Sensors Characterization System for Educational Laboratories

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Abstract - **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 sensors, electronic devices 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 electronic 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 system, I-V characteristics, Parametric Measure Unit, Virtual instrumentation**

I. Introduction

In robotics are used different types of sensors for controlling movable elements. In the articulation of walking robot with pneumatic muscles is needed a sensor for leg's angular deviation Fig 1. This sensor and many others could be realized by different physical ways: optical, magnetic, inductive and others. During the design and development of the various pneumatic muscles, it is needed to check the work abilities of sensors in different conditions. The results of these measurements are needed to be saved and archived for later analyzing.

The realization of this kind of measurement device for electric parameters of the sensors is difficult due to the large number of supply and measurement devices. Because all these reasons, the alternative is to implement universal stimulating and measurement device, managed by personal computer (PC). Specific integral schematic are being proposed by various producers. For reaching wanted technical parameters, it's needed turning on of other, additional electronic components. The management of the stimulating and measurement system is done by specialized software environment LabVIEW in order to realize modern virtual measurement tool.

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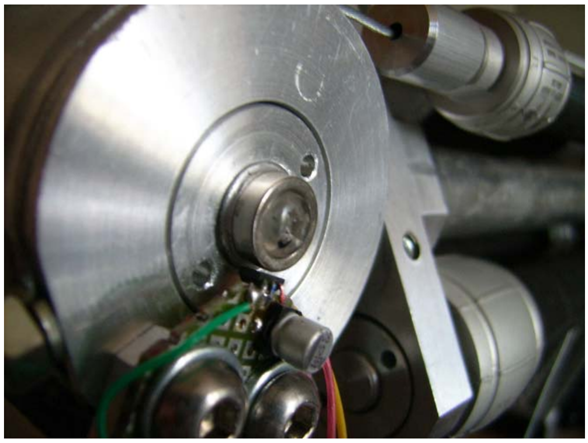

Fig. 1 Articulation of walking robot with magnetic sensor for angular deviation

II. Base Electrical Characteristics of Sensors

As electrical component the sensors for robots elbow is described by a number of characteristics and parameters. Voltage and electricity measurement, as well as their parametrical dependency is mail part of the measurement device for every single type sensor. Fig 2 shows typical connections and instruments needed to measure characteristic of the sensor point by point.

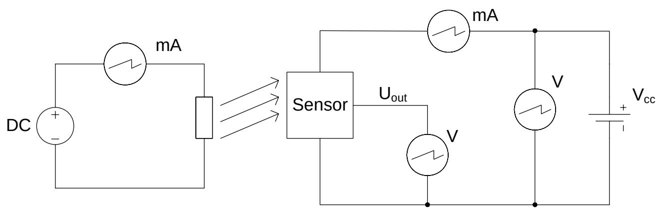

Fig. 2 Base test circuit for electrical characteristic of sensors

The voltage source V_{CC} from the Fig. 2 supplies the sensor. Its value could be different aiming working abilities control on measurement of the feeding. In the feeding chain is switched on miliampermeter for measurement of electricity consumption of the sensor. Depending on given influence of the DC source the sensor generates output signal which is measured with voltmeter. In order to measure most popular sensor for robots elbow it is necessary to use voltage source with output current up to 500 mA and voltage to 9 V. 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 500 mA.

By using and analyzing of different type of sensors, the test schema from Fig. 2 could be changed. In some cases, for example, sensors with magnetic type of electric influence insured from the DC source can be omited. Because of this, in proposed realization are provided two channels of the simulating measurement device in the laboratory system.

Electrical parameters of sensors 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 sensor devices. All test circuits can be grouped in general circuit containing current or voltage source and one ammeter or voltmeter connected directly to device under test.

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 electronic educational laboratory.

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

- It had to be relatively inexpensive.
- It had to allow students to determine I–V curves of electronic and 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.

III. System Description

The block diagram of designed virtual system for static characteristic of electronic 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.

