Development of a wireless glove based on RFID Sensor

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***Abstract*— Sensor gloves are devices used to implement interfaces for human-machine interactions which are utilized in a wide range of applications such as control of embedded systems, translation of sign language, gestures recognition, medical rehabilitation etc. This paper presents a wireless sensor glove based on the use of RFID sensors. For this type of sensors, the energy supplied for measurement and for the communication of measured data back to the reader is provided exclusively by the reader via the electromagnetic field. Therefore, it was important for the device to be designed so that the power consumption be minimal. For this reason, our sensor glove is designed using devices capable of harvesting the electromagnetic energy from the reader, monitor this energy and consume it only when needed by using a microcontroller which features several very low power consumption modes.**

Keywords—wireless sensor glove, RFID sensor, flex sensor, low power modes.

I. Introduction

Increasing the processing capacity of computing systems makes them suitable for more and more applications. In order to facilitate the use of these systems it is important to develop advanced interfaces allowing for a simpler and natural interaction between man and machine.

An example of such an interface is the sensor glove which allows the development of useful applications in the most diverse areas. A sensor glove commonly consists of a glove on which are mounted different sensors that acquire data related to hand movement or position, finger bending, finger movement and position pressure, or other vital signals such as temperature, pulse, humidity etc.

Among the most important applications of sensor gloves we can mention the following: control of embedded systems, gesture detection, deciphering and translation of sign languages, development of new signaling systems [1], ambient assisted living, medical rehabilitation and the gaming industry.

A large number of applications make use of sensor gloves for gesture control of various embedded systems [2-4]. The advantage of this type of control is the use of a small number of natural gestures to control the embedded system (ex. moving of a car or a robotic arm [5]).

Another important area in which sensor gloves are used is that of deciphering and translating the sign language [6-9]. Such a language is used by people with hearing and spoken impairment.

Rehabilitation applications are aimed at detecting hand movements of patients who have suffered various conditions that affect their normal finger and hand movements [10]. Combined with a sensory-motor simulation system, such a sensor glove can help patients to learn again the control of movements in order to significantly reduce the effects of such diseases.

Over time, various implementations of sensor gloves have been created. The main problems encountered in creating such a glove are: the choice of the right sensors to measure the parameters required for the intended purpose (finger bending, finger movement or position in plane or in space, pressure, and temperature), fixing these sensors on the glove, making measurements and transmitting measured data to the processing system and eventually glove control.

Data transmission via wire is the easiest solution but it involves a large number of wires for guiding the signals from sensors to the data acquisition system. This makes the handling of the glove more difficult. Newer variants of sensor gloves use wireless technologies based on various communication protocols. A disadvantage of wireless systems is the need to provide a power supply local to the glove, usually in the form of a glove-mounted battery, for supplying the sensors and communication modules.

The sensor glove version proposed in this paper eliminates the need to employ such a battery by using the RFID technology [11]. In this case, the energy required to perform measurements and to transmit the result back to the reader is provided entirely by the reader. In this way, the sensor system of the glove will only work when it is energized by a reader, eliminating the need of batteries and their maintenance.

RFID technology was primarily developed to identify beings or objects, which are stationary or moving by using RF waves. The most important features of RFID technologies are: identification without contact, unobtrusive identification (radio waves can pass through many types of materials such as plastics or textiles, wood, masonry, water etc.), identification of items in places with special conditions (hard-to-reach, presence of high heat, presence of chemicals or biological contaminants, radioactivity etc), and using no direct visibility identification (no line-of-sight).

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The basic structure of an RFID system must contain at least one RFID tag and one RFID reader. The RFID technology is using four frequency bands: LF - Low Frequency (30 kHz to 300 kHz), HF - High Frequency (3 MHz to 30 MHz), UHF - Ultra High Frequency (300 MHz ÷ 1 GHz) and Microwaves (>1 GHz). The following criteria are used to select the frequency of RFID systems: the RF wave propagation pattern in the presence of various materials, the distance between the reader and the tag, the maximum data transfer rate, the immunity to external RF disturbances, the cost of the RFID components, etc.

The communication between the reader and the tags is based on standardized protocols for each frequency band. For example, the EPC Class 1 Gen 1, EPC Class 1 Gen 2 and ISO 18000-6A / 6B / 6C are defined for the UHF band. Additional information on RFID technologies and systems can be found in [12,13].

