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Design of an Industrial Automated System which Measures Parameters in a Real Time Environment

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Abstract

Industrial Workers are often prone to accidents in the course of the discharge of their duties especially in high temperature or high frequency areas; hence the need to minimize the rate of exposure of these workers to these precarious environments. This paper discusses a way out of these avoidable scenarios through the design of an automated system, which is capable of measuring parameters such as voltage and temperature in an industrial environment. Two Universal Serial Bus (USB) PIC Microcontrollers were used; one functioned as the Master Controller attached to the Microcomputer and the other as a slave, driven by the Master Controller. The USB PIC Microcontroller was connected by only three wires to the Microcomputer where the I/O pins could be read or set using a simple ASCII protocol sent from a Microcomputer USB port. The communication between the PC and the system was very fast due to the use of a high speed USB V2.0 as the interface having a data transfer rate of 480MBits/s. The use of high-performance Microcontrollers with programmable I/O lines and powerful integrated peripherals reduced the number of electronic components and in turn simplified the entire system. The use of the PIC18F4550 Microcontroller especially improved the acquisition rate performance. It is therefore recommended that a Digital Signal PIC Microcontroller (DSPIC) be used in place of the regular PIC18F4550 Microcontroller for improved processing techniques and so on.

Keywords

Automated, System, Measures, Parameters, Environment

1. Introduction

In the past, connecting multiple peripheral devices to computer had been a major problem. This is because there were too many port types available. These include, RS-232 serial port, parallel port, Peripheral Component Interconnect (PCI) and Industry Standard Architecture (ISA) ports and so on. The use of these ports imposed limitations such as, no hot-plug ability and automatic configuration. There are very limited numbers of ways to attach the peripheral devices in the original IBM PC implementation due to the requirements in terms of non-shareable Interrupt Request (IRQ) lines and Input / Output (I/O) address space. Why Universal Serial Bus (USB) was created was to provide proper replacement for those legacy ports on a computer to make the addition of the peripheral devices quick and easy for end user [1].

Other benefits of USB include provision of an expandable, fast, bi-directional, low-cost, hot-plugable Plug and Play serial hardware interface that makes the life of the computer user easier, allowing them to plug different peripheral devices into a USB port and have them automatically configured and ready to use. Using a single connector type, USB allows the user to connect a wide range of peripheral devices such as keyboards, mice, printers, scanners, mass storage devices, telephones, modems, digital still-image cameras, video cameras, audio devices and lot more to a computer. USB devices do not directly consume system resources. They are not mapped into I/O address space, nor do they use IRQ lines or Direct Memory Access (DMA) channels. The only system resources required by a USB system are the memory buffers used by the USB system software. Due to its success and widespread acceptance, USB became the de-facto' industry standard for connecting peripheral devices to PCs and laptops. [1].

In recent years, sensors with USB connectivity have been developed for industrial applications. Therefore, temperature, humidity, pressure and other sensors are utilizable, in order to accomplish specific tasks [2].

Real-time control systems that operate on inputs from USB peripheral devices have become more common because the USB interface eases the task of installation with plug and play [3].

There are various ways for connecting a microcontroller-based system to a PC: the ISA or PCI connector, the serial port, the parallel port, or the USB port. The first solution imposes the opening of the PC, which is a risky and tedious operation. While the following two solutions have limitations in their performances, the last solution is the most efficient and attractive due to the high communication speed of the USB port and the quick and easy installation of the peripherals to the PC.

A Data Acquisition (DA) system with USB interface is described in [4]. It is based on the Phillips P89C51RD2 microcontroller. An ISP1181 circuit achieves the USB interface and two TLC0820 Analog - Digital Converters (ADC) do data acquisition. The system is divided into 3 parts: implemented by the P89C51RD2 microcontroller and the USB interface, implemented by the ISP11881 circuit. It can be used in different applications. An example is an oscilloscope on a PC [4].

Such systems, as the one described above exist. Reference [5] describes a data acquisition system based on a PIC16F877 microcontroller connected through the USB port to a host PC. The ADC from the PC is used for a slow event, unlike the Phillips P89C51RD2 microcontroller based data acquisition system with USB interface which must deal with a fast external event. In [6] another similar system is presented, based on the same microcontroller.

