Microcontroller-Based Distributed Serial Communication and PC-Based Supervision and Control for an Automated Greenhouse

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Abstract. In order to have a better and bigger plants production, it is necessary to have a regulated micro-environment, in a greenhouse. Inside a hydroponics greenhouse it is possible to regulate the main physical variables (temperature, humidity irrigation cycles, etc.) as well as the variables involved in the rates of plants growing (nutrients, sun radiation, water, etc.). Then, a greenhouse must be constantly supervised in order to regulate the main physical variables which are involved in the production process. For instance, temperature and humidity can be regulated by opening or drawing the ventilation system or domes or by heating or circulating the air inside the greenhouse. These tasks should be supervised all days, and it demands constantly, a supervised distributed communication system. In this paper we proposed a distributed serial communication system based on microcontrollers to monitoring and supervising the process via Internet. With this system, it can be achieved the on-line supervision and control of the greenhouse operation and conditions meteorological, as well as the main variables (temperature, humidity irrigation cycles, etc.).

Keywords: Greenhouse, Virtual Instrumentation, Supervision, Microcontroller

1 Introduction

Greenhouses can provide an excellent controlled environment for plant production. The greenhouse should provide uniform lighting, heating, and water to all plants. For this reason is important to have a system for supervising all this variables in order to control them, thus it can cultivate plants in excellent conditions. The advantages that offer us the greenhouses production are enough to consider automating it. These advantages are: low-

costs productions, better control of pests, better quality, save of water and more than one crop per year.

Furthermore, the fast evolution of the Personal Computer (PC) in the last two decades generated a revolution in virtual instrumentation for test and measurement. Virtual instrumentation offers several benefits to engineers and scientists who require increased productivity, accuracy, and performance (National Instruments, 2005).

A virtual instrument consists of an industry-standard computer or workstation equipped with powerful application software, cost-effective hardware such as plug-in boards, and driver software, which together perform the functions of traditional instruments (National Instruments, 2005).

Our objective in this paper is to design a minimum system using the PIC16F877 microcontroller in order to create a distributed serial communication system and a resource network to control and supervise via a website. The main goal of the minimum system called Slave is the acquisition and digital conversion of analog signals, to be sent to another minimum system called Master. The Master sends these signals to the PC that achieves three main tasks: stores the acquired data in a database, keeps a Domain Name Server (DNS)[1] finally generates the user interface. The minimum systems control the actuators of the system and can achieve the acquisition of the physical variables. These variables are digitals and analogical signals, such as speed and wind direction, solar radiation, internal and external temperature of the greenhouse, internal and external humidity, rain detector, heating actuator and shadow opening (Figure 1).

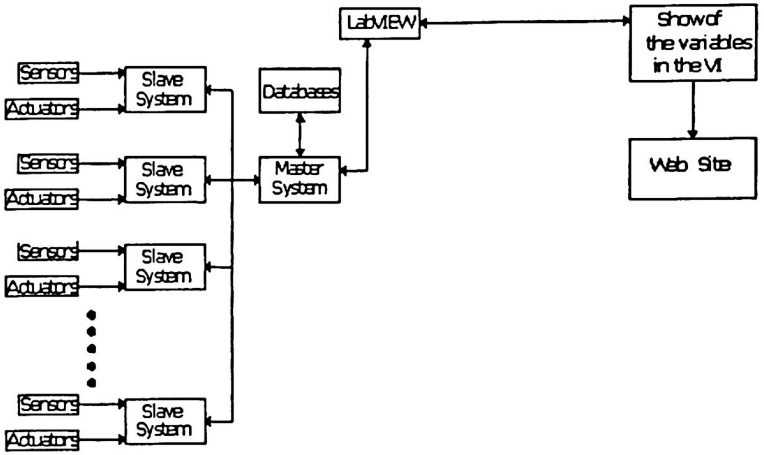

Fig. 1 Block Diagram

[1] Domain Name Server is an Internet service that translates *domain names* into IP addresses. We used this server to public our own page in the Web.

The slave minimum systems are interconnected by a RS485 protocol to the PC through Master-Slave architecture.

We use the RS485 Serial Communication Interface, since it allows us a multipoint communication (Table 2) and others relevant characteristics. Thus, it is necessary to realize a conversion from the RS232 Serial Communication Interface (shipped on PIC16F877) to the RS485 bus protocol.

