



TECHNICAL REPORT

PULSE SHAPE DISCIMINATOR ELECTRONICS MODULE

for National Array Neutron Detectors at IUAC

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Silk screen TOP, BOTTOM layers

Drill drawing

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TECHNICAL REPORT

TITLE : Technical Report on Pulse Shape Discriminator Electronics Module

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CATEGORY : Instrumentation

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PULSE SHAPE DISCIMINATOR ELECTRONICS

Module for National Array of Neutron Detectors at IUAC

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Abstract: At IUAC, we have developed a compact, high density Pulse Shape Discrimination (PSD) electronics module for National Array of Neutron Detectors (NAND)¹. The single width NIM module contains two independent channels of all necessary front end circuits namely Shaping amplifier, CFD, PSD, TAC and TOF Logics. The performances of the module under identical test conditions are compared with commercial electronics setup.

Acknowledgment:

We would like to thank Dr. Swapan Kumar Dutta, R.P.Singh, Rakesh Kumar of IUAC for specifying and evaluating overall timing functioning of the prototype and preproduction versions of the module. We also acknowledge the help of Mr.Saini S.K., Workshop, IUAC and M/s.Midan India for panel preparation and apprentices participated in this work during assembly. Our sincere thanks to Dr.Amit Roy, and Ajith Kumar. B.P, for their constant encouragement and providing the necessary infrastructure in order to complete this project successfully.

Dedication:

This development project work is dedicated to Dr.S.K.Datta on his retirement from Academic responsibilities during the year 2006.

Specifications:

Pulse Shape Discriminator Electronics module for Neutron Array

Shaping Amplifier²

Input Impedance, Signal Range	: 1 kilo ohms, $\pm 1\text{V}$
Output Impedance, Signal Range	: 10 ohms, $\pm 10\text{ V}$
Gain	: ~ 10 , Inverting Type* , Polarity is opt.
Coarse Gain Selection	: $x1$, x 0.8* , $x 0.5$
Fine Gain	: From front panel
Shape & Shaping time	: Bipolar Quasi Gaussian , $1\mu\text{S}$
Input	: BNC, Rear Panel (Dynode IN)
Daughter card Size	: 48mm x 38mm x 15mm (dual row)

Constant Fraction Discriminator (CFD)³

Input	: BNC, Rear panel, Anode IN.
Input Impedance, Signal Range	: ~ 50 ohms, $\pm 5\text{ V}$
Constant Fraction	: $x 0.2$
CFD Delay	: $\sim 5\text{ nS}$ ($Z_0 : 50$ ohms) Internal
LL Threshold	: -10 mV to -250mV (~ 10 to 250 KeV energy of recoil electron)
LL Threshold Monitoring	: -100 mV to -2.5V through 2mm Front Panel socket
WALK Adjust	: On Front Panel
Blocking Time_CFD	: $1.5\mu\text{S}$
Width_CFD	: 75 nS
Output_CFD (Prompt)	: F/NIM on Front Panel
TOF Delay	: 250nS to $1.25\mu\text{S}$ Adjustable, 700nS
Output_TOF Delay	: F/NIM on Front Panel, Width of 75 nS

Pulse Shape Discriminator (PSD)

Zero Cross-over (Z/C) ⁴

Shaping Constant	: ~300 nS, two stage Gaussian shaper
Dynamic range of Z/C Amplifier	: 0 – 10Volts, Limited to +/-5V at the output
Monitors	: Zero Cross (Z/C_MON), STROBE (STB) Attenuated ECL, Lemo_00 on Front Panel.
PSD Delay	: 100nS to 500nS.. Adj. on Front Panel.
PSD Strobe Width	: 40ns to 200nS Adj. on PCB 100nS .
PSD Z/C Adjust	: On Front Panel with readout 2mm test point
TAC START/RESET Signal	: Fast NIM, 2.5μS (Internal)
Typical Figure of Merit	: ~1.9 @ 1MeVee LLTH
TAC_STOP	: F/NIM_ 75nS accessible on Rear panel.
Typical Resolution	: 2.2 nS ** (FWHM)

Time to Amplitude Converter ⁵

TAC Range	: 100nS
Resolution	: better than 50pS ⁵
Inputs	: START, STOP, RESET of Fast NIM
Output range & Width	: 0 – 10Volts, 2.5μS
DC Supply required	: ±12Volts and -6V
Card Dimension	: 44mm, x 70mm x 10mm
Control Voltages for various parameters	
Drift	: better than 10 ppm / deg.C
Module Dimension	: Single width standard NIM cabinet
Module DC Power Supply	: +/-12V_0.2A/0.6A and +/- 6V, 0.1A/1.7A

Recommendation : To assemble **5 Nos.** of this module in a standard **200 watts NIM Crate** with forced air cooling from bottom of the NIM crate at ambient temperature of 25 deg.C

** Measured with actual set up.Consult Electronics Lab, IUAC. **@13KeVee LLTH**

* Bold letters parameter values set on default.

Pulse Shape Discriminator Module for Neutron Detector Array at IUAC

Introduction:

The Pulse Shape Discrimination (PSD) module based on Zero cross technique is adopted to discriminate $n-\gamma$ in National Array of Neutron Detectors (NAND)¹ at IUAC. This technical report describes various building blocks adopted to realise a custom built, single width NIM module that contains two independent channel of electronic circuits. The block diagram and illustrations as well as other referred internal technical reports may be referred. Essentially this module is developed in line with already developed module at IUAC⁶ in the past and provides more features and reliability.

The module contains various functional blocks namely Shaping amplifier with bipolar semi-Gaussian shape having time constant of 1 μ S for energy spectroscopy. The timing channel includes a CF Discriminator (CFD), fast 2nd order Pulse shaping amplifier with peaking time constant of 300nS, a Pulse Shape Discriminator (PSD), Time to Amplitude converter (TAC)⁵ and Time of Flight Logic (TOF) circuits which are interconnected. Essential connections including monitoring points are provided on the front and rear panels. The entire high density circuitry is realised with state of the art surface mount technology (SMT) components. The performance of this module is tested and compared with commercial modules.

Principle of Operation:

In Z/C method, the anode signal from the fast Photomultiplier Tube (PMT) having rapid rise and fall time is equally divided through resistive signal splitter and coupled to 1. CFD section and 2. PSD section for a proper wide band impedance matching. The CFD parameters are chosen as

