

# Prototype of the Multichannel Acquisition System Developed for ICTM Pressure Transmitters

P. Poljak, B. Vukelić, M. Vorkapić and D.V. Randjelović

**Abstract**— This paper presents a prototype of the multichannel acquisition unit AKV-100 developed for purposes of pressure and temperature measurements using proprietary ICTM pressure transmitters TPa-110 based on MEMS piezoresistive pressure sensors and thermocouples TMMU01. Details about the acquisition unit, dedicated software, measurement setup and test procedure are given. Measurements results are presented and the directions of future research activities are discussed.

**Index Terms**—acquisition, pressure measurement, pressure transmitter, thermocouples, MEMS pressure sensors.

Original Research Paper  
DOI: 10.7251/ELS1519066P

## I. INTRODUCTION

THE ACQUISITION unit AKV-100 was realized because of need for the development of a low-cost and flexible system that would allow simultaneous data acquisition from pressure transmitters and thermocouples fabricated by ICTM – CMT. Commercially available acquisition systems dedicated for data acquisition from pressure transmitters and K-type thermocouples have a significantly higher price than AKV-100. Besides, the existing systems usually are of modular type, with a separate module for pressure transmitters and another module for the thermocouples. They are connected with the central unit and power supply, which are also independent modules. Previous research at ICTM-CMT was following that direction too [1].

The AKV-100 unit enables user to perform data acquisition from 9 channels, 4 of which are dedicated for ICTM pressure transmitters TPa-110 [2, 3], while 5 channels are to be connected with K-type thermocouples TMMU01.

Manuscript received 08 November 2015. Received in revised form 15 December 2015.

This work has been partially supported by the Serbian Ministry of Education, Science and Technological Development within the framework of the Project TR32008.

P. Poljak, B. Vukelić, M. Vorkapić and D.V. Randjelović are with the Centre of Microelectronic Technologies, Institute of Chemistry, Technology and Metallurgy, University of Belgrade, Njegoševa 12, 11000 Belgrade, Serbia, (corresponding author to provide phone: +381-11-2628-587; fax: +381-11-2182-995; e-mail: predrag.poljak@nanosys.ihm.bg.ac.rs).

The first part of the paper gives details about the acquisition system, AKV-100 unit, measurement setup and dedicated software. In the second part, experimental results obtained in laboratory conditions, using one active channel for pressure transmitter are given. Finally, the obtained test results and the directions of future research are discussed.

## II. ACQUISITION SYSTEM

### A. Acquisition Unit AKV-100

The Acquisition unit AKV-100 is developed at ICTM for acquisition of measurement data from 9 channels. The block diagram in Fig. 1. shows the acquisition module together with other components, PC with the installed special software developed at ICTM-CMT, 4 pressure transmitters TPa-110, 5 thermocouples TMMU01 and the external supply 24V/850mA.

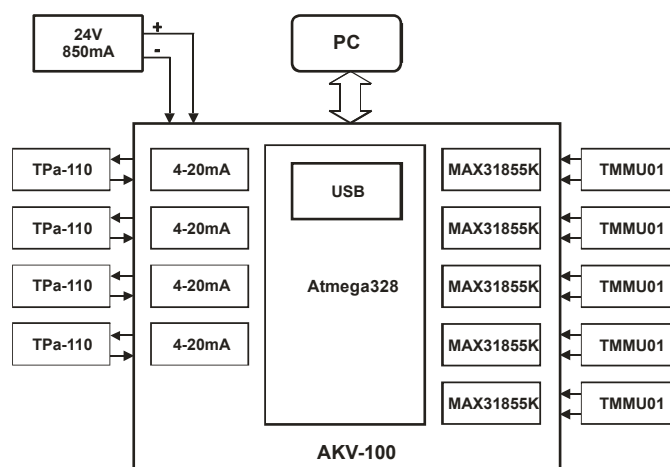


Fig. 1. Block diagram of the acquisition module AKV-100 illustrating pressure transmitters (TPa-110) and thermocouples (TMMU01) connected to all available measurement channels. PC with special software and external power supply for the pressure transmitters is also shown.

