Research Journal of Applied Sciences, Engineering and Technology 8(16): 1814-1823, 2014
DOI:10.19026/rjaset.8.1169
ISSN: 2040-7459; e-ISSN: 2040-7467

Submitted: June 14, 2014 Accepted: August 03, 2014 Published: October 25, 2014

Research Article

Enhanced Data Acquisition System Using Embedded Ethernet for Industrial Applications

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Abstract: Aim of study a novel design of an Advanced Reduced instruction set computing Machine (ARM) system is proposed by means of embedded TCP/IP boards and using internet as the communication network between the systems. A new methodology of data acquisition and control based on embedded ARM platform is researched and developed here. This platform concentrates on the industrial safety by using ASP.NET. The proposed system reduces the data transfer time by efficiently collecting real-time data through the router and enables high security by user authentication. This system with ARM processor achieves impressive response and high speed data acquisition compared to the conventional approaches done using other processor. Further poor security system design and delay in data acquisitation faced in conventional methods have been eliminated and improved version with better reliability is achieved. This solution can be applied for upgrading the existing industries.

Keywords: Acquisition system, automatic collection, data acquisition, data logger, device management, industrial monitoring, protocol stacks

INTRODUCTION

The Internet has now been providing a new and highly-efficient medium for sharing information all over the world. The development of web technologies allows information to be displayed numerically and graphically on any conventional internet browser. Via Internet browsers (or web-browsers), end users can access, monitor the real-time data and even control the field devices and equipments. Transmission Control Protocol/Internet Protocol (TCP/IP) board helps to create an internet protocol based network which provides high flexibility with several security tools for secure operations (Zhao *et al*., 2009; Fabiano *et al*., 2009).

A remote data acquisition system using power system's hardware was presented by Daogang *et al*. (2010). This application software, based on the server/client module, dose the task of performing the data communication over the Internet. Data Socket Server module and virtual instrumentation created by National Instruments., Bogdan *et al*. (2010) which eliminates the difficulties of Transmission Control Protocol (TCP) programming, was used. The system was protected by password-authentication, approved Internet Protocol (IP) addresses and a physical protection scheme for the power hardware. The research gives users the ability to monitor data, which had been logged and saved in the server's database, in the form of trends and tables via web-browser (Krisada *et al*., 2007; Sun *et al*., 2009a; Sun and Yi, 2009; Sun *et al*., 2009b). Khusvinder *et al*. (2009) this paper identifies the reasons for this slow adoption and evaluates the potential of ZigBee based home automation system and Wi-Fi network are integrated through a common home gateway.

In order to provide a solution to improve the communication ability, a model of a web-based remote load supervision and control (Ali Ziya and Mehmet, 2009; Daogang *et al*., 2010) was built. These papers dealt with data acquisition system of an industry. The work acts as both monitoring and commanding system. Both the process is done through internet using server client technique. In the conventional technologies for data acquisition system, there were many problems such as very low data transmission speed, no secure data acquisition system and the user can only view data but cannot control the field devices through internet. An advanced Reduced Instruction Set Computing (RISC) system is proposed and designed with embedded TCP/IP boards and Internet for industrial automation. This resulted in a high speed and secured data acquisition system. This proposed system used the server/client frame work that is the system consists of several Remote Terminal Units (RTUs) and one Central Unit known as Advanced Reduced instruction set Machine (ARM). Sensors are used to collect data from and give control to field devices and these data are stored in the server using transmission control protocol stack. The main feature of the system includes automatic collection of system's latest data and display of real-time

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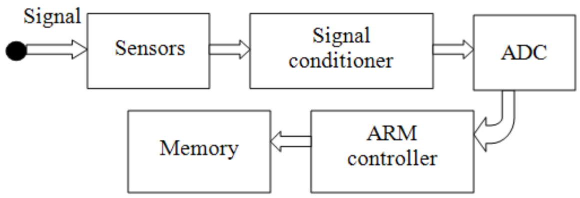

Fig. 1: General block diagram of data acquisition system

data on web-browser interfaces. Users can manage and issue control commands on system's devices from anywhere through an internet-connected system. Security issue is carefully considered with server protection by router and user authentication. This helps to reduce the threat of public nature in the internet.

The proposed system provides a solution by implementing Internet-based ARM systems with the presence of embedded TCP/IP Protocol stacks. This application software provides the following features:

- Automatic collection of the latest system's data and display of real-time data on web-browser interfaces.
- Users can manage and issue command controls on system's devices from anywhere through an internet-connected system.
- Security issue is carefully considered with reduced threat and improved public nature.
- New sites/devices can be added/deleted/tracked easily.
- System operation can be tracked for each user by the event log tool.

Proposed system: A novel design procedure is proposed for an ARM Device which drives embedded data acquisition system (an application Specific embedded Board). The proposed design is prepared using C language, which could drive the Embedded Data Acquisition System. This design is capable of installing the embedded data acquisition system device in any target environment.

The proposed system will also enforce study of embedded data acquisition and study of secure data transfer through internet. The data logger which plays a vital role in many areas is used which will help us to have an accurate idea about the data collection. Data logger is used in many environments such as aircraft, CNC machine, space vehicle, satellite (Ali Ziya and Mehmet, 2009; Daogang *et al*., 2010). This proposed data acquisition system collects the data from the real time system and records the collected data to a file system or a database is as shown in Fig. 1. This unit is very helpful during research, development and maintenance of any such system.

