# A Reconfigurable On-Chip Multichannel Data Acquisition and Processing (DAQP) System with Online Monitoring Using Network Control Module

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*Abstract*-**The data acquisition and processing architecture covers the most demanding applications in continuous patient monitoring for chronic diseases in medical field and also measuring the signals from industrial plants. The multichannel data acquisition is essential for acquiring and monitoring the various biomedical signals from biomedical sensors or signals from industrial sensors. The problem is that the data storage, hardware size and remote monitoring of the sensed signal/data, so the multichannel data obtained is processed at runtime and stored in an external storage for future reference and remote monitoring of the system is done using Ethernet/Wi-Fi supportive network control module. The method of implementing the proposed design is the system on-chip via field programmable gate array (SoC-FPGA) to reduce the hardware size and for memory size. The Soc-FPGA attains high resolution and real time processing of data acquisition and signal processing. A four channel data acquisition and processing (DAQP) was designed, developed using the Lab VIEW graphical programming. NI DAQ and NI FPGA module is used to test and implement the design for real time. The module was designed in order to provide high accuracy, storage and portability.**

Keywords-Data acquisition and processing, real-time, SoC-FPGA, multichannel, data storage, Network Control Module

## I. INTRODUCTION

The purpose of a DAQ system is to measure a physical phenomenon such as light, temperature, pressure, or sound. A DAQ system includes the following building blocks transducer, signal conditioning, DAQ device, driver level and application level software. With these five building blocks, we can bring the physical phenomenon we want to measure into the computer for analysis and presentation. Data acquisition systems (DAQ) are devices and/or software components used to collect information in order to monitor and/or analyze some phenomenon. As electronic technology advances, the data acquisition process has become accurate, versatile, and reliable [1] [2]. Typically, data acquisition devices interface to various sensors that specify the phenomenon under consideration. Most data acquisition systems obtain data from different kinds of transducers that produce analog signals. Many applications require digital signal processing. Therefore, analog signals are converted to a digital form via an analog to digital converter (ADC) to be processed.

Existing DAQs, can acquire single channel or multi-channel signals. Many applications require a multi-channel DAQ. Particularly, simultaneous multi-channel DAQs are employed in numerous applications such as medical diagnosis and environmental measurements. If the signals are simultaneously acquired, simultaneous acquisition of additional data can be used to obtain additional information within the same acquisition time. Multi-channel data acquisition (DAQ) is a crucial component in digital instrumentation and control. It typically involves the sampling of multiple analog signals, and converting them into digital formats so that they can be processed either on-board or externally. In either case, DAQ systems also involve microprocessors, microcontrollers, digital signal processing, and/or storage devices. Multi-channel DAQs, which utilize some sort of processing for simultaneous input channels, are needed in home health care monitoring devices.

In this paper, a low-cost real-time multi-channel analog signal acquisition and processing (ASAP) system is presented. It is divided into five systems. First, the multi-channel analog signal acquisition system is used to acquire multi-channel real-time analog signals. Second, archiving system stores the acquired data into a flash memory or SDRAM [1]. Third unit performs digital signal processing. Fourth, the frequency deviation monitoring (FREDM) system detects any change in input channels' frequencies. Finally, the heterogeneous maximal service (HMS) scheduler is presented to be integrated with FREDM system [2]. In home health care devices also in case of industrial data acquisition, storage is limited and power consumption need to be minimum. Therefore, fixed sampling rate is not the optimal solution for multi-channel data acquisition. Hence, heterogeneous sampling rates are identified for each channel, and optimized for best data quality with minimal storage requirement and power

consumption [1]. The fidelity of the ASAP system is increased by using reconfigurable chip technology, where flexibility, concurrency and reconfiguration can be achieved in hardware. This in turn decreases the size, the power consumption, and the cost of the system. Hence, another DAQ technology is needed, which is adaptive to the changing requirements, robust against faults, and small in size. Dynamically reconfigurable DAQ systems will have a crucial impact in some applications such as hazardous environments or isolated areas for remote architecture reconfiguration. Implementation of the design in FPGA brings the system energy efficient, reduction of size and low cost [7].

