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Initial Results on Low Cost Microprocessor and Ethernet Controller based Data Acquisition System Developing for Optical Tomography System

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Abstract: Due to high cost of data acquisition card in the market, this research concentrates on developing a high speed, low cost microprocessor and Ethernet controller based data acquisition for optical tomography system. Microprocessor is the main core to control the sensor circuitry while the Ethernet controller has the responsibility of transmitting data to PC and thus insuring the reliability of data. The data transfer rate will be up to Megabit per second (Mbps). In this optical tomography system, a projection geometry combining two orthogonal and two rectilinear in one layer is modeled. *Copyright © 2007 IFSA.*

Keywords: Data acquisition system, Optical tomography system, Mbps, Microprocessor, Ethernet controller, Infrared, WinSock.

1. Introduction

Optical Tomography involved projecting a beam of light though some medium from one boundary point and detecting the level of light received at another boundary point. Basically, the optical tomography system can be subdivided into four sub-systems: the sensor array, the signal conditioning system, the data acquisition system and the image reconstruction and display system.

Data acquisition system is essential in communicating hardware and PC. Commonly, data acquisition (DAQ) card that make the system high cost is used. Besides FPGA technology in DAQ card, there are several types of technology that can be implemented as the bridge between hardware and PC, such as parallel link, RS232 serial communication, Universal Serial Bus (USB), and Ethernet. Ethernet is a local area network (LAN) technology that transmits information at high speed. Network application exchanges data between physically separated machines. A base-level Ethernet network appeared logically to be two or more computers transmitting and receiving on a single shared medium (10 Base T cable). One of the important characteristics of Ethernet Networking is any node may transmit on the network when it is idle. They do not need ask a permission before transmitting on the network; they simply wait for a suitable gap in the network traffic [1]. Generally, most of the network application use the Ethernet technology to exchange data between several computers. However, it is possible to implement Ethernet technology in communicating hardware and PC.

The Ethernet technology consists of three basic elements, the physical medium used to carry Ethernet signals, a medium access control rules embedded, also terms as protocol in each Ethernet interface, and Ethernet frame. Writing a network application would not be feasible if the application developer had to understand all the details of accessing communication links and include the ability to access multiple kinds of transmission media. The solution to this issue is the TCP/IP network protocol stack, which provides applications with a higher level interface for accessing the network. Protocol is the specification and exact format of data exchanged between two entities. Besides TCP/IP, other protocol stacks widely used on local PC networks are Netware Stack and NetBEUI stack [2]. However, network communication can only occur between machines running the same protocol stack. In this system, TCP/IP is chosen because it is the most widely used protocol stack and is implemented on most computer platform.

The operation of the optical tomography system starts with the projection of an array of controlled light (visible or infrared) into the conveyor. Photo-detectors are then being used to generate electrical current within a range of micro Amperes that propagates to the intensity of the detected light. The output signal from each of photo-detector is dependent on the position of the component boundaries within their sensing zones. The generated current is being converted, amplified and then transferred into the computer through a data acquisition system. By using certain data reconstruction and image display algorithm, tomogram and mass flow rate measurement can be carried out.

2. Sensor Array

Optical tomography includes two main sensor arrangements. There are parallel beam optical tomography and fan beam optical tomography. In the parallel beam optical tomography, arrangement is in two orthogonal projections, two rectilinear projections, or combination of two orthogonal and two rectilinear [3]. A series of angular projections of the light source and detector are used to interrogate the measurement section, these are termed fan beam projections.

In this system, the chosen sensor arrangement is one layer of combination two orthogonal and two rectilinear due to speed limitation by sensor switching in fan beam optical tomography. A total of 64 sensor pairs are in use to acquire the physical signal. The sensor pair is placed in oppose sensing mode, which the emitter (represents as red icon in Fig. 1) and the receiver (represents as yellow icon in Fig 1) are positioned opposite to each other so that the light from the emitter shines directly at the receiver.

