INGA and NAND Instrumentation at IUAC

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We present the development of high density front end electronics modules for Indian National Gamma Array (INGA) and National Array of Neutron Detector (NAND) at IUAC. The successful development and implementation of these modules reduce the overall infrastructure and operational cost while the setup and tuning of electronics with above detector setup is made simple and convenient. The various functional blocks built inside these modules and their performances as well as their present status are discussed.

Introduction

A large array of compton suppressed Clover HPGe detectors for in beam gamma ray spectroscopy known as Indian National Gamma Array [1] (INGA) and a large array of neutron detectors known as National Array of Neutron Detector [2] (NAND) are being established to use with Super Conducting Linac at IUAC. These arrays are a national collaborative effort of IUAC, UGC-DAEF-CSR, TIFR, BARC, VECC, SINP and Indian universities. The required detectors for these arrays are pooled from different participating institutions.

The INGA experimental facility consists of 24 numbers of High Purity Germanium (HPGe) Clover detectors along with Anti Compton Shield (ACS) detector that surrounds the clover detector giving out nearly 200 energy and timing signals at high (10kcps) count rate. For front end electronics signal processing each detector channel requires a high quality low noise Spectroscopy amplifier, Timing Filter Amplifier (TFA) and Constant Fraction Discriminator (CFD) and associated Logic circuits to generate mandatory ADC GATE, Pile up rejection (PUR), Time (TDC-Stop), Anti Coincidence (ACS) to indicate the leaking of radiation into ACS as well as Master Gate Input signal. The required entire front end analog and logic electronics to process signals from a 4 element clover detector and a ACS detector as proposed in [3] is housed in a double width NIM cabinet.

The present NAND array consists of around 30 numbers of 5 ”x 5 ” NE213 organic scintillation detectors. The energy and timing signals generated in these detectors are further processed to discriminate neutron from gamma radiations with zero cross discrimination (ZCD) technique. A single width NIM cabinet houses two channels of complete front end electronics required to process the above signals. The high compactness is realised with surface mount electronic devices with start of art components. These modules are successfully developed, demonstrated and mass produced at IUAC and they have been used successfully with INGA and NAND arrays.

For large detector arrays conventional NIM and CAMAC standard setup would require a large number of general purpose modules which occupy large area, high power consumption, large number of interconnecting cables and connectors at huge cost. Other option of custom made VME, VXI standard modules would impose dependency on hardware and software suppliers. The NIM modules developed at IUAC contains all necessary front end analog and logic electronics with user specified parameters.

INGA Clover Electronics Module

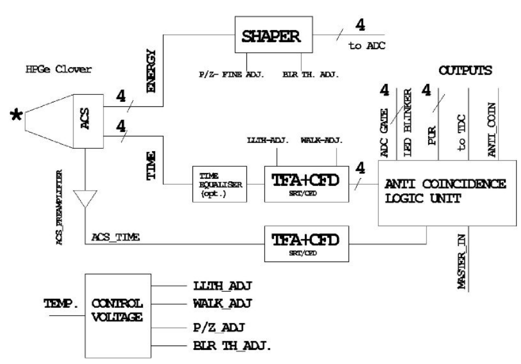

Fig.1 Block diagram of Clover electronics

A clover electronics module [4] handles entire front end electronics of a 4 element Clover detector of INGA. This double width NIM module consists four numbers of high quality shaper amplifier and corresponding four numbers of Timing Filter Amplifier and Constant Fraction Discriminator (TFA+CFD) cards as shown in Fig.1. Additional TFA+CFD card is provided to handle signal from ACS detector to generate Anti-Coincidence (ACOIN) signal. All the timing signals generated are processed in Anti Coincidence Logic (ACL) card in order to generate ADC Gate, Pile Up Rejection (PUR), ACOIN, TDC STOP logic signals. These discretely assembled daughter cards are plugged into mother board. The interconnection of these blocks are done through mother board PCB. The entire circuitry is placed in a double width NIM module which essentially contains circuit blocks as shown here.

Spectroscopy Amplifier [5]

The signals (Energy) from the the detector having sensitivity of ~200 mV/MeV (HPGe) are fed to the spectroscopy amplifier card. The high resolution spectroscopy amplifiers have fixed shape and shaping time constant (semi-gaussian, 3 μs) and 3 fixed gain settings (2/4/6 MeV) which are jumper selectable as shown in Fig. 2 .

