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An integrated pulse-width trigger unit for triggering EAS events

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Abstract

An integrated pulse-width trigger unit is reported. The unit is developed in the Mini Array Research Laboratory, UHE Cosmic Ray Research, Gauhati University, Assam, India. The modest design and low cost make it favourable for the use in Extensive Air Shower experiments among small research groups. A description of the operation and tests of the unit is presented. This electronics is presently used in an EAS experiment, Gauhati University, Assam, India, to trigger the UHE Cosmic Ray events (Bezboruah et al., Astro. Part. Phys. 11(3) (1999) 395). We present here details about the hardware, test, calibration and results of the unit and the performances of the unit in the experiment. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

The detection of UHE Cosmic Rays with enough statistics is important in an astrophysical aspect. Since the intensity of the UHE Cosmic Rays is very low, a large area ground based particle detector array for their detection is required. But a comparatively cheap and novel method was proposed by Linsley, to detect UHE Cosmic Rays in the atmosphere. This method is based on measurement of thickness of the shower front, at large core distances by using a rooftop Mini Array (Linsley's Effect). Based on his idea, a Mini Array detector consisting of eight plastic scintillation counters has been setup in the Physics Department, Gauhati University (a project funded by DAE/BRNS, Govt. of India). This detector is specially designed to measure both the charged particle density and their arrival time spread at the detector level.

To detect the UHE Cosmic ray events using Mini Array method, it is essential to trigger the Mini Array experimental setup under some pre-requisite criterion. An integrated pulse-width trigger circuit is suitable for triggering UHE Cosmic Ray events when used with the following properties: low cost, low power consumption, easy calibration and fast test. An integrated pulse-width trigger unit with the above properties is designed, fabricated and tested. The unit is specially designed to trigger the present experimental setup

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for the detector array to record the genuine UHE cosmic ray events from a large number of irrelevant low energy events. We present here the hardware aspect of the electronics including the triggering criterion for recording the cosmic ray events.

2. The experimental arrangement

Fig. 1 shows the experimental arrangement of the detector system. The detector system consists of eight plastic scintillators (Type : BC-416) each viewed by fast photomultiplier tube (Type : Thorn EMI 9807B) covering a total carpet area of $2\,m^2$. The signals from the eight scintillation detectors are amplified using double stage differential amplifiers designed around μA 733 video amplifier. The rise time of the amplifier is 2 ns with an overall bandwidth of 200 MHz. The amplified outputs are then transmitted to the control room via coaxial cables (Type: RG58U). In the control room, all the eight signals are discriminated using an eight-channel pulse shape comparator [1]. Each output of the comparator corresponds to logic signals. The discriminated outputs are then regenerated into narrow pulses of 20 and 700 ns widths. The 20 ns pulses are OR'ed together to give a serial pulse train. The serial pulse train is finally branched into the time digitizer [2], the digital storage oscilloscope (DSO, Tektronix, TDS520, 500 MHz, 500M samples per sec) and the trigger unit. The trigger circuit senses the incoming pulse train and generates the necessary trigger pulse. Once triggered, the number of detector pulses and their relative time positions are stored in the time digitizer and the scope. The microprocessor (μP, 8086) stores the data from the time digitizer in RAM and transmits the data to the computer via serial port. The triggered pulse waveform is recorded by the DSO and is transferred to the PC (486DX2) via GPIB interface. The 700 ns

