Multi-Channel Data Acquisition System Design for Spiral CT Application

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ABSTRACT

We have designed X-ray detection system and multi-channel data acquisition system for Spiral CT application. X-ray detection system consists of scintillator and photodiode. Scintillator converts X-ray into visible light. Photodiode converts visible light into electrical signal. The multi-channel data acquisition system consists of analog, digital, master and backplane board. Analog board detects electrical signal and amplifies signal by 140dB. Digital board consists of MUX(Multiplex) which routes multi-channel analog signal to preamplifier, and ADC(Analog to Digital Converter) which converts analog signal into digital signal. Master board supplies the synchronized clock and transmits the digital data to image reconstructor. Backplane provides electrical power, analog output and clock signal. The system converts the projected X-ray signal over the detector array with large gain, samples the data in each channel sequentially, and the sampled data are transmitted to host computer in a given time frame. To meet the timing limitation, this system is very flexible since it is implemented by FPGA(Field Programmable Gate Array). This system must have a high-speed operation with low noise and high SNR(signal to noise ratio), wide dynamic range to get a high resolution image.

Keywords: X-ray, Spiral CT, Data acquisition system, Detector

1. INTRODUCTION

Continuous volume can be acquired by spiral X-ray projection and continuous data acquisition. Hence the spiral CT could shorten the scanning time such as a single breath scan. The true volume data acquisition and short scanning time of a spiral CT has many benefits over conventional CT such as 3D reconstruction, multi-planar data reformation, imaging of moving organs. Data acquisition circuit, positioned between the detector array and the computer, performs the following three major functions ;

(1) amplification of the signal from detector, (2) conversion of the analog signal to the digital data, (3) transmission of the digital data to the computer for reconstruction and further image processing. The signal flow consists of detector, data acquisition circuit, and image reconstruction system. Among these, the detector and the data acquisition circuit are fairly significant parts in upgrading the final quality of images. Not only the data acquisition circuit receives very weak signal, it also can be greatly affected by the noise. It is important to have low noise performance to achieve a high SNR.

In this paper we have achieved continuous data acquisition from multi-channel detector array and data transmission. Phantom image was acquired and reconstructed using standard back projection algorithm.

2. MATERIALS AND METHODS

2.1. Configuration of the system

X-ray source and image reconstruction system were supplied by LISTEM corp. 16 channel scintillator and photodiode array were prepared by KAIST and OD Tech. 16 channel integrator, MUX, digital, master, backplane board are designed using ORCAD, Altera tool.

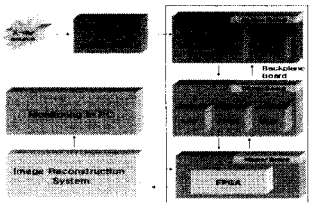


Fig 1. Block Diagram of Data Acquisition Circuit

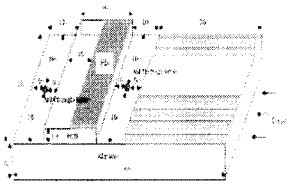


Fig 2. Photodiode Array

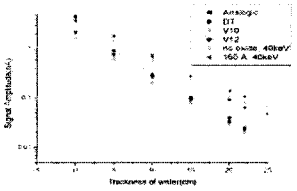


Fig 3. The comparison of Photodiode sensitivity

2.1.1. Detector

Detector module consists of 16 $CdWO_4$ crystal and photodiode array. Detector must have a condition of high capture efficiency and high absorption efficiency and high conversion efficiency. Figure-2 shows photodiode array module. Detector consists of scintillator and photodiode. Scintillator converts X-ray into visible light and photodiode converts visible light into electrical signal. Fig-3 shows that the sensitivity of photodiode which is used to the experiment is better than the existing photodiode.

2.1.2. Analog board

Analog board amplifies a very small amount of current(several pA ~ several hundred nA), which flows from photodiode, into voltage. The dual switched integrator, which is internally implemented C_{INT} to 100pF amplifies 1nA current to 1V in 1msec, are used for the trans-amplification. Hold, Reset and Select signal as the control signal are used for the integrator. This control signal is supplied by 84pin PLD(Programmable Logic Device) and implemented by VHDL. High-speed programmable gain instrumentation amplifier(PGA) is used for further possible amplification, then the signal is transmitted to digital board for digitization.