RFID technology has been used successfully not only for identification but also for the development of sensor applications [14]. In this type of applications, sensors are connected to one active or passive RFID tag. When energized, the tag will transmit to the reader the identification information and data gathered from the sensors.

In this paper we present the design and test of a sensor glove based on an RFID tag sensor working in the UHF band.

II. System for Controlling a Wireless Glove Using an RFID Sensor

In this section, a system for reading data from a wireless glove using an RFID sensor is proposed and presented. The elements of the systems are shown in Fig. 1.

The system consists of a glove equipped with a set of flex resistors whose resistance is read using an RFID platform from Farsens. Measurements of flex sensors are controlled by an RFID reader who sends commands to the RFID sensor and also powers it via the electromagnetic field. The reader is connected using a USB cable or wireless connection to a PC, tablet or smartphone. Data received from the sensor can then be processed and interpreted according to the application.

The development of the wireless glove has been done in two stages. In the first stage the design and development of the acquisition part of the sensor and communication with the RFID front end has been performed. In the second stage the prototype of the final sensor including the RFID platform and the sensor part has been developed.

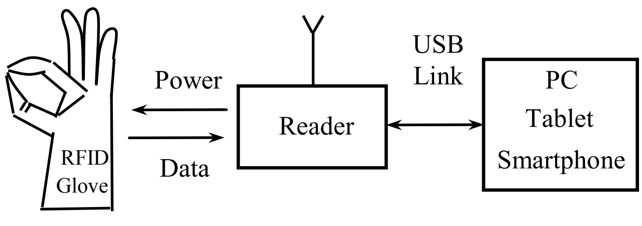

Fig. 1. System for controlling a wireless glove using an RFID sensor.

A. Microsystem for Development of Wireless Glove

A microsystem was designed for the development of the wireless glove. The microsystem depicted in Fig. 2 consists of five 2.2" flex sensors (1) from Spectra Symbol, an ADG608 [15] high performance analog multiplexer (2) from Analog Device, a Launchpad MSP-EXP430R2433 kit (3) from Texas Instruments [16] based on the MSP430FR2433 microcontroller and an Arduino Uno microcontroller board (4).

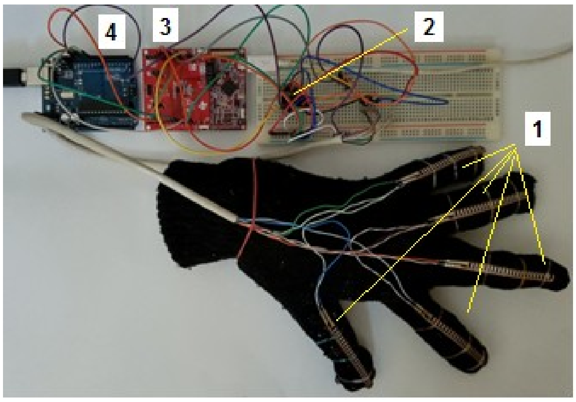

Fig. 2. Microsystem for wireless glove development.

The schematic of the system is given in Fig. 3.

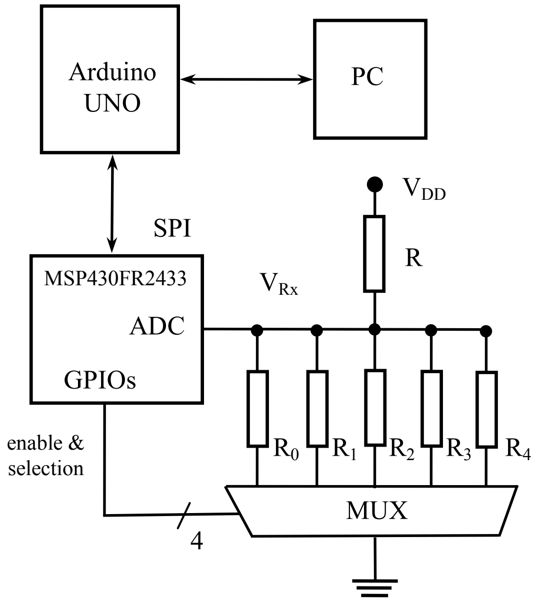

Fig. 3. Schematic of develpment module for wireless glove.