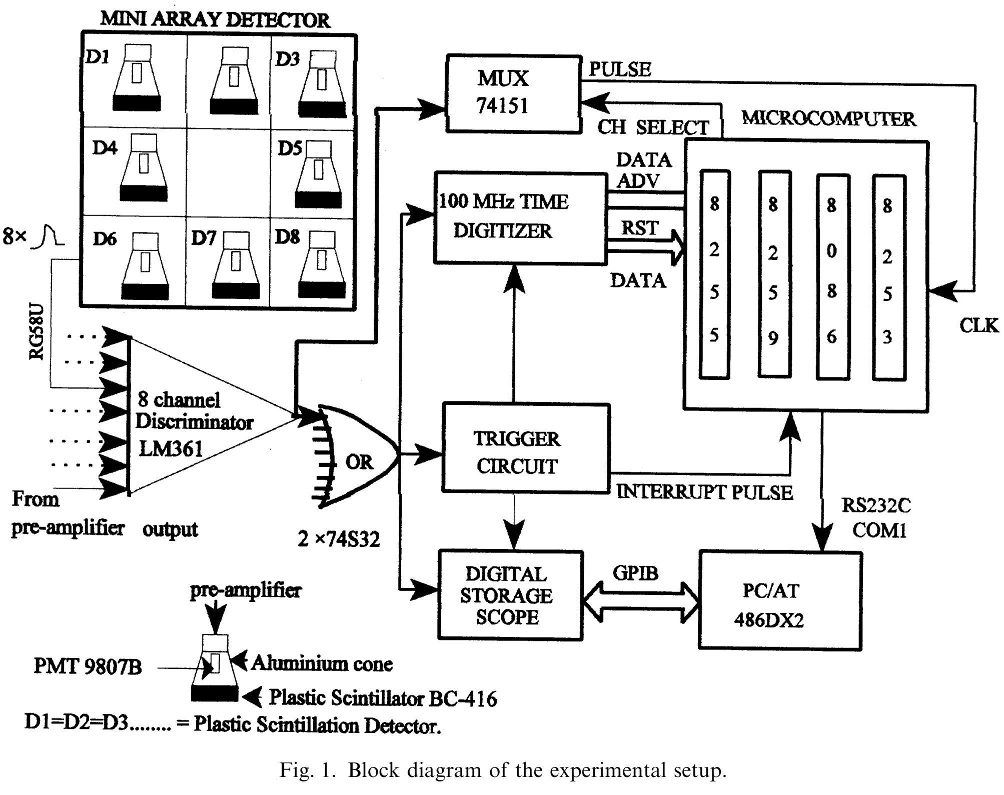

Fig. 1. Block diagram of the experimental setup.

outputs are fed to the counting unit to study the counting statistics of the detectors. The data acquisition system is presented elsewhere [3,4].

3. The triggering criterion

A Mini Array should be able to pick out the very few large air shower events from a swarm of irrelevant events including the counter noises, the background soft radiations and small air showers. In order to eliminate the large number of small air showers a minimum time spread has to be assigned for the array. For a Mini Array of $2\,\mathrm{m}^2$ area, a minimum acceptable shower size of 7.5×10^6 requires a minimum time spread $\sigma_1 = 100\,\mathrm{ns}$. In view of the small particle density encountered, each scintillator of the detector array is not expected to receive more than one particle at a time from a shower. For recording an event, the trigger pulse is generated by using the integrated-pulse width trigger unit under some prerequisite criteria. The criteria for recording an event are:

1. A hardware trigger requiring: particle in the range of 2 or above within the $2\,\mu\mathrm{s}$ time window.
2. The minimum arrival time spread between the particles must be 100 ns.

4. The integrated pulse-width trigger unit

4.1. The hardware

The present trigger circuit was designed on an idea by Refs. [5–7]. The circuit is shown in Fig. 2. The unit performs the function required under triggering criterion 1. The output pulse train from the OR Gate charge the capacitor C (220 pF-Ceramic disk) through the diode D1 (IN914) for a particular time period. This time period is determined by the timing pulse at the CMOS Gate, IC2 (4016-Quadruple analog switch). The timing pulse is generated by applying the pulse train to IC1

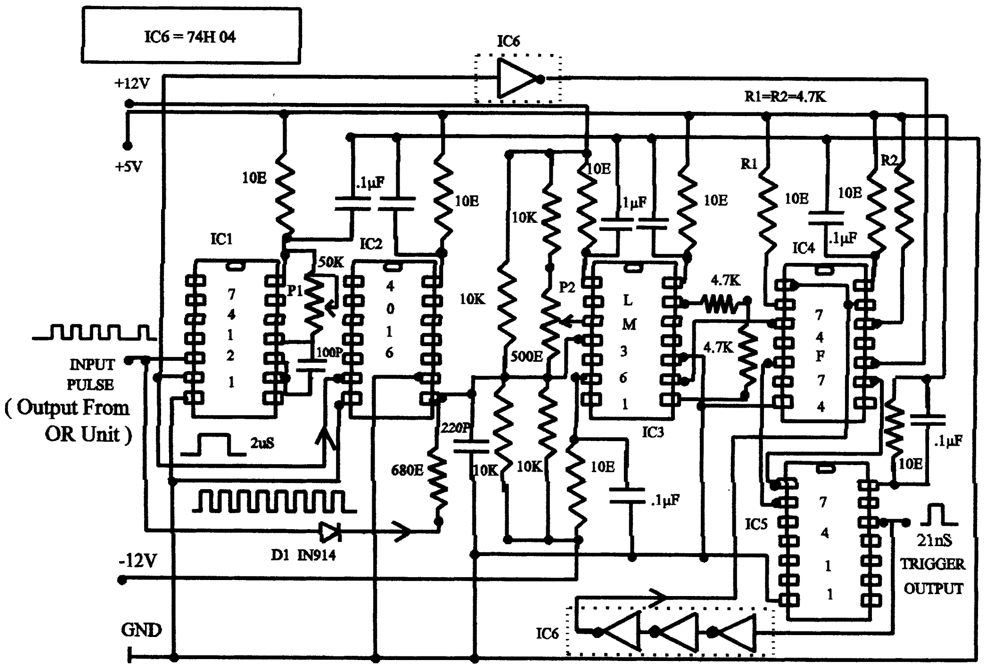

Fig. 2. The integrated pulse-width trigger unit for the experimental setup.

