Fully Digital Gamma Camera for Small Organ Imaging

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Introduction

Single Photon Emission Computerized Tomography (SPECT) is a medical study where the spatial distribution of the injected radioisotope is imaged to give the functional information of the organ under interest. The most important aspect of SPECT is the spatial resolution which has its roots in signal degradation at Photo Multiplier Tubes (PMT), analog Data Acquisition electronics.

The single-crystal design with conventional detector electronics, and traditional Anger-positioning algorithm [1] hinders higher count-rate imaging because of the pileup of signals of the detected events in the detector. Multiple events may be merged into one artifact event in the detection system; hence, true events are lost while artifact events are generated.

There arises a need to digitize the individual pulses before the Signal Conditioning and Image reconstruction techniques are applied.[2] In this paper, the ongoing work in the design of the Small field of View Gamma Camera (SFOVGC) is presented.

SFOVGC can be used to image breast and myocardial perfusion, and other small organs of interest. These include thyroid scans, bone hot spot study, localized areas of interest such as cancer activity, lesion etc.

Hardware Design

I. Crystal

The most commonly used crystals for SPECT are Sodium Iodide (NaI) and Cesium Iodide (CsI). Even though the light yield of CsI is more compared to NaI, NaI crystals are a preferred choice for SPECT applications due to NaI's faster decay time.

Most of the SPECT applications use Tc-99m as an imaging agent which produces 140KeV primaries. A monolithic 100mm x 100mm NaI crystal with 10mm thickness was chosen to maximize the number of detected hits.

Table 1 summarizes the properties of NaI crystal. The emission maximum is well matched to the sensitivity curve of photomultiplier tubes (PMTs) with bialkali photocathodes.

Table 1: Properties of NaI crystal

Density (g/cm^3)	3.67
Light yield (photons/KeV γ)	38
Primary Decay time (ns)	250
Hygroscopic	Yes
Wavelength of emission max (nm)	415

II. Position Sensitive PMT

SPECT needs a good pixel identification to obtain images with higher quality. The new generations of PSPMT [3] with anode array with smaller step have been developed. H8500 flat panel 5mm x 5mm PSPMT has 64 anodes and 6mm pitch between two anodes.

Table 2: Comparison between Bulk and PSPMT

Parameter	Bulk PMT *	PSPMT [3]	Improve- -ment
Length	38mm	6.28mm	400%
Area of 1 PMT	~4500mm^2	39mm^2	1x10^4
Detection area	76%	98%	128%
Quantum Efficiency	~12%	~30%	250%
Anode Gain	5x10^5	1.5x10^6	30%
Rise Time	1.6nA	0.8ns	200%

* SIEMENS E-Cam Model. Crystal – 59.1 cm x 44.5 cm, 59 PMT

Comparison between a conventional 'bulk' PMT and PSPMT shows that Hamamatsu H8500 is a better choice keeping in mind the spatial resolution and sensitivity requirements of SFOVGC.

III. Data Acquisition Electronics

The 10mm x 10mm crystal is coupled to four H8500 in a 2 x 2 matrix which gives 256 anode outputs. Figure 1 is the block diagram of a fully digital DAQ. The pulse is immediately digitized after the PMT which offers several advantages. [4]

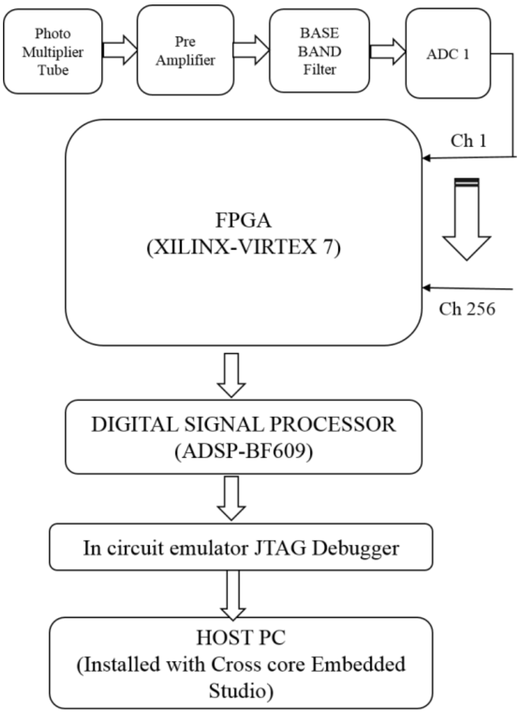

Fig: Block Diagram of DAQ of SFOVGC

The digitized pulses from 256 channels are given as input to FPGA. FPGAs, due to their flexible and reconfigurable hardware architecture, allow large scale parallel processing and pipelining of dataflow. It provides plenty of processing resources, huge on-chip RAM and support very high clock speeds. Efficient and effective pipelining in FPGAs is possible due to high I/O capability that allows FPGAs to access multiple RAM banks simultaneously. FPGAs use multiple distributed memory banks for partitioning and pipelining of algorithms thus bringing about significant improvements in performance compared to the processor based implementation. FPGA is programmed to process the digitized pulses from 256 channels using Digital Pulse processing techniques to form a DICOM image. [4]

The DICOM image formed using FPGA is given as an input to the Digital Signal Processor for post processing. DSP is a specialized microprocessor developed to perform dedicated "pipelining" tasks, unlike "parallel" tasks as in FPGA. The post processing includes Segmentation, Edge Detection, various image processing operations and digital signal processing functions. The commands for post processing from the Host PC is interfaced to the DSP using an In Circuit Emulator 100B through a JTAG interface.

This FPGA-DSP architecture allows for a greater acquisition efficiency and speed. [5]

IV. Acknowledgement

The authors acknowledge the financial support received from the DAE-BRNS via sanction no. 2012/35/14/BRNS/1605 dated 3/10/12, to carry out R&D activity of this project.

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