The pressure transmitters TPa-110 are intended for the measurement of absolute or gauge pressure, utilize MEMS-based piezoresistive pressure sensor chips fabricated in ICTM-CMT and give the standard 5-20 mA industrial output.

Apart from a lower cost, as mentioned before, the acquisition unit AKV-100 has the following advantages:

1. User-friendly power supply realized through a USB communication cable. The same supply is used for thermocouples, while an independent additional supply 24V/0.84A is used for pressure transmitters,

2. Analogue to digital conversion of the signal collected from the thermocouples is performed in modules which contain MAX31855K integrated circuit which performs conversion and then transfers the data to the local microcontroller via SPI interface bus,

3. The same two connection lines of the transmitters serve not only for the signal transfer like in available commercial solutions, but also for the power supply provided by AKV-100 itself.

The central part of the AKV-100 acquisition unit is an 8-bit microcontroller Atmel Atmega328 [4] with external modules. Pressure transmitters generate an analog current signal in the 4-20mA range. The current signal produces voltage drop across a resistor, which is input into internal 10-bit A/D converter. Since current is linearly dependent on the pressure, and voltage drop is proportional to current, pressure value for each channel, can easily be determined using the next equation:

$$U_{ad}[i] = \frac{V_{ref}}{2^{10}} * voltage\_read[i],$$

$$I\_current[i] = \frac{U_{ad}[i]}{R_{ref}} * 1000, \quad (1)$$

$$pressure[i] = k * I\_current[i] + n,$$

where  $voltage\_read[i]$  is the current digital value of voltage generated by A/D converter,  $U_{ad}$  is analogue value of the same voltage,  $V_{ref} = 5\text{ V}$  is the reference voltage of A/D converter,  $I\_current[i]$  is analogue value of the current in mA,  $R_{ref}$  is the reference resistor,  $pressure[i]$  is the value of the measured pressure. Coefficients  $k$  and  $n$  depend on the pressure range of the transmitter. The TPa-110 pressure transmitters are optimized for a pressure range of (0-10) bar.

Analogue signals collected from the thermocouples are firstly sent to the integrated circuit MAXIM MAX31855K and the obtained digital signals are transferred afterwards to the microcontroller via SPI interface bus. AKV-100 contains 5 MAXIM MAX31855K circuits which share one SPI interface bus with the microcontroller.

### B. Experimental Setup

The experimental setup is shown in Fig. 2. ICTM transmitters are placed inside the temperature test chamber HERAEUS VÖTSCH VMT 08/140 which assures good temperature control. The transmitters are connected with the acquisition unit AKV-100, which performs, among other operations, pressure calculation.

Fig. 3 shows a photograph of the four ICTM TPa-110 pressure transmitters connected with the AKV-100 acquisition unit.

The pressure calibrator (MENSOR APC-600) sets the pressure in ascending and then descending order in the range from 0.1-10.1 bar with the step of one bar. User application

software performs communication with the pressure calibrator as well as with the AKV-100 acquisition unit.

