Design of ARM Based Data Acquisition and Control System for Engine Assembly Monitoring

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Abstract – *For any engine to work properly with minimum maintenance, its assembly quality plays important role. This is accomplished by introducing industrial automation techniques in complex assembly operations of engines. ARM based data acquisition system presented here is an intelligent unit based on embedded technology for data acquisition, monitoring & output control. The system is used with DC Nutrunner (an assembly tool for fastening the bolts) to control the assembly process torque value by giving the value as OK or NOK. Compared with conventional solutions to control and data acquisition, the device based on embedded system gives more features with flexibility and ease of installation in low cost. Ethernet module interfaced with ARM is used to achieve networked control and acquisitions through TCP/IP communication protocol in an industry.*

Key Words: ARM7, Ethernet, TCP/IP, SPI, Data Acquisition

1. INTRODUCTION

With the development of network technology and communication technology, the need that industrial control can be completed via network has become a trend. In traditional industrial control system or data acquisition system, the structure that one host connects multiple serial devices through multiport serial cards is adopted. The task of host is to communicate with each serial device, process data and interact between the operator and computer. This structure is feasible in the case of fewer devices, lower transmission rate. But when a host needs to connect more serial devices at the same time with higher transmission rate and the data processing is more complex, the system performance is poor. In addition, these serial devices connect the same host may be geographically far and this will increase the length of wiring and drop communication quality. So a solution need be found to realize the communication between industrial control devices and Ethernet. As the embedded system itself has the performance of network and human-computer interaction, it is possible that the embedded system replaces the previous control method based on microcontroller. So an ARM processor based embedded Ethernet interface system is designed. This microcontroller based data acquisition system consist of assembly tools (DC Nutrunner), embedded control panel, client PC and server PC. The introduced Philip's ARM7 TDMI LPC2148 16/32-bit RISC Microcontroller can communicate with serial data acquisition equipments at the terminal through SPI interface and can transmit data to remote host computer through Ethernet interface. Compared with the method, the conventional Distributed Control System (DCS) is too complicate. The Field bus technique made the industry control system simple, but the application of Field bus has been limited due to the high cost of hardware and the difficulty in interfacing with multivendor products [6]. The computer network technology, especially Ethernet, is being adopted by the industrial automation field [7]. 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 systems come to reality.

2. 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 [9]. The processor has the dominant influence on an embedded system. The control and acquisition system uses ARM7 LPC2148 16/32-bit RISC microcontroller which is based on a 16-bit/32-bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combine microcontroller with embedded high-speed flash memory ranging from 32 kB to 512 kB. A modular design approach is used in the system design. The main modules of the system are Processor module, Ethernet module, UART interface, MMC card. The block diagram of the proposed system is shown in the **fig.1**

The processor module is connected to Desautter machine through RS232 by UART interface, whereas DC Nutrunner is connected through inbuilt Ethernet port. LCD is connected to the general purpose input/output ports (GPIO) of the ARM. It is used to display the information like status

lower computers can't deal with. So the smart processor can greatly optimize the controller's performance.