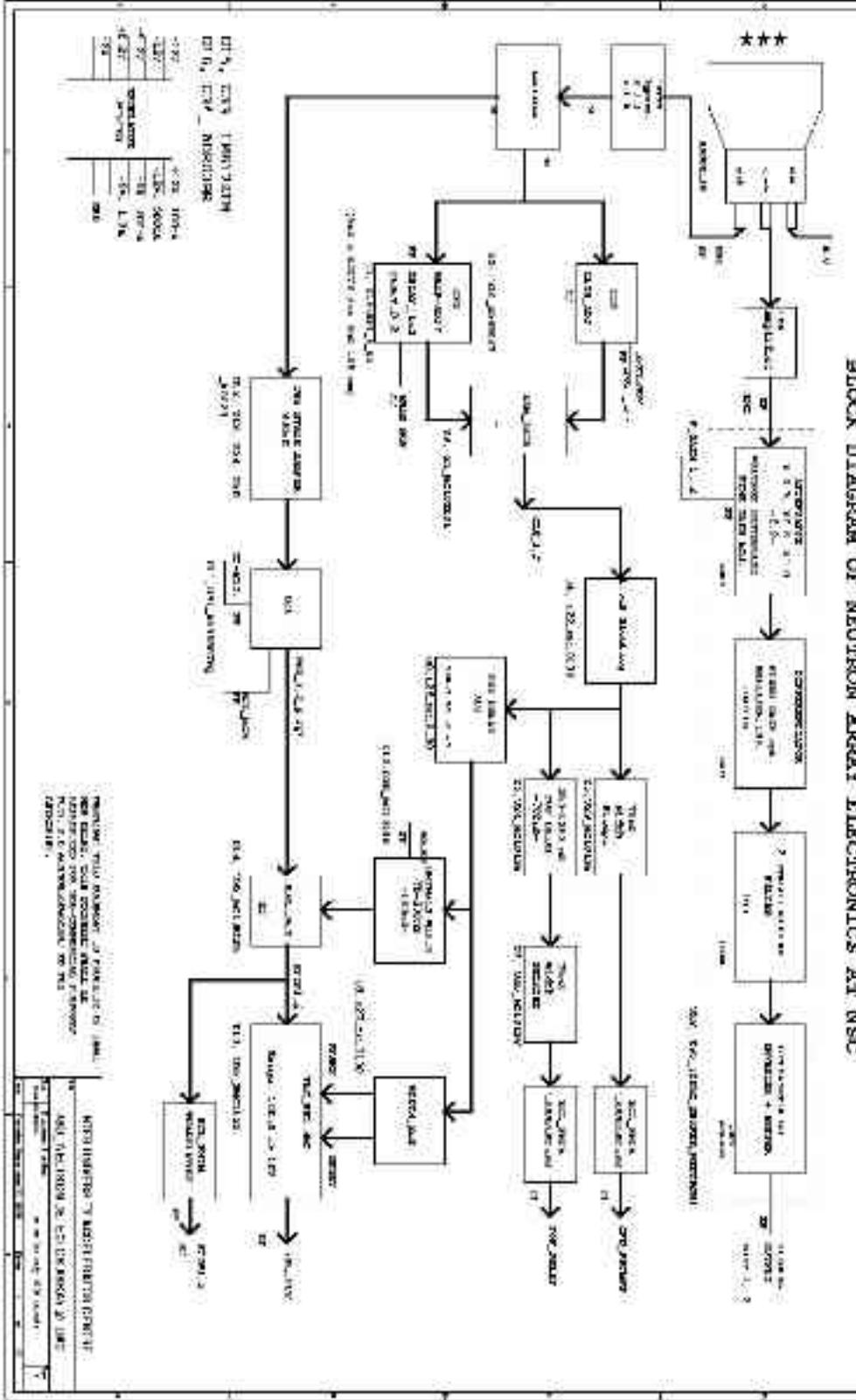
Delay: 5nS and **Fraction : 0.2.**

The CFD section and LL-Threshold discriminator section share dual ultrafast Comparator. The CFD signal is ARM gated with LLTH signal in a NAND/AND (U3,U21) gate. Thus generated CFD signal (CLK) is further blocked for $1.5\mu S$ in order to reduce false triggering. This signal is further processed to generate CFD “Prompt” and delayed to generate “TOF” Logic signals.

The signal applied to Zero Cross-Over amplifier section is suitably differentiated and integrated ($\sim 300\text{nS}$) to realise a semi-Gaussian bipolar signal. 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 large dynamic range, low noise, wide band frequency compensated amplifier to build signal level of required level. Thus generated bipolar signals have different zero cross over time, utilised for recording $n-\gamma$ separation. This signal is level limited ($\pm 5\text{V}$) before further processed in a Pulse Shape Discriminator (PSD).

The PSD amplifier is an ultra fast comparator, whose bandwidth and linear amplification capabilities are utilised to generate timing signals corresponding to $n - \gamma$. The generated logic signals corresponding to $n - \gamma$ are ARM ed with STROBE signal to generate TAC_STOP signal. The STROBE signal is derived from CFD signal after a delay, which also utilised to START/RESET the TAC with suitable width (2.5 μ S). The alignment of STROBE by DELAY control is possible from front panel control.

BLOCK DIAGRAM OF NEUTRON ARRAY ELECTRONICS AT NSC



The built-in Time to Amplitude Converter (TAC)⁵ is a daughter card plugged into motherboard. The necessary control signals like TAC_STOP, TAC-START/RESET of FNIM level are generated by the PSD section and fed to generate TAC output in the range of 0 to 10Volts. The TAC range is set as ~100nS for this application.

In order to monitor, critically adjust and align various circuits, critical test points like CFD_Z/C (WALK), PSD_Z/C, STROBE signals are accessed on the front panel. The critical signal levels applied like LLTH Discriminator and PSD_Z/C correction levels are monitored for reproduction of results. For further convenience, additional TAC_STOP (F_NIM) signals are provided on rear panel. The inside temperature can be monitored through TEMP test point on front panel.

The ENERGY signal derived from Last Dynode of the Neutron Detector PMT is routed through a Charge sensitive Preamplifier and applied to the built in Shaping Amplifier² through rear panel. The COARSE gain selection is possible on PCB by selecting the jumper, while the fine gain adjustment is possible through front panel potentiometer. The Energy output is available on front panel. The Shaping amplifier output is essentially a bi-polar semi-Gaussian shape (2nd order Active filter) with shaping time of ~1uS.

The circuit having numerous monoshot functions, is realised with MC10198P, a 10KECL integrated circuit of M/s.ON SEMI. Since this IC is obsolete, sincere efforts are being made to replace this IC with equivalent circuit in future model.

Assembly Procedure:

Preparing the Mother board:

The entire circuit including daughter cards are assembled on a mother board and fitted on side rails of a single width NIM module. The mother board marked **ELAB-2006** shall be used. Before assembling the components, following points shall be noted.

- Check the dimensions of PCB for fitting within available space. Apply smooth file if needed.
- Check the corresponding fitting holes on PCB and rails of NIM cabinet.
- Check carefully with magnifier (x10) / eyepiece for solder bridges formed due to poor etching/artwork process.
- Check the power supply line tracks for any short circuit / open circuit with ohmmeter.
- Check the correctness of PTH / drill holes before mounting any components.

Starting from bottom layer of PCB, all SMD components are to be assembled in an order on both layers. Begin with small foot print, low profile components, Polarised capacitors, ICs and interconnecting control cables, where potentiometer wires, Toroid inductors, delay lines are to be soldered at the end.

Preparing the Cabinet:

The front and Rear panel of a cabinet are to be prepared as per dimensions given elsewhere in this report. These panels are to be powder coated and screen printed. The interconnecting wires are to be precut and prepared as per the attached spreadsheet in this report.

