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Verification of a Readout Design for Multiple Energy Discrimination working in Single Photon Processing Pixel Array

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Abstract: ***The improvements in CMOS technology can be used for increasing the range of applications for X-ray imaging sensors. This paper shows measurement results for multiple energy discrimination in single photon processing pixel array. The measurement used technique demonstrates colour resolution based on colour sub-sampling with intensity biasing for three-level energy discrimination that corresponds to colour imaging systems for visible light with R, G, and B colour components. It is the result of balancing the circuit complexity and the image quality. The coloured X-ray could be used to expose dense object and projecting the colour of depth layers without fragment the sample, it also useful to develop X-ray spectroscopy and florescence systems realistic radiology for both materials and biological substances.***

Keywords: Colour, X-Ray**,** Readout, Design, Verificatio

1. Introduction

In medical X-ray imaging applications, in order to limit X-ray dose, the major early developments focused on increasing the sensitivity of the detection elements, this include introducing colour in imaging. The feature of the colour recognition by X-ray projection can develop the prosperities of reflecting the colour from the surface of the object to project the penetrated X-ray photons viewing the colour of the deep layer, which might be implemented in boosting the radiology imaging capability, replacing the pseudo colour in angiography and facilitating the computed tomography with realistic presentation of the slice texture, reducing surgical interventions by providing colour distribution of the internal tissue, introducing new applications of X-ray in other medical laboratory diagnosing such as microscopic investigation in histopathology, replacing dying processes in some investigation. Such challenges improve the imaging facilities, reducing surgical complication and recover cure, minimizing the cross contamination probability and biological hazards and speed up medical laboratory examination time. Recently colour X-rays were studied using multiple exposures of X-ray wavelengths to create any possible additional information that they might contain. This technique has disadvantages, including the need for total X-ray exposure and for this reason colour X-ray has not achieved widespread use [1]. Colour image sensors of various types have been used in visible light. One approach to enable colour imaging in image sensor for light is a Bayer pattern model proposed in [2]. Low circuit complexity is achieved in this model because each pixel discriminates only one energy range, these pixels are arranged in the array in groups of four, with two centres energy ranges green (G) and a low energy range red (R) and one high-energy range blue (B). This means that each pixel of the array contains information about only one color component, whereas the output digital image must contain all three components R, G, and B for each group. Another method with high circuit complexity is to have full energy resolution in all pixels. Using multiple-channels, in each pixel will provide full colour resolution, but the circuits in the pixel will be very large. In this work a technique balanced between Bayer pattern model and full energy resolution is using for measuring colour X-rays used Medipix2 chip working in single photon processing pixel array.

2. Methodology

The equipment used in these Measurements includes X-ray sources, a Medipix2 chip, a Field Programmable Gate Array FPGA, a desktop computer for analysis and presentation and a Labview to control the thresholds values of comparators in the circuit architecture. This involves developing and implementing circuit architecture and mounting a Printed Circuit Board PCB to Medipix2 chip, see Figure 1

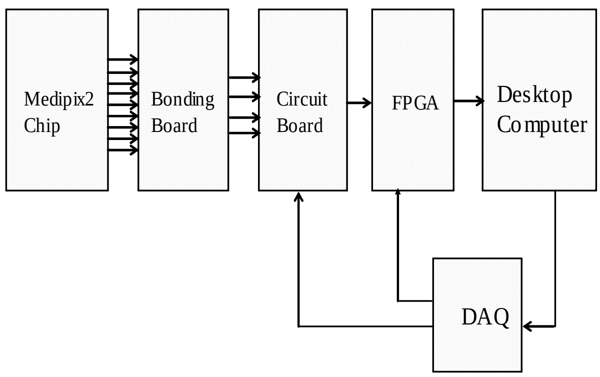

Figure 1: block diagram of the tools used in the colour X-ray measurements

2.1 Medipix2 Photon counting pixel arrays

The core radiation detector in this experiment is the Medipix2 chip, which is a hybrid pixel detector readout chip developed by the Medipix collaboration. The chip function as direct detection system consists of 256x256 pixels with a pixel pitch of 55 um, working in a single photon counting processing for positive or negative input charge based in CMOS technology [3]. The architecture of the chip designed as matrix of 64k pixels each pixel of detection area at top of the chip cover up to 87% of the total area. when the interaction of incident photon or charge particles occurred, electron-hole pair liberated and then drifted by high electric field, the collection is fed to conditioning circuitry ,e.g. holes are detected as positive pulses in the cathode of the detector , which is deferential CMOS charge sensitive amplifier (CSA) working in operational Tran conductance amplification (OTA), consist of leakage current compensation, shaper charge preamplifier combined with feedback capacitor to reduce under zero biasing, the shaped signal split to identical discriminator level which is automatically adjustable via 3 bit current source DAC to in suite interest signal window.