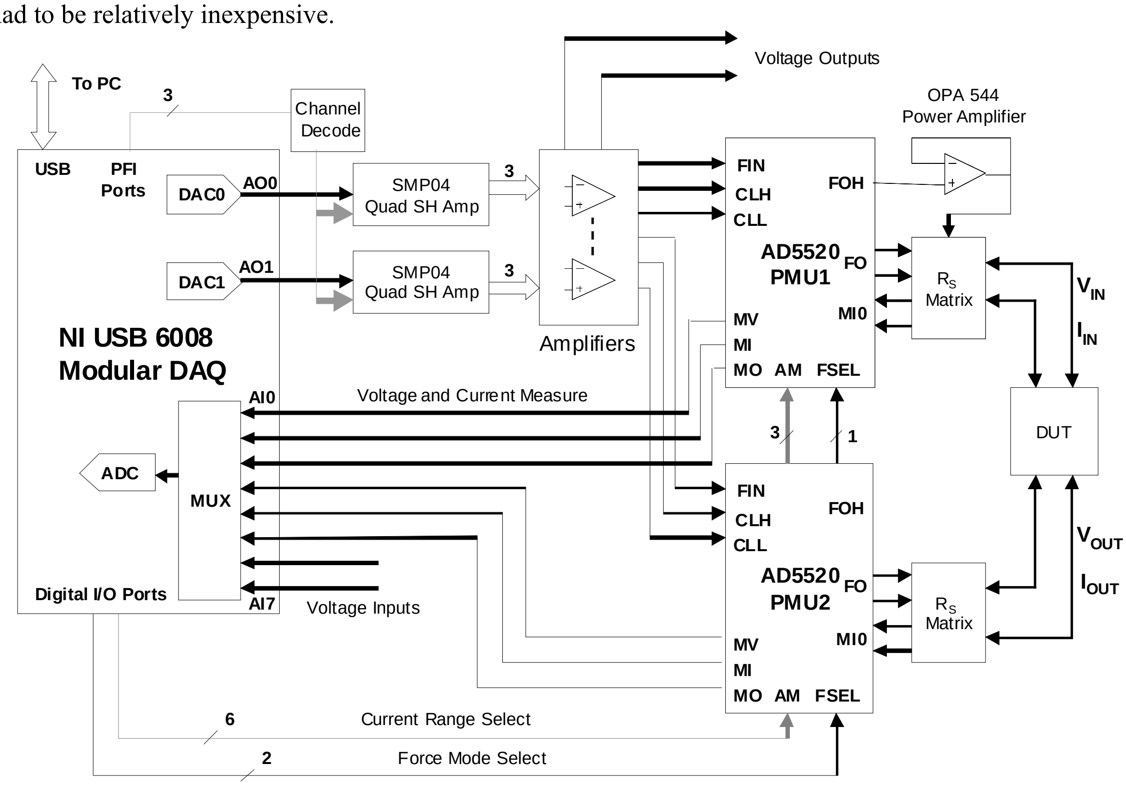

Fig. 3 Block diagram of designed system

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:

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

Where I_{DUT} is current flowing into investigated device, VFIN is voltage applied to FIN input and RS 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.

Because the software management of the virtual measurement system is relatively complicated, more complex software design pattern is needed to implement. The Classic State Machine is appropriate for programs and routines of low to medium complexity but is not flexible enough for complex virtual systems, top-level programs, and graphical user interfaces. Alternative state machine implementations that utilize queues and Event structures are more functional and efficient for these applications.

Most appropriate for the designed stimulating and measurement system is the queued state machine architecture. This software design pattern has gained support and widespread use in large LabVIEW based applications in the developer community over the last three years [7, 8]. Queued state machine is one essential architecture that significantly facilitates programming advanced LabVIEW based projects. A common application for this design pattern is in programs that send commands for asynchronous processing in a parallel loop so that event cases can exit code execution quickly and avoid lockup. Another application is in multiple parallel virtual instruments programming such as in parallel data acquisition, alarm monitoring, and results analysis, where this method empowers any parallel application to send and receive commands and data across other parallel applications with no data loss. Generally, a queued state machine is a LabVIEW programming method that sends commands and other data from multiple source points, such as from user events and from one or more parallel processes, and gets these handled in one state machine process in the order in which they were added to the queue [7]. With such approach, a state can determine not only the next state to be performed, but a series of states that must be performed in order. The series of states that must be executed are placed in a queue. The states are removed from the queue one at a time and executed in the order they were inserted into the queue. The base building blocks of the architecture are Event structure, Queues and data, While loop, Dequeuing element, Case structure, Error handling element and one or more parallel processes objects [8]. Event structure and parallel processes objects are the multiple producer processes responsible for sourcing commands and data and adding them to the queue. The innovative element in this architecture is that it uses a queue element data type consisting of a cluster that contains the enumerated type definition bundled together with a variant. The variant is used to pass data from one state to another, using the queue functions instead of shift registers. Programs that run in parallel with the main consumer process can be data communications, data acquisition, results analysis, and much more software components.