Test Results:

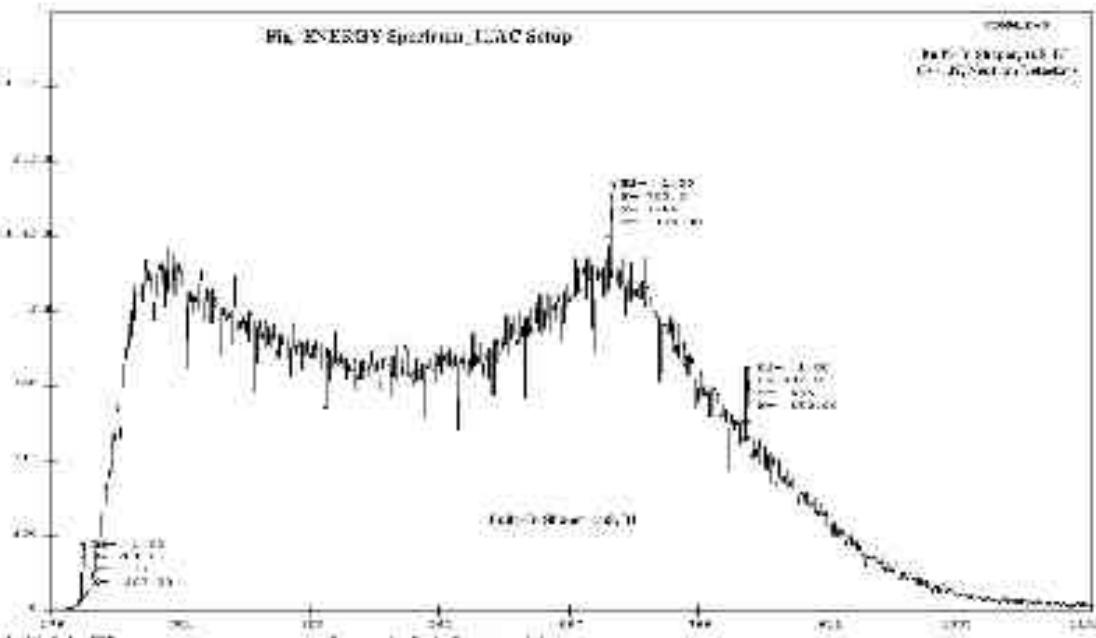
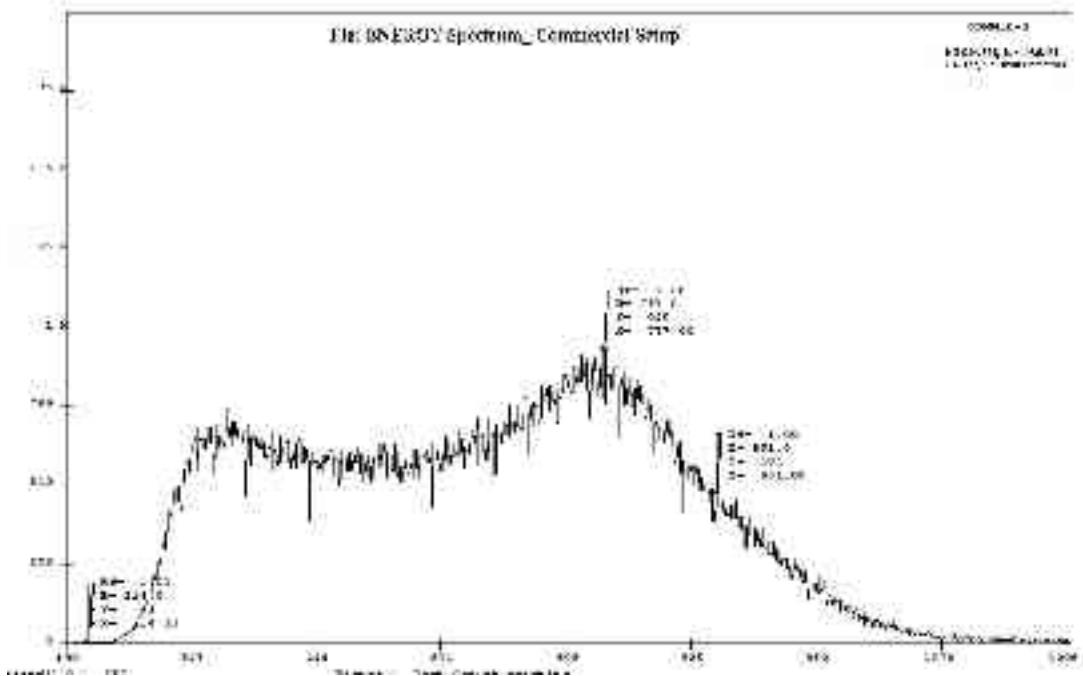
The module has been subjected to various tests as mentioned in the Ref: 7, with a set of Neutron detectors along with a strong Cf-252 source for PSD- Z/C performances and a Plastic Scintillator mounted on XP-2020Q of Philips along with Co-60 source for TOF performances. After initial energy calibration with Cs-137 source, various other tests performed were PSD setup at High count rate (4Kcps), Neutron detector shielded with a thick lead sheet for improvements in FWHM in gamma radiation peak as well as TOF performance. The test setup have been wired to evaluate the IUAC made module with commercial electronics (CANBERRA 2160A PSD) available. Some of the tests carried out were to evaluate both the channels of IUAC made module. The typical setup used is as shown in block diagram, and the final results obtained under various test conditions are shown in the specifications as well as attached figures.

1. Energy Calibration:

Commercial: Ortec 572 Amplifier, BI Out, 1uS, (X6.5), Source: Cs-137 (662KeV)

