ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
Tome VI (Year 2013) – FASCICULE 1 [January–March]
ISSN 2067–3809

[1.] Mirosław LUFT, [2.] Radosław CIOĆ, [3.] Daniel PIETRUSZCZAK

INTEGRATED MEASUREMENT SYSTEM BASED ON THE IEEE-488 BUS

[1,2,3.] KAZIMIERZ PUŁASKI TECHNICAL UNIVERSITY OF RADOM, FACULTY OF TRANSPORT AND ELECTRICAL ENGINEERING, MALCZEWSKIEGO 29, 26-600 RADOM, POLAND

ABSTRACT: The paper presents a description of the measurement systems in terms of their configuration and system components. The measurement system based on IEEE-488 interface is described and its advantages are pointed out. Examples of measurement applications are also given.
KEYWORDS: IEEE-488, GPIB, SCPI, VEE Pro environment, measurement system

INTRODUCTION

The work of modern measuring, manufacturing or other processes requiring reading of measurement data is based on the data provided by sensors located in the crucial - from the point of view of the process control and performance - places. Data obtaining, transmission and processing are accomplished within the measurement system which is defined as a set of devices, organizational means and information processing programs used to ensure correct performance of the production process. A characteristic feature of such a measurement system distinguishing it from the measurement setup is the presence of a system built-in device responsible for the information flow which is referred to as a controller. Usually it is a microprocessor controller or a computer.

Architecture and configuration of the measurement system affect the way of information flow and the system's further expandability. Three different types of the measurement system are distinguished - those of the bus, loop and star topology.

MEASUREMENT SYSTEM CONFIGURATIONS

Bus topology

In the bus topology (Figure 1) all the devices of the measurement system are linked to the common line of data transmission (data bus). None of the devices connected to it has a distinctive position and each of them can fulfill the function of the device reading measurement data as well as managing the system (controller) provided it has such an option. However, there is one restriction imposed, namely, that at the same time only one device fulfilling the managing function can be active. The aim of such a device is to control information transmission and reception between devices. It necessitates assigning unique addresses to all devices of the system and this is accomplished by giving permission for data transmission and reception, the so called transmission and reception addressing.

The advantage of the data bus system is its structural and functional flexibility in the field of the system's expansion and the ease of changing its configuration.

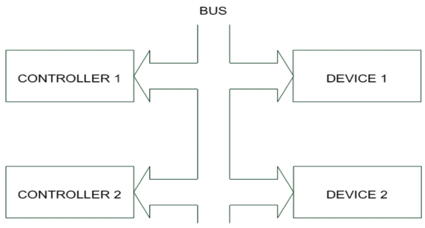

Figure 1. Data bus topology

Loop topology

A characteristic feature of the loop topology (Figure 2) is the uni-directional, set flow of information. In this system the controller has no special position and can be located at any place of the loop.

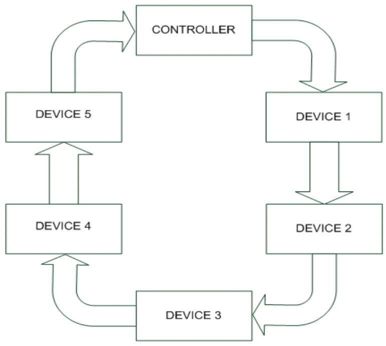

Figure 2. Loop topology

The transmission starts with sending information by the controller (controlling command or data) to the nearest device. If the information is not intended for this device it is immediately sent on until it reaches its destination. Such a transmission method requires addressing individual devices to transmit and receive. After the information has reached the targeted device (its destination), its content is analyzed and the command executed or, alternatively the data is received and then, sent further on in the unchanged

© copyright FACULTY of ENGINEERING - HUNEDOARA, ROMANIA

form. Sending the information on by a given device which it was to reach means that controlling commands have been executed or the data have been received. When the controller receives the information which was sent earlier it means that all the devices to which the information was sent confirmed its reception and it can send new information.

An advantage of the loop configuration is a small number of signal lines and its drawback is slow performance resulting from the fact that information has to flow through all the elements of the measurement system.

Star topology

In the „star" system (Figure 3) the controller has the central position and it is the only element communicating with other devices. Individual devices can communicate with each other only via the controller. Due to the difficulty in expanding such a system, it is used in simple measurement systems with a small number of devices.