Table 1. Comparison of RS-232, RS-422, and RS-485 Serial Communication Interfaces

Specifications	RS-232	RS 442	RS 485
Mode Operation	Single-Ended	Diffrential	Differential
Total Number of Drivers and Receivers on One Line (One driver active at time for RS-485 networks)	1 Driver 1 Receiver	1 Driver 10 Receivers	32 Drivers 32 Receiver
Maximum Cable Length	50ft (2500 pF)	4000 ft	4000 ft
Maximum Data Rate (40ft.4000ft for RS-422/RS-485)	20KB/s (by spec-can be higher)	10 Mbits/s	10 Mbits/s

2 System Overview

In this section, it is shown in detail the main components and devices used in our complete system. The system consists of two main parts: the PC connected to the Internet and the Master-Slave System (Figure 2).

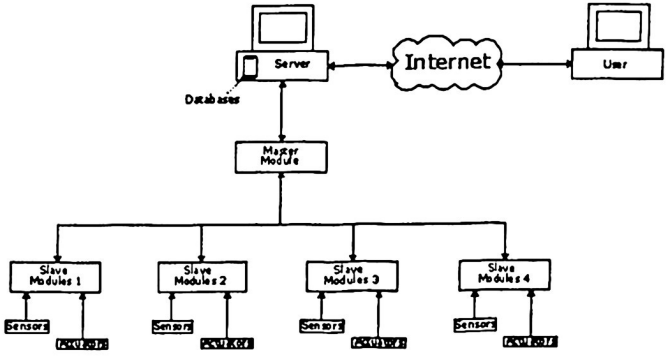

Fig. 2 General Structure

The physical variables are measured by the Sensors and then sent by the Slaves Module to the Master Module and then retransmitted to the PC.

The PC stores in a database the physical variables. In addition keeps the Web server, displaying the data via Internet.

3 Master-Slave system

The minimum system developed has eight analog inputs where the signals of the sensors are connected to be converter in digital signals using the Analog-Digital Converter Module. After the conversion the values are stored in a variable and it is ready to be sent to the master and then to the PC. The communication between devices is through the Addressable Universal Synchronous Asynchronous Receiver Transmitter (USART). In this case the USART[2] is configured as a full duplex asynchronous system and the baud rate is 9600.

Each Slave has a nine bits direction to be identified, thus the master can send the user request to the correct slave, and then it is useful to prevent errors between information transmission and request from the master to the slaves. The communication between master and PC is within eight bits since the LabVIEW only allows eight bits transmission.

When a request arrives to the correct slave, this receives code (from the master) which indicates the information that the slave has to transmit. This information comes from the temperature sensor, humidity sensor and solar radiation sensor. Thus the user can supervise the greenhouse and control these variables by sending control signals to the actuators connected to the slaves according to the control law programmed in LabVIEW.

Moreover the analog input module, the SCI module (transmission- receive) and the digital outputs module (to the actuators), the minimum system has the necessary implementations to be used in our system. These implementations are: the keyboard, the display, one free port and the Master Synchronous Serial Module. The display it is used to locally supervise some parameters in the same module instead of going necessarily to PC. The others shipped-on modules are not been used at this moment, but they will integrated in a future development works.

The linkage of these digital devices and components must be made by some software components. We have used some commercial packages and developed all the algorithms and VIs to have an open architecture to perform easily different control and supervision schemes.

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[2] USART Asynchronous mode uses standard non-return-to zero (NRZ) format (one START bit, eight or nine data, bits, and one STOP bit). The USART transmits and receives the LSb first. The transmitter and receiver are functionally independent, but use the same data format and baud rate [4].

4. Software Features

In order to keep some compatibility among the different devices and software components and reliability of the proposed architecture, it was chosen some commercially software as described in the following.

4.1 LabView

LabView is a graphical programming language that uses icons instead of lines of text to create applications; furthermore, it allows achieving different forms of communication between a PC and external digital devices. This communication can be made by a serial or a parallel port, and all of this is programmed under an easy graphic user interface. Since the master and slaves, based on the microcontroller 16F877, have two serial ports, we have chosen a LabView based on serial communication interface.

The virtual instrumentation is achieved via virtual instruments (VI). This VI, defined by LabView, seems and operates as a physical instrument, such as an oscilloscope or a multi-meter. Furthermore, it can be used a VI in another VI, it is called a subVI.

In this work, each VI is used to manipulate functions for example the VI presents data on the screen or sends it to another files or PC's (Figure 3).