## II. LITERATURE SURVEY

DAQs involving FPGAs can be redesigned while mounted on the target system (hence the name field programmable) to reach fine-tuned performance or to reroute a faulty circuit to a new place. The recently introduced high-capacity FPGA allows for the integration of multiple components on a single chip. In addition, it can have all the processing, storage, and input–output capabilities that are needed by a DAQ system. It also has only dual channels. Therefore, it is not scalable. It also lacks the adaptive optimized sampling technique. Some other DAQs such as those in Lyrtech, Bittware, Hunt Engineering, and Southwest Research Institute only use the FPGA for limited purposes, where the FPGA works as a coprocessor for fixed-architecture-based processing units. [1],[2]. This prevents the design from achieving low-cost and compact-size advantages, should the design be fully integrated in a high-capacity FPGA.

Other research teams have utilized the FPGA (fully or partially), but they can only acquire a single input channel However, the proposed system is unique as related to existing technologies. Instead of using multiple ADCs for simultaneous multichannel DAQ, the proposed design uses a single high-speed ADC along with a multiplexer (MUX) to perform quasi-simultaneous DAQ. In the medical field, for example, where various biomedical signals are in the low frequency range from 25 Hz to 5 kHz, the proposed DAQ can be appropriate without the need for additional hardware or cost. For applications that require very fast simultaneous multichannel DAQ, such as in the military field, a dedicated ADC per channel will be more appropriate. A single super high-speed ADC can be efficiently used with an optimal sampling schedule to acquire multiple channels. Hence, this can reduce the circuit size, the cost, the power consumption, and the system scalability. Second, full system re configurability based on the FPGA is the best solution in terms of fault tolerance and portability, and the system can be reused with different configurations.

Third, hardware real-time adaptive sampling is only available in the proposed system. It leads to the design security where using the hardware design makes the reverse engineering immune and secures the design. In some cases the development of a wireless sensor Microsystems containing all the components of data acquisition system, such as sensors, signal-conditioning circuits, analog-digital converter, embedded microcontroller (MCU), and RF communication modules has become now the focus of attention in many biomedical applications [4]. This paper discusses innovation circuits and system techniques for building advanced smart medical devices (SMD). Low power consumption and high reliability are among the main criteria that must be given priority when designing such wirelessly powered Microsystems. Even though this system is highly wireless based and in advanced applications in biomedical field.

One of the most common problems that affect the system above is the stability of the sensor with time and that the interface circuits are able to follow the sensor signals at all times. No matter how desirable this situation is, in real life most sensors cannot fulfil this requirement. As a case study, a multi-sensor wireless system has been presented as an example of development a smart active telemetry system. Two mechanisms have been adopted to reduce further the overall power consumption. These are power scheduling and wakeup circuit for the capacitive interface. The first one is implemented fully by the MCU in order to switch on/off all the system units. A wakeup circuit has been designed to interrupt the MCU when it is in the sleep mode and the capacitive samples are changing significantly. It was found that such design is more suited for the capacitive interface than the resistive one where the circuit consumes much less power even if it is kept working continuously. This method talks only about single channel input and output Data acquisition.

The research is processed in the field of stem cell culture process. The system aims to measure in real-time the most important physical and chemical culture parameters of hematopoietic stem cells, including physicochemical parameters, nutrients, and metabolites, in a long-term culture process. The system is designed in a modular manner. Each hardware module can operate as an independent gain programmable, level shift adjustable, 16 channel data acquisition system specific to a sensor type [6]. Up to eight such data acquisition modules can be combined and connected to the host PC to realize the whole system hardware. The control of data acquisition and the subsequent management of data is performed by the system's software which is coded in LabVIEW. In the case of input signals with different bandwidths, the hardware real-time adaptive sampling is the best way to optimize the ADC sampling rate. Meanwhile, it also reduces the overall sampling rate that is required, which leads to the reduction of the cost of the required ADC with a large number of channels, particularly in high-frequency inputs.

## III.    DATA ACQUISITION AND PROCESSING (DAQP) MODULE

### A.  Multichannel inputs

The sensors or transducers used to measure the non-electrical signals as electrical signals. Generally in industrial applications the sensors are used in various type to measure heterogeneous parameters such as velocity, viscosity, pressure, temperature, level, friction and vibrations etc. In medical applications by measuring the electrical signals produced by the human body such as ECG, EEG,EMG and etc. Since they are the signals which are in analog it should be converted into digital [2][3]. These signals are typically a wave forms as sinewave or sawtooth wave or cosine wave. In existing methodology a signal generator used to generate the 1- 4- 8- 10 kHz of sine waves for four channel inputs [1] [2]. The n channel inputs can be used and it was multiplexed as n:1 using an multiplexer B. Host Interface Module The host interface module consists of different sub modules are analog MUX of n:1, analog to digital converter, and multichannel data buffer.

