

# TECHNICAL REPORT

<b>TITLE</b>	<b>: Technical Report on Shaping Amplifier for Neutron Detector Array</b>
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<b>CATEGORY</b>	<b>: Instrumentation</b>
<b>REFERENCE NO</b>	<b>: NSC/TR/AG/2006-07/</b>

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# **Technical Report on Shaping Amplifier for Neutron Detector Array**

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# Technical Report on Shaping Amplifier for Neutron Detector Array

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## **Abstract**

As a part of the on going nuclear electronics development activities for Neutron Detector Array at IUAC, we have developed a high density Spectroscopy amplifier. It is designed with fixed Pole-zero correction, 1 $\mu$ s shaping time constant and gain ranging from  $\sim$  0.25 to 10. It accepts negative pulses from the preamplifier and gives bipolar output. Linearity of the amplifier is compared with ORTEC 572 amplifier using Canberra Pulser (model 8210). The principle of operation of various circuit blocks are explained in this report along with representative test point signals which will be very useful for troubleshooting. The amplifier specifications and test results are also given.

## **Acknowledgment**

We would like to thank Dr R.K. Bhowmik of IUAC for evaluating the performance of the amplifier. We also would like to thank Apprentice trainees participated during assembling. Our sincere thanks to Dr. Amit Roy, and B.P. Ajith Kumar, for their constant encouragement and providing necessary infrastructure in order to complete this project successfully.

## **Specifications: Shaping Amplifier for Neutron Detector Array**

Input impedance	: $\sim 1\text{k}\Omega$
Input Signal and Signal range	: -ve pulses with decay time $\sim 50\mu\text{s}$ , $\pm 1\text{V}$
Output impedance	: $10\Omega$
Output Signal and Signal range	: Bipolar, $\pm 10\text{V}$ Active filter shaped
FWHM	: 2.09keV (122keV), 5.3keV (1408 keV) of $^{152}\text{Eu}$
Gain	: $\sim 10$ , Inverting type
Fine Gain	: $\sim \times 0.025$ to $\times 1$ (Front Panel Potentiometer)
Input attenuator	: $\times 0.4$ , $\times 0.7$ and $\times 1$ (On-board Jumpers)
Pole/Zero	: Fixed for input pulse with decay time $\sim 50\mu\text{s}$
Shaping time & type	: $1\mu\text{s}$ Fixed
Power required	: $\pm 6\text{V}$ , $\pm 20\text{mA}$ : $\pm 12\text{V}$ , $\pm 45\text{mA}$
Size (W x H x L)	: 1.5" x 0.6" x 1.9"

## **Introduction**

A Shaping amplifier with fixed pole-zero correction and 1 $\mu$ s shaping time constant has been developed for Neutron Detector Array at IUAC and is being used as a daughter card of “Pulse Shape Discriminator Electronics Module”. It essentially consists of input attenuator, fine gain control, differentiation stage with Pole-Zero (P/Z) compensation, gain stages, active shaping followed by 2<sup>nd</sup> differentiation stage for bipolar output and output amplifier. Three on-board jumpers have been provided to select the attenuation factor i.e. x1, x0.7 and 0.4. Amplifier Gain can be adjusted by front panel potentiometer in the range of ~ 0.25 to 10. The output Bipolar output was chosen for convenience in zero crossover timing applications. A block diagram has been attached for quick reference.

The amplifier is assembled as a daughter card of “Pulse Shape Discriminator Electronics Module” on a double sided glass epoxy PCB with surface mount components to achieve the required high density.

