A HIGH - PRECISION SMART HANDHELD DEVICE TO CALIBRATE PRESSURE TRANSMITTERS

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Abstract *-This publication presents the design of the microprocessor equipped, high precision pressure calibrator. It describes the calibrator errors compensation method and the calibrator tests results.*

Keywords: pressure, calibration, hand-held calibrator.

1. INTRODUCTION

The basic function of modern calibrators is to determine with adequate accuracy the conversion characteristics of transmitters undergoing checking or calibration.

In case of pressure calibrators it is done by a parallel measurement of pressure (the input signal of a transmitter) and the corresponding electrical signal (the transmitter output signal).

At present the required accuracy of discussed object calibrators can not be worse than 0.1% of a measured value (or 0.05% of the measurement range).

All pressure transmitters will function with desired accuracy in process plants if they are accepted or re-calibrated by the operators and maintenance people using an appropriate hand-held calibrator.

The calibrator presented here makes possible testing and calibrating such instruments as pneumatic and electronic transmitters, P/I and I/P traducers, pressure gauges, and pressure switches designed for field use. The calibrator is also convenient in the laboratory.

Although the traditional SMART pressure transmitter configuration can be provided by the Hart communicator, the calibrator is also required for checking transmitter conversion and correction for stored curve (digital trim procedures).

2. CALIBRATOR DESIGN

The pressure calibrator developed by PIAP-OBRAP is a portable, high precision instrument intended for measurements of pressure and electrical signal [1]. The block diagram of the microprocessor pressure calibrator is shown in Fig.1.

3. CALIBRATOR MODULES

3.1 PressureSensors Module

To widen applications range the calibrator is equipped with two sensors (standard), or with three sensors (option).

The sensors measuring pressures P1 and P2 are fixed inside the calibrator housing, and are integral parts of the instrument. They can be replaced at user’s request but only by the manufacturer. These sensors cover the pressure range from 0...100 kPa to 0...700 kPa. The optional P3 sensor is intended for high pressures (to 10 MPa). This is an external sensor that enables connecting any measurement medium.

Piezorezistive, silicone sensors encased in the stainless steel head are used in the discussed calibrator. The head is closed by the separating membrane made of stainless steel, what makes possible using the calibrator for aggressive or contaminated measurement media. The sensors selected for the calibrator have small non-linear errors, and are initially compensated within the range of temperatures 0÷70°C.

The temperature influence on the zero value of the measurement range and the span is precisely compensated by the microprocessor system using software introduced compensation coefficients. These coefficients are determined in the process of measuring the influence of temperature on the calibrator measurement characteristics. This module is equipped with both high stability current sources excitation to the sensor bridges and matching circuit ensuring the standardised span value of of sensors.

3.2 Measurement and Signal Processing Module

The module consists of the following circuits:

- pressure sensors signal forming circuit
- current and voltage signal forming circuit
- analogue multiplexer
- analogue/digital converter (ADC)

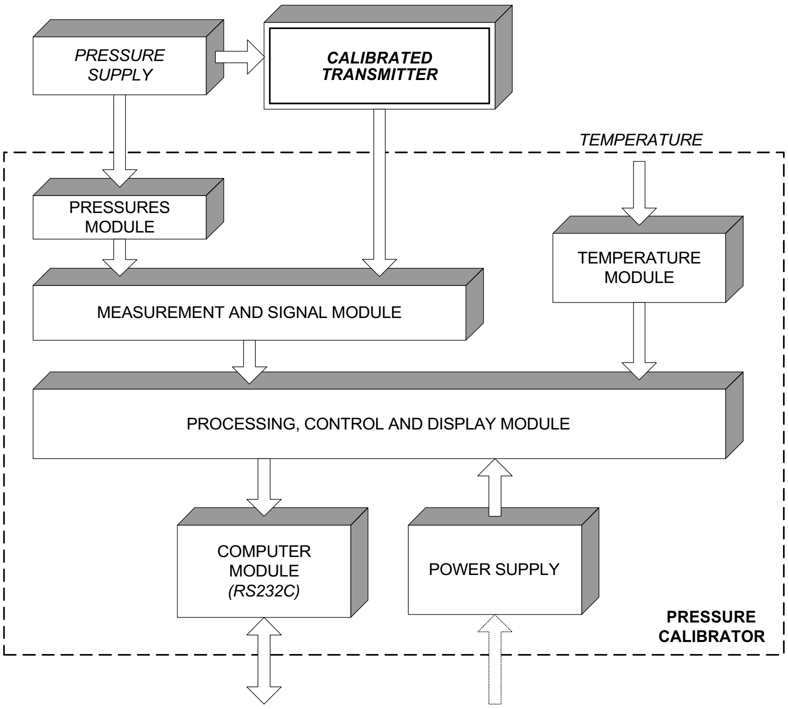

Fig.1 - Block diagram of the microprocessor pressure calibrator

The forming circuits match the pressure sensor signal (0-100 mV), the voltage signal (0-10 V), and the current signal (0-20 mA) to the full range of the ADC converter. A twenty four-bit converter is used in this module. The analogue multiplexer connects the signal channel, selected by the microprocessor system to the ADC converter.