The information generated by the database is used to analyze the functionality of the system with large number of parameters. During research this unit helps engineers to collect database about the behavior of the system that is under development. During maintenance this unit will provide valuable information which would help the engineers pin point the section which needs service/maintenance. This unit could also be coupled with a server unit which in turn is used to generate control words to various counter controls. The developed logger system using an ARM LPC 2292 controller is a powerful, high performance, controller which can be used in high volume application. The intention of using ARM controller is to achieve impressive response.

System architecture: The proposed system is built based on the client-server model with Internet being the communication network (Fig. 2). Several network

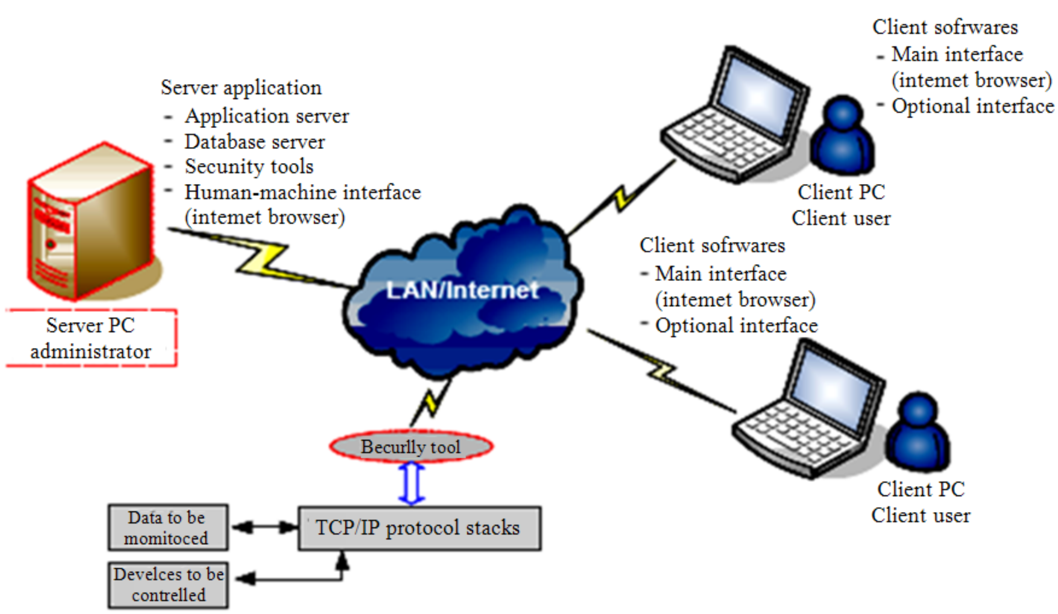

Fig. 2: System architecture

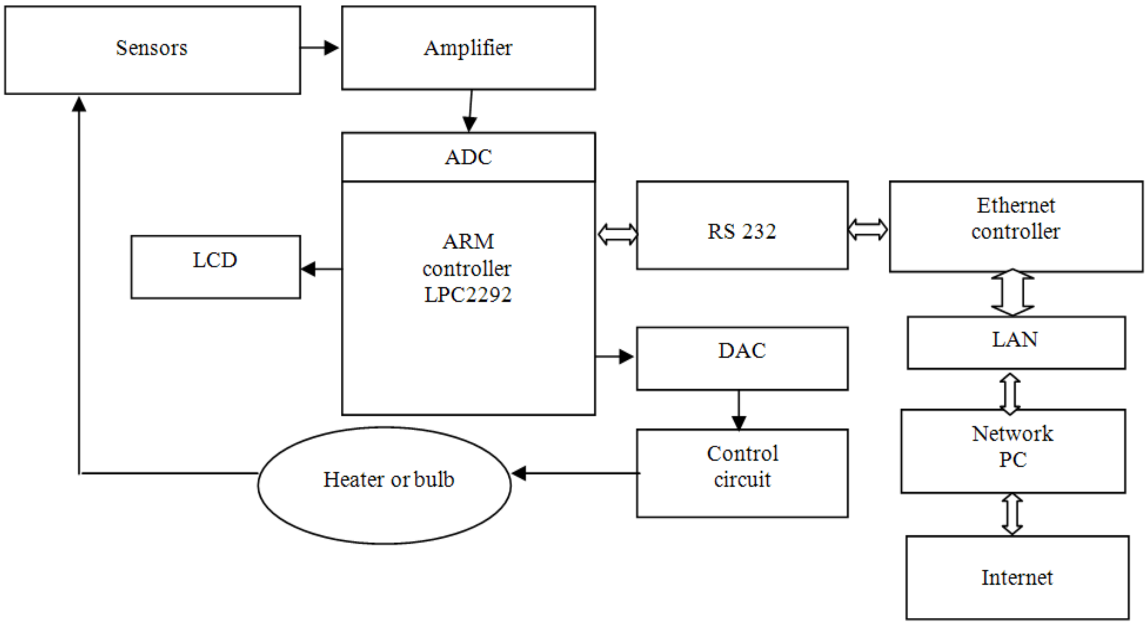

Fig. 3: Overall block diagram for embedded data acquisition system

programming techniques which are used to develop the system's software are discussed.