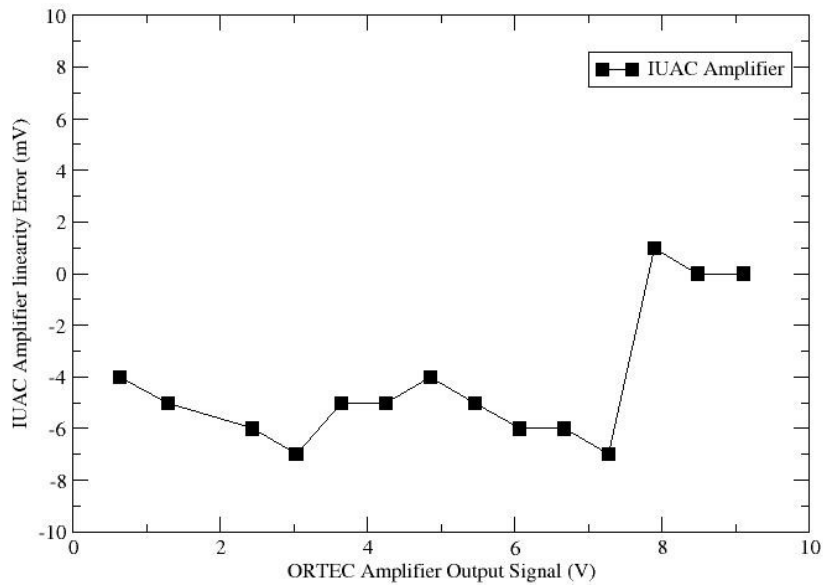
## **Principle of Operation**

The amplitude of the pulses from Neutron detector preamplifier range from few 100mV to 5.5V with decay time of 50 $\mu$ S. To handle such a large signal we have put 3 stage on-board jumper selectable attenuator network. This is followed by four quadrant analog multiplier U3 (AD835) which is being used to control the fine gain of the amplifier from 0.025 to 1. AD835 inputs are rated for +/- 1V maximum so a protection circuit is added at its input to prevent voltage excursions greater than 1V in magnitude. The early differentiation is done with passive RC components for 1 $\mu$ S (C5, R14). The Pole-Zero(P/Z) correction is done with (R10, C5).

