XIX IMEKO World Congress
Fundamental and Applied Metrology
September 6−11, 2009, Lisbon, Portugal

THE MEASURING INSTRUMENT WITH DISTRIBUTED DATA PROCESSING

Jakub Bach [1], *Romuald Masnicki* [2], *Janusz Mindykowski* [3]
[1,2,3] Gdynia Technical University, Gdynia, Poland
[1]jakubwb@gmail.com
[2] romas@am.gdynia.pl
[3] janmind@am.gdynia.pl

Abstract – In the paper a concept of the measuring instrument with distributed data processing, cooperating with PC is presented. A functional configuration of the instrument performing additional functions connected with measurement result accuracy assessment as well as respective algorithms are shown. The principles of cooperation with PC computer are discussed. The laboratory implementation of the designed instrument and scope of its use for teaching process is proposed.

Keywords: distributed data processing, calibration, uncertainty

1. INTRODUCTION

The idea of distributed data processing in measuring systems was known already more than 30 years ago [1,2]. The assumptions were set that at least four physical components of such system might be distributed:

- hardware,
- processing logic,
- processed data,
- the control (such as the operating system).

Some consider that if a system has anyone of these components distributed, it can be called as a ‘distributed data processing system’.

Throughout the 1970’s the prevalent end-user workstations for interactive work with mainframes were non-programmable display terminals. Several displays were connected to a controller. The application programs run on the host and initiate reading and writing of the display screen by invoking available system interfaces.

One of the first solution enabling to the end-user more flexible data managing for distributed data processing was the mainframe computer interfacing to the IBM personal computer (PC).

Over the next years, the distributed processing data acquisition system, which handles data collection and scattering instrument control, were developed. The important position in such systems takes the PC. The greatest strength of contemporary PC is the richness and immediacy of their interaction with the end-user. These features are connected with the rapid development of new applications, personalized software, attachment of new devices, and ease of use for the incidental computer user.

The integrated programming environments for designing, maintaining and managing of distributed data processing systems allow the measurement and control systems to be easily developed by accessing programmable instrumentation, which can be located either locally or in almost any place of the world. They are the environments for the fast and efficient development of distributed measurement and control applications. The considered systems are easily extensible to accommodate new processing tasks, interfaces, and instruments. In this environment the PC acts as an intermediary making remote resources available without exposing the end-user to the full complexity of a distributed system.

The distributed data processing systems are essential to today’s computing environments. The nowadays natural tendency is to build networks with PC‘s providing most of the user interfacing and connected hosts supplying the services which cannot economically be distributed or replicated at each PC. The LAN networks were made for distributed data processing, intended basically for multimedia information exchange, with more and more industrial measurement and control applications.

In a PC-based measuring system with an analog input, an analog-to-digital converter (ADC) is necessary to convert input analog signals into digital signals which may be next processed by the computer. ADC is the end-element of the hardware part of measuring channel converting the analog signals. The last part of measuring channel is performed as a digital data processing in respective software running in PC computer.

Although more and more digital measuring instruments are equipped with several processors concurrently converting data, there in the ordinary instruments the data processing is usually performed by single microprocessor and obtained results are transferred to the instrument indication unit. It is advantageous taking into account the overall costs of the instrument, however the single processor instrument meets often the limitation in data processing and obtained results indication. Thanks to communication interface, the measurement data can be transferred to PC and processed there much more effective using available software tools, much more flexible than instrument processor software.

As a rule, the PC is not equipped with the dedicated interface for the analog data acquisition. Then the PCI interface can be used for applying additional data acquisition board (DAQ card).

On the other hand, the functions of the DAQ PC board can be fulfilled by microprocessor module. In laboratory condition, that module can be very useful for demonstrating the basic procedure concerning the analog-to digital data conversion, digital data processing and transmission via standard interface and its further processing in PC software environment.