IUAC: Built in Shaper, BI Out, 1uS, Coarse: Middle

Calibration: **0.57 KeV /Channel.**



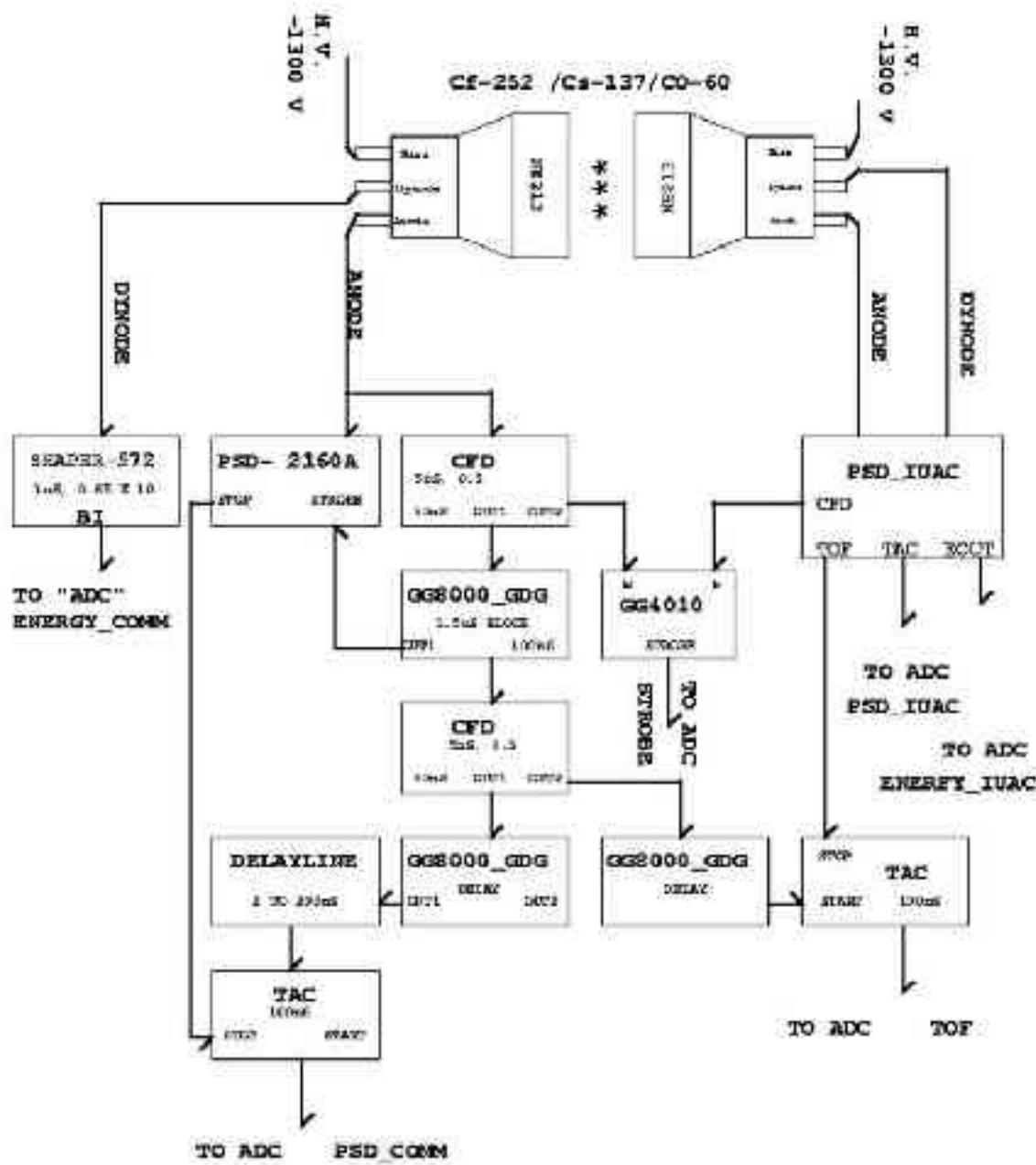


FIG: TEST SETUP FOR PSD ELECTRONICS

Pulse Shape Discrimination Performances under various Energy gates

Conditions: Commercial and IUAC set up, TAC: 100nS, Source: Cf-252 (Strong)

Count rate: ~1.5Kcps, ADC: 4K Philips

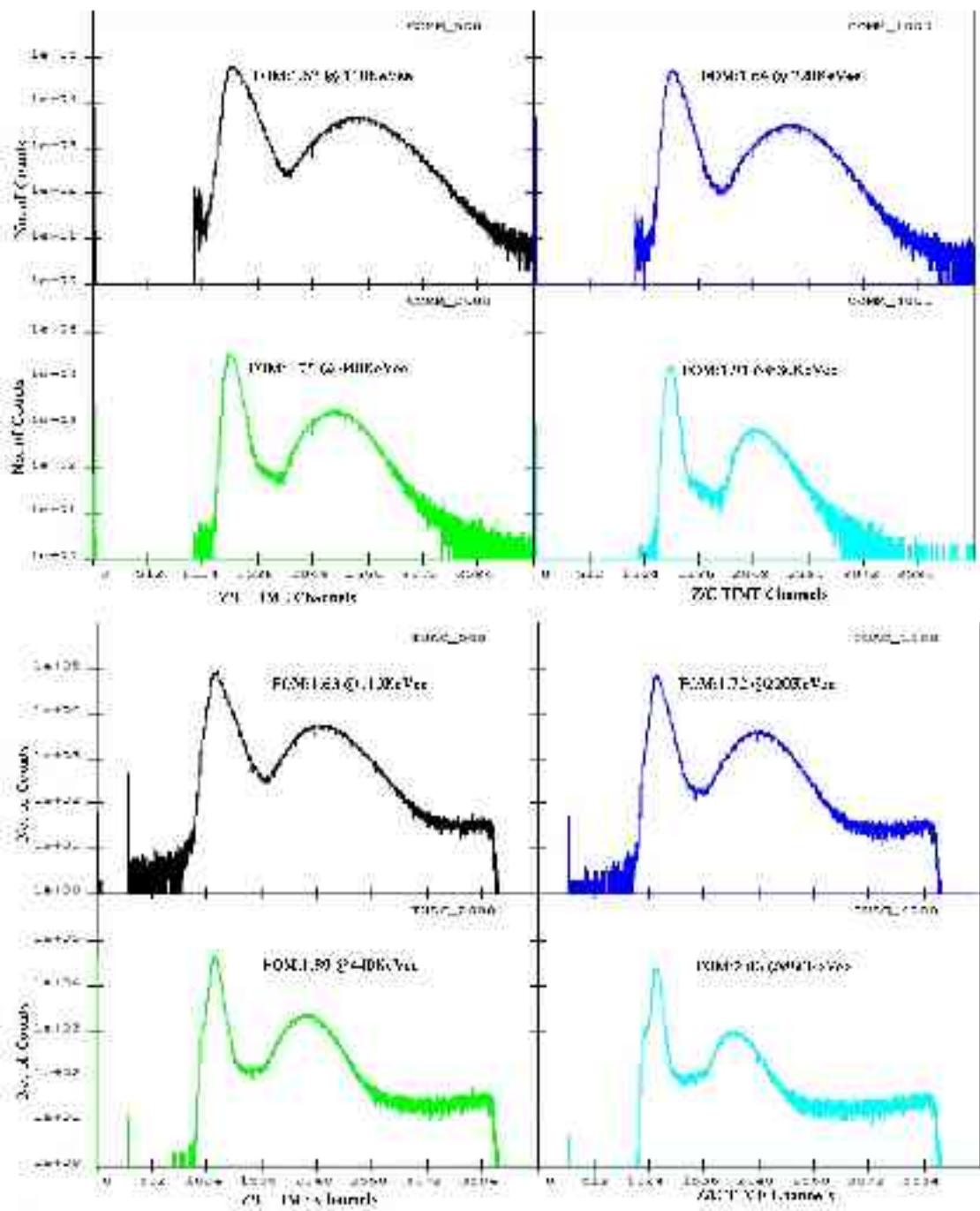
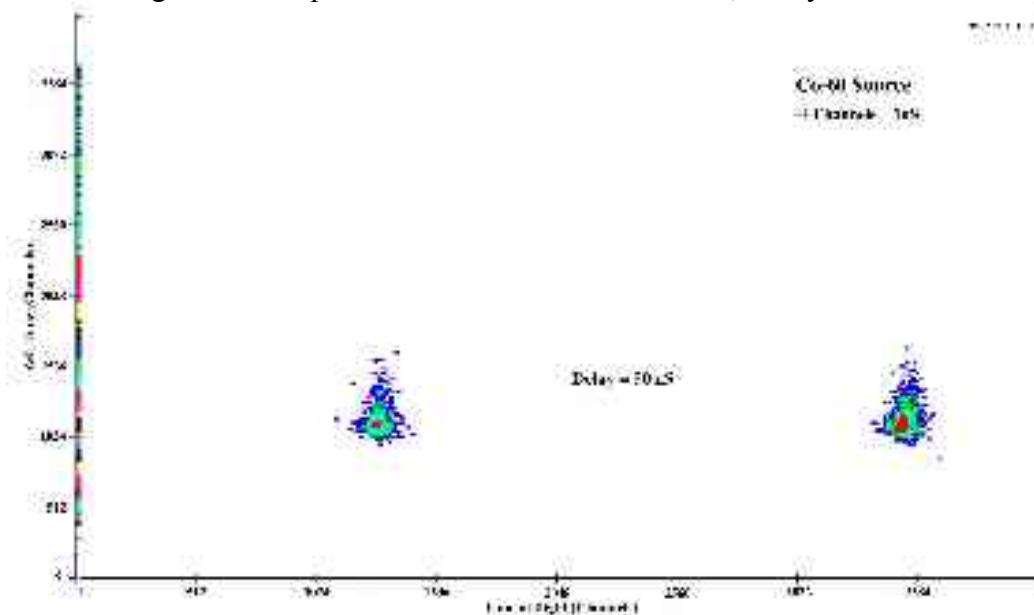
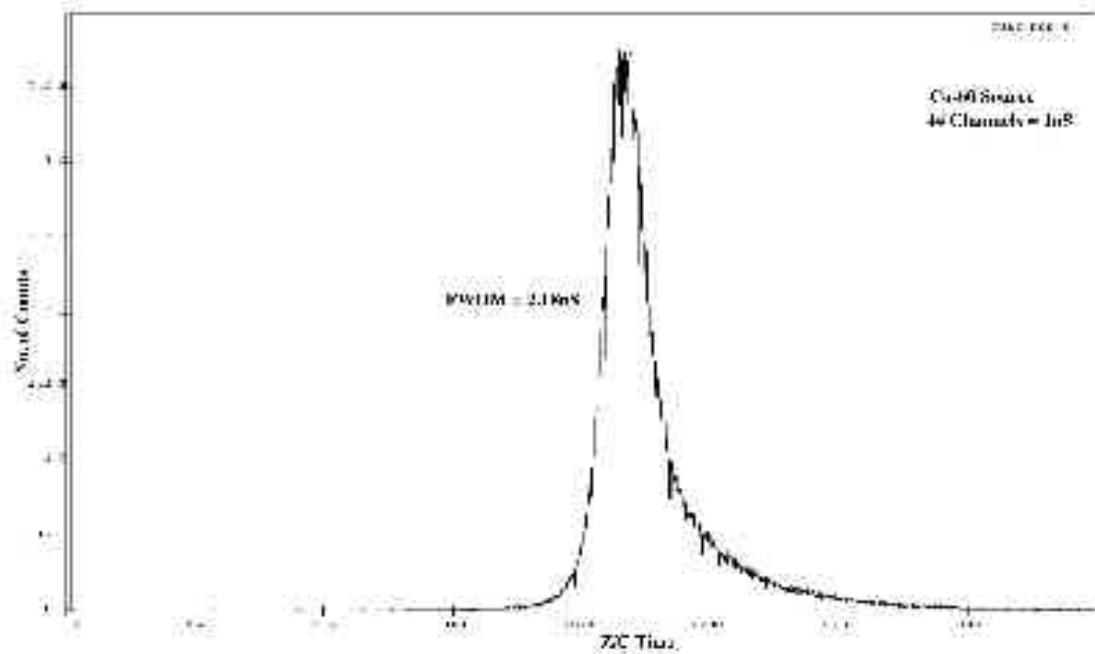