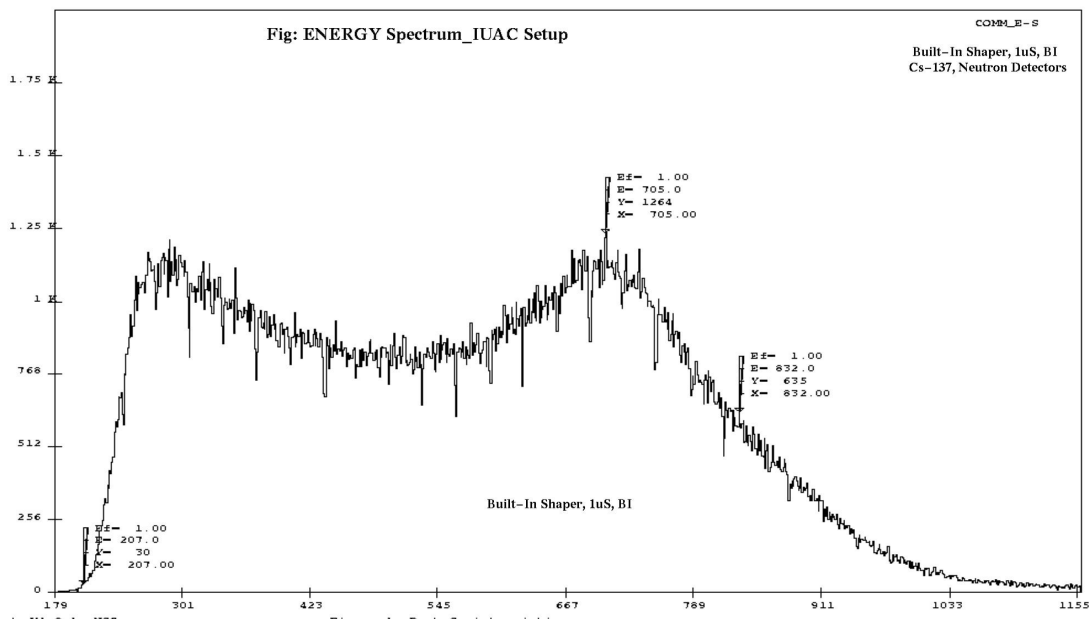
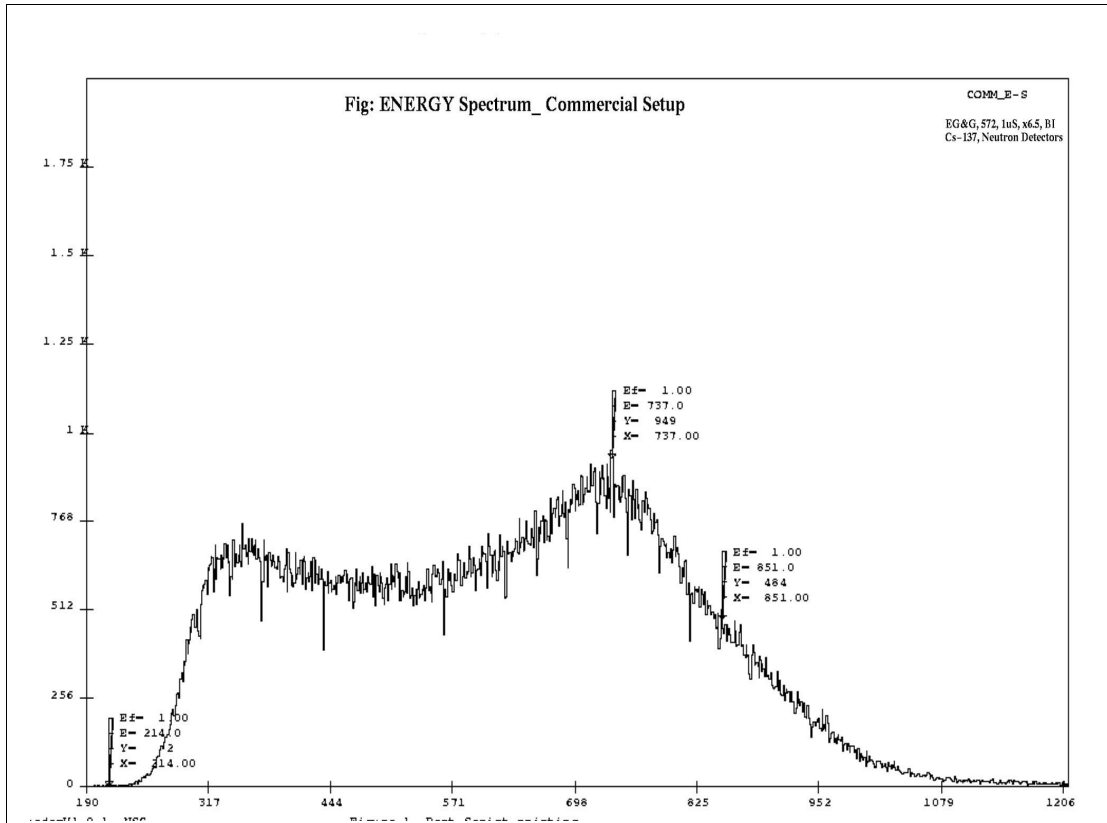
The differentiated pulse is amplified with low noise high quality operational amplifier (U2). This stage is wired with clamping circuit in feedback path to speedup overload recovery. The amplified pulses are shaped with, 2 stages of 2<sup>nd</sup> order active integration (U1 A&B) and one stage of differentiation (C19, R31), where RC components are chosen for required shaping time constant of 1 $\mu$ S, to get bipolar output. This is further followed by an output amplifier stage in closed loop with push-pull buffer to improve the current driving capability of the amplifier.

## **Test Result**

As a preliminary test, linearity of the IUAC amplifier is compared with ORTEC 572 amplifier using Canberra Pulser model 8210. Linearity graph (FIG.1) have been attached for reference. Later on it was tested with liquid scintillator (BC 501). Testing has been carried out with different  $\gamma$ -sources to ensure the linearity of the amplifier. FIG.2 shows a typical energy spectrum obtained with  $^{137}\text{Cs}$  neutron source. The gain of the amplifier is adjusted in such a way that the neutron energy region of our interest would fall well within the dynamic range of the amplifier.



**FIG 1: Linearity error of IUAC amplifier w.r.t. ORTEC 572 amplifier at specified output voltages using Canberra Pulser Model 8210.**



**FIG 2. Energy Calibration:**

Commercial: Ortec 572 amplifier, Bi Out, 1uS, (X6.5), Source: Cs137 (662 keV)

IUAC: Bi-Out, 1uS, Coarse Middle

Calibration: **0.57 keV/channel**

## **Troubleshooting Procedure**

1. Ensure that +/-12V and +/-6V supplies are not grounded anywhere on the PCB.
2. Insert the card in the respective slot on the mother board.
3. Provide power connections to the module. Confirm that +/-12V and +/-6V are reaching the board.
4. Refer the Shaper schematic diagram showing dc conditions of the circuit to check dc voltages at various points in the circuit. (Annexure 1.1)
5. Apply negative input signal to DYNODE input on the back panel of the PSD module using BNC pulser model DB-2 ( $V_{in} = -1V$ ,  $T_r = 100nS$ ,  $T_d = 50uS$ ).
6. Follow the schematic diagram with waveform representation to check signals at various points in the circuit. (Annexure 1.2)

## **Assembly Procedure**

The currently (Shaper\_PT2/Aug-2005) available PCB is of glass epoxy, double sided with 0.6mm drill PTH having dimension of 1.5" x 1.9" with all above features.

