

## Design and Implementation of Low Cost Multi-Purpose SCADA System using Embedded Ethernet

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**Abstract:** This study introduces the design and implementation of proposed multi purpose SCADA system. The design is based on the utilization of an efficient micro-controller, which permits to minimize the hardware and software of the implemented system. A small size RTU unit can be used as an Ethernet server for the management of all the required activities in the remote terminal. The proposed system is of low cost, small size, easy to implemented and efficient to be used in different applications.

**Key words:** SCADA, monitoring/control, Embedded Ethernet, web server/RTU, micro-controller, web based/MTU

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### INTRODUCTION

Control systems designed to monitor processes are referred to as data acquisition systems, if the system allows also, remote control to function based upon the acquired data, it is referred to as a SCADA system (Daneels and Salter, 1999).

Modern SCADA provides proper monitoring of equipment to maintain operations at an optimal level by identifying and correcting problems before they turn into significant system failures (Ahmed and Soo, 2008).

Microcontrollers with their small size and modules like the A/D convertors, CCP, Serial Ports, I2C built into their hardware platform provides an efficient solution toward building small, low cost, industrial environmental compliant devices and low power consumption make them perfect solutions for industrial control and other applications.

Ethernet Known as 802.3 is the most widespread wired LAN technology. It has been in use from around 1980 and it has replaced, almost all the other networking technologies (Todd, 2007). Only in the past few years Ethernet has penetrated the networking world, starting to deliver improvements in productivity through enterprise-wide integration (Omron Electronics, 2002). The ability to monitor and display real time data on the enterprise's intranet, plus generating and sending emails of alarm events to remote locations for operation supervisors has finally been realized. This capability can provide significant benefits in the area of remote diagnostics and statistical data gathering, both of which help keep

maintenance costs down and maximize productive manufacturing time (Abhilash, 2004).

This study shows, the design and implementation of a low cost Web based/Embedded Ethernet SCADA system in which:

- Any PC connected to the network of the system and provided with a web browser can act as the MTU unit, the designed MTU provides two mechanisms regarding the MTU:
  - Monitoring
  - Control
- RTU unit was designed to use a single chip (PIC18F87J60) to perform all the functions of the RTU from data collection till Ethernet connectivity (Embedded Ethernet) and the use of Ethernet Controller Boards, which is the usual solution for Embedded Ethernet now days, without the use of external A/D converters
- Ethernet was used as the communication channel (Media)

### MATERIALS AND METHODS

The proposed system layout is shown in Fig. 1, which consists of Master Terminal Unit (MTU) and Remote Terminal Unit (RTU).

**Remote Terminal Unit (RTU):** A micro-controller (PIC18F87J60) connected to an Ethernet jack RJ-45 provides an Embedded Ethernet platform, which replaces