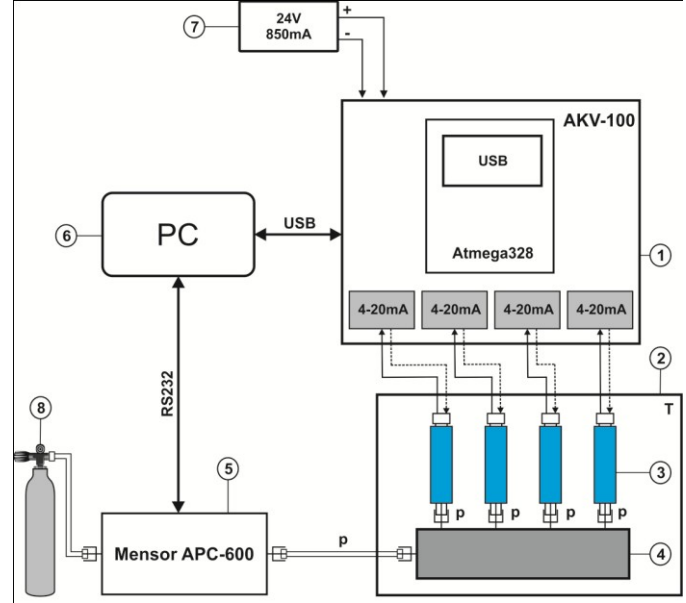


Fig. 2. Experimental setup: 1) AKV-100 acquisition unit, 2) temperature test chamber, 3) Pressure transmitters, 4) pneumatic manifold, 5) Pressure Calibrator Mensor APC-600, 6) PC with software for AKV-100, 7) external power supply, 8) nitrogen container.

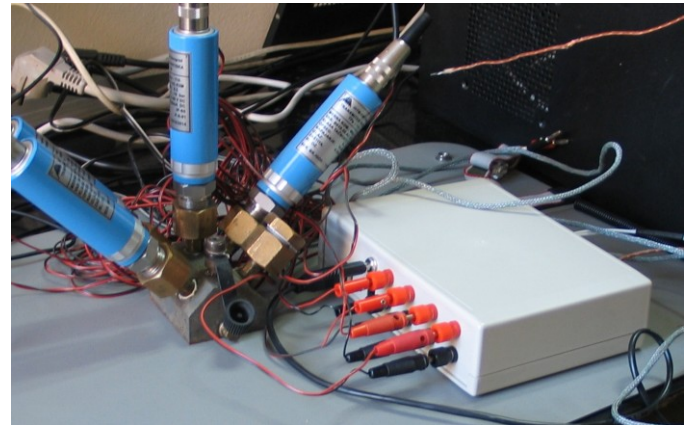


Fig. 3. Photograph of the four ICTM TPa-110 pressure transmitters connected with the AKV-100 acquisition unit.

### C. Software for AKV-100

For the development of user application, ANSI C language was used as one of the most widespread test and measurement programming languages. Source code was created within the ANSI C integrated development environment LabWindows/CVI [5].

Communication between PC and MENSOR APC-600 pressure calibrator is realized by a "Virtual Serial COM Port". The user chooses the relevant "Virtual Serial COM Port" and afterwards the switch "Start Mensor" is set to "ON" position. In this way communication is established and the value of pressure generated by MENSOR APC-600 [6] is shown in the associated field of the user application window as shown in Fig 4.

Communication with the acquisition device AKV-100 is established in a manner similar to the one described above. The user chose the relevant “Virtual Serial COM Port” and this time the switch “Start AKV” is set to “ON” position. As soon as communication is established, the value of the current output signal generated by the pressure transmitter is displayed in the associated field of the user interface window. After choosing the appropriate transmitter pressure range, the pressure value proportional to the measured current is calculated. This value is also displayed in the associated field of the user application window.

The user application has two internal “timers” which are invisible and not available to user. One timer performs periodic voltage acquisition from the AKV-100 unit, while the other calculates the value of the pressure measured by ICTM pressure transmitter based on the collected data using (1).

Automatic data acquisition from the pressure calibrator and the acquisition device is enabled by the switch “Automatsko Merenje”. During the automatic acquisition, pressure and current values are collected subsequently and the data are stored in dedicated file.