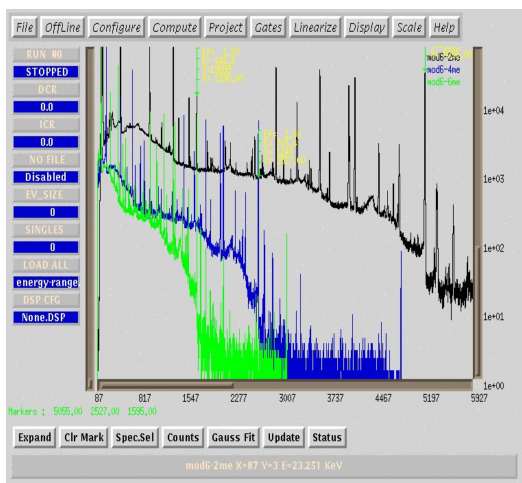

Fig. 2 Histogram with different gain settings

The semi-gaussian unipolar output has been achieved with 2 stages of active filters with a dynamic range of 10 volts. The gain blocks along with overload recovery circuit are realised with low noise, high slew rate operational amplifiers. The DC baseline is stabilized with Gated Base Line Restorer (BLR) circuit, while Pole Zero (P/Z) correction and BLR (manual) threshold adjustments are voltage controlled from front panel. The P/Z correction and manual baseline adjustments are possible while monitoring required signals on the front panel. As a general principle, all front panel adjustments are through voltage control, making it possible to replace them by remote control in future.

Timing Filter Amplifier (TFA) & Constant Fraction Discriminator (CFD) [6]

The signals (TIME) from the the detector (HPGe) segments are fed to four Timing Filter Amplifiers cum Constant Fraction Discriminator (TFA+CFD) cards. The TFAs have fixed and identical time constants and gain settings (200nS, 1V/MeV) are provided for processing TIMING signals from Clover detector. These compact amplifiers are DC baseline restored with twin diode Robinson restorer circuit and have rise time of better than 10 ns across their dynamic range of 2.5 volts across 100 ohms.

The Constant Fraction Discriminator (CFD) with amplitude and rise time compensation (ARC) is realized with fixed delay of 25ns and fraction of x0.3. The CFD outputs corresponding to clover segments having fixed width of 50ns and dead time of 2 μs are available on rear panel. The Lower Level Threshold (LLTH dynamic range 1:100), WALK adjustment and monitoring are possible on front panel. Anti-Compton shield (ACS) signal received from ACS preamplifier is processed with identical TFA + CFD card as mentioned above but without any added dead time.

Anti Coincidence Logic [7]

The raw timing logic signals received from CFDs of Clover HPGe detectors, AC Shield detector and external GATE signals are further processed as shown in Fig. 3 to effect anti-coincidence in Anti-Coincidence Logic (ACL) card. The logic functions performed here are Individual ADC GATE generation, PUR, Anti-Coincidence Signal generation and Delayed STOP signal for TDC. All these logic outputs are buffered and available in standard logic levels (FAST NIM, TTL) on the panel.

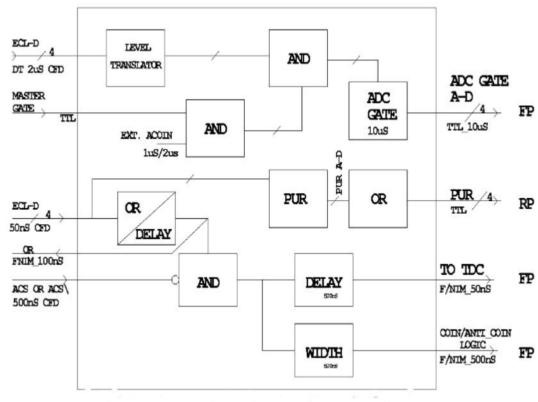

Fig. 3 Block diagram of Anti coincidence logic

The individual timing signals of clover segments can be time aligned with builtin tapped analog delay in order to match the TAC spectrum from different detectors in the array.

Performances

The modules have been subjected to various systematic tests with ^{60}Co and ^{152}Eu sources in order to evaluate the performances in parallel with commercial modules. The tests carried out are to evaluate energy range, peak drift, linearity of amplifier and time alignment.

Typical resolution obtained is ~1.3 keV @122 keV, 2.0 keV @1408 keV of ^{152}Eu @ ~10 kcps count rate.

Energy drift: Repeated study of all modules mass produced have undergone the energy drift test and typical drift observed is better than 1 part in 10^4 over a period of 24 hours. The observed energy shift of 1408 keV peak of ^{152}Eu is plotted for different modules is shown in Fig. 4.