3.3 Processing, Control and Display Module

The processing, control, and display module has been developed basing on the 8-bit processor of 8031 family and the LCD monochromatic graphics matrix of 128 x 64 points of resolution.

The module controls the calibrator functioning, supervises the work of modules responsible for pressure, temperature, and electric signals measurements, and communicates with the operator by means of the display and keyboard.

An important element of the module is the large display (graphic matrix) ensuring comfortable readout conditions to the operator. The display has been equipped with the two-size set of characters. Characters of 5 x 8 size are used in the normal mode of work. This makes possible displaying up to 21 lines of text, 21 characters in one line.

Large characters (10 x 16 size) are used for displaying digital measurement results in the enlarged (zoom) mode of display work. This mode makes possible displaying up to 4 lines of text, 11 characters in one line.

An additional set of icons has been also developed for displaying information on e.g. battery status (the blinking sign of discharged battery), or indicating the currently selected pressure sensor. To emphasise specific information the display software makes possible displaying it in negative, i.e. white characters on dark background. Such mode is (for example) used for displaying descriptions of functional keys located directly under the display.

Measurements result can be recorded and stored in the module memory. The calibrator can store the complete set of data and measurement results for 20 already checked instruments. For each instrument up to 60 measurement points can be stored. Measurement data can be transmitted through the built-in RS232C port to the computer for further processing and recording on any media.

3.4 Temperature Measuring Module

The temperature-measuring module is based on the thermometer (Touch Thermometer) intended for using in electronic circuits. It makes possible measuring temperature inside the calibrator within the 0 - 70°C range with 0.5°C accuracy. Using this type thermometer has made possible reducing the circuitry of the temperature measuring module. The thermometer belongs to the Touch Memory type family characterised by the two-wire supply and signal line (the same two wires are used for power supply and serial communication). Temperature measurement is used for correcting temperature influence on the measurement characteristics of the calibrator.

On user's request temperature can also be indicated on the LCD.

3.5 Power Supply Module and Pressure Setting Kit

The power supply module ensures:

- generating stabilised voltages necessary for calibrator electronic circuitry
- checking the battery discharge level

In the course of calibrator operation the power supply module checks the voltage of the supply source (9V alkaline or rechargeable battery). A voltage drop below the admissible level is indicated to the control system displaying in turn the corresponding icon on the calibrator LCD. The calibrator can be equipped with a pump assembly for setting the inspection pressure.

4. CALIBRATOR BASIC FUNCTIONS

Table 1 presents the set of calibrator functions together with dialogs defining test parameter values.

The calibrator is intended for use of different users, so the form of dialogues has been prepared to make possible using the calibrator even by unskilled personnel.

We have assumed the solution where executing individual steps of the user program is guided by instructions successively displayed on the calibrator display.

Table 1. Calibrator functional structure

No.	Calibrator function name	Parameter defining dialogue	Calibrator indications
1	Built-in self test	Calibrator switching "on"	Successive displaying calibrator data (after positive self-test)
2	Transmitter calibration or checking	Pressure unit: Measurements range: Number of measurement points: Electric signal type: Characteristics type (linear, square root):	Procedure test and measured values of: • pressure • current or voltage signal • processing error
3	Manometer calibration or checking	Pressure unit: Measurements range: Number of measurement points:	Measured: • pressure • manometer indication error
4	Recorded measurement results review	Indication of the instrument identifying date (type, serial number)	Measurement results table
5	Sending measurement results form calibrator memory to an (external) computer	Selecting a data bloc to be sent	Transmission executing procedure
6	Temperature measurement	Temperature scale	Ambient temperature
7	Pressure and electrical signal measurement	Pressure unit: Measurement range: Type of electrical signal (current or voltage)	Measured: • pressure • current or voltage

5. COMPENSATION METHOD

The process of calibration and temperature compensation of the calibrator is fully automated, and executed in two stages in a computerised measurement stand.