The numerous microcontrollers have, apart from the microprocessor units, the 10-bits and more resolution ADC integrated inside the common IC, RAM and even Flash memory. Such microcontroller structure enables the designing of measuring channel with minimal hardware configuration. The mixed signal processor MSP430 family (Texas Instruments) can be a good example of the microcontroller dedicated for such application [5,6]. There in one cover are incorporated integrated i.e. the 16-bits DSP core, 12-bits fast ADC, RAM (2 kB) and Flash (64kB) memories. The expanded periphery contains also the communication ports (UART).

The well designed device, containing microcontroller and appropriate program, can fulfill the same function as DAQ board. It can perform i.e. the measurement data acquisition and can use the PC resources. Finally, microcontroller device is able to perform the data processing much more flexible, depending on the algorithm applied in processor program. The results obtained this way can be given to the user on the device indication unit. The use of PC resources extends significantly the possibilities of verifying of applied measurement procedures and improves the efficiency of the data processing. The laboratory implementation of the microcontroller device in cooperation with PC is focused on the explanation for students of the basic problems connected with analog and digital data processing in measuring channel. The concept of the instrument with distributed data processing meets many requirements connected with didactic implementation of considered measuring device.

2. THE CONFIGURATION OF THE LABORATORY INSTRUMENT UNDER CONSIDERATION

In Fig.1, the functional configuration of laboratory measuring instrument cooperating with running at PC LabVIEW application is shown. The instrument is based on the MSP430F149 microprocessor (Texas Instruments) and equipped with auto-calibration unit consisting of Howland current source charging capacitor [3,4].