3. Signal Conditioning System

The principle of an optical tomography system is to investigate the light attenuation level for each detector. Basically, a light radiation measurement device in the signal conditioning system consists of infrared sensors, current to voltage converter (pre-amp), voltage amplifier, noise reduction and voltage comparator circuits. The obtained measurement depends on the more particles that intersect a light beam, the greater the output signal.

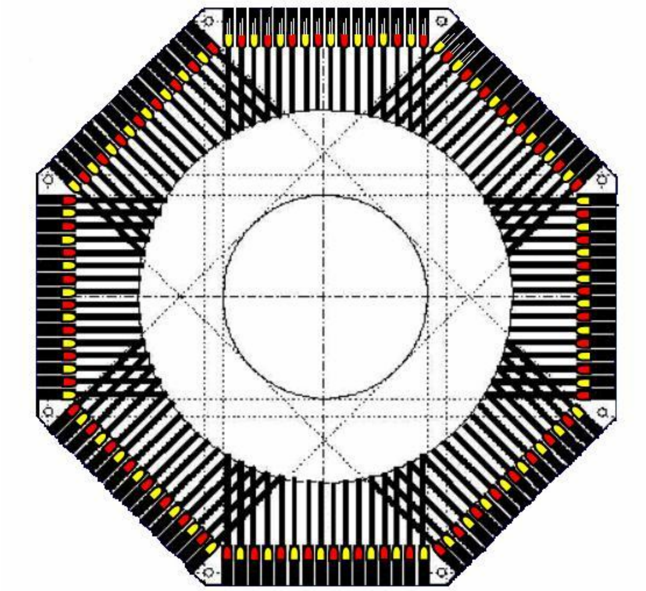

Fig. 1. Sensor Fixture.

The physical signal (emitters' light) is converted from current to voltage, and then being amplified. The range of voltage is between 0 till 5 Volts. The outputs from the signal conditioning are flown to the data acquisition system, which is controlled by Rabbit 2000, one of microprocessor from the Rabbit company.

The difference of circuitry in orthogonal layer's signal and rectilinear layer's signal is the existence of the comparator circuit in the rectilinear layer, while the output signal from orthogonal layer is feed into ADC circuit in data acquisition system. Therefore, the rectilinear layer acts as the masking layer to reduce the ambiguities and false image in the tomogram.

In the infrared emitter circuit, constant current driving circuit is applied as shown in Fig. 2.

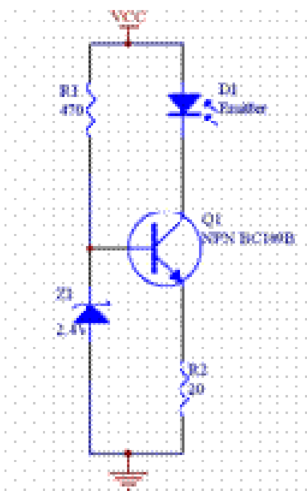

Fig. 2. Constant Current Circuit.

4. Design Core of Data Acquisition

In the microprocessor and Ethernet controller based data acquisition system, two tasks are performed. First, the amplified signals from the orthogonal sensor are converted to digital signals by using analogue to digital converters (ADC). The outputs from ADC is then stored in the memory of microprocessor. In this system, Rabbit microprocessor has been chosen as the core to control the signal conversions and also drive the Ethernet controller.

ADCs are used in order to convert the amplified orthogonal layer's signal. These ADCs convert the signals concurrently, but the output from the ADCs is feed into the Rabbit microcontroller successively. The purpose of using more then one ADC in this system is to reduce the conversion time of the signals. By using ADC with the build in sample and hold feature, the ADC outputs can be controlled directly using microprocessor I/O port. At the meantime, outputs from comparators are flown to latches. The microprocessor I/O port controls the latches output sequences.