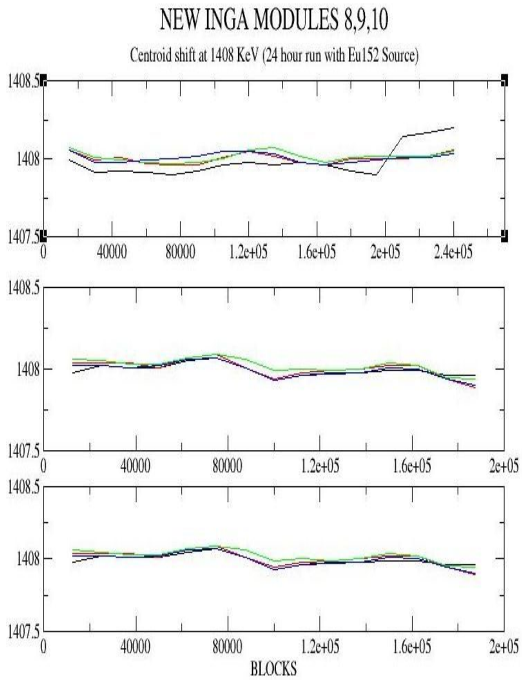

Fig. 4 Energy peak shift of Shaping cards

Integral non-linearity: Approximately ±100 eV for ^{152}Eu spectrum or 1part in 10^4 is obtained with 2 MeV energy range. Typical non linear behaviour plotted and shown in Fig. 5 for IUAC and commercial shaper cards .

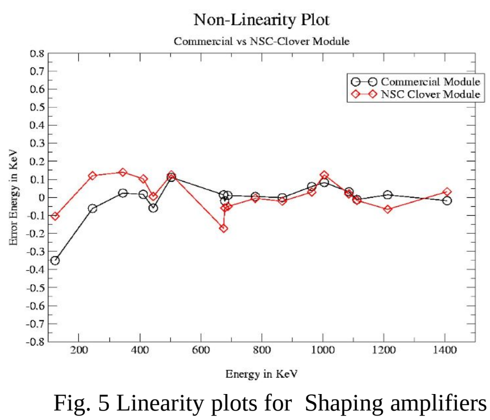

Fig. 5 Linearity plots for Shaping amplifiers

Present status: The INGA clover electronics modules have been used successfully with INGA campaign at VECC, Kolkata with minimum downtime. The modules for INGA at IUAC have been mass produced and evaluated for the performances.

Pulse Shape Discriminator Module [8]

The PSD module is a single width NIM module containing two independent channel of electronics for neutron-gamma Pulse shape discrimination based on zero cross method. Each channel of electronics contains various functional blocks as shown in Fig.6. The energy channel includes Shaping amplifier to process PMT dynode signal and the timing channel contains a CFD, fast 2nd order Pulse shaping amplifier (PSA), Pulse shape discriminator (PSD), Time to amplitude converter (TAC), and Time of Flight (TOF) logic circuits which are interconnected. The entire high density circuit assembly is realised with surface mount technique. The performances achieved are comparable with commercial setup.

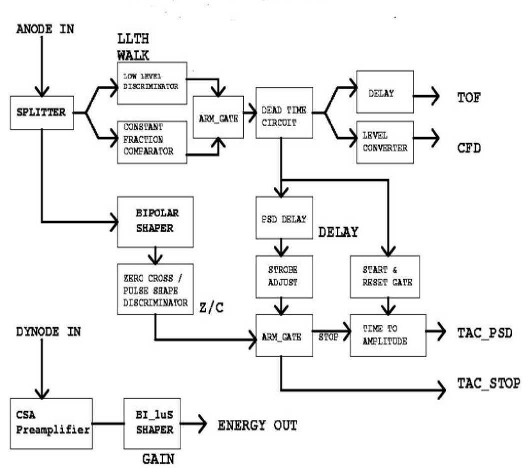

Fig. 6 Block diagram of PSD electronics module

Shaping Amplifier

The energy channel derived from the neutron detector PMT dynode is routed through a home made low cost charge sensitive

Preamplifier which is placed near the detector. The inbuilt shaping amplifier has multiple gain settings which are jumper selected on board, whereas the fine gain adjustment is voltage controlled from front panel. The shaped output is a bipolar semi-gaussian (2^{nd} order active filter) with time constant of 1uS. The buffered (50 ohm capable) shaper output is accessible from front panel.

