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Ethernet Controller Arm Processor

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***Abstract* - There is a strong interest of using cheap and simple Ethernet technology for industrial control networks. Its low price and robustness, has resulted in its wide acceptance and deployment, has created an eagerness to expand its responsibilities to the factory-floor where real-time requirements are to be fulfilled. We describe a Temperature control experimental setup that can be accessed (Monitored/Controlled) via the Internet. It consists of two primary elements communicating with each other: i) a server consisting of an ARM microcontroller, LPC2294, interfaced with an Ethernet IC, RealtekRTL8019AS, and ii) a client computer. The client computer sends/receives data to/from the microcontroller using TCP packets. The client computer connects to the server using Internet Explorer that allows the user to command the Temperature controller. We describe a method using microcontroller LPC2294 based on a 16/32-bit ARM7TDMI-S CPU, its architecture is based on RISC principles, and embedded HTTP web server to realize Ethernet communication.**

***Keywords* — Embedded, Ethernet, Temperature, Internet, Local Area Network (LAN).**

I. INTRODUCTION

There is a general consensus that in years to come more and more Internet devices will be embedded and not PC oriented. Just one such prediction [1] is that by 2010, 95% of Internet-connected devices will not be computers. So if they are not computers, what will they be? They will be Embedded Internet devices.

With the integration of communication networks and distributed control in the modern manufacturing and process industries, Networked Control Systems (NCS's) or Ethernet Control Systems (ECS's) are becoming increasingly important due to its simplicity, scalability, flexibility, maintainability, and cost effectiveness. However, there are still significant challenges that result in the application limitation of NCS technologies, such as transmission time delay and data packet dropout [1, 2]. To reveal the performance of NCSs, researchers built various experimental platforms based on different software and hardware environment. Chow [3] used a PC running RT Linux working as a central controller and a Siemens C-515C microcontroller board serving as a remote controller with RS-232 connection. Nie [4] used ARM7TDMI with running µC Linux to work as a remote controller and a PC with MATLAB Simulink (RTW) to work as a central controller. Hu [5] proposed a kind of NCS simulation platform based on switched Ethernet though using two computers to simulate actual controller and plant by Matlab. Liu [6] designed a simulation platform of NCS using Matlab to build models of real systems. The transfer speed of Ethernet has been developed from initial 10Mbit/s up to 1000Mbit/s, even 10Gbit/s today. It makes the application of Ethernet spread from Office Automation to Industrial Automation. Due to the low price [3][4] and robustness resulting from its wide acceptance and deployment, there has been an attempt to build Ethernet-based networks for industrial automation.

The traditional communi-cation interfaces like RS-232 and RS-485 etc still occupy the majority numbers of domestic industrial automation, and because of inconvenience for transmission of data and inapplicability of share information, these cannot meet need of the development of measuring and control system.

Using embedded and Ethernet technology for industrial network has become an important point for technology of measuring and instrument, corresponding to huge development in computer and Internet technology.

II. HARDWARE

The embedded system is developed on a ETM150, 32bit ARM based Prototyping Board interfaced with an ETM121 [6] by Embed Technologies Pvt. Ltd., is used to control Temperature form remote location through internet. The ETM 150 microcontroller interfaces with temperature sensor LM35 using PO.29 of an on chip Analog to Digital converter (ADC). P1.19 of LPC 2294 from ETM 150 is used with relay driver circuit for controlling action. We have considered relay driver for experiment purpose. Ethernet data communication between the microcontroller and a remote web-client is performed using the ETM121. Specifically, the ETM121 receives reference commands from the remote web-client and communicates the same to the microcontroller. In addition, the ETM121 receives sensory data from the microcontroller and communicates the same to the remote web-client. *ETM 150* ETM150 is a general-purpose development board for ARM Controller. ETM150 can be used extensively to test and validate

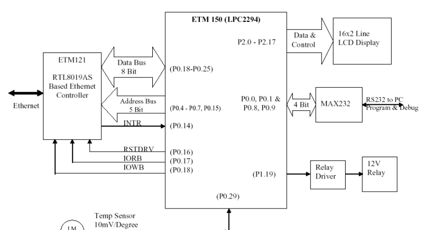

Figure 1: Network Controlled System (NCS)

programs. At the heart of the development board is Philips LPC2294, which provides advance features like ISP and IAP. The micro controller has 256KB internal flash memory and 64KB on-chip RAM. The development board comes with RS-232 interface to allow user to program the micro controller directly from PC.

