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Industrial remote data acquisition and control system based on embedded ARM9 platform integrated with mobile communication

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Abstract− Compared with the conventional solutions to control and data acquisition, the device based on the embedded system offers the widest range of features and flexibility, with an overall design for reliability, durability and ease of installation**.** The design and development of embedded data acquisition and control is presented along with alert system inclusion by the integration of GSM module. Using an advanced and high integrated 32-bit RISC microprocessor, the electronic systems are compact and the device has high performance. Friendly ARM9 board which is having an inbuilt DM9000 Ethernet controller was tried as web server for data acquisition, online supervisions, control and data recording for future purpose. GSM module is interfaced to on/off the devices, to vary the set point and to get the alert message to the user to avoid instrumental damage and accidents in the industry.

Keywords− Embedded system, Data acquisition, Monitoring, Control, ARM9, GSM, and Local Area Network.

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I INTRODUCTION

Embedded systems are developing fast and have been used in control and data acquisition. As embedded system is of high performance and the cost is low, it has the tendency to play the great role of control and data acquisition (2). In this paper, we are describing an embedded system with an onboard Ethernet interface allowing remote device monitoring, control and data acquisition and GSM module to give monitoring control and critical data to particular user in case of system failure. The embedded device of the system can be an important element for building networked manufacturing systems that shows a very promising prospect for industrial applications.

Data Acquisition Systems, as the name implies, are products and/or processes used to collect information to document (or) to analyze some phenomenon. The purpose of the data acquisition system is generally the analysis of the sensed and measured data at the remote location in the industry and process it and transmitting to the control room consisting of PC.

The data acquisition system is normally electronics based, and it is made of hardware and software. The hardware part consists of sensors and electronics. The software part is made of the data acquisition logic and the analysis is software.

Most controls are based on semiconductor technique and computer science. Since Micro Control Unit (MCU) appeared, it has been widely used due to its low cost and high reliability. Recently, real-time distributed industrial control systems are becoming one of the most important areas in embedded control applications research. In this sense, control and supervision of those systems is accomplished through an industrial Local Area Network (LAN). In order to solve multi-vendor interfacing problems, the computer network technology, especially Ethernet, is being adopted by the industrial automation field. With the use of Ethernet and embedded technique at low level of factory automation, a more flexible and convenient way for distributed control and data acquisition system come to reality.

GSM devices can be used in the alarm management in the industry. In this paper our

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aim is to design an embedded system with an onboard Ethernet interface allowing remote device control and data acquisition. GSM module is used in communication of SMS alerts on critical stages of control failure, also to on/off the device and to vary the set point through mobile.

II. SYSTEM OVERVIEW

Many embedded systems have substantially different designs according to their functions and utilities. There is no single characterization for all kinds of embedded systems. Processor based real-time embedded systems are playing an important role in most control applications. An embedded system interacts continuously with its environment and carries out various tasks with certain timing constraints to meet the requirements of system performance [7]. The processor has the dominant influence on an embedded system. The control and acquisition system uses S3C2440 32-bit CMOS RISC Microprocessor that is the product of SAMSUNG Ltd. The S3C2440 microprocessor is designed to provide a cost-effective and high performance micro-controller solution for general applications. An outstanding feature of the S3C2440 is its CPU core, a 32-bit ARM9 RISC processor (400MHz) designed by Advanced RISC Machines, Ltd. Hence the processor has low power consumption and small size with a high instruction throughput and an excellent real time interrupt response. Besides, S3C44B0X has abundant integrated on-chip functions such as bus interfaces, Watch Dog Timer (WDT), Real Time Clock (RTC) and so on [8]. All these facilitated the controller's hardware and software design. Because the processor uses a pipeline to increase the speed of the flow of instructions, it allows several operations to take place simultaneously and the processing and memory systems to operate continuously. On the basis, μC/OS-II or μC-Linux operation system can be ported to the embedded system. Thus the controller based on the ARM processor can deal with much more complicated control tasks that most conventional lower computers can't deal with. So the smart processor can greatly optimize the controller's performance. The architecture of the control and acquisition system based on the S3C2440 microprocessor is shown in Fig. 1.