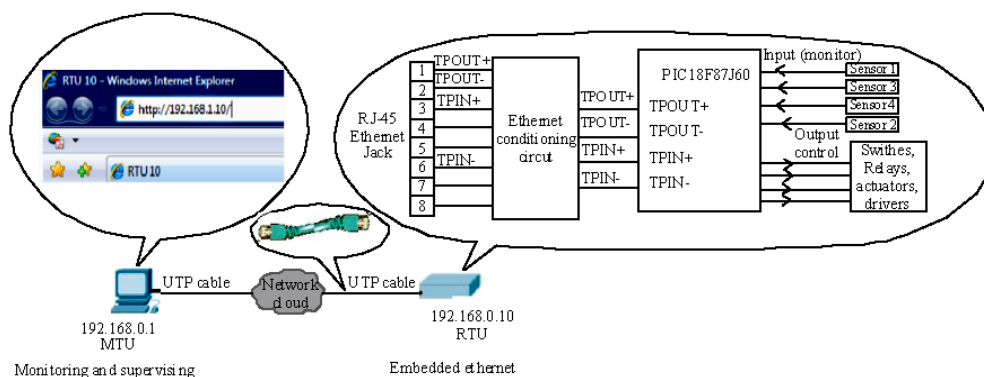


Fig. 1: The proposed SCADA system layout

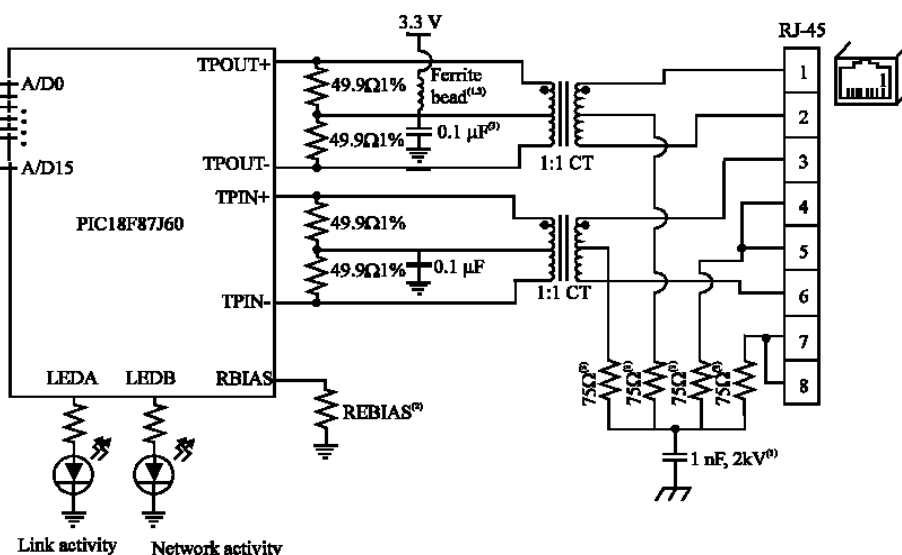


Fig. 2: Proposed RTU unit

the traditional Embedded Ethernet platform, which consists of an Ethernet controller board connected to a microcontroller, PIC18F87J60 replaced the external A/D converters also, with its built in 15 channels A/D converter, the proposed RTU will provide the Embedded Ethernet functionality and A/D inputs on a single chip, the proposed RTU consists of three sections:

**Data acquisition and control section:**

- The PIC18F87J60 contains 55 pins, which can be configured individually as logic input or logic output
- The PIC18F87J60 contains 15 A/D pins (channels) that work within 0-5 V with 10 bits resolution

With such facilities any sensor (input/monitoring) with its output within 0-5 V can be fit directly into the proposed RTU and even if its signal is not within 0-5 V it can be conditioned with an external circuit to 0-5

V, for control (output) the pins are capable of sourcing 25 mA, driver circuits can be used to provide higher currents if required

**Microcontroller section:** In this study, PIC18F87J60 is chosen to be the core of the RTU in the proposed SCADA system, it has:

- ROM: 128 K bytes
- RAM: 3808 bytes
- 55 Pins Input/output
- 15 A/D converters 10 bit resolution
- 802.3 compatible Ethernet controller
- 80 Pins in Total

**Ethernet interfacing section:** The Ethernet signals TPOUT+, TPOUT-, TPIN+, TPIN- can't be connected directly to a UTP cable it has to be conditioned, the conditioning circuit is show in Fig. 2.

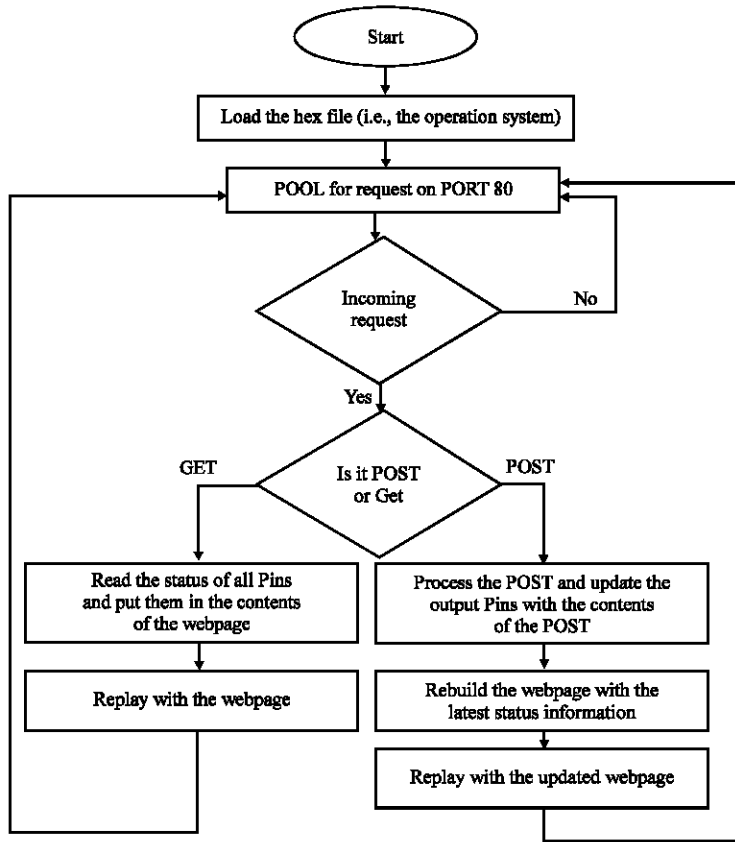


Fig. 3: Flowchart of the implemented software in the RTU

In this study, for the proposed SCADA system an application was developed in the RTU unit, which will make it provides web server service in such a way that the RTU unit will generate dynamic webpage contains the status of its hardware pins that are connected to the system to be monitored.

