Time Recording Unit for a Neutron Time of Flight Spectrometer

Praful Puranik[1], S. Ajit Kiran[1], *R M Chandak[2], S K Poudel[2] and R Mukhopadhyay[2]
[1]*Indian Institute of Technology, Kharagpur-721302, INDIA*
[2]*Solid State Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
** email: rohitc@barc.gov.in*

Introduction

We describe here the architecture and design of Time Recording Unit for a Neutron Time of Flight Spectrometer. The Spectrometer would have an array of 50 Nos. of one meter long linear Position Sensitive Detector (PSD) placed vertically around the sample at a distance of 2000 mm. The sample receives periodic pulsed neutron beam coming through a Fermi chopper.

The time and zone of detection of a scattered neutron in a PSD gives information of its flight time and path length, which will be used to calculate its energy. A neutron event zone (position) and time detection module for each PSD provides a 2 bit position/zone code and an event timing pulse see Fig. 3. The path length assigned to a neutron detected in a zone (Z1, Z2 etc)in the PSD is the mean path length seen by the neutrons detected in that zone of the PSD.

A Time recording unit described here receives event zone code and timing pulse for all the 50 detectors, tags a proper time window code to it, before streaming it to computer for calculation of the energy distribution of neutrons scattered from the sample.

Architecture and Design of the Time recording Unit

A pulsed beam of monochromatic neutron falls on the sample through a Fermi chopper. The chopper pulse in the timing diagram Fig. 1 starts the reference timer inside the Field programmable Gate Array (FPGA). The periodic time window ticks defines the time window (here 1µs) and are used for measurement of flight time of neutrons detected in all the 50 detectors.

If slots starting from t µs is referred as time zone t, we see in Fig. 1 Detector 1 and 50 has seen a neutron event in time zone 1, Detector 2 and 50 has seen and event in time zone 4. Thus the flight time assigned to the neutron detected in time zone t would be t µs.

From each detectors neutron event zone and time detection module, the time recording unit receives 3 bit information viz. one event timing pulse and two bit position code of neutron detection position in the PSD. Thus for 50 detectors the time recording unit has to handle and acquire 150 bits of data during each time zone.

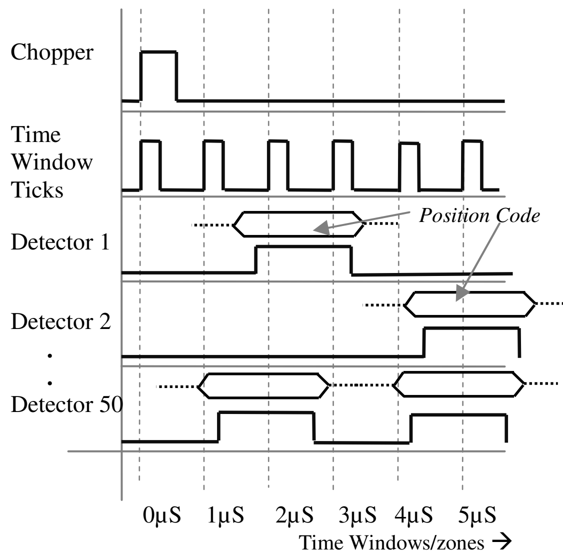

Fig 1: Typical timing diagram of detector event timing pulses and position codes

The rising edge of time window/zone tick defines the start of the time zone. At the start of each time zone 150 bits from all the detectors are latched in the FPGA. If detector timing pulse is 1 at the start of a time zone, it indicates occurrence of a neutron event in the previous time zone.

← D1 →← D2 → ← D50 →

Time Zone 10-bit	1	0	1	0	1	1	....	1	1	0

← 150 bits, Event-zone code for each detector →

Fig. 2 Structure of the Data Packet

Such events have to be recorded. Thus at the start of every time zone if any one of the 50 detector event is detected then all the 150 bits are sent to computer by tagging a 10 bit time-zone code to it. The format of the data frame is shown in Fig 2. These 20 bytes of data is filled in the FIFO of high speed USB microcontroller byte wise (by a strobe signal for each byte) by the FIFO Filler section in the FPGA. These 20 bytes of data is processed by the computer by extracting position information for detectors which reported neutron event, and incrementing the histogram of time channel of that particular detector.

A 10 bit register for time-zone code divides the time between successive chopper pulses in 1024 channels of 1 µs. The user may not need the data immediately after the chopper pulse and may be not for the whole time duration. A measurement time window is definable by the user and is incorporated into the Timing ref. section of FPGA. 'Ticks' are pulses that appear at every time window and drive the data latching and streaming. Say, if the user wants to record data between 200µs and 700µs, ticks appear only in this interval, i.e. 500 times.