In this we are controlling the physical parameter temperature. To measure the temperature we are using LM35 temperature sensor which measures the temperature continuously. In ARM there are inbuilt ADC and DAC. The ADC to convert the analog data from the sensor and convert it to the digital value and DAC is to convert the Digital data from the microcontroller and convert it Analog form to the RS-485. The microcontroller continuously reads the temperature from the sensor and will be compared with the set point. Device 1 and 2 are the two devices which we are going to control these devices may be the boilers (or) machines. The measured temperature from the measured sensor will be compared continuously with the set point if the measured temperature is below the set point the S3C2440 ARM9 microcontroller will switch on the heater and if the temperature is above the set point it will switch on the heater with the help of webpage we can change the set point also based on the application. If the system fails to maintain the set point +/- 5^0c then the microcontroller gives the information to the GSM module which will sends message to the particular user that the temperature is 'x' and the system failed to maintain the set point.

Samsung's S3C2440A is designed to provide hand-held devices and general applications with low-power, and high-performance microcontroller solution in small die size. To reduce total system cost, the S3C2440A includes the following components. The S3C2440A is developed with ARM920T core, 0.13um CMOS standard cells and a memory complier. Its low power, simple, elegant and fully static design is particularly suitable for cost- and power-sensitive applications [5]. It adopts a new bus architecture known as Advanced Micro controller Bus Architecture (AMBA).The S3C2440A offers outstanding features with its CPU core, a 16/32-bit ARM920T RISC

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processor designed by Advanced RISC Machines, Ltd. The ARM920T implements MMU, AMBA BUS, and Harvard cache architecture with separate 16KB instruction and 16KB data caches, each with an 8-word line length. By providing a complete set of common system peripherals, the S3C2440A minimizes overall system costs and eliminates the need to configure additional components.

With Ethernet, the system can communicate with desktop computers or Workstation so that the control and acquisition of a distributed industrial system can be realized within a LAN. A RS-485 serial port is backed up for more widely applications.

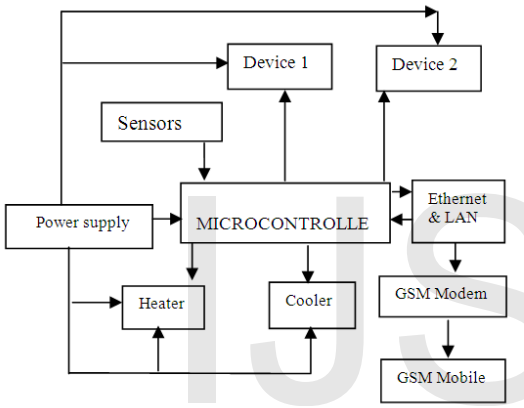

Fig.1 Block dia of Data acquisition and control system

Sensors

There are so many kinds of sensors. Sensors Applications covers all major fields of applications. In this paper we are controlling temperature (physical parameters), for this purpose LM35 temperature sensor used to measure the temperature. The LM35 thus 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. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level.

ADC:

The 10-bit CMOS ADC (Analog to Digital Converter) is a recycling type device with 8-channel analog inputs. It converts the analog input signal into 10-bit binary digital codes at a maximum conversion rate of 500KSPS with 2.5MHz A/D converter clock. A/D converter operates with on-chip sample-and-hold function and power down mode is supported.

A/D Conversion Time:

When the GCLK frequency is 50MHz and the prescaler value is 49, total 10-bit conversion time is as follows.

$$A/D\ converter\ freq. = 50MHz/(49+1) = 1MHz$$

$$Conversion\ time = 1/(1MHz / 5cycles) = 1/200KHz = 5\ us$$

This A/D converter was designed to operate at maximum 2.5MHz clock, so the conversion rate can go up to 500 KSPS

GLOBAL SYSTEM FOR MOBILE COMMUNICATION (GSM)

Global system for mobile communication (GSM) is a globally accepted standard for digital cellular communication. The GSM specifications define the functions and interface requirements in detail but do not address the hardware. A GSM modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone. From the mobile operator perspective, a GSM modem looks just like a mobile phone. When a GSM modem is connected to a computer, this allows the computer to use the GSM modem to communicate over the mobile network. While these GSM modems are most frequently used to provide mobile internet connectivity, many of them can also be used for sending and receiving SMS and MMS messages.