In the second task, the Rabbit microprocessor acts as a Client to request connection upon PC. Thus, Ethernet network application is applied. Once the connection is accepted by the PC, which acts as a Server, the bridge between hardware and PC has been established. The RTL 8019 Ethernet controller will transmit data in frames to PC through the Ethernet cable (10 Base T). A Client/Server Model is carried out using WinSock Programming. The TCP protocol in the TCP/IP network protocol stack is selected in this network communication instead of UDP protocol due to the fact that TCP application is connection-oriented and thus data transmitted is lossless.

5. Window Socket (WinSock) Programming

Window Socket is an application program interface (API) specification used to access network functionality. Window Sockets or WinSock, as it is most commonly referred to, is an open specification. Thus it allows for the independent development of network applications [2]. The Window Sockets specification defines an application binary interface (ABI) for access to the TCP/IP protocol stack in a Windows or Windows NT environment. WinSock programming has exactly the same procedure calls as Berkerly sockets as shown in Fig. 3.

Maximum data throughput for the Ethernet using the 10 Base T cable is 10Mbps. The throughput depends on the length of cable, data size per frame, frame's segment size in Ethernet, and the CPU speed of both communication machines, in this case, referred to the Rabbit microprocessor and the PC.

Fig. 4 shows basic Client/Server module in network application. In this sample, the Ethernet controller RTL8019 driven by Rabbit 2000 acts as a Server, and the directly connected PC acts as a Client.

5. Hardware Development

Fig. 5 shows the block diagram of the system. It consists of four following parts: the sensor array, the signal conditioning system, the data acquisition system, and data reconstruction and image display system.

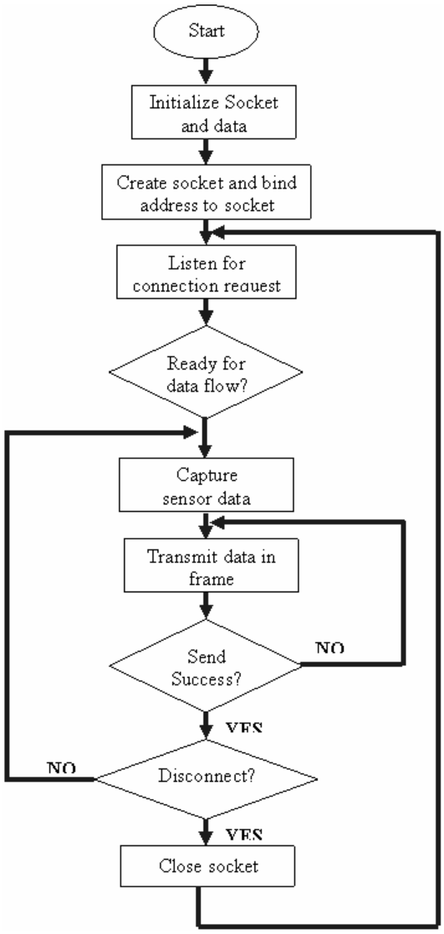

Fig.3. Server Flow Chart.