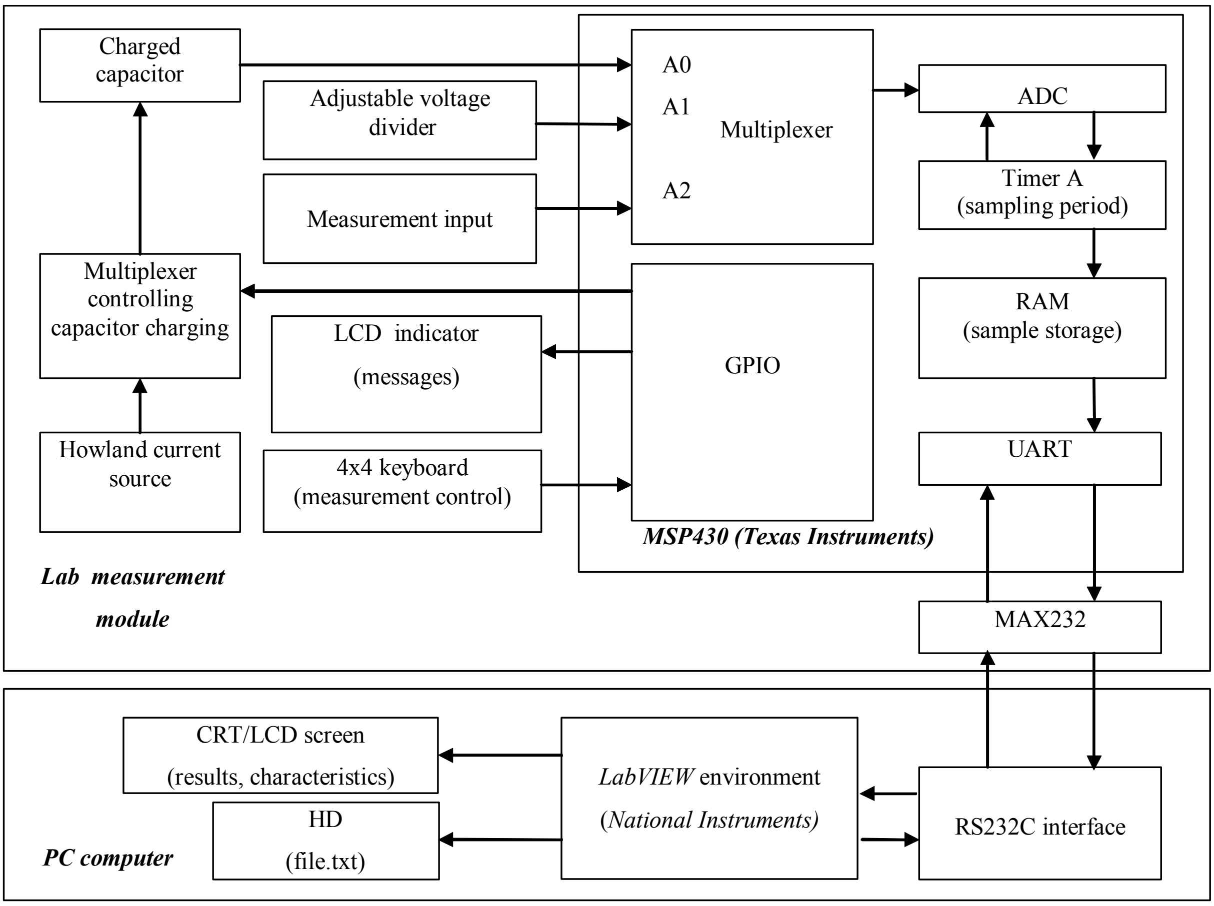

Fig.1. The functional configuration of laboratory measuring instrument cooperating with PC.

When the capacitor is charged, its voltage rises linearly and it is used as a calibration reference voltage on the input of the ADC. The charging process is controlled by processor program, with help of analog multiplexer.

The voltage samples, converted at ADC into digital words, are stored in memory until the voltage reaches the ADC upper reference level. This procedure is performed for designation of ADC actual characteristics as well as for assessment of actual level of disturbances influencing the measuring channel.

After the ADC full input range samples storing is completed, the collected data are sent via RS232C interface to PC. Further data processing is carried out in LabVIEW program. It brings much wider scope of calibration results presentation possibilities than at the LCD indicator installed onboard of the instrument.

3. THE INSTRUMENT ALGORITHMS

The ADC input voltage samples digital representation is used for estimation of uncertainty of the results obtained at the measurement process. The results are indicated in desired form in front panel of LabVIEW program as well as sent via RS232C to instrument to be indicated at its LCD panel.

The applied algorithms illustrating the relations between performed procedures connected with the distributed data processing are shown in Fig.2. The program consists of two main procedures: channel actual characteristics designation and measuring of channel input voltage. For both procedures, the data are obtained in instrument then sent to PC for further processing. At the end, the final results are sent back to the instrument for local indication at LCD panel.

The samples acquired during calibration procedure are analyzed taking into account the straight line $\overline{x}$ (Fig.3) designated using linear regression method [4]. The expanded uncertainty U is calculated with use of standard experimental deviation σ (1) and coverage factor k =2.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \overline{x}_i)^2}{N \cdot (N-1)}} \qquad (1)$$

where:
σ – the standard experimental deviation,
x_i – the digital representation of i-sample converted and collected during calibration process,
$\overline{x}_i$ – the value of projection of i-sample on the characteristics approximating line (Fig.3),
i – the sample number,
N – the number of converted samples.
Then, the expanded uncertainty is expressed as:

$$U = k \cdot u \qquad (2)$$

where:
u – the standard uncertainty ($u = \sigma$).