Mobile Internet user can connect using a wireless modem to a wireless Internet Service Provider (ISP) to get Internet access. Mobile phones, smart phones, and PDAs can be employed as data modems to form a wireless access point connecting a personal computer to the Internet (or some proprietary network)

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[9]. In this use the mobile phone is providing a gateway between the cellular service provider's data network technology and Point-to-Point Protocol (PPP) spoken by PCs.
The main features of the GSM technique, compared to other technologies, are as follows:

- SMS between each registered mobile is completely supported. As well as SMS broadcasting from the central administrator to all users or group of users.
- Mobile phones have the ability to operate as PBX extensions while users are online. This brings many more advantages, such as the:

  ability to transfer calls among handsets;
  ability to make internal calls between handsets;
  shared agenda and phonebook;
  support for caller ID;

- Specifically for industrial environments there are more types of mobile devices available which are water/dust/shock proof and have functions such as emergency button call or push to talk (Walkie-talkie mode).

GSM modem must support an "extended AT command set" for sending/receiving SMS messages.

- **AT Commands** AT Commands are used to control a modem. AT means Attention. Every command line starts with "AT". These are of two types : Basic and Extended.
- ATEO – Echo off
- ATE1- Echo on
- ATD –Call a dial no.
- Syntax : ATD 9479555640
- ATDL- Redial last telephone no.
- ATA- Answer an incoming call
- ATH-Disconnect existing connection
- AT+CMGS-To send SMS
- Syntax: AT+CMGS="some ph. no"
- Type text and press ctrl+z
- AT+CMGR – To read SMS
- Syntax : AT+ CMGR=1 ; reads first SMS in sim card
- AT+CMGD – To delete SMS
- Syntax : AT+CMGD = 1 ; deletes first SMS in sim card

V. ETHERNET

Industrial Ethernet (IE) refers to the use of the Ethernet family of computer network technologies in an industrial environment, for automation and process control. A number of techniques are used to adapt Ethernet for the needs of industrial processes, which require real time behavior. By using standard Ethernet, automation systems from different manufacturers can be interconnected throughout a process plant. Industrial Ethernet takes advantage of the relatively larger marketplace for computer interconnections using Ethernet to reduce cost and improve performance of communications between industrial controllers. IE components used in plant process areas must be designed to work in harsh environments of temperature extremes, humidity, and vibration that exceed the ranges for information technology equipment intended for installation in controlled environments.

A **local area network (LAN)** is a computer network that interconnects computers in a limited area such as a home, school, computer laboratory, or office building using network media. The defining characteristics of LANs, in contrast to wide area networks (WANs), include their usually higher data-transfer rates, smaller geographic area, and lack of a need for leased telecommunication lines. ARCNET, Token Ring and other technology standards have been used in the past, but Ethernet over twisted pair cabling, and Wi-Fi are the two most common technologies currently used to build LANs.

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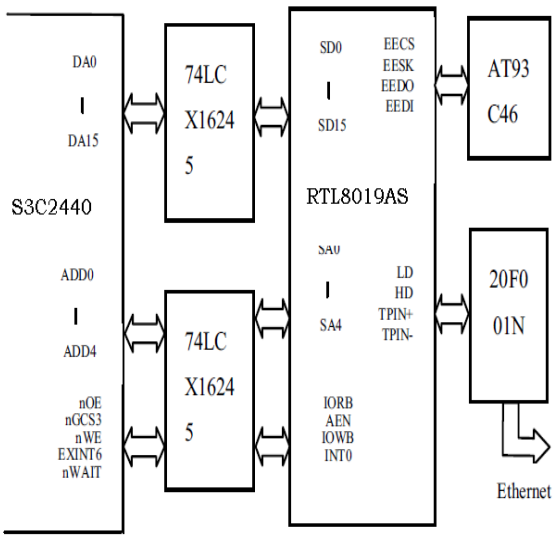