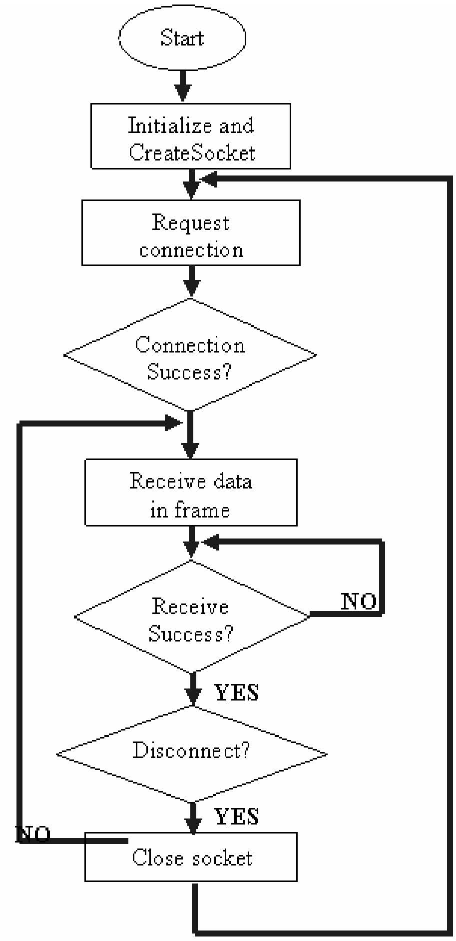

Fig. 4. Client Flow Chart.

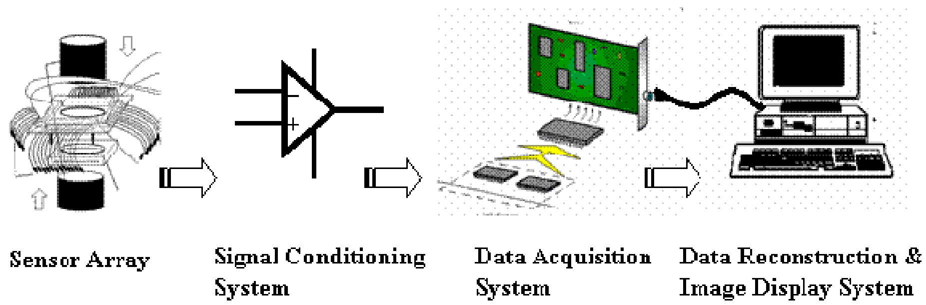

Fig. 5. Block Diagram of the system.

A total of 64 sensor pairs are in use to acquire the physical signal. The sensor pair is placed in oppose sensing mode, which the emitter and the receiver are positioned opposite to each other so that the light from the emitter shines directly at the receiver. Sensor arrangement is in combination of two orthogonal and two rectilinear in one layer. Compare to previous research, the projection geometry from the sensor arrangement mentioned above allows smaller particle being detected.

Infrared emitters (IR LED) are chosen to transmit the light due to the fact that there is a requirement for high optical penetrating power in the optical tomography system. Infrared LEDs emit more light intensity, as compared to visible LEDs. While for the photodiode, it is being chosen over phototransistor because of the linearity of photodiode, and faster response compare with phototransistor. Furthermore, photodiode produces lower noise due to no gain in photodiode. The gain of phototransistor leads to the amplification of noise.

Emitter driving circuit fall into three main categories: DC driving, AC driving (including modulation systems) and pulse driving system. In the parallel beam optical tomography system, it is very important to choose a driving system which can stabilize the radiant flux of LED, provide the large radiant flux with less influence of disturbing light and maximize the intensity of light. DC driving circuit with constant current will be designed. The photodiodes' signal is a current-type signal. In the signal conditioning system, the current-type signal is need to be interfaced with a circuit that is expecting a variable-voltage. The current-to-voltage conversion and amplifier is used to provide this linear conversion. The sensors in rectilinearly placement are used for the masking process. A "High" signal indicates that particles exist in the ray path of that particular emitter and receiver pair. Meanwhile, "Low" signal indicates non particle exists in the ray path of corresponding sensor pair. Due to this masking purpose, the amplified signal will be fed into voltage comparator.

In the microprocessor and Ethernet controller based data acquisition system, two tasks will be performed. First, the amplified signals from the orthogonal sensor will be converted to digital signals by using analogue to digital converters (ADC). In order to increase performance of the system, the analogue to digital converter need to have the characteristic of fast response and high speed analogue-to-digital conversion. The outputs from ADC will then be store in the memory of microprocessor. In the case of this research, the Rabbit microprocessor has been chosen as the core to control the signal conversions and also drive the Ethernet controller. In the second task, the Rabbit microprocessor will act as a Client to request connection upon PC. Once the connection is accepted by the PC, which acts as a Server, the bridge between hardware and PC has been established. Thus, the RTL 8019 Ethernet controller will transmit data in frames to PC through Ethernet cable (10 Base T). A client/Server Model is carried out using WinSock Programming. The TCP protocol in the TCP/IP network protocol stack is selected in this network communication instead of UDP protocol due to the fact that TCP application is connection- oriented and thus data transmitted is lossless.