Server tier: The server is built as a Web-based application using ASP. NET composed of four functional modules: Real-time Data Acquisition, Device Management, Event Logs and Security Management.

These modules bring the ability to collect the system's data and display data on Internet browser in real time; to give control commands to devices; ensures the security of the entire system and tracks the system deals (Kai *et al*., 2009; Zhao *et al*., 2009).

Client tier: There can be more than one client computers in the system, as long as authenticated. Client users can monitor data in real-time and issue supervisory control commands. There are two communication methods:

- Through Web-browsers authorized users can access and use the provided functions of the system through the web-based interface.
- Through the IP addresses of the TCP/IP Protocol Stack With IP-supported Protocol Stack, client users can interact directly with system's data and devices by a VB program.

TCP/IP protocol stack: This is a special hardware embedded with a Dynamic Link Library (DLL) module. Supporting TCP/IP protocol, this module interfaces with the field device, collects data and sends these data to the Internet. It also has the tasks of receiving the control commands from the users and placing them on the field devices.

Field devices: The Protocol Stack collects data from these field devices. They perform the actions following the control commands from system's users. This unit is the data acquisition system which will collect the data from the real time system and record the collected data in a file system or a database. The database which is generated by this unit is used to analyze the functionality of the system with large number of parameters. In the proposed design powerful, high performance logger system using an ARM LPC 2292 controller. The block diagram of the proposed system is as in Fig. 3.

Several sensors such as temperature sensor, humidity sensor, fuel level sensor, attitude level sensor, oxygen level sensor, speed sensor, wind speed sensor; voice recorder can be used with the ARM processor to control the sensors.

These eight inputs to the controller can be from any device. In this system the board was designed in such a manner to analyze the temperature of the bulb and to control the bulb temperature by using a TRIAC controller. The ARM used is LPC 2292 (Fig. 4). This ARM is programmed in such a way to accept 8 different inputs from 8 different sensors to convert the analog data to digital data and then to display the digital data in the LCD display. The ARM is programmed using KEIL C programming. KEIL C programming is very similar to that of C programming but it has many specialties. This helps us to develop a human interface between the circuit board and the system. After embedding the KEIL C program into the ARM, the ARM will start its own process and then it senses the value and prints it on the LCD. In order to have the data output in the nearby system or on any human interface, another program is used which acts as a linker between the circuit and system and vice versa. So whenever the

