LabVIEW-based Virtual Vacuum Gauge Controller Using a Thermocouple Sensor

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***Abstract*—The article presents an innovative virtual vacuum gauge made on the base of the vacuum sensor Duniway DST-531. For receipt and sending a signal from the sensor the block NI6210, while for data processing and visualization the LabVIEW graphical programming environment are used. The virtual vacuum gauge proposed by us for the first time applies an approach, where without a vacuum controller, by using only a thermocouple and a multifunction input/output device, a rather accurate measurement of vacuum in the ~ 4×10^{2} – 4×10^{-1} Pa range is carried out and fixed in the real time.**

Keywords*— *Vacuum sensor, vacuum meter, multifunction I/O device, LabVIEW, virtual device

I. INTRODUCTION

For measuring different physical parameters and controlling technological processes, the virtual devices [1-4] made in the LabVIEW graphical programming environment [5-7] are gaining popularity. They make it possible to measure different physical quantities (temperature, pressure, vibration, humidity and so on) without measuring systems, using a multifunctional I/O device and a computer.

Such approaches are important for controlling simultaneously different physical parameters in the real time in different places and in the course of an experiment. For example: upon synthesis of Hg-based superconductors in the controlled pressure environment, the temperature and pressure need to be at same time controlled [8]; for full-value helium filling in the cryostat, necessary need simultaneously control of the nitrogen temperature and vacuum in it [9]. In the course of operation, the amount of helium should be controlled in the cryostat, using several temperature sensors.

Sensors of different principles of operation are used to measure vacuum: diffused, thermocouple, capacitance, ionizing, induction [10-12]. The most popular type of sensors measuring low and medium vacuum is the thermocouple vacuum sensor that can measure vacuum within the range of ~ 1×10^{2} – 1×10^{-1} Pa. Such sensors are cheap and noted for high reliability and accuracy [13,14].

In design, they represent a heater and a thermocouple, placed in a tube. During operation, upon reduction of pressure, the temperature of the heater and correspondingly the thermocouple output voltage increase. The vacuum meter's circuit ensures supply of stable current to the filament and amplification of a weak analogous output signal of the thermocouple, its digitalization and indication.

In spite of high accuracy of the traditional measuring systems, the number of parameters measured in them is limited (usually 1-2 channels). An increase in the number of channels leads to an increase the number of equipment and is, correspondingly uneconomic.

The objective of the presented work is to demonstrate an innovative approach to vacuum measurement and monitoring, where the traditional measuring device is substituted with a virtual software device. The number of measured parameters depends only on the number of channels of the multifunction I/O device and is thus economically rather profitable.

The proposed virtual vacuum gauge controller for the first time applies an approach, where without a vacuum controller, by using only a thermocouple and a multifunction data input/output device NI6210, a rather accurate measurement of vacuum is performed and continuously fixed in the real time.

II. EXPERIMENTS AND DISCUSSION

The measurement of the weak analogous signal released from sensor thermocouple (0-10 mv) without a controller, might lead to a rather significant error. Inasmuch since the heating element and the thermocouple are located in a tube, their resistance also depends on the pressure and if the current through them is conducted, we can judge on the amount of vacuum according to a change in the withdrawn voltage. At the same time, if the current is sufficiently big, the output signal will be correspondingly important and easy to measure.

For example, in pressure within the range of ~ 4×10^{2} – 4×10^{-1} Pa, as an experiment demonstrated, upon conduct of optimal current (150-160 mA) through the heating element of the thermocouple sensor, a change of the voltage produced by the heating element makes only 15 mV, which is not enough for accurate calibration of the virtual vacuum gauge controller. However, upon conduct of current of the same magnitude through the thermocouple, a change in the output voltage within the same pressure range made ~ 60 mV. In this case, the magnitude of the voltage (~300-400 mV) provides proper calibration.

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The functional scheme for calibrating of the virtual device by means of the sensor Duniway DST-531 is given in Fig. 1. The mechanical pump EDWARDS E2M18 is used to produce vacuum, the controller Zhenghua Electronic Instrument ZDF-X-Led with the sensor ZJ- 52T used for measure pressure in the range of $2.5\times10^{3} – 1\times10^{-3}$ Pa.