As for the data reconstruction and image display system, new data reconstruction method will be carried out. The signals from rectilinear sensor will be used as masking process to investigate existence of particles in the ray path of sensor pair. Where else, the signals from orthogonal sensor will be reconstructed as tomogram. Visual C++ is chosen as the programming platform due to the popularity, fast processing time, and it also supports powerful API functions.

5.1. Ethernet Communication between Hardware and PC

Basic Client/Server has been modeled in microprocessor and PC respectively. Therefore, basic Ethernet communication which enables the transmission of data from hardware to PC is established. The results are shown in Fig. 6 and Fig. 7. Fig. 6 shows that connection failed due to link error, where no hardware found at the Ethernet port. Fig. 7 shows the successfully connection between PC and a RabbitCore module hardware. The client application listens to the server 10.1.1.2 and port 2 (which initially set to the RabbitCore module), and result shows that simulation data in the RabbitCore module transmitted in PC with data transfer rate of 1442 kbps. Investigation of optimizing the data transfer rate will be done after the completed hardware circuitry has carried out.

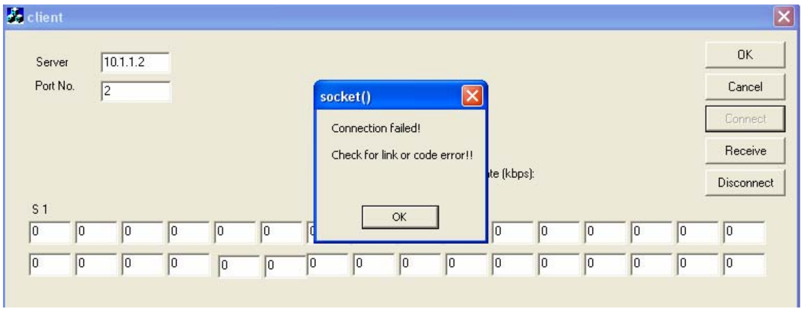

Fig. 6. Connection failed due to no hardware attaches to Ethernet port.

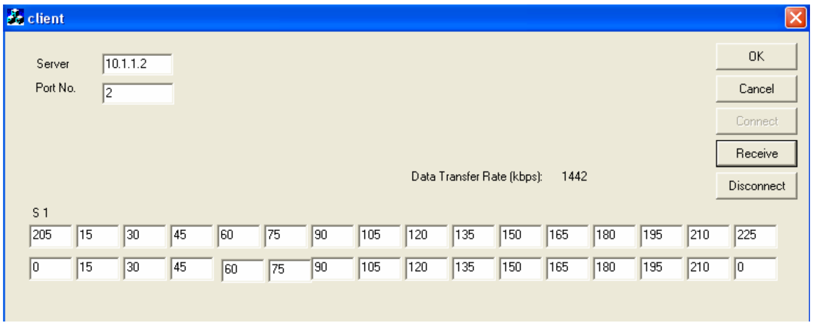

Fig. 7. Successful connection between hardware and PC with data transfer rate 1442 kbps.

6. Results

Experiments had been carried out to test the suitable infrared sensor in the research. Agilent company product, HSDL 5420 photodiode is chosen as the receiver, whereby VISH company product, TSHA 4401 is chosen as photo emitter. Both of the sensors' wavelengths are 875 nm and lens size 3 mm.

