Development & Characterization of Charge Sensitive Pulse Converter using VECC003 ASIC for Neutron Flux Monitor

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

Introduction

Variable Energy Cyclotron Centre uses plenty of Neutron Flux Monitors (NFM) for the purpose of radiation safety at different places around cyclotron installations. The NFM monitor is mainly composed of a Charge Sensitive Pulse Converter (CSPC) at the first stage after detector and a controller module connecting other units for the purpose of monitors, indicators, safety relays and remote communication. The CSPC of the existing commercial monitor, using BF3 neutron detector, faltered due to drift in the discrete components for aging effect. These components are presently obsolete and as an alternative, Cremat Inc. based CSA and shaper modules with large dynamic range/output voltage (2.1pC/~3V) were used which worked successfully [1].

Nevertheless, the charge produced by the neutron detector is in the range of hundreds of femtocoulomb depending upon the sensitivity and volume of the detectors. In order to keep the dynamic range of the CSPC within that limit and to have a maximum detectable voltage of one volt for high SNR, the feedback capacitor of the CSA would be in the range of hundreds of femtofarad. Such small value of capacitance is not implementable using discrete components due to parasitic effects. Moreover, as the sensitivity of BF_3 detector for thermal neutron lies between 0.4-0.5 cps/nV, an optimization of equivalent noise charge is important to detect neutron flux correctly from other backgrounds [2]. The optimization techniques require alteration of the parameters of the input MOS of the CSA, bandwidth of CSA and shaper etc. which is difficult to design with discrete components and therefore a monolithic circuit is the ideal choice.

With this motivation, VECC003, a preamplifier and shaper ASIC was envisaged, designed and fabricated and CSPC was engineered using VECC003. This paper describes the details of the ASIC, CSPC and characterization of the same in the subsequent sections.

Design & Specifications of VECC003

VECC003 has been designed with dynamic range of 500 fC, sensitivity of 2 V/pC, a rise time of 50 ns and a decay time of 22 µs. It is followed by a 5th order semi-Gaussian shaper which has one real pole and two complex conjugate pair of poles for better noise performance. The shaping time can be set to 1 or 3 µs. A pole zero compensation was placed in between the preamplifier to reduce undershoot of the falling edge of the shaper.

Fig. 1: VECC003

The technical specifications of VECC003 ASIC are summarized in Table 1.

VECC003	
Detector Type	Boron Trifluoride (BF_3)
Electronic Resolution	< 1% of Dynamic Range
Peaking Time	1/3µs
Sensitivity	2 mV/fC (CSA); 1 mV/fC (Shaper)
Linearity	< 1%
Shaper Type	Fifth Order Complex Pole (Semi-Gaussian)

Table 1: Technical specifications of VECC003

Development of the Charge Sensitive Pulse Converter

A four layer PCB was developed for the CSPC of NFM. The PCB circuit consisted of VECC003 ASIC followed by amplifier, a Schmitt trigger and a mono-shot circuit. The amplifier output was used to generate a trigger pulse through the Schmitt trigger. A hysteresis of about 40 mV and a threshold of 1 V was applied to the Schmitt trigger which prevented any noise firings during operation. The mono-shot was used to generate a 5 V output pulse of constant width at the rising edge of the input trigger pulse. The output of the Schmitt trigger and the mono-shot were clearly high frequency signals which could introduce lot of noise in the PCB ground plane. This noise when coupled with the input distorts the analog signal. To get rid of this noise, isolation and separate ground planes connected at a star ground point were incorporated [3]. The CSPC was tuned for operation within the range of 20-100 fC for the present BF_3 detector to ensure measurement of minimum to maximum neutron flux correctly bypassing other backgrounds noises.

Fig. 2: NFM CSPC PCB

The CSPC module required 2 V, 3.3 V and 5 V power supply which were generated through fixed-value regulators placed on the PCB. All these regulators accepted input supply in 6-20 V range. Apart from this, the PCB also consisted of a high voltage section. The high voltage section was essentially composed of RC filter circuits which was used to bias the BF_3 detector through the preamplifier. Test input pins were also kept on the PCB so that it could be readily tested in laboratory environment.

Experiment & Results

The CSPC module of NFM was tested in laboratory with a 1.8 kV bias applied to the BF_3 detector. The shaper was used with 1 µs peaking time and the mono-shot was set to give a pulse output of 5 µs width. Results with test input showed that the module can cater up to 30 KHz counting rate maintaining excellent linearity (Fig 3). The reduction in noise levels due to VECC003 ASIC and intelligent layout design of PCB allowed detection of test input signals as low as 20 mV. This result was obtained irrespective of the ground noise introduced by high voltage bias. An Am-Be source surrounded by paraffin was placed 50 cm away from the detector to test the performance of the ASIC and a flux of 44 nv was obtained which was same as that of commercial modules.

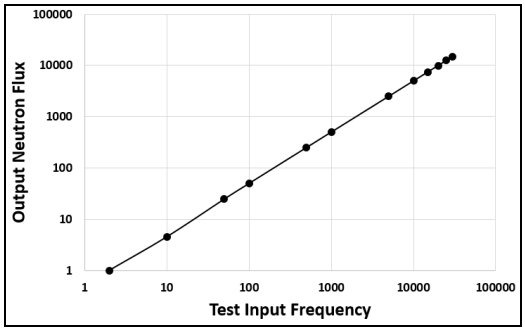

Fig. 3: Plot of Neutron Flux vs Test Input Frequency

References

[1] Cremat Inc., "CR-110-R2 charge sensitive preamplifier: application guide", Oct 2018.

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[3] W. Kester, "A Grounding Philosophy for Mixed-Signal Systems." Electronic Design Analog Applications Issue, pp. 29, June 23, 1997.