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System of data accumulation for multidirectional muon telescopes

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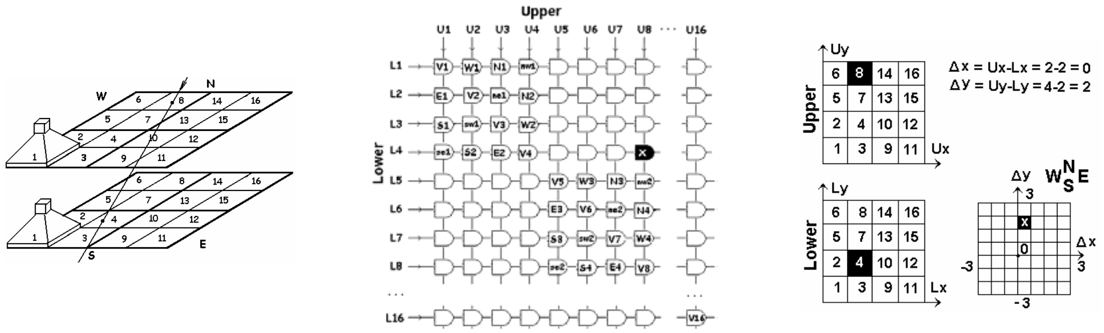
The system of data accumulation integrated with the selection system by coincidence is proposed for multi directional telescopes and hodoscopes. The system of data accumulation is created on a program level by using high-speed processor, when coincidences and decoding of particle arrival directions as well as pulses counters for a necessary number of channels are realized at the program level. The system of data accumulation is made as a universal external device. Depending on the control program loaded this device can be used as: 1) a system of telescope data collection integrated with the system of selection by double coincidences; 2) a system of data collection from 32 channels, for example, the neutron monitor; 3) a register of multiple neutrons generated in the neutron monitor.

1. Introduction

The characteristic of systems of data collection from multidirectional telescopes and hodoscopes is that a relatively small number of input channels correspond to a large or very large number of output channels. This problem is similar to the problem of registration systems of accelerator experiments. In the last case the original method of selection by coincidences integrated with the system of data collection is used [1, 2]. This solution is optimal for our problem as well. There are three possibilities, which in principle differ by speed performance. The first providing the highest speed is totally an apparatus way, when at the device level systems of coincidence and decoding of particle arrival directions are performed as well as a necessary number of channels for pulse counters are organized and asked with a given interval. Today these systems



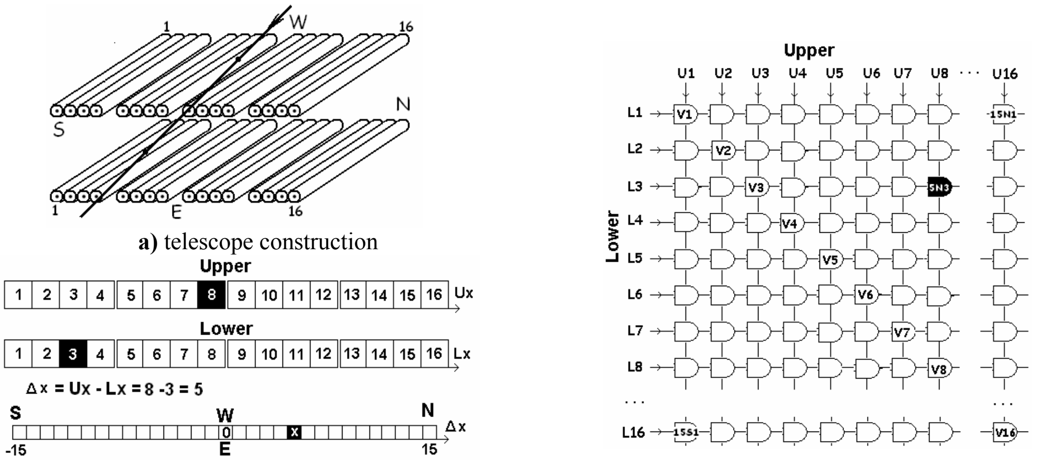
a) the telescope scheme **b**) a realization of coincidences (only a part is shown) **c**) a selection of independent directions