Constant Fraction Discriminator (CFD)

The CFD has a builtin delay of 5 nS and a fraction network of 0.2. Blocking time of 1.5 uS is provided to eliminate multiple trigger. A Fast NIM CFD output is available on front panel. The CFD output is further utilised on board to decide various logic functions like TOF logic, TAC start, PSD strobe and PSD delay.

Pulse Shape Discriminator [9]

In the PSD section of timing channel, the anode signal from the fast photo multiplier tube (PMT-XP4512B) having fast rise and fall time is equally power divided through wide band passive power splitter and fed to 1). CFD section and 2). Pulse shape amplifier in order to preserve timing informations.

The signal applied to PSD section is suitably differentiated, integrated and amplified to realise a semi-gaussian shape bipolar signal with crossover time of ~ 300 nS, which is optimised for the liquid scintillation detector of the array. The signal shaping is done in a cascade fashion, where the first stage is an integrator and followed by a differentiator. Each section contains a wide band, large dynamic range, frequency compensated low noise operational amplifier in order to build suitable amplitude level before cross over detection. The PSD section utilises an ultra fast comparator and ECL 10EL logic family devices to detect zero cross over. The zero cross over signal is validated with a STROBE signal, whose width can be adjusted for selection of TAC spectrum corresponding to neutron and gamma radiation.

The validated zero cross over signal is used to stop the built-in Time to amplitude converter (TAC). The TAC card utilises indigenously developed TAC (BMC1522) [10] hybrid chip which is suitably wired to generate 0 to 10 volts output signal. The control signals START, STOP and RESET for TAC are of fast NIM type and are suitably level converted on board. The TAC conversion time is programmed as ~100 nS for NAND application.

For further convenience the TAC stop signal can be accessed from the rear panel. In order to monitor and control various control parameters discussed so far, the test points like CFD Z/C, PSD Z/C, STROBE signals are accessed for monitoring purpose on front panel. Critical controls like LLTH & Z/C are adjusted and measured through front panel test points.

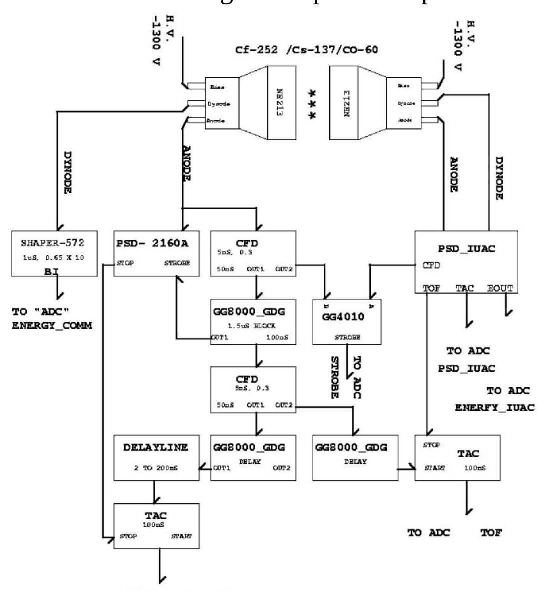

Fig. 7 Test set up for PSD modules

Performance results The module has been subjected to various tests with setup shown in

Fig.7 with strong radiation sources and results are compared with commercial setup (Canberra 2160A) as well as with similar electronics developed elsewhere.

The η-γ separation spectra obtained with this module and ^{252}Cf at various energy thresholds ranging from 110 keVee to 880 keVee are plotted in Fig.8. The typical figure of merit (FOM) are given in Table1. The FOM is defined here as