It is recommended to have solder mask and silk screen printed on both sides for easy assembly as well to protect it from solder bridges etc. Use of 0.8mm sharp solder tip, IC solder tips are recommended in order to solder narrowly spaced SMT devices. SMT devices shall be picked only by fine quality tweezers. While soldering a magnifier x5 (large) and x12 (eye piece) is used to assure the soldering. It is essential to use solder cleaning liquid with cotton swab to remove dust attracting solder paste.

The PCB shall be checked with magnifiers and multimeter for any unwanted connections and PTHs. Then components shall be soldered in a orderly manner, to start with all low profile chip resistors and capacitors. It is essential to check the impedance between various nodes after soldering resistors, capacitors and inductors. Active components like diodes, transistors and ICS are soldered thereafter. At last tantalum capacitors, connectors, jumpers and any non-SMT devices. All PCBs shall be marked distinctly with unique number for any future references.

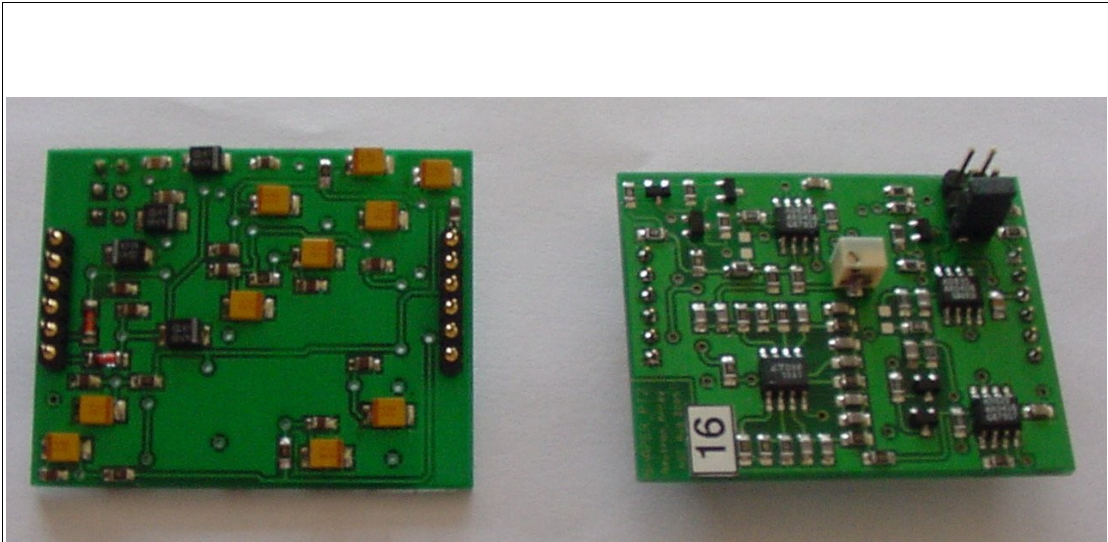


## **Conclusion**

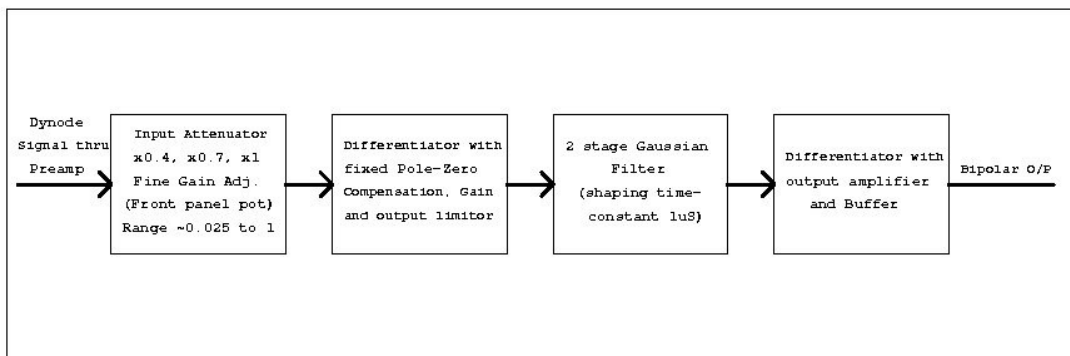
A high density Shaping amplifier is successfully developed, tested and used with Neutron detector array setup at IUAC.