To conduct stable current through the thermocouple of the test sensor, the source of supply TP3005DM is used. To limit the current magnitude (~160 mA), a high-precision resistor (nominal – 100 ohm) with a cooling system is connected in series. The output signal (~300 mV) is communicated to the multifunctional I/O device - National Instruments device NI6210. The result is displayed on a computer monitor by means of the virtual vacuum gauge controller made in the LabVIEW graphical programming environment.

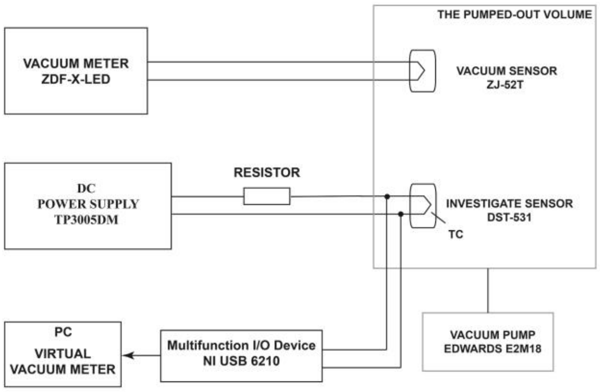

Fig. 1. The functional scheme for calibrating the virtual vacuum gauge

Fig. 2 shows a block scheme of the virtual vacuum gauge controller (VirtVac) program, made in the LabVIEW graphical programming environment.

Initially, the value of the output signal from the thermocouple (V1) is measured upon atmospheric pressure. Thereafter, to increase the measurement accuracy, this value is subtracted from the measured signal (V2).

In addition, to increase the measurement accuracy, the arithmetical mean of the 2000 values measured per second from the sensor thermocouple – block 1 is used. In block 2, the whole range of pressure is divided in two, where the range limits are checked and a appropriate formula is selected. In blocks 3-4, the formulated result is adapted for display on the digital and graphical indicators. Block 5 represents pressure indicators. In block 6, indication of the pressure/time dependence in real time is given. In block 7, the pressure/time dependence is recorded in Excel files. In block 8, the current time and date are formed on the front panel.

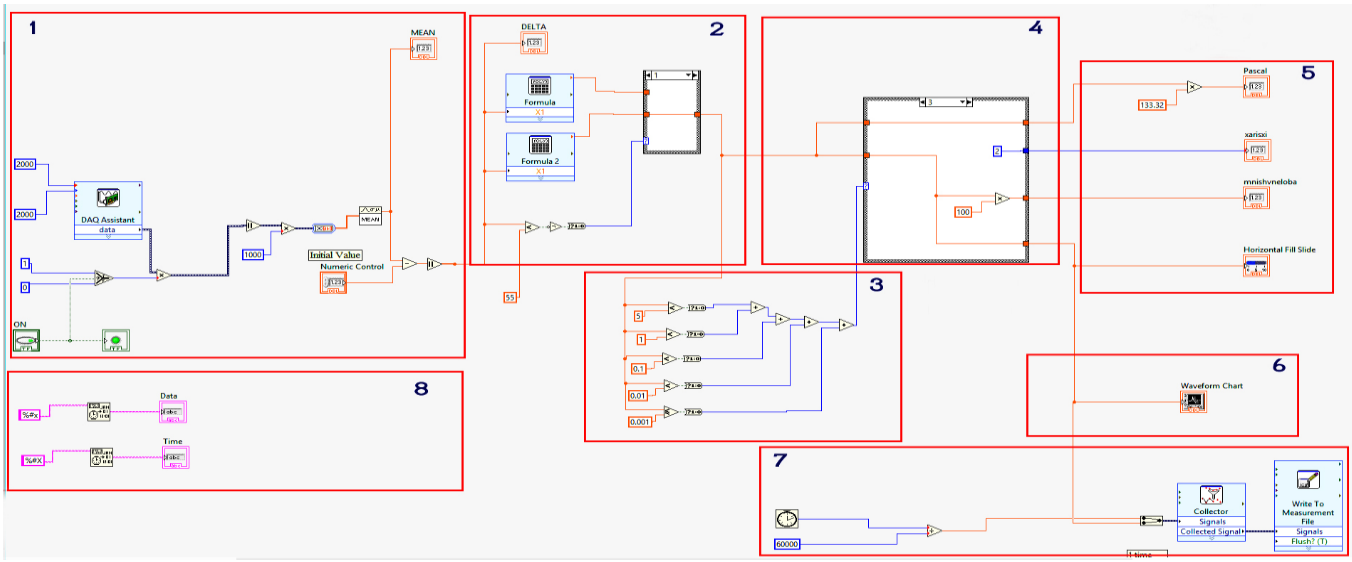

Fig. 2. Block-scheme of the virtual vacuum gauge controller (VirtVac) program made in the LabVIEW