$$(\text{Peak separation}) / (\text{FWHM}\eta + \text{FWHM}\gamma)$$

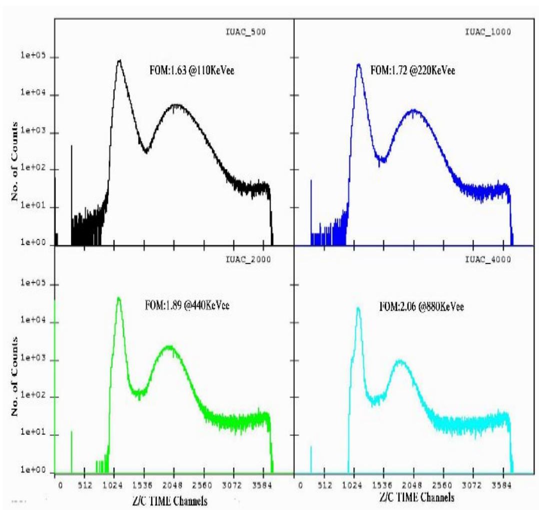

Fig. 8 PSD with different thresholds

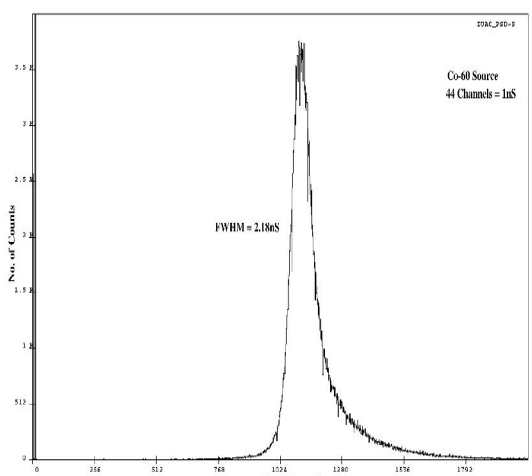

Fig. 9 PSD with ^{60}Co γ ray source

In order to ascertain the PSD capability of the module, Z/C spectrum was obtained with ^{60}Co γ ray source. The FWHM of Z/C distribution obtained at energy gate of 500 keVee is ~2.2 nS as shown in Fig. 9.

Threshold (keVee)	**IUAC**	**Comm.**	**Neut.wall [11]**	**Demon [11]**
50	1.4	1.27	NA	NA
110	1.6	1.52	1.15	1.09
240	1.82	1.65	1.54	NA
300	NA	NA	NA	1.65
500	1.89	1.75	1.84	NA
1000	2.06	1.91	2.1	2.05

Table 1 FOM obtained with PSD electronics at different energy thresholds compared with commercial modules and other arrays

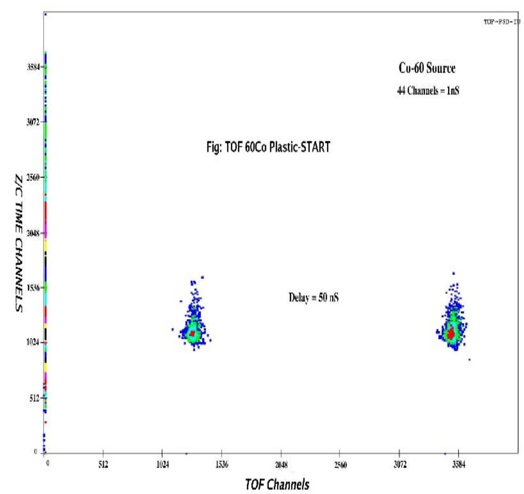

Fig. 10 TOF with ^{60}Co γ ray source

The Fig.10 shows the 2D spectrum of TOF versus Z/C time measured with ^{60}Co γ ray source. The two peaks in spectrum are obtained by adding delay of 50 nS in TOF circuit. The START signal for TAC for this measurement is taken from a thin plastic detector (2” dia., 1” thick) and STOP from a neutron detector and typical FWHM obtained with TOF spectrum is

~1.2 nS. This spectrum clearly shows the absence of any other events coming in the region, where neutron events are expected.

Present Status

We have built prototypes before successfully developing the present design of the module and the same module design is duplicated for the existing NAND array at IUAC. The modules have been successfully used in a couple of experiments with Linac and Pelletron beams at IUAC. The PSD Vs Energy spectrum in a typical experiment is shown in Fig.11. The module did not show any cross talk related problems between two channels within the same module. Meanwhile, the PSD module for NAND with minor alterations in time constants, tested with Si-PAD detector at BARC and test results are being presented in this symposium.

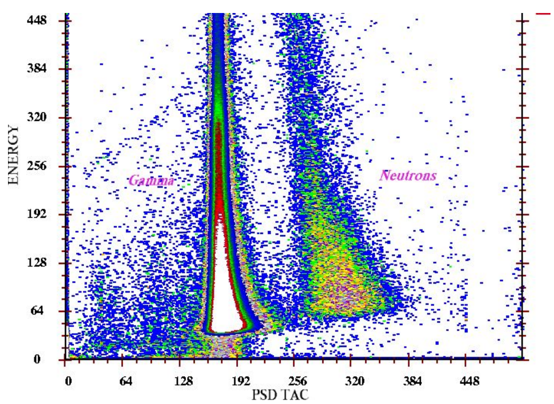

Fig. 11 PSD Vs Energy obtained with ^{28}Si on ^{181}Ta

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