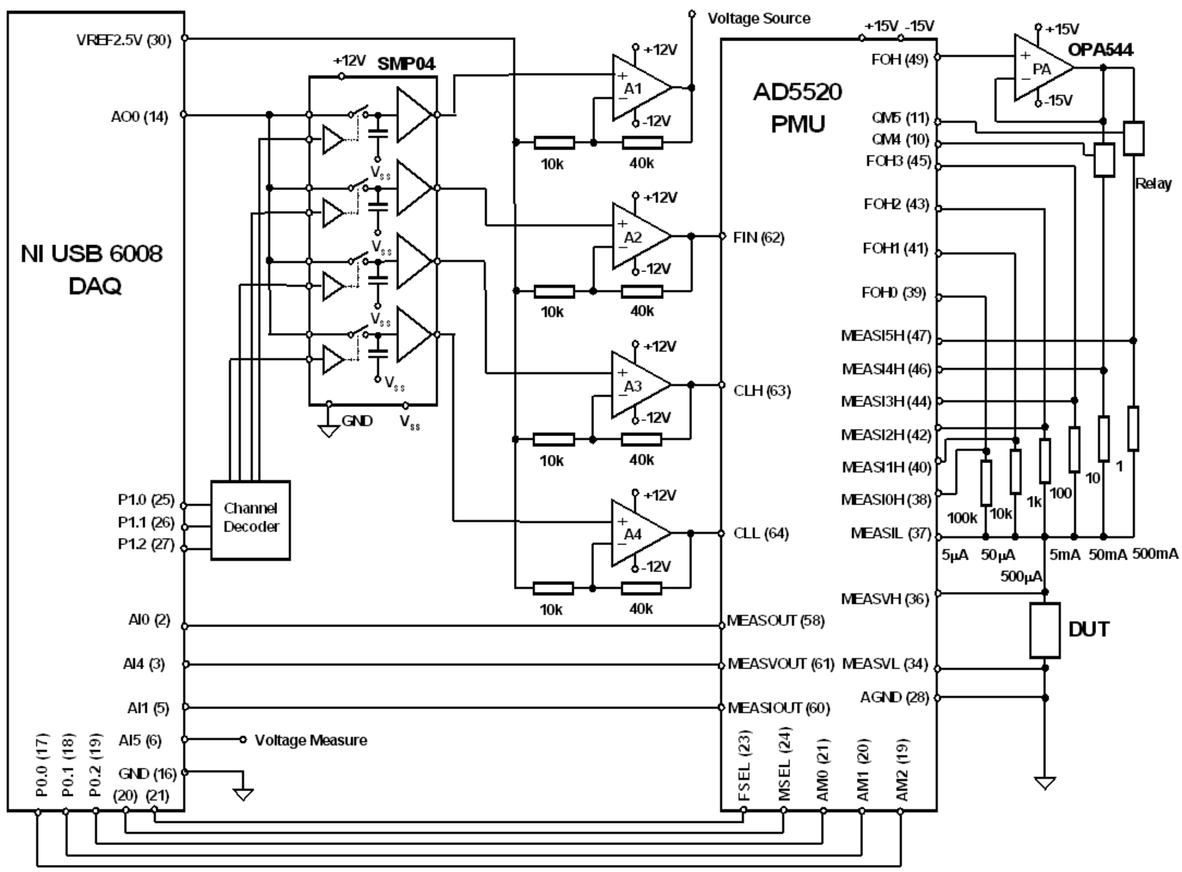

Fig. 4. Connection between DAQ and PMU.

IV. 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.

V. CONCLUSION

The sensors characterization tool presented in this paper offers excellent opportunities for measurements and investigation of various devices treated in educational laboratory. The system has been designed using modern integrated parametric measure unit, portable modular DAQ, power operational amplifiers and graphical programming environment LabVIEW. Presented approach significantly simplifies the measurement procedures and reduces the system's cost. Using the graphical programming environment allows easy upgrade of the system and the implementation of new features. The system can be used both in basic and in advanced courses in electronics, measurement and instrumentation.

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