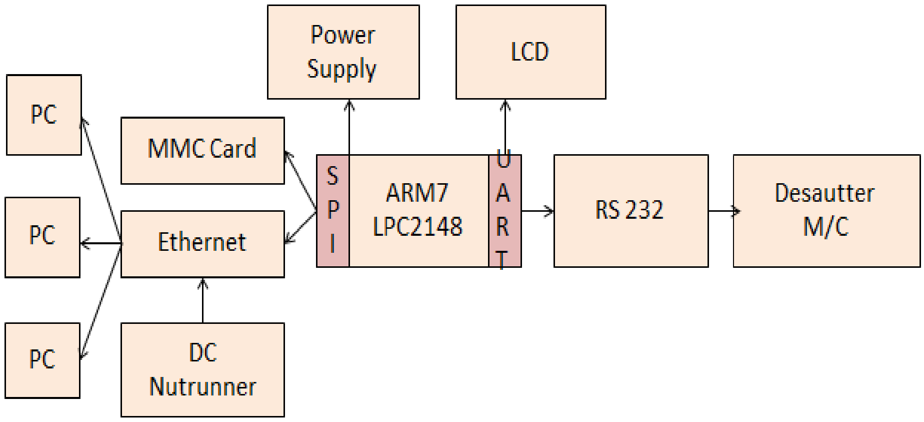

Fig.1 Block Diagram of Data Acquisition System

of the connectivity to respective machines, value of torque applied and number of bolts fastened. The MMC card is interfaced with the system to store the acquired information from the machine. It is also called as a non-volatile memory. It is interfaced with ARM through SPI bus. By using Ethernet with industrial LAN, the system is networked with workstations (Computers placed on workstations). DC Nutrunner and Desautter machine are the assembly tools based on newest tightening strategy designed for quality assurance of complicated joints.

3. MODULE DESIGN

3.1 Processor Module

The Present Control and Acquisition System uses LPC2148 16/32-bit RISC Microcontroller. It is cost effective and has high performance for general applications. An outstanding feature of the LPC2148 is its CPU core, a 16/32-bit ARM7TDMI RISC Processor (66MHz) 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, LPC2148 has abundant integrated on-chip functions such as Bus Interfaces, Watch Dog Timer (WDT), and Real Time Clock (RTC) and so on[7]. All these features facilitate 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, Windows 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 .

The embedded system uses FLASH and SDRAM memories for storage and program running.

3.2 Ethernet Module

Internet works on a set 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 to provide the ability for any machine connected to a particular 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 is performed fast [11].

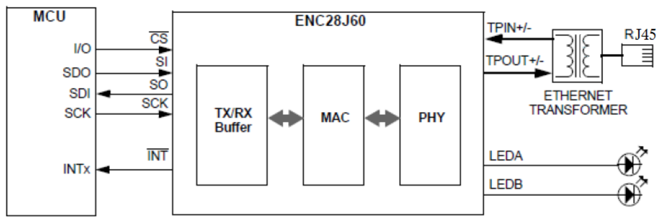

Fig.2 Typical ENC28J60-Based Interface

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. 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. Considering the cost, the control and acquisition system uses ENC28J60 Ethernet Controller for network communication. The ENC28J60 is a stand-alone Ethernet controller with an industry standard Serial

Peripheral Interface (SPI). It is designed to serve as an Ethernet network interface for any controller equipped with SPI. The ENC28J60 meets all of the IEEE 802.3 specifications. It includes a RJ45 socket with activity lights and integrated transformer. This Ethernet module enables to connect a particular embedded device onto a network. It works with any microcontroller operating at 3.3v or 5v. During the control and data acquisition of a distributed system, any workstation or desktop computers on the LAN are processing data "spies" on the network traffic by placing its Ethernet port in promiscuous mode and picks off data frames for reassembly as required. The data are transmitted only once and the embedded devices do not influence the data flow. Similarly, the data flow does not affect the processing performance of other embedded devices within the network, as would be the case for a simple data broadcast that targets every machine on the network [8].

3.3 UART Interface

The serial communication interface UART is used for transferring data between processor module and RFID reader/ GSM Modem/Wi-Fi module. It is one of the basic interfaces with advantages like less cost, simplicity and which is highly reliable for communication between controllers or a controller and a PC.UART is an abbreviation of universal asynchronous receiver and transmitter which is usually used in conjunction with communication standards like RS-232. UART takes bytes of data and transmits the individual bits in a sequential fashion. The 8-bit shift register in UART is used for conversion between serial and parallel forms. Communication will be in simplex, half-duplex or

