Ethernet Based Data Acquisition System Using LabVIEW

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Abstract— In scientific research organizations like Institute for Plasma Research (IPR), Data Acquisition system is widely used for acquiring signal emanated from sensors in different systems. Thus multifunction board is designed which acquires as well as generate analog voltage. The hardware consists of ADC, DAC, FPGA and Ethernet controller. The control signal for interfacing Ethernet controller, ADC and DAC is generated in FPGA. The data is transferred from board to host PC through Ethernet. The software for acquisition is developed in LabVIEW.

The present work proposes a simple, robust multifunctional data acquisition with industrial standards for isolation and compactness. It is suitable for slow sampling analog data acquisition where data accuracy and resolution is more important than the rate of sampling.

Keywords — ADC, DAC, Data acquisition, Ethernet Controller, FPGA, Host PC, LabVIEW.

INTRODUCTION

Data Acquisition, a process of Measuring and study of various physical world parameters such as voltage, temperature, or pressure, etc. in digital domain, i.e. any monitoring and control system, which acquires the signals emanating from sensors or transducers, and an acquiring system or board which conditions the signals as a data for analysis, measurement and control as well. The most basic Data Acquisition system consists of various sensors and detectors mounted for capturing the respective physical condition, data acquisition hardware, and a monitoring and control unit.

The data acquisition system is focused at establishing the communication interfaces between front-end signals. During operation a large amount of data is generated from various front end components. The creation of more data per pulse will challenge our ability to analyse and assimilate all of the data. Enhanced visualization tools will be required that allow this increasing data volume to be effectively used for decision making by the experimental team and to advance the science. The Data Acquisition is the unit which serves this purpose. The goal of Data Acquisition is to make every bit productive, which means no physics information should be lost and at the same time no unnecessary data should be obtained. [11] .The needs of loss-less data acquisition have significant effect on instrumentation and specifically on the selection of acquisition hardware. [12]. In Industries, research centers and research institutes most of the machines and experimental setups are placed in a remote environment, such as a high magnetic field or high temperature etc. During the operation it's unsafe to access various instruments or devices. Hence in such cases the machine access control and personnel safety is a major issue and forms an integral part of its operational guidelines. Controlling, measuring and monitoring of different parameters and properties are done quite far from the machine. If done manually, then the probability of occurrence of human error cannot be neglected. Hence the design, development and deployment of an automatic and remotely operable system for the whole of these electronics systems and Data Acquisition and control unit are highly desirable.

MOTIVATION

In most of the diagnostic systems, the flow of signal acquired from the sensors to the Data Acquisition & control unit is as shown in figure below.