The LPC2292/LPC2294 microcontrollers are based on a 16-bit/32-bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, together with

256 kB of embedded high-speed flash memory. A 128-bit wide memory interface and unique accelerator architecture enable 32-bit code execution at the maximum clock rate. For critical code size applications, the alternative 16-bit Thumb mode reduces code by more than 30 % with minimal performance penalty.

The THUMB set's 16-bit instruction length allows it to approach twice the density of standard ARM code while returning most of the ARM's performance advantage over a traditional 16-bit processor using 16-bit registers. This is possible because THUMB code operates on the same 32-bit register set as ARM code. THUMB code is able to provide up to 65% of the code size of ARM, with minimum performance penalty, and 160% of the performance of an equivalent ARM processor connected to a 16-bit memory system. In sending a frame a controller receives the message to send and the destination address from higher-level software. It calculates the Ethernet frame check sequence and places data, addresses and other information in the frames field. Half duplex interface Detects collisions, cancels any transmitted frame with a collision and tries according to protocol standard IEEE 802.3; in full duplex Ethernet segment doesn't need to support collision detecting because there are no collisions to detect and provides an indication of success or failure of a transmission. In receiving a frame a controller detects and synchronizes to new received frames. It ignores any frame that is less than the minimum size, ignores any frames that do not contain the interface's address or a valid multicast or broadcast address in the Destination Address field. It calculates the frame check sequence value, compares the result with the received value and indicates the errors if they don't match.

ETM 121 (Network Interface)

The ETM121 board is design and developed to interface almost any circuit to Ethernet (LAN). The ETM121 board is designed using Realtek RTL8019AS Ethernet controller, over which the application circuit is developed. The controller has unique features such as 8K of On-Chip RAM and 8/16 bit operations with interrupt capabilities. . The selection of the communication media (cable) to ETM-121 depends upon network speed, Ethernet controller speed and IEEE standard. In our application ETM-121 is compliant to Ethernet II and IEEE 802.3 10Base5, 10Base2, 10Base-T Ethernet interface.

The ETM121 board can be connected to embedded microcontroller and microprocessor for direct connectivity to the LAN. ETM121 Board works with + 5V Regulated power supply. ARM microcontroller will read RTL1809AS interrupt INT0 (which is on INTR in ETM-121) whenever there is an interrupt ARM microcontroller will read interrupt register of RTL8019AS to know the cause of interrupt. It will provide status of transmission if the frame transmitted earlier, otherwise new reception status will be there. RTL8019AS is programmed to receive either broadcast destination address (FF: FF: FF: FF: FF: FF) or physical destination address as programmed in PAR0-5. Input to Ethernet controller (ETM-121) is the Ethernet Frame from network as shown in figure 2.

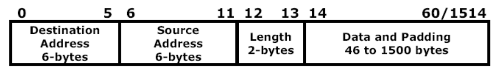

Figure 2-Inputs to Ethernet Controller (ETM-121)Ethernet Controller (ETM-121) will process the frame, stores it in buffer and delivers the processed frame to higher-level layer as shown in figure 3.