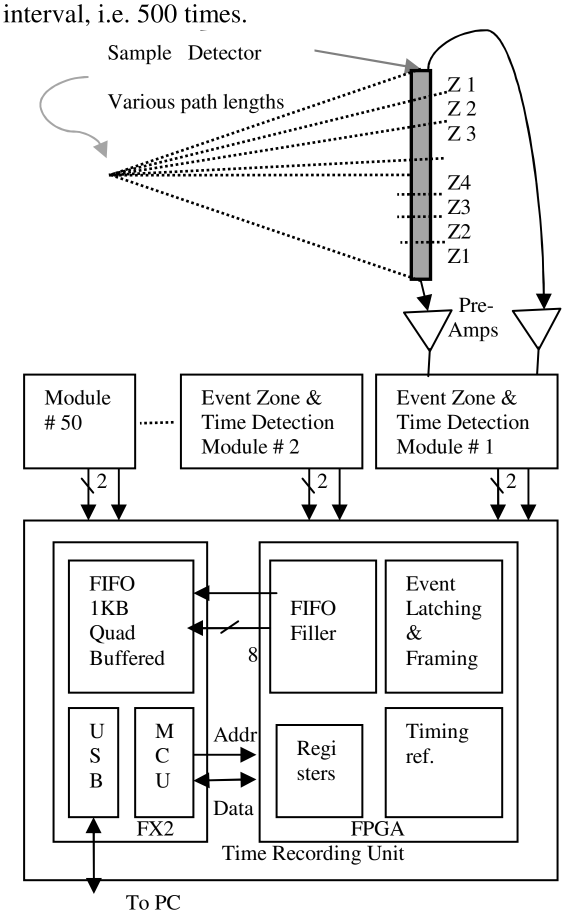

Fig 3. Time of Flight Spectrometer and its Time recording unit's internal block diagram

For computer connectivity USB is now a very popular and handy option for connecting embedded devices. Amongst the variety of chips available for USB interface; we have used Cypress FX2 series USB device [1]. This chip has been chosen since it, (1) supports high speed mode USB transfers, (2) has a 8051 microcontroller (MCU) and, (3) its FIFO once configured can directly stream data via its own USB interface engine without microcontrollers intervention. Microcontroller firmware configures the FIFO, timers, counters etc. The microcontroller firmware also configures the time window parameters in the registers in the FPGA.

Results

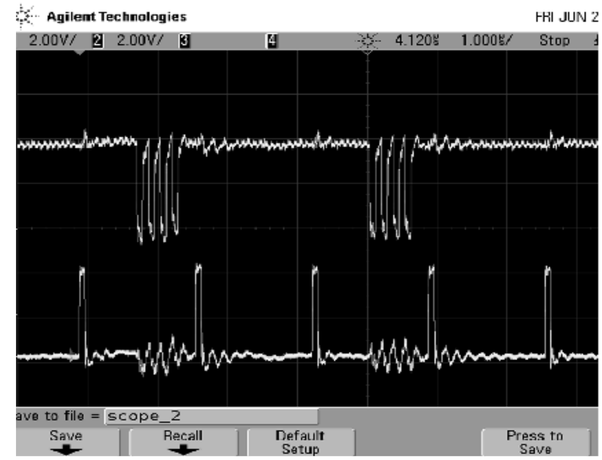

Fig.4 Time Window Ticks and FIFO write strobes

Figure above shows ticks (lower) and the strobe signals (upper). There are 4 rising edges of the strobe signal in a time window, which means that there are 4 bytes of data to be transferred. This testing has been done using pulses emulating only 3 detectors.

If the event lathing section sees a detector event showing '1' in two consecutive ticks, it is taken to be that the event has happened in the first tick and is considered '0' for the for two consecutive ticks, This has been done since event pulse width is set to be 1.5 times the time zone width.

The USB Data link has been tested to transfer upto 2 M Bytes per sec. to computer. This FIFO can be filled at rate of 96M Bytes. The transfer rates we have tested were more than needed, for our case we need less than 10^5 bytes per sec. Such streaming of data to computer eliminates need of any other local high capacity storage chip on the time recording unit.

The FIFO reading and communication with the microcontroller is done over USB by using the Class Library functions [2] provided by the microcontroller manufacturer. The computer can do the needed time channel histogram building to be used for knowing the energy distribution of scattered neutrons.

References

1. Cypress CY7C68013A Data Sheet and Technical Reference Manual.
2. Cypress CyAPI Programmer's Reference