THE ANDRZEJ SOLTAN INSTITUTE
FOR NUCLEAR STUDIES

EUROBALL
NEUTRON DETECTORS ELECTRONICS

"BARTEK" NDE 202

Świerk 2001

CONTENTS

1. INTRODUCTION

The EUROBALL Neutron Detectors Electronics NDE 202 is a dedicated electronics module designed for the neutron wall.

It is well established that one of the most effective method of fast neutron detection is the use of NE213 or BC501A liquid scintillator cells coupled to a photomultiplier together with n-γ discriminator based on zero-crossing techniques (Z/C) [1-4]. The n-γ discrimination method is utilizing a difference in the intensity of the slow component of the light pulse in organic scintillator generated by recoil protons and electrons. Taking into account that the intensity of the slow component is of order of 20% of the total light [5] produced by recoil proton and that the decay time constants of the slow component are within several hundred nanosecond this method needs a precise electronics circuit to distinguish a difference in the light pulse shape.

A complementary technique for n-γ separation is a measurement of time-of-flight (TOF). Difference in the velocity of neutrons and γ-rays can be utilized when a precise time reference signal is in the experimental system. The best observation of the quality of n-γ discrimination and time-of-flight is achieved measuring 2D spectra versus energy. Thus a good signal proportional to the total charge of anode signal is of importance.

The module NDE 202 allows getting the zero-crossing spectrum, time-of-flight spectrum and energy spectrum of neutrons and γ-rays detected in the neutron detector. It produces, at the output, linear signals from Time-to-Amplitude Converters (TAC) corresponding to zero-crossing time distribution and time-of-flight spectrum, as well as, the linear signal from Charge-to-Voltage Converter (QVC) corresponding to the energy spectrum of detected neutrons and γ-rays. Moreover, numerous logic signals, as Constant Fraction Discriminator (CFD) output, Z/C discriminator output and logic signals corresponding to γ and neutron events.

The NDE 202 module consists of two channels for two separate neutron detectors.

2. SPECIFICATION

2.1. Performances

Measured quantities:	Zero-crossing time distribution Time-of-flight spectrum in relation to the external signal, Charge of PMT anode signal.
n-γ discrimination	Logic signals corresponding to γ and neutron events
Timing signal of neutron Detector	Output of Constant Fraction Discriminator
N and γ multiplicity	n and γ current pulses to be connected in the daisy chain

2.2. Controls

CFD threshold	20 mV – 2 V, Screwdriver precision potentiometer, common for two channels
SD – selection delay:	Screwdriver precision potentiometer to control selection of neutron and γ logic pulses
G width (γ width):	40 – 350 ns, by screwdriver precision potentiometer, common for two channels,
N width (neutron width)	40 – 350 ns, by screwdriver precision potentiometer, common for two channels
TAC & QVC width:	0.6 – 1.5 μs, width of linear output signals, adjusted by screwdriver precision potentiometer, common for two channels,
Z/C stop signal	Toggle switch at the rear panel: CFD or Tref.

2.3. Inputs

IN (Linear input):	Negative current pulse from PMT anode, ≤ 5 V at 50 Ω, input impedance = 50 Ω
TREF (Time reference):	Fast NIM, input impedance = 50 Ω

2.4. Outputs

Z/C TAC	Linear, rectangular signal, 0 – 10 V, or 0 – 5 V at 50 Ω, width 0.6 – 1.5 μs, output impedance = 50 Ω
CFD TAC (TOF TAC)	Linear, rectangular signal, 0 – 10 V, or 0 – 5 V at 50 Ω, width 0.6 – 1.5 μs, output impedance = 50 Ω
QVC	Linear, rectangular signal, 0 – 10 V, or 0 – 5 V at 50 Ω, width 0.6 – 1.5 μs, output impedance = 50 Ω
AMP	Test signal of shaping amplifier, up to 0.4 V at 50 Ω, (30 x attenuation)
CFD	Output of CFD, fast NIM, width 40 ns
Z/C	Output of Z/C discriminator, fast NIM, width 40 ns
N (neutrons)	Fast NIM signal corresponding to neutron events, controlled by SD (selection delay) adjustment, width 40 – 350 ns,
G (γ - events)	Fast NIM signal corresponding to γ events, controlled by SD (selection delay) adjustment, width 40 – 350 ns,
N, G at the rear panel:	Two parallel outputs of current signals for neutron and γ-events, respectively, to be connected in daisy chain for measuring multiplicity, 1mA/hit (50 mV at 50 Ω), the width of the signals are the same as the logic n and γ signals (40 – 350 ns)

2.5. Power required

+ 6 V	190 mA
- 6 V	2.2 A
+ 24 V	120 mA
- 24 V	20 mA

3. GENERAL DESCRIPTION

The block scheme of one channel of the Neutron Detectors Electronics Module is presented in Fig. 1. The anode signal of PMT is sent to the passive splitter and then to constant fraction discriminator, shaping amplifier and via delay line to the half of charge-to-voltage converter. The threshold of CFD, controlled by the screwdriver potentiometer at the front panel, determines the sensitivity threshold of all the electronics circuits. Its output signal controls zero-crossing discriminator, selection delay and shaping circuit and produces gate for the QVC. The direct signal from CFD is sent to the front plate of the module.

The shaping amplifier produces the bipolar pulse with the shaping time constant of 200 ns. Output signal from the amplifier triggers Z/C discriminator. The attenuated output signal (x 30) is used as the test pulse at the front panel of the module. Z/C discriminator output signal starts TAC 1, which is stopped by the delayed CFD output or external TREF selected by the toggle switch at the rear panel. TAC 1 allows to measure Z/C time distribution spectrum and its output signal is sent to the front panel.