### B.  Multiplexer

A multiplexer (or mix) is a device that selects one of several analog or digital input signals and forwards the selected input into a single line. A multiplexer of 2n inputs has n select lines, which are used to select which input line to send to the output.[1] Multiplexers are mainly used to increase the amount of data that can be sent over the network within a certain amount of time and bandwidth. A multiplexer is also called a data selector. The analog MUX merges the the n number of input channel into an single output using an multiplexer. Each and every channels have different sine wave signals with different kHz frequencies, also here audio signals can also be used for different channels with varying frequency range.
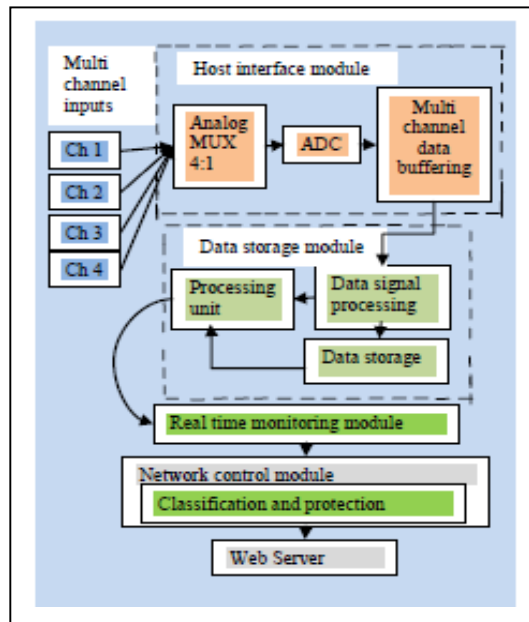


Figure 1. Block diagram of DAQP module

### C.  A/D converter and Multichannel data buffer

The analog MUX merges the the n number of input channel into a single output using a multiplexer, which force the input to the ADC. The analog to digital convers converts the multiplexed analog input signals into a digital output. The multi-channel data buffer is a temporary storage which collects the signals output produced by ADC for continuous time variation. Let n channels be simultaneously acquired by the proposed instrument design. Each channel is assigned a different number of time slots of the MUX time schedule [1] [2]. The acquired samples from the first channel are stored in a buffer. If the buffer is not full the buffer index is incremented, and the channel-assigned time slot is checked. If this channel has more time slots, ADC will acquire more data from this channel. If not, the selection lines (sel) are changed. This change provides collecting data from another channel. C. Data Storage and Processing Unit In the data storage and processing unit the digital data which obtained from ADC through the multichannel input signals are stored in a data storage unit it may be a flash memory. Data storage plays an increasingly essential role in data monitoring, control, and safety protection. Analog data storage is subject to deformation with time and poor privacy protection. On the other hand, digital instrumentation technologies are known for high processing capabilities, which allow them to perform intelligent onboard computing that supports functionality such as universal data storage. In addition, they also provide improved accuracy, flexibility, and easier data protection.[1][4] This is because the conversion from various analog signal types to a digital format simplifies universal data archiving and unifies data protection and communication schemes. While designing the data storage

block, our main purpose was to provide continuous data-acquisition capability along with random access to selected blocks of acquired data. The solution we have chosen consists of building a large block of memory, addressed circularly, where acquired data are directly saved under the responsibility of control logic contained in the data storage block.[5] This control logic also answers the host requests by fetching the required blocks of data. The only other intervention of the host processor in the process is the initial programming of the desired mode of operation of the data storage block. D. Real time monitoring module (Display unit) a virtual instrumentation user interface module is designed for the display of raw data and waveforms. This module has controls and indicators for controlling and monitoring which is developed using Lab VIEW platform [6]. The data log module is designed to record measured data into data files for further use.

### D. Network control module

The method of monitoring and controlling the Multichannel DAQP module through the internet is carried out using Network control module, where the virtual view of the system database can be controlled and monitored through internet. The need for remote monitoring is vital to measure some acquired signals. Any mobile system should consist of three main modules, these are: non-invasive technique to measure biological signals without doctor interfere, wireless system for transmitting data captured, and a user interface software to enable data acquisition.
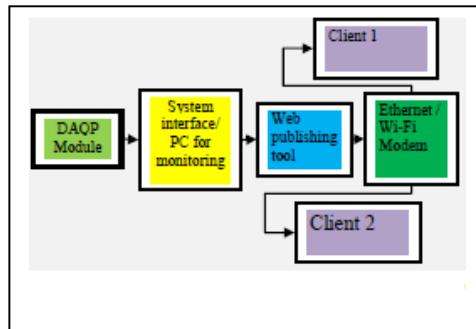


Figure 2.Network control module

The network control module (NCM) will securely transmit the acquired runtime signal and stored data to the internet. Which is highly used for runtime monitoring and controlling. The classification of various signals and protection of data form unauthorized access is carried using NCM shown in Figure 2. The protection is made possible by creating user ID for each individuals who accessing the data through web.