Different solutions are described in [7] based on a DSP circuit, and in [8] where a more complex data acquisition system, based on a less used microcontroller, MSP430F149, from Texas Instruments, is used, both solutions have USB interfaces. Finally in [9] a more general solution is presented, in which the self-reconfigurability feature was focused.

The Phillips P89C51RD2 microcontroller based data acquisition system and the ISP1181 circuit are used to achieve the USB interface while two TLC0820 analog-digital converters are used for the data acquisition. From the aforementioned setup, it can be deduced that the USB port choice for communicating with PC offers easy connection possibility, faster rate of transfer while ensuring at the same time, increased data integrity. However, there are other ways for connecting such a system to PC, but the chosen solution has proven advantages as articulated above.

With the advantages of the use of USB as an interface to PC for a Data Acquisition (DA) System, a more compact system is proposed in this work using the Micro Chip ™ PICF4550 Microcontroller as the processor for the DA system. The PIC18F4550 is a more compact and robust controller that has a fully featured USB communication module and is compliant with the USB specification revision 2.0 with a data rate of 480Mbp/s. This attribute provides it with an edge above Philip P89C51R2 microcontroller DA system that requires an external USB communication module (the ISP1181 circuit was used to implement this). The ISP1181 interface device complies with USB specification revision 1.1 which has a data rate of 12Mbps (this is lower when compared to the speed of the PIC18F4550 microcontroller) [10].

Also the PIC18F4550 has a 10bit ADC module, which has a fast data processing time. This module incorporates programmable acquisition time allowing for a channel to be selected and conversion to be initiated without waiting for a sampling period, thus reducing code overhead [10]. However, the Phillips P89C51R2 DA system, an external TLC0820 8bit ADC circuit is incorporated into the system, for Analog-Digital (A/D) conversion. The conversion rate of this ADC is lower than that of the PIC18F4550. As a result, the proposed DA system that is based on the PIC18F4550 is faster than the system based on the P89C51R2.

2. Methodology

A lot of challenges and bottlenecks are associated with interfacing external devices with PC for data acquisition and transfer especially with the old interface ports like; parallel port, serial port, ISA and PCI port for data transmission in Industrial Process Control. This work has therefore been developed to overcome these problems. Some of the main problems associated with the industries are:

- Excess heat in furnaces that may lead to explosion of furnace and cause damage to the industry and the employees who work near the furnace.
- Electric short circuit due to overloading may cause serious problems in an industry.
- People are not allowed in areas where high temperature condition (steel industry) and high frequency radio waves (Uranium plants) as exposure may result in loss of lives.

To mitigate these identified challenges, this work therefore sought to demonstrate how the PIC Microcontroller based data acquisition system could communicate with other systems like the PC using the USB version 2.0. The study also sought to demonstrate that the USB 2.0, which is a serial bus standard when used as a form of device interface is a faster and simpler way of communication between the Host and a device than the traditional interface standards like the ISA and PCI, parallel and Serial interfaces etc.

In this work, (1) Microcontroller (PIC18F4550) which serves as the MASTER is interfaced with the PC through the USB port and the other Microcontroller (PIC18F4550) which serves as a SLAVE is connected to the MASTER. The Master Microcontroller has 2 analog inputs and 4 digital inputs while the slave is connected to 4 output devices (LEDS). The PC scans the inputs by sending the particular set of commands in such a way that it will get the responses from the USB Microcontroller at a speed of 480Mbp and it can control the device in an ON and OFF condition by sending particular commands. According to that input, the PC can perform any operation within itself and is also capable setting the outputs of any Microcontroller.

3. System Design and Analysis

The rapid development of digital systems has led to their frequent use in the monitoring, control and command of the external world. Few examples are: systems for monitoring parameters, such as the temperature, the pressure in close spaces, systems for commanding different execution elements etc. In many cases the digital system is between sensors and actuators.

A wide spread application from the above is the data acquisition system**.** The data from the external world is read, processed, and eventually used for decisions. The data comes from sensors, directly in digital form (the most convenient way) or analog form. In the second case an analog to digital converter (ADC) will be necessary in the digital system [11].

The system is designed, to have two controller nodes, which have to sense the analog parameter from real time environment. These analog parameters are then converted to digital bits using the ADC of the controller. The data have to be transmitted over a wired connection.