Fig: Energy Spectrum gated at 500KeVee along with TOF, PSD-Z/C Spectrum s to highlight the separation of neutron and gamma peaks.

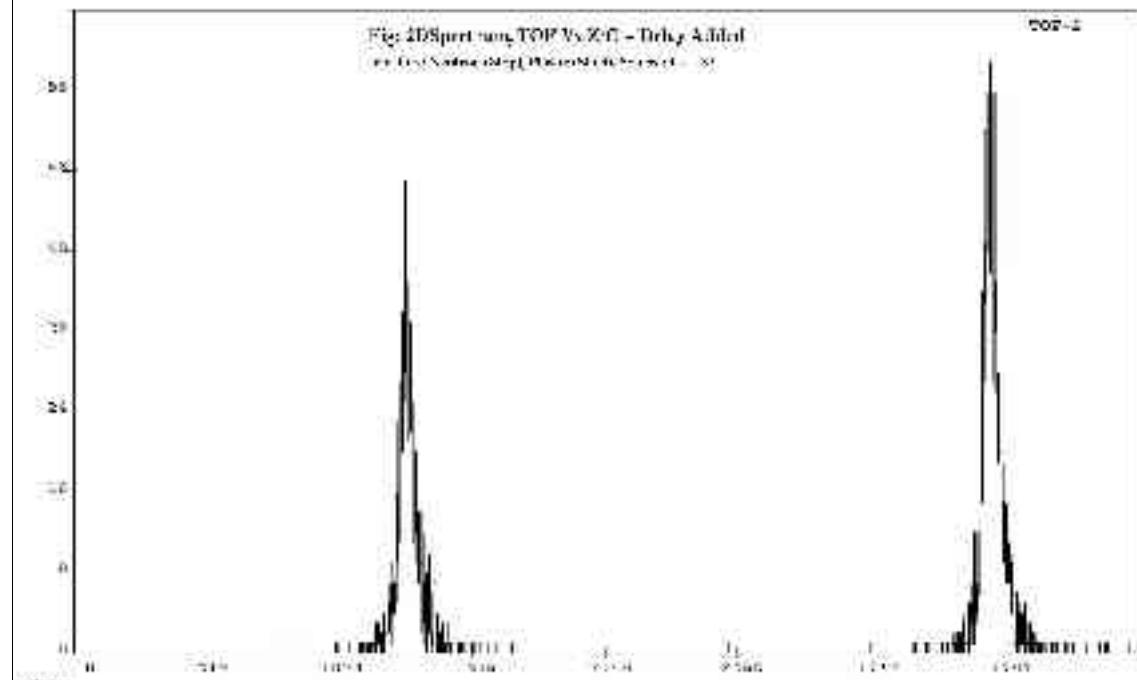
Fig: Time of Flight Vs PSD performance with Source: Co-60, Delay Introduced 50nS



TOF Resolution : 1.2nS, PSD Z/C Resolution for Gamma peak : 2.18nS



PSD_NAND@IUAC_2K6



Conditions: Neutron Detector with and without Shield at 45cm, LLTH: 13KeVee

Source: Cf-252 (Strong).

Performance:

FOM: 1.39, **TOF:** 1.25 nS **With Shield**

FOM: 1.28 **TOF:** 1.50 nS **Without Shield**

Observation: 8% Improvement in both results noticed due to shielding of Neutron detector with Lead Sheet.

Conditions: The PSD and TOF performance at high count rate at 4 Kcps,

LLTH: 13KeVee, Source: Cf-252 (Strong), Poor Statistics.

