Universal Recording System for the Stations of Cosmic Rays

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Abstract— **On the basis of serial producing input-output modules Fastwell (similarity Octagon Systems, 2008) the universal data gathering system from the cosmic ray stations network MARS-08 has been created. The main part of modules UNIO96-5 is 4 programmable micrologic units (FPGA - Field-programmable Gate Array), that allows them to be used easy for solving the different problems of data gathering. In dependence on loaded control programs this device may be implemented in different ways: 1) as multichannel (up to 96) data gathering system, for example neutron supermonitor; 2) as detector of the multiple neutrons generated in the neutron monitor; 3) as multichannel data gathering system of telescope, combined with the selection system of double coincidence. These three operating modes can be realised simultaneously, using various micrologic units FPGA from 4 possible.**

The data gathering system is solved completely at a hardware level without use of the processor resources and therefore it differs by high speed of operation (up to 50 MHz). Modules are fulfilled in MicroPC format (basically there is also PC 104 format) and intended for operation in a range of temperatures -40°C ч +85°C. Modules can be used, as portable together with other modules of MicroPC, and as a part of the personal computer.

1. Introduction

The feature of the data gathering system of multidirectional telescopes and hodoscopes is that rather small number of input channels after the system of directions selection leads to a lot of numbers of output channels [1,2] Secondly, at registration of the multiple neutrons generated in the neutron monitor, we also have a small number of input channels, such as a total signal from each section of the neutron monitor, and at output we receive enough great number of output channels defined by maximum multiplicity of registered stars. Moreover, the number of output channels can be very big if the problem of registration of time intervals distribution between beams of stars is set [3-8]. And, thirdly, in the most simple case when data selection is carried out independently, it is hardware way more often, and the data gathering system is used in usual counting mode. Thus, if the data selection system (on coincidences, on multiplicities or other criteria of selection) is integrated with the data gathering system it leads to three types of registering systems.

At construction of such systems some approaches which differ only by speed of operation are possible. The first is when data selection and data gathering tasks are solved completely at program level [2]. Speed of operation in this case is defined only by speed of the used processor. The second is hardware-software approach. Selection of events is executed at hardware level, and organization of counting channels is carried at program level. And at last, the third approach providing the greatest speed of operation, it is completely the hardware approach. At hardware level coincidences and decoding of directions of particles arrival are executed, and also the necessary number of impulses counters which are interrogated with the set interval is organized. Such systems are very floppy and effective and today are built only on units of programmable logic ([1,9,10]. Just on this principle the universal data gathering system of cosmic rays stations offered in this paper has been constructed, and it is constructed on the basis of mass serial production input-output UNIO96-5 modules of Fastwel or Octagon Systems and so can be applied on many cosmic rays stations.

2. The general description of data gathering system

The input-output module UNIO96-5 is fulfilled in MicroPC standard and intended for input/output of 96 signals with logical levels of CMOS or TTL. Four of 24-channel (on input/output) matrixes FPGA realized on programmable micrologic units of XC5204 XILINX type and appropriate signal connectors are installed in the module (fig. 1). Loading binary files of schemes variants for matrixes FPGA and their descriptions are placed on File-Servers of Fastwel ftp://fastwel.ru/pub/hardware/ and Prosoft ftp://ftp.prosoft.ru/pub/Hardware/Fastwel/. From all the offered variants for our tasks the following load programs are important. Module c00 (24x16 bit of channel impulses counters up to 50 MHz) and n04 module (the builder of hardware interrupts on events of 24 inputs.

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If it is necessary to realize data gathering system in usual counting mode, then, having loaded into each of 4 matrixes the c00 module, we realize the 96-channel 16-digit detector of impulses (Mars08c).

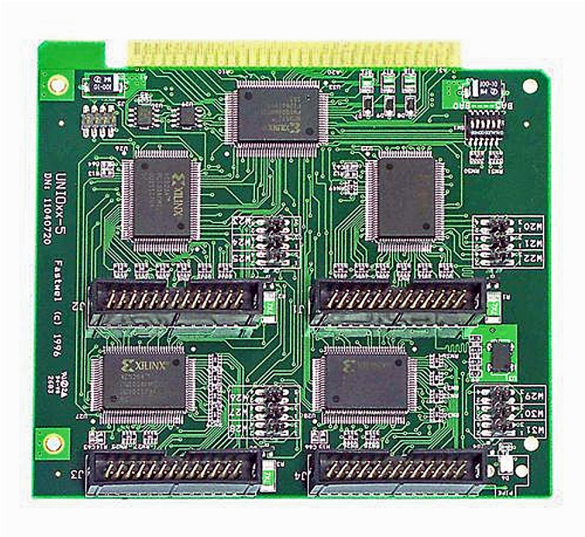

Fig. 1. Input/Output module UNIO96-5.

