voltage or current applied to the DUT exceeds the clamp levels. This voltage or current compliance is controlled from CLL and CLH inputs of the integrated circuit. The clamp circuitry also comes into play in the event of a short or open circuit. When in force current range, the voltage clamps protect the DUT from an open circuit. Likewise, when forcing a voltage and a short circuit occurs, the current clamps protect the DUT. The clamps also function to protect the DUT if a transient voltage or current spike occurs when changing to a different operating mode, or when programming the device to a different current range.

The important component of the designed I-V characterization system is a modular DAQ. The multifunctional DAQ boards perform a variety of tasks, including analog measurements and generation, digital measurements, and timing I/O. Using well-designed software drivers for modular DAQ, the engineers can quickly access functions during concurrent operation [6].

As voltage generation and measuring part of the virtual system reported in this presentation, the National Instruments' multifunctional DAQ USB-6008 is used. This is a part of new generation of portable low-cost modular DAQ that provides connection to eight analog input (AI) channels, two analog output (AO) channels, 12 digital input/output (DIO) channels, and a 32-bit counter with a full-speed USB interface. It ships with one detachable screw terminal block for analog signals and one detachable screw terminal block for digital signals. The detailed connection between parametric measurement unit and DAQ is shown in fig. 4.

The DAQ is controlled from PC using high level application development environment [6]. One of the world's best virtual instrumentation software platforms is LabVIEW. This software is chosen as the development environment not only because of its unique capabilities to acquire, process and manipulating real world data, but also because it has the required data visualization capabilities.

4. CONNECTION BETWEEN DAQ AND PMU

A detailed notion about DAQ and PMU connectivity can be obtained from fig.4. In the figure are shown selected values for electronic components and the input and output pins of USB6008 and AD5520. The operational amplifiers A1 to A4 can be any with low input offset voltage and bias current.

In either two modes of operation the voltage drop across the sense resistors is used to measure the current flowing at the output. By sensing the voltage drop the DAQ can determine the current flowing through the resistor which is the same as the current flowing through the DUT. In presented development the values of sense resistors are selected to achieve the source and measure current ranges from 5µA to 500mA as is shown in fig.4.

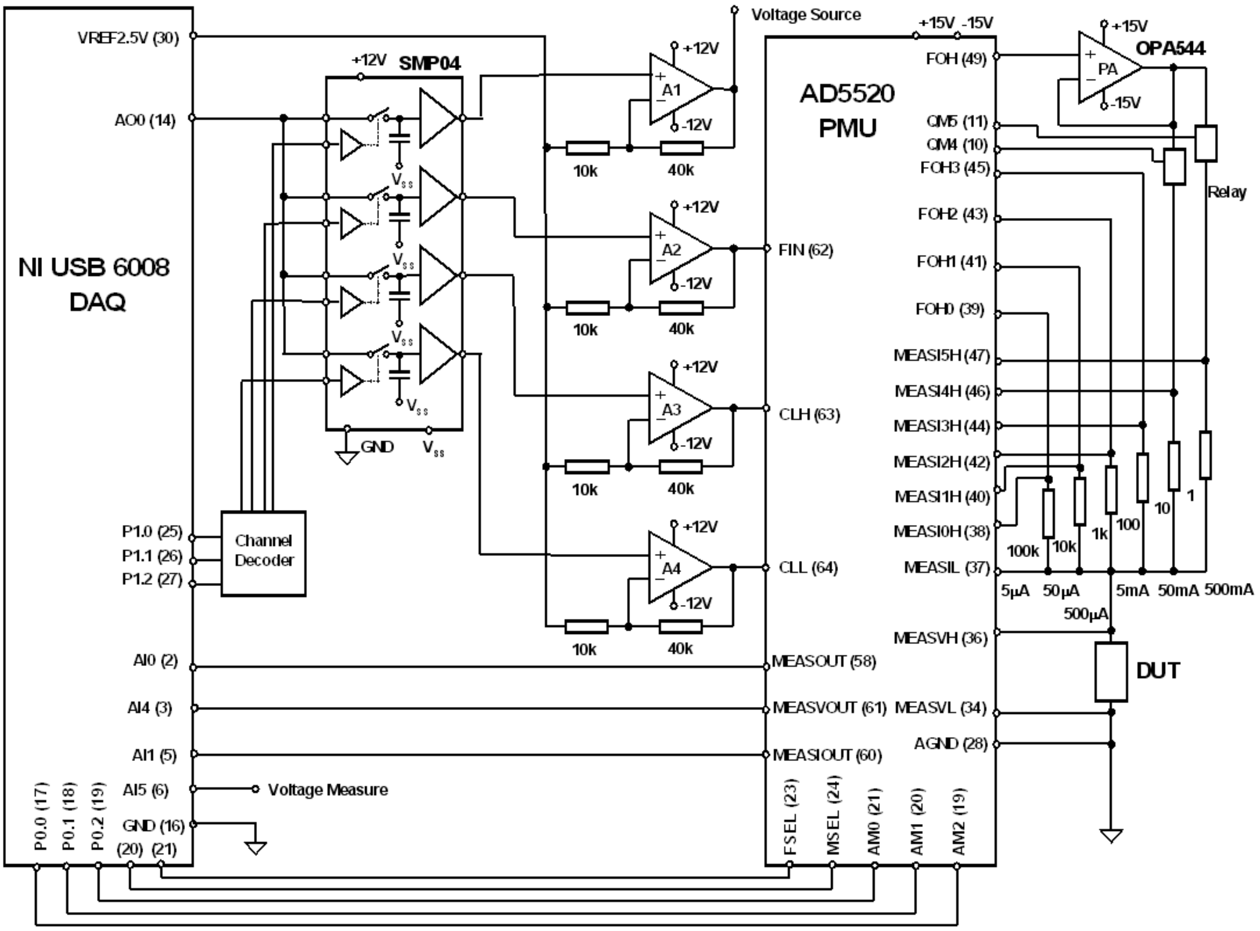

Fig. 4. Connection between DAQ and PMU

5. Conclusion

The optoelectronic devices characterization tool designed in this paper has demonstrated it is capable of a wide range of measurements on various devices treated in educational laboratory. The system has been designed using modern integrated parametric measure unit, portable modular DAQ, power operational amplifier and graphical software LabVIEW. More importantly, presented approach greatly simplifies the measurements and reduces the system's cost. While the measurements described here are simple enough for students to perform, they are also sufficiently sophisticated that senior students taking such a laboratory course as a terminal course in their undergraduate education may develop a greater appreciation of details described in more advanced electronics courses.

6. Acknowledgements

This investigation has been carried out in the framework of the research project № 08014ни-3/2008.

7. References

[1] Keithley Instruments, *Model 2400 SourceMeter Service Manual*, Cleveland, Ohio, U.S.A Document Number: 2400-902-01 Rev. D, 2006

[2] Stoyanov, I., B. Nikolova, G. Nikolov, *Computer-based measurement systems*, TU-Sofia, 1997, (in Bulgarian)

[3] Mark Johnson, "Photodetection and Measurement", McGraw-Hill, New York, 2003.

[4] Analog Devices, *CMOS Quad Sample-and-Hold Amplifier SMP04*, Data Sheet, rev.D, 1998.

[5] Analog Devices, *Per Pin Parametric Measurement Unit/Source Measure Unit AD5520*, Data Sheet, rev.B, 2006.

[6] Nikolov, G., B. Nikolova, M. Marinov, "Hazardous Gas Monitoring Using VI Server", Proceedings of the Technical University – Sofia, Vol. 57, book 2, 2007, ISSN 1311-0829, pp. 176-182.