FOM: 1.31 **TOF:** 1.82 nS

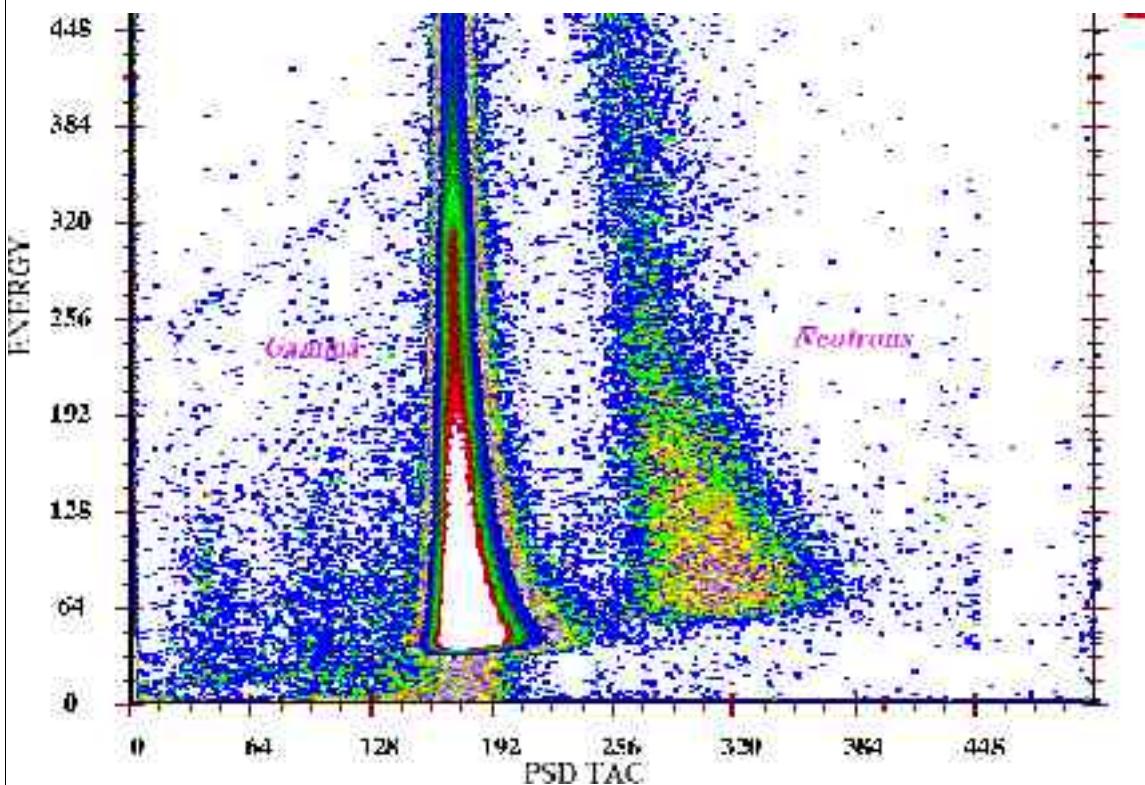


Fig: PSD Z/c Vs Energy from inbeam experiment with NAND at IUAC

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1. National Array of Neutron Detectors at NSC, International Conference on “Nuclear Structures at Extremes New Directions”, held at Shimla, India, March 2005.
2. Technical Report on Shaping Amplifier for Neutron Array at IUAC, by Arti Gupta, S.Venkataramanan, Ranjan Bhowmik (to be submitted)
3. Technical Report on TFA + CFDiscriminator by S.Venkataramanan, R.K.Bhowmik NSC/TR/SV/2002-03/27
4. Pulse Shape Discrimination, Suvendu Ghosh, SINP, Kolkatta.
5. Technical Report on “TIME TO ANALOGUE CONVERTER” for Neutron Array at IUAC, by S.Venkataramanan, Arti Gupta, Ranjan Bhowmik (Submitted)
6. Fabrication of Pulse Shape Discrimination Module for Neutron-Gamma Separation by Rakesh kumar et al. in Vol:34, #4, Journal of the Instrument Society of India.
7. The EURO BALL neutron wall-design and performance tests of neutron detectors, O.Skeppstedt et al., NIM -A 421 (1999) 531-541

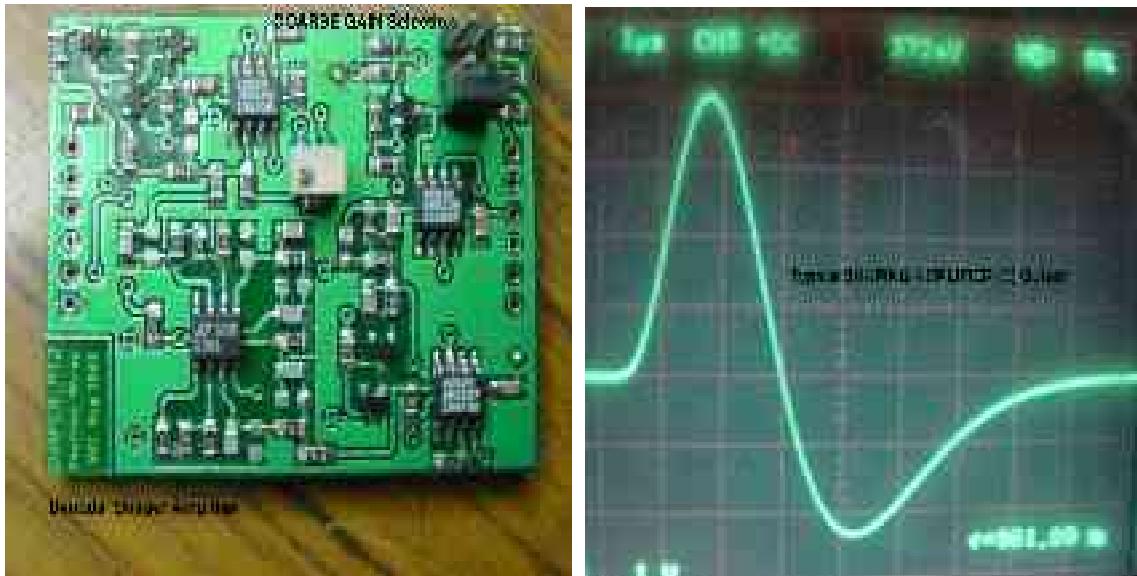
Fig: Front & rear Panel of PSD Electronics Module for NAND





PSD_NAND@IUAC_2K6

Fig: Shaping Amplifier and Typical Pulse shape with Pulser.