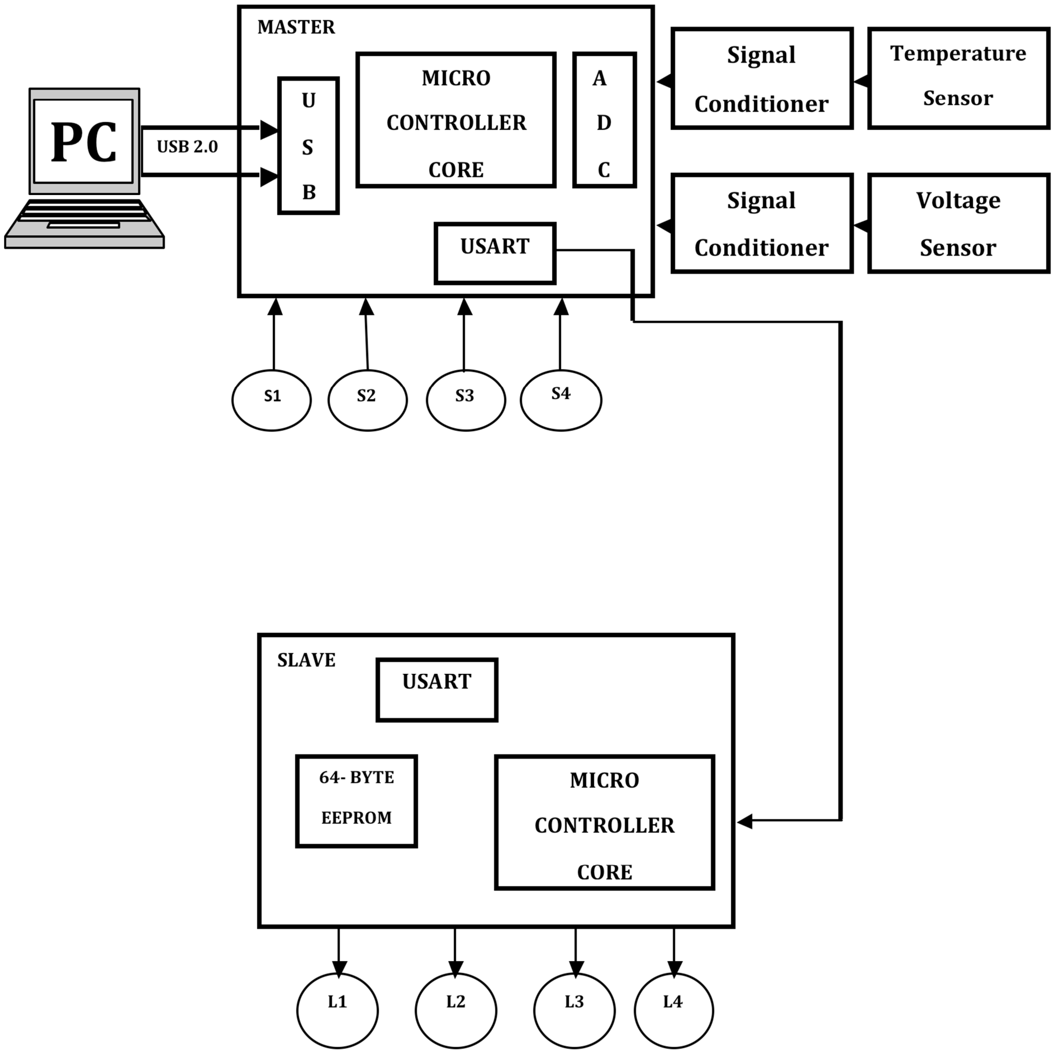

Figure 1. *Functional Block Diagram of the System.*

This work is implemented using two PIC18F4550 Microcontrollers connected by wires. The set up is named as a MASTER and a SLAVE as shown in Figure 1 above.

The two analog inputs to the MASTER microcontroller contain values of the temperature and voltage sensors, while its four digital inputs are the toggle switches S1-S4 (Figure 1). The four digital output devices are the LEDs L1-L4, which are connected to the SLAVE microcontroller (Figure 1)

4. Observations and Discussion

4.1. Temperature Measurement

As the temperature sensor was heated with the soldering gun, the output voltage (which is linearly proportional to the Celsius (centigrade) temperature is amplified by the op-amp so that this voltage is readable by the microcontroller. This voltage value was fed to the microcontroller and accordingly it was used to generate the digital data, which was obtained and was displayed on the digital terminal as shown in Figure 2. The corresponding temperature is also displayed on calibrated analog temperature meter on the VB program [12]. The variation in the amplified output voltage of the temperature sensor is continuously displayed on the VB screen as long as the soldering gun remains on the LM35 temperature sensor.