## **References**

1. Technical Report on Spectroscopy Amplifier by S. Venkataramanan, Arti Gupta (NSC/TR/SV/2002-03/29)
2. EG&G ORTEC 572 Spectroscopy Amplifier Operating and Service Manual.



**Shaper PCB Bottom & TOP side photographs**

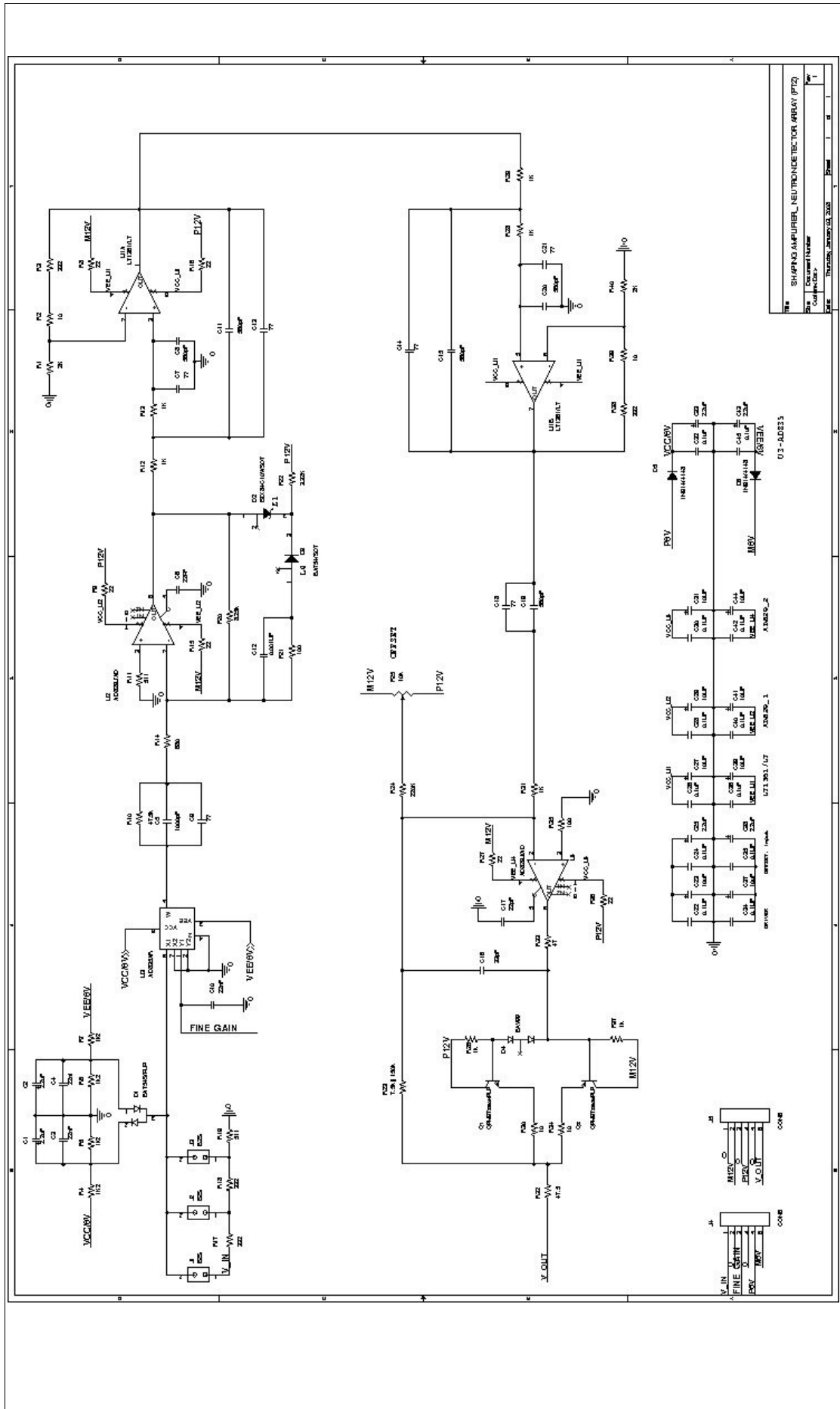