Fig. 3-Sketch map of Ethernet interface

The Internet suite of protocols, commonly known as "TCP/IP", is the set of rules used as a standard to communicate between computers. TCP/IP can be used in addition to the existing set of LAN protocols and provides the ability for any machine connected to the LAN to communicate with other. The evolution of factory communication systems is now proposing the use of Ethernet at low level of factory automation (systems usually referred to as "device level"), where data transfer between controllers and sensors / actuators fast is performed [10]. Ethernet is a Local Area Network standardized by the IEEE 802 committee originally conceived for general-purpose data transfer at a maximum speed of 10 Mbit/s. Recently, the performances of Ethernet have been significantly enhanced by the increase of the data transfer speed and by the introduction of switches[3]. The maximum data transfer speed has been elevated to 100 Mbit/s, maintaining the same protocol for the data link layer; this new version is commercially known as Fast Ethernet, or with the acronym 100BASE-T. The information of Ethernet settings is stored in the 3-wire serial EEPROM AT93C46. The 74LCX16245 and 20F001N are bus transceiver and low-pass filter respectively. The Ethernet interface is shown in Fig. 3. The information of Ethernet settings is stored in the 3-wire serial EEPROM AT93C46. The 74LCX16245 and 20F001N are bus transceiver and low-pass filter respectively. The procedure of the Ethernet communication includes the following steps:

Step 1: Reset RTL8019AS from microprocessor;
Step 2: Initiate the registers of RTL8019AS;
Step 3: Framed the data, and send the data frame to the buffers of
RTL8019AS through remote DMA;
Step 4: Send out the transferring command.

The control and acquisition system in a dedicated LAN is shown in Fig. 5. Such a system structure can make the management layer exchange data with basic control and acquisition layer directly, which is different from conventional structures. The advantage of the embedded device can make the system more efficient. In order to add more flexibilities to the system, the embedded control and acquisition device has been collocated a RS-485 serial port. The port was derived from one of UART channels of the S3C2440 microprocessor, allowing data transmission at data rates up to 212Kbps or higher.

VI. SOFTWARE DESIGN

To put the embedded system into practice, software design is very important. Firstly, Bootloader should be programmed to start up the ARM system. Bootloader is an assemble program that mainly accomplish the register settings of the ARM processor and initiate the system. The on-chip functions of the processor are realized by setting the related registers. After running the Bootloader, the system begins to execute an operation system or user program. If the control or acquisition process is not complicated, there can be only a user program in the embedded system to accomplish the whole task. However, if the process consists of many tasks, an operation system should be ported to the embedded system to manage the Multi-Task. It is recommended that μC/OS-II or μC-Linux operation system be ported to the embedded system. Both operation systems are widely used to ARM embedded systems and proved

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to be very successful. Real-time Database is essential to deal with various information of the control and acquisition process. Generally the embedded device is used as a lower PC, and the involved Real-time Database includes the information of various items such as acquisition items, output control items and medium variant items. Each item embraces much information including item index, item name, specification, display, alarms and management information. Real-time Database is a common data area that input module, output module, control algorithm module and communication module can directly visit.

LWIP can be added to communication module or managed by an operation system to realize the Ethernet communication. LWIP is an implementation of the TCP/IP protocol stack that is able to reduce memory usage and code size, which is suitable for use in small clients with very limited resources such as embedded systems[11]. To realize the networked control and acquisition, the supervisor software is indispensable. Many software products for industry have network communication functions that will facilitate the supervisor software design. Real-time Database is also important for the supervisor software, but the design is different from the lower PC's. The Real-time Database of the embedded system has a large amount of information and the data structure is very complicated, while the Real-time Database of supervisor software only comprises the item values and display information that are frequently used in supervisor software. Thus the database structure is simpler. When design, data refreshing and backup should take into consideration. As data refreshes, the data of the Real-time Database accumulates gradually. When the Real-time Database is full, the data are backed up to the hard disk, and the Real-time Database is cleared at the same time. The obtained data can also be analyzed in supervisor software. As for the Ethernet communication of supervisor software, the form of the communicated data depends on the requirements of practical applications. The data format and communication mode are related to user's program. If the user's program adopts message-driven processing mode, the upper PC transfers the operation commands or parameters to the lower embedded system each time when a message is triggered. Under the condition, the length of the transmitted data is short. The data format can be set as: Data ID followed by the Data Frame. The embedded system disposes of the data according to its ID. Furthermore, advanced control algorithms can be realized by supervisor software. Generally an industrial control system consists of many loops and advanced control algorithms are computed in upper PCs or a workstation for the main control. The Control values are transferred down to embedded devices to execute field operations.