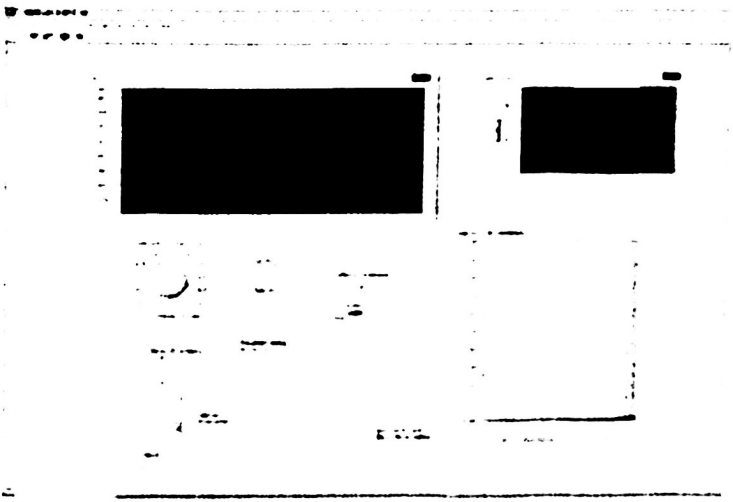

Fig. 3 LabView graphic interfaces

For the database, the data came from the Master and is directly saved in an Excel file due to the LabView input output format requirement. Thus, the created file is called for another program which manages databases (MySQL).

4.2 MySQL and PHP

MySQL is a compact database server ideal for small applications. In addition to supporting standard SQL[3] (ANSI), it compiles on a number of platforms and has different operating systems multithreading abilities on UNIX servers[4], providing a great performance.

This software is used to import information from an Excel file to a database admitted by PHP[5] software. PHP can access most any SQL or ODBC database. It can both read and write information in the database.

4.3 Dreamweaver

The visual editing features in Dreamweaver[6] allow us create some pages without writing a line of code and it can view all the site elements or assets and drag them from an easy-to-use panel directly into a document. We can streamline the development workflow by creating and editing images in Macromedia Fireworks or another graphics application, then importing them directly into Dreamweaver, or by adding Macromedia Flash objects.

How it was mentioned, Dreamweaver is only a tool that helps to the design of the Web page, and can be shown in a Web navigator in any kind of platform with Internet connection.

5 Website

The website (Figure 4) shows pictures for the crop plantation and the greenhouse construction architectonic, the different access to read the physical variables databases, and the LabView virtual instruments to supervise the different modules.

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[3] The SQL part of MySQL stands for "Structured Query Language" - the most common standardized language used to access databases

[4] Red Hat 9 Linux is the leading platform for open source computing.

[5] (Personal Home Page) Hypertext Preprocessor

[6] Macromedia Dreamweaver MX 2004 is a professional HTML editor for designing, coding, and developing websites, web pages, and web applications. It allows us the control of hand-coding HTML or a visual editing environment

The website involves a DNS Server and a Dynamic Host Configuration Protocol (DHCP) due to the necessity of a DNS server to have a communication with Internet, since this convert the domain name to an IP address used in the TCP/IP protocol. The DHCP allows us the generation of an IP address automatic (to the user connected in the network) in a range of IP addresses, thus it is viable to have a multipoint network instead of a point to point network.

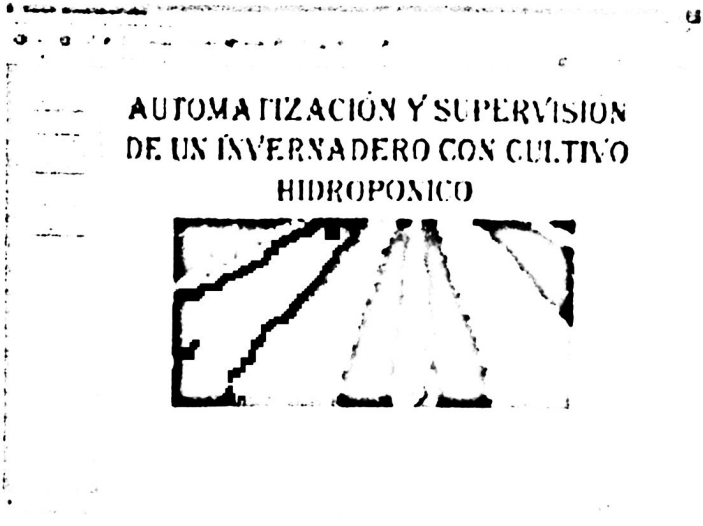

Fig. 4 Web Site

6 Conclusions

Based on the PIC 16F877 microcontroller, we have proposed a distributed serial communication system to supervise the external variables and control the internal variables in a greenhouse. The serial communication protocol used is RS485, since it allows us a multipoint communication and others relevant characteristics (number of receivers and cable length). Also some communication failure test has been carried out in order to check the robustness performance.

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