**Master Terminal Unit (MTU):** Any PC equipped with an Internet browser, connected the network of the RTU can access the RTU unit. To access the RTU, the user will type the IP address of the RTU unit as <http://192.168.0.10>.

Assuming the IP address of the RTU to be accessed is 192.168.0.10.

**Communication channel:** The use of Embedded Ethernet and web service in the RTU unit gave the system the flexibility and strength to integrate the powerful processing and interfacing features of the microcontroller with the Ethernet technology thus, the RTU behaves just like any other web server (PC) in the Ethernet Network

and it is able to utilize any Ethernet network regardless of its topology or devices as long it is compliant Ethernet network.

**Software design:** An Embedded web server, which is "a microcontroller that contains an Internet software suite as an application code for monitoring and controlling the system (Todd, 2007), was implemented in the RTU i.e. the RTU is a web server, in which its contents is a dynamic page reflects the status of the hardware pins that is connected to the system to be monitored and controlled.

The use of the Web server facilitates the access to the system thus, no special software is needed and no special frame or packet format is needed, the web server uses the POST and GET methods to send and receive the commands and status data from the RTU as follows:

The flowchart of the implemented software in the RTU unit is shown in Fig. (3).

The POST and GET processes between the MTU and RTU is illustrated in Fig. 4.