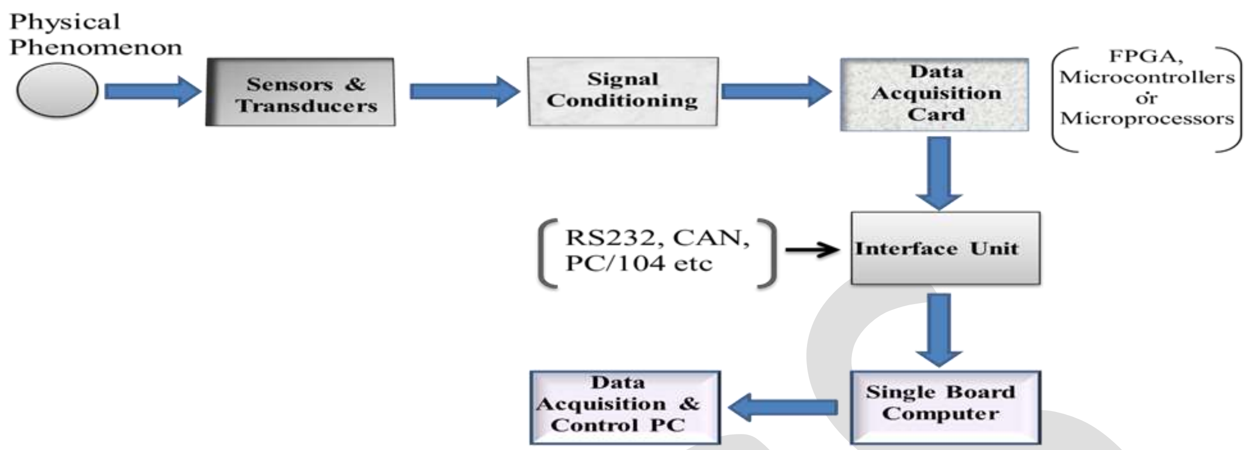

FIGURE 2: DATA ACQUISITION AND CONTROL FLOW

As can be observed, the signals from various sensors and transducers that acquires it from the physical architectures, are fed to the signal conditioning unit, which further sends the processed signal to the Data acquisition hardware board centralized with FPGA, where the signal is acquired and digitized. Now the data so obtained is sent to the Single Board Computer (SBC) through interfacing unit. The purpose here can be served using various interfacing and communication standards such as Serial communication through RS 232 based lines, or based on CAN bus, etc. But these options have some limitations as described below –

RS 232 :

- RS-232 Bus has a limitation of length.
- RS-232 found its applications where very low cost is more important than performance.
- RS-232 is comparatively slower.
- RS-232 supports peer to peer communication.
- RS-232 is a "Physical Layer" within the ISO/OSI model (not more).

CAN :

- Max speed is limited to 1Mbit/sec.
- All messages get broadcasted and there can be many recipients.
- Max length at full speed is limited to 30-40 Meters.
- Undesirable interaction more probable in case of CAN based communication.

Considering and overcoming these limitations we have selected the Ethernet communication.

ETHERNET :

The Ethernet has following hike over the options stated above:

- Ethernet is much faster than RS-232, max speed 10/100/1000 Mb/sec.
- Ethernet has a better shielding against magnetic disturbances (also in case of optical cables it's possible). On the other side RS-232 does not provided such property.
- Ethernet covers "Data Link as well as Physical Layer".
- Ethernet can go very long distance, i.e. not bound with length limitations.

Currently, for serving the purpose of transferring data to controlling PC using Ethernet is done with the help of an external processing unit i.e. a Single Board Computer (SBC). The single board computer is interfaced to acquisition module through PC/104 bus. The SBC used has its own limitations such as length and speed of PC/104 is limited; it requires an external separate power supply using SMPS. Use SMPS may cause damage to the circuitry due to its limitations which is undesired for the sensitive acquisition modules and circuitries. Also the whole assembly so made is bulky so as to be used as a general purpose board, and it also hikes the overall cost of the system.

These flaws can be resolved if any alternate module can be used which can serve the whole purpose with similar or enhanced efficiency and performance and using less power, space as well be cheaper than the current one.

RELATED WORK

In [2] authors used RS232 protocol based communication link between FPGA on DAQ board and the host PC. The signals digitized by serial ADC are sent to DAQ module centralized on SPARTAN 3 FPGA and further transmitted to the host PC as data via a RS232 interface. Authors associated with [3] used TCP/IP based communication to link the server and the client PC. The server PC communicates with the National Instruments (NI) make DAQ card over USB interface. The developed system provides good long range acquisition, but may cost high. Authors of [4] have proposed the concept and advantages of customized stand alone DAQP system with reconfigurable FPGA over the other DAQ boards present in market. For their design they have used NI make DAQ card with closest similarities with their proposed device, with multichannel multiplexed ADC for attaining 4 semi-simultaneous channels. In [5] authors have designed a data acquisition system with embedded PC/104 platform to cope with the ADITYA TOKAMAK's data acquisition system. The CPLD core is used to ensure control and bus interface logic. The embedded single board computer that supports PC/104 bus is used as a main processing unit which has Windows XP embedded operating system support. The designed system has MDSPlus and MATLAB based client application on host PC. A microcontroller based DAQ with PIC microcontroller as a core is designed by the authors of [6]. The system communicates with control PC via USB and the application program for the PC is developed using MATLAB. In [7] Authors had designed a Versa Module Europe (VME) based DAC for the SST-1 TOKAMAK's ECRH system based on gyrotron operation. The system uses Motorola make SBC, Power PC MPC107 and VME hardware as a target server while Fedora 6.0 based PC as a client. Here, Host PC and PowerPC are linked with 100 Mbps Ethernet link. MDSPlus has been used for the data management using the client/server model. In [8] authors with their work presented a Data Acquisition system in an Altys system from Digilent having FPGA core, and an ADC is attached with the Altys board. Instead of using any external processor like SBC the authors had implemented an 8-bit RISC processor with ATMEGA168 AVR architecture. A MAC logic core for system to support Ethernet compatibility is also implemented on FPGA.