If to load n04 module which realizes system interrupts on 24 lines with fixing of a line number and the interruption moment, and to organize for each channel the counting of system interrupts number thus we realize the 96 channel impulses detector. However in this variant there are also additional possibilities. If to organize measurement of time intervals between interruptions it is possible to realize registration of time intervals distribution between beams of stars and after the subsequent processing of such signal to obtain the data about multiple neutrons for input signal of the neutron monitor (Mars08n). If input signals are impulses from detectors of muon telescope, thus analyzing the coincidences of interruptions moments at program level, it is possible to realize selection in directions of muon telescope. However the analysis of time intervals between impulses with selection of multiple events or selection of possible coincidences in this case is carried out at program level and because of it the speed of system essentially decreases. Nevertheless, this speed of operation is enough for work with counting detectors with typical times mks.

For faster nanosecond detectors the best solution in this case is development of a special loadable xCC module for programming of micrologics for selection of possible coincidences. It allows solving the task completely at hardware level. XCC module realizes double coincidences between detectors 3x3 at each level and counters for each of possible coincidences.

For each variant of data gathering system the interface program in which the operating mode is established is developed, time intervals are generated, and the saved up data is brought in archive or a database. The controller is rated at operation in stringent conditions and the working range of temperatures is from - 40 °C to + 85 °C, an average time between failures is 10^6 hours.

Characteristics of universal registration system for each case are resulted in more details more low, and the total result is in table 1.

3. The 96-channel 16-digit detector of impulses (Mars08c).

Such system is developed under the OS Windows and OS Linux. By development of the interface under the OS Windows it was necessary to solve two problems. The first is a generation of time intervals with accuracy necessary for us. For the used controller there is a possibility, both external synchronization for the time interval definition and its definition by means of the standard internal timer. In the latter case the timer allows to count intervals with accuracy of 50-60 milliseconds, and this accuracy very strongly depends on computer loading. However there are high-speed multimedia timers which are applied to multimedia applications. Their application (http://z-oleg.com/delphi/systimer.htm) has allowed increasing in 10 times the accuracy of measured intervals and to eliminate influence of the computer loading that is the most important. Accuracy of a second interval is about 1 millisecond and it is already 0.1 %. Such accuracy is quite satisfactory for our tasks as for the main minute interval this accuracy even more than 10 times better - 0.01 %.

The second problem is that in OS Windows exchange instructions with INPUT and OUTPUT ports are blocked and accessible only to applications of a ring 0 (drivers).

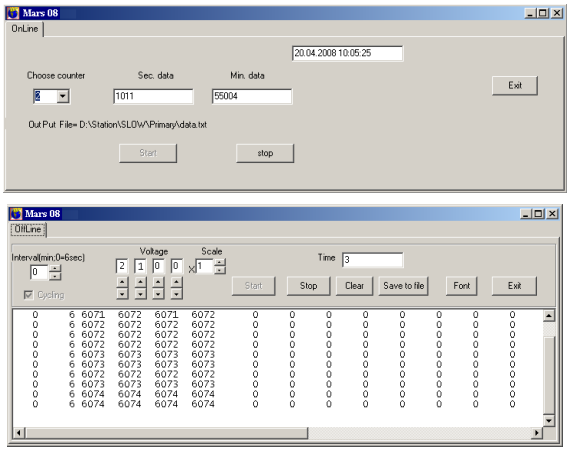

Fig. 2. The working window of system program Mars08c/Windows. On the top panel – window for working mode, on the bottom panel – working window in a debug mode.

TDLPortIO component has been developed (http://www.torry.net/vcl/system/portaccess/dlportio.zip). This component works with its universal driver, allowing to exchange by data with COM port and parallel ports with addresses from $100 to $FFFF.

On Fig. 2 the working window of the interface program is shown. On the top panel is the working window for the main counting mode, a working window of the program in a debug mode, for example at removal of counting curve, is shown on the bottom panel. The result of minute measurement in the form of text string ” DateTime & Data of channels” is

put down into the file LastData the data from which within the next minute should be calculated and put down into a database by a specially developed application. The software and the documentation necessary for installation of the described version are free and are on File-Server ftp://cr0.izmiran.ru/hardware_softwere/main.htm.

The version of the interface program under the OS Linux/Dabian on functional capabilities is approximately similar and are on File-Server also.

4. The detector of interimpulse intervals and multiple neutrons (Mars08n)

Such system can be most simply developed under the OS DOS. To provide such good response to interruption in OS Linux, as well as in DOS, it is necessary to develop the appropriate driver. By this time the system has been developed under the OS DOS.

By interface development it was necessary to solve a problem of interimpulse intervals measurements with necessary accuracy and without use of additional hardware. In Pentium processors and in all subsequent Intel's processors so-called Time Stamp Counter is built in. It is the 64-bit counter which increases its value on each beat of the processor. Reading out the timer display after each interruption, very small times between impulses are defined with very big accuracy. At frequency of the processor of 3 GHz the accuracy will be better than 10^{-4} %. Essential shortcoming is dependence of algorithm on frequency of the processor.