**Block Diagram of Neutron Detector Shaping amplifier**

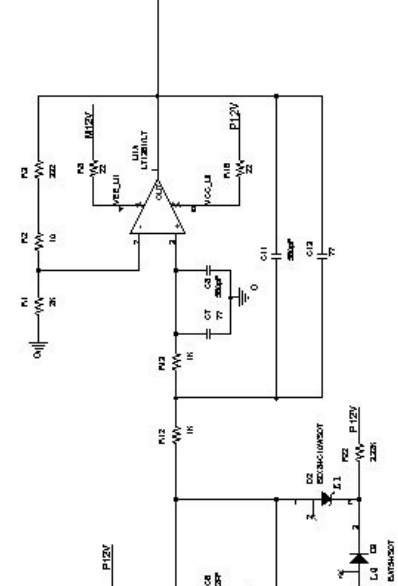
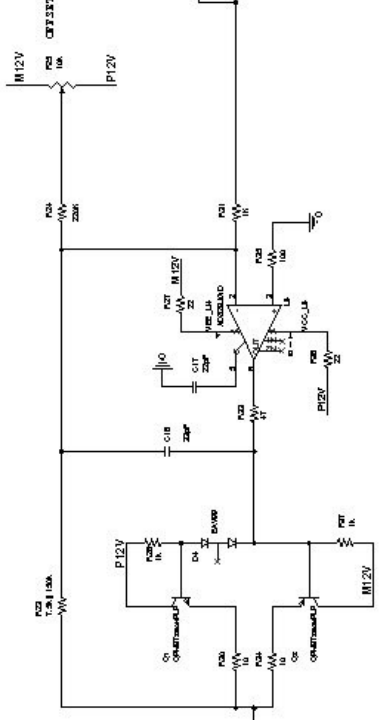
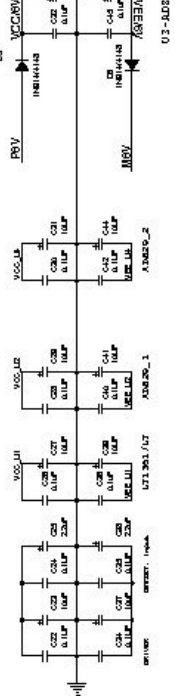
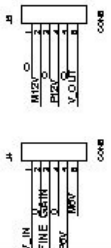
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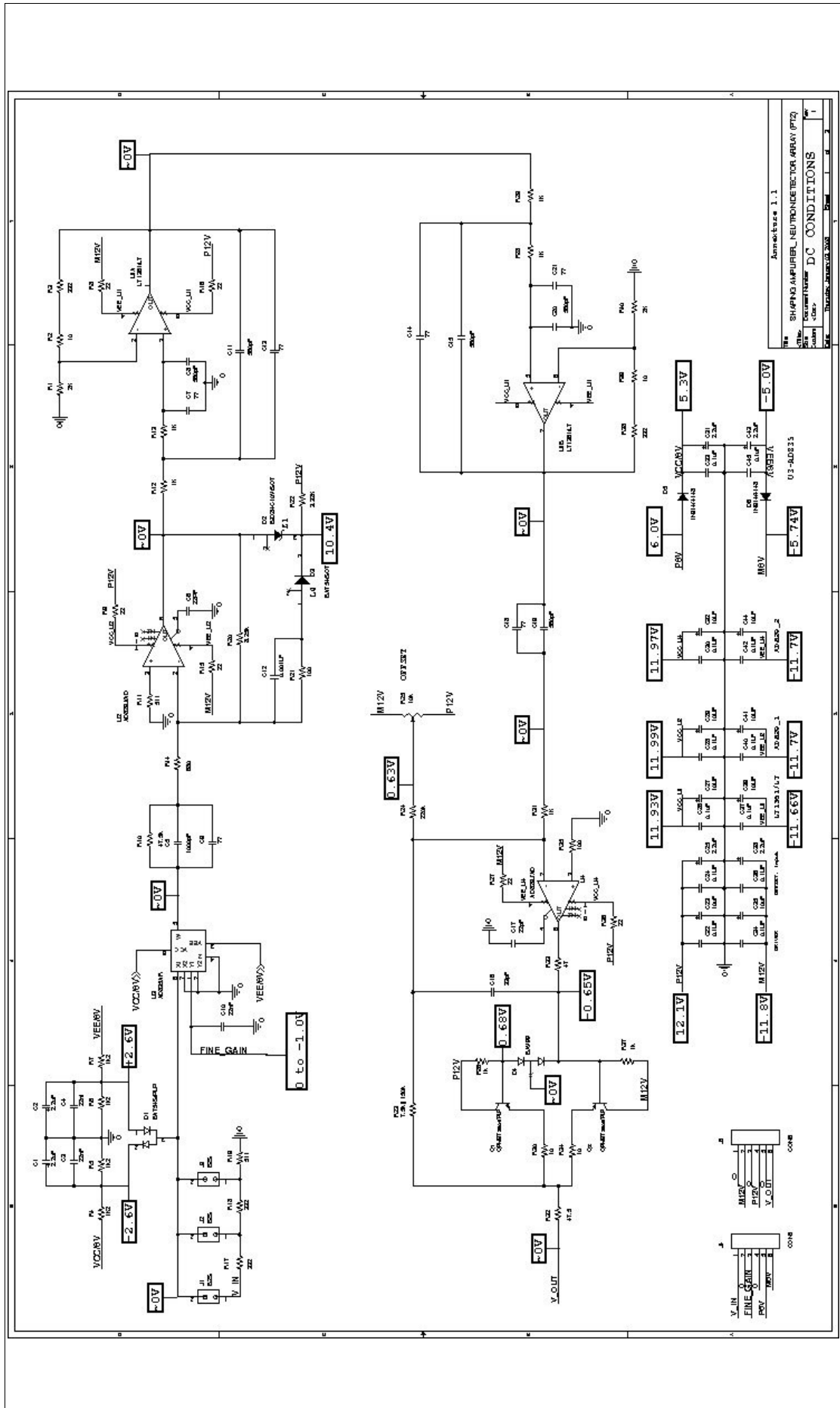
Bill Of Materials January 3,2008 8:33:02 Page1

