Development and characterization of MCSA-16 module using multichannel CSA ASIC for in-house application

M. K. Jha*, P. Bahre, T. Bhattacharjee, S. K. Pal
Variable Energy Cyclotron Centre, 1/AF Bidhan Nagar, Kolkata – 700064, INDIA
** email: mjha@vecc.gov.in*

Introduction

The charged particle detector Array for kinematic reconstruction and analysis (ChAKRA) [1], developed for intermediate energy (~10–60MeV/A) nuclear physics experiments is using an imported 16-channel commercial module for first-stage signal processing of the current signal from detector. An indigenous multichannel ASIC has been designed and developed at VECC to replace this imported module and the characterization of the ASIC has been carried out successfully for low power and low noise application.

Although this ASIC has the ability to couple itself directly with the detector inside the vacuum chamber for its low power dissipation (~10mW/ch) as compared to the commercial module (~100mW/ch), however, presently, the development of a similar module, MCSA-16 (in respect of mechanical dimension, connectors etc. of the imported module) using the CSA ASIC has been undertaken for import substitution and easy transition of the existing front-end signal processing of ChAKRA. The design, development of MCSA-16 module has been described in this article followed by the characterization in respect of using it with ChAKRA. The comparison of the specification with the imported module is also carried out and shown in this paper.

Design and Development of MSCA-16 Module

The block diagram of the MSCA-16 module is shown in Fig. 1. This module consists of three sections. The HV processing and detector protection circuit is kept at the front, followed by the ASIC, and then conversion of single-ended CSA voltage output to differential signals with impedance matching to further processing of signals through commercial shaper module. The detector protection circuit consists of back to back diodes, and 1 pF test capacitors to test all the channels of ASIC offline without source. The HV section is common for all sixteen channels. As per the requirement of ChAKRA, SSSD (signal from p-channel) or DSSD (signal from p-channel and n-channel) will be used and hence two MCSA-16 modules needs to be coupled for completion of HV loop for the signal processing from both SSSD and DSSD.

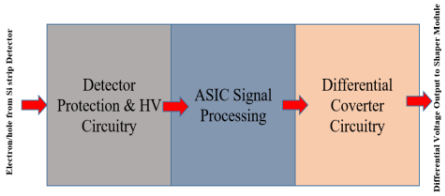

Fig. 1: Single channel block diagram of MCSA-16 Module

The flow of electron/hole from the detector is integrated by the ASIC and converted to single-ended voltage pulse having full-scale of ±1V. The decay time of the CSA output is of the order of 100µs considering the pole/zero cancellation ability of the commercial shaper module. It is important to note that improper cancellation of pole from CSA feedback will introduce undershoot of the shaped signal and introduce additional noise thereby deteriorate energy resolution. The single-ended voltage output of the CSA is converted to differential signal using the conversion circuit where the option for additional gain has been introduced. The impedance of the differential output is matched with the input impedance of the commercial shaper module. The true differential circuit of MCSA-16 as compared to the pseudo-differential circuit of the commercial module provides additional ground noise cancellation capabilities. However, the additional input referred noise from the differential OpAmp in terms of electron is much higher than the ASIC which limited the application of MCSA-16 where requirement of electronic noise is lower.

Characterization of MSCA-16 Module

The performance analysis for identifying the capability of MCSA-16 to use it in ChAKRA has been carried out in the laboratory setup. The modules as shown in Fig. 2 have a common LEMO connector by which a step pulse can be fed to all the sixteen channels of the CSA through the 1pF capacitors connected in series as described in the detector protection circuitry above. The amplitude of the step pulse is directly proportional to the dynamic range of the module. The differential output of the module through the output connector has been fed to the commercial shaper module and the output of the shaper is connected to a 13 bit ADC for spectroscopy. The Gaussian output of the channel vs. count plot is taken for analyzing the linearity within the whole dynamic range and linearity-deviation of less than 1% has been measured.

Fig. 2: MSCA-16 modules, PCB and CSA ASIC

The noise of ASIC and entire module was measured using two similar set-ups, one with ASIC and other without ASIC where signal input was directly shorted with the differential block. Noise contribution of ASIC comes as 2.5 keV at 0 pF (16.5 keV at 350 pF) detector capacitance with slope of 0.04 keV/pF. Noise contribution of entire module was found to be around 25keV. This additional noise of 8.5 keV in the MCSA-16 module is introduced by differential block OpAmps. However, the analysis of parameters for both MCSA-16 module and the imported module (as shown in Table 1) exhibits that noise is comparable for both of them, considering detector capacitance of 350pF and shaping time of 1µs. Although, the additional noise due to differential block OpAmps introduced in the MCSA-16 makes the imported module superior in case of lower detector capacitance, the performance of MCSA-16 module in terms of noise is better when the shaping time is set to 0.5µs. MCSA-16 is also superior in terms of power consumption. Considering the experimental requirement of 1% energy resolution during the experiment, the result as obtained from the laboratory test should be sufficient.

Table 1: Comparison of performance between MPR-16 and commercial imported module.

Specification	**MSCA-16**	**Imp. module** [2]
Dynamic Range (MeV Si)	100	100
Power (mW/ch)	30	100
Linearity	<1%	<1%
Noise (keV) (entire assembly)	25 (C_d=350 pF)	5+0.06/pF
Noise (keV) (ASIC)	2.5+ 0.04/pF	
Energy Resolution (keV) (detector) (^{241}Am α-source)	50	
Channels	16	16

Conclusion and Future Scope

The MSCA-16 module, capable to work in 100MeV (Si) dynamic range, has been developed successfully and compared with the commercial module. The differential conversion circuit needs to be checked for improving noise performance. The preliminary test of the assembly with the detector has been carried out and the energy resolution with both the module ^{241}Am α-source has been obtained. It has been identified that the ground noise is increased in case of MCSA-16 unlike commercial module when HV is applied. The source of this additional ground noise is being identified before proceeding into in-beam experiment with the beam from K-130 cyclotron.

References

[1] Samir Kundu et al., "Chakra: The high resolution charged particle detector array at VECC," Nucl. Instrum. Methods Phys. Res. A, vol. 943, 2019.

[2] https://www.mesytec.com/products/datasheets/MPR-16.pdf