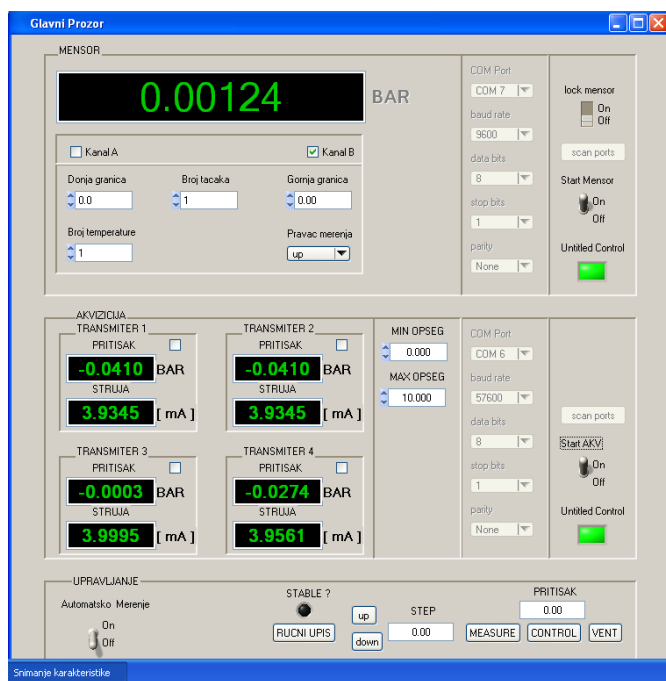


Fig. 4. User application window.

### III. MEASUREMENT RESULTS

Measurements were performed in laboratory conditions using the above mentioned temperature test chamber which is limited to a relatively narrow temperature range ( $-80 - 180^{\circ}\text{C}$ ), far below the operating range of the K-type thermocouples, therefore the channels for the thermocouples were not used. Pressure transmitters were connected to the respective channels of AKV-100. The transmitters were placed in a temperature test chamber HERAEUS VÖTSCH VMT 08/140. Measurements were done at three different temperatures, ( $-10, 17.7, 50$ )  $^{\circ}\text{C}$ . Reference pressure was generated by a MENSOR

APC-600 pressure calibrator.

After setting the chamber temperature, 30 minutes were allowed for the temperature stabilization. At each selected temperature measurement sequence was controlled by software. For each reference pressure value, the transmitter output was recorded. MENSOR APC-600 generated several pressure values and for each reference value, the transmitter output was recorded.

Fig. 5 shows dependance of the raw transmitter output, which is a current signal, on all reference pressure values in one measurement sequence obtained at a temperature of  $17.7^{\circ}\text{C}$ .

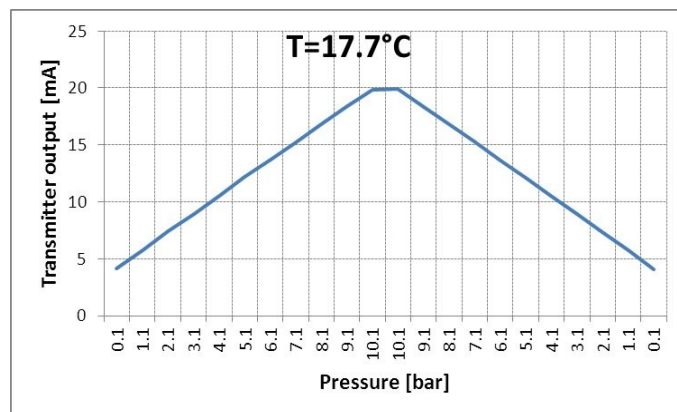


Fig. 5. Dependence of the raw transmitter output (current signal) measured at temperature  $17.7^{\circ}\text{C}$  on reference pressures generated by MENSOR APC-600 pressure calibrator.

The current value recorded at the output of pressure transmitter was further transformed into measured pressure value which was displayed in the user interface window.

Fig. 6 shows pressure values measured by the ICTM transmitter and the corresponding reference values generated by MENSOR APC-600 pressure calibrator. Pressures measured at all test temperatures for each calibration pressure are listed in Table I.