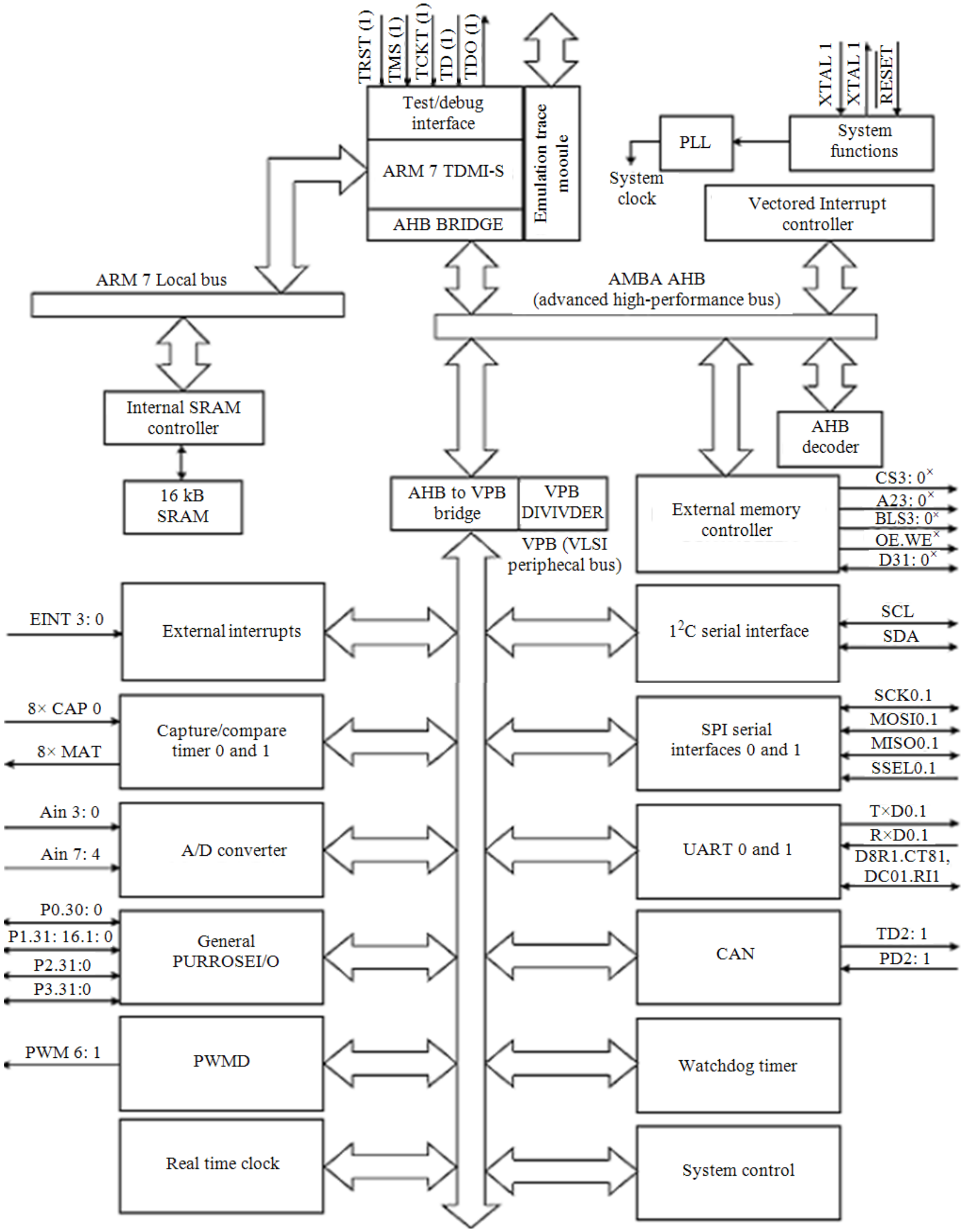

Fig. 4: Internal architecture of ARM LPC2292

board gets started, data displayed in the LCD is also recorded in the system.

This helps in easy recovery of data when needed. The system transfers data not only through the RS232 cable but also through the internet and LAN creating multiple data recovery system.

ARM architecture: This LPC2292 comes under the vendor of Philips. It is based on a 16/32 bit ARM7TDMI-S CPU with real-time emulation and embedded trace support. The 16-bit Thumb Mode reduces code by more than 30% with minimal performance penalty. With its 144 pin package, low power consumption, various 32-bit timers, 8-channel 10-bit ADC, 2 advanced CAN channels, PWM channels and up to 9 external interrupt pins this microcontroller is particularly suitable for automotive and industrial control applications. With a wide range of additional serial communications interfaces, it is also suited for communication gateways and protocol converters as well as many other general-purpose applications. On-Chip static RAM is used for code and/or data storage. The SRAM is accessed as 8, 16 and 32 bits, respectively. It provides 16 kB of static RAM. The Vectored Interrupt Controller (VIC) accepts all the interrupt request inputs and categorizes them as Fast Interrupt Request (FIQ), vectored Interrupt Requests (IRQ) and non-vectored IRQ as defined by programmable settings (ARM Ltd., 2007; Meijuan *et al*., 2008).

These schemes prioritize the interrupts from various peripherals dynamically. Fast Interrupt request (FIQ) has the highest priority. If more than one request is assigned to FIQ, the VIC combines the requests to produce the FIQ signal to the ARM processor. The fastest possible FIQ latency is achieved when only one request is classified as FIQ, because then the FIQ service routine can simply start dealing with that device. Sixteen interrupt requests can be assigned to this category.

Any interrupt requests can be assigned to any of the 16 vectored IRQ slots, among which slot 0 has the highest priority and slot 15 has the lowest. The external static memory controller provides an interface between the system bus and external memory devices. It provides support for up to four independently configurable memory banks simultaneously. Each memory banks is capable of supporting SRAM, ROM, Flash EPROM, Burst ROM memory, or some external I/O devices. Each memory bank may be 8, 16, or 32 bits wide, respectively. It supports emulation and debugging via a JTAG serial port. A trace port allows tracing program execution. Debugging and trace functions are multiplexed only with GPIOs on Port 1so that all communication, timer and interface peripherals residing on Port 0 are available during the development and debugging phase, when the application is run in the embedded system itself. It also contains two/four CAN controllers. The CAN is a serial communications protocol which efficiently supports distributed real-time control with a very high level of security by Qishen *et al*. (2010) and Krisada *et al*. (2007). Its domain of application ranges from high-speed networks to low cost multiplex wiring.

Control circuit: The control circuit used is TRIAC controller. This TRIAC controller will control the heater or bulb. The input of the bulb is reduced and then the brightness of the bulb is also controlled.

Temperature sensor: The temperature from the heater or bulb is measured and these analog values are sent to the ARM controller. Here LM35 sensor and thermistor is used to transmit the received data to ARM controller. The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius temperature. This has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient centigrade scaling. This does not require any external calibration or trimming. It has low output impedance, linear output and precise inherent calibration making interfacing readout control circuitry especially easy. Figure 5 shows the temperature sensor specification used in this study.

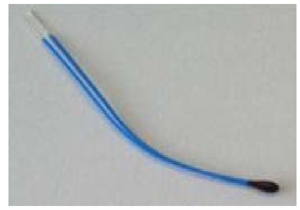

Fig. 5: The temperature sensor

MATERIALS AND METHODS

Experimental system: The hardware and software used to develop the proposed application software using ARM processor is described below.

Simulation software: The entire coding for ARM LPC 2292 is written and simulated using KEIL C software. The Simulator is the only debugger that completely simulates all on-chip peripherals of the ARM devices. The code coverage feature of the simulator provides statistical analysis of the program's execution. The simulated coding of KEIL C is converted into HEXA file and the same is burned into ARM controller using RS232. This ARM accepts all the analog value from different sensor and converts it to digital. These digital values are stored in a register and the same was displayed in the LCD. These values can also been viewed in the serial communication window of any system by setting the baud rate.

Hardware components:

Server computer: The computer used is equipped with Windows XP Service Pack 2 (SP2), 3.0 GHz CPU Speed and 1 GB RAM Memory.

The server computer contains 80 GB for the hard disk space and it will serve as both application server and database server.

Client PCs: The client is equipped with Windows XP SP2, 2.0 GHz CPU Speed and 1 GB RAM Memory.