## IV. DESIGN IMPLEMENTATION

The experimental setup of this system was designed under Lab VIEW and National instruments (NI) DAQ board. The design consists of NI ELVIS II board which act as the DAQ card for interfacing the sensors, a NI cRIO (compact reconfigurable input and output) is used for design the complete system of applications and the biomedical sensors are used for acquiring the signals and NI SD memory storage module used for storing the acquired signal values. Shown in Figure 3.



Figure 3. Experimental setup of DAQP system

The NI Educational Laboratory Virtual Instrumentation Suite (NI ELVIS) is a hands-on design and prototyping platform that integrates 12 of the most commonly used instruments including the oscilloscope, DMM, function generator, and Bode analyzer into a compact form factor ideal for the hardware lab or classroom. A 100 MS/s oscilloscope option is available on the NI ELVIS II+. Based on NI LabVIEW graphical system design software, NI ELVIS, with USB plug-and-play capabilities, offers the flexibility of virtual instrumentation and allows for quick and easy measurement acquisition and display. This NI ELVIS II has analog input channels of 8 differential or 16 single ended, ADC of 16 bit resolution, input frequency upto 50 to 60 Hz. [8].

CompactRIO (cRIO) is a reconfigurable embedded control and acquisition system. The CompactRIO system's rugged hardware architecture includes I/O modules, a reconfigurable field-programmable gate array (FPGA) chassis, and an embedded controller. Additionally, CompactRIO is programmed with NI LabVIEW graphical programming tools and can be used in a variety of embedded control and monitoring applications. CompactRIO systems consist of an embedded controller for communication and processing, a reconfigurable chassis housing the user-programmable FPGA, hot-swappable I/O modules, and graphical LabVIEW software for rapid real-time, Windows, and FPGA programming. The cRIO has the processor performance of upto 400MHz, FPGA performance upto 43,661 logic cells upto 58 multipliers and run under real-time OS [8][9]. NI 9802 is a secure digital removable storage module which is connected with compactRIO, it holds the capability of Maximum storage of up to 4 GB per module, Sustained data write/read speeds of 2 MB/s

The NI 9225 C Series analog input module has a full measurement range of 300 Vrms for high-voltage measurement applications such as power metering, power quality monitoring, motor test, battery stack testing, and fuel cell tests. We can perform transient and harmonic analysis with high-speed simultaneous sampling at 50 kS/s per channel. In addition, we can prevent ground loops and add safety to a system with 600 Vrms channel-to-channel isolation between the three NI 9225 channels. The NI 9227 C Series current input module was designed to measure 5 Arms nominal and up to 14 A peak on each channel with channel-to-channel isolation. When used with the NI 9225 high-voltage module, the NI 9227 current module can measure power and energy consumption for applications such as appliance and electronic device test. With up to 50 kS/s per channel simultaneous sampling, we can not only measure and meter current and power but also look at quality factors such as noise, frequency, and harmonics.