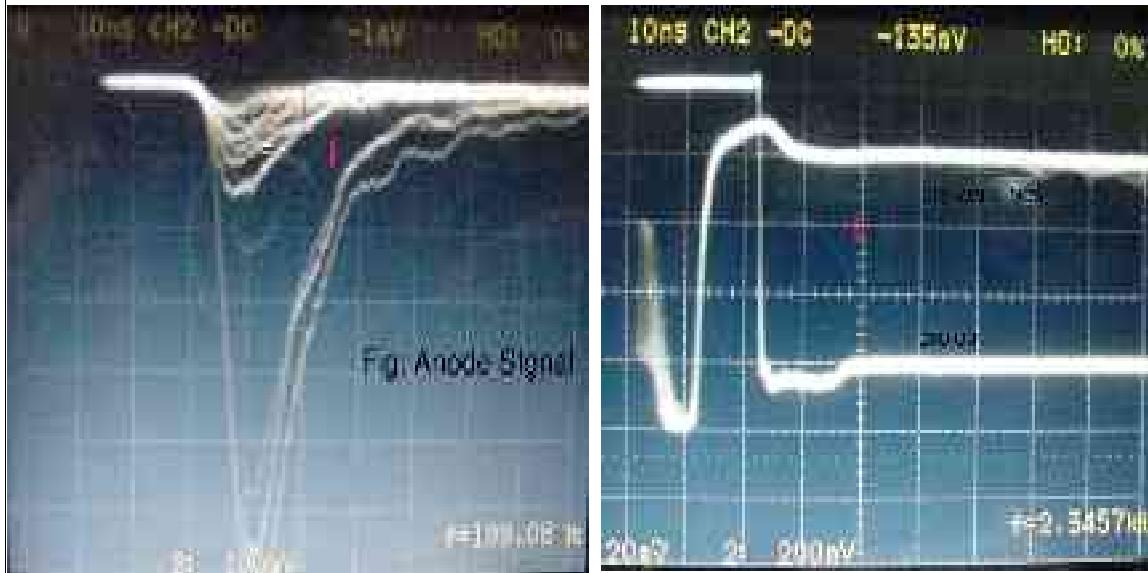


Figs. Actual Dynode Signal* and Energy Output of Shaping Amplifier

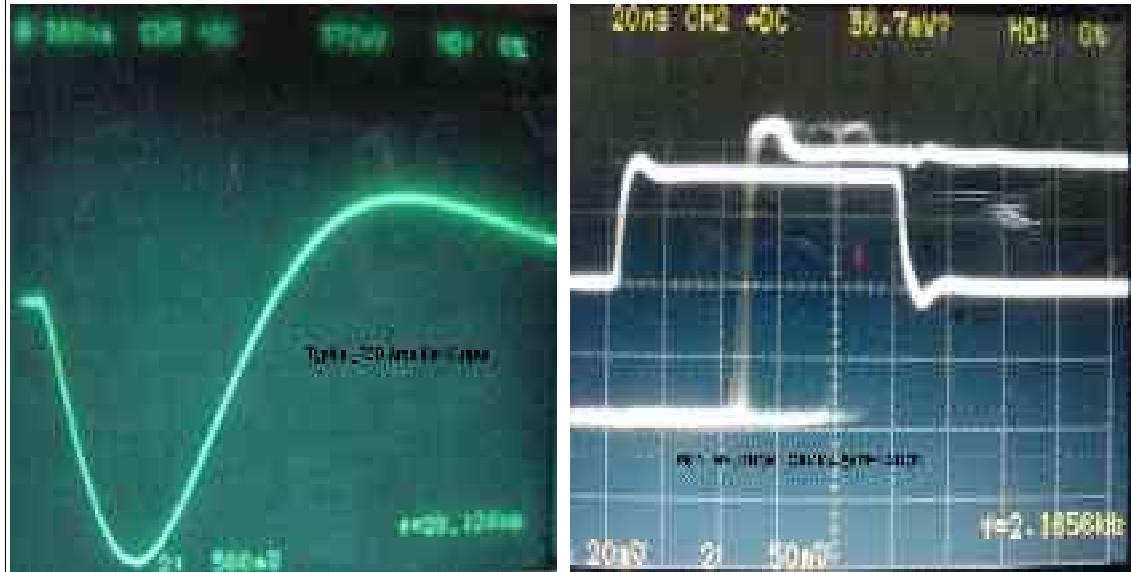


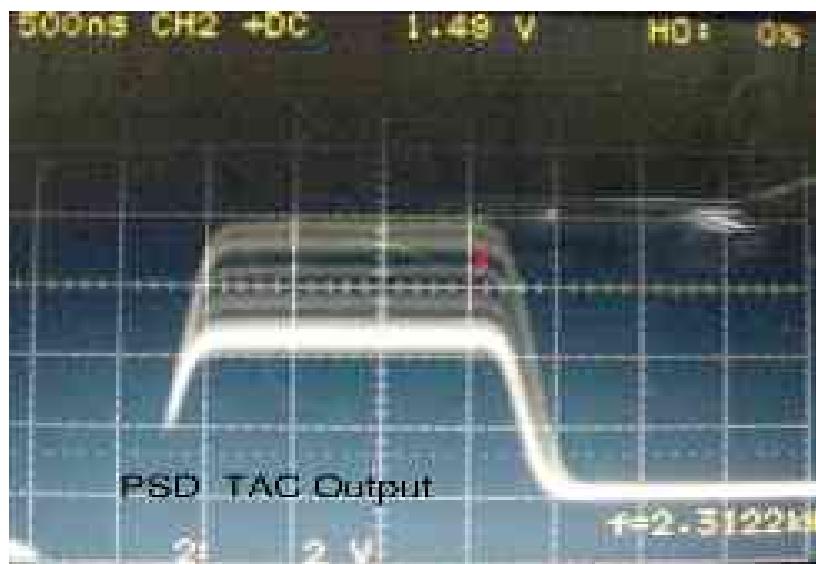
* Terminated Preamplifier output across 50 ohms.

Figs: Actual Anode Signal, CFD out, WALK_MON



Figs. Typical PSD Amplifier Output with Pulser and actual PSD Z/C_MON & STROBE_MON





Figs: Actual TAC output of a PSD Modules and TAC Daughter card.

PSD_NATIONAL ARRAY OF NEUTRON DETECTORS @ IUAC**Revised: Thursday, April 13, 2006****Revision: PT-3, APRIL 2006****INTER UNIVERSITY ACCELERATOR CENTRE****PB:10502****ARUNA ASAF ALI MARG****NEW DELHI, INDIA****Bill Of Materials**