In the first stage the pressure sensors intended for using in the calibrator undergo selection based on measuring their pressure – temperature characteristics.

These sensor (sensor heads) have to be initially calibrated and temperature compensated, their processing accuracy should be better than 0.2% F.S. [2].

To ensure the correct functioning of the assumed compensation algorithm the sensor characteristics should be monotonic in its measurement range.

Sensor pressure characteristics are measured only in three points (0%, 50%, and 100% of the measurement range) for the following temperatures: 20°, 30°, 40°, and 5°C.

The results of measurements for sensors qualified for use in calibrators are recorded and used as initial data for the compensation algorithm.

The second stage consists of:

- entering values of measurement points obtained in the first stage for the sensor installed in the calibrator to the calibrator memory
- measuring the pressure – temperature characteristics of the calibrator in three points: 0, 50, and 100% of the measurement range at 20°C and 30°C.

Activating the temperature compensation algorithm of the calibrator completes this process. The algorithm is based on the line segment approximation of the relation between temperature and shift of the sensor measuring signal [3].

The presented solution uses modified line segment approximation with corrections for temperature coefficients. These corrections are determined basing on comparing temperature influence on the unprocessed sensor signal to the sensor signal in the calibrator arrangement for 20°C and 30°C. The calibrator is equipped with the internal temperature sensor monitoring temperature necessary for compensation. The instrument is calibrated in ambient temperature for 11 inspection points within the measurement range. This procedure is used for generating correction tables used for the software linearity improvement of calibrator measurement characteristics.

6. RESEARCH RESULTS

Table 2 presents the pressure calibrator parameters obtained in the course of research discussed in this paper.

Table 2. Results of the pressure calibrator research

Parameter	Unit	Value obtained
Pressure measurement range	kPa	0...200
Current signal measurement range	mA	0...20
Voltage signal measurement range	V	0...10
Work temperature range	°C	5...50
Pressure indication basic error	% FS	0.025
Current indication basic error	% FS	0.008
Voltage indication basic error	% FS	0.01
Pressure indication temperature error	% / °C	0.0075
Current indication temperature error	% / °C	0.0015
Voltage indication temperature error	% / °C	0.001

Fig.2 illustrates the linearity errors of the pressure sensor characteristics and the calibrator indication errors after correction using the same sensor.

Fig.3 presents the dependence of the calibrator indication errors from ambient temperature within 5°C to 50°C temperature range.

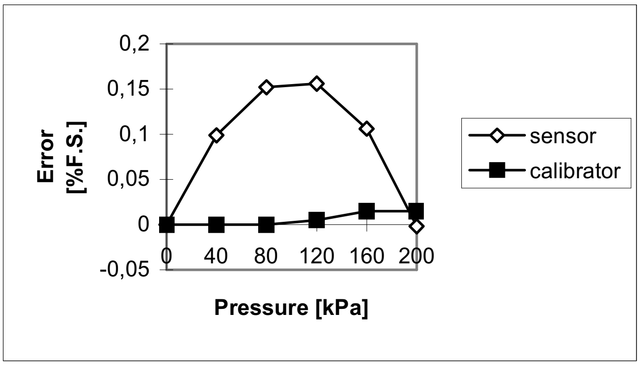

Fig.2 - Pressure sensor linearity error and pressure calibrator indication error curves

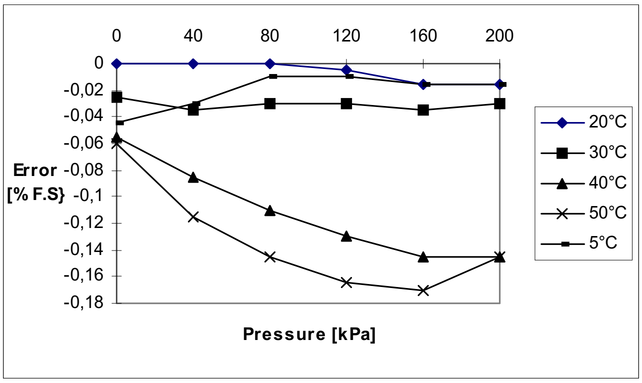

Fig.3. Relationship between pressure calibrator error curves and ambient temperature

7. CONCLUSION

1. The publication describes the design and the compensation method used in the microprocessor pressure calibrator.
   Calibrator model test results are also presented.
2. The calibrator can be equipped with two (optionally three) sensors what significantly widens its measurement range
3. The compensation method applied here makes possible obtaining the calibrator precision at the 0.05% F.S.
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