Ethernet Based, Industrial Furnace Control and Data Acquisition

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Abstract— Developments in technology and the marketplace now make it possible for embedded systems to communicate in local Ethernet networks as well as on the Internet. Network communications can make an embedded system more powerful and easier to monitor and control. Ethernet solves the problem of remote communication with the embedded application. Challenges like application monitoring, control, diagnostics and data logging can all be accomplished from a remote, centralized location. With the ability to access the application remotely, corporations can eliminate the need to send a service person to the application and thus save labor time and money. The presented system enables Ethernet connectivity to the digital and analog signals in the industries so that they can be accessed from internet. This system uses Arduino Mega 2560; a microcontroller board based on the ATmega2560. Data acquisition hardware acts as the interface between the computer and the outside world. It primarily functions as a device that digitizes incoming analog signals so that the computer can interpret them. Theme of the system is industrial automation by monitoring and controlling various analog and digital signals via ethernet communication. The user should be able to get all the information about the field sensor status, status of various switches, in the real time. He should also get the information about analog signals on the field such as temperature of furnace, furnace bath level, etc. For this purpose a built in ADC should present in the system.

Keywords— ATmega2560, Data acquisition, Ethernet, Internet protocol, Local Area Network, Transmission control protocol

I. INTRODUCTION

The embedded systems and Ethernet networks existed in separate worlds for many years. Ethernet was available only to desktop computers and other large computers. Embedded systems that needed to exchange information with other computers were limited to interfaces with low speed, limited range, or lack of standard application protocols.

Developments in technology and the marketplace now make it possible for embedded systems to communicate in local Ethernet networks as well as on the Internet. Network communications can make an embedded system more powerful and easier to monitor and control [1].

Ethernet solves the problem of remote communication with the embedded application. Challenges like application monitoring, control, diagnostics and data logging can all be accomplished from a remote, centralized location. With the ability to access the application remotely, corporations can eliminate the need to send a service person to the application and thus save labor time and money. The presented system enables Ethernet connectivity to the digital and analog signals in the industries so that they can be accessed from internet. This system uses Arduino Mega 2560; a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. Nowadays, Internet has spread worldwide and most of the internet connections use Ethernet as media for data transfer. In industries or in home appliances, most of the time we need to monitor and control different parameters using microcontrollers. Once we enable Ethernet interface to such systems, we can communicate with them remotely over the internet. So this system is very simple and affordable to use in industrial control and monitoring applications.

II. LITERATURE SURVEY

A. Overview of Industrial Data Acquisition

Data acquisition is widely used in many areas of industry. Data acquisition is used to acquire data from sensors and other sources under computer control and bring the data together and store and manipulate it.

Data acquisition systems can take many forms from very simple manual systems to high complicated computer controlled ones. The simplest form may be a technician manually logging information such as the temperature of an oven. However this form of data acquisition has its limitations. Not only is it expensive because of the fact that someone has to be available to take the measurements, but being manual it can be subject to errors.
Readings may not be taken at the prescribed times, and also there can be errors resulting from the manual fashion in which the readings are taken. As can be imagined the problems become worse if a large number of readings need to be taken, as timing may become more of an issue, along with the volume of work required. Various existing methods for industrial data acquisition and control have been studied before development of the presented system. The survey has been given here in the brief.

B. Data Acquisition Systems Then and Now

Data Acquisition (often abbreviated as DAQ) has become an industry standard term that refers to almost any type of computer based system comprised of analog and/or digital inputs and outputs. Today most systems are based upon PCs, but there is still a large market for systems based upon other platforms such as VME, PXI as well as those based on proprietary embedded controllers. It was not that long ago the stereotype of an engineer was someone in a white lab coat watching one or more meters and writing results on a clipboard. The advent of extremely low cost computers, combined with the development of a wide variety of powerful data acquisition interfaces has driven this stereotype farther back in history than black and white movies. Also, most college graduates in science and engineering disciplines have enough programming training and experience to make the programming required for DAQ applications quite straight forward.

C. 2.3 History of Data Acquisition

In 1963, IBM produced computers which specialized in data acquisition. These include the IBM 7700 Data Acquisition System and its successor, the IBM 1800 Data Acquisition and Control System. These expensive specialized systems were surpassed in 1974 by general purpose S-100 computers and data acquisition cards produced by Tecmar /Scientific Solutions Inc. In 1981 IBM introduced the IBM Personal Computer and Scientific Solutions introduced the first PC data acquisition products.

D. Ethernet Networking

Ethernet is as ubiquitous in the PC industry today as USB. It enjoys such wide acceptance because it is easy to understand, deploy, manage, and maintain. When you plug in an Ethernet cable, it just works. For data acquisition applications, Ethernet offers an extended range (up to 100 m per segment) for highly distributed or remote measurement applications.