(74121-Monostable multivibrator) which is at present set to 2 μs by using the preset P1. The Gate pulse discharges the capacitor at the end of the 2 μs period. The voltage at the capacitor varies as the number of pulses received in the 2 μs duration. This voltage across C is fed to IC3 (LM361-High speed voltage comparator) and the trigger pulse is generated by the IC4 (74F74-dual edge triggered flip flop) and IC5 (7411-Triple 3-input Positive-And Gate). The 2 μs Gate pulse is inverted and brought to the CLK2 input of the flip-flop and both the outputs are combined by IC5 to ensure that the trigger pulse is generated at the end of 2 μs period.

The unit is operated at ±12 V and +5 V DC supply. A low voltage unit is designed and fabricated for this purpose in the laboratoray.

4.2. The PCB and component layout

We have utilized Computer Aided Design (CAD, Smartwork) technique for designing the artwork of the circuit. The artwork for the circuit pattern was printed on one side of a double sided PCB, the other side being maintained at ground potential. Components were soldered like surface mount devices by using temperature controlled soldering station (XYRTRONIC, Model: XY9-60D).

4.3. Test and calibration of the hardware

The integrated pulse-width trigger circuit for the present experimental setup is tested by using a standard pulse generator (HM 8035, Scientific) and the DSO. A pulse train from the generator is applied to the input of the trigger unit. This pulse train charged the capacitor C of the unit. The charging voltage across the capacitor is varied with the number of pulses in the pulse train.

Thus, the capacitor C is charged first by feeding a single pulse to the input and the corresponding charged voltage across it is recorded by the DSO. Then it is charged by feeding a pulse train containing two pulses in the input and the capacitor voltage is again recorded. This procedure is repeated by feeding pulse train containing three, four, five pulses, etc. and the corresponding voltages across the capacitor are recorded. For one, two, three, four, five and so on pulses, the corresponding capacitor voltages are found to be 0.42, 0.58, 0.84, 1.06, 1.48 V, etc., respectively. The recorded voltage is plotted against the corresponding number of pulses at the input. Fig. 3 shows the calibration curve for the unit. The tests made point out the linearity of the system and its capability for using the unit to trigger the UHE Cosmic ray events.

Fig. 4 shows a typical trigger pulse corresponding to an EAS event trigger. CH1 shows the event

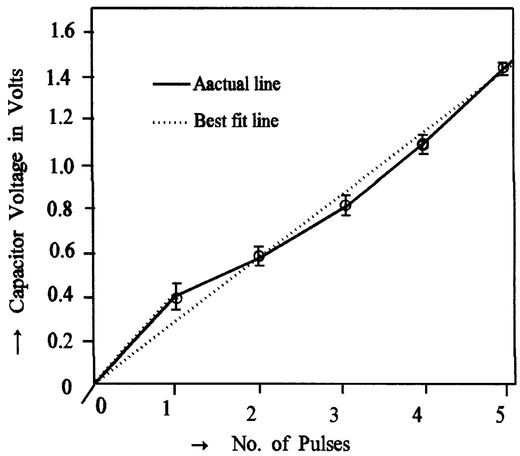

Fig. 3. Linear characteristics of the trigger unit.

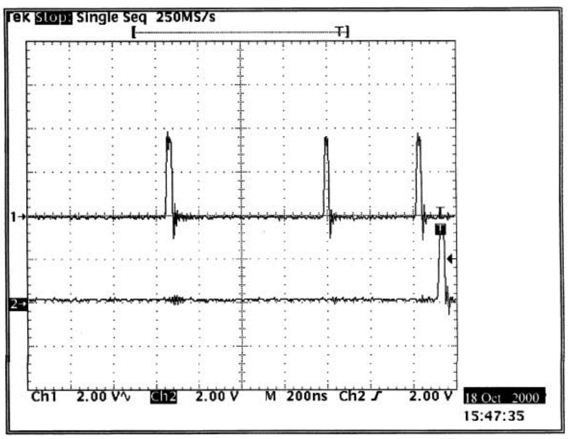

Fig. 4. CH1: An event with $\rho = 1.5\,\mathrm{m}^{-2}$, CH2: Typical integrated pulse-width trigger output.

and CH2 shows the trigger pulse generated by the integrated pulse-width trigger unit due to the event. For this particular event triggered by the unit, the number of particles hitting the Mini Array is 3 particles per $2\,m^2$. This means, the number of particles hitting the array is $\rho = 1.5/m^2$. This ρ is the particle density of the Mini Array for the particular event.

5. Results and discussions

This electronics is presently used in an EAS experiment, Department of Physics, Gauhati University. The error in estimation of shower front thickness using this device in the above experiment is, $d\sigma = \pm 10\,ns$ instrumental error. The artificial shower simulation shows an average error of 37% in estimation of shower size using the device. Investigation of the characteristics of the trigger unit and its performance in the present experiment shows that this device can work excellently to trigger the UHE cosmic ray events. It can become a widely used electronic device since the required circuitry is very low cost and simple.

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