PROPOSED DATA ACQUISITION SYSTEM

The main drawbacks of the present systems are slow data acquisition speed, low throughput, need of keen maintenance and bulky system due to SBC with PC/104 bus and the cost.

The focus of the work proposed is that if somehow SBC can be removed with suitable replacement that must be compact, having larger data throughput, reliable as well as easily reconfigurable.

The block diagram of the proposed system is shown in figure 2 below. In the proposed system, to avoid the bulkiness of the system, the whole assembly of the Single Board Computer (SBC), its power supply is replaced with the module of Ethernet controller, i.e. WIZNET's W5300 for the Ethernet communication operation. The purpose of control, processing and implementation of TCP server for the communication is fulfilled by the use of MicroBlaze's IP core of Micro Controller System (MCS), which is programmed using system C language in Xilinx Software Development Kit (SDK) Platform. The MCS serves the role of interfacing the FPGA with the Wiznet. The acquired data from the various sources are passed through MCS to the Wiznet and are then are feed to the network using Ethernet. Here, the flow of signal from FPGA to Wiznet is much higher as compared to the 1mbps speed of the PC/104 bus, due to a much faster 40 MHz clock which drives the MCS.

Now the Control PC connected to the same server as that of the assembly can access the data from Ethernet by the help of GUI made by graphical programming on the LabVIEW platform, which make the PC as a TCP client. The front panel of the GUI is shown in Figure 3. The analyst or controller can view, acquire, and also control the operation by manipulating various properties sitting far distant from the machine through Ethernet and proposed system.

