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DualGain: A programmable multichannel amplifier system to increase dynamic range in nuclear physics digital ACQ architectures

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Summary. — In the framework of high granularity nuclear physics multidetectors, it is relevant to develop complex digital ACQ architectures. In this paper, we present a new high-frequency programmable multichannel amplifier system proposed for the CHIMERA and FARCOS detectors. The main system feature, other than very low signal degradation, modularity and remote programmability, is to improve the dynamic range of the ADC converters without the use of oversampling technique or the use of higher resolution ADC devices.

1. – Introduction

A new high-frequency programmable multichannel amplifier system for complex digital ACQ architectures has been designed to operate for CHIMERA and FARCOS detectors fully operational at Laboratori Nazionali del Sud (LNS) of the Istituto Nazionale di Fisica Nucleare (INFN) in Catania (Italy).

CHIMERA [1] is a 4π multidetector for light charged particles and fragments operational at LNS in Catania (Italy). It is made by 1192 Si-CsI(Tl) telescopes placed in a 4π geometry arranged in 35 rings along the beam axis, for a total length of $\simeq 4$ m. The forward 18 rings are assembled in 9 wheels covering polar angles between 1° and 30°; the remaining 17 rings covering the angular range between 30° and 176° are assembled in a sphere of 40 cm of radius. The main features of the detector are a systematic measurement of the Time-of-Flight, allowing velocity and mass determination, a low multifiring probability, and the low energy threshold.

FARCOS [2] is a novel Femtoscope ARray for COrrelation and Spectroscopy designed to perform studies of two and multi-particle and Intermediate Mass Fragments (IMFs) correlations in heavy-ion collisions at Fermi energies with stable and radioactive beams. It is based on a hodoscope configuration and it is composed of 20 telescopes in its complete configuration. The FARCOS telescope is composed of two silicon detection stages based on the Double-Sided Silicon Strip Detector technology (DSSSD), with different thicknesses (300 μm and 1500 μm, 32 + 32 orthogonal strips) and by 4 CsI(Tl) troncopyramidal scintillator crystals (3.2 cm $\times$ 3.2 cm, 6 cm thick) readout by a Si photodiode (1.8 cm $\times$ 1.8 cm, 300 μm thick silicon PIN diode). The total number of output channels is 2560 for the DSSSD and 80 for the CsI(Tl) scintillators.

2. – The GET system

The GET system [3] was chosen for the readout of the FARCOS signals and for the upgrade of the ACQ system of the CHIMERA CsI(Tl) detectors. The GET system was designed and built primarily as compact electronics for TPC readout, however, it was conceived as a generic system with the possibility of adapting it to several different cases. Its main component, the AGET chip, is an ASIC that includes 68 channels (4 are dedicated to intra-device noise measurement and 64 connected to external inputs) with a complete electronic chain inside it. The input chain consists of a preamplifier specifically designed for TPC, followed by a filter stage, a discriminator for trigger and readout line and a capacitor array where the signals are stored with adjustable frequency. The flexibility of the GET system is evidenced already by the fact that the input signal can be connected to different stages of the electronic chain, preamplifier, filter, or directly to the capacitor array by simply changing one bit in the chip setting. Four of these ASIC are mounted on a board called ASAD designed by the GET Collaboration. In this board 4 digitizers, one for each AGET chip, are mounted and digitize the charge stored in capacitors sequentially. The input signals are digitized at 12 bits at a frequency that can go up to 100 MHz (our standard is 50 MHz). From the logic line of each channel a multiplicity signal is built and digitized by the ASAD card. This signal is summed for up to 4 ASAD cards in the COBO readout boards, and processed by the trigger board of the system, the MUTANT board.

3. – The DualGain system

The DualGain system is studied to optimize the dynamic range of the reaction to the available range of the GET system (from 0 mV to 700 mV). The use of GET electronics is relatively simple due to its flexibility. However, it requires some adjustments to the input connector and to adapt the input signals characteristics. If the filter or the capacitor array are used as input, a positive baseline must be added to the signal. This baseline is essential to process the signal on the ASIC logic line. Furthermore, as anticipated above, the 12 bits ADCs of the ASAD cards are not sufficient for the dynamic range covered by the FARCOS telescopes, so, at least for the front strip silicon signals, a stage is inserted that duplicates the input signal and applies different gain values to each copy to improve the effective dynamic range. The DualGain module, originally developed for the CsI(Tl) signals of the CHIMERA detectors, adapts the offset input signal to the one needed by the ASAD card and duplicate the input signal. The gain of the two signal copies can be adjusted independently to manage a greater dynamic range than that guaranteed by the 12 bits of the GET system. For the back signals, to save channels, double gain is not used, so single gain modules were developed by the Politecnico di Milano group. For the

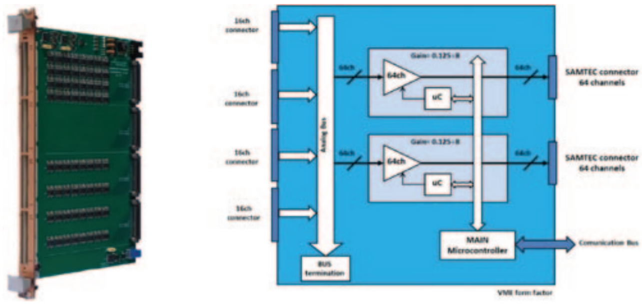

Fig. 1. – A view ot the DualGain module. The DualGain module general architecture.