The LaunchPad MSP-EXP430R2433 kit was selected as it is based on the same low power application microcontroller (MSP430FR2433) available on the Medusa-R RFID sensor selected to be used for the implementation of the final system. The Arduino UNO board was used to emulate the Farsens Rocky 100 circuit that communicates with the MSP microcontroller using the SPI protocol and to display the values read from the flex sensors. The microcontroller parameters we are interested in are: power supply voltage 1.8 ÷ 3.6V, power consumption 126μA/MHz in active mode and <1μA in standby mode, 10-bit ADC, programmable SPI interface, 1.5kB Low-Power Ferroelectric RAM (FRAM), 512B RAM and optimized ultra-low power modes.

The following microcontroller resources were used: the SPI port implemented with the USCI_A0 module, one analogue channel of the ADC10 module, four GPIOs for MUX selection and enable signals, the interrupt system, the

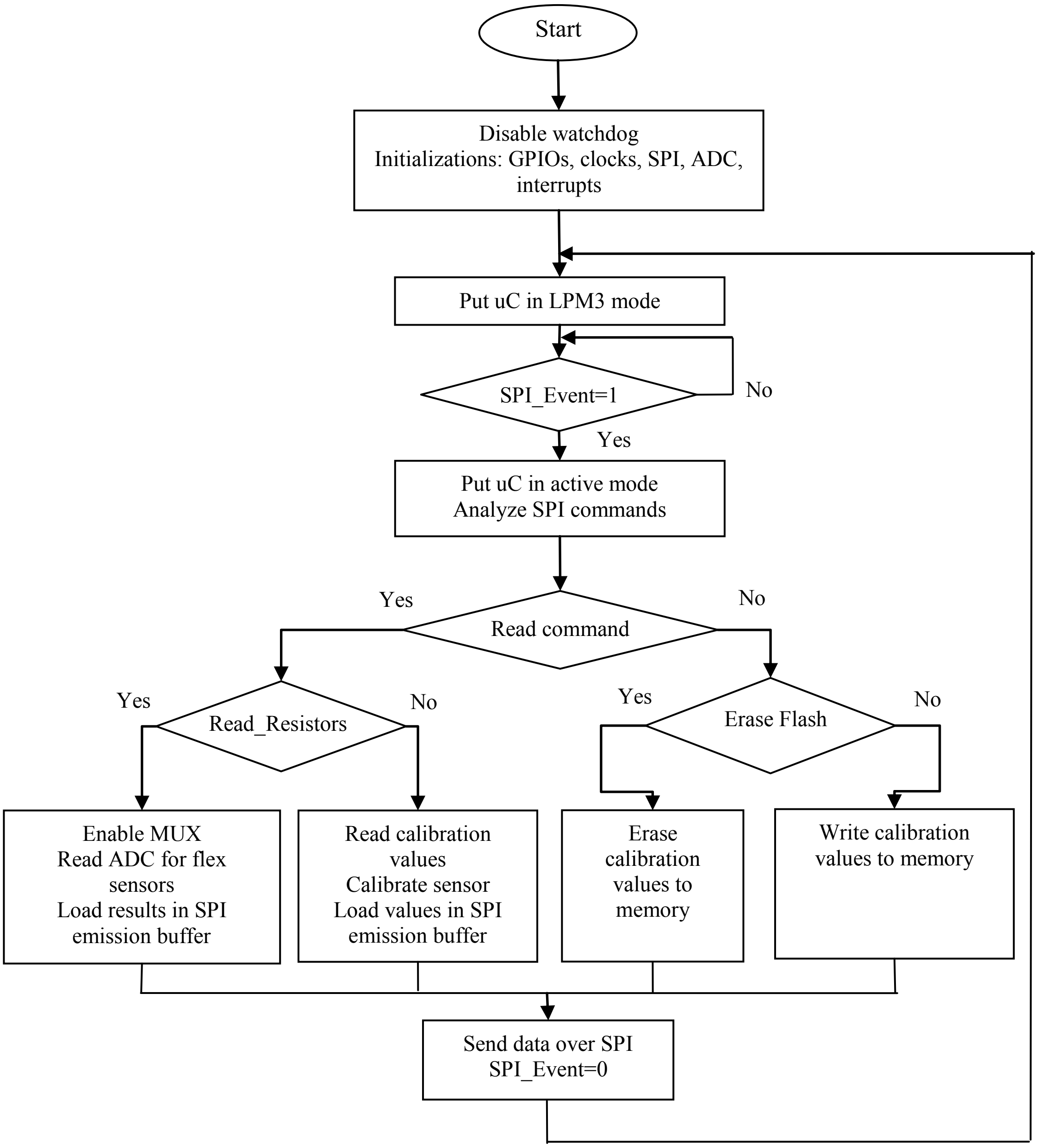

Fig. 4. Flowchart of the microcontroller application.

reset system, and the Spy-Bi-Wire programming system. The MSP-EXP430R2433 LaunchPad kit has a programming module which also provides power supply and all the necessary connections to the other modules. The program running on the microcontroller was developed using Code Composer Studio 8.1.0 programming environment. The flowchart of the program is given in Fig. 4.

After applying the supply voltage, the microcontroller is reset and the program starts running. Because the Watchdog circuit is active by default, it will be disabled first. It follows: initialization of global variables, selection of clocks (MCLK / SMCLK = 8MHz DCO, ACLK = 12kHz), configuration of I/O pins according to their functionality (to minimize unused pins consumption they are defined as level 0 outputs), initialization of SPI (USCI_A0, mode 3, Slave 3 pins), and ADC module (analogue channel, internal 5MHz ADC clock / 8, 1.5V internal reference) and finally validation of individual interrupts.

