DEVELOPMENT OF AN ETHERNET ENABLED MICROCONTROLLER BASED MODULE FOR SUPECONDUCTING CYCLOTRON ECR BEAM LINE CONTROL

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Abstract:

An Ethernet enabled control and data acquisition module is developed for remote control and monitoring of the ECR beam line equipment of the Superconducting Cyclotron. The PIC microcontroller based module supports multiple general purpose analog and digital inputs and outputs for interfacing with various equipments and an embedded web server. The remote monitoring and control of the equipment are achieved through the web based user interface. The user authenticated access to control parameters and module configuration parameters ensures the operational safety of the equipment under control. This module is installed in Superconducting Cyclotron ECR beam line for the control and monitoring of vacuum pumping modules, comprising of pumps, gate valves and dual vacuum gauges. The installation of these modules results in a distributed control with localised field cabling and hence better fault diagnosis.

INTRODUCTION

The Electron Cyclotron Resonance Ion Source (ECRIS) plays a major role in generation and injection of the different ions to be accelerated by the Superconducting Cyclotron. ECR ion source develops multiply charged ions which are transported to the cyclotron through the injection line.

A large number of beam line equipments including various types of magnets, beam diagnostics elements, vacuum system components etc are required to be monitored and controlled for efficient transportation of the ion species. Among these elements, the vacuum pumping modules, though crucial for maintaining high level of vacuum inside the ion source and the injection line, are operated less frequently. Each pumping module again comprises of a scroll pump, a turbomoleculer pump, various valves and vacuum gauges which altogether can be considered as a complete unit of one pumping station. Hence a generalised, modular, distributed control and data acquisition system for the pumping stations as well as for other diagnostic elements result into a compact, less complicated and cost effective solution.

Microcontroller is the obvious choice considering its cheaper cost, faster development, and rich in built external interfaces. But the connectivity for data communication to PC is limited to serial interface for the microcontrollers.

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In recent time, the Ethernet protocol has been widely adapted for data communication over wide area. Therefore a microcontroller based control and data acquisition module with embedded Ethernet connectivity is the optimum choice for the above mentioned control system.

In this paper, the development of an Ethernet enabled control and data acquisition module with embedded web server is explained along with the hardware and software environment detail. The schematic in Figure. 1 shows the basic architecture of the module.

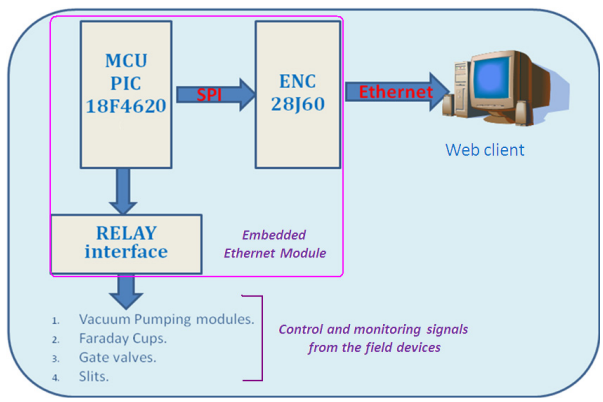

Figure 1: Block schematic of the control architecture.

HARDWARE OVERVIEW

The Ethernet enabled control and data acquisition module is developed for remote control and monitoring of these ECR beam line equipments. An embedded web server along with the other essential hardware makes the module suitable for control and monitoring of the field devices over LAN. The schematic in Figure .1 shows the basic architecture of the module.

Microcontroller

The microchip PIC controller 18F4620 is used as the main controller. It is an 8 bit microcontroller with 64kbytes of Flash, 10 bit, 13 channel ADC, 31 level stack and 36 Inputs and outputs (I/O). The 1Kbyte of EEPROM data memory available in this IC is used to store the configuration data. The Master Synchronous serial port (MSSP) module in this microcontroller supports 3 wire SPI communication, used for communicating with Ethernet controller.