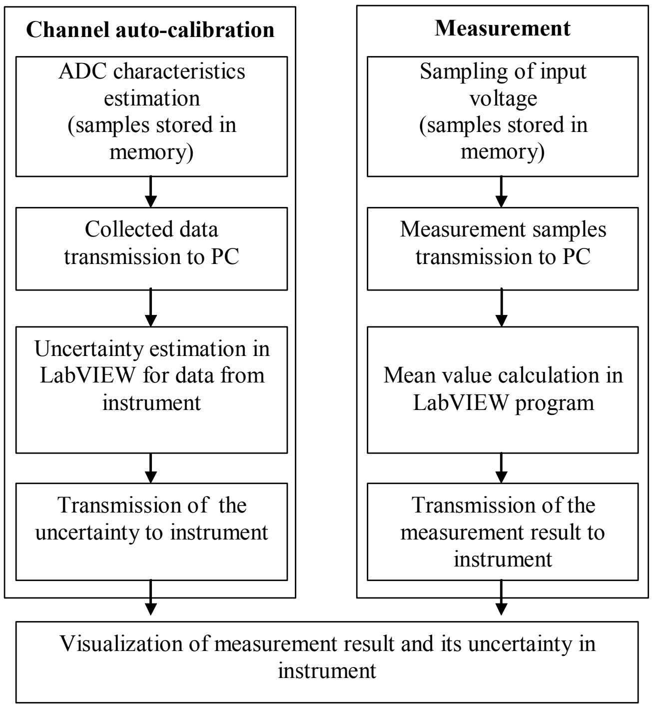

Fig.2. The general algorithms of distributed data processing.

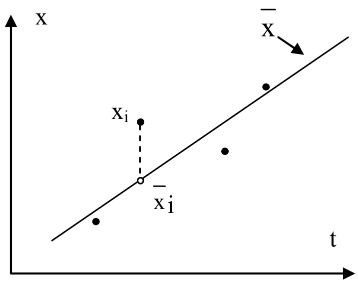

Fig.3. The components obtained during channel calibration, used for measurement result accuracy assessment.

The instrument processor program is created in IAR Embedded Workbench programming environment (Fig.4). It provides a completely integrated development environment including a project manager, editor, build tools and debugger [7]. The microprocessor embedded applications can be elaborated using assembler, C or C++. In a continuous workflow, students can create source files and projects, build applications and debug them in a simulator or on hardware. IAR Embedded Workbench offers the same intuitive user interface coupled with general and target-specific support for microprocessor and generates very compact and efficient code. Depending on the flash programmer version, the connection of the module with PC can be established via its parallel (LPT) or USB port. The exemplary view of IAR development tool window is shown in Fig. 4. The window enables to do easy access to all resources of microcontroller, e.g. RAM, stack, Flash, CPU register, ports, etc.