E. History of Furnace

A furnace is a device used for heating. The name derives from Latin furnax, oven. In American English and Canadian English usage, the term furnace on its own refers to the household heating systems based on a central furnace (known either as a boiler, or a heater in British English), and sometimes as a synonym for kiln, a device used in the production of ceramics. In British English, a furnace is an industrial furnace used for many things, such as the extraction of metal from ore (smelting) or in oil refineries and other chemical plants, for example as the heat source for fractional distillation columns. The term furnace can also refer to a direct fired heater, used in boiler applications in chemical industries or for providing heat to chemical reactions for processes like cracking, and are part of the standard English names for many metallurgical furnaces worldwide. The heat energy to fuel a furnace may be supplied directly by fuel combustion, by electricity such as the electric arc furnace, or through induction heating in induction furnaces.

F. Uses of Furnaces

Furnaces are used for different heat treating operations depending upon their heat treat requirements
1. 150 °-700°C used for nitriding, tempering, Annealing etc...
2. 650 °-1000°C used for Hardening, Normalizing, annealing etc...
3. 0°C-1000°C –used for hardening of hot work steel, high speed steel, sinting etc...

Furnaces are divided into Batch type and continuous type. Depends upon Batch type the Quench sealed furnace is available as horizontal or vertical furnaces. It may use for annealing, hardening, carburizing, nitriding, nitrocarburizing etc...In these two types of chamber used Heat chamber, quench chamber. The heat chamber is used for heating of materials. Quench chamber is also call as Cooling chamber. The process used in this chamber is heat treatment. Heat treatment is the heating and cooling of metals to alter their physical and mechanical properties without changing their shape. Heat treatment is often associated with increasing the strength of material, but it can also be used to alter certain manufacturing properties such as improve machining, improve formability, and restore ductility after a cold working operation.
G. Furnace Monitoring Parameters

The controlling and monitoring of furnace is done by using the following parameters:
Temperature
Pressure
Oxygen
Raw materials level and
Flow switch.

The furnace is also known as Chamber. Any industry will have various parameters that are to be continuously monitored and controlled from a remote place. In most of the cases the use of manpower becomes almost impossible and therefore remote monitoring and control systems are extensively developed and used.

- Temperature Control of a Furnace

The most important measurement variable in industrial furnaces is the temperature. This application monitors the temperature of a furnace with multilevel outputs. A Temperature Sensor detects the temperature in a furnace whereas the application controls and monitors according to the temperature and the outputs are displayed on the webpage.

Type K is recommended for use in oxidizing and completely inert environments. Because its oxidation resistance is better than Types E, J, and T they find widest use at temperatures above 1000 °F. Type K, like Type E should not be used in sulfurous atmospheres, in a vacuum or in low oxygen environments where selective oxidation will occur. The temperature range for Type K is -330 to 2300 °F and its wire color code is yellow and red.

The type K thermocouple consists of two different nickel alloys called Chromel (90% nickel and 10% chromium) and Alumel (95% nickel, 2% manganese, 2% aluminium and 1% silicon). In the following the abbreviations CHR for Chromel and AL for Alumel are used. The sensitivity of the type K thermocouple is approximately $41 \mu V/K$.

- Thermocouples

A thermocouple is a temperature-measuring device consisting of two dissimilar conductors that contact each other at one or more spots. It produces a voltage when the temperature of one of the spots differs from the reference temperature at other parts of the circuit. Thermocouples are a widely used type of temperature sensor for measurement and control, and can also convert a temperature gradient into electricity. Thermocouples for practical measurement of temperature are junctions of specific alloys which have a predictable and repeatable relationship between temperature and voltage.

Different alloys are used for different temperature ranges. Properties such as resistance to corrosion may also be important when choosing a type of thermocouple.

| Table 2.1: Temperature Range for Basic Thermocouples |
|--------------|-----------------|-----------------|-----------------|
| Calibration | Temperature Range | Std. limits of error | Spec. Limits of Error |
| J           | 0°C to 750°C (32 °F to 1382 °F) | Greater of 2.2°C or 0.75% | Greater of 1.1°C or 0.4% |
| K           | (-.200°C to 1250°C) (-.328 °F to 2282°F) | Greater of 2.2°C or 0.75% | Greater of 1.1°C or 0.4% |
| E           | (-.200°C to 900°C) (-.328 °F to 1652°F) | Greater of 1.7°C or 0.5% | Greater of 1.0°C or 0.4% |
| T           | (-.250°C to 350°C) (-.328 °F to 662°F) | Greater of 1.0°C or 0.75% | Greater of 0.5°C or 0.4% |