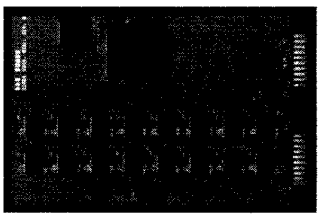


Fig 4. Analog board

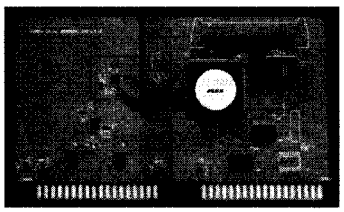


Fig 5. Digital board

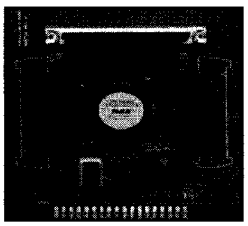


Fig 6. Master board

2.1.3. Digital board

Digital board converts transmitted analog signal to digital signal, and transmits the data and its address to master board Clock buffer is used to synchronize the clock. ADC of internal 2.5V reference, 16bit, 500kHz sampling rate is used. 244pin PLD supplies the control signal of MUX and ADC and the synchronization clock of analog board.

2.1.4. Master board

Master board supplies the whole synchronized clock for each board and control signal for image reconstruction system and transmits the address and data to image reconstruction system.

2.1.5. Backplane board

Backplane board supplies the power(+15, -15, +5, -5V) and is designed to stick 16 analog (256channel), digital, master board. The data is transmitted from analog board to digital board and synchronization clock from digital board to analog board.

Fig 7. Backplane board

2.1.6. Image reconstruction system

The last processed data is transmitted to the computer by 100pin SCSI type connector. We used PCI-7300(ADLINK Tech. Inc.) for data processing.

3. TEST AND RESULT

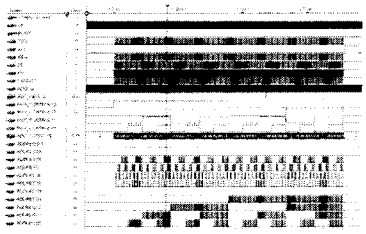


Fig 8. Simulation Result

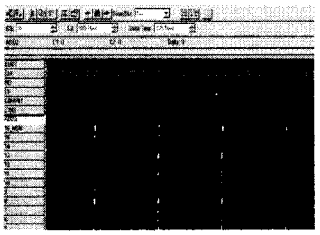
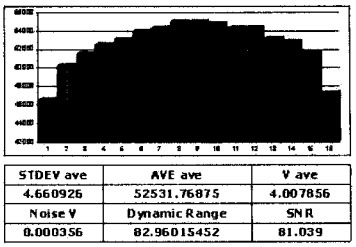


Fig 9. Output with Logic Analyzer



STDEV ave	AVE ave	V ave
4.660926	52531.76875	4.007856
Noise V	Dynamic Range	SNR
0.000356	82.96015452	81.039

Fig 10. LED Test Result

The control signal is designed by VHDL and Fig-8 shows that the control signal is correctly supplied to the board. The whole design is tested through the simulation and verified by the Logic Analyzer. After converting LED light into electrical signal by the photodiode, multi-channel data acquisition circuit amplified electrical signal and transmitted the data to the computer. Fig-10 shows the result of LED test.

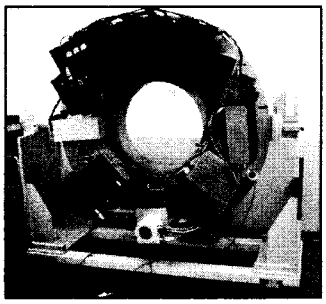


Fig 11. DAS in Gantry

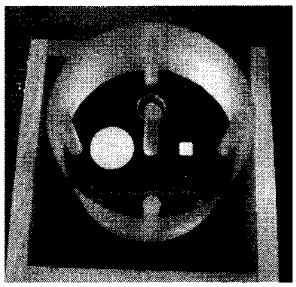


Fig 12. Phantom

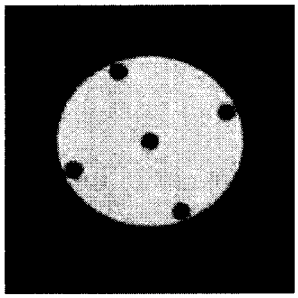


Fig 13. Reconstruced phantom image

Multi-channel data acquisition circuit and detector array are set up in the gantry as in Fig.11. A standard CT phantom in Fig.12 was imaged through X-ray and the reconstructed image by back projection algorithm is shown in Fig-13.

4. CONCLUSION

In this paper we designed multi-channel data acquisition system for spiral CT application and were bench tested by LED and X-ray. Then data acquisition system located on the CT gantry and operated successfully. The image parameters, such as noise, SNR, artifacts, are yet to be analyzed. Multi channel data acquisition circuit can be applicable at various fields which related to detection of X-ray.

ACKNOWLEDGMENT

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REFERENCES

1. Jerald G. Graeme, "Photodiode Amplifiers", McGrow Hill, 1996.
2. Glenn F. Knoll. "Radiation Detection and Measurement", Wiley, 1999
3. Allen Dewey, Analysis and Design of Digital System with VHDL,` PWS Publishing Company, 1997
4. Clenn M. Glasford, Digital Electronic Circuits` , Prentice-Hall, 1998
5. Product Data Sheet of Burr-Brown, Analog Devices, and Altera Co.