The n - γ selection circuit consist of Selection delay and shaping, γ selection and n selection circuits. It is controlled by the precision screwdriver potentiometer at the front panel. As a result, the logic signals corresponding to neutron and γ events are sent to the front panel. Moreover, the direct signal from Z/C discriminator is sent also to the front panel of the module.

Time-of-flight of neutrons and γ-rays is measured by TAC 2 circuit started by delayed CFD signal and stopped by the external reference signal, common for all the neutron detector channels.

The energy signal proportional to the charge of PMT anode pulse is produced in the QVC gated by the reshaped output pulse of CFD with the width of 300 ns.

All the three linear signals of rectangular shape, with the width adjustable at the front panel of the module, are ready to be analyzed by external ADCs. Moreover, a number of logic signals, as output of CFD, output of Z/C discriminator and signals corresponding to neutrons- and γ-events produced in the unit by n-γ selection circuit are extracted at the front panel.

The NDE 202 module allows adjusting, at the front panel, a threshold of CFD, n-γ selection circuit, a width of neutron and γ pulses and width of linear signals. The toggle switch at the rear panel is used to select stop signal of TAC 1, by internal CFD signal or external time reference signal.

Two channels of the electronics are built in a single NIM block.

Fig. 2 presents the timing diagram of signals in different points of NDE 202 module.

Fig. 3 presents the front panel of NDE 202 module.

Fig. 4 presents a detailed scheme of one channel.

4. INSTALLATION AND SETUP PROCEDURE

4.1. Connection to Power

The NDE 202 contains no internal power supply and must obtained the necessary DC operating power from the NIM bin and power supply in which it is installed for the operation. Some series of NIM bin and power supply have convenient test points on the power supply control panel to permit monitoring those DC levels. If any one or more of the levels indicates an overload, some of modules will need to be moved to another bin to achieve operation.

4.2. Connection to Photomultiplier Base

The anode signal from a photomultiplier (PMT) is sent directly to the input of the module. For the best performance of the NDE 202, the output signal from PMT should correspond to 0.5 V at 50 Ω for γ-rays from a ^{137}Cs source or 1 V for γ-rays from a ^{60}Co source seen at a fast scope (bandwidth ≥ 300 MHz). A similar test at the AMP OUT testing output should show 50 mV or 100 mV for γ-rays from a ^{137}Cs or ^{60}Co sources, respectively. It allows getting a good n-γ discrimination up to about 4-5 MeV of recoil electrons energy.

4.3. Adjustment of CFD threshold

To adjust the CFD threshold connect the signal from the test output of the Shaping Amplifier (AMP) to the scope triggered by CFD output signal. A 100 mV signal corresponds to about 1 MeV energy of recoil electrons. Adjust CFD threshold to observe signals larger then 5 mV (50 keV) to 10 mV (100 keV).

4.4. n-γ discrimination spectrum, adjustment of n-γ selection delay

To check a quality of n-γ discrimination send the output signal of Z/C TAC to a multichannel analyzer (MCA). Observed well-resolved neutron- and γ-peaks, see Fig. 5. Note that the quality of discrimination depends on neutron detectors. Use coincidence gate at ADC triggered by neutron (N) or γ (G) signals. Turning the potentiometer of selection delay (SD) adjust separation to observe neutron or γ-events at MCA, respectively.

4.5. Time-of-flight spectra

Connect timing signal from CFD triggered by the reference detector to the time reference (TREF) input of NDE 202. Send output signal of CFD TAC to multichannel analyzer. For ^{60}Co γ-rays, a single peak with FWHM of about 1-2 ns is seen. The same spectrum measured with Am-Be source will show well-defined γ-peak and a continuous distribution of neutrons shifted earlier in time in relation to the γ-peak. Note that at the beginning of time range single events are observed. TAC circuit used in the unit produces them, when only start signal without stop is sent to TAC.

4.6. Energy spectra

To observe energy spectrum of γ-rays and neutrons detected in the neutron detector the output signal of QVC has to be sent to a multichannel analyzer. Note that a lower energy threshold depends on CFD threshold adjusted in the module.

4.7. Two-dimensional spectra

Sending all three linear signals, Z/C time, time-of-flight and energy signals to ADCs one is able to observe 2D-spectra showing precisely separation of neutron and γ-events. It is shown on Figs 5 to 9 where Z/C time versus energy, time-of-flight versus energy and finally Z/C time versus time-of-flight 2D spectra are presented, as measured with this particular module. The measurement was done with the 5”x5” BC501A liquid scintillator coupled to 5” in diameter XP4512B PMT and using Am-Be source. The reference detector for the time-of-flight measurement consisted of BaF_2 crystal coupled to the XP2020Q PMT was about 20 cm far from the neutron detector. Energy threshold at CFD corresponding to 100 keV of electron recoil energy was set at CFD.

Note excellent separation of neutron and γ-rays particularly at Z/C time vs. time-of-flight spectrum. The measurement was done with a strong source and a large contribution of scattered neutrons is seen on the spectra.

4.8. Multiplicity measurement

To measure multiplicity of neutron and γ-events connect two parallel outputs of current signals in daisy chain. The outputs deliver 1mA/hit (50 mV at 50 Ω) current signal. Its width is the same as that adjusted at front panel for the logic signals (40 – 350 ns). A number of channels, which can be connected in the daisy chain, depends on the width of the signals. For 100 ns wide pulses, 4 channels can be safety connected. This is limited by the slowing down of signals from to many channels.

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