CsI(Tl) and pulser signals of the FARCOS array another double gain card was developed using the same scheme as the single gain module also from the Politecnico di Milano.

The DualGain module is a 64 channels digitally Programmable Gain Amplifier (PGA). An image and the general architecture of a DualGain module is shown in fig. 1.

The module is provided with three microcontrollers that take care of the module slow control, the signal parameters setting and the user remote RS485 communication. The basic amplifier cell used to amplify or attenuate the input signal is based on a commercial device. It consists of a separate low-noise input preamplifier and a digitally Programmable Gain Amplifier (PGA). This module was originally designed for the signals of the CsI(Tl) preamplifiers of the CHIMERA detector, having a dynamic range up to 6 V. Therefore, to adapt the gain to the GET system maximum amplitude (0.7 V), the DualGain, other than to amplify the signal must also be able to work as an attenuator. Seven gain values are available in a group of 16 channels and the module is also able to add the necessary offset to the output signal adjustable from 0 to 2000 mV. The DualGain module has been developed with a form-factor as the one used for the ASAD board (VME) to optimize the hardware connection between the two boards. To prevent the output signal from swinging outside the common-mode input range of the ASAD card, each DualGain channel provides both high and low output clamp protection and signal baseline setup. One ASAD card is connected to two DualGain modules using a very compact adapter card connected to the rear side of the two modules. The front input of the module is adapted to the insertion of cables of the CHIMERA standard, with 8 SCI (3M) single cables. In this configuration, each ASAD card is connected to two DualGain modules to perform a 128 channels DAQ system. A block diagram and an image of this configuration is shown in fig. 2.

The typical PGA channel bandwidth at unit gain is 68 MHz while a minimum bandwidth of 47 MHz is obtained at the maximum gain of 4 V/V (+12 dB). A rise-time of 5 ns is obtained for 1 V pulse response *versus* different gain values. We have good linearity for all gain values in the output range from -3.1 V to 3.8 V at 50 Ω output load impedance and from 6.2 V to 7.6 V at high output load impedance. The PGA channel electrical characteristics are shown in fig. 3. Using the RS485 command set, the user can remotely adjust the channel gain in the range from 0.032 V/V to 4 V/V (from -30 dB to +12 dB) at 50 Ω output impedance and the signal baseline (the gain range can be doubled by using high impedance load). A series of slow-control command allow the user to remotely monitor the temperature of the various sections of the module and the main microcontroller can turn off the PGA channels if limit values are reached to prevent

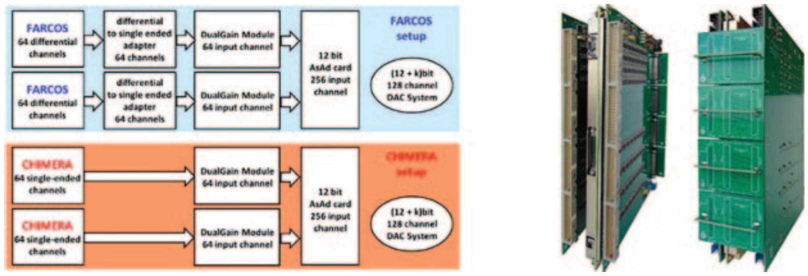

Fig. 2. – Block diagram of a 128 channels DAQ System. A view of the DualGain with ASAD card connection.

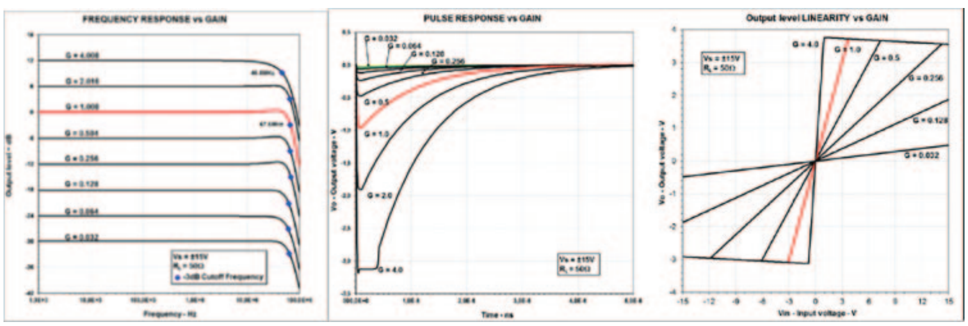

Fig. 3. – PGA frequency response, pulse response and output linearity *versus* DualGain channel gain value.

damage to the electronics. The module is fully remotely programmable and the RS485 command set allows you to control channels turn on/off, module reset, register reset, gain values, positive and negative voltage clamp values or monitor the module status of all the parameters.

4. – Conclusions

The DualGain System has been extensively tested at various beams and in a full CHIMERA CsI(Tl) and FARCOS configuration. This electronics is essential for the use of FARCOS in various laboratories around the world and in correlation with other detection systems. The DualGain System programmability feature allows to adapt the ADC dynamic range to a variety of physical needs. By using a DualGain channel and two DAQ channels for each detector signal we can increase the effective dynamic range of the DAQ system. This feature is used for CHIMERA and for FARCOS array signals.

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