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In figure. 3, presents the pressure dependence (P) on (ΔV=V2-V1), on the basis of which, the program Origin by the linear and polynomial fitting, determines the value of the real pressure. The results are visualized on the front panel of the virtual vacuum gauge controller in the pressure units Pascal and Torr by digital indicators and graphical forms. Digital data also is written to the computer as an Excel file.

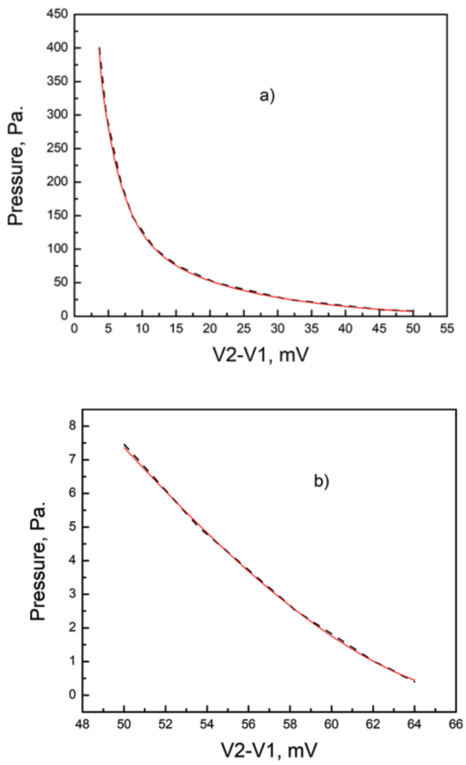

Fig. 3. Derivation of formulas in software package Origin: a) Pressure range 400 – 7.5 Pa.); b) Pressure range 7.5 - 0.4 Pa. (Dash lines – Experimental data, Solid lines - Fitting Data).

Front panel of the VirtVac is shown in Fig. 4.

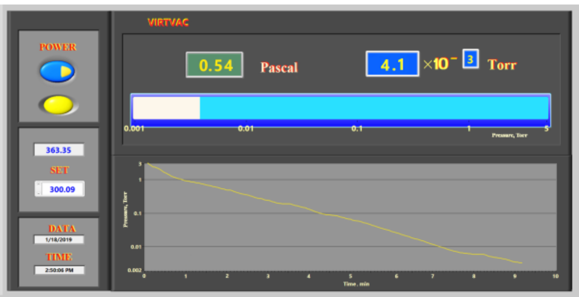

Fig. 4. Front panel of the VirtVac

The first line of Table 1. Indicated the pressure measured in (Pa) by means of the ZDF-X-Led vacuum gauge meter.

Below given is the assessment of errors of the results for each of the pressures, measured 10 times, by means of standard statistical functions of the Excel program.

Table.1
Assessment of errors of the results

Pressure Pa.	400	10	1	0.4
Standart Deviation	4.60	0.123	0.015	0.013
Sample Size	10	10	10	10
Square Root of the Sample Size	3.16	3.16	3.16	3.16
Standart Error of the Mean	1.455	0.039	0.005	0.004
%	0.36	0.39	0.48	1.04
95% Confidence Interval				
Upper Limit	401.35	10.05	1.01	0.41
Lower Limit	395.65	9.90	0.99	0.40

III. CONCLUSION

An innovative virtual vacuum gauge controller has been designed and made in the LabVIEW graphical programming environment, where, without a vacuum controller, by a simple scheme, using the Duniway DST-531 sensors and a multifunction I/O device NI6210, is possible pressure measurement in the range $4\times10^{2} – 4\times10^{-1}$ Pa. In addition, in such virtual vacuum gauge controller, the number of measured parameters depends only on the number of channels of the multifunction I/O device and thus is economically rather profitable.

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