## V. EXPERIMENTAL RESULTS

The design for the entire system is designed and developed using Lab VIEW block diagram panel window and the results are monitored with Lab VIEW front panel window. The Figure 3 shows the block panel design of multichannel data acquisition, processing and data storage and retrieval. First the signals are acquired from sensors using DAQmx function with necessary time limits and clock frequency and the task was created for continuous data acquisition and the task get ended. After the end of this task the data is stored and retrieved using TDMS file viewer where this function will store the individual signal performance values with respect to time and it was stored in an excel sheet. Then the data can be stored in a removable SD memory module. The sensors are circuited in NI ELVIS II board to collect the signals and each signal output from sensors are pinned to the CDAQ in cRIO chassis connected with SD memory module. The design was initialized and downloaded to the NI ELVIS and cRIO. The system will run continuously until the user stop the process.
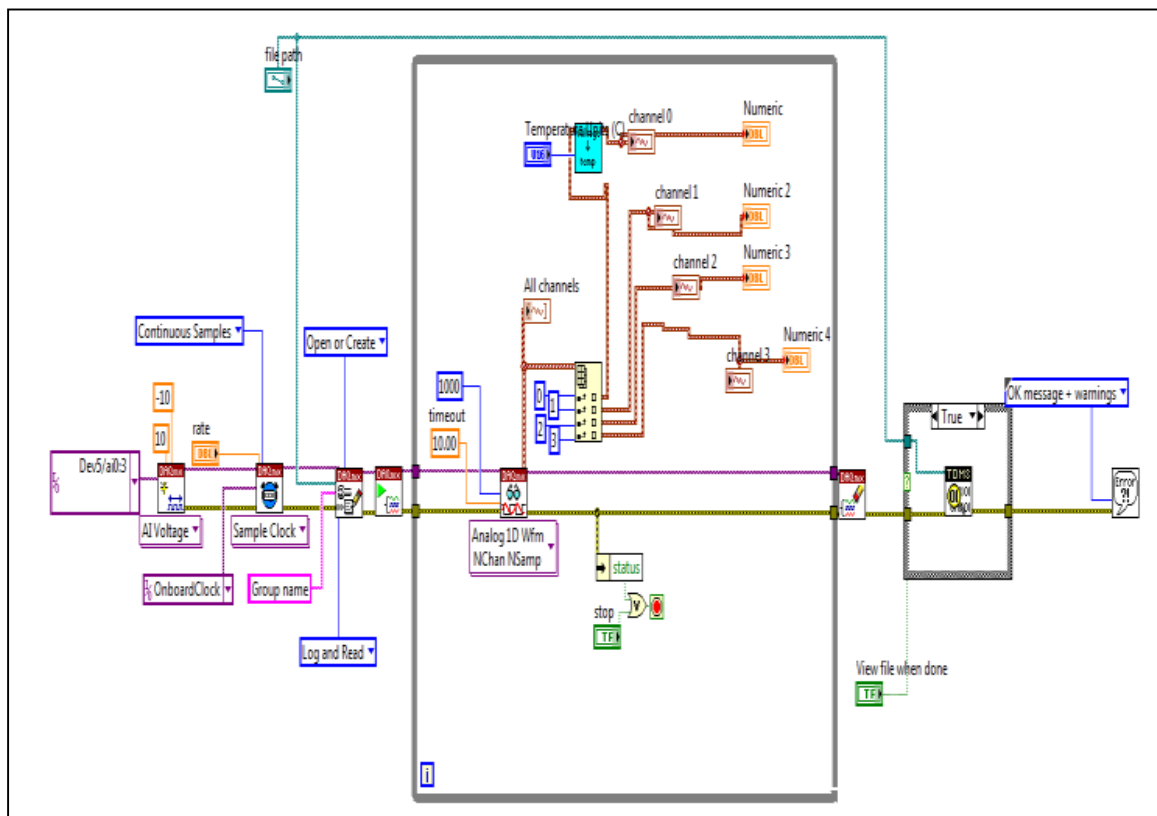


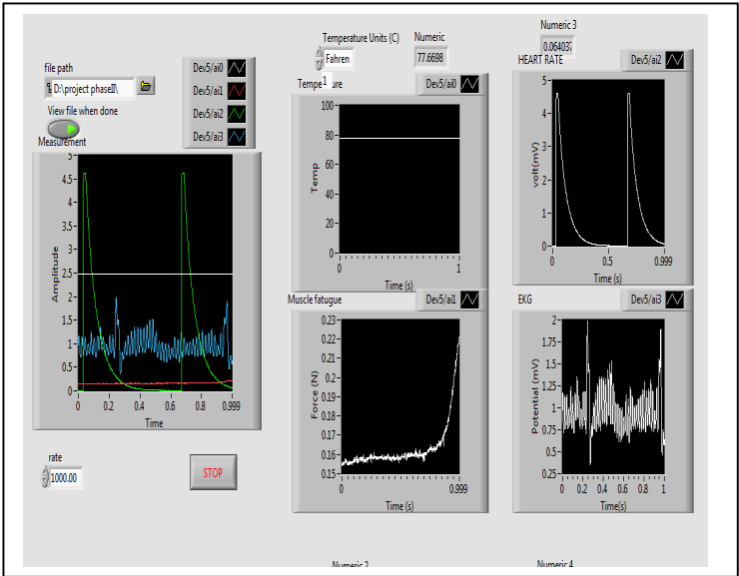Figure 4. LabVIEW G-code for Multichannel DAQP module