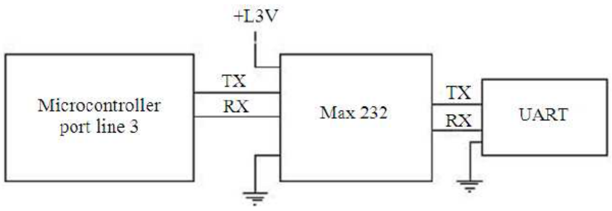

Fig.3 UART Interface

duplex forms. All the operations of the UART are controlled by a clock signal which runs at a multiple of data rate. For fast processing, most UART chips have a built in buffer which is 16 to 64 kilobytes in size. This buffer is used for caching data that is coming in from the system bus while the data that is going out to the serial port is still being processed. The concept of Flow control is a very important aspect of serial communication. It is the capability of a device to tell another one to stop sending data for a certain time. The commands Request to Send (RTS), Clear to Send (CTS), Data Terminal Ready (DTR) and Data Set Ready (DSR) is used to enable flow control [6].

3.4 MMC Card

The memory card is interfaced with the system as a data logger. It is interfaced with microcontroller using SPI bus. The SPI module in the ARM 7 microcontroller is configured as per the MMC cord configuration. This module has SCL, SDA, SDO, SDI which is useful for clock of the SPI module, acknowledgement, data out and data in respectively [10].

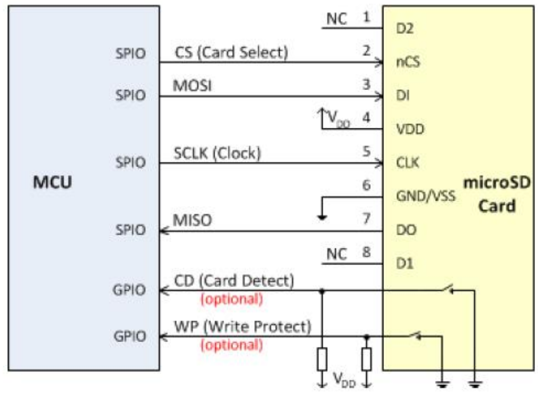

Fig.4 SD card interfaced via SPI bus

4. 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 [5].

4.1 Application Software-Client Side

To realize networked control and acquisition the supervision software is indispensable. As we are using this data acquisition system for engine assembly line, client software is developed for each workstation to collect respective data. Client software will create TCP connection and keeps on listening to the port and as soon as data is available, it will read & display the data on the screen. Flowchart for this process is shown in **fig.5**

Then, comparing with the set value for that process, it will display the status of the process as OK or NOK.