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Ethernet Controller

The ENC28J60 is used as Ethernet controller. It is a IEEE802.3 Compatible, stand alone Ethernet controller with integrated MAC and Phy with SPI interface. The operating frequency of the ENC is 25MHz. This controller supports one 10Base-T port with automatic polarity detection. The MAC layer in this controller supports Unicast, Broadcast and multicast packets, whereas the Physical layer supports the loopback mode. There are two programmable LED outputs for LINK, Tx/Rx, collision and Full/Half duplex status. The proper connectivity to magnetic and terminations are important for the completion of Ethernet interface. More information about these two ICs can be found in [1].

This embedded Ethernet module works as a web server and is placed in the local area network through which it communicates with the client PC. The hardware of this module is developed in house.

All the digital Inputs and Outputs (I/Os) from the field devices are interfaced to the controller card via a relay interface card. Each module with Ethernet connectivity can support three numbers of digital inputs, three digital outputs and two analog inputs. The IP (Internet Protocol) address of this module can be configured remotely over the LAN from the client PC and the module can be booted either with the default IP or the IP configured by the user by using jumper selectable switches. A temperature sensor (AD22100KT) with inbuilt ADC for monitoring temperature in the range of 0ºC to 100ºC is also provided in this module. The analog field signals e.g. pump speed, vacuum reading etc, are converted to digital by the internal ADC of the microcontroller. A LCD provided on local panel displays the IP address and the ON/OFF status of the field devices besides other parameters.

FIRMWARE FEATURES

Stack Component	*Protocol*
Application	HTTP
Transport & Session	TCP
Network	IP
Data Link	Ethernet
Physical Link	10Base-T

Figure 2: TCP/IP stack and the protocols used.

The Microchip TCP/IP stack [1] has been implemented in this module with minor modifications. The stack and the protocols used are shown in Figure 2. This stack mainly includes the ARP, IP, ICMP, TCP and HTTP. The ARP (Address resolution protocol) converts the IP address to physical address. IP (Internet protocol) provides the routing information for the packet. ICMP (Internet control message protocol) used for network management. ICMP supports ping, by which the modules presence in the network can be detected. TCP (Transfer control protocol) provides reliable data flow over the network and the HTTP (Hyper text transfer protocol) is responsible for the Data transmission and reception from the Webpage.

The CCS C compiler [2] with MPLAB [1] environment is used to develop the code and Ethereal [3] software has been used extensively during the development for trouble shooting. The program flow is shown in Figure 3.

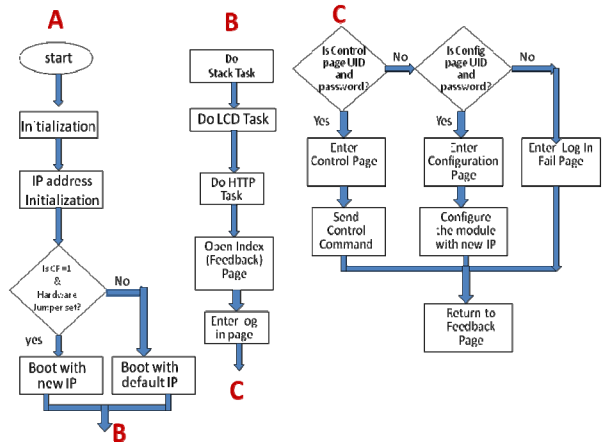

Figure 3: Program flow.

WEBPAGE FEATURES

The control and monitoring of the equipments is achieved through a web based user interface. The web page is developed using hyper text markup language (HTML). Total six numbers of pages are hosted by this module. These are *Default (Feedback)* page, *Log In* page, *Access verification success* page (shown in Figure 4), *Access verification fail* page, *Control* page, and the *Configuration* page. On connection, the default page is hosted by the module. The default page shows the digital and analog feedbacks from the associated devices e.g. ON/OFF indication, vacuum information, and pump speed etc. The automatic refresh time of this page is kept 5 second. The access to the control page is restricted by user ID and password to ensure operational safety.