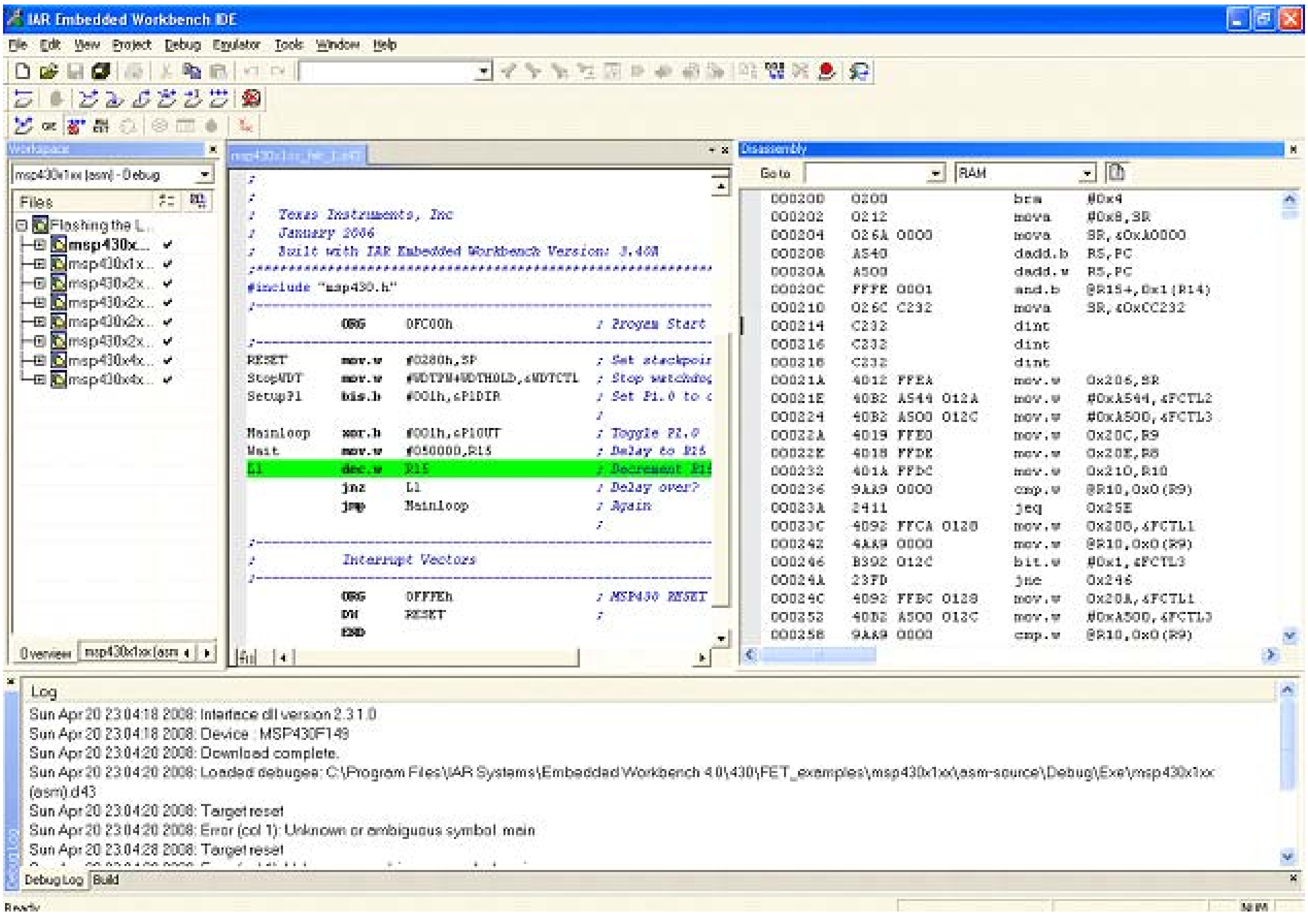

Fig.4. The view of IAR Embedded Workbench panel.

In Fig.5, the LabVIEW control panel designed for ADC auto-calibration data and its characteristics designation is shown.

In Fig.6, the LabVIEW control panel designed for instrument input voltage measurement is presented.

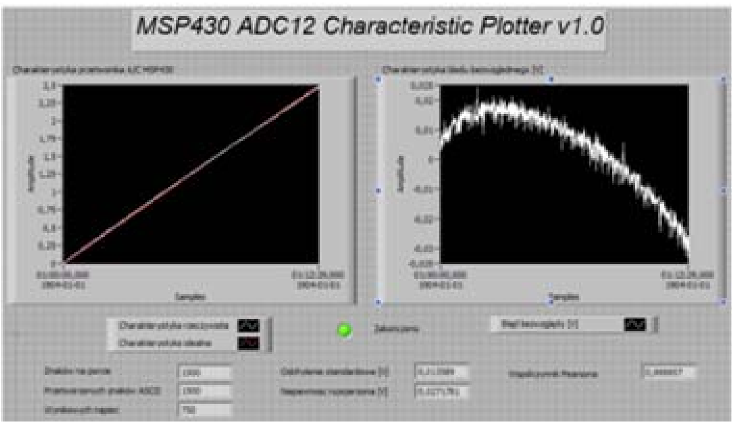

Fig.5. The control panel for ADC characteristics designation.