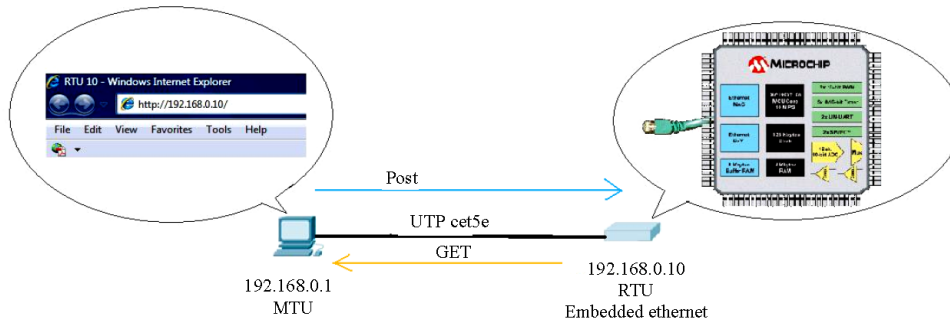


Fig. 4: POST and GET processes between the MTU and RTU

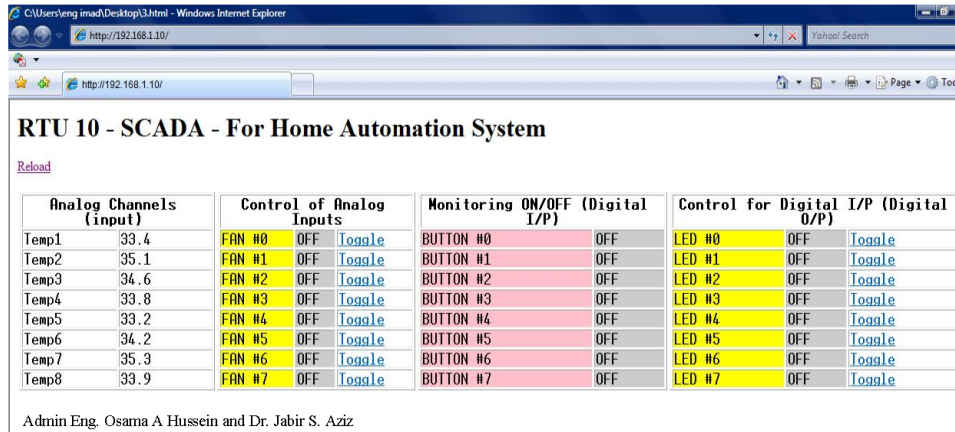


Fig. 5: Index page of the web server in RTU

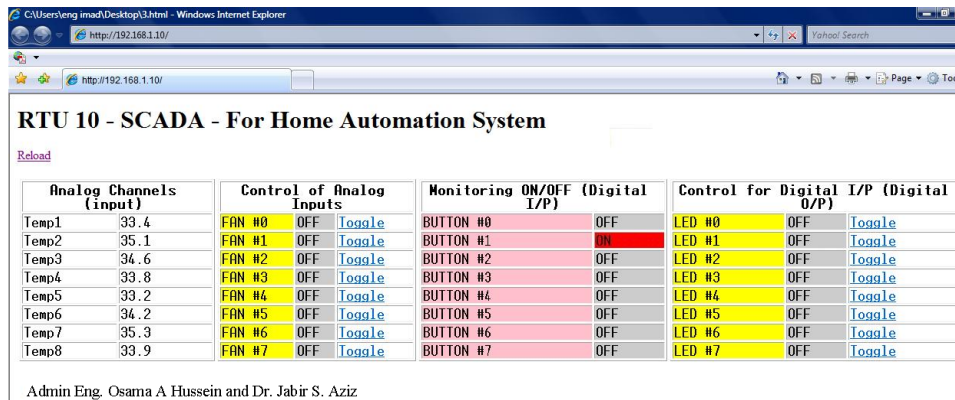


Fig. 6: Status of input pin (push button 2) changed from OFF to ON (marked in RED)

## RESULTS AND DISCUSSION

Home Automation was taken as a case study for the proposed system, in which 8 temperature sensors LM35 were connected to 8 A/D channels (Analog input) and 8 output lines (Control pins) were used to turn On/Off 8 fans in compliance with the A/D readings.

Eight push button switches were connected to 8 input pins (Digital input) and 8 output pins were used to turn ON/OFF 8 Leds (digital output).

Figure 5 shows the index page of the SCADA system, in which it contains four columns:

**Column one:** Eight LM 35 temperature sensors were attached to eight A/D pins and were placed in different places one for each room (monitoring/Analog Input).

**Column two:** Eight lines were connected to 8 fans and each fan can be individually controlled to On/Off from the Toggle button (Control/Digital Output).

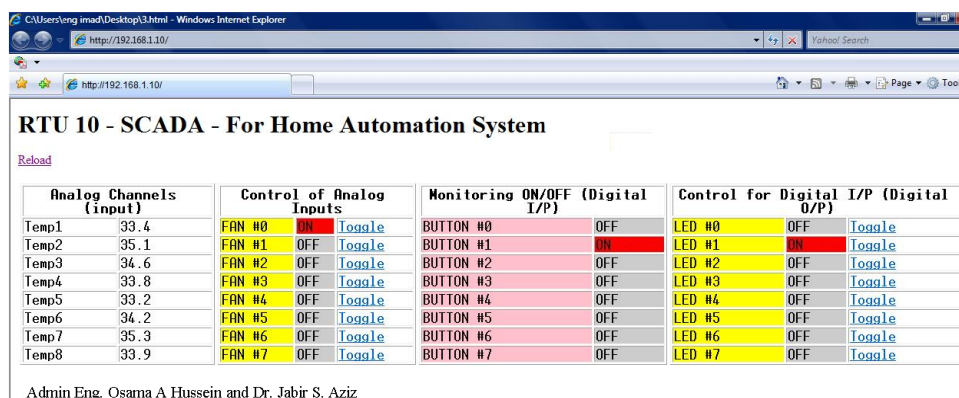


Fig. 7: Two output pins (control lines) are toggled high (marked in RED)

**Column three:** Eight push button switches representing ON-OFF sensors were used for Monitoring/Digital Input.

**Column four:** Eight leds were used to represent the digital output and each led can be controlled individually from the page by pressing to the Toggle button (Digital Output/Control).

Figure 6 shows, the change in status of button one when it is changed to ON Monitoring.

Figure 7 shows, the control, in which the Admin toggles LED 1 to ON as well as FAN 0.

### CONCLUSION

In this study, a SCADA system was designed and implemented to utilize the embedded Ethernet in its RTU, which run a web server allowing the admin (MTU) to easily connect to the RTU via the web browser and using the Ethernet technology. The proposed system has the following features:

- Low cost and small size RTU unit
- The high performance of the PIC18F87J60 microcontroller gives the proposed system the ability to be used in different applications
- The use of Ethernet facilitates the communication mechanism allowing the proposed system to run over any Ethernet compliant infrastructure "wire 802.3 or wireless 802.11a/b/g
- The use of Internet Browser eliminated the need to design a special software to handle the communication, but in the same time the browser can't respond in real time due to its limitations in the refresh process (3 sec) and the post process (1 sec). So that if a real time monitoring and control is required an application written in java, VB or VC++ can solve this issue

- Usually, the Server was located in the MTU and the data was transmitted by the RTU, but this study proposed to use the server in the RTU to minimize the amount of the data broadcasted on the Ethernet Network by the RTU, which leads to increase the overall performance of the Ethernet network
- The use of TCP ensured the delivery of packets on the contrary of the use of UDP, which is unreliable

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