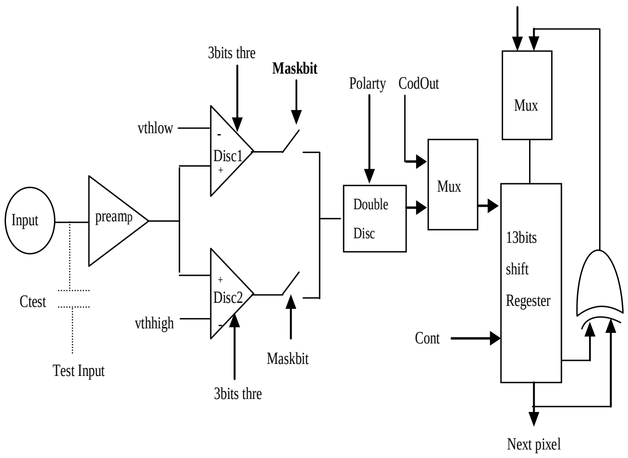

Figure 2: Block diagram of the functional units in a pixel.

The input signal could be simulated through couple the test capacitor in duty, these technique reduce most of the noise incorporate with nuclear spectroscopy, the digital portion of chip dual discriminator logic (DDL) to allow the pulse that approve the working mode configuration to pass for further processing. A13 bit shift register based compensation is introduced to perform two major function counting or digital control and configuration for the analogue portion of the pixel circuitry. Polarity of detected signal is assigned by controlling DDL (polarity bit). Global communication of the chip readout can be configured either serial or parallel mode.

In this chip there are 9 special pixels at the bottom of the matrix, organized as a 3x3 matrix as shown in Figure 3. The CSA amplifies the analog output from the 9 pixels. Finally, the outputs are connected through a double stage analog buffer to the output pads [8].

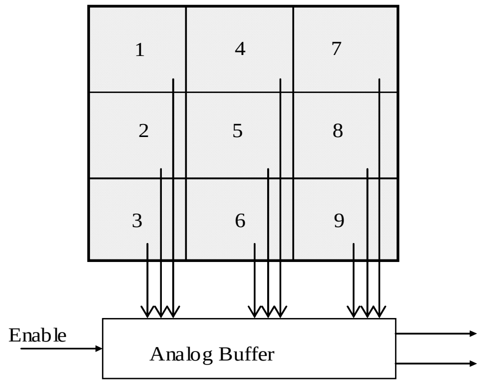

Figure 3: the 9 pixel special pixels organized as 3x3 matrixes

The output pads of the 9 pixels are mounted to the bonding board (small PCB circuit board with coaxial connectors)

2.2 Circuit board

The circuit design is based on the circuit architecture presented in [4], [5]. The proposed architecture uses full spatial resolution for the intensity and uses sub-sampling to resolve the energy ranges. For sub-sample the architecture is implemented by adding two discriminators and two counters shared between each four pixel cells, these form Red and Green energy range, the Blue energy range will calculated by the equations presented in [4] after readout, then a total of six channels are required for each group of four pixels. Thus there is a reduction in the circuit complexity from twelve to six channels compared to that for a full resolution technique.

Sub-sampling is commonly used as an efficient solution for the display problem [6]. It is a good way to reduce the circuit complexity without losing colour information. This technique has been used in this circuit architecture for colour X-ray imaging.

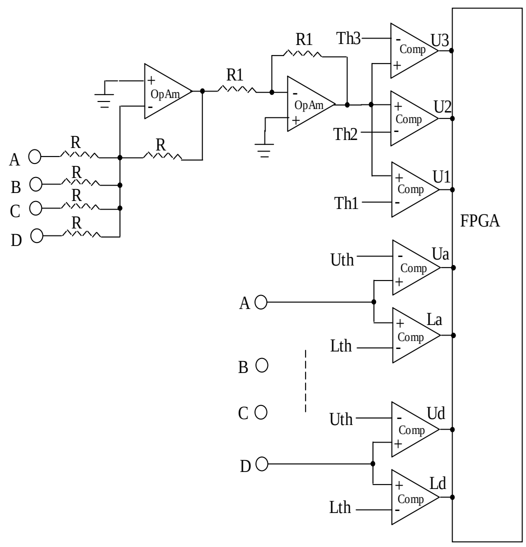

Figure 4: Schematic diagrams for the circuit design for colour X-ray

In this measurement 4 neighbour's pixel are choosed from the 9 pixels matrix in Medipix2. For each pixel the analog output of the CSA signal is needed. In Figure 4 the four CSA signals from the Medipix2 (A, B, C and D) are fed through coaxial cables to the circuit board.