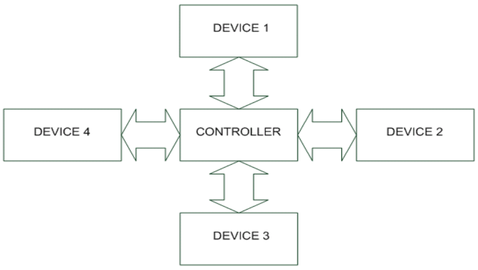

Figure 3. Star configuration

MEASUREMENT SYSTEM COMPONENTS

The structure and individual elements of the measurement system depend on its function. Nevertheless, the system always contains basic elements indispensable in the process of measuring the measured quantity. They are:

- *a device controlling the information flow in the system (controller) which is an appropriately programmed microprocessor or computer;*
- *a sensor converting the measured value into an electrical signal;*
- *an analog-to-digital converter converting the analog signal into its digital representation which can be interpreted by a digital device;*
- *an interface bus.*
- *Usually the measurement system also contains:*
- *signal conditioners - adjusting the input signal from the sensor to the form suiting the next element of the measurement system;*
- *model signal generators;*
- *devices visualizing measurement results (oscilloscope, computer monitor, printer, etc.);*
- *recorders.*

From the point of view of their functions, measurement system elements can be divided into:

- *the object of measurement whose parameters are read by the measurement system;*
- *measurement sensors processing the measured quantity into a signal which is readable for the measurement system;*
- *the controller, whose task is to coordinate the measurement process, in other words, to define/determine the conditions of the information flow, measurement time, the layout of devices, data acquisition, execution of the measurement data processing algorithms. It can be a microcontroller system with a written in program for controlling the measurement system or a computer with appropriate cards of the interface data bus connecting the measurement system devices and appropriate software;*
- *the block generating model signals and, less frequently, signals affecting the object of measurement and controlling its executive elements;*
- *the signal acquisition block collecting the measurement data;*
- *the data processing block executing set computation algorithms based on the measurement data;*
- *the block of communication with the user introducing information from the user into the system and taking the information out of the system.*

Division of the measurement system into functional units does not always overlap with their actual execution which, to a large extent, depends on the interface bus used and measuring devices. An example here can be provided by the modern measuring cards fulfilling the function of the data acquisition block and the block generating model signals. Moreover, the actual execution of the measurement system functional blocks can be carried out in the form of hardware or software. Currently both these methods are combined.

MEASUREMENT SYSTEM IN THE IEEE-488 INTERFACE

The pursuit of the ease of the measurement system configuration changes, its flexibility in the choice of the types of the quantity measured and expandability determines the measurement system chosen which the one of the data bus configuration is. The IEEE-488 is one of such types of interfaces.

The structure of the IEEE-488 interface known also as the GPIB (General Purpose Interface Bus) is based on the common data bus configuration to which all instruments are connected in a parallel manner (Figure1). Both interface messages (commands, addresses) and data from instruments are sent via this bus. Devices in this interface are divided into:

- *transmitters: sending messages and data to one or more receivers;*
- *receivers: receiving messages and data;*
- *controllers: monitoring connections and addressing the transmitter and the receiver with each other.*

Instruments can at the same time fulfill the roles of transmitters, receivers and controllers, e.g. a computer equipped with a GPIB interface card. At the moment, however, the device can fulfill only one of these functions.

Fifteen (15) devices including controllers can simultaneously be connected to the interface data bus. Each of them has the same access to the bus. The interface system is managed by the controller which organizes and manages the information flow (by sending addresses and commands). There can be *many controllers in the system but at a given moment only one controller can be active, the so called CIC (Controller-In-Charge). Controllers can pass control over the system to each other but always one of them must have the superior role in relation to others. Such a controller is known as the System Controller and is it's initiated as the active controller the moment the system is started. It identifies the device through individual 5-bit Device Addresses (DA) being the numbers from 0 to 30. These addresses are assigned to devices at the moment of the system setting up. This is accomplished by means of jumpers or switches on the device or by a program. The addressing method depends on the producer of a given device. Addressing is sending the TAD (Talk ADress) via the system bus received by the device as MTA (My Talk ADdress).*

At a given moment of the system's work only one data transmitter can exist while there are many receivers. Activating the transmitter or receiver features is a result of appropriate addressing by the controller. In the case of the systems consisting of two devices where one is addressed as the transmitter and the other as the receiver direct communication between such devices is possible, for example, a multimeter configured to transmit and a printer configured to receive. In such a case the system does not need the controller.

