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SPACIROC: A Front-End Readout ASIC for the JEM-EUSO observatory

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The SPACIROC ASIC is designed for the JEM-EUSO observatory onboard of the International Space Station (ISS). The main goal of JEM-EUSO is to observe Extensive Air Shower (EAS) produced in the atmosphere by the passage of the high energetic extraterrestrial particles above a few 10ˆ19 eV. A low-power, rad-hard ASIC is proposed for reading out the 64-channel Multi-Anode Photomultipliers which are going to equip the detection surface of JEM-EUSO. Two main features of this ASIC are the photon counting mode for each input and the charge-to-time (Q-to-T) conversion for the multiplexed channels. In the photon counting mode, the 100% triggering efficiency is achieved for 50fC input charges. For the Q-to-T converter, the ASIC requires a minimum input of 2pC. In order to comply with the strict power budget available from the ISS, the ASIC is needed to dissipate less than 1mW/channel. The design of SPACIROC and the test results are presented in this paper. SPACIROC is a result of the collaboration between OMEGA/LAL-Orsay, France, RIKEN, ISAS/JAXA and Konan University, Japan on behalf of the JEM-EUSO consortium.

Summary 500 words

The primary purpose of JEM-EUSO mission is the detection of the Extensive Air Showers (EAS) created by the Extreme Energy Cosmic Rays (EECR >10ˆ19 eV), inside the atmosphere. JEM-EUSO, which is a fluorescence telescope, looking downward, should be installed on the JEM module of the International Space Station, will detect the fluorescent photons released by the EAS. By observing these phenomena from the upper side of the atmosphere, this telescope will be able to identify the EECR.

Multi-anode photomultipliers (MAPMT) are proposed to be the sensitive device of the telescope's focal surface. SPACIROC was designed to accommodate the readout of these MAPMTs. For this mission, the ASIC is required to count detected photons and to perform charge to time (Q-to-T) conversion. SPACIROC offers 64 inputs dedicated to the anodes of one MAPMT and 1 input for the last dynode. For the following, the MAPMT gain is assumed to be 106 in order to have 1 photoelectron (1 p.e.) around 160fC.

The specifications for the chip are the following:
• 64 channels preamplifier with independent gain (8-bit) adjustment.
• Photon Counting : 64 channels.
• Q-to-T converter : 1 channel for last dynode + 8 internal channels (multiplexed inputs).
• 100% trigger efficiency for charge greater than 50fC (˜1/3 p.e.).
• Q-to-T converter input range: 2 pC –400 pC (13 p.e –2500 p.e.).
• Power consumption : 1 mW/channel.
• 9 data serial outputs.

For the photon counting, the preamplifier, the shapers and the discriminators are largely inherited from the MAROC3 chip. The input signal passes through a low-noise and low input impedance preamplifier with an individual variable gain of 8-bit. Afterwards, the amplified signal could be fed through shapers or into the Q-to-T converter. Currently, the chip offers 3 different discriminator outputs for discriminating the detected photons. Depending on the selected shaper and discriminator, this chip could reach a double pulse resolution up to 30ns. To count the detected photons, a digital module was built for each channel around an 8-bit counter which could operate up to 100 MHz. At the end of each acquisition window (GTU=2.5µs), the counter values are transmitted through 8 serial links.

As mentioned earlier, the first 8 inputs of the Q-to-T converter will take the pre-amplified signals from the photon counting (sum of every 8 channels). However, the 9th input takes a signal coming directly from the last dynode of the MAPMT. An impedance converter and a charge integrator are used to transform the input signal into a voltage signal. A network of capacitors is used to integrate the input signal. Later, a variable length discriminator output is obtained by comparing the integrated pulse to an adjustable reference value. Adjusting this discriminator pulse width is simple: it is done via a variable gain current source. Finally, this discriminator output will be sampled by a 40MHz clock. In a similar manner to the photon counting readout, the discriminator length data are sent through a serial link at the end of each GTU. This converter was designed in collaboration with RIKEN, ISAS/JAXA & Konan University, Japan. The design is based on the KI02/03 chip.

Several precautions have been taken during the design of SPACIROC to make sure it could operate in extreme conditions. For instance the layout was done carefully in order to minimize the Single Event Latchup effect. A mechanism to detect Single Event Upset was also added. Concerning the consumption, the ASIC should not exceed 1mW per channel. The design was done using AMS SiGe 0.35µm process. The final chip dimensions are 4.6 mm x 4.1 mm (19 mm²). The ASIC was submitted for fabrication in March 2010 and a batch of 5 packaged ASICs arrived in October 2010.Extensive laboratory tests for characterising the ASIC are currently underway. The preliminary results have shown that the ASIC is working and exhibits a good behaviour.

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