4.2. Voltage Measurement

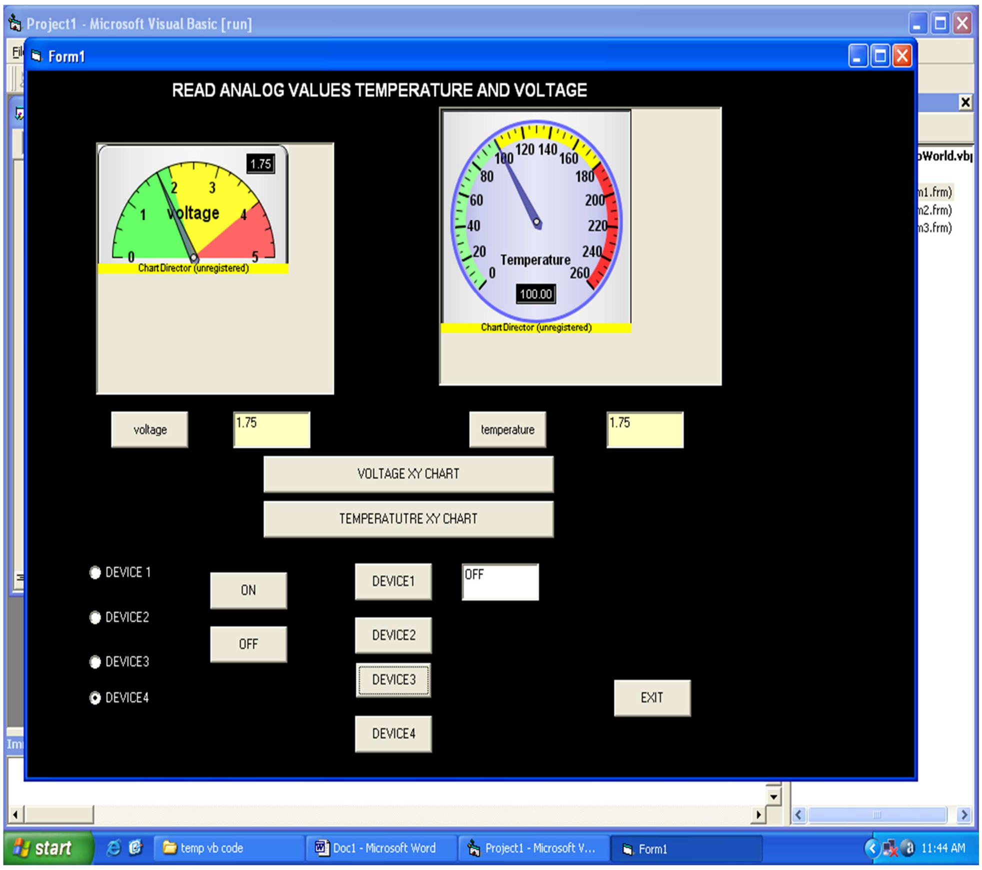

Figure 2. *The interface that measures temperature.*

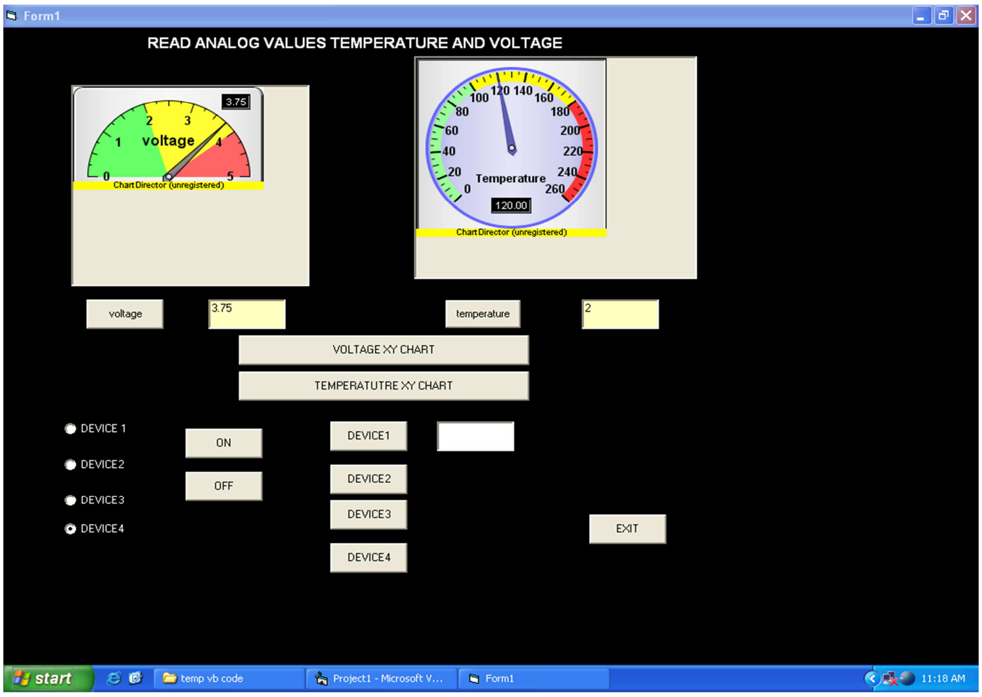

Figure 3. *The interface that measures voltage.*

To display the voltage variation in the potentiometer, the voltage button on the VB program must be activated. When the potentiometer was varied, the respective changes in the voltage is shown on the VB screen digitally and also in the voltage analog meter display. From Figure 3, it can be seen that when the knob of the 10k ohms pot was varied from minimum anticlockwise, the variation in voltage was seen to vary from 0v to 3.75v DC.

The entire project module was powered from the PC through the USB interface (i.e. power is supplied by the USB bus to the entire system, wherein an external standalone power supply is not needed). Also it was observed that the communication between the PC and the project module was very fast due to the use of a high speed USB v2.0 as the interface which has a data transfer rate of 480Mbps. The plug and play capability of the USB [13] was also an added advantage as the operating system software of the PC automatically identified, configured and loaded the appropriate device driver when the project module was connected to the PC. After the testing of the project module, the USB interface was unplugged while the PC was still running so there was no need to reboot the PC. The entire process was so simple and straightforward. Hence the Project module was tested and it worked as designed to do.

5. Conclusion

The core objective of this work is to show how USB can be used as an interface to a PC with a view to measuring real time data (temperature and voltage) in a real time environment. The effectiveness of this study can be attributed to user friendly and convenient USB features like Plug and Play and Hot-Swap, through which it can be easily plugged to a common PC or notebook. It can be seen that USB is all about convenience. This is the single most important reason USB is witnessing such a widespread adoption.