Item	Quantity	Reference	Part
1	6	C1,C2,C25,C33,C38,C43	2.2uF
2	3	C3,C4,C10	22nF
3	1	C5	1000pF
4	2	C6,C17	22pF
5	6	C7,C9,C13,C14,C18,C21	??
6	5	C8,C11,C15,C19,C20	560pF
7	1	C12	0.001UF
8	1	C16	33pF
9	12	C22,C24,C26,C28,C30,C32, C34,C35,C36,C40,C42,C45	0.1uF
10	8	C23,C27,C29,C31,C37,C39, C41,C44	10UF
11	1	D1	BAT54S/PLP
12	1	D2	BZX84C10V/SOT
13	1	D3	BAT54/SOT
14	1	D4	BAV99
15	2	D5,D6	1N914/4148
16	3	J1,J2,J3	B2S
17	2	J4,J5	CON6
18	1	Q1	QPMBT3904/PLP
19	1	Q2	QPMBT3906/PLP
20	2	R1,R40	2K
21	4	R2,R30,R34,R39	10
22	4	R3,R17,R18,R38	332
23	4	R4,R5,R6,R7	1k2
24	6	R8,R9,R15,R16,R27,R36	22
25	1	R10	47.5k
26	2	R11,R19	511
27	7	R12,R13,R26,R28,R29,R31, R37	1K
28	1	R14	680
29	1	R20	8.25k
30	2	R21,R35	100
31	1	R22	3.32K
32	1	R23	7.5k    150k
33	1	R24	220K
34	1	R25	10k
35	1	R32	47.5
36	1	R33	47
37	1	U1	LT1361/LT
38	2	U2,U4	AD829J/AD
39	1	U3	AD835AR