Figure 1. Realization of double coincidences for the scintillation telescope.

use only elements of programmed logic [3, 4]. The second is an apparatus-program way. At the device level systems of coincidence and decoding of particle arrival direction are performed; at the program level count channels are organized and necessary events are selected. At least, the third way, when the whole task of data collection is resolved at the program level. In this case the processor type only determines the speed of performance. Since the system of data collection is integrated with the scheme of selection by coincidences, then it is necessary considering a particular types of telescopes, for which this system of data selection is devoted.

2. Detectors

We consider two types of telescopes: the scintillation telescope and the count telescope of double coincidences, each plane of which has up to 16 detectors. For the telescope with two planes of detectors (U, L) with k_X , k_Y detectors for each coordinate using the corresponding number of coincidences it is possible organizing $m = (k_X \times k_Y)^2$ telescopes and selecting $n = (2k_X - 1) \times (2k_Y - 1)$ independent directions. Figure 1a shows a construction of the scintillation telescope. Each plane contains 4×4 = 16 detectors forming m=256 independent double coincidences and providing n=49 independent directions of particle arrival. Figure 1c illustrates a principle of selection of independent directions for the scintillation telescope. The left part of this figure shows detectors in upper and lower panels, which have registered simultaneously incoming particle. Determining coordinates of the upper (Ux, Uy) and lower (Lx, Ly) detectors by the corresponding coordinate difference, as shown in Figure 1c, it is possible determining the arrival direction of



a) telescope construction

c) selection of independent directions

b) realization of coincidences (a part is depicted)

Figure 2. Realization of double coincidence for counter telescope.

particle. The count rate of single counter is N =200 imp/sec, the vertical count rate is 40 imp/sec. A duration of output pulses is τ =0.5 mks.

The left part of Figure 2b shows a construction of the counter telescope. For determining a direction of particle arrival the telescope has two coordinate planes with 16 counters in each forming m=256 independent double coincidences and selecting n=31 independent directions of particle arrival. Figure 2c illustrates a principle of selection of independent directions in a case of the counter telescope of double coincidences. The method is similar to the method of inclined direction selection for the scintillation telescope. A count rate of single counter is N =50 imp/sec, a vertical count rate is 10 imp/sec. A duration of output pulses is τ =5 mks. These parameters are necessary for estimates of missed counts, which are estimated as $N_r = 2\tau N^2$ in a case of the telescope of double coincidences.

3. **System Features**

The system of data collection is made as universal external device. Depending on a control program loaded this device can be used as: 1) a system of data collection from telescope integrated with a system of double coincidence selection; 2) a system of data collection with 32 input channels, for example, the neutron monitor; 3) as a register of multiple neutrons generated in the neutron monitor. On this stage we consider only the systems of data accumulation from telescope integrated with the system of double coincidence selection.

A basement of the system of data collection is a high-speed processor RISC of the series ARM 710T (36,864 MHz) that can execute code up to frequency of 50MHz. Signals from the sensors are directly delivered to common BUS I/O. The maximal number of input channels is 16 for each of two layers of detectors, i.e. all 32 ranges BUS. Data transfer to external systems (for instance, PC) for further analysis can be performed as by using the USB port well as directly to the Ethernet (HUB – SWITCH connectivity on IP network). Maximal speed of data transfer for USB or Ethernet connection is 965 Kbps. In a case of direct connection to local network or IP net an IP address should be assigned. Therefore there is a possibility of direct connection with distant computer. This is important for data collection in real time from network of stations resolving the problem of time synchronization for them. In our case this is ideal for counter telescopes integrated with different sections of neutron monitor. Data are transferred by net to the server and processed there. The start is performed each second by using the external real time clock (RTC). For time synchronization the external GPS system is used.