The use of high-performance microcontrollers with programmable I/O lines and powerful integrated peripherals reduced the number of electronic components and in turn simplified the project. The use of the PIC18F4550 microcontroller especially improved the acquisition rate performance.

This work has many real time applications in the market today. The latest computers and laptops are using only USB port as against the serial port, parallel port or the PCI/ISA interface port to communicate to the external world. The project, which proved to be inexpensive to construct when, compared to its application. The work also allows for time efficiency in its operation and a low power consumption rate due to the technology used.

It is worthy of note that the principle behind this work provides a very strong level of human control and limits the physical level of human contact with systems in danger-prone environments. This is one of the laudable goals, which this research work articulates in a much distilled manner. Also the accuracy and efficiency of the system status report generated on the PC is actually on the high side due to high reliability of the USB interface that was used. The data is digitally transmitted and given the fact that digital data are less prone to errors than their analog counterpart.

Recommendation

It is recommended that an onboard Graphical LCD is built in place of the PC to allow for compatibility and easy of transfer. Also a Digital Signal PIC microcontroller (DSPIC) is used in place of the regular PIC18F4550 microcontroller for improved processing techniques. The DSPIC is a much more advanced controller chip than a regular PIC that offer a wide range of improved peripherals like much speedier buffered 12Bit ADC, auto multiplexing for reading a chain of inputs with a single read, motor control stuff, low latency flash read, linear memory space and so on. A wireless technology like the *Zigbee* could be incorporated into the project module for connectivity between the microcontrollers. This will enhance the speed of communication between the MASTER and SLAVE controllers and reduce data loss between them.

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