The physical structure of the interface consists of 16 signal lines: 8 data lines, 3 handshake lines (NRFD, NDAC and DAV) and 5 control lines (ATN, EOI, IFC, REN and SQR).

Data transfer over the GPIB bus is an asynchronous operation with confirmation of the reception. The length of the cable between individual devices should not exceed 2 m, and the total length of all cables - 20 m. There is a possibility of extending the number of the devices used and making the length of cables longer with the help of the so called expander. The expander is a device which has two GPIB ports. You can connect 14 devices to each of them, including the controller which gives a possibility of connecting 28 instruments and extending the bus length to 40 m. Physically, the system consists then of two electrically separate networks that function as one logical network.

Easy configuration of the measurement system based on the IEEE-488 interface relies on clearly set standards of the interface hardware and software (in the form of the SCPI language) which is supported by the biggest companies manufacturing measurement equipment.

SYSTEM FOR MEASUREMENT OF DIFFERENT QUANTITIES

On the basis of the IEEE-488 bus the measurement system has been made which allows the measurement of: current, voltage, frequency, resistance and temperature and enables controlling of the arbitrary waveform function generator parameters (type of waveform function, frequency and amplitude) and programmable DC power supply (voltage and current).The system consists of:

- *a computer with the GPIB controller and software for creating applications;*
- *a multimeter - 2 pieces;*
- *programmable DC power supply;*
- *an arbitrary waveform function generator;*
- *a function generator;*
- *a programmable constant voltage source;*
- *a set of sensors.*

The measurement system software is based on applications written in the graphical programming environment of the VEE Pro software and on controllers of actual devices integrating this environment with the GPIB interface.

The VEE Pro is an object-oriented programming environment offering a possibility of developing an application controlling the measurement system, measurement acquisition, measurement data analysis, data processing and presenting as well as creating virtual tools supplementing or even replacing the object and measurement instruments.

The basic feature of the environment is representation of the program instruction in the form of the object's icon on whose input signals certain operations are performed. Instruction sequences are accomplished by connecting the object's output with the input of the following object. Graphically the program resembles a block diagram on which the directions of the information flow and control information are indicated.

The object may be a physical representation of the actual device functions (e.g. multimeter, function generator, etc.) together with their front panel and regulators/adjusters or typically program-related functions (e.g. if-then-else statement). One's own application can be provided with a graphical interface containing different types of ready-to-use indicators, regulators/adjusters and displays.

The VEE Pro built-in ActiveX mechanisms allow us to use external dynamic libraries and integrate the designed application with external software, such as Microsoft Excel, Word, etc.

Controllers dedicated to specific devices enable communication between them within the standards of the IEEE-488, VXI and RS-232 interfaces.

The VEE PRO packet is available for the systemic platforms of Windows, Linux, Unix and Sun.

EXAMPLES OF MEASUREMENT APPLICATIONS

The measurement of current, voltage, resistance and frequency was carried out with the use of the Picotest M3500A multimeter being in the IEEE-488 interface network. It enabled the measurement of such quantities as current, voltage, resistance and frequency. Figure 5 shows a sample solution of such an application with the use of the SCPI language and the VEE Pro environment.

Figure 5 shows the control panel of the remote control application for the Rigol DG DG2041A arbitrary waveform function generator. Application has an option of transmitting all its control commands to the device. To use it one must know the commands of the SCPI language. Commands are written from the command line field Read parameters or Set parameters depending on the type of the service command. In the Instruction field the manner of application service and an example of the command syntax are described.

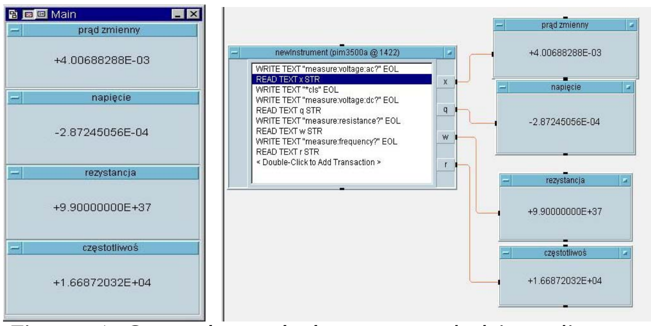

Figure 4. Control panel elements and object diagram of the application for measuring current, voltage, resistance and frequency (prąd zmienny – alternating current, napięcie – voltage, rezystancja – resistance, częstotliwość – frequency).