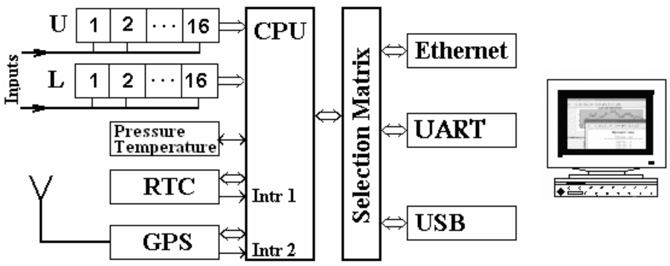


Figure 3. The Data acquisition system structural block diagram.

<u>Time synchronization</u>. There are two clocks of real time and one clock of relative time. The first clock of real time is on the board and synchronized by GPS one time per day. The second clock me is the real time clock of GPS itself and used for time corrections and generates a pulse each second with accuracy 1 msec for purpose of the synchronization. The relative clock is organized by the program for measurements of intervals between pulses, for example, in a case of registration multiple neutrons.

<u>As GPS</u> it is possible using any model (for example, Leadtek GPS 9520), which has a USB or serial port and synchronization pulses. Besides this model should be an external device.

<u>Analog channels.</u> We have 8 analog channels on processor that measure with 12-bit resolution any analog voltage from 0-2,5Volts. Therefore on the board the semiconductor pressure sensor MPX4115 and temperature sensor are mounted.

CPU is working on a multitasking manner. We call the different works that CPU executes as task. Task is the term that used on modern real time multitasking embedded systems. Tasks that CPU executes simultaneously are:

1. The detectors cells reading and storing
2. The GPS system synchronization
3. The RTC reading and storing
4. The pressure sensor reading and storing
5. Collected data transfer to other system over interconnection interfaces.
6. A general purpose task that run for calibration and firmware update reasons
7. A management task that supervisor the above tasks

The tasks run pseudo–concurrently. Task switching happens in a prioritization scheme that obtain accurate measurements. The prioritization order at this moment follow the order that task are has described above.

The whole cycle of data processing is performed using the client computer, which receive data from the data accumulation system. After this primary data analysis data are incorporated to corresponding the database.

4. Conclusions

The expected loading of scintillation or counter telescope is less than 1 kHz for each of 32 detectors. For this loading the processors provide a number of missed counts much less than the expected statistical accuracy (0.05 %).

Table 1. Main characteristics of the data accumulation system

Block	**Description**	**Characteristics**
Input channels	1+1 to 16+16 any arrangement software configurable	from 100.000 to 400 imp/sec
Output channels	1x1 to 16x16	100.000 imp/sec (polling method)
Resolution	16 bit	
CPU	high Speed RISC microprocessor	operation freq: 0-50 MHz step 1: 36,864 MHz
Clock, GPS	12 channel	timing accuracy 10^{-6}sec altitude 8Km
USB	full duplex	965 kbps
Ethernet (IP ready)	full duplex	965 kbps
Input signal		TTL logic, open collector
Period of time interrogation	Data resolution	1 sec, 1 min
Power supply	Build in	± 12 V, 400 mW

5. Acknowledgements

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References

[1] Bushnin B.B., Van’ev V.S., Goncharov P.I. at al., Prerint IHE, N 88-47, 1988.
[2] Karpekov U. D., PTE, N 6, p. 19-26, 2002.
[3] Yasue S., Munakata K., Kato C., Kuwabara T., Akahane S., Koyama M., Fujii Z., Evenson P., Bieber J., “Design of a Recording System for a Muon Telescope Using FPGA and VHDL”, Proc. 28th ICRC, Japan, **6**, 3461-3464, 2003.
[4] Yanin A.F., Kompanees K.G., Amelchenko M.B. at al., PTE, N 3, p. 61-63, 2004.