The summing amplifier is the first part in the circuit architecture it gives the sum of the four input signals. Since the four input resistors and the feedback resistor are equal, the input voltages will be inverted as they are added. As the output signal from the summing amplifier is inverted, second inverting amplifier with unity gain is used. The output pulse is then fed to three comparators (sub sample). The function of the thresholds for the comparators are based on if the signal exceed the threshold value generate clock signal. By setting the global threshold values such that $Th_1>Th_2>Th_3$, the sub-sample is made on this sum by first comparing the magnitude with three global threshold values. As a result sequences of binary events will appear on the outputs of the comparators (U_1, U_2 and U_3). The energy levels of sub-sampled can be made which means that there are two channels (for the ranges Th_1-Th_2 and Th_2-Th_3) for four pixels that are denoted by U_{12} and U_{23}.The decision whether the signal is in U_{12} or U_{23} range is made by two All-Digital Window Discriminator ADWDs modelled in the FPGA.

The second part of the circuit forms the full resolution for the intensity for each pixel. The signals A, B, C and D are the output of the four CSA amplifiers that summed in the summing amplifier; each signal is fed to the two comparators form energy window. The outputs of the comparators (Ua, -Ld) are the clock signals generated depends on the value of the charge signal compared to the threshold, these signals will be fed to the four ADWDs implemented in the FPGA.

The threshold voltages for all comparators in the circuit architecture are controlled by using Labview and DAQ. The VI implemented in Labview has to do two tasks, first to generate continues analogue output by means of voltage to control the threshold for the comparators in the circuit board and secondly to generate clock on digital output channels of DAQ USB-6008 for reset the counters in FPGA.

For continuous analogue voltage two DAQ Express VI`s are used to produce voltages on DAQ USB-6008 analogue output channels, in the case presented by this paper variable voltage is appear on four channels of DAQ USB-6008. The Multifunction DAQ USB-6008 device is connected to the PC via USB port. The voltage can be varied infractions by using Dial Knobs. For generating a fixed clock an array of Boolean values is generated and projected towards digital output channel. The whole VI is enclosed in a single while loop to produce continuous output.

2.3 ADWD and Counter

The ADWD is a digital circuit whose inputs are the sequence of outputs from the comparators. It carries out a window-discrimination function and conditionally generates a clock pulse to the event-counter if the energy is within the window defined by the threshold values given to the comparators. The ADWD is a self-timed circuit that does not rely on any timing assumptions or external timing references. The ADWD is modelled in VHDL based on an asynchronous finite-state machine (AFSM) presented in [7].

The output clock signals of the ADWDs for sub-sample and full spatial resolution are fed to the counters. In order to be able to measure images with a large dynamic range, the capacity of the counters has been implemented in VHDL as 16 bits.

3. Measurement Results

System is setup and an Americium-241 with energy level 59.5 KeV radio isotope is placed in front of the Medipix2 detector, the resultant electrical signal is plugged to the oscilloscope. Figure 5 shows an oscilloscope trace of four CSA pulses.

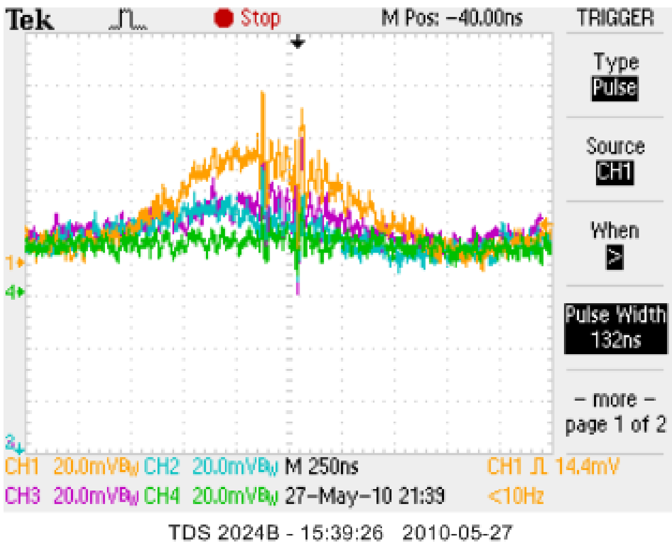

Figure 5: CSA output pulses of a four pixels after exposed Medipix2 to an Americium-241 radioactive source. X=250 ns/div and Y = 20mV/div