III. SYSTEM DEVELOPMENT

A. Overview and Introduction of the System

The main control of the system is being monitored by Atmega 2560. Ethernet shield is used for the data communication. Whereas the main function of this system is to monitor and control the temperature of the furnace. These operations can be done with the help of the following major components and thus they are as follows. The Atmega 2560 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture, by executing powerful instructions in a single clock cycle, the Atmega 2560 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed. The main task of the controller is to monitor and control the main functioning of the system. In this project Atmega 2560 plays a vital role but Ethernet shield also has its importance. The Atmega2560 provides four hardware UARTs for TTL (5V) serial communication. The ATmega2560 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus.
DAQ (Data Acquisition) is the process of bringing a real-world signal into the computer, for processing, analysis, storage and data manipulation. Data acquisition systems (DAQs) gather information from one or more signal inputs or sensor sources and process this information for further analysis. These data acquisition systems are mainly means for monitoring and regulating manufacturing processes and systems. Thermocouple is used for measuring the temperature of the Furnace. Thermocouples consist of two dissimilar metals and provide a means of sensing temperature in a variety of processes. Temperature is the most widely measured process variable and its measurement is critical in many manufacturing processes. Thermocouples can be constructed in a variety of ways from flexible wires smaller than a human hair to rugged sheath one half inch in diameter. They can measure temperatures from -454°F to 4200°F. Thermocouples are low-impedance devices that work by producing electromagnetic forces and these EMF’s are correlated to a temperature based on a curve specified for that particular thermocouple calibration.

B. System Block Diagram

C. Main Components of the System

1. Arduino Microcontroller board with: ATmega2560
2. Ethernet Shield W5100
3. K-type Thermocouple
4. Horizontal Solution Heat Treat Furnace
5. RTC
6. Signal Conditioning circuits

1. Arduino Microcontroller board with: ATmega2560

This system utilizes an Arduino Mega 2560 which is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

2. Ethernet Shield W5100

The Arduino Ethernet board has an RJ45 Ethernet connector, power connector, connector for an external USB board for programming and micro SD card socket. The Arduino Ethernet Shield allows an Arduino board to connect to the internet. It is based on the Wiznet W5100 ethernet chip. The Wiznet W5100 provides a network (IP) stack capable of both TCP and UDP. It supports up to four simultaneous socket connections. The Ethernet Shield has a standard RJ-45 connection, with an integrated line transformer and Power over Ethernet enabled. There is an onboard micro-SD card slot, which can be used to store files for serving over the network.

IV. PERFORMANCE ANALYSIS

A. Result Analysis of the System

The analysis of this system can be done with the help of a digital thermocouple. Temperature can be measured as follows; comparison of k-type thermocouple temperature sensor is carried out with a digital thermocouple by using them at the same time for same temperature. The k-type thermocouple can be applied easily in the same way as other integrated-circuit temperature sensors. A thermocouple circuit contains the two alloy junctions, wire sand connectors and a voltage measuring device. When the two junctions are experiencing different temperatures, measurable current flows through the circuit. The current is related to the temperature differential. Because the measurement is relative, one of the temperatures must be known in order to calculate an absolute temperature.
In early thermocouples, one junction was kept at 0°C by immersing it in an ice water bath. Today, one of the junctions, the "cold junction," is electrically compensated to maintain a standard. The other junction, the "hot junction," is exposed to the environment to be measured. This presumes that the ambient air temperature is almost the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature of the k-type thermocouple die would be at an intermediate temperature between the surface temperature and the air temperature.

B. Accuracy

Accuracy of thermocouples is based on the purity of the wire and the wire junction. Each type of wire has its own limits of error based on materials deviations.

- Standard: ± 2.2°C or ± .75%
- Special Limits of Error: ± 1.1°C or 0.4%

Deviations in the alloys can affect the accuracy of thermocouples. For type K thermocouples the tolerance class one is given as ± 1.5 K between -40 and 375 °C. However, deviations between thermocouples coming from the same production are very small and a much higher accuracy can be achieved by individual calibration. Metallurgical changes can cause a calibration drift of 1 to 2°C in a few hours, increasing to 5 °C over time. A special grade of Type K is available that can maintain special limit accuracy up to ten times longer than the regular grade.

V. CONCLUSION

An Ethernet-based measurement device does have a unique set of requirements, relative to a standalone or PC-based measurement system. Reliable, autonomous operation of a distributed measurement device requires a more intelligent device with a local microprocessor that handles communications, system management, and diagnostics. Ethernet's potential as a network for distributed measurement and control is virtually unlimited. As Ethernet continues to be enhanced with greater performance, higher determinism, and lower cost implementations, Ethernet can provide a very capable measurement network, and even consolidate control network applications.

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