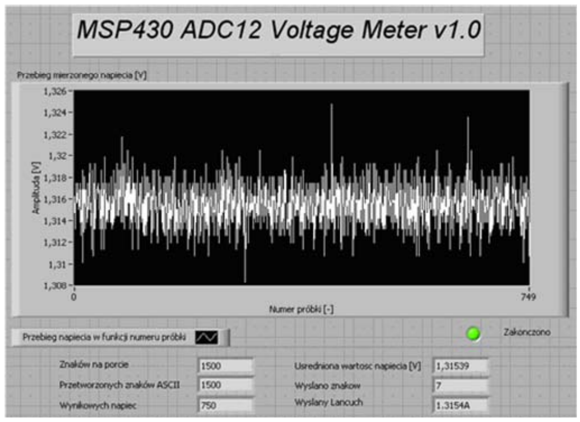

Fig.6. The control panel for instrument input voltage measurement.

In presented figures, the exemplary results acquired within the instrument and processed in LabVIEW application are shown.

The elaborated instrument measures the input voltage, which can carry an information about any quantity converted to voltage in respective converter. At the same time the measuring channel calibration operation is fulfilled.

Its effects are used for designation of measurement result uncertainty.

The rough data, as well acquired in instrument in calibration as measurement procedures, are transmitted to PC and elaborated in LabVIEW program. Then, the user is able to modify the data processing algorithm in easy way, e.g. accordingly to the type of measured quantity and applied converter, without interference with instrument processor program. After transmission from PC to instrument, the measurement result and its assessed uncertainty are indicated locally at the LCD panel as well as available in LabVIEW application running in PC.

The instrument can perform more universal functions than typical DAQ card, e.g. the preliminary processing of the collected data, the respective results indication and so on. On the stage of the instrument program designing, the instrument configuration based on distributed data processing is helpful for instrument procedures modeling.

The laboratory implementation of the instrument is focused on student classes carrying out. The students have at their disposal the source programs for both the microprocessor and the PC. They are designed in a clear and logical way, and are provided with the rich set of explanations and comments. For each subprogram, a transparent algorithm is present.

The teacher tutoring the laboratory class instructs the students to perform particular tasks, which can be done by modifying the basic set of programs and observing and analyzing the results. All microprocessor subprograms can be adapted depending on the measurement channel model and indispensable sequences of the measurement procedures.

The students are obliged to perform several exercises giving them fundamental knowledge about the measuring systems and forming their competencies and skills within:

- the processor program designing using professional tools in assembler as well as C^{++} languages,
- using of processor resources for external data exchange, for measured as well as control tasks,
- recognizing standard measuring channels, e.g. for temperature with use of PT-100 sensor or analog 4..20 mA interface,
- using of keyboard, LCD panel and other processor peripherals,
- controlling of the time occurrences and interrupt processes,
- applying of digital data processing algorithms in microprocessor ,
- the standard communication interfaces managing,
- designing of the LabVIEW application,
- the measuring channel model implementation with share on hardware and software part,
- data processing sharing between instrument and PC,
- the measuring channel calibration procedures,
- the measurement and control processes modeling,
- assessment of the measurement result accuracy,
- planning the measurement process.

Summarizing, the proposed laboratory station cumulates many important problems concerning the use of currently available techniques and technology for measurement and control information managing. It enables the students to investigate and analyze several processes connected with data handling in distributed measurement and control systems.

4. CONCLUSIONS

The main goal obtained in presented paper is the successfully finished research focused on the instrument having original features. The performed preliminary tests of the measurement and functional properties of the instrument confirmed the correctness of its work. Further investigations will be aimed on verification of the uncertainty assessment results for various levels of external disturbances.

In final configuration, the instrument is intended as standalone device with direct indication of the uncertainty of the measurement result.

The concept of the instrument with distributed data processing is useful for didactic needs. It enables to demonstrate the various problems connected with the measuring systems exploitation.

The instrument configuration with distributed data processing is the way to simplify the measurement algorithms and verification of processor programs correctness.

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