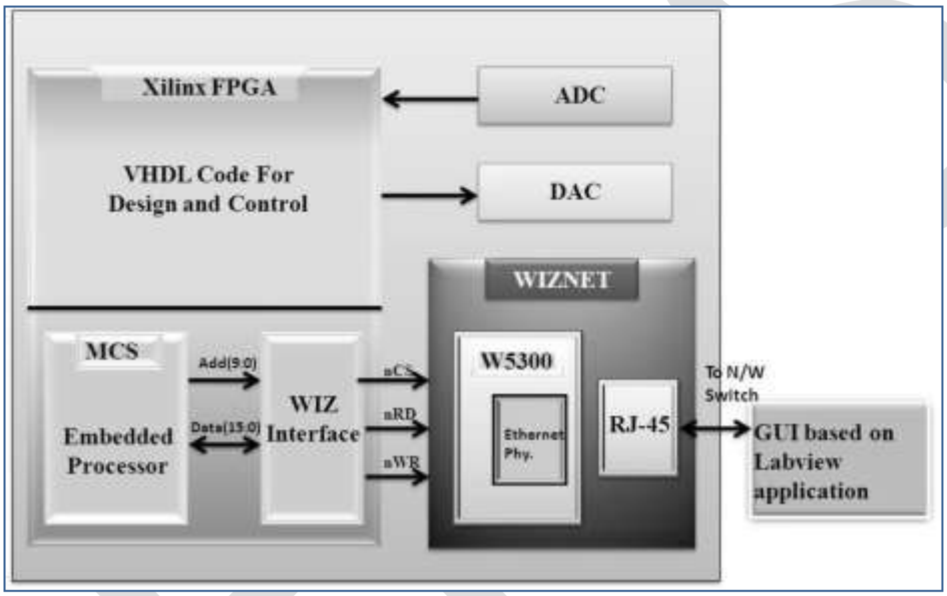

Figure 2: The Block Diagram Representation of the Proposed Hardware

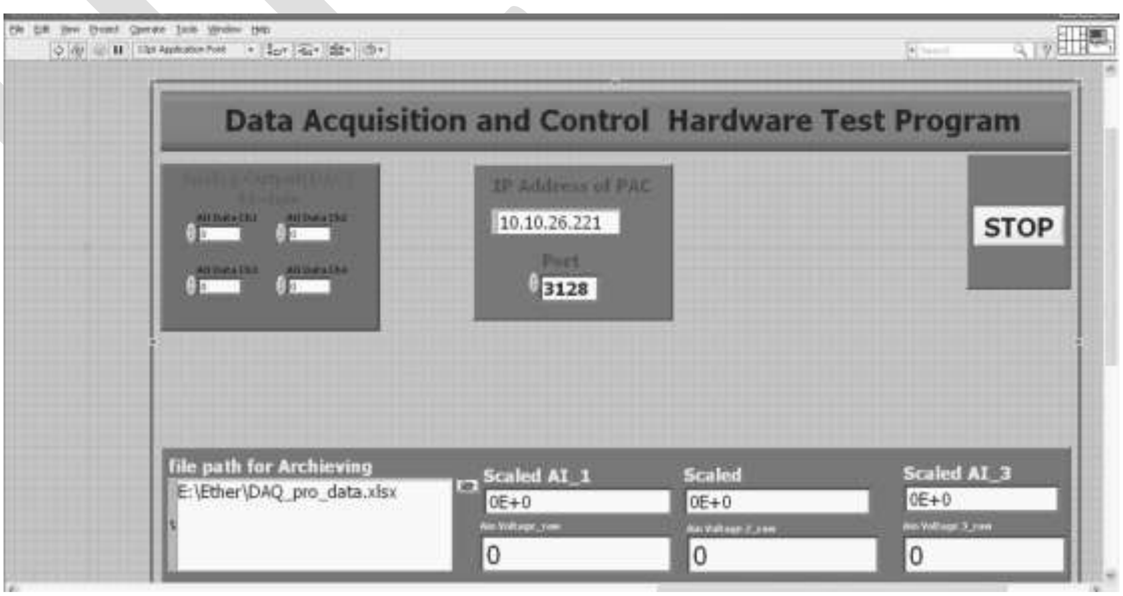

Figure 3: The Front panel of Client GUI on LabVIEW

There are various software platforms which can be used for serving the purpose of acquiring data and controlling for data acquisition system. Such as, MDSPlus, SCADA, LabVIEW, and various open source platforms for Linux O.S. based systems.

Among these, MDSPlus only have the characteristics of acquiring data but the purpose of controlling cannot be served by it, as well as it is not necessary that all the control and analysis systems have the Linux OS. Also, for fast data acquisition the hardware's made by National Instruments (NI) are well known and are used in the IPR. So, taking these aspects in mind the LabVIEW by NI is used Data acquiring and controlling.

To monitor and recording of the signals from the sensors or front end instruments a data acquisition system requires it to be digitized first. So for converting these analog signals to the digital equivalent Anlog to Digital converters (ADC) are essential. Here for our system, a Texas Instrumentation make, 4-channel ADC ADS1274 with 24 bit resolution is selected to get the better throughput and high precision of conversion. The ADC is interfaced with the Spartan 6 FPGA using SPI mode. The interfacing can be seen by the block diagram shown below:

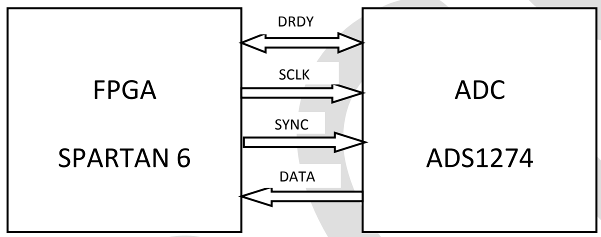

Figure 4: Interfacing of FPGA with ADC using SPI format

This ADC provides the sampling rate of about 128ksps with a wide bandwidth of 62MHz. The digitized data received by FPGA is then fed to DAC as well to the Ethernet controller (W5300), which feds this data further to the network through Ethernet link and hence to the control PC having TCP client GUI on LabVIEW. The flow of signal or data between client program on LabVIEW and Ethernet controller via Ethernet link is a two way flow, i.e. the control signal sent from the client GUI on LabVIEW is also sent to the DAQ via the Ethernet link which can be routed to analog out channels after conversion from digital form to analog by DAC. The flow can be seen in figure 2.

The digital control signals in digital domain need to be converted to the analog domain so as to feed the front end instruments. So a Digital to Analog Converter (DAC) comes to lime light. For proposed design AD5684 a 12 bit DAC made by Analog Devices (AD) is used. It is a 4 channel, low power DAC which offers 12 bit buffered voltage output. The DAC supports SPI interface, so it communicates with the FPGA via SPI link. The interfacing block diagram is shown below:

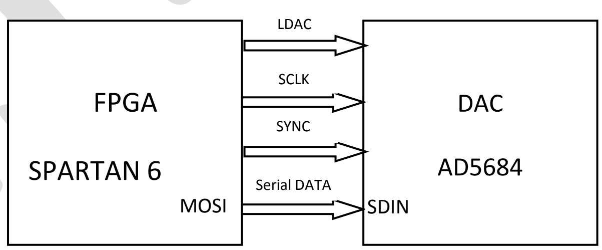

Figure 5: SPI interface between FPGA and DAC

IMPLEMENTATION AND RESULT

All the components are placed and properly interfaced with each other. Now, the software codes are written for FPGA on Xilinx ISE 14.6, using Very High Speed Integrated Circuit Hardware Description Language (VHSIC HDL or VHDL). A soft IP core of 32 bit

RISC micro-controller system (MCS); MicroBlaze is implemented on SPARTAN 6 FPGA. The firmware part that includes control signals for all the devices and the TCP server specifications are written on it using one of the Xilinx Embedded Development Kit; Software Development Kit (SDK). This program helps to configure Wiznet's Ethernet controller W5300 to establish the TCP/IP communication link between the TCP server, FPGA in DAQ board and the TCP client program on LabVIEW.

As a result of establishing TCP/IP link between DAQ board and the control PC, The board should respond to the PING command having IP address allocated to board. The response of Pinging is shown below:

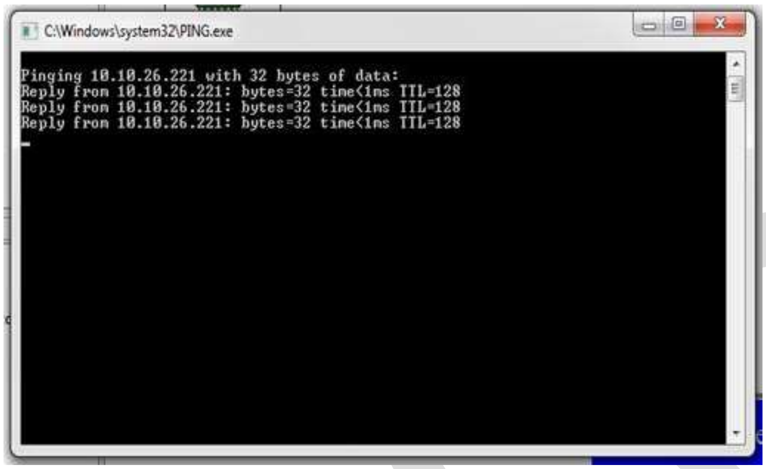

Figure 6: Response of PING command

The goal of the work is to design a Data Acquisition System which can acquire the external analog signals and the observer sitting far from the operational setup should be able to monitor and store those signals as a data for future calculations and study. Also, there is a provision that a observer or controller can manipulate the instrument's physical control parameters by sending a control signal with the help of control made on LabVIEW GUI from a remote location over an Ethernet link.