Modem/router: Containing a built-in modem, the router has the task of connecting the system with one

Fig. 6: Ethernet IO board

ISP (Internet Service Provider), making the system available on the Internet.

TCP/IP protocol stacks: The boards named Ethernet IO (Fig. 6) developed by Design-Gateway Co is used. It contains a LAN connector, as connected into the Ethernet network together with the server computer. They collect data from the field devices and transmit these data to the server. Additionally, with a network processor, the boards can support the TCP/IP protocol.

System software's: The same data can also be stored in the server and that server is designed using VB. The server window is shown in Fig. 7. This server is a highly secured one and the data stored in the server is transmitted over internet using ASP.NET, where the internet acts as a client. The client windows are as shown in Fig. 8 (Lucia *et al*., 2008; Qishen *et al*., 2010). These clients access the data and command the system connected with the server. Each client is given their respective username and password for providing high security on the client side. From the client side, the communication mechanism in the network start with client's requests being sent to the server application software. Server processes these requests and forwards them to Ethernet board modules. The modules react to these requests and respond with the latest data back to the server and then server will send these data to the client interface. Users can also operate the system right at the server computer. From the server computer, the system communication happens within the Ethernet network, achieving higher communication speed. However, in most cases, users will work from client computer over the Internet and the server computer will run 24 h a day.

The server application software is written in Visual Basic as a website to provide all the functionalities including user management, device and data management, event log and security management. The Web-based application in the server is built using the latest technologies from Microsoft, including Internet Information Service (IIS) 5.1,. NET Framework 2.0, MySQL 4.1 and ASP.NET 2.0. MySQL is used to build