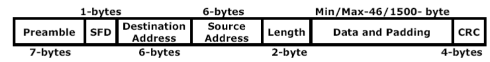

Figure 3- Processed frame from Ethernet Controller (ETM-121)

III. Software

Software can be divided into two parts – remote control system firmware and PC remote software. The firmware is developed in Keil uVision3 and written 100% in Keil uVision3's Micro Assembler. It includes RTL8019AS control functions, communication protocols (ARP, IP, ICMP, and TCP) i.e. TCP/IP Protocol Stack [9] [10] [11], and HTTP web server with inbuilt HTML page for temperature controller [12] [13] and all I/O peripheral routines. NCS uses TCP Sockets in the realization of our program's transport-layer protocol. Socket is a kind of interface between communication protocol and application program, a relationship between both sides of network was established by socket. Control System firmware is divided into software routines as, Main Module, Ethernet Controller Driver, Address Resolution Protocol (ARP), Internet Protocol (IP), Internet Control Message Protocol (ICMP), Transmission Control Protocol (TCP), and Hypertext Transfer Protocol (HTTP).

The main module initializes UART, LCD, ADC, RTL8019AS, & TCP Stack according to requirement. Algorithm for main module is shown as below

1. Initialize all devices, hardware and software packages.
2. Open TCP server port on TCP port 80 and wait for client to connect.
3. Set point = 40, Loop count = 0
4. If (loop count>5000)
a. Read temperature, print on LCD
b. Check current temperature with set point
c. If (Temperature>Setpoint+1)
d. Turn off relay
e. If (Temperature<Setpoint-1)
f. Turn on relay
g. Loop count = 0
h. Data Len=0
5. If (Interrupt from RTL8019AS)
a. Read_RTL8019AS
6. Loop count = Loop count + 1
7. go to step 4

The RTL8019AS is programmed to receive either broadcast destination address (FF: FF: FF: FF: FF: FF) or physical destination address. Main module reads RTL8019AS, it checks for INT0 (INTR), and finds out the cause of interrupt (T_X/R_X). If T_X previous transmission attempt was successful else R_X new frame received successfully (according to initialization of RTL8019AS). In both the cases it will inform higher-level layer (TCP/IP Protocol Stack) which takes the necessary action.

Normally Web server is a computer in which lot of Web pages are stored. Web server for hosting a corporate Web page should have the capability to handle more traffic. The aim of this work is to neither hosting a corporate Web pages nor handling much traffic. NCS functions as a Web server it has non-volatile memory to hold pages to be served. It support for TCP and IP, requests for Web pages and the pages sent in response travel in the data portion of TCP segments. It support for HTTP, the server must be able to understand and respond to receive requests for Web pages. The HTTP standard specifies the format for the requests and replies. It has a Local-Network or Internet connection. To serve pages on the Internet, the Web server must have an Internet connection with Public Static IP. It has one or more pages to serve.

HTTP works using TCP. HTTP Server is provided as part of the TCP/IP stack. The embedded HTTP server implementation is divided into three segments. The implementation segments are divided based upon their place within the module hierarchy as HTTP Socket Server, HTTP Message Protocol, and Dynamic Content. The HTTP Socket Server is a typical TCP stream socket server implementation. In this implementation the socket is bounded to specified port (80), and a queue of maximum 12-TCP listen ports. This allows to queue up to maximum TCP listen ports outstanding requests while server will fulfill the current one. So the HTTP server opens one or more TCP server ports on TCP port (80) and waits for client to connect. When client connects, the TCP stack acknowledges the connection.

The Web pages are blocks of text that use a form of encoding called Hypertext Markup Language (HTML). The HTML encoding specifies the formatting of text, including text size, fonts, font size, colour (for text & background) and the positioning of text and other elements on the page. In serving a Web page with dynamic content, the software must have a way of inserting the dynamic content as the page is being served.

IV. Experimental Evaluation

The performance of the NCS is analyzed in private network that is in a Local Area Network (LAN) and public network (Internet) where ARM microcontroller is used in 16-bit THUMB Mode and then 32-bit ARM Mode Instruction Set. In all these cases Round Trip Time (RTT) is verified. RTT is a measure of delay between two hosts. RTT consists of the total time for a single packet or datagram to leave one machine, reach the other, and return. Wire shark Network Monitoring Software [12] [13] is used to capture client-server communication and for result analysis. For debugging serial communication is used. The code is written in such a way that it supports serial communication. With the help of HyperTerminal we can verify the internal states of program execution sequence.