Figure 5. Front panel window showing acquired waveform

The above Figure 5 shows the front panel window of the multichannel data acquisition and processing system, this window shows the scope of all the channel output and the individual channel output. The sensor outputs of all channels are collected in a storage file for future reference appeared and stored in an excel sheet. The each column stores the performance with respect to time.
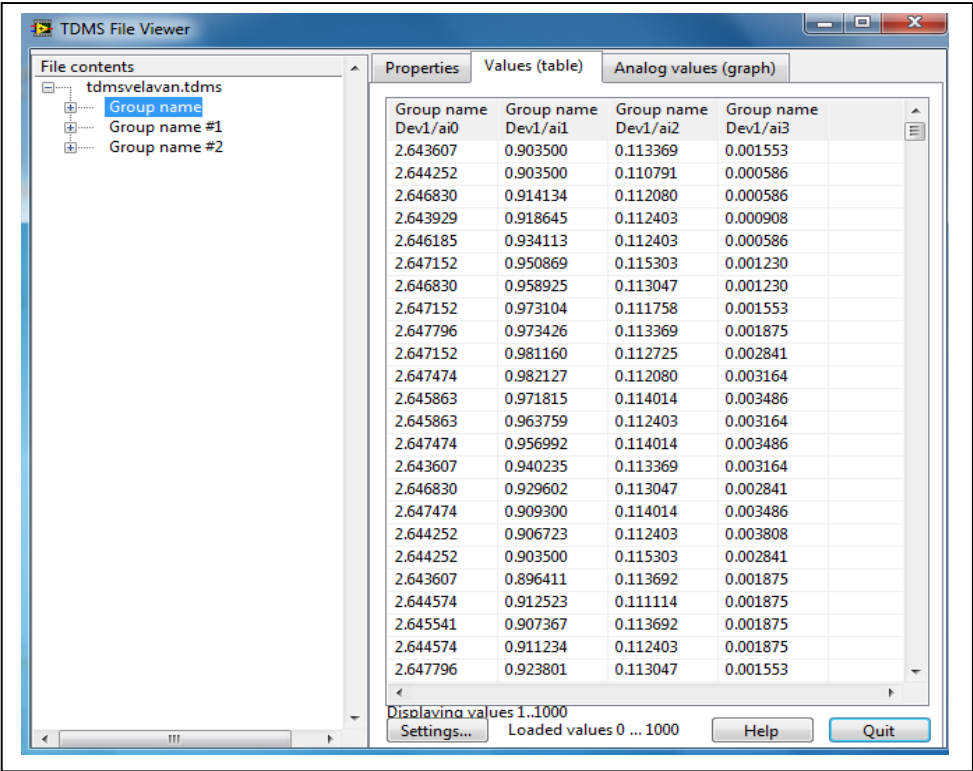


Figure 6. TDMS file viewer

TDMS files shown in Figure 6 organize data in a three-level hierarchy of objects. The top level is comprised of a single object that holds file-specific information like author or title. Each file can contain an unlimited number of groups, and each group can contain an unlimited number of channels. In general the analog signals from some measuring devices are stored in .wav file format which is machine readable. Here the TDMS file viewer will store the acquired signals in terms of .xml file format this will be both human and machine readable. By using the stored numerical values the user can retrieve the data in waveform for convenient and keen observation.

Figure 7. Real time monitoring on internet

The Figure 7 shows the real time monitoring of Multichannel DAQP system on internet for continuous monitoring and control through online. The use of TCP/IP can be applicable for this real time monitoring. Here the Ethernet data transmission and receiving can be accessed in high speed and accuracy.

## VI. CONCLUSION

This paper proposed a technique of on-chip multichannel DAQP system to monitor the human physiological parameters such as skin temperatures, heart rate, blood pressure and body strain. The novel aspect of the design is to bring the system into small size, portability, reduced cost, power consumption, and data storage. And publishing the real time database on internet for continuous monitoring. This is an enormous improvement over the existing products. The configurability brings the system to support with recent updating OS platforms. This entire system was designed and tested successfully using the lab view tool, NI DAQ and NI FPGA instruments. the tool lab view achieves the design simpler due to its graphical programming technique, code reusability and an easiest way to test the target system in real time while compared with the other programming languages like verilog, VHDL, etc,.

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