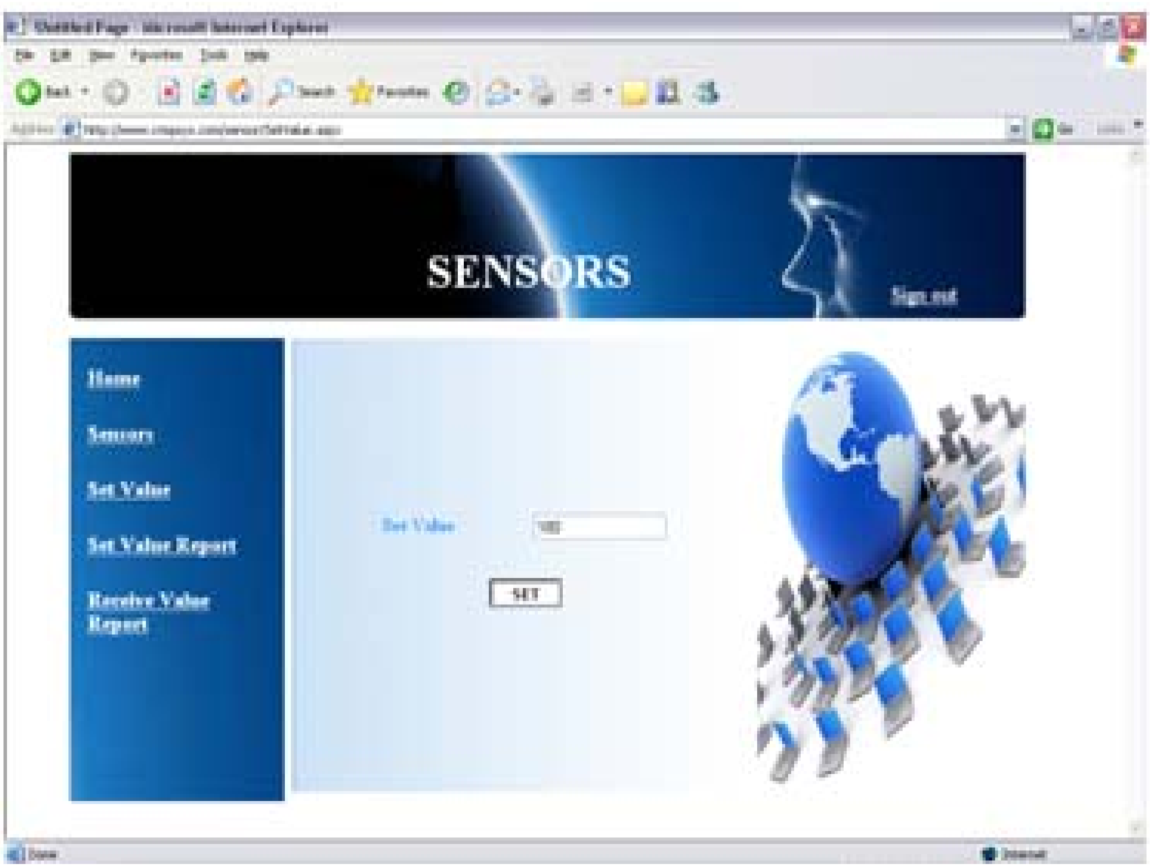

Fig. 7: Server window

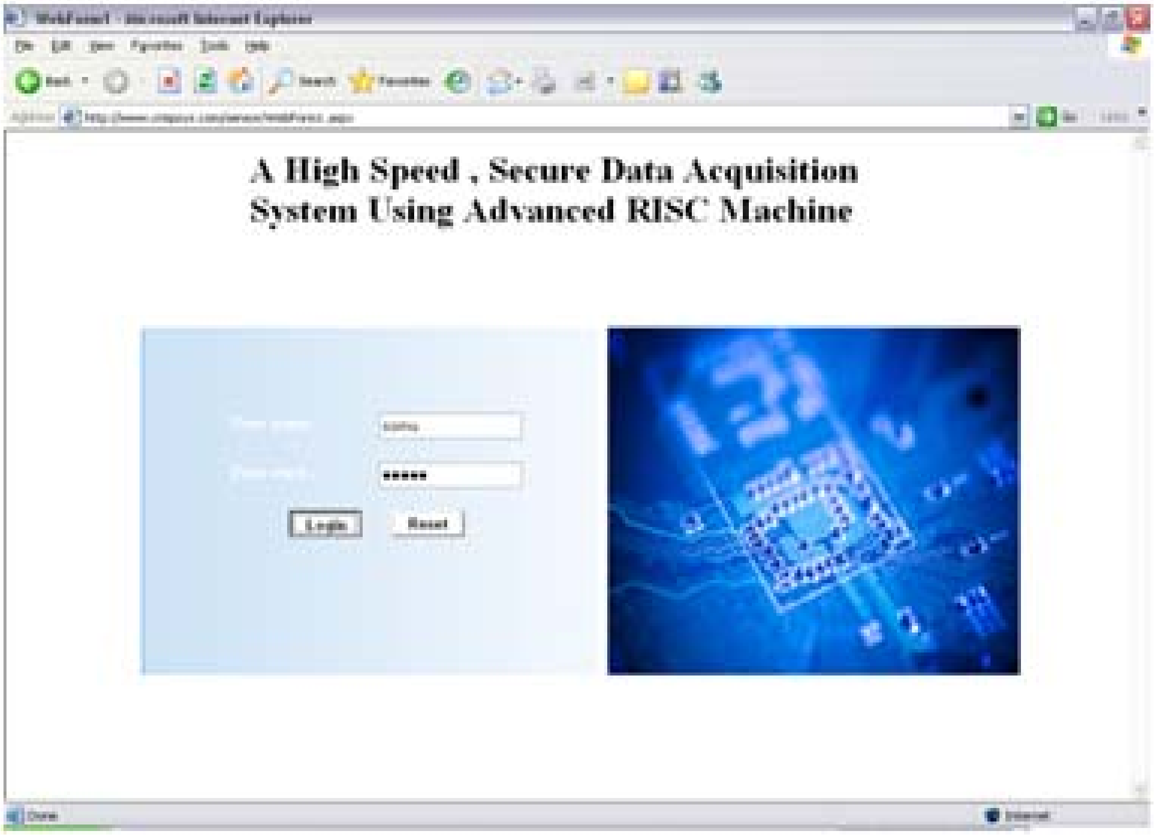

Fig. 8: Client login window

the system Database (DB) and all connections made to the system's DB conform to ODBC standard. The DB contains tables and each table intern contains information about a group of objects which are to be used in each system's functionality by Li *et al*. (2010) and Chen *et al*. (2010).

Each item in a DB table is considered as an object. The model object-controller is used throughout the system's operation, which handles the corresponding controller for any object in the system such as user, device and event. This system software is compatible with other DB platforms such as SQL Server or Oracle. ActiveX technology is used for the management on system's data and devices. This ActiveX is written in Visual Basic and stored in the server application software. Once the client users open the server's website, this ActiveX is automatically downloaded and installed to the client computer. Client users can then perform system management via their Internet browsers (Chen, 2009).

Users management: The system defines two types of users: administrator and client users. Each user possesses an information profile and has to be authenticated by a specific username and password to gain access to the system. There can be only one administrator at a time. The administrator has full control on all the system's functionalities and normal users. Client's users can have specific rights on system's devices and data but do not have the management functionalities. In necessary cases, even the existing normal users might be locked from accessing the system.

Data management: Server will keep requesting the Ethernet board to send back their latest data every 0.25 sec. These data will also be displayed in real time manner. Real-time data are sent over the Internet and displayed on client's Internet browser. During system's operation, client computers keep sending requests for data to the server computer with the same interval of 0.25 sec. The application software provides users the ability to view history data on selected date and time. History data will be recalled from the client's DB and displayed upon requests as shown in Fig. 10.

RESULTS

The proposed system output is viewed online in all three different methods and the results are as shown in Fig. 7. The entire database of all sensors is connected with the server. The high peed secured data acquisition system using advanced RISC machinec by the proposed system can be viewed in client window is as shown in

