Application of CPLD for the Mexico Solar Neutron Telescope

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Abstract

We have adapted the Complex Programmable Logic Device (CPLD) technique for the direction measurement circuit used in the Mexico Solar Neutron Telescope. Before designing this application, we performed some basic tests for XILINX CPLD XC95108. The device satisfied our requirements for the Solar Neutron Telescope, that is, a response for a high frequency input, a response for a narrow width pulse input, and no or negligible jitter of the delay in the circuit. The use of such programmable devices enables us to upgrade the detector in future and reduces circuit design errors. The result of each test and the performance of the direction measurement circuit are presented in this paper.

1. Introduction

Neutrons emitted during a solar flare (solar neutrons) carry information on accelerated ions [1]. Solar neutron telescopes have been designed for the observation of solar neutrons [2]. For this specific purpose, the telescopes have the capability of energy and direction measurement, and have anti-coincidence counters. All these measurements are impossible using traditional neutron monitors. Recently, by virtue of the direction measurement capability, two interesting events have been reported [3][4].

The direction of a solar neutron, that is a charged particle recoiled in the detector, is measured using orthogonally-aligned Proportional Counters (PRC). According to the hit pattern of the counters, the direction can be deduced and counting rate measured for each direction. To carry out this process on-line, specific logic circuits are prepared for each station. Because such circuits can not be produced a mass production basis, they have been produced as hand-made modules. Although the logic itself is simple, the number of channels and logic gates become large for a hand-made circuit. In the case of the Tibet Solar Neutron Telescope, the number of PRC amounts to 120 and the measurement of 81 directions requires 600 logic gates.

There are many risks in producing such a circuit by hand, for example, a mistake in logic, a wiring mistake, soldering problems and the difficulty of adding

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Fig. 1. Download process from a PC to the chip via a MultiLINX.

or changing the logic. To avoid such problems, we have investigated the use of a Complex Programmable Logic Device (CPLD) for the Solar Neutron Telescopes. This would largely reduce the risks outlined above and realize fast production at low cost. Also, such devices can be used in future detectors [5]. In this paper, we first introduce the CPLD used in this study and consider the results of some basic tests. Finally, the performance of the directionality circuit prepared for the Mexico Solar Neutron Telescope [6] is presented.

2. CPLD

Programmable Logic Devices are classified into CPLD and Field Programmable Gate Array (FPGA). Among their merits and demerits, here, we emphasize the difference of the retention. Although a FPGA has a large number of gates inside, it can not retain a circuit once power supply turns off. It requires an extra memory device and a download process every time it is powered on. In contrast, the number of gates in a CPLD is smaller but the CPLD can retain its circuit even when the power supply is cut. For the observation of solar neutrons, we install detectors in high mountains. In such an environment, the simplicity of the CPLD is preferred and the number of gates is still enough for our purpose.

We chose XILINX CPLD XC95108 in this study. This device has 2400 gates and 108 pins are available for Input/Output. The physical size of the chip is 30mm × 30mm. Software for the circuit design, simulation and download is distributed without cost and the design is available both with GUI and the HDL language. When downloading the circuit from a PC to the chip, an adapter named Multi LINX is used. (Fig.1.) The chip is rewritable more than 10,000 times.

3. Basic Tests

Some basic tests have been performed on XC95108 to investigate if the chip is suitable for use in the Mexico Solar Neutron Telescope.

1.Response for narrow pulses. A single 2-input AND circuit is produced on the chip and identical TTL signals are injected in both inputs. Output pulses are counted using a scaler. For an input pulse width varying from 10 nsec to 200 msec, no apparent difference was found in the output count. This means even for 10 nsec pulses the device responds correctly. Because the signal from the PRCs required for direction measurements is $\sim$1 μsec, the response for 10 nsec pulse is sufficient. We also have signals from Photomultiplier Tubes(PMTs), but because their signal is even wider than 10 nsec, the device is suitable even for treating PMT signals.

2.High frequency response. Similar measurements were carried out with the configuration as above but with the pulse width fixed at 50 nsec. The frequency of the input pulse was varied from 100 Hz to 2 MHz. No miscounting occurred even at 2 MHz. Because the maximum expected counting rate for the Mexico Solar Neutron Telescope is less than 10 kHz (actually it was 6 kHz at site), this response speed is sufficient for our detector.

3.In-chip delay and jitter. To realize correct logic operation, the delay in the chip must be stable and ideally predictable. We measured the delay time of the pulses in the circuits with different depth. Here circuit depth means the number of logic gates a pulse passes. For circuit depths from 1 to 4, the delay time was always 5 nsec and no apparent jitter was found. A 5 nsec delay is sufficiently small for our purposes. Furthermore, a predictable delay time and no apparent jitter in order of less than 1 nsec enables us to use the device for the PMT signals.

4. Application to the Mexico Solar Neutron Telescope

From the results described in the previous section, we have concluded that the device is suitable for the direction measurement circuit of the Mexico Solar Neutron Telescope. Details of this telescope are presented elsewhere in these proceedings [6].

The telescope was constructed and operated for a time at Nagoya University. For the measurement of direction, 3 NIM modules were produced using XC95108. Two of them defined 5 directions in the North-South (East-West) planes and the third combined these outputs and results for 25 directions.

The 1 minute counting rate for 25 direction channels is shown in Fig.2.. Because the anti-counters were not ready at the time, the detector mainly counted muons. The counting rate from the zenith direction (central white part), is consistent with that expected from the muon flux, solid angle and detector area. A decrease of the counting rate with increasing zenith angle can be seen in the

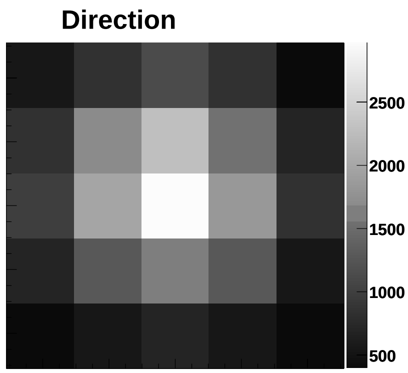

Fig. 2. 1-min counting rate of the 25 directions measured using the CPLD circuits. The total aperture is 51°×51°.

Figure. In 3 days continuous operation, the counting rate was stable. Consuming power was measured to be 0.5 watts for each module, that is less than the modules made of fully TTL ICs.

5. Conclusions

The properties of the XILINX CPLD XC95108 have been investigated. The results of some basic tests show that it is suitable for Solar Neutron Telescopes. We have produced direction measurement circuits using this device for the Mexico Solar Neutron Telescope. In test observations carried out in Nagoya, the circuit worked correctly. The telescope has already been constructed at the summit of Sierra Negra (4580m a.s.l.) in Mexico. Continuous observation in Mexico will have begun by the time of ICRC. The ease of circuit production and high performance of CPLD will enable us to design more complicated and intelligent circuits for the detectors proposed in [5].

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