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Multiple Pulse Generator for Telescope Calibration

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Abstract

We have developed a low cost programmable multiple pulse generator (MPG) intended for calibration of semiconductor energetic particle telescopes used on space applications. The system is able to generate at different rates several synchronized test pulses with different amplitudes. These amplitudes are obtained by a simulation of the telescope response to a cosmic ray flux. Comparing the original amplitudes with those provided by the detector, after test acquisition, we can check easily the accuracy of the instrument.

1 Introduction:

The design and development of an instrument that is going to be placed onboard a satellite can be decomposed, from the technical point of view, on several steps. First of all, once defined the scientific goals and the functionality of the system it is necessary to receive from the scientific team its requirements and specifications. The next step deals with the high level design or structural design. At this point we can check the consistency of the specifications and ask for modifications if necessary. After that, low level design and implementation are performed, as a consequence we obtain a laboratory model of the system. Successive refinements of this model allow us to develop the engineering model and finally the flight model. For solar and cosmic ray particle telescopes the main problem is how to perform the tests in order to evolve from laboratory model to flight model and to validate the whole system. Several test can be done using standard methods, i.e. vibration tests, EMI-EMC tests, thermal vacuum test, etc., but, what about functional and calibration tests?

Usually, functional test can be done using standard NIM or CAMAC instrumentation, but calibration test should be done in a similar environment to that of the satellite orbit. In our case a calibration on a particle accelerator is the method selected. The success of calibration on accelerator requires that, prior to the experience, all detectors and electronic parameters (polarization voltages, amplifier gains and shaping times, noise level thresholds, etc.) have nearly definitive values. In order to afford with the maximum guaranties this calibration, we propose a pre-calibration procedure based on a Multiple Pulse Generator (MPG) that has been designed and developed in our laboratory. The pre-calibration system has been built for a specific instrument called PESCA (Peral et al. 1997), but it can be easily modified for similar experiments.

2 MPG General Description:

As noticed on the introduction, the Multiple Pulse Generator has been designed to perform the pre-calibration of a cosmic ray telescope called PESCA. Due to the particular features of the PESCA instrument, the MPG is able to:

1) Generate four different signals, one for each detector, that may differ on amplitude.
2) Provide pulses with different rise and fall times and also different frequencies.
3) Process data files stored on a PC file that represent particle lost of energy on every channel. Those files can be generated by a Monte Carlo simulation or they can store real data acquired by similar experiments.

The calibration is performed connecting a personal computer to MPG via RS-232-C serial line and the MPG to the instrument via test inputs (see Figure 1). A PC file containing different amplitudes of every channel for each particle (four channels in total in our case) is sent to the MPG. MPG waits until it receives periodically four amplitudes and then generates four independent signals that are sent to the instrument. Comparing the original file with that obtained after calibration we can check the accuracy of the instrument (Sánchez et al. 1996).

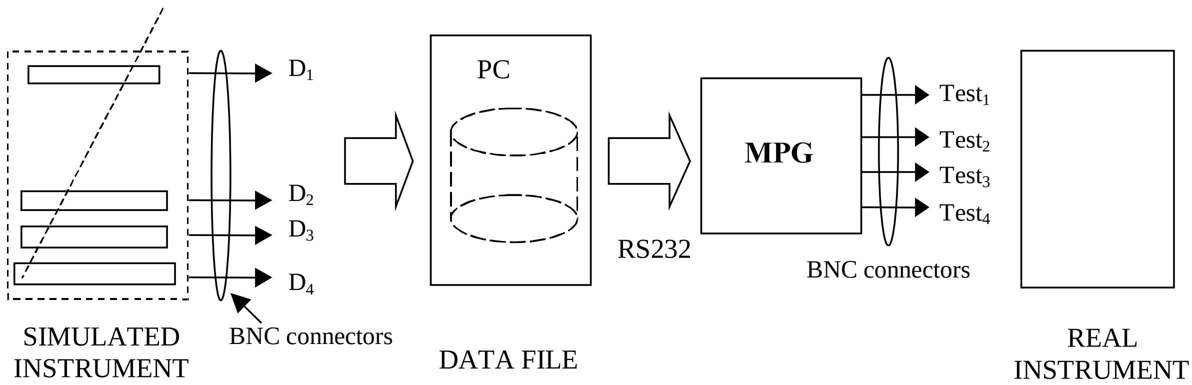

Figure 1: Schema of the calibration test using MPG.

3 MPG Structure:

MPG is composed by two modules: digital electronic module and analog electronic module (Figure 2). The core of the digital electronic is the Intel 87C51 microcontroller. The communication between MPG and the PC is based on a bidirectional RS-232-C line. In nominal mode, the MPG expects to receive four values of amplitude from the PC, corresponding to detectors D1 to D4. Once received, these values are sent to four 12 bits digital to analog converters (DACs).

The analog electronic module takes voltages from DACs and when it receives a start pulse, it modulates a main pulse, that is generated internally, and it provides four output signals corresponding to each detector. The main pulse generator is a critical module, its accuracy will define the MPG noise characteristics.

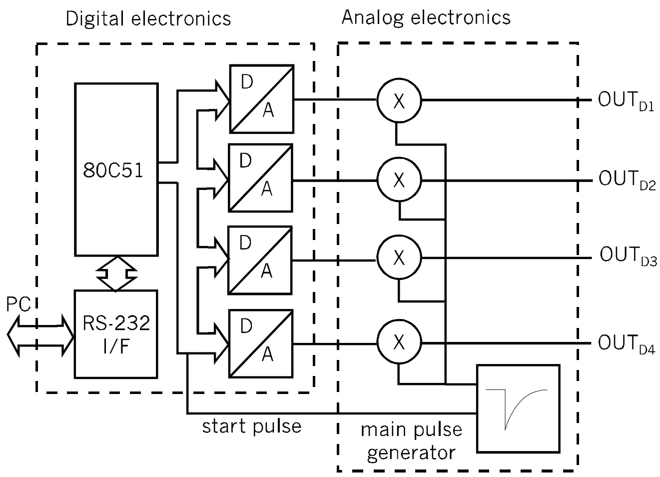

Figure 2: MPG block diagram. Enclosed in dashed boxes we can see the analog and the digital modules.

3.1 Digital Electronic: As it has been already pointed out, the main task of the digital electronics is to provide to the analog electronics the different voltage levels listed in a PC data file. When the MPG works in nominal mode, the data calibration file used is obtained by a Monte Carlo simulation program. This file comprises four data columns which represent the energy lost by every particle in each detector. In order to test the behavior of the system during the pre-calibration process, files with this structure can be used. The interface between digital and analog module is the conversion module. It is composed by four digital to analog converters (DACs) with identical configuration. The DAC that has been used is the MAX530BCNG manufactured by Maxim. The MAX530 is a low-power, 12-bits, voltage-output digital-to-analog converter that can use single +5 V or dual ±5 V supplies. Unipolar supply has been used. This device has an on-chip 2.048V voltage reference plus an output buffer amplifier. The parallel logic inputs are double buffered and are compatible with 4-bit, 8-bit and 16-bit microprocessors. The output voltage range depends on the following parameters: voltage supply, voltage reference and output operational amplifier gain. Unipolar supply, internal voltage reference and gain x2 have been used, so a 0 V to +4.096 V unipolar output range have been obtained. In this range, 1LSB = $2 \cdot REFIN \cdot 2^{12}$ = 1 mV, where LSB (Low Significant Bit) is the resolution and REFIN is a voltage reference.

3.2 Analog Electronic: The MPG is able to produce the same signals than those generated by the particles when they pass through the semiconductor detectors (Bertolini, and Coche, 1968). Figure 3 shows the typical pulse provided by the detectors (time axis is not scaled). The most important signal parameters are:

A: amplitude, it should be variable and defined by software.

t_r: rise time, it is about 10 ns and can be changed using a knob.

t_f: fall time, it is about several microseconds and can be changed using a knob.

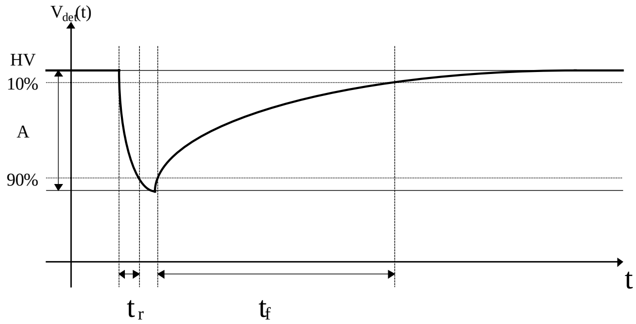

Figure 3: Typical semiconductor detector pulse generated by an energetic particle

The signal shape is generated by the main pulse generator. It is composed by a RC circuit combined with a charge circuit and a mercury relay. When the digital electronics module sends the "start pulse", the main pulse generator produces the pulse shown in Figure 3. The pulse generator is the most critical element of the system because the final results depend on its accuracy.

The amplitude of the signal is obtained using multipliers. There are four multipliers, one for each channel. Their task is to modulate the amplitude A_n provided by the digital electronics with the main pulse generator. As result, four identical and synchronized pulses with possible different amplitude are obtained. The multiplier should be able to deal with high frequency signals in order to respond properly to the input pulse. The multiplier that has been used is the AD834, which presents a 4 ns transition time and it is able to respond up to 500 MHz. Its output range is ±1 V and its transfer function is: $W = (X1 - X2) \cdot (Y1 - Y2)$. The inputs X and Y are differential and W is the output signal with 75 Ω as characteristic impedance.

4 Functional Tests:

In order to evaluate the characteristics of the MPG we have perform two tests regarding to their linearity and dispersion.

Linearity test: This test checks the linearity of the system. Pulses of identical amplitude (associated with different input channels) were generated. Afterwards, the values of the output channels were measured. Figure 4 shows graphically the correspondence between the input channel and the output channel. As it can be seen, the system is linear through all the output range. The maximum error obtained, after fitting the results by a first order polynomial expression, was less than 2%.

Dispersion test: The other test that has been performed is the MPG dispersion. In order to perform it, a Canberra series 40 multichannel analyzer has been used. The dispersion at FWHM is only three channels over all the range.

5 Conclusions:

The electronic system that has been designed and built, complies with the original requirement it was design for. Its main characteristics are the following:

1) The pulses are the same than those provided by the detectors.
2) It provides four self independent outputs.

3) The four signals are synchronized.
4) The amplitude of each pulse is independent of those that have been previously generated.
5) The dispersion at full-width-half-maximum (FWHM) is less than 3 channels over a maximum of 4096.
6) Its non-linearity is less than two percent.
7) It provides a suitable way of checking the coincidence-anticoincidence logic.
8) For the four detectors, the amplitude of each pulse can be stored on a PC file. This data can be generated by a simulation program or they can represent real particle energies.
9) The communication between the MPG and the PC is done via standard RS-232-C connection, and therefore avoiding internal cards.
10) All the system (hardware and software included) can be built for less than $350.

Due to the inclusion of a well structured design, the system can be easily adapted to perform the calibration of experiments that are similar to PESCA. The programmable multiple pulse generator (MPG) developed presents several advantages over previous pulse generators, the most important one is that it provides the possibility of testing nuclear electronics with real test data files.

References

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