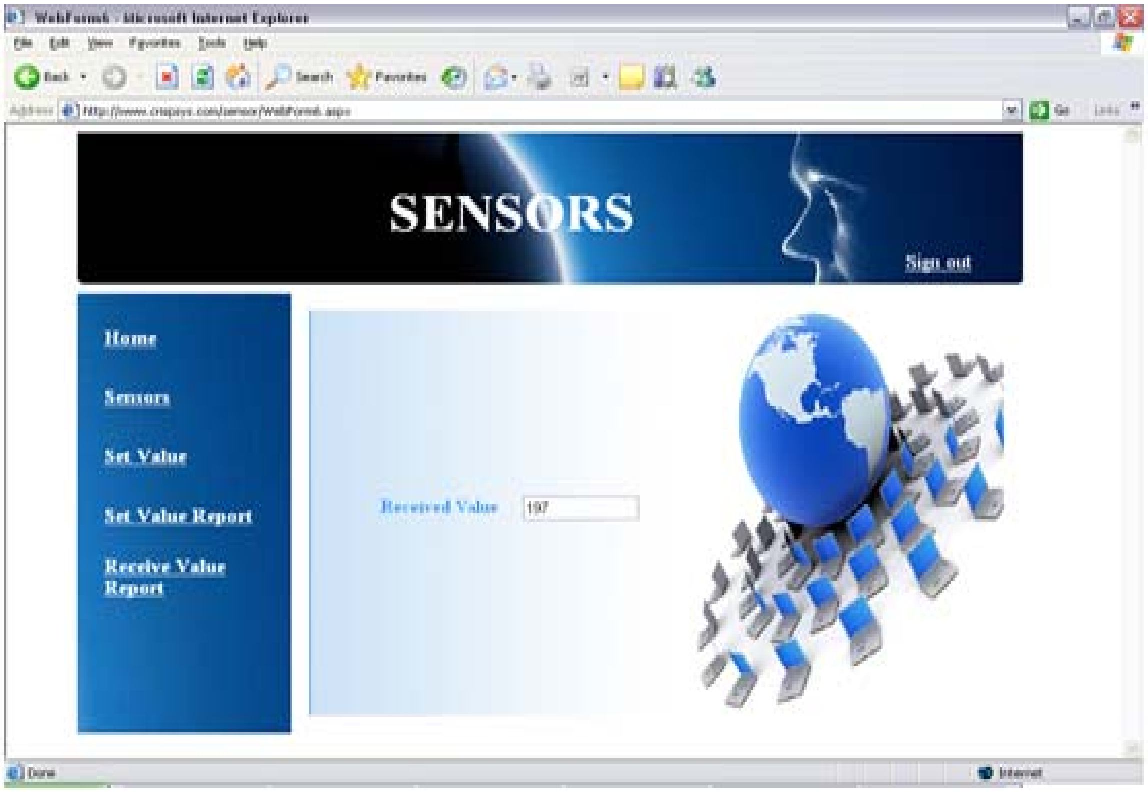

Fig. 9: Received value of temperature sensor

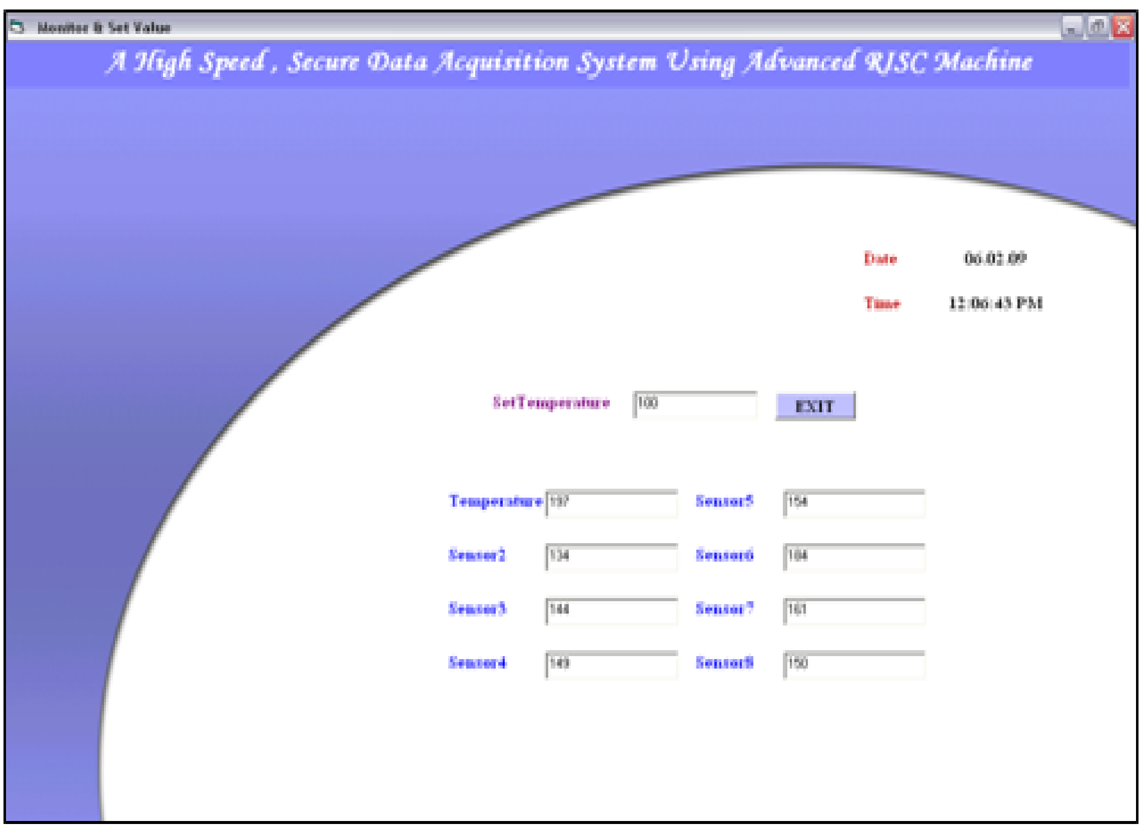

Fig. 10: Commanding window from client

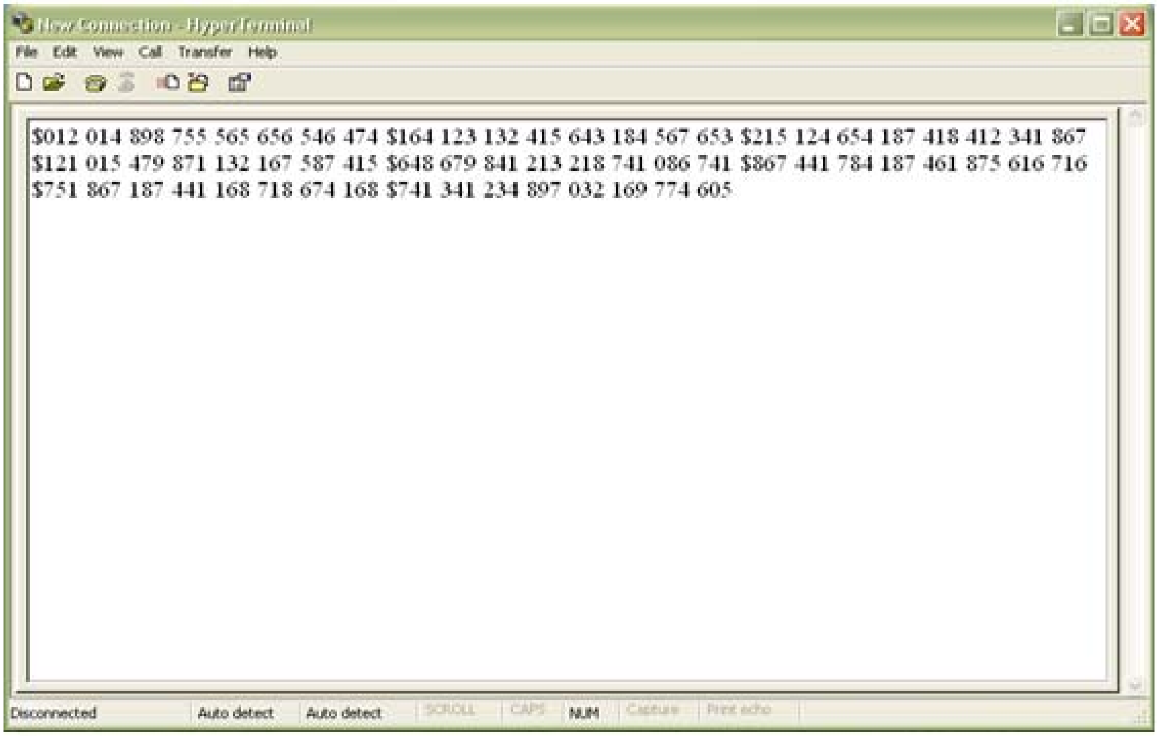

Fig. 11: Serial communication window with all sensor value

Fig. 8. The output of various sensors and its command window developed by this technique is highly secured and user friendly as viewed from Fig. 9 to 11. History data will be recalled from the client's DB and displayed upon request as shown in Fig. 10.

DISCUSSION

Device management: In this operation, users can place control commands and manage the system's devices using IP addresses. Overall principle for device controlling for both client users and administrator is by using IP addresses.

Security management: The system is protected by several tools from the router to the device themselves. The router provides the ability to manage and allow the types of connections that might be made to the server computer. In the server application, connections are restricted by the IP addresses of the client computers wishing to work on the system. Either only one IP address or a range of IP addresses or any IP address might gain access to the system.

Comparative analysis: On comparison with different methods the proposed system has the following features:

- Less Memory usage
- High Execution speed
- Low application code size and less power consumption

On comparison with other conventional processor application the proposed system has better performance.

CONCLUSION

It is now becoming more viable and desirable to monitor data and even to place control commands on devices in a real-time manner with Internet as the communication network. In the proposed system, an ARM systems based on internet is implemented with real-time data monitoring, device control and security features. The proposed system is built with web-based