The controller works under the OS MS DOS 7.10. It is DOS which has been "pulled out" from under Windows 98. Unlike pure DOS, it can work with FAT32. Microsoft Network Client for DOS v3.0 is added to DOS – the software allowing DOS-computer to be connected to MicroSoft network. It is enough to initiate the network protocol NetBEUI which allows to install connections only inside a local network.

Primary data (i.e. distance between impulses) of such system occupies enough great volume and should be processed operatively by the specially created application. The software and documentation necessary for installation are on also the File-Server ftp://cr0.izmiran.ru/hardware_softwere/main.htm.

The variant of data gathering system under the OS Linux is developed also, but this system works not in a user mode but in a kernel mode. Creation of such software is more labour-consuming, but the main thing depends on the used Linux version.

5. The data detector of the multidirectional muon telescope (Mars08x)

To reduce the number of communication associations in case of muon telescope, it is necessary to integrate the scheme of selection of the data on coincidence with the data gathering system. Now this task can be solved on the basis of programmable micrologic units when the signal arrives into impulses counters for each channel after selection on coincidence. In this case the interface software works in a user mode, but not in a kernel mode, i.e. there is no necessity to process interruption, as in case of Mars08nCC/Linux.

For a telescope consisting of two planes of detectors (U and L) on k_X and k_Y detectors on each co-ordinate, by means of appropriate coincidences number it is possible to organize $m = (k_X \times k_Y)^2$ of telescopes and to select $n = (2k_X - 1) \times (2k_Y - 1)$ of independent directions of particles arrival. In the elemental case for a telescope consisting of 2x2 detectors in each plane, k_X =2, k_Y =2, m=16, and n=9. Now telescopes with geometry 4x4 detectors in each plane k_X =4, k_Y =4, m=256, and the number of independent directions of particles arrival n=49 are built most often. For hodoscope systems the number of detectors in each plane is even more and k_X =16, k_Y =16, m=65536, and n=961.

However each programmable micrologic unit of UNIO96-5 controller has only 24 input lines and therefore we receive restriction k_X =3, k_Y =4, m=144, n=35. For increase the number of input lines to 96 it is necessary to use UNIO96-1 controller.

As the data gathering system is integrated with the scheme of selection on coincidences it is necessary to consider the concrete constructions of telescopes for which such of data gathering system can be used.

Name of version	Loaded unit	OS	Interface programming language	Functionality
Mars08c	c00	Windows	Delphi	16-digit impulse counter (up to 96 channels)
		Linux	C++	
Mars08n	n04	Linux		The detector of interimpulse intervals and multiple neutrons. Selection system on coincidences and the detector of impulses.
		DOS	C	
Mars08x	xCC	Windows	Delphi	The integrated scheme of coincidence and the detector of the muon telescope data, two planes - 3x3 detectors on each
		Linux		

Table 1. Comparative functionality of data gathering system on the basis of the UNIO96-5 unit. Mars08n/Linux and Mars08x versions at a development stage.

6. Conclusion

On the basis of serial producing input-output modules the universal data gathering system of cosmic rays stations MARS-08 is created. A basis of UNIO96-5 modules are programmable micrologic units. It allows to use the system for the decision of various problems of data gathering for physical experiment. The next systems are developed:

1) Multi-channel (up to 96) data gathering system Mars08c, for example, for neutron supermonitor in a countable mode of impulses. The system is developed under the OS Windows and OS Linux.

2) The detector of the multiple neutrons generated in the neutron monitor. The system is developed under the OS DOS. The versions Mars08n/Linux are at development stage.

3) Multi-channel data gathering system of telescope Mars08n/CC, combined with selection system on double coincidences. The system is developed under the OS DOS.

In the first case the system is completely realised at a hardware level, in the second and third cases at hardware-software level. It is necessary to develop the additional module of loading of programmed logic xCC for the full decision at a hardware level.

Controller UNIO96-5 has one essential shortcoming – it is fulfilled in standard ISA bus, and modern PC have no such slots any more. But this shortcoming can become advantage if to take an offer of ARS Technologies Inc (http://www.arstech.com/cat--usb2.0.html) which offers device USB2-ISA which converts USB port in virtual ISA slots.

Fig. 3. Controller USB2-ISA-x3.

Controller USB2-ISA-x3 allows plugging and handling of up to three standard or custom ISA cards. Our usb2isa-x3 provides simple migration from ISA form factor to USB, full access to memory and I/O space of the ISA card, and handling of IRQ and DMA events. On the basis of such device the external information collection system can be easily created, for example, to a notebook through USB port or to any modern PC. On Fig. 3 one of variants of such connector is shown. The controller usb2isa-x3 works under the OS Windows 98, ME, 2000, XP, Server 2003, Vista or Linux – with a kernel 2.4.xx and 2.6.xx.

Besides, as ISA bus became the industry standard, the Winbond company has released controllers of input/output W83C553F and W83C554F which fulfil bridge functions between PCI and ISA buses ([11] Rakovich, 2001).

Acknowledgments

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