General interrupts are validated and low power mode 3 (LPM3) is programmed for the microcontroller, as the microcontroller consumption in this mode is below 1μA. This is the waiting state with system consumption less than 4μA, the state in which the system remains until the occurrence of an activity on the SPI interface.

The SPI port is programmed as slave and can run in any LPM mode. It will be controlled by an external SPI master from whom it receives commands and receives or transmits data as a result of commands. By receiving of a command (*SPI_Event* = 1), the microcontroller becomes active, analyzes the command, executes the command, deletes the SPI event variable (*SPI_Event* = 0), goes back again in LPM3 low standby mode.

Two *Write* commands have been implemented: *Erase_Flash* (deletes the Flash area corresponding to the calibration parameters for the system), *Write_Flash* (programs the Flash specific area with calibration values for system, parameters contained in the command sequence).

The following two *Read* commands have been implemented: *Read_Resistors* command (reads the result of ADC conversion of voltages for the five flex resistors expressed by 2 bytes corresponding to V_{Rx} voltage) and *Read_Flash* (the configuration calibration values are read from the Flash. These values are used for correct computation of the result obtained by the command *Read_Resistors*). An example of a common sequence of operating commands would include the following commands: *Erase_Flash*, *Write_Flash*, *Read_Resistors*, *Read_Resistors*, ..., *Read_Resistors*.

In order to lower power consumption, SPI and ADC ports work in interrupt mode with the efficient use of low-power modes. The compiled program occupies 6722B of Flash and 454B of RAM.

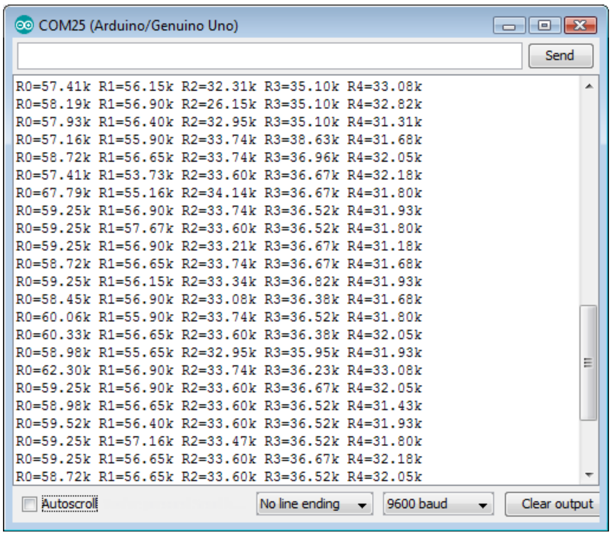

Fig. 5. Measurement results displayed on a serial terminal.