As for the signal conditioning circuit, design and experiments with selected infrared sensor pair had been done. Signal conditioning circuit including the amplifier circuit and comparator circuit. Fig. 8, Fig. 9, Fig. 10 and Fig. 11 show us the result of testing signal conditioning circuit with selected infrared sensor pair. Fig. 8 is the result of infrared sensor pair testing in the daylight. It shows that ambient light or day light may effects the response of the photodiode**.** Fig. 9 shows the response of photodiode while inside the pipeline, where the sensor pair is in opposing mode at distance 120mm and there is a light blocking inside the pipe. The ripple signal most probably contributes by the noise of wire. Fig. 10 shows the response of photodiode while full light emission (non-blocking) of infrared emitter inside pipeline. No noise detected and the voltage achieved is 4.32V. Fig. 11 shows the response of photodiode and comparator while blocking and non-blocking inside pipeline.

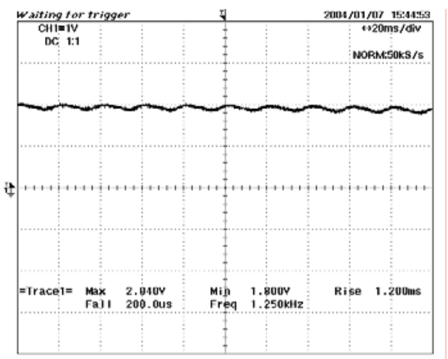

Fig. 8. Photodiode response in daylight.

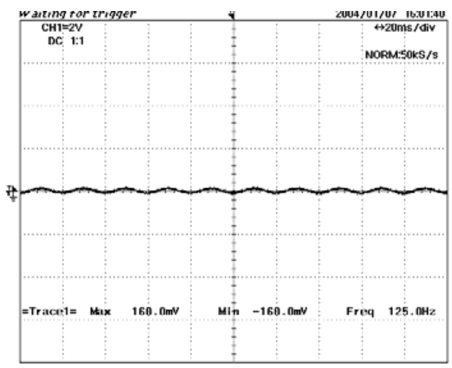

Fig. 9. Photodiode response inside pipeline.

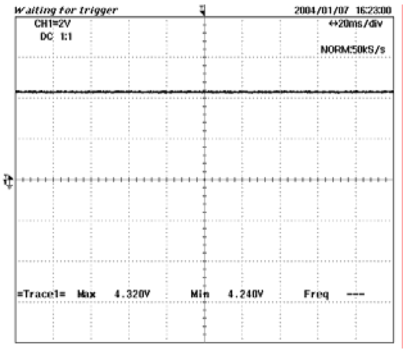

Fig. 10. Photodiode response while full light emission of infrared emitter inside pipeline.

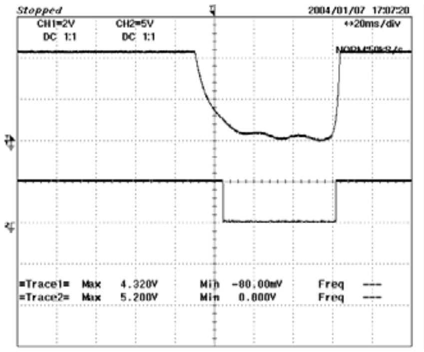

Fig. 11. Response of Photodiode (1) and comparator (2) when blocking and non-blocking inside pipeline.

7. Conclusion

Application of sensor arrangement in combination of orthogonal and rectilinear in one layer will increase the ability of scanning smaller particles in pipeline and also the resolution of the reconstructed image. On the other hand, implementation of Ethernet based data acquisition system in an optical tomography system can prevent the system speed be restricted and the transmitted data be lost. Further more, data reconstruction algorithm by using masking process and Visual C++ 6.0 as the programming platform has the ability in optimizing the data/ image processing time. Overall, a parallel beam optical tomography system combining orthogonal and rectilinear sensor arrangement, fast data transfer rate of Ethernet based data acquisition system and Visual C++ programming can provide more accurate and better flow visualization.

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- Sensor instrumentation;
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- Nanosensors;
- Microsystems;
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