So, our system is able to achieve the above stated goals, the images below the LabVIEW front panel, the measurement of the output taken from DAC. The figure shows the measured output from analog output pins of the proposed board i.e. nearly equals the control voltage provided from the front panel of LabVIEW and also the input voltage to DAQ board can be monitored on LabVIEW (represented by white arrows).

Figure 7: Acquired voltage and control voltage output monitoring

CONCLUSION

The discussion on results shows that the proposed system performs as expected. A Data Acquisition board is designed keeping the survey results [1] in mind. A MicroBlaze IP core is included in the design. We have succeeded to establish a TCP/IP link between the designed Data Acquisition Board with the help of Wiznet's Ethernet controller and client GUI on LabVIEW. With the designed system we are able to acquire the voltage from outside and monitor it on LabVIEW front panel. Also the control voltage provided as an input from the LabVIEW client GUI on host PC to the board is received from the analog out pin of the board. As a future work it is thought to increase the number of channel, to increase the functionality of the board by making it compatible for Digital I/O and inclusion of memory. The improvement in throughput will also be on focus.

REFERENCES:

[1] Hemant Shrivastava, Utsav Malviya, "Survey and Analysis of Data Acquisition Systems" , International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE), Vol. 3, Issue 11,11341-11344, November 2015

[2] Swamy TN, Rashmi KM, "Data Acquisition system based on FPGA", International Journal of Engineering Research and Applications (IJERA), Vol. 3, Issue 2, pp.1504-1509, April 2013.

[3] Bingsheng Wu, Chaozhi Cai, "Remote Data Acquisition and Signal Processing System Based on LabVIEW", Proceedings of the International Conference on Measuring Technology and Mechatronics Automation, 2009.

[4] Mohammed Abdallah, Omar Elkeelany, and Ali T. Alouani, "A Low-Cost Stand-Alone Multichannel Data Acquisition, Monitoring, and Archival System with On-Chip Signal Preprocessing", IEEE Transactions on Instrumentation and Measurement, Vol. 60, No. 8, August 2011.

[5] Rachana Rajpal, Jigneshkumar Patel, Praveena Kumari, Vipul Panchal, P.K. Chattopadhyay, Harshad Pujara, Y.C. Saxena "Embedded data acquisition system with MDSPlus" Fusion Engineering and Design 87, 2166– 2169, 2012.

[6] Anindita Bora, Kanak Chandra Sarma, "Design of a USB based Multichannel, Low Cost Data Acquisition System using PIC Microcontroller", International Journal of Computer Applications, Volume 59– No.6, 0975 – 8887, December 2012.

[7] Jatinkumar Patel, H. Patel, N. Rajanbabu, P. Dhorajiya, B. K. Shukla, R. Jha and D. Bora, "VME Based Data Acquisition and Control System for Gyrotron Based ECRH System on SST-1", Fusion Engineering (SOFE), 2013 IEEE 25th Symposium on; 01/2013

[8] A. Mazare, L. Ionescu, G. Serban, I. Lita, "FPGA-based system for data acquisition and remote communication", IEEE 20th International Symposium for Design and Technology in Electronic Packaging (SIITME), 23-26 Oct, 2014.

[9] Yonghai Ning, Zongqiang Guo, Sen Shen,Bo Peng , "Design of Data Acquisition and Storage System Based on the FPGA", International Workshop on Information and Electronics Engineering (IWIEE) ,pp- 2927 – 2931, 2012.

[10] David Potter "Using Ethernet for Industrial I/O and Data Acquisition" IEEE Instrumentation and Measuring Technology Conference, pp: 1492-1496,1999

[11] T. W. Fredian, M. J. Greenwald, D. C. McCune, D. P. Schissel, J. Stillerman "A Discussion On Data Acquisition, Data Management And Remote Participation For ITER" presented in Columbia university's fusion department.

[12] **www.ipr.res.in**