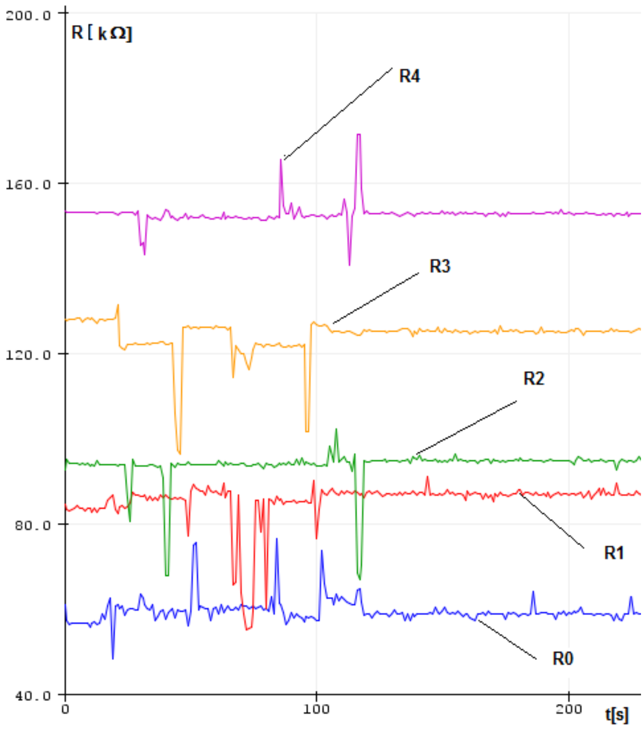

Fig. 6. Measurement results displayed using Arduino Serial Plotter tool.

For the verification of correct program operation, the Arduino UNO micro system was used as the SPI master. The test program was written using Arduino software environment and allows displaying data received from the sensor in a serial terminal. The results of the SPI transfer from the Read_Resistors command and the processed data, displayed on the serial terminal, are depicted in Fig. 5.

The variation of the values read for the five flex sensors is depicted in Fig. 6 using the Serial Plotter tool of the Arduino environment. In order to better visualize the signals, the values were translated on the vertical axis.

The current consumption of the system (without the Arduino module) can be measured by using the 3V3 jumper provided by the Launchpad kit for this respect. The current measured was 444µA, consumption corresponding to the estimated one. These inputs are: 340µA (LPM0 Supply Currents Into VCC) + 104µA (consumption in the sensor network). The average is smaller as the microcontroller is most of the time in LPM3 mode with consumption <1µA@3.3V).

B. *RFID Tag Sensor For Wireless Glove*

An RFID tag was designed and tested for the measurement of finger bending in order to implement a low power wireless glove. The sensor consists of: a set of five flex sensors (1), a connection board containing also the high performance analog multiplexer module (2), a Medusa-R platform (3) [17], and the Nordic ID Stix Reader (4), see Fig. 7. The schematic diagram of the sensor is depicted in Fig. 8.

The flex sensors and the analog multiplexer module are the same as those described in the previous paragraph. The Medusa-R Platform (3) allowing the development of RFID applications in the UHF band, is built around the Rocky 100 transponder and implements the EPC C1 G2 standard [14]. The platform also contains a capacitor for storing energy accumulated from the electromagnetic field, a voltage monitoring module, and a MSP430FR2433 microcontroller. The MSP430FR2433 microcontroller was reprogrammed to run the program depicted in the logic diagram from Fig. 4.

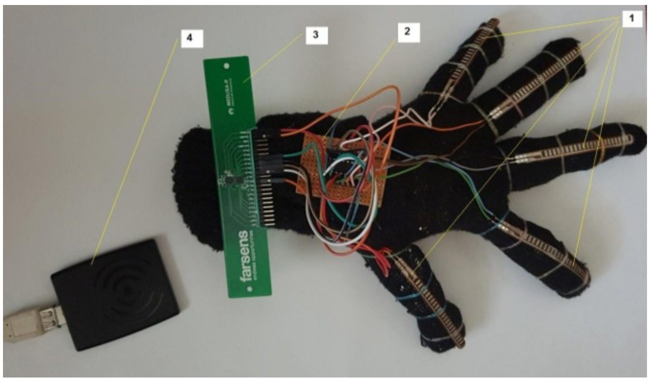

Fig. 7. Wireless glove with RFID tag sensor.