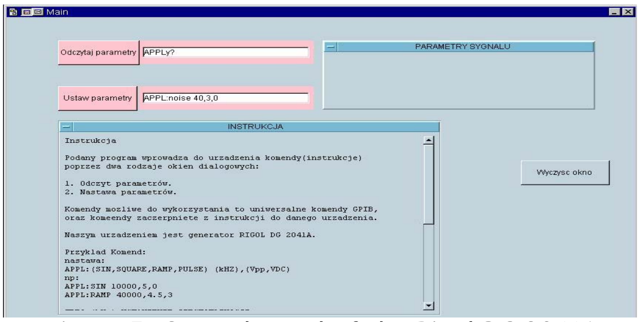

Figure 5. Control panel of the Rigol DG 2041A generator (instrukcja – instruction, parametry sygnału – signal parameters, wyczyść okno – clear, zapytanie o parametr – request parameter).

Figure 6 shows blocks of an object programming which the application is built of.

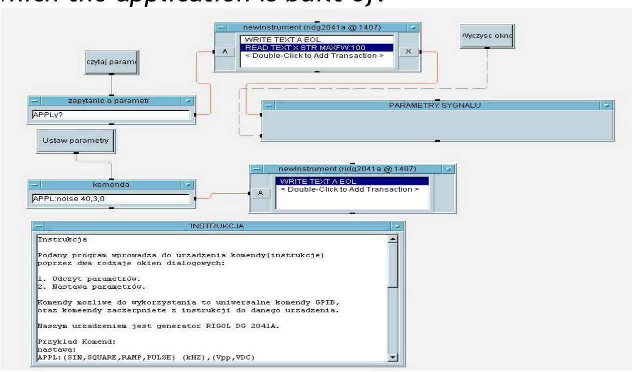

Figure 6. Control application for the Rigol DG 2041A generator

CONCLUSIONS

The unique contribution of the authors of this paper is an approach to measurement allowing the simultaneous measurement of several different quantities of the measuring system, or even its single device.

Typically, only one device is used to measure quantity even if it is a multimeter. The authors try to take advantage of measuring equipment to the “maximum”. Figure 4 shows an example multimeter which measures four different quantities. In practice all terminals are connected to relevant units of measurement points and whether such a measurement is made depends only on the programming device by means of a computer. Measurements and device configuration is performed remotely. For easy handling of measurement the Agilent VeePro programme and IEEE-488 bus were used.

The above mentioned solutions make it possible to simultaneously applied to: 1) remote measurements, 2) using many capabilities of the device for the measurement of several different quantities in a single measurement, 3) using the IEEE-488 bus, and 4) controlling and perfoming measurement through the use of object-oriented programming of the VeePro Agilent environment.

The use of interfaces integrating numerous measuring devices for measurement purposes creates many possibilities of the measurement system architecture thanks to which measurements of various quantities are possible as well as controlling the devices in such a way that they can systematically interfere in the course of measurements. The standardised interface and programming language allow us to integrate the measurements of many devices in one application.

REFERENCES

[1] *Luft M., Cioć R., Pietruszczak D.: Measurement system with IEEE-488 bus, ISSN 1231-5478, Logistyka 3(2012), (in Polish)*

[2] *Luft M., Cioć R., Pietruszczak D.: Measurement system for diagnostic tasks in transportation based on the IEEE-488 bus, Praca naukowo-badawcza PRad., Radom (2011), (in Polish)*

[3] *Mielczarek W. Measuring devices and systems compatible with SCPI standard, Helion, Gliwice (1999), (in Polish)*

[4] *Nawrocki W. Distributed measurement systems, Wydawnictwo Komunikacji i Łączności, Warszawa (2006), (in Polish)*

[5] *Standard Commands for Programmable Instruments (SCPI), SCPI Consortium (1999)*

ACTA TECHNICA CORVINIENSIS – BULLETIN of ENGINEERING

ISSN: 2067-3809 [CD-Rom, online]

copyright © UNIVERSITY POLITEHNICA TIMISOARA,
FACULTY OF ENGINEERING HUNEDOARA,
5, REVOLUTIEI, 331128, HUNEDOARA, ROMANIA
http://acta.fih.upt.ro