Figure 6 shows an oscilloscope photo of the summing amplifier and discriminators outputs. The upper plot represents the summing amplifier output (sum of the 4 outputs of the CSA from Medipix2). The lowers signals are binary signals which are generated by the three comparators with the values of U1 and U2 are high as shown in the Figure and U3 is low. The decision whether the signal is within U12 or U23 range is made by the ADWD is modelled in FPGA

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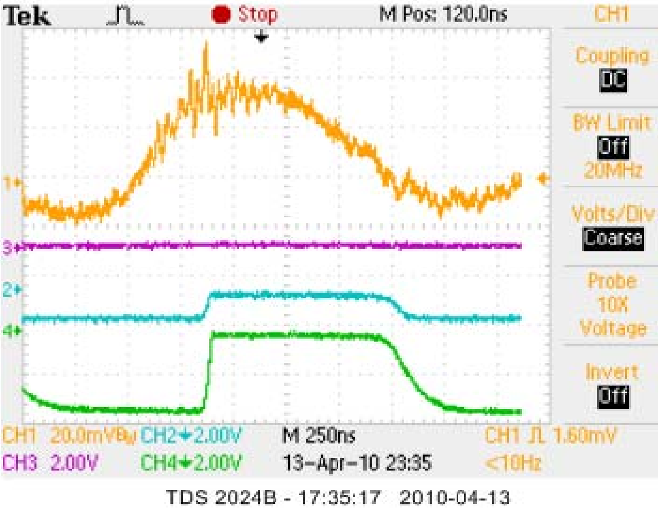

Figure 6: The summing amplifier output with X=250 ns/div and Y = 20mV/div and the lower plots are the comparators digital outputs for sub-sample, with X=250 ns/div and Y = 2V/div

Universal Asynchronous Receiver Transmitter (UART)) module was implemented on the FPGA. The UART module was used to communicate the result of the multiple energy discriminators to a desktop computer for analysis and presentation. An example of the result obtained over UART is shown in Figure 7 and Figure 8. Figure 7 shows counting for an 8-bit system for sub-sample. Figure 8 shows counting for an 8-bit system for full spatial resolution for three counters. This was chosen for ease of analysis on the desktop computer in which the hyper-terminal was set to 8-bit at 9600 baud rate. In the final system, 16-bit colour X-ray counter output will be used and there will be no use for a UART module.

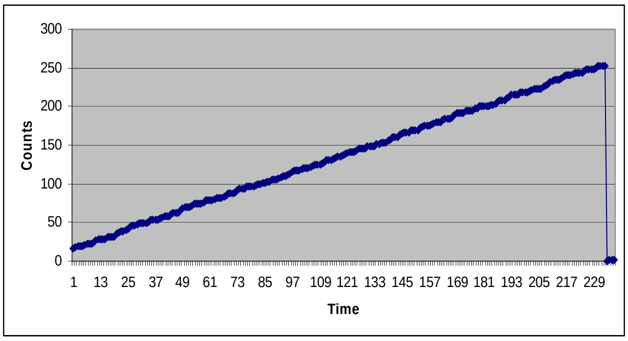

Figure 7: Counter output for sub-sample

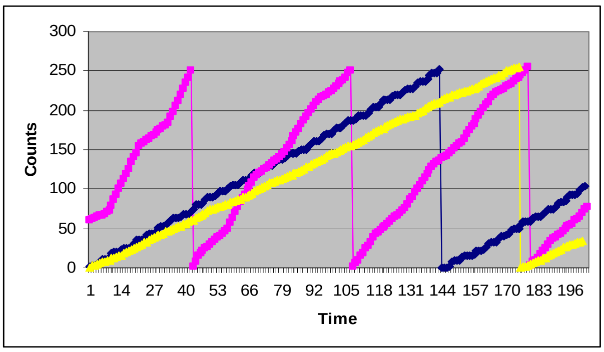

Figure 8: Full special resolution counters outputs for three pixels

4. Conclusion

The presented experiment describes the circuit configuration which is characterized by its optimality and simplicity (high image quality). The technique of sub-sampling was implemented for three-level energy discrimination, that representing the three basic colour component Red, Green, and Blue. Such technique could be used in medical radiology to develop realistic imaging for the deep biological structure.

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Author Profile

Suliman Abdalla received the B.S.c in Electronics Engineering from Faculty of Engineering and Technology, University of Gezira, Sudan in 1999 and Licentiate Degree, in Electronic Engineering at the Mid Sweden University, Sundsvall, Sweden in 2007. He employed as an Electronics Engineer in the department of Electronics and Instrumentation in the Sudan Atomic Energy Commission (SAEC). .He now doing his PhD at the Sudan Academy of Science, his research focus on the design of the read-out electronic interface between detectors and the intelligent data acquisition systems, the main read-out detector types of interest are photon counting pixel detectors for X-ray imaging