Results and discussion

One of the main goal of this project is to design ARM9 module to control temperature variation. Gang li(2010) was utilized ARM7 for data acquisition. In this project Arm9 is used for data acquisition and control. The results obtained in data acquisition and control with ARM 9 device proved to be high accuracy and performance compared to earlier designs. Lm35 sensor is used to read the temperature and ARM 9 continuously reads the temperature and checks with the set points and analyzes the temperature variations. If it is above the set point it operates coolers and if it is below to the level heaters will be operated.

During control action failed GSM Module is utilized for critical information communication. This can be well utilized in the avoiding fire accidents in the industry, damage of instruments which will lead to financial loss in the industry.

Table showing the remote data controlling through GSM module

	Message sent	Action done	Message received

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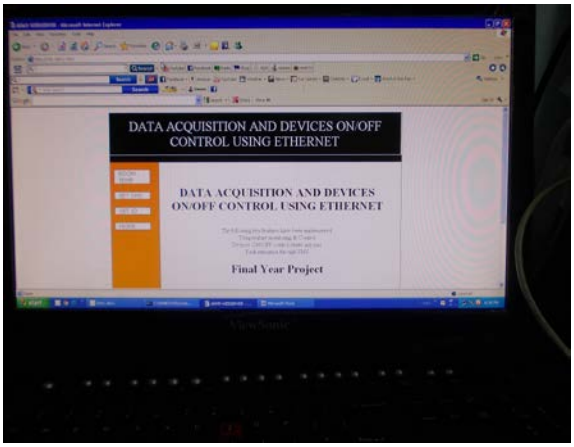
To switch on/off the devices	#00001# #00000# #00011## 00010#	Device 1 will be on Device 1 will be off Device 2 will be on	"Done" if action done "Failed" if not done
To increase the 'set point'	#01000#	To increase the set point 1 unit	The set point will be set to setpoint+1
To decrease the 'set point'	#00100#	To decrease the set point 1 unit	The set point will be set to setpoint-1
If the system failed to maintain the set point within the limit +/- 50c			Temperature =26.4

SAMPLE OUTPUTS

To control through LAN



To control through Ethernet there are 3 columns provided

1. Room temp:- present room temperature will be shown
2. Set sms :- to set the set point
3. To set the i/o devices on/off

If the system fails

In case the system fails to control the temperature, failure message will be sent to the mobile through GSM.

CONCLUSION

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With the advancement of embedded technology more and more embedded devices (such as wireless sensors, intelligent instrument etc.,) are demanding for embedded network connectivity. ARM processor is presented as a new method for distributed controls and data acquisitions. It offers necessary mighty functions to developing fast and efficient applications. The system can be used to perform real-time controls where there have standard electrical interface. High precision data acquisition can be realized by the embedded system as well. In this project the design of ARM 9 processor for industrial application, utilizes and analyze hardware configuration and software implementation. This design brought compactness to the system. In this Project we are implementing a WEB server with 32 bit ARM Processor – S3C2440 from Samsung. Data acquisition plays an important role in real-time controls and online supervisions. Many important data should be stored as a record for the future. Using the Ethernet port of the embedded system, networked control and acquisitions can be achieved through an industrial Ethernet LAN. The hardware and software provide a platform for diverse control and acquisition applications, including industrial process controls and factory automations. By using GSM module we can adjust the set point through mobile. Mobile communication technology can also be utilized to switch on / off the devices. In the case of emergency by the use of alarm option necessary action can be initiated.

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