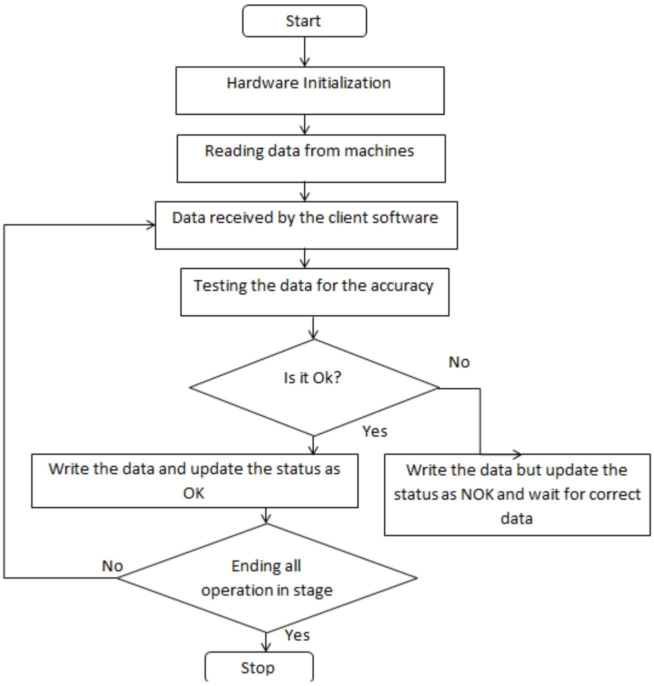

Fig.5 Flowchart for Client Software

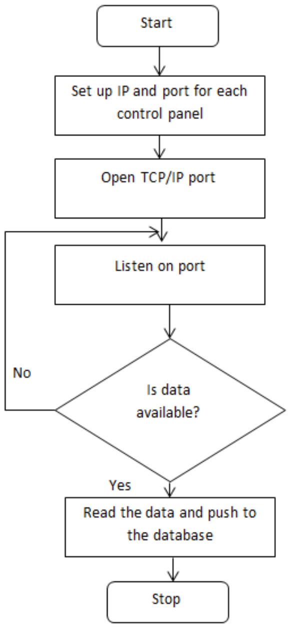

Fig.6 Flowchart for Server Software

4.2 Application Software-Server Side

Server software manages the database of the system. Here, there is provision to add the description for processes coming under the respective station and their required specifications of torque and batch count. It makes the system flexible as user can add the process parameters whenever required.

Database is developed using MySQL database server which fast, reliable, scalable and easy to use relational database management system which runs as a server.

For any assembly process, to tight the joint minimum and maximum allowance torque is defined. To get an OK status, applied value of torque should lie between this limit. The database consists of the information about assembly process, torque limits and batch count (number of bolts to tight under the respective process) of each model of engine.

5. RESULTS

The result shows that the torque data from assembly tools is transferred to the client software over the Ethernet connection in industrial LAN. Then client software verifies the data for its status as OK or NOK and stores it in the database of the Server and is accessed by the user whenever needed. **Fig.7** gives the idea about client software. **Fig.8** shows the details of assembly process along with the description about torque and batch count (no. of bolts required for that operation) required by the particular engine model. The advantages of the system are low power consumption, convenient, low cost and high data rate.

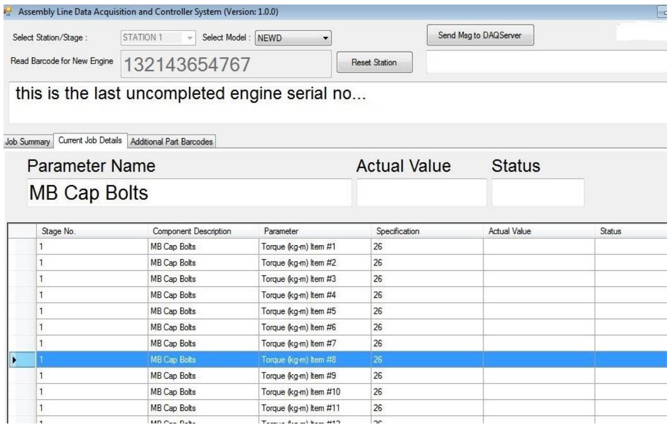

Fig.7 Working of Client Software

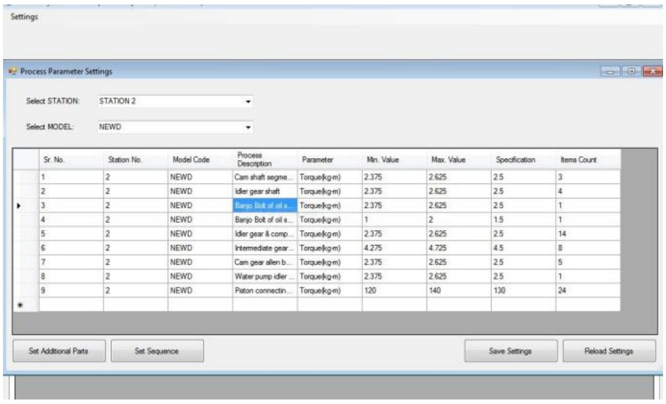

Fig.8 Parameter Feeding to Server Software

5. CONCLUSION

Design of ARM based data Acquisition & Control using Ethernet & TCP/IP Network is presented as a new method for data acquisition of mechanical part assembly like engine. It offers necessary mighty functions to developing fast and efficient an application. The system can be used to perform real-time controls like standard electrical interface. High precision data acquisition can be realized by the embedded system. 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. Since the embedded system is able to deal with Multi-Tasks and can run operation systems, field operations, supervisions and managements can be done by the lower embedded devices, hence the upper PC or workstation in the industrial LAN will do fewer works, which lowers the concentration degree of the whole system.

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