May 29, 2006

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Item	Qty	Ref	Part	COST USD	Total
1	77	C1,C2,C3,C4,C5,C6,C7,C8, C10,C11,C12,C13,C17,C18, C19,C20,C21,C22,C23,C24, C26,C27,C28,C29,C34,C35, C36,C37,C42,C45,C46,C48, C49,C58,C63,C64,C77,C78, C81,C82,C83,C92,C93,C108, C109,C110,C111,C112,C115, C116,C118,C119,C126,C127, C129,C131,C132,C143,C147, C148,C161,C162,C165,C166, C167,C176,C177,C193,C194, C195,C196,C199,C210,C211, C213,C215,C217	0.1uF	.1	
2	12	C9,C14,C15,C16,C25,C30, C31,C32,C33,C38,C39,C40	10uF	.2	
3	22	C41,C43,C44,C47,C57,C60, C102,C103,C114,C117,C128, C130,C133,C137,C142,C186, C188,C200,C201,C212,C214,C216	2.2uF	.2	
4	78	C50,C51,C52,C53,C54,C55, C56,C59,C65,C66,C67,C68, C69,C70,C71,C72,C73,C74, C84,C85,C86,C87,C88,C89, C90,C100,C101,C104,C105, C106,C107,C113,C120,C121, C122,C123,C124,C125,C134, C135,C136,C138,C139,C140, C141,C144,C149,C150,C151, C152,C153,C154,C155,C156, C157,C158,C168,C169,C170, C171,C172,C173,C174,C184, C185,C187,C189,C190,C191, C192,C197,C198,C204,C205, C206,C207,C208,C209	10nF	.1	
5	8 (10)	C61,C79,C98,C99,C145, C163,C182,C183	330pF	.1	
6	4	C62,C76,C146,C160	10pF	.1	
7	2	C75,C159	800pF (330pF+470pF)	.2	
8	2 (4)	C80,C164	470pF	.1	
9	2	C91,C175	100pF	.1	
10	4 (6)	C94,C95,C178,C179	47pF	.1	
11	4	C96,C97,C180,C181	33pF	.1	
12	0	C202,C203	220nF	.1	
13	2+2	D1,D2,D3,D4	D1N4007, 6A4	.1	
14	1	D5	YELLOW(1210)	.1	

Item	Qty	Ref	Part	COST USD	Total
15	14	D6, D7, D8, D9, D10, D11, D12, D15, D16, D17, D18, D19, D20, D21	BAV70	.1	
16	2	D13, D22	BAT54S/PLP	.1	
17	2	D14, D23	BAV99	.1	
18	14	J1, J2, J3, J4, J5, J6, J7, J8, J22, J29, J30, J56, J63, J64	CON1		
19	64	J9, J10, J11, J13, J14, J15, J16, J17, J18, J19, J20, J21, J24, J25, J26, J27, J28, J31, J32, J33, J34, J35, J36, J37, J38, J39, J40, J41, J42, J43, J44, J45, J47, J48, J49, J50, J51, J52, J53, J54, J55, J58, J59, J60, J61, J62, J65, J66, J67, J68, J69, J70, J71, J72, J73, J74, J75, J76, J77, J78, J79, J80, J84, J85	CON2		
20	2	J12, J46	CON4A		
21	2	J23, J57	JUMPER_1	.2	
22	3	J81, J82, J83	CON4A_0	.2	
23	20	L1, L2, L3, L4, L6, L7, L8, L9, L10, L11, L12, L13, L15, L16, L17, L18, L19, L20, L21, L22	10uH	.3	
24	2 (6)	L5, L14	47uH	.3	
25	1	Q1	BD680A	1.0	
26	1	Q2	QMMBT3906	.1	
27	20	Q3, Q4, Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12, Q13, Q14, Q15, Q16, Q17, Q18, Q19, Q20, Q21, Q22	BFR92A/PLP	.2	
28	17	R1, R52, R75, R85, R124, R125, R127, R138, R143, R191, R214, R224, R263, R264, R266, R275, R282	1k	.1	
29	1	R2	750	.1	
30	15	R3, R47, R48, R62, R76, R93, R94, R109, R186, R187, R201, R215, R232, R233, R248	3.32K	.1	
31	17	R4, R28, R46, R60, R74, R92, R105, R108, R118, R167, R185, R199, R213, R231, R244, R247, R257	220	.1	
32	26	R5, R30, R31, R32, R33, R36, R64, R67, R82, R83, R95, R96, R113, R114, R169, R170, R171, R172, R175, R203, R221, R222, R234, R235, R252, R255	110	.1	
33	1	R6	330	.1	
34	2	R7, R146	4.7	.1	
35	18	R8, R16, R21, R25, R27, R88, R99, R100, R102, R147, R155, R160, R164, R166, R227, R238, R240, R241	47.5	.1	
36	22	R9, R44, R45, R58, R59, R72, R73, R106, R107, R115, R116, R149, R183, R184, R197, R198, R211, R212, R245, R246, R251, R253	51	.1	
37	6	R10, R11, R12, R148, R150, R151	16.6	.1	

Item	Qty	Ref	Part	COST USD	Total
38	4	R13, R142, R152, R281	0	.1	
39	16	R14, R22, R23, R90, R101, R103, R123, R141, R153, R161, R162, R229, R239, R242, R262, R280	332	.1	
40	2	R15, R154	68	.1	
41	6	R17, R86, R98, R156, R225, R237	475	.1	
42	4	R18, R130, R157, R269	100	.1	
43	2	R19, R158	15	.1	
44	63	R20, R26, R29, R37, R38, R40, R41, R50, R51, R54, R55, R61, R63, R65, R66, R68, R69, R77, R78, R80, R81, R84, R87, R97, R104, R111, R112, R117, R131, R134, R136, R159, R165, R168, R176, R177, R179, R180, R189, R190, R193, R194, R200, R202, R204, R205, R207, R208, R216, R217, R219, R220, R223, R226, R236, R243, R250, R254, R256, R271, R272, R274, R277	2K	.1	
45	6	R24, R122, R140, R163, R261, R279	4.75K	.1	
46	25	R34, R35, R39, R42, R43, R49, R53, R56, R57, R70, R71, R79, R173, R174, R178, R181, R182, R188, R192, R195, R196, R206, R209, R210, R218	511	.1	
47	2	R89, R228	680	.1	
48	11	R91, R128, R129, R132, R133, R137, R230, R267, R268, R273, R276	10K	2.0	
49	2	R110, R249	10	.1	
50	8	R119, R120, R121, R135, R258, R259, R260, R270	1.5K	.1	
51	2	R126, R265	8.25K	.1	
52	2	R139, R278	1.3K	.1	
53	2	R144, R283	22	.1	
54	2	R145, R284	75	.1	
55	1	SH1	SCREEN_8500	5	
56	6	TP1, TP2, TP3, TP4, TP5, TP6	TEST POINT		
57	2	TP7, TP8	TEMP		
58	2	U1, U19	SP3_5_50	5	
59	4	U2, U11, U20, U31	AD96687BQ	10	
60	4	U3, U14, U21, U32	MC10EL05D	6	
61	14	U4, U5, U6, U7, U8, U9, U10, U22, U23, U24, U25, U26, U27, U28	MC10198P	10	
62	4	U12, U13, U29, U30	AD829/AD	5	
63	2	U15, U33	LT1361/LT	5	
64	2	U16, U34	ADR03/SO	5	
65	2	U17, U35	TAC_PT2	500	
66	2	U18, U36	SHAPER_NEUTRON	200	
67	1	PCB NIM SIZE	PSDPT3	10	
68	16	LEMO_00 + EARTH CAP		6	
69	3M	COAXIAL CABLE	RG178	2	
70	3M	CONTROL WIRE	RG192	2	

Item	Qty	Ref	Part	COST	Total
				USD	
71	1	PUNCHED + SCREEN PRINT CABINET WITH CONNECTOR MECHTRONICS -	101, 10	130	
72	10	PLASTIC HOOD	BOURNNS/SPECTROL		
73	AS REQUIRED	HEATSINK KIT, TEFLON WIRE, 4 Nos. 4/32 SCREWS X 4, T-12 TORROIDS	100		68000
74		OVERHEAD		500	32000
			TOTAL		1,00,000