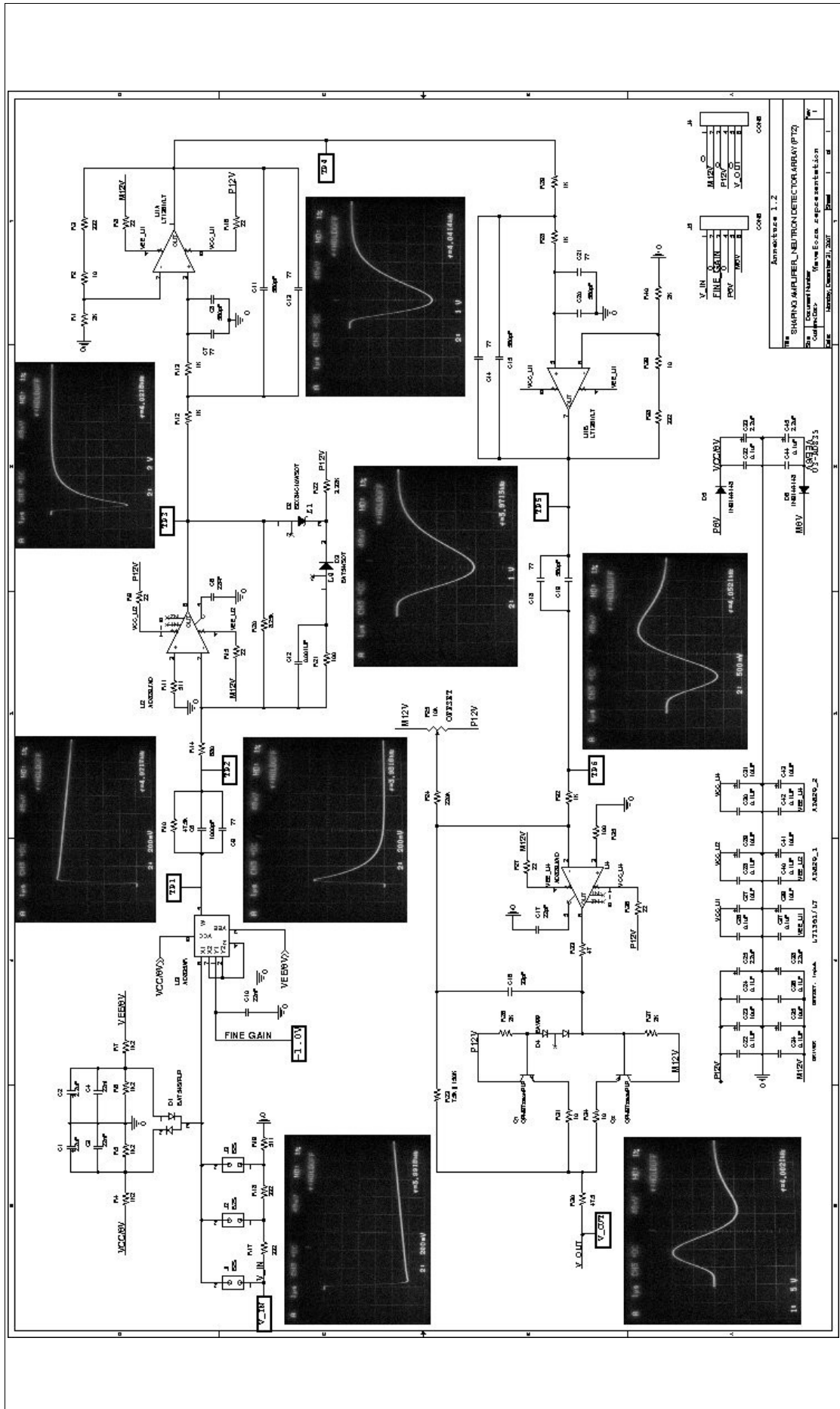


Title: SHARP NS-4019REBEL NEUTRON DETECTOR AREA (PTZ)  
 Design: [Blank]  
 Date: Thursday, January 03, 2008  
 Author: [Blank]





Annexa 1.1  
 Titlu: SHAPAS APURBEL NEUTRONECTOR 4R6X (P12)  
 Data: 1992  
 Autor: [blank]  
 Clasa: [blank]  
 Data: [blank]



Annexure 1.2  
 THE SHARPNR AMPLIFIER WITH FEEDBACK DETECTOR ARB04 (PT2)  
 Date: \_\_\_\_\_  
 Component Name: Eoem Representation  
 Class: \_\_\_\_\_  
 Roll No: \_\_\_\_\_