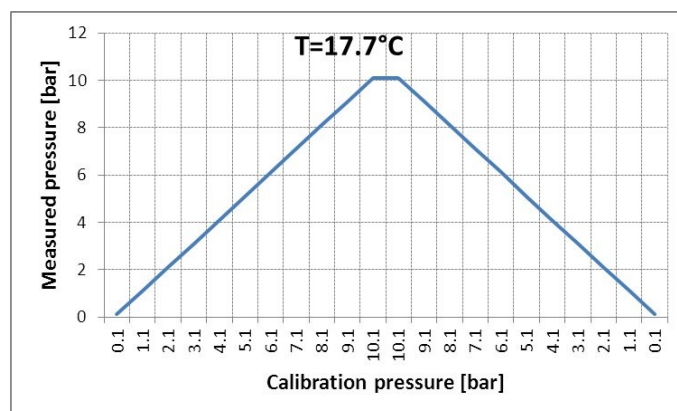


Fig. 6. Dependence of the pressure values measured by transmitter and displayed in the User application window on reference pressures generated by MENSOR APC-600 pressure calibrator.

TABLE I  
PRESSURES MEASURED BY ICTM TRANSMITTER AT THREE DIFFERENT  
TEMPERATURES FOR EACH REFERENCE PRESSURE GENERATED BY  
SENSOR APC-6000 PRESSURE CALIBRATOR

SENSOR [bar]	AKV-100 [bar]		
	T=50°C	T=17.7°C	T=-10°C
0.1	0.100086	0.100043	0.099841
1.1	1.10001	1.10001	1.10001
2.1	2.10001	2.09998	2.1
3.1	3.10001	3.09999	3.09999
4.1	4.1	4.09999	4.10001
5.1	5.10002	5.10001	5.1
6.1	6.10001	6.1	6.1
7.1	7.10002	7.10001	7.1
8.1	8.10002	8.10001	8.10001
9.1	9.10002	9.10001	9.10001
10.1	10.1	10.1	10.1
10.1	10.1	10.1	10.1
9.1	9.10001	9.09999	9.09998
8.1	8.10001	8.10002	8.1
7.1	7.1	7.10001	7.10001
6.1	6.09998	6.10002	6.10003
5.1	5.10003	5.1	5.1
4.1	4.09999	4.09999	4.10002
3.1	3.1	3.10002	3.1
2.1	2.1	2.09999	2.10001
1.1	1.09999	1.1	1.09998
0.1	0.099872	0.099943	0.099936

#### IV. CONCLUSION

A prototype of the multichannel acquisition system dedicated for use with ICTM pressure transmitters and thermocouples was developed. The system was successfully tested in a configuration with one ICTM pressure transmitter connected.

As expected, the main limitation of the realized prototype, is the low accuracy. For the future solution, it is planned to use an A/D converter with higher resolution.

Research and development of various types of transmitters for the industrial use is one of the main activities at ICTM-CMT. In order to successfully place transmitters on the market, it is of interest to develop various interfaces as well as specialized acquisition devices compatible with international industrial standards. The prototype presented in this work is the first device of such kind developed at ICTM-CMT. In the near future we expect to develop improved acquisition systems.

#### REFERENCES

- [1] M. Vorkapić, M. Starčević, B. Popović, M. Frantlović, P. Poljak, S. Minić "Model of improvement transducers in small series production", *Tehnika*, pp. 1043-1047, 2011.
- [2] M. Matić, Ž. Lazić, K. Radulović, M. M. Smiljanić, M. Rašljčić "Experimental Determination of Optimal Piezoresistive Pressure Sensor Linearity" in *Proc. of 57th ETRAN Conference*, Zlatibor, Serbia, June 3-6, 2013, pp. MO3.1.1-6 (in Serbian)
- [3] M.P. Frantlović, V.J. Jovanov, B.L. Miljković, „Intelligent Industrial Transmitters of Pressure and Other Process Parameters“, *Telfor J.* Vol. 1,2, pp. 65–68., 2009.
- [4] <http://www.atmel.com/devices/atmega328.aspx>
- [5] <http://www.ni.com/lwcv/technical-resources/>
- [6] [http://www.mensor.com/cpc6000\\_en\\_co.WIKA](http://www.mensor.com/cpc6000_en_co.WIKA)