Similarly while configuring the module, one has to go through the successful log in and enter into the configuration page. The network configuration of the module like IP address, subnet mask, and gateway can be changed or configured from a remote PC over the LAN. Entering any wrong user ID and password, the 'Access verification fail' page appears. The newly configured IP address along with the subnet and gateway are saved in the internal EEPROM of the microcontroller. The device can be rebooted either with the default IP or the new one depending on the jumper set in the hardware at the time of booting.

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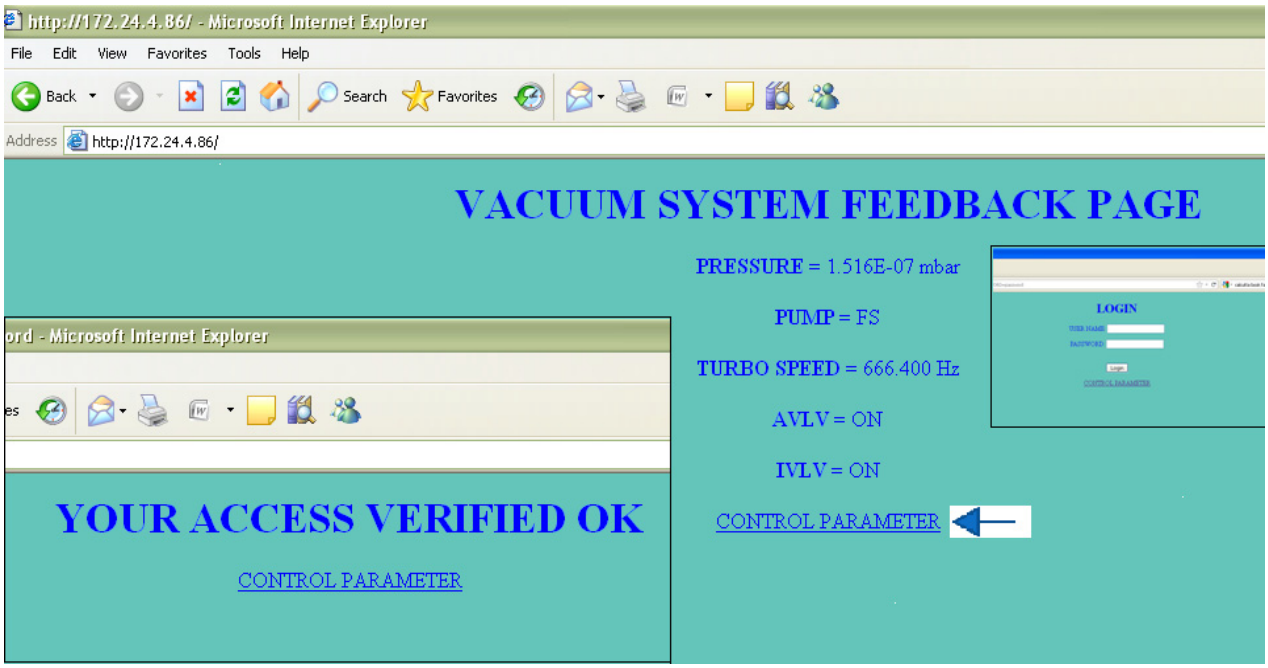

Figure 4: Snapshots of Feedback, Log in and Access verification success web pages.

FUTURE ENHANCEMNETS

The future scope of this module is to make it more generalised with more number of I/Os available at user end. The data collected from the field device can be stored in either the internal or external EEPROM for future reference which can be recollected whenever required.

Figure 5: Complete assembled module.

CONCLUSION

One set of this embedded Ethernet module has been installed in the SCC ECR beam line and working reliably over a considerable amount of time. Figure 5 shows the picture of an assembled module. This module is used for control and monitoring of one pumping station comprising of Scroll pump, Turbo molecular pump, Angle valve, Isolation valve and the adjacent vacuum gauge. It also reads the pump temperature and speed and displays it on the web page. Installation of this module made it possible to control the pumping modules from a client PC anywhere on the local area network with a minimum of field cabling.

REFERENCES

[1] www.microchip.com
[2] www.ccsinfo.com
[3] www.ethereal.com

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