A. Testing of ping (Packet InterNet Groper)

The client invokes “ping” command to send ICMP echo request to Web server. Ping command is not only used to test whether destination is reachable and responding, but also to check packets sent, packet received, percentage loss, and approximate RTT in ms. We found that in private network (LAN) and in public network (Internet) the performance of 32-bit processing is better than that of 16-bit processing. In private network 16-bit THUMB mode has average RTT performance penalty is of 2ms and in public network it is 32ms.

B. Testing of Web page

The client uses Web servers IP address in his web browser and, in response, Web server delivers web page as shown in Fig. 4.

Fig. 5 & Fig. 6 shows a plot of round trip times (RTT) as measured for successive TCP segments in public network, for ARM and THUMB mode respectively. It is a statistical analysis of TCP stream graph for round trip time taken with the help of Wireshark Network Monitoring Software.

In private network (LAN) and in public network (Internet) we observed that the performance of 32-bit processing is better than that of 16-bit processing. (Private Network Plot and analysis not given) From Fig. 5, ARM mode average RTT is 0.074 seconds (74ms.) and from Fig. 6, THUMB mode average RTT is 0.081 seconds (81ms). Hence 16-bit THUMB mode has average RTT performance penalty of 0.007 seconds (7ms) in public network.

C. PC SOFTWARE

Special application or GUI which runs on a remote client computer, for communication with ECS can be written. It communicates over TCP and can be developed with Delphi, [14] Visual Basic, Java applet [15] etc. The easiest way for communication with ECS by remote client computer is to use web browser. The advantage of using web browser and not using special application or GUI is any computer on the internet can access ECS because it is available with almost all the computers.

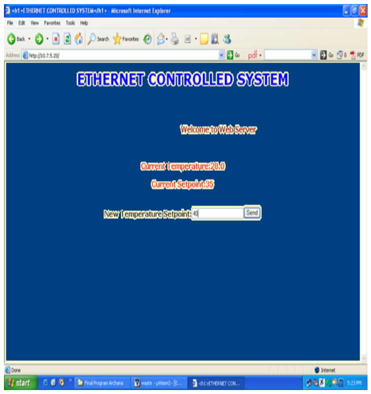

Figure 4- Photo of Web Page served by NCS.

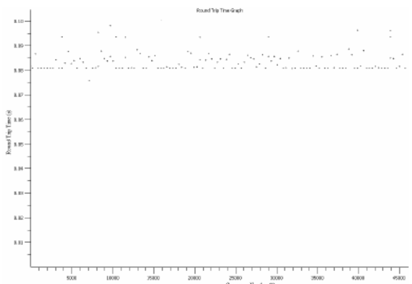

Figure 5- ARM Mode in Public network.

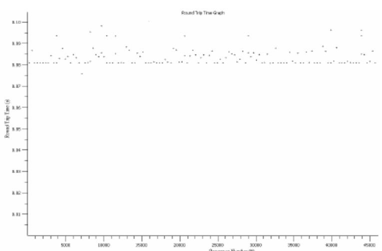

Figure 6- A Plot of Round Trip Times THUMB Mode in Public Network

CONCLUSION

The presented Network Control System can be used to perform real-time controls. The Network Control System is low cost and highly integrated. By using 32-bit ARM Microcontroller, the embedded system becomes highly precise and gives better performance over traditional 8/16-bit Microcontrollers. The system can also communicate with PC through RS-232 Serial Port. It supports online-supervision and control not only within Private Network (LAN) but also in Public Network (Internet). The hardware and software provide a platform for diverse control applications, including industrial process control and factory automation. Hence the Ethernet control system is a general controller that can be widely used. However, it should be noted that no protocol guarantees timed delivery of packets over the internet as Internet is a shared resource.

So by giving Internet Communication capabilities to any embedded system like NCS, such embedded system will then be capable to communicate with every corner of this planet.

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