ASP.NET programming. The solution has addressed and solved the weak points which are security, reliability and real timeliness of existing system and the experimental results validate it. Users, as long as they stay connected to Internet, can monitor system's data in a real-time fashion and perform control actions on system's devices. With all the tools provided, the security issue had also been considered carefully and ensured at a higher level. This also helps the system protect itself while other researches on Internet-based ARM systems are only focusing on data and device management. The presented solution is easy to implement and familiar to use with Internet browsers, while it still brings high flexibility feature by using the IP-supported hardware components. Other concerns regarding the Quality of Service (QoS) such as dropped data packets or delay or out-of-order delivery had been rarely found during system's operation. With the development of hardware devices and Internet-based software technologies, the proposed research is most suitable for applications like Fuel Unloading/storage and Feed, Water Supply Monitoring, Irrigation, Flood Warning, Oil and Gas Tracking. Further study on this research can be based on other web technologies such as Java or Ajax to provide a more interactive operating environment in the system. In case of being applied onto real hardware's, web camera servers can also be added at the device or process places to provide the visual image of the devices' reaction for better system's performance evaluation. The addition of the IP (Internet Protocol) camera along with the Wi-Fi network can be extended as the future work of this proposed system.

ACKNOWLEDGMENT

The authors would like to thank the reviewers and editors for the useful comments, which helped us improve the quality of this study.

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