The Arduino UNO module is now replaced by the Rocky 100 circuit which controls the operation of the microcontroller by SPI interface using the same protocol. The Medusa-R platform is controlled by the Nordic Stix reader for which the *Sensor Glove Reader* application was developed. The operation of the sensor is controlled by using the software graphical interface that can be used to send commands to the transponder-microcontroller-reader. The sensor sends back the results obtained by the execution of the commands which are displayed in numerical or in graphical format. The system is energized by the reader's electromagnetic field, but can also include a 3V auxiliary battery.

The interface is designed to also allow saving the measured data for later processing in a file using the Comma Separated Value (CSV) format. Fig. 9 gives an example of displaying the variation of values read from flex resistors.

The *Sensor Glove Reader* application was created based on application examples from Farsens using the .NET package and the C # language. The application was developed based on the NUR API libraries that provide the appropriate functions for interaction with the NordicID Stix and the OxyPlot library for displaying graphical data.

III. Conclusions

This paper presents the possibility of making a wireless sensor glove based on an RFID tag sensor designed to be used for applications in translating the sign language, wireless control of devices, operator interfaces in industrial IoT applications [18], or ambient assisted living. The sensor is based on a set of five flex sensors connected to an RFID tag, resulting in an RFID tag type sensor. Because in principle, the RFID tag type sensor is only working with the energy provided by the RFID reader's electromagnetic field, the system was optimized to work taking advantage of microcontroller efficient low power modes. In order to reduce the sensor network power consumption, the supply of the network is restricted only for the short period of time of the measurement.

Further work will aim to add other sensors in order to improve information received from the wireless sensor glove.

Additional flex sensors or acceleration sensors can be used to detect not only finger bending but also the change in position of finger relative to the neighbour fingers or change of hand position in space.

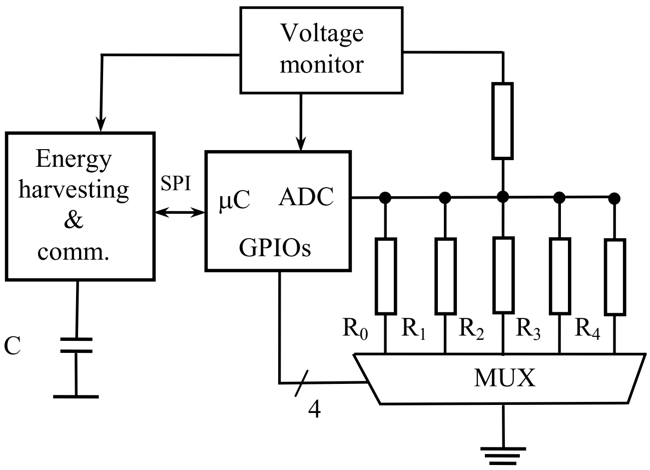

Fig. 8. RFID sensor for wireless glove.

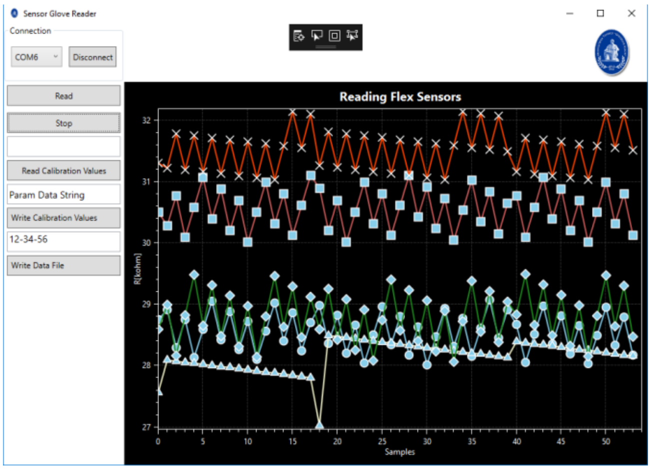

Fig. 9. Displaying values read from the flex sensors in Sensor Glove Reader application.

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