Nucleon experiment

The space NUCLEON project is designed to investigate the cosmic ray nuclei energy spectrum from 100 GeV to 1 TeV as well as the cosmic ray electron spectrum from 20 GeV to 3 TeV. A method of energy determination by means of a silicon tracker for measuring the particle charge of space rays and a calorimetric system were developed. The main parameter, that determine the quality of calorimetric systems, is the dynamic range of input signals, which should reach tens thousands of single charge particles. Important parameters of read-out electronics are the consumed power, as well as the weight-size characteristics and reliability.

The ASIC with a unique high dynamic range (1 – 40 000 mip) at low power consumption (< 1.5 mW per channel) has been developed for the experiment. The ASIC allows to record signals of relativistic particles and nuclei with charges from Z = 1 up to Z > 50 from silicon detectors, having capacitances up to 100 pF.

ASIC structure

The chip structure includes 32 analog channels, consisting of a charge sensitive amplifier (CSA) with a PMOS input transistor (W=8mm, L=0.5 μm), shaper (peaking time of 2 us) and a T&H circuit. All analog chain outputs are collected by an analog multiplexer with output current driver and supplemented by a calibration system. Two test channels are arranged near the edges of the crystal to decrease the technological spread of the parameters of the main channels. The ASIC has digital logic to readout the data and control the calibration system.

The transfer function of CSA, having two subranges of different slopes (gains), allows to reach a high dynamic range of the readout electronics. The splitting of the full dynamic range (from noise to saturation) into automatically switched subranges is considered as a specific feature of the designed circuit. An auxiliary class B amplifier is added to the CSA output. For small signals this amplifier is off and the CSA gain is determined by a relatively small feedback capacitance value and set to 0.15 V/pC. For higher amplitudes (≥ 3 pC), the class B amplifier is dynamically switched on. In this case, an additional capacitor is added into the CSA feedback via the class B amplifier. That defines the equivalent feedback capacitance value of the CSA at a level of 10 times higher, decreasing the CSA gain in the large amplitude region. The CSA showed a 120 pC dynamic range at SNR of 2.5 for the minimal energy of 1 MIP. The inflection point of the transfer characteristic can be changed by external potentials. The family transmission characteristics for different control potentials is shown in the figure below.

Specifications

- Polarity of the input signal - positive
- Dynamic range - up to 120 pC
- Nonlinearity for the range up to 3000 MIP - 3%, above 3000 MIP - 10%
- Gain for the small signal range - 130 mV/pC, for the range of large amplitudes - 20 mV/pC
- Signal / noise ratio for the capacitance of 100 pF (for a signal of 1 MIP) - 2.5
- Peak time of the shaper – 2 us
- Detector capacitance – up to 100 pF
- The reading out frequency of the analog channel – not less than 3 MHz
- Supply voltage – bipolar 1.65 V
- Power consumption – 1.5 mW / channel

Conclusion

In order to register the signals of silicon detectors within the project “Nucleon” there was developed a 32-channel application specific integrated circuit, having a dynamic range of 120 pC at SNR = ±2.5 for the minimum-energy particles. Parameters are achieved at consuming 1.5 mW / channel. IC testing confirmed the possibility of its use for a wider range of calorimetric applications requiring wide dynamic range at detector (sensor) capacitance of up to 100 pF.

The chip is embedded in the hardware of